IOWA
GEOLOGICAL
SURVEY

VOL. VIII

ANNUAL REPORT
1897

IOWA

GEOLOGICAL SURVEY

VOLUME VIII.

ANNUAL REPORT, 1897,

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.
1898.

DES MOINES:
F. R. CONAWAY, STATE PRINTER.
1898.

GEOLOGICAL BOARD.

Geological Corps.

Samuel Calvin .... State Geologist
H. F. Bain .... Assistant State Geologist
W. H. Norton .... Special Assistant
S. W. Beyer .... Special Assistant
J. L. Tilton .... Special Assistant
Nellie E. Newman .... Secretary

CONTENTS.

LIST OF ILLUSTRATIONS.

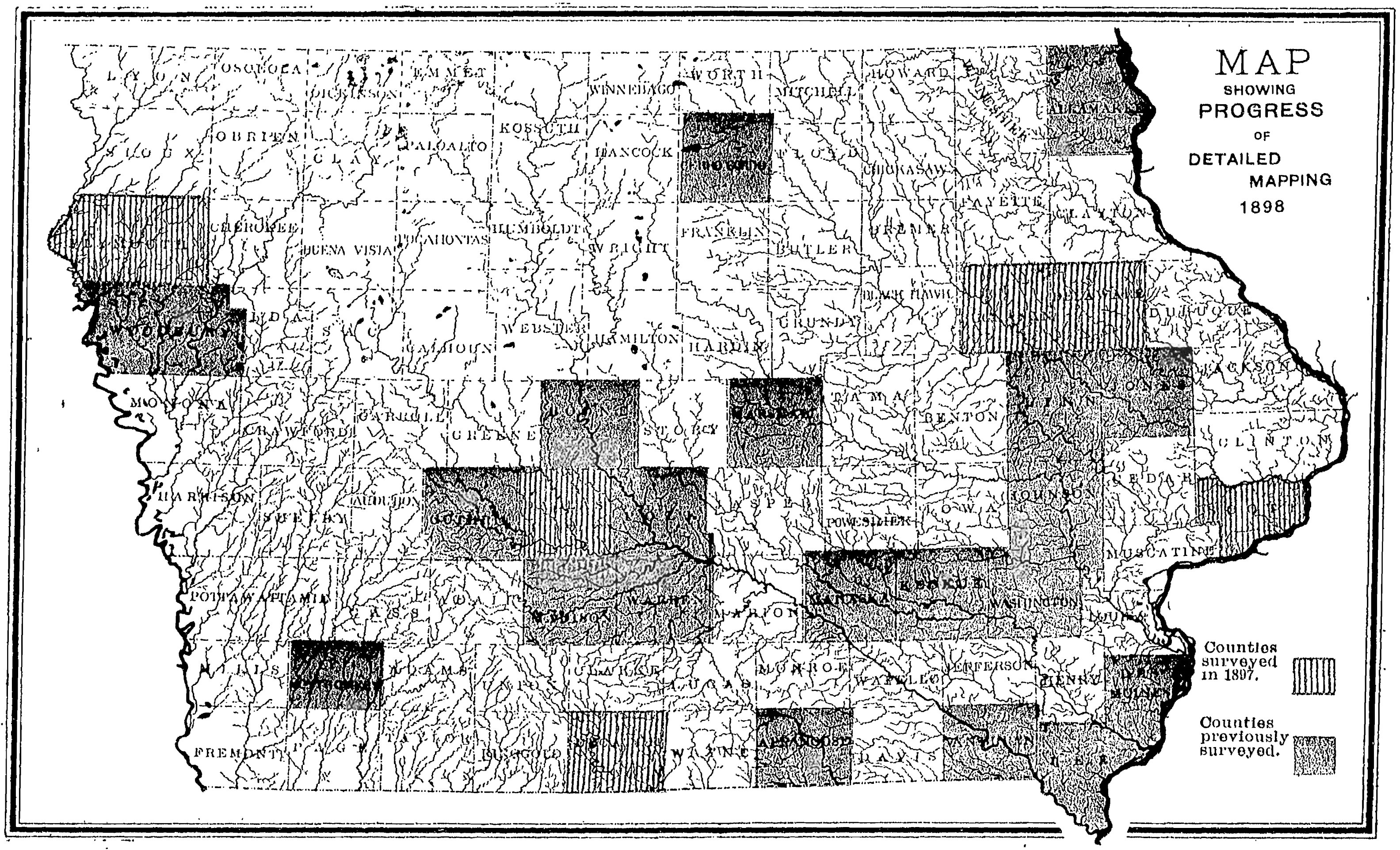
PLATES.

FIGURES.

CROSS-SECTIONS.

MAPS.

ADMINISTRATIVE REPORTS.


MAP
SHOWING
PROGRESS
OF
DETAILED
MAPPING
1898
Counties surveyed in 1897.
Counties previously surveyed.
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
OBRIEN
CLAY
PALOALTO
KOSSUTH
HANCOCK
CHICKASAW
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
FAYETTE
CLAYTON
BLACK HAWK
GRUNDY
DUBUQUE
JACKSON
CALHOUN
WEBSTER
HAMILTON
HARDIN
MONONA
CRAWFORD
CARROLL
GREENE
STORY
TAMA
BENTON
LINN
CLINTON
HARRISON
SHELBY
AUDUBON
POWESHIEK
IOWA
JOHNSON
CEDAR
MUSCATINE
POTTAWATTAMIE
CASS
ADAMS
MONROE
WAPELLO
JEFFERSON
HENRY
MARION
KEOKUK
WASHINGTON
MAHASKA
FREMONT
PAGE
TAYLOR
WAYNE
DAVIS
LEE

SIXTH ANNUAL

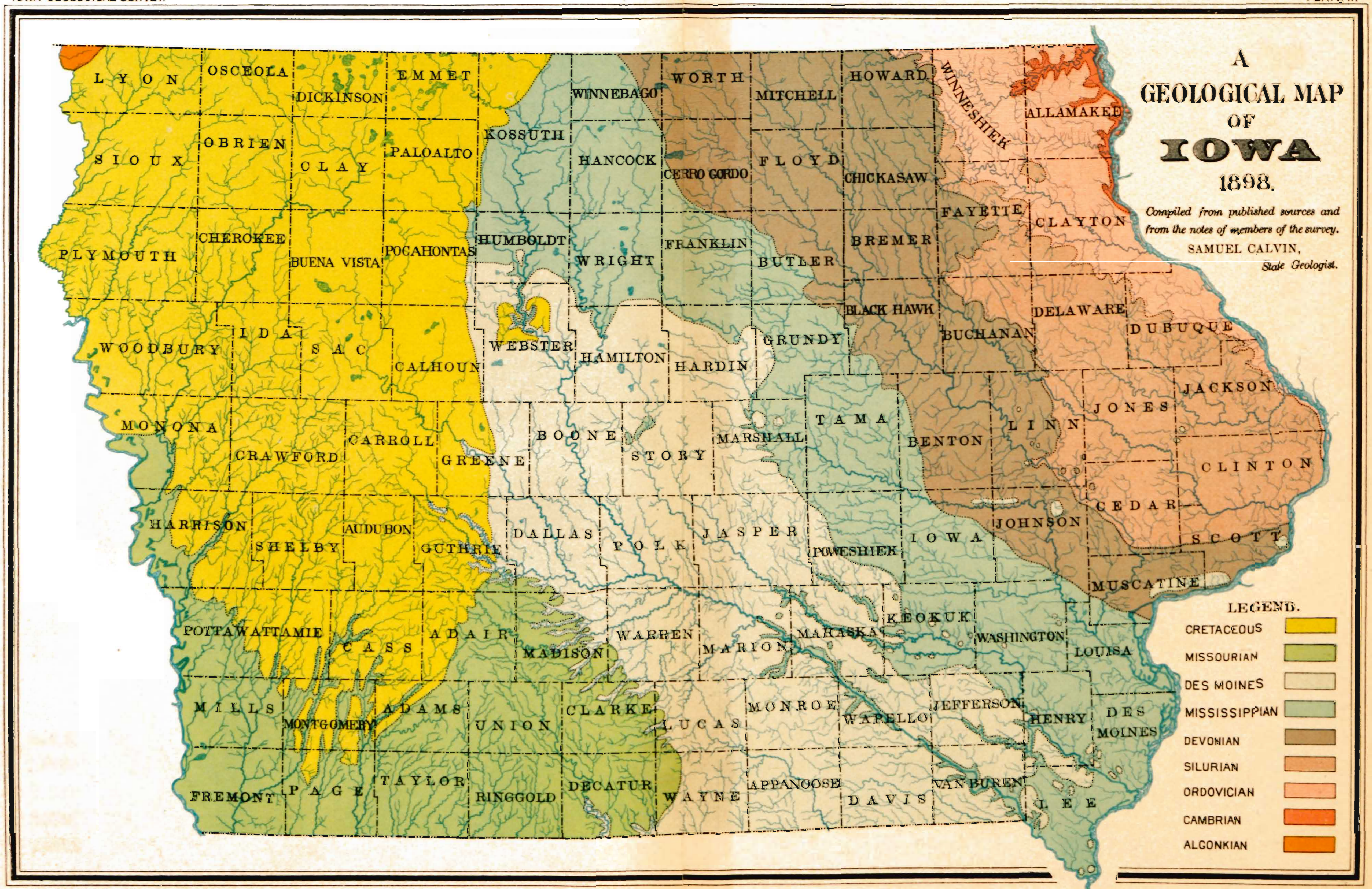
Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1897.

To Governor Francis M. Drake and Members of the Geological Board:

GENTLEMEN—The work of the Iowa Geological Survey for the year 1897 has followed, in general, the plans submitted and approved at the beginning of the year. The relation of the Survey to the public, however, is such that it is impossible to provide by any general scheme beforehand for all the lines of work that must necessarily be followed during any given year. Special cases arise, unexpected problems are met from time to time, and each must be dealt with promptly in accordance with the degree of importance that it seems to possess. The past year has been no exception. It has brought its share of new problems, and more than the usual share of work not foreseen when the general plans were made at the beginning of the season.

The areal work has been fully completed in accordance with the original plans. Mr. A. G. Leonard finished the survey of Dallas county, and has submitted a full manuscript report with the necessary maps and illustrations. Prof. W. H. Norton devoted the field season to making a thorough survey of Scott county, though the written report is not yet in hand. Mr. H. F. Bain completed the work in Decatur and Plymouth counties; and I was able to finish the survey of Delaware and Buchanan counties. Reports on the counties mentioned are



Lith. by A. Hoen & Co., Balto., Md.

herewith submitted, and their publication as volume VIII of the reports of the Iowa Geological Survey is recommended.

With the work of the present year the mapping has been completed in twenty-six counties. The area so surveyed is indicated on the accompanying map (plate i). It is to be understood that only those counties in which the areal work has been completed are indicated. Some work has been done in every county in the state, and in many it will require but little additional work to make a complete report. It should also be noted that the map shows only the progress of the areal work. The special studies of coal, clay, artesian waters, gypsum, lead, zinc, etc., which have quite legitimately absorbed so considerable a portion of the funds and time of the Survey, have been in addition to the work of mapping.

The regular office work of the Survey has been carried on as heretofore. During the first six months Mr. Leonard remained in charge, but at the end of that time Mr. Bain's leave of absence expired, and he resumed active duties. During the entire year Miss Newman has as usual been employed in the work of correspondence, distributing reports, checking exchanges, typewriting manuscripts, and attending to other routine work inseparable from effective office management.

Within the year the final portion of volume VI was printed and the volume has been distributed. Volume VII has been printed and bound, and has been partially distributed. Both volumes have met with a very cordial reception. Volume VI especially has been widely reviewed and generously commended by scientists and practical engineers who are devoting themselves to problems of water supply, in all parts of the country. The report of Mr. Bain on the geology of Polk county, in volume VII, is one of the most important so far published, from an economic point of view, and it is a pleasure to note that it has received the public recognition which it deserves. The report on Cerro Gordo county was regarded as of so much local importance as to deserve publication almost entire, in the newspapers of Mason City, and each of the other reports in this volume has been welcomed locally as a contribution to knowledge of the highest practical value. Beyond the limits of the state the reception has been no less flattering, and the many letters of commendation received give assurance that the work of the Survey is meeting the just expectations of the people of Iowa in disseminating a knowledge of the great resources of our matchless state.

In connection with three of the formations incidentally brought under view in following out the original plans relating to areal geology, a large amount of unexpected field work was rendered necessary. In company with Mr. Bain I spent several days in Madison and Guthrie counties, making detailed studies, chiefly for purposes of correlation in other counties, on the limestones of the upper coal measures. In this work we were accompanied part of the time by Professor Tilton of Indianola. Problems connected with the Rockville conglomerate and other formations in Delaware county, necessitated investigations in Dubuque and Allamakee counties. In part of this work I was assisted by Mr. Bain, and in Delaware and Dubuque counties we had the advantage of being accompanied by Professor Salisbury of the United States Geological Survey. Mr. Leverett, special assistant in Pleistocene geology on the United States Survey, joined us in an investigation of the drift and associated deposits in Muscatine and Scott counties. We also had the assistance here of Professor Udden, of Augusta College, whose special knowledge of the region was of great value. The work of Mr. Bain in Plymouth county could not be satisfactorily completed without extended observations in a number of adjacent counties, of which observations an account will be found in his annual report hereto appended.

As in the preceding years, a considerable portion of our time has been spent in the study of problems connected with the drift, and very gratifying progress has been made. It has been our object to map the different drift sheets and surface formations as a preliminary step toward making an accurate soil map of the state. By the close of the present field season it was felt that the work had progressed sufficiently to warrant the undertaking of soil studies *per se.* The Survey itself has, however, neither the funds nor the laboratory necessary for this work, so an application for assistance was made to the United States Department of Agriculture and proposals for co-operation in the work submitted. The chief of the division of soils, Prof. Milton Whitney, readily agreed to take up the work as soon as the means at his disposal would allow it, and has incorporated in his requests for the coming year an item with reference to the Iowa work. If this be allowed, the more direct work of soil study will be immediately taken up and the characteristics and proper treatment of the soils resulting from the various formations outlined on our maps, will be determined.

Some unforeseen work became necessary on account of the meeting of the International Gold Mining convention, in the early part of July last, at Denver, Col. At the request of Governor Drake, I prepared a paper on the "Mining Resources of Iowa," and attended the convention in person as a delegate from this state. On the organization of the convention, however, it was ruled that only papers relating directly to gold mining should have a place on the program; but though the paper could not be formally presented to the convention, it was widely published in the journals of Iowa, as well as in some located outside the state.

By request, a paper on the Pleistocene history of our state was contributed to the Annals of Iowa, and another dealing with the history and genesis of our soils was prepared for the meeting of the State Horticultural society.

Mr. Bain was asked to prepare for the London meeting of the Federated Institution of Mining Engineers, a paper upon "Coal Mining by Machinery in Iowa," a subject to which he had devoted some attention. The paper was prepared and read, though Mr. Bain was unable to attend the meeting in person. It is now being printed in the transactions of that body and it is hoped ultimately that this and other phases of mining as carried on in Iowa may be adequately treated in one of the Survey reports. The fact that some of the first mining machines were tried in Iowa mines, and that some of the most successful have been invented here, makes the subject one of particular interest.

A not unimportant portion of the work of the Survey consists of answering inquiries relative to the location of deposits of various minerals in the state and their possible development. On the one hand, various citizens send to the Survey office samples of clay, stone, coal, sand or other minerals which they think are valuable, and on the other, intending investors inquire with reference to the location of deposits which they are interested in developing. It is the province of the Survey to bring these two classes together; a work which is greatly aided by the industrial departments of the various railway lines. It is not possible, of course, in every case to give a favorable report, but if the sample selected is of good quality and the other factors which must be taken into account in any development seem favorable, a personal inspection of the deposits as far as possible, is made; and the matter is then brought to the attention of parties likely to be interested. There are many inquiries, of course, for substances which do not occur in the state, but within the year inquiries have been received relating to the following substances, all of which occur, and probably at no distant date may be developed: Cement, chalk, clay, coal, flint, gypsum, lime, marble, ochre, stone, lead, iron, mineral paint, peat, and limestone pure enough for use in connection with the manufacture of beet sugar. In certain cases our work has led directly to placing orders with Iowa firms, and in other cases negotiations are now under way for the opening up of hitherto unworked deposits. The office has received many letters of thanks for such services, showing that our efforts are appreciated by those interested.

It should not be forgotten that a report by a disinterested state officer receives much more consideration than any given by local commercial bodies or interested parties; and, that entirely aside from these immediate and special instances, the resources of the state are being widely advertised in the best possible way by the regular reports of the Survey. Indeed these special inquiries usually follow the purchase of one or more of the Survey reports. Several of the substances noted above are in great demand and the Survey can readily interest capital in the development of most of them if the beds are up to the standard in quality. We would be glad to have notes on deposits of any of the minerals mentioned, since in the large portion of the state yet unsurveyed, there must be many beds worthy of development. In this work we have been somewhat hampered by reason of the fact that we have neither a well equipped laboratory nor sufficient funds for the exhaustive chemical and physical tests so often desirable. In many cases, however, the latter are not necessary, and much can be done even with the present facilities.

Early in the spring a local company was organized at Stuart for the purpose of prospecting for coal. Mr. Bain visited Stuart and consulted with the officers of this company with regard to the work. He told them that there was coal in the region, and that extensive prospecting would probably develop a good field, but that a few drill holes would not be decisive either way. The company decided to spend a small sum at least in the work, and two holes were put down. The first was evidently in an abandoned river channel as is shown by the record inserted in the Guthrie county report while the latter was in press*. The second showed slightly thicker coal. The prospecting was not extensive enough to settle the question of the presence or absence of workable coal in the region, but the results, so far as the work went, are on the whole favorable.

In accordance with resolutions passed at your July meeting, statistics of production of various minerals mined in the state are now being collected. Blanks have been made out and mailed to the various producers, and the returns so far

*Vol. VII, p. 476.

made indicate that the report will be general and hearty. There has heretofore been in Iowa no regular bureau for the collection of such statistics year by year, except in the case of coal, where the returns are made for the fiscal year and are published biennially. The statistics collected by outside agencies are necessarily incomplete, and each year injustice is done to the Iowa fields, thereby discouraging investment and making it more difficult to obtain adequate capital for the development of the resources of the state. It is believed that the careful collection and prompt publication of statistics, showing the production and value of the various minerals for each calendar year, and so allowing comparisons with other states to be made, will be of very great benefit to the state. Such a result can only be accomplished with the assistance of the producers themselves. We wish to do full justice to all interests, and have urged upon them the necessity of co-operation. In no case will the facts relating to the details of private business be published or disclosed. It is desired to publish the totals for the state, and to show the products county by county, whenever this can be done without disclosing facts of private character.

The importance of this work is very great. The collection and prompt publication of statistics allows something of an estimate to be made of the probable demand for the ensuing year. It also shows the growth of the various industries and so encourages investment and opens up the way for the development of new industries. The educational value is inestimable. By some peculiar trait of mind, we constantly minimize the value of the mining development going on around us, while the much more hazardous risk of investment in gold mines far away exerts a seductive influence hard to withstand. It is undoubtedly true that the best policy for any people is the fullest and most complete development of the natural resources of their own territory, and anything promoting that development deserves their hearty support. In the present case the producers are quite uniformly aiding the

Survey in its work, and as from year to year the mailing lists become more complete, it is hoped that the statistics may be more and more accurate. It is too early to give results more than to say that there has in general been a gratifying increase in business in several lines. Many brick companies report the trade for 1897 from 40 to 100 per cent better than for 1896; but in a large number of cases considerable stocks had been carried over from the preceding year. The paving brick industry has expanded remarkably. The gypsum industry is in a healthy condition, the Duncombe mill having been rebuilt with increased capacity and a new company having begun work. It is hoped that full statistics will be in hand before this volume has gone through the press, so that they may be published in it. Otherwise, they will be published as a special bulletin designed for immediate distribution. The work of collecting and tabulating the figures has been placed in the hands of Miss Newman.

The topographic work in Iowa, which was renewed last year by the United States Geological Survey, was continued during the working season of 1897. The territory covered by the United States topographers embraces a part of Dubuque county lying within the Driftless Area, and it is a pleasure to report that it is the purpose of the Director of the United States Survey to continue the work until the whole of the Driftless Area included in Iowa has been topographically mapped. It is also a pleasure to note here the care being taken in making these maps, and their great accuracy. It is impossible to estimate the importance of this work to the Iowa Survey. A good topographic base map is absolutely essential to successful geological work in such a region as the Driftless Area. It would be impossible, under present conditions, for the Iowa Survey to bear the great expense involved in making such a map, and yet without it we are practically prohibited from taking up work in some of the most important counties in Iowa. In the drift covered portions of the state three is no very intimate relation between topography and geological structure; in the Driftless Area topography and geological structure are inseparable. In the extreme northwestern portion of the state mapping has also been carried on, portions of Lyon and Sioux counties having been covered this season.

The officers of the Survey have been in communication with the Iowa Commission of the Omaha and Trans-Mississippi Exposition, relative to co-operation between the two organizations in the work of securing for Iowa an adequate representation of her mineral wealth. It is thought to be particularly important that the mineral resources of the state be fully displayed, since the exposition, being distinctly a western affair, will naturally attract many mining engineers and mine owners; men who, it is particularly desired, should have clear ideas of the importance of our coals, clays, cement rocks, etc., since they can be of especial assistance in securing the adequate development of these beds. It is also important to correct the misapprehension, widespread in the popular mind, that Iowa possesses no important sources of wealth other than agricultural. While the state must always depend largely upon its soils, its mining interests are by no means unimportant. When our mineral resources are fully developed, the disparity will be even less. I believe it to be within the province of the survey, in its work of educating the people of the state and advertising our resources to outsiders, to undertake an exhibit at Omaha, and I would respectfully urge upon your honorable body the advisability of taking some action looking to that end. The commission has shown itself very ready to co-operate with the Survey in the work, and it is believed that a fitting exhibit can be made at comparatively low cost. To this end I would respectfully ask that permission be given to lend for this purpose such specimens, cases, maps, photographs and data as may seem advisable, provided that the matter can be arranged without diverting the funds appropriated for the regular work of the Survey; and provided, also, that suitable guarantees be given for the safe return of the property. I would also ask that the officers of the Survey be allowed to spend such time as may be necessary in this connection, provided the matter can be arranged without interrupting the regular Survey work.

The Museum.—Additions of scientific and economic importance have been made to the museum during the past year, but it should be understood that the Survey is not prepared at present to expend much effort in making geological collections. The collection of specimens suitable for museum purposes requires time, and our field parties have usually been compelled to devote all the time at their command during the field season, to simply observing and recording the phenomena presented by the area they are directed to cover. In the second place parties in the field are not provided with means for transporting heavy material from the geological exposures to the railway stations. The cleaning, labeling and arranging of specimens in the museum is a task of no small magnitude, and it is believed that other lines of work are just now more pressing and better deserve the attention of the force in the office. Lastly, our present quarters are too small to afford space for the display of collections. Nevertheless some specimens are gathered as a matter of necessity, for there are many things that can only be satisfactorily studied in the office or the laboratory. Those that are of permanent value are added to the collections, but some are of no further use after they have been determined. In all cases parties in the field are directed to preserve specimens of more than usual interest, and the economic side of geology, as far as our space permits, is well represented by materials kindly contributed by manufacturers and quarrymen. A large amount of valuable material, in the form of the well borings collected and studied by Professor Norton in the preparation of his monograph on Artesian Wells, has been deposited at the office of the Survey, but this cannot be displayed, nor even made accessible to students at present, for lack of space.

As in previous years no effort has been made to build up by purchase the Survey library. The excellent facilities offered by the state library and the continued co-operation of the State Librarian have relieved the Survey from this drain upon its funds. Nevertheless we are receiving in exchange for our reports a considerable number of books and pamphlets, many of which could not be obtained by purchase, and all of which are valuable. The leading mining and geological publications both of this country and Europe come regularly to the office of the Survey, and are of great service in its work. A list of the more important serials, aside from the publications of the national and various state surveys, is appended. Many not found in this list come to the state library and in such cases no effort has been made to effect an exchange:

Archi. Sci. Phys. et Nat. (Genève.)
Acta Regia Soc. Physiog. (Lund.)
Amer. Manf. Iron World. (Pittsburg.)
Ann. Rep. Dept. Mines, Agri. N. S. W. (Sydney.)
Ann. Rep. Min. Mines Brit. Col. (Victoria.)
Atti. Soc. Ital. Sci. Natur. (Milano.)
Ber. Thät. St. Gallischen Nat. Wis. Gesell. (St. Gall.)
Black Diamond. (Chicago.)
Bol. Inst. Geol. Mexico. (Mexico.)
Bol. Soc. Geog. Italiana. (Roma.)
 Mem. idem. (Roma.)
Brickbuilder. (Boston.)
British Columbia Mining Record. (Victoria.)
Bul. Com. Géol. Finlande. (Helsingfors.)
Bul. Geol. Inst. Upsala. (Upsala.)
Bul. Lib. Mus. St. Laurent Col. (Montreal.)
Bul. Minnesota Acad. Nat. Sci. (Minneapolis.)
Bul. Nat. Hist. Soc. New Brunswick. (St. Johns.)
Bul. Soc. Géol. de Normandie. (Havre.)
Canadian Geol. Surv. Reports. (Ottawa.)
Cement Eng. News. (Chicago.)
Chicago Acad. Sci. Bul. (Chicago.)
Clay Record. (Chicago.)
Clay Worker. (Indianapolis.)
Coal Trade Journal. (New York.)
Colorado College Studies. (Colorado Springs.)
El Minero Mexico. (Mexico.)
Eng. Min Journal. (New York.)

Festsch. Naturfor. Ges. Zurich. (Zurich.)
Geol. Comm. Cape Good Hope Repts. (Cape Town.)
Helios. (Berlin.)
Industrial Advocate. (Halifax.)
Iowa Agri. Ex. Sta. Bul. (Ames)
Johns Hopk. Univ. Circulars. (Baltimore.)
Jour. Cincinnati Soc. Nat. Hist. (Cincinnati.)
Kansas Univ. Quart. (Lawrence)
Liverpool Geol. As. Jour. (Liverpool.)
Meddel. fran Industries Finland. (Helsingfors.)
Meded. Omtr. Geol. Van Nederland. (Amsterdam.)
Mem. Soc. Géol. du Nord. (Lille.)
Mem. and Proc. Manchester Lit. Philos. Soc. (Manchester.)
Mines and Minerals. (Scranton.)
Mining. (Spokane.)
Mining Bulletin. (Sta. Col. Pa.)
Mit. Min. Mus. Univ. (Bonn.)
Mit. Nat. Wis. Ver. Steiermark. (Graz.)
Mon. Rev. Iowa Weather Ser. (Des Moines)
Mus. Civ. Storia Nat. (Milano.)
Proc. Amer. As. Adv. Sci. (Salem)
Proc. Calif. Acad. Sci. (San Francisco.)
Proc. Colorado Sci. Soc. (Denver.)
Proc. Portland Acad. Sci. (Portland.)
Proc. Rochester Acad. Sci. (Rochester.)
Repts. Dep. Mines Victoria. (Melbourne.)
Repts. Govt. Geologist Queensland. (Brisbane.)
Sitzber. k. Böhm. Gesel. Wiss (Prag.)
Societatum Litteræ. (Frankfurt, A. O.)
Stone. (Chicago.)
Term. Fuz. Magyar Tudo. Akad. Segelyerel. (Buda Pest.)
Trans. Amer. Inst. Min. Eng. (New York.)
Trans. N. of E. Inst. M. M. E. (Newcastle-upon-Tyne.)
Trans. Roy. Geol. Soc. Cornwall. (Penzance.)
Trav. Sec. Géol. du Cab. de Sa Maj. (St. Petersburg.)
Univ. Calif. Bul. Dept. Geol. (Berkley.)
Univ. Idaho Exper. Sta. Bul. (Moscow.)
Verh. Schweizerischen Natfor. Gesell. (Zurich.)
Vierteljahr. Natfor. Gesell. (Zurich.)

It is gratifying to note the increased use of the reports of the Survey, as works of reference, or works for general study, in high schools and other educational institutions. Progressive teachers have been quick to recognize the educational value of trustworthy texts relating to the physical geography and geological phenomena of regions with which the students are personally acquainted. The economic problems treated in the reports are subjects with which all persons of liberal culture should become familiar before leaving the schools and entering business pursuits. A man of broad information relating to the actual structure of the earth's crust in his own locality, one who looks at the world intelligently and knows what geological products of economic value may with reason be expected to occur, and what may not, will be a far more useful citizen than he who without intelligence organizes companies and wastes means in attempts to exploit natural products where such products could not, by any possibility, exist. Untold sums of money have been wasted in searching for oil, gas, coal, lead and other useful substances in regions where such substances could not occur. All the waste of such energy and means, and all the consequent disappointment might have been spared had the persons concerned possessed the information which a survey, such as is now in progress, places within the reach of every individual of ordinary intelligence. Knowledge is vastly more valuable to every community than ignorance, and to the extent that the Survey reports diffuse knowledge, to that extent, if in no other way, are they performing a mission of incalculable value to the state of Iowa. And so I repeat that it is gratifying to note the increasing use of our reports as texts in institutions devoted to higher education. Applications for reports for use in classes, coming from high school men, are very numerous, and normal schools and colleges are using them in a way that promises a more intelligent appreciation of the natural resources of our grand state by the generation soon to become the leaders in business and other lines of human activity.

I have the honor to remain, gentlemen, with great respect,

Your obedient servant,

SAMUEL CALVIN,
State Geologist.

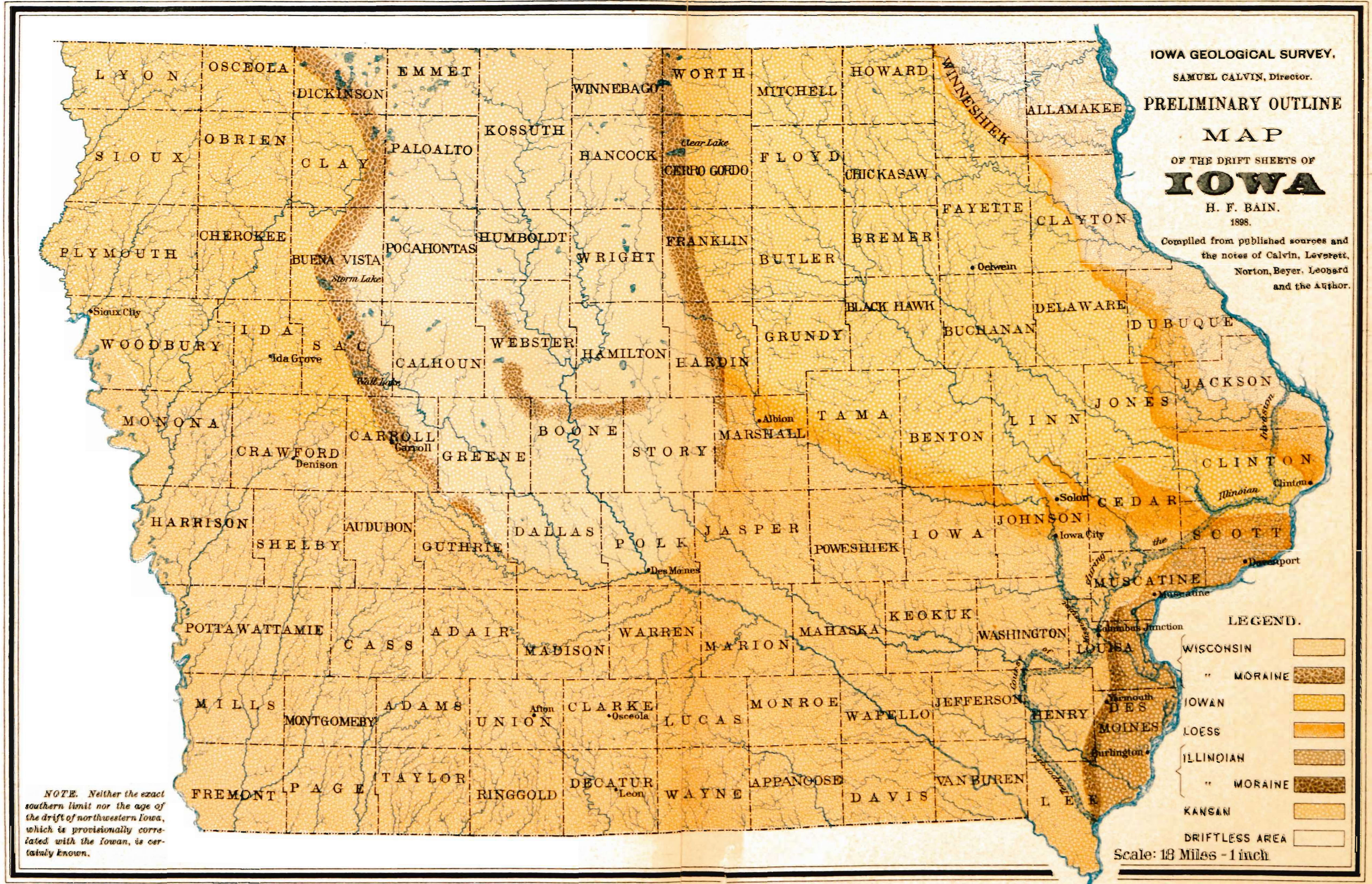


Photo-Lith. by A. HOEN & CO., Balto., Md.

REPORT OF THE ASSISTANT STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1897.

MY DEAR SIR—Upon my return to Des Moines in June, I assumed charge of the office work, at that time in the hands of Mr. Leonard. I have since been employed as usual in the routine work of the office and museum. Such time as could be spared has been spent in the field. Two general classes of problems have been under study. The first related especially to the Carboniferous of the southern and southwestern portion of the state, the second to the drift exposures of the northwestern counties. In connection with the former, the drift of the southern counties was to some extent studied, and the latter afforded the opportunity to add something to our knowledge of the Cretaceous.

After a review of the Carboniferous exposures of Madison county, a trip down Grand river, starting at Afton in Union county, was made for the purpose of correlating the Missourian rocks of the southern portion of the state with those found in the central portion. The section first made out in company with yourself and Professor Tilton in Madison county, and consisting of the four limestones called the Fusulina, Winterset, Earlham and Fragmental, were easily recognized as far south as Bethany, Mo., the typical locality for the Bethany limestone. In later excursions, the limestone and underlying beds were studied and mapped in detail in Decatur county, and have been less exactly mapped in Clarke county.

The study of the gravels and associated deposits at Afton was taken up early in the season, and several field trips were made through Union county, the reconnoissance work being carried as far as Bridgewater in Adair county and Albia in Monroe county. It was found that, except by taking more time than seemed advisable just at this time, it would be impossible to make a full report upon the subject within the present year; and, accordingly, after consultation with you, the field of operations was changed from Union to Decatur county. A full report upon the latter has been completed and is herewith submitted. A preliminary report upon the Aftonian beds was prepared and read before the winter meeting of the Iowa State Academy of Sciences. Incidentally, but in connection with the study of the drift, some attention was paid to the ballast clays burned at Maxon, Brush and Davis City. The clay ballast industry is rapidly making headway. The introduction of improved machinery, largely invented in Iowa, has cheapened the cost so much that the material, under certain conditions, competes with gravel by virtue of this alone. Over much of southern Iowa gravel is very rare or entirely absent, so that in this region burned clay must always be the main reliance of railway engineers. Its many peculiar advantages make it a welcome substitute for gravel, and will, in time, doubtless lead to its wide use on country roads, as well as in railway construction and maintenance. It is pleasant to be able to report that the supply of suitable material is, so far as Iowa is concerned, very widely distributed and practically inexhaustible. A paper upon the subject has been prepared for the Mineral Industry, with a view to attracting attention to our resources in this line. In connection with the work in this region, a careful study was made of the coal fields of Lucas county, and advice to certain parties prospecting there, relative to depths of holes and similar matters, given. The results have been all that could be desired, as the drill located workable coal to the extent of between two and three million tons.

In the work in the northwestern portion of the state, the main results have been (1) the discovery of certain chalk and clay beds near Le Mars, the second important exposure of these beds found east of the Missouri-Big Sioux valley; (2) the approximate determination of the southern limits of the Iowan (?) drift sheet in the region, and (3) the gaining of considerable light upon the physiography of the region and the history of the loess deposits. A detailed report upon Plymouth county has been written and is now being illustrated.

In addition to the work in Plymouth and Decatur counties, together including 1,394 square miles, work has been carried on in various counties as given below:

Union.—A study of the drift at Afton Junction and Thayer has been made. The Carboniferous rocks along Grand river have been visited and correlated. The clay pits of the entire county have been visited and some attention has been paid to the surface materials near Creston and in the western portion of the county.

Adair.—A reconnoissance trip was made to Bridgewater and notes on the surface formations collected.

Clarke.—The quarries of the county were visited and the eastern edge of the Missourian mapped in detail over most of the county. The buried gumbo east of Osceola was carefully studied. The ballast pit at Brush was visited.

Madison.—A general review of the rocks, particularly of the eastern portion of the county, was made.

Monroe.—The ballast pit at Maxon was visited and notes collected upon the surface deposits of the vicinity.

Sac.—The limits of the Wisconsin drift near Wall Lake and Carnarvon were made out, something was learned of the history of the lake and the upper Boyer, and the presence of the Iowan at Carnarvon and its relations to the loess were determined.

Carroll.—In excursions south and west of Carroll the presence of the Kansan was proven and notes on the loess and certain clays collected.

Ida.—The presence of the Iowan at Ida Grove, and for some considerable distance south, was determined.

Crawford—The presence of certain old gravels, in the Boyer valley near Denison, and of the Kansan with typical characteristics as far north as the northern tier of townships, was determined.

Woodbury.—The presence of Iowan near Correctionville and at Sioux City was noted and the southern limit of the formation accordingly considerably extended.

Sioux.—The gravels, clays, and soils near Hawarden and southeast of Orange City were especially studied. The noting of the presence of beds resembling the Pierre in the bluffs opposite Hawarden makes more certain the previous reference of the Hawarden beds to that formation. The character of the drift and the distribution of the loess in the eastern portion of the county was noted.

Lyon.—The presence of Iowan drift and a later loess, at several points near Rock Rapids was noted, harmonizing the work in the neighboring counties. The exposures along the Big Sioux and near Sioux Falls, suggest that this will prove one of the crucial counties in the study of the drift as it has in the work on the underlying rocks.

Cherokee.—The Wisconsin gravel train at Cherokee and southward was studied; the famous Pilot Rock, a large Sioux quartzite erratic, was visited, and the relations of the loess and Iowan drift noted.

Buena Vista.—The character of the Altamont moraine in and near Storm Lake was noted and the presence immediately outside of it of a fresh (Iowan) drift and a later loess was determined. At one point within the moraine undecisive evidence of a loess under the Wisconsin was noted.

Jasper.—The limit of the Wisconsin was traced across the northwestern corner of the county.

Hardin.—The age of the Eldora sandstone was determined to be Des Moines.

In addition certain general field trips were taken in your company and certain other rapid journeys, in which notes on the physiography of the regions passed through, were made. The usual letters of inquiry were answered, specimens examined and intending investors advised. The general volume of the latter work is rapidly increasing as the facilities of the Survey become better known and the general commercial situation improves. Respectfully yours,

H. F. BAIN,
Assistant State Geologist.

TO PROF. SAMUEL CALVIN,
State Geologist.

REPORT OF THE SECRETARY ON MINERAL PRODUCTION.

IOWA GEOLOGICAL SURVEY,
DES MOINES, February 23, 1898.

DEAR SIR—I submit herewith tables showing the production of the principal minerals mined in Iowa in 1897. In all cases the short ton, 2,000 pounds, has been used. No attempt has been made to calculate the tonnage or amount of stone or clay, though the number of thousands of brick will be found. Wherever in the tables a blank is left, the fact indicates that but a single producer in that county is reported for 1897.

Respectfully yours,

NELLIE E. NEWMAN,
Secretary.

TO PROFESSOR SAMUEL CALVIN,
State Geologist.

INTRODUCTION.

(BY H. F. BAIN.)

The importance of accurate statistics of production is now recognized by the masters of all great lines of industry. Their value is so well known that it would be superfluous to dilate on the subject. Most of the great mining interests of the country esteem such figures so highly that by combination and co-operation they provide for their collection at their own expense. This is not true, however, for all the mining industries, and particularly in the case of stone, clay and similar materials, where the production is scattered and the individual operations small, no very reliable agency for collecting statistics has existed. For local details one has been obliged to rely mainly on the infrequent census returns. It is true that for some years the United States Geological survey has collected statistics of the stone industry, and has more recently extended its work so as to cover the clay interests. The publication of these highly valuable returns, however, is so frequently delayed, and the reports reach so small a proportion of our own citizens, that there is a distinct want which they do not fill. The compilations of the Mineral Industry and the Engineering and Mining Journal have also the drawback that they reach a very small proportion of the citizens of Iowa. It has been felt for some time that there was an important work here which should be undertaken by some one of the state bureaus, and that it was particularly within the province of the Geological Survey. The difficulties in the way were, however, so considerable, and the time of the officers of the Survey so taken up, that some hesitation was felt as to the advisability of taking up the work. Furthermore, we already have carefully collected statistics of the coal industry through the office of the State Mine Inspectors, and it was recognized that the filling of numerous blanks is not a thing which operators especially delight in. Nevertheless, when it was finally decided to undertake the work, it was thought better to include coal in the subjects inquired after for several reasons. In the first place, the report of the Mine Inspector is required by law to be made biennially, and, while earlier returns have always been given the newspapers, details are not at hand for the use of the operator except every second year. Again, the reports heretofore published include only lump coal, a fact not usually noted in quoting them, so that the state is not credited abroad with its full production. It is also true that returns from many of the states, and in all other industries, are made up for the calendar year, so that for purposes of comparison it is best to have statistics for the same period. The fiscal year on the other hand accords more nearly with the mining year, so that for purposes of showing the growth of the industry, figures for that period are better. Each set of figures has a value and for certain purposes each has its use.

The very prompt and hearty co-operation shown by the operators deserves, and has, the fullest thanks of the Survey. They have, almost without exception, either sent in the returns asked, or written explaining the cause, delay in making up the books, change of firm, or other reason, why they could not yet do so. Not a single important clay or stone producer in the state has failed to give us the figures asked for. The returns for these industries and for lead and zinc are believed to be practically complete; certainly so within one or two per cent. In the figures given for coal there is an estimate of about nine per cent, very carefully made and believed to represent minimum figures. Most of the returns here estimated have been promised, but it is believed better not to longer delay publication by waiting for them. The gypsum returns are largely estimated by one familiar with the industry, but are believed to be close.

The hearty response which the Survey has met in this work indicates apparently that there is a demand for it, not in opposition to agencies already engaged in the task, but supplementary thereto.

MINERAL PRODUCTION OF IOWA IN 1897.

Total Production.

The value of the total mineral production of the state in 1897 was $7,446,800.42, distributed as follows:

Coal	$5,098,103.84
Clay	1,591,866.00
Stone	587,144.58
Gypsum	195,000.00
Lead and zinc	5,616.00
Iron	250.00
Total	$7,477,800.42

The production is shown by counties in table I.

TABLE I.

Total value of mineral production by counties.

COUNTIES.	Total clay.	Total coal.	Total stone.	Miscellaneous.
Adair	*	$ 5,000.00		
Adams	$ 10,350.00	16,967.00		
Allamakee			$ 8,237.50	$ 336.00
Appanoose	12,600 00	738,266.29	20.90	
Aububon	*			
Benton	7,200.00		3,564.00	
Black Hawk	11,255.00		2,667.50	
Boone	36,212.00	421,766.87		
Bremer	*			
Buchanan	*		175 00	
Buena Vista	*			
Butler	*			
Calhoun	3,850.00			
Carroll	3,600.00			
Cass	8,065.00			
Cedar	*		105,552.59	
Cerro Gordo	*		6,408.64	
Cherokee	*			
Chickasaw				
Clarke	*		1,347.50	
Clay	*			
Clayton	*		7,434.50	800.00
Clinton	7,090.00		3 051.00	
Crawford	9,300.00			
Dallas	35,107.00	22,281.16		
Davis	*	4,471.80		
Decatur	2,760.00		10,102.00	
Delaware	*			
Des Moines	38,053.00		82,179.60	
Dickinson				
Dubuque	25,479.00		33,072.85	2,680.00
Emmet				
Fayette	*		2,475.00	
Floyd	*		4,709.60	
Franklin	*			
Fremont	8,365.00			
Greene		29,892.32		
Grundy				
Guthrie	32,635.00	31,072.14		
Hamilton	51,725.00			
Hancock				
Hardin	20,445.00		9 850.00	
Harrison	5,380.00			
Henry	15 400.00		1,850.00	
Howard	*		1,755.00	
Humboldt				
Ida	*			
Iowa	13,375.00			
Jackson	*		59,070.00	
Jasper	12,314.00	172,747 08	4,350.00	

TABLE I—CONTINUED.

COUNTIES.	Total clay.	Total coal.	Total stone.	Miscellaneous.
Jefferson		$ 1,237.08	$ 3,400.00	
Johnson	$ 19,930.00		2,616.50	
Jones	*		44,141.45	
Keokuk	13,380.00	264,434.10	1,364.50	
Kossuth	*			
Lee	13,675.00		32,009.85	
Linn	14,824.00		10,095.00	
Louisa			2,275.00	
Lucas	3,400.00	14,530.00		
Lyon				
Madison	2,600.00		14,945.60	
Mahaska	41,284.00	1,402,929 15	5,285.00	
Marion	5,300.00	114,750.09	990.00	
Marshall	145,387.00		59,467.50	
Mills	13,510.00			
Mitchell			2,955.00	
Monona				
Monroe	600.00	542,206.17		
Montgomery	24,050.00		1,030.00	
Muscatine	13.000.00		213.75	
O'Brien				
Osceola				
Page	11,400 00	4,940.00		
Palo Alto				
Plymouth	*			
Pocahontas				
Polk	362,526.00	700,758.20		
Pottawattamie	28,283.00			
Poweshiek	7,770.00			
Ringgold	7,550.00			
Sac	*			
Scott	42,524.00	5,435.34	47,634.20	
Shelby	7,400.00			
Sioux	*			
Story	6,170.00	19,445.85		
Tama	37,150.00		575.00	
Taylor	*	16,330.02		
Union	6,140.00			
Van Buren	3,300.00	7,438.39	4,050.00	
Wapello	46,176.00	263,956.00	5,975.00	
Warren		13,622.18		
Washington	23,785.00		4,750.00	
Wayne	*	77,811.51		
Webster	61,183.00	205,810 10	1,600.00	$ 195,000.00
Winnebago				
Winneshiek	*			
Woodbury	122,920.00			
Worth				
Wright	11,350 00			
Single producers	107,474.00			
Estimated additions	20,000.00		2,000.00	
Total	$1,591,886.00	$5,098,103.84	$587,144.58	$ 195,000.00

*Single procedures in 1897.

COAL.

The year was, so far as tonnage was concerned, one of the best the Iowa field has yet experienced. Prices, however, were low, dropping a little below those of preceding years. The year opened dull and the summer trade was even lighter than usual. The fall trade was, however, heavy enough to redeem the year. The strike in Illinois threw considerable trade into the hands of Iowa operators and the heavy hauling in the fall largely increased railroad sales. A few cases of car famine were reported. From the tables given below it will be seen that 49 per cent of the Iowa coal is used by the railways; and 8 per cent is used at the mines or sold to local dealers. The remainder is sold at points within and without the state where there are no mines. In Table II is given the number of mines reporting, total tonnage, average value and total value.

TABLE II.

Coal output by counties.

COUNTIES.	Mines reporting.	Tons.	Price per ton.	Value.
Adams	16	8,555	$ 1.94	$ 16,967.00
Adair	.....	2,500	2.00	5,000.00
Appanoose	44	653,333	1.13	738,266.29
Boone	14	261,967	1.61	421,766.87
Dallas	7	14,102	1.58	22,281.16
Davis	3	3,084	1.45	4,471.80
Greene	2	19,666	1.52	29,892.32
Guthrie	9	15,693	1.98	31,072.14
Jasper	11	159,951	1.08	172,747.08
Jefferson	3	1,014	1.22	1,237.08
Keokuk	6	251,842	1.05	264,434.10
Lucas	4	7,265	2.00	14,530.00
Mahaska	19	1,336,123	1.05	1,402,929.15
Marion	8	126,099	.91	114,750.09
Monroe	14	547,683	.99	542,206.17
Page	2	3,800	1.30	4,940.00
Polk	16	620,140	1.13	700,758.20
Scott	5	3,462	1.57	5,435.34
Story	1	12,097	1.61	19,445.85
Taylor	2	9,226	1.77	16,330.02
Van Buren	5	5,857	1.27	7,438.39
Wapello	12	239,960	1.10	263,956.00
Warren	9	9,526	1.43	13,622.18
Wayne	5	60,319	1.29	77,811.51
Webster	8	150,230	1.37	205,815.10
Total	225	4,523,494	$ 1.12½	$ 5,098,103.84

In Table III is the percentage of lump, nut and slack and the percentage of local shipping and railway sales by inspection districts.

TABLE III.

DISTRICTS.	SIZES, PER CENT.			SALES, PER CENT.		
	Lump.	Nut.	Slack.	Local.	Shipping.	Railway.
No. 1	79	10	11	7	46	47
No. 2	80	7	13	5	14	63
No. 3	81	9	10	25	48	18
State	80	10	10	8	43	49

In comparing the figures in Table II with those of former years it must be remembered that the figures are for all coal and for the calendar year. The best obtainable figures on the same basis for former years is given below.

TABLE IV.

YEARS.	TONS.	PRICE.	VALUE.	AUTHORITY.
1892	3,918,491	$ 1.32	$ 5,175,060	U. S G. S.
1893	3,972,229	1.30	5,110,460	U S. G. S.
1894	3,967,253	1.26	4,997,939	U. S. G. S.
1895	4,156,074	1.20	4,982,102	U. S. G. S.
1896	3,954,028	1.17	4,628,022	U. S. G. S.
1897	4,523,494	1.12½	5,098,104	Iowa Survey.

Since the growth in the production is in the case of coal better shown by reports for the fiscal year the following table compiled from the reports of the State Mine Inspector is reproduced:

TABLE V.

Lump coal production in tons for the fiscal years 1892-1897.

COUNTIES.	June 30, 1892	June 30, 1893	June 30, 1894	June 30, 1895	June 30, 1896	June 30, 1897
Adams	13,940	18,925	30,640	35,000	21,220	30,500
Adair	....	....	2,500	2,642	1,600	2,500
Appanoose	524,400	631,875	528,640	350,000	346,453	372,402
Boone	202,507	185,916	189,000	191,972	286,763	229,285
Dallas	31,841	36,188	17,500	16,503	18,701	16,781
Davis	2,065	2,220	2,520	2,900	2,800	3,120
Greene	29,012	49,453	14,000	38,296	10,328	17,085
Guthrie	12,042	14,000	12,340	11,240	10,840	11,340
Jasper	293,255	292,000	240,985	160,300	121,200	153,000
Jefferson	5,020	4,940	4,840	4,000	4,200	5,000
Keokuk	312,250	272,150	215,625	260,000	222.300	201,000
Lucas	7,495	10,200	7,564	12,000	8.500	9,055
Mahaska	1,048,030	1,172,530	965,696	902,430	1,100,900	1,184,850
Marion	219,411	233,582	172,847	150,361	198,554	138,019
Monroe	521,785	641,805	512,240	315.354	401,650	389,706
Page	....	1,450	....	4,200	6,420	7,250
Polk	371,389	466,408	355,000	334,881	415,695	572,895
Scott	9,850	14,500	13,500	10,100	13,100	13,500
Story	....	....	....	4,620	10,340	12,240
Taylor	14,930	35,170	35,475	13,000	10,100	13,200
Van Buren	27,330	28,680	22,000	11,000	15,000	14,300
Wapello	253,075	279,160	186,748	205,900	150,405	152,203
Warren	9,570	14,575	25,454	12,000	12,120	16,150
Wayne	33,600	61,835	68,330	45,700	30,100	32,120
Webster	104,679	145,274	153,247	103,349	106,201	101,643
Total	4,047,479	4,612,872	3,776,691	3,195,836	3,525,490	3,799,734

According to the United States Geological Survey the average number of days worked in recent years has been as follows:

1892	236
1893	204
1894	170
1895	189
1896	178

In 1897 the average was 190, ranging by counties from 88 to 254. Only a few of the largest mines having big railway contracts worked full time. There was a wide variation in the price of coal, as is shown by the table already given. Lump coal averaged $1.25. It is impossible to give a very good estimate of the nut and smaller sizes, as the coal is not all screened alike and much is sold as mine run. The percentages of sizes given were obtained by including only the coal reported separately. They do not mean necessarily that 80 per cent of the coal was actually sold as lump. There is a wide variation in these percentages, depending on the character of coal, arrangement of screens and care in handling. The range, was, lump, 65.93 per cent; nut, 20.8 per cent; pea and slack 18.4 per cent.

According to the United States Geological Survey, Iowa in 1895 ranked sixth in bituminous coal tonnage, and first among the states west of the Mississippi. The production for the ten leading states was as follows:

		TONS.	VALUE.
1.	Pennsylvania	50,217,228	$ 35,980,357
2.	Illinois	17,735,864	14,239,157
3.	Ohio	13,335,806	10,618,477
4.	West Virginia	11,387,961	7,710,575
5.	Alabama	5,693,775	5,126,822
6.	Iowa	4,156,074	4,982,102
7.	Indiana	3,995,892	3,642,623
8.	Maryland	3,915,585	3,160,592
9.	Kentucky	3,357,770	2,890,247
10.	Colorado	3,082,982	3,675,185

In 1896 Maryland went ahead, though Iowa remained the leading state west of the Mississippi. The figures for the latter year are as follows:

		TONS.	VALUE.
1.	Pennsylvania	49,557,453	$ 35,368,249
2.	Illinois	19,789,626	15,809,736
3.	West Virginia	12,876,296	8,336,685
4.	Ohio	12,875,202	10,253,461
5.	Alabama	5,748,697	5,174,135
6.	Maryland	4,143,936	3,299,928
7.	Iowa	3,954,028	4,628,022
8.	Indiana	3,905,779	3,261,737
9.	Kentucky	3,333,478	2,299,928
10.	Colorado	3,112,400	3,606,642

CLAY.

The trade in clay products is in the most satisfactory condition which it has been since 1893. The outlook for the paving brick industry is especially encouraging. The Des Moines producers, for example, in 1896 marketed 18,000,000 pavers, a large portion being old stock and very little manufacturing being done. In 1897 the same plants turned out and sold 36,300,000 brick for the handsome sum of $252,984. The Northwestern Sewer Pipe works at Sioux City this year turned their attention to pavers and could have sold three times their actual output. In the building brick industry producers report trade from twenty to forty per cent better, except in the case of small producers shut out of the general market. The year started with heavy stocks carried over and dull trade, but soon livened up and the old stocks went off rapidly. Many plants which had been shut down half or full time in 1896, ran full time in 1897. The demand was for low priced goods. The fancy grades of brick have never had a large sale in Iowa, and for the present are a drug on the market. One large and well equipped plant, after a hard struggle to develop a trade in these lines, has gone out of the market and other manufacturers are turning their attention to common grades. The long haul to foreign markets and the absence of large local cities makes it impossible at present to develop a trade, despite the fact that the best of goods are offered.

The returns show 284 plants in operation this season, and give the total value of the brick produced at $1,142,014, and of all clay products, $1,562,886. These amounts are distributed as follows:

	NO. THOUSANDS.	PRICE PER M.	VALUE.
Common brick	141,032	$ 4.80	$ 678,208
Stock pressed and enameled	10,669	6.10	66,058
Pavers	56,315	7.14	402,018
Fire brick	269	17.58	4,730
Drain tile			303,524
Sewer pipe			47,165
Terra Cotta hollow brick, etc			41,155
Miscellaneous			11,121
Raw clay			2,032
Pottery			15,875
Total			$1,571,886
Estimated additional			20,000
Total			$1,591,886

The totals for 1894 and 1895 as given by the United States Geological Survey were as follows:

	1894.	1895.	1896.
Common brick	....	$ 1,095,074	$ 1,003,624
Stock, pressed and fancy	$ 1,320,423	89,430	47,386
Pavers	376,951	243,928	112,985
Fire brick	36,000	5,900	5,198
Tile and Terra cotta	566,407	309,809	659,391
Sewer pipe	58,000	55,131	73,039
Pottery	....	25,600	43,035
Miscellaneous	21,200	45,400	....
Total	$ 2,379,506	$ 1,870,292	$ 1,944,658

In 1894 the average price of common and pressed brick is given as $6.33, while pavers brought $8.29. In 1895 common brick were $6.07, pressed brick $7.81 and pavers $7.69. In 1896 the corresponding figures were $5.83, $7.78, and $7.85.

The production by counties is given in Table VI. Counties in which but one plant is reported as active in 1897 are mentioned in their proper order, but their production is not given separately.

TABLE VI.

	COUNTY.	THOUSANDS. Common brick.	THOUSANDS. Total brick.	VALUE. Common brick.	VALUE. Total brick.	VALUE. Total clay.
1	Polk	9,443	45,748	$ 58,527	$ 311,611	$ 362,526
2	Marshall	15,310	21,360	64,207	95,462	145,387
3	Woodbury	14.100	20,730	69,500	116,470	122,920
4	Webster	4,500	5,350	21,200	28,200	61,183
5	Hamilton	2,050	2,050	12,350	12,350	51,725
6	Wapello	3,045	7,285	15,995	44,676	46,176
7	Scott	2,310	6,063	25,030	42,254	42,524
8	Mahaska	2,600	4,612	17,400	32,484	41,284
9	Des Moines	2,490	5,290	11,678	34,078	38,053
10	Tama	4,350	4,975	22,250	27,400	37,150
11	Boone	1,337	3,212	7,612	23,287	36,212
12	Dallas	1,033	2,145	9,631	19,684	35,107
13	Guthrie	1,457	1,457	8,680	8,680	32,635
14	Cerro Gordo					
15	Pottawattamie	4,897	5,397	23,883	27,883	28,283
16	Dubuque	5,995	6,015	25,359	25,479	25,479
17	Montgomery	3,030	3,020	17,200	17,500	23,050
18	Washington	2,405	2,405	14,580	14,580	23,785
19	Hardin	383	583	2,523	3,143	20,445
20	Johnson	2,835	2,835	14,300	14,300	19,930
21	Greene					
22	Henry	1,130	1,130	6,400	6,400	15,400
23	Linn	1,550	1,550	9,870	9,870	14,824
24	Lee	2,400	2,500	12,550	13,350	13,675
25	Mills	2,070	2,070	13,510	13,510	13,510
26	Keokuk	1,147	1,147	6,830	6,830	13,380
27	Iowa	850	850	5,225	5,225	13,375
28	Muscatine	900	900	4,500	4,500	13,000
29	Appanoose	400	1,900	2,000	12,000	12,600
30	Jasper	1,398	1,398	7,914	7,914	12,314
31	Wright	400	400	2,650	2,650	11,350
32	Page	1,100	1,100	6,600	6,600	11,400
33	Black Hawk	20,060	20,060	10,300	10,300	11,255
34	Adams	2,000	2,000	10,050	10,050	10,350
35	Wayne					
36	Crawford	1,300	1,320	9,100	9,300	9,300
37	Fremont	1,420	1,480	7,945	8,365	8,365
38	Cass	1,072	1,072	8,065	8,065	8,065
39	Poweshiek	500	500	3,000	3,000	7,770
40	Ringgold	950	950	6,500	6,500	7,550
41	Shelby	1,200	1,200	7,200	7,200	7,400
42	Benton	700	700	3,600	3,600	7,200
43	Cedar					
44	Clinton	415	415	2,840	2,840	7,090
45	Story	340	340	2,420	2,420	6,170
46	Union	856	856	5,965	5,965	6,140
47	Harrison	776	776	4,630	4,630	5,380
48	Cherokee					
49	Marion					
50	Delaware	300	300	1,800	1,800	5,185
51	Jefferson					
52	Adair					

TABLE VI—CONTINUED.

	COUNTY.	THOUSANDS.		VALUE.		
		Common brick.	Total brick.	Common brick.	Total brick.	Total clay.
53	Franklin	....	....	....	....	....
54	Calhoun	6	6	50	50	3,850
55	Carroll	600	600	3,600	3,600	3,600
56	Lucas	550	550	3,400	3,400	3,400
57	Van Buren	100	104	700	1,500	3,300
58	Taylor	....	....	....	....	....
59	Decatur	460	460	2,760	2,760	2,760
60	Fayette	....	....	....	....	....
61	Jackson	....	....	....	....	....
62	Jones	....	....	....	....	....
63	Bremer	....	....	....	....	....
64	Floyd	....	....	....	....	....
65	Davis	....	....	....	....	....
66	Winneshiek	....	....	....	....	....
67	Clayton	....	....	....	....	....
68	Howard	....	....	....	....	....
69	Clay	....	....	....	....	....
70	Ida	....	....	....	....	....
71	Buena Vista	....	....	....	....	....
72	Plymouth	....	....	....	....	....
73	Clarke	....	....	....	....	....
74	Kossuth	....	....	....	....	....
75	Audubon	....	....	....	....	....
76	Warren	....	....	....	....	....
77	Sioux	....	....	....	....	....
78	Monroe	120	120	600	600	600
79	Buchanan	....	....	....	....	....
80	Sac	....	....	....	....	....
81	Butler	....	....	....	....	....
82	Single producers	10,312	10,312	63,729	66,749	107,474
	Total	140,032	208,098	$673,208	$1,142,014	$1,562,886

It is impossible as yet to state what the rank of Iowa in 1897 was. In 1895 it was ninth in the total value of its clay goods, and in 1895 fifth in the value of its paving brick. In 1896 it stood seventh in the latter. These facts are shown by the following tables, taken from the reports of the United States Geological Survey.

TABLE VII.

Total clay, 1895.

STATES.	Number of firms.	Value.	Per cent of total.
Ohio	980	$10,649,382	16.30
Pennsylvania	513	8,807,161	13.48
Illinois	678	7,619,884	11.67
New York	280	5,889,496	9.02
New Jersey	130	4,899,120	7.50
Indiana	659	3,117,520	4.77
Missouri	221	2,799,218	4.29
Massachusetts	112	2,221,590	3.40
Iowa	412	1,870,292	2.86
California	94	1,421,154	2.18

Total clay, 1896.

Ohio	1,021	$ 9,949,571	15.96
Pennsylvania	536	9,063,313	14.54
New York	295	6,414,206	10.29
Illinois	836	5,863,247	9.40
New Jersey	140	4,728,003	7 58
Missouri	290	2,680,245	4.30
Indiana	827	2,674,325	4.29
Massachusetts	125	2,262,974	3.63
Iowa	519	1,944,658	3.12
Maryland	137	1,450,055	2.33

TABLE VIII.

Paving brick in 1895.

STATES.	Thousands.	Value.	Price per M.
Ohio	96,555	$ 787,878	$ 8.16
Illinois	82,526	643,997	7.80
West Virginia	62,330	449,388	7.21
Pennsylvania	36,268	305,035	8.41
Iowa	31,704	243,928	7.69
Indiana	22,313	204,000	9.14
New York	10,896	121,892	11.19
Kansas	7,902	62,190	7.87
Missouri	6,816	54,640	8.01
Rhode Island	4,000	48,000	12.00
United States	381,591	3,130,472	8.20

Paving brick in 1896.

Ohio	72,254	$ 619,463	$ 8.57
Illinois	60,955	486,519	7.98
Pennsylvania	47,229	404,182	8.57
New York	23,723	259,550	10.94
Indiana	41,292	175,670	4.25
Kansas	16,934	125,293	7.39
Iowa	14,385	112,985	7.15
Kentucky	7,000	70,000	10.00
Missouri	7,500	61,500	8.20
Rhode Island	4,000	48,000	12.00
United States	347,167	2,794,585	8.05

STONE.

The quarries of Iowa are mostly small. The stone quarried includes limestone, dolomite and a limited amount of sandstone. The industry is yet in its infancy and there are many excellent quarry sites yet unoccupied. Returns from 242 producers, including every important quarry in the state and most of the small ones, show that $584,944.58 worth of stone was marketed in 1897. To this may be added $2,000 as the value of stone from small quarries not yet reported. This production was distributed as follows:

Rough and rubble	$ 130,005.69
Dimension stone	66,792.30
Crushed for concrete and road use	74,862.95
Lime	123,193.65
Miscellaneous	156.531.74
Unspecified	33,758.25
Total	$ 585,144.58
Estimated addition	2,000.0C
Total	$ 587,144.58

The stone used for miscellaneous purposes was mainly quarried for rip-rap in the Mississippi river improvements.

The production by counties is given below.

TABLE IX.

Value of stone produced in Iowa in 1897.

COUNTIES.	Total.	Rough and rubble.	Dimensions.	Concrete and road use.	Lime.	Miscellaneous
Cedar	$ 105,552 59	$ 4,156.45	$ 934.95	$ 6,579.30	$ 22,620.15	$ 71,261.74
Des Moines	82,179.60	14,062.00	7,017.60	3,500.00	300.00	57,300.00
Marshall	59,467.50	1,557.00	16,800.00	27,093.50	58,550.00	....
Jackson	59,070.00	460.00	....	60.00	....	....
Scott	47,634.20	14,501.20	300.00	10,158 00	675.00	22,000.00
Jones	44,141.45	9,736.50	14,082.25	3,228.25	....	250.00
Dubuque	33,072.85	17,537.85	3,600.00	1,250.00	10,500.00	185.00
Lee	32,009.85	14,097.85	3,275.00	9,137.00	....	5,500.00
Madison	14,945.65	4,984.85	1,000 00	8,920.80	40.00	....
Linn	10,095.00	2,425.00	2,570.00	100.00	5,000.00	....
Hardin	9,850.00	8,100.00	400.00	150.00	1,200.00	....
Allamakee	8,237.50	600.00	7,400.00	....	237.50	....
Clayton	7,434.50	3,268.50	542.50	12 50	3,611.00	....
Cerro Gordo	6,408.64	2,186.64	198.00	24.00	4,000.00	....
Wapello	5,975.00	5,250.00	500.00	....	250.00	....
Mahaska	5,285.00	2,095.00	40.00	....	3,150.00	....
Washington	4,750.00	2,925.00	1,825.00	....	....	....
Floyd	4,709.60	1,550.00	600.00	1,509.60	1,050.00	....
Jasper	4,350.00	950.00	500.00	900.00	....	....
Van Buren	4,050.00	2,250.00	....	....	1,800.00	....
Benton	3,564.00	500.00	64.00	....	3,000.00	....
Jefferson	3,400.00	1,150.00	2,250.00	....	....	....
Clinton	3,051.00	1,376.00	....	....	1,675.00	....
Mitchell	2,955.00	735.00	45.00	125.00	2,050.00	....
Black Hawk	2,667.50	2,577.50	30.00	15.00	45.00	....
Johnson	2,616.50	1,842.00	109.50	265.00	400.00	....
Fayette	2,475.00	....	....	....	2,475.00	....
Louisa	2,275.00	2,025.00	250.00	....	....	....

TABLE IX—CONTINUED.

COUNTIES.	Total.	Rough and rubble.	Dimensions.	Concrete and road use.	Lime.	Miscellaneous
Henry	1,850.00	450.00	500 00	....	....	....
Howard	1,755.00	1,470.00	85.00	200.00	....	....
Webster	1,600.00	1,400.00	....	200.00	....	....
Keokuk	1,364.50	789.70	385 00	150.00	40.00	....
Clarke	1,347.50	237.50	1,075.00	....	....	35.00
Montgomery	1,030.00	630.00	300.00	100.00	....	....
Decatur	1,002.00	857.50	....	145.00	....	....
Marion	990.00	650.00	100.00	40.00	200.00	....
Tama	575.00	350.00	....	....	225 00	....
Muscatine	213.75	213.75	....	....	....	....
Buchanan	175.00	45.00	500.00	....	125.00	....
Appanoose	20.90	12.90	8.00	....	....	....
Total	$ 585,144.58	$ 130,005.69	$ 66,792.30	$ 74,862.95	$ 123,193 65	$ 156,531.74

In general the trade conditions in stone were not greatly different from those of 1896. The small quarries report larger sales and there seems to have been a general, though slight, increase in the amount of stone taken out for building purposes. There was no great change in the amount of rock used for concrete and road uses.

In 1896 the state ranked nineteenth among the stone producers, and contributed 1½ per cent of the total.

The value of the stone produced in Iowa in recent years, according to the U. S. Geological Survey, has been as follows:

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

The production for 1896 was distributed as follows:

Limestone—	
Building and road making	$329,123
Lime	80,914
Marble	39,740
Sandstone	12,351
Total	$462,128

According to these figures there was a considerable increase in 1897, particularly in the production of lime. This seems, however, to have taken place in the minor rather than in the chief lime-burning centers where the trade is reported little, if any, better than in 1896.

LEAD AND ZINC IN 1897.

The Iowa lead and zinc field is continuous with that of Wisconsin and Illinois. The ores are found mainly in the Trenton-Galena limestone, but one mine takes ore from the Oneota (Lower Magnesian). Of recent years the production has been small, lead mining which once gave importance to the Dubuque mines having almost ceased. Zinc is now the principal ore. In 1897 a total of 3,600 pounds of lead, valued at $736, was mined in three counties. This was reduced in part at Dubuque, but in the main went to Chicago and Aurora, Ill. Zinc was mined at four points; a total of 14,800 pounds of ore was raised. The total value was $4,880. The ores went to Mineral Point, Wis., and brought an average of $6.59 per ton. Most of the ore brings at current prices $7, but one mine ships a lower grade of ore which reduces the average to the figures given. This property, the Durango mine, has not been heavily worked since 1891, when it shipped 310 tons in one month. There is a large amount of ore in sight which can be cheaply mined. The company expects to considerably enlarge their output in 1898. The Buena Vista mine in Clayton county has recently passed into the hands of the E. T. Goldthorp & Sons Mining Co., and has been thoroughly overhauled. This property includes a large body of ore. It was discovered in 1857, but has not been much worked of recent years. It can easily produce 100 tons per month of zinc and 2,000 pounds of lead with a small force of men, and if present prices are maintained it may be expected to yield well up to the limit.

An interesting development in the region is the opening by the Limonite Ore Co. of a body of low grade iron ore for mineral paint. This mine was opened in 1896 and 1897, and 250 tons at $1 per ton were shipped. The work is yet in an experimental state. There are in the region considerable bodies of limonite which may prove of considerable value in this connection. Analyses of sample lots are as follows:

NUMBER.	IRON.	SULPHUR.	PHOSPHOROUS.
275	54.32	None	1.30
278	66.92	.047	.503
279	58.68	None	1 15

GEOLOGY OF DALLAS COUNTY.

BY

A. G. LEONARD.

GEOLOGY OF DALLAS COUNTY.

BY A. G. LEONARD.

CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Dallas county is located just south and west of the center of the state. It is in the fourth tier of counties from the southern boundary, and is fifth in number from the Missouri river. Townships 78 to 81 north and ranges XXVI to XXIX west of the fifth principal meridian are included within the limits of the county. It thus embraces sixteen congressional townships, and has an area of 588 square miles. A correction line causes a slight increase in the length of the southern tier of townships. The county is bounded on the north by Boone and Greene, on the east by Polk, on the south by Madison and on the west by Guthrie.

PREVIOUS GEOLOGICAL WORK.

The first geologist who visited Dallas county was Mr. O. H. St. John, who in 1867 made a hurried exploration of this and neighboring counties. A brief statement of results published in a preliminary report* mentions the occurrence of the coal measures within the county. The coal seam at Redfield is noted, and mention is also made of the thick bed of sandstone present at this place.

A more extended account of the geology of the county, written by Mr. St. John, was published in the final report of the Survey.† It is devoted largely to a description of various exposures along the Raccoon river and its chief tributaries. The Upper, Lower and Middle Coal Measures of White are shown to occur in the county.

The presence of the Wisconsin drift in Dallas county is referred to incidentally by Upham,‡ who traced the limits of the Wisconsin lobe in adjacent counties and states, who stated that its border probably extends across the southwestern part of the county.

Keyes visited the exposures at Van Meter and De Soto and has published the sections occurring at those localities.§ Numerous references to the coal beds of Dallas county are also contained in the report on Coal Deposits.‖

*First and Second Ann. Rep., State Geologist, pp. 84-87. Des Moines, 1868.

†Geol. of Iowa, Vol. II, pp. 13-46. Des Moines, 1870.

‡Geol. Nat. Hist. Surv., Minn., Ninth Ann. Rept., 1880, p. 307. Minneapolis, 1881.

§Iowa Geol. Surv., Vol. I, p. 98. Des Moines, 1893. Bul. Geol. Soc. Am., Vol. II, p. 281. 1891.

‖Keyes: Iowa Geol. Surv., Vol. II, pp. 253-267. Des Moines, 1894.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface features of Dallas county may be briefly characterized as those of a drift plain which for the most part has been but slightly modified by erosion. Over the larger portion of the area the original surface of this plain has been little affected by the action of streams, and it is the absence of erosion effects that at once strikes the observer. It is only in the southern townships of the county that the original plane has been much cut up by rivers. Here broad valleys with numerous side ravines have been carved in the soft, superficial deposits. The southern part of the county, therefore, presents a much more diversified and a rougher appearance than the northern area.

While the line separating these two topographically distinct regions cannot be sharply defined, since they merge more or less into each other, it may be said that in a general way the boundary follows the Raccoon river. Its greatest divergence from the latter stream is from Van Meter east to the county line and between these points it lies from two to three miles north of that stream. West of Van Meter for a distance of four or five miles the boundary approaches the river quite closely. Throughout most of its course in Adams township, and as far as the bend at Cottonwood mill, in Union township, it lies from one to two miles north of the river. From this latter locality to a point about one mile south of Linden it follows the Raccoon quite closely. At no place does it seem to have crossed over to the south side of the river except at a point about two miles northwest of Redfield, to be mentioned later.

The region north of this line, including more than three quarters of the county, furnishes an excellent example of a drift topography and is sharply contrasted with the region lying to the south which exhibits a characteristic erosion topography. It will be necessary, therefore, to consider the two regions separately.

The peculiar topography of the northern area reaches its typical development in Washington, Lincoln and Dallas townships, and also along Beaver creek. The surface is that of a flat or very gently rolling plain. Away from the immediate neighborhood of the streamways the eye sees on either side nothing but long stretches of level country reaching out to the horizon. There is, however, one striking feature in the landscape and that is the presence of shallow, saucer-shaped depressions in the drift, which are usually filled with water. These small ponds or lakelets are in some parts of the county extremely common, as, for example, south and west of Perry, in Dallas and Spring Valley townships, where one may often see a dozen or more at one time. They vary in size from those a few rods in diameter to others many acres in extent. Associated with these depressions are low, gently rounded swells, which may be compared to inverted saucers. Hence this peculiar configuration of the drift has been called "saucer topography."

The evidence is abundant that the retreat of the Wisconsin ice sheet, which once covered all of Dallas county nearly as far south as the Raccoon river, took place in comparatively recent times, geologically speaking. The surface now has much the appearance that it presented when at the close of the last ice invasion it was first exposed to the action of atmospheric and aqueous agencies. It has, as a rule, been little modified by the action of streams, and erosive processes have not gone far enough to thoroughly drain the land, except in the immediate neighborhood of the water courses. Hence the numerous lakelets have not yet been drained, and it is not uncommon to find one of these ponds within a few rods of a well developed valley, as in the case of one observed near the deep gorge of the Des Moines river, in the northeast corner of the county.

This drift topography, which reaches such typical development over the northern part of the area, is not so well marked farther south, in Colfax and Adel townships, and, as the Raccoon river is approached, it gives place to the erosion topography of the region south of the border of the Wisconsin drift. The surface features are in the latter region due to the action of running water and to weathering. The flat surface left by the retreat of the earlier ice has been carved and modified by these agencies until the country presents quite a rough and hilly appearance. The streams have cut their channels through the thick Pleistocene deposits and well into the underlying coal measures. They flow in deep, broad valleys with abruptly rising sides. There is everywhere evidence that the drift here has been exposed to erosion longer than in the northern region. The surface is well drained, and nowhere do we find the saucer topography so characteristic of the younger drift. The principal streams have broad and deep valleys, which are cut to a depth of from 150 to nearly 200 feet below the general level of the upland. For these and other reasons to be mentioned later, the Kansan drift of the south is known to be considerably older than the Wisconsin drift of the northern portion of the county.

Along the larger streams of the district bottom lands of greater or less extent have been formed. Thus, for example, the Raccoon river east of Van Meter has broad bottoms, from one to two miles in width, the stream for the most part keeping quite close to the bluffs on the south side of the valley. As a result of this tendency of the river to follow the south escarpment, there is at various points along its course a marked difference between the north and south sides. On the south the bluffs rise abruptly from the water's edge to the height of from 160 to 180 feet, while on the north the rise is much more gradual, being often accomplished by a gentle slope merging gradually into the upland. The southern escarpment is commonly covered with timber, while the opposite slope is dotted with cultivated fields.

TABLE OF ELEVATIONS.

The following table gives the elevation of the towns of the county, with others near its borders, together with that of a few other important points. The figures have been taken from the profiles of the Chicago, Rock Island & Pacific, Chicago, Milwaukee & St. Paul and Des Moines Northern & Western railroads.

	FEET.
Adel	885
Booneville	869
Bouton	961
Commerce	845
Dallas Center	1,074
Dawson	1,044
De Soto	904
Dexter	1,144
Earlham	1,116
Jamaica	1,040
Kennedy	952
Linden	1,123
Madrid	1,005
Minburn	1,051
Ortonville	1,039
Perry	969
Redfield	952
Waukee	1,032
Woodward	1,069
Van Meter	876
D. M. & N. W. track at bridge over Mosquito creek	937
D. M. & N. W. track at bridge over Panther creek	920
C., M. & St. P. track at Des Moines river bridge	861
C., M. & St. P. track at Beaver creek bridge	939

From the above table it will be noted that the general elevation of the upland plain is between 1,000 and 1,100 feet, and that the streams have cut their channels nearly 200 feet below this. The highest part of the county is in the southwest corner, in Union and Linn townships, where the plain reaches an elevation of more than 1,100 feet. At Dexter, which has the greatest elevation of any point whose altitude is known, the surface rises nearly 1,150 feet above sea level.

DRAINAGE.

With the exception of several townships in the northeast corner, Dallas county is drained entirely by the Raccoon river and its tributaries. The Coon river, as it is commonly called, crosses the county near its southern border and is formed by the confluence of the North, Middle and South Raccoon rivers. A portion of the courses of all three of these streams lies within the area. The north branch enters it near the northwest corner, flows east for five or six miles and then turning, takes a general southerly course through the central part of the county until it joins the main stream at Van Meter. About two and one-half miles from the west county line, in Union township, the Middle Raccoon empties into the South Raccoon from the north, between eight and nine miles of its course falling within the limits of the county. The principal tributaries of the Raccoon are Mosquito and Panther creeks, which enter from the north, and Bulger and Bear creeks flowing in from the south. East of the North Raccoon there are two small tributaries, Sugar and Johnson creeks, which drain Boone and part of Van Meter townships. The valley of the former stream is marked by a well developed alluvial plain nearly one quarter of a mile wide and extending up the stream over a mile from the Raccoon valley. Mosquito and Panther creeks have courses nearly parallel to the North Raccoon, namely, a little east of south, and like the latter stream they have very few branches. In some portions of their courses these three streams are not more than three or four miles apart.

Bear creek drains portions of Union and Adams townships and enters the Raccoon nearly opposite the mouth of Panther creek. Bulger creek enters Adams township from the south, and flowing north and east drains a portion of Adams and Van Meter townships. It flows through a rather broad valley with gentle slopes and has cut its channel well into the Missourian limestone and into the shales and sandstones of the Des Moines stage. Walnut creek, though its course lies mostly in Polk county, has its source in, and drains, Walnut township.

Through the extreme northeast corner of the county the Des Moines river has cut a narrow trench fully 140 feet deep. Beaver creek, a tributary of the Des Moines, drains part of the region between that stream and the North Raccoon. It has a broad and shallow valley, bounded in some parts by low bluffs twenty-five to thirty feet high, while in other portions of its course the bottoms merge into the higher land on either side.

Concerning the origin of the present drainage system of Dallas county it may be said that some of the streams evidently flow in preglacial channels, others in valleys formed since the advent of the ice. To the former class belong apparently the Raccoon river (including the South and Middle Raccoon) and its two tributaries from the south, Bear and Bulger creeks. All these streams have well developed valleys with rock walls capped by drift. The Raccoon, as already stated, has along a large portion of its course a broad flood plain which of itself would signify a valley of considerable age. At various points along all three streams the Kansan drift and loess are seen to follow down the sides of the valleys and also to occupy the bottom. These streams flow in valleys excavated in the coal measures probably just previous to the ice invasion. Upon the disappearance of the ice sheet these preglacial valleys were left filled with drift which upon settling would leave shallow depressions or swales in the surface. These would then naturally become channels for the present streams, which belong therefore to the class of resurrected rivers. The remainder of the streams of the county appear to be postglacial in age, with the possible exception of the North Raccoon, which is, at least in the lower part of its course, probably preglacial. For several miles above its confluence with the main stream it has a very broad valley with an extensive flood plain, and the sides are composed, in part at least, of rock. At Adel the valley again broadens out and is bordered by rather low bluffs.

The Des Moines river, with its narrow and steep-sided valley, bears evidence of being postglacial in age, and the same may be said of Beaver, Mosquito and Panther creeks. Their channels are excavated almost wholly in drift and are evidently of comparatively recent origin.

STRATIGRAPHY.

General Relations of Strata.

Two great systems of strata are represented in Dallas county, the Carboniferous and Pleistocene. The loose deposits belonging to the latter system are made up of clay, sand and gravel, and cover the indurated rocks to the depth of 100 feet and more. At no place are the indurated rocks exposed except along streams. The Upper Carboniferous beds are divided into an upper and lower division. The strata of the Upper or Missourian stage occur only in the southwestern corner of the area, the larger part of the county being covered by the beds of the Des Moines stage.

The Pleistocene deposits are also divisible into an older and newer drift. The former or Kansan drift with its covering of loess appears only to the south, since over the greater portion of the county it is itself covered by the younger Wisconsin till. The following table will show the relations of the strata.

Synoptical Table of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene or Quaternary.	Recent.	Alluvial.
		Glacial.	Wisconsin
			Iowan.
			Kansan.
Paleozoic.	Carboniferous.	Upper Carboniferous or Pennsylvanian.	Missourian.
			Des Moines.

STANDARD SECTIONS.

The sections which follow are given with the view of showing the general characteristics of the coal measures as they occur within the county. The best exposures are found along the Raccoon river, and these are described first.

In a small ravine on the south side of the valley and about one and a half miles from the Polk county line (Tp. 78 N., R. XXVI W., Sec. 35, Nw. qr.) the following section occurs.

SECTION I.

		FEET.	INCHES.
7.	Drift		
6.	Shales, black		8
5.	Shales, gray, sandy below	2	
4.	Sandstone	4	
3.	Shales	6	
2.	Limestone, dark blue, fossiliferous, in three layers separated by marly partings	2	4
1.	Shales, exposed	2	

The limestone layers with marly partings (No. 2) are doubtless the same as those found in the Commerce section* about three miles to the northeast.

* Iowa Geol. Surv., Vol. I, p. 97. Des Moines, 1893.

At Booneville the following beds are found outcropping in the bluff.

II. BOONEVILLE SECTION.

		FEET.	INCHES.
14.	Drift, overlain by loess	30	
13.	Sandstone	10	
12.	Shale, black, fissile	1	
11.	Shales, gray and red	10	
10.	Shales, black	1	
9.	Shales, gray	3	
8.	Coal		10
7.	Shales, gray	9	
6.	Limestone, fragmental, fossiliferous	2	
5.	Shales, gray	13	
4.	Limestone	2	
3.	Shales	16	
2.	Sandstone		3
1.	Unexposed to river	20	

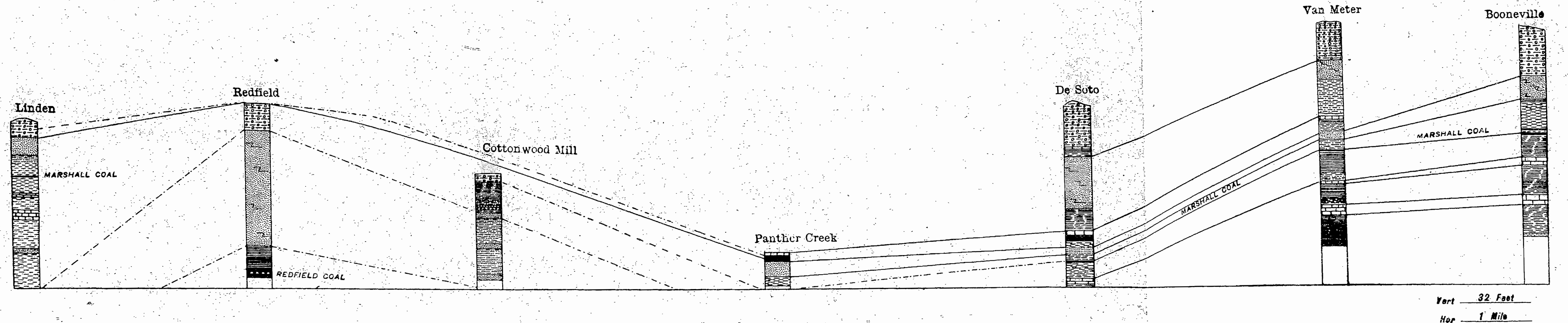
The two limestones (Nos. 4 and 6) outcrop across the river from Booneville, in section 32, where they are well exposed. At Booneville only the upper one appears. It carries numerous fossils, among which *Productus muricatus* and *Productus cora* are common.

The limestone bands of the previous section would be carried by their dip below the river level at this point and therefore fall below the base of the Booneville section.

In the bluff on the south side of the river one mile east of Van Meter (Tp. 78 N., R. XXVII W., Sec. 26, Nw. qr.) and in a ravine near the river a good section is exposed.

III. VAN METER SECTION.

		FEET.	INCHES.
17.	Drift		
16.	Sandstone, soft, gray with yellow mica	8	
15.	Shales, sandy, gray	15	
14.	Limestone, fossiliferous, compact	1	2
13.	Shales, bituminous, coaly below	1	4
12.	Shales, gray	4	
11.	Sandstone, heavily bedded, with lepidodendrons	4	
10.	Shales, sandy above	6	
9.	Coal		6



SECTION ALONG RACCOON RIVER IN DALLAS COUNTY.

	Feet.	Inches.
8. Shales, gray and red	12	
7. Limestone, gray	1	
6. Shales, gray	8	
5. Shales, bituminous	2	
4. Limestone, fragmentary	4	
3. Shales, blue	6	
2. Shales, bituminous, with concretionary layers above	2	
1. Shales, blue, exposed	5	

The upper limestone (No. 14) carries many of the common coal measure fossils, including *Axophyllum rude*, *Productus costatus*, *Productus longispinus*, *Athyris subtilita*, *Spirifer cameratus* and corals. The lower limestone (No. 4) outcrops at several points along the railroad west of town. Number 7 is not well exposed at Van Meter but occurs on either side at Booneville and De Soto. In the high bluff at the mouth of Bulger creek a nine-foot ledge of hard and heavily bedded sandstone has been quarried. This bed is evidently the same as No. 11 of the above section, the sandstone having become thicker toward the west. The fossiliferous limestone (No. 14) near the top of the exposure has been traced in the field into a similar bed in Madison county, and it is known to occur also in Guthrie county. It forms one of the best marked horizons in the entire region. The limestone is always accompanied by the same succession of strata which occurs in the following order:

Limestone.
Black bituminous shales with coaly layer.
Gray shales.
Sandstone.
Gray shales.
Coal.

The limestone is not found at Booneville, the topmost bed exposed at that point being the underlying sandstone (No. 11 of Van Meter section).

The next exposure met with is at the mill, about four miles above Van Meter (Tp. 78 N., R. XXVII W., Sec. 18, Nw. qr.).

IV. VAN METER'S MILL SECTION.

		FEET.	INCHES.
8.	Drift	2	
7.	Shales, with vegetable material partially altered into coal	2	6
6.	Sandstone, buff, ferruginous above, in three ledges, shaly below, with plant stems	8	2
5.	Shales, gray	3	
4.	Coal		7
3.	Shales, gray	8	
2.	Limestone, blue very compact, fossiliferous, heavily bedded	2	7
1.	Shales, gray and red, exposed	12	

The six-inch coal seam (No. 4) is the Marshall coal of White and is the same vein as No. 7 of the Van Meter section. At both places there is a sandstone above the coal and a limestone below, each separated from the vein by shales.

At De Soto, two miles south of the above locality, a section is expose along Bulger creek, which at this point has cut into the bluff for a distance of nearly half a mile, furnishing an excellent outcrop.

V. DE SOTO SECTION.

		FEET	INCHES.
14.	Drift		
13.	Limestone, gray fossiliferous	1	
12.	Shales, variegated	2	
11.	Sandstone, soft, buff, shaly in part	24	
10.	Shales, gray, lower part ferruginous	10	
9.	Limestone, blue, compact, fossiliferous	1	9
8.	Shale, gray		4
7.	Shale, black, carbonaceous		10
6.	Clay	1	
5.	Sandstone, hard and compact above, thin bedded and shaly below, contains plant remains	6	6
4.	Shales, gray	2	
3.	Coal		8
2.	Clay shales, with lime nodules and much iron at one horizon	7	
1.	Limestone, fragmentary	2	

The most common fossil in the limestones of this section is, as usual, *Athyris subtilita*. It will be noted that the lower beds (Nos. 1 and 6) are the same as those exposed along the Raccoon, two miles to the north. The strata here have a very perceptible westward dip, amounting to nearly forty feet to the mile. The sandstone (No. 5) has a hard eight-inch layer above and is filled with carbonized plant stems.

The next good exposures along the Raccoon river is on the north bank of that stream at the mouth of Panther creek (Tp. 78 N., R. XXVIII W., Sec. 16, Nw. qr.) where the following section occurs.

VI. PANTHER CREEK SECTION.

		FEET.	INCHES.
6.	Limestone, blue, compact, fossiliferous........	1	5
5.	Shale, coaly................................	1	8
4.	Shale, yellow, sandy, with plant remains......	1	
3.	Sandstone, hard, shaly above.................	6	
2.	Shale, gray, somewhat sandy.................	4	
1.	Unexposed to river......................	2	

The beds exposed at this place agree well with Nos. 6–10 of the De Soto section, and they may safely be correlated with those beds.

A short distance below Cottonwood mill (Tp. 78 N., R. XXIX W., Sec. 2, Ne. qr.) about fifty feet of strata are exposed in the bluff on the north side of the river.

VII. COTTONWOOD MILL SECTION.

		FEET.	INCHES.
11.	Drift..	3	
10.	Shales, sandy, buff	10	
9.	Sandstone, yellow		6
8.	Shales, sandy, buff	1	
7.	Shales, blue..................................	1	
6.	Sandstone, yellow, soft	3	
5.	Shales, sandy, buff and gray..................	10	
4.	Sandstone, soft, gray	3	
3.	Shales, sandy, blue............................	12	
2.	Sandstone, yellow	1	
1.	Shales, sandy.................................	4	

There is a marked difference between the character of the beds of this section and those previously described. The limestone bands as well as the coal seams or bituminous shales are entirely wanting and the shales are all more or less sandy. The entire section might not incorrectly be described as composed of sandstones which are shaly in places. There is great variation in the thickness of some members of the above section, the more heavily bedded sandstones thickening at one point and thinning out or disappearing entirely at another, and all within a distance of not more than 180 feet.

The sudden change in the character of the strata at this point is to be accounted for by the presence of an anticline whose axis extends approximately northeast and southwest. This gentle fold brings to the surface the lower beds of the Des Moines stage. Further evidence relating to the presence of a low anticline in this region will be discussed in another place in this report. Massive sandstones are exposed at numerous points along the river from the bend at Cottonwood mill to the mouth of the Middle Raccoon and up that stream as far as Redfield, at which point the sandstone again disappears. In the bluff opposite the latter town is exposed the following section.

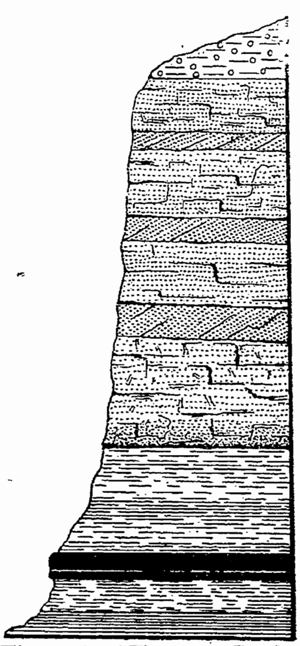


Figure 1. "Hanging Rock" section. Redfield.

VIII. REDFIELD SECTION.

	FEET.	INCHES.
7. Drift	10	
6. Sandstone, massive, rather fine grained, buff to dark brown in color	50	
5. Shales, ash color to drab, somewhat sandy in places	10	
4. Coal	2	
3. Clay, drab color, fossiliferous		1
2. Coal	1	
1. Shale, somewhat sandy, drab, in places carbonaceous, exposed	5	

The massive bed of sandstone, wherever it outcrops, forms a steep escarpment, such as that seen in the bluff opposite the

FIG. 1. Hanging rock, coal measure sandstone, Redfield.

FIG. 2. Cottonwood mill sandstone, showing cross-bedding,

picnic grounds just south of Redfield, at what is called the "Hanging Rock." The stone is rather soft, and forms a continuous mass, undivided by bedding planes. Between two and three miles above Redfield, not far from the mouth of Mosquito creek, and also near the county line, in section 6 of Union township, there are several exposures, from which St. John* constructed the following section.

IX. COUNTY LINE SECTION.

		FEET.	INCHES.
27.	Black shale, overlaid by impure limestone....		
26.	Sandstone, shaly, yellow......................	5	
25.	Clays, sandy, laminated.......................	4	6
24.	Marshall coal, impure		6
23.	Shales, yellow, blue	5	
22.	Limestone, compact, heavy bedded, buff.......	2	
21.	Clays, blue, with nodular band................	4	
20.	Limestone, blue, earthy, two thin layers......		
19.	Clays, blue and red...........................	3	6
18.	Limestone, fragmentary, impure...............	4	
17.	Clays, blue...................................	2	6
16.	Shales, alternating red and blue..............	55	
15.	Sandstone, gray, shaly, micaceous............	2	
14.	Shales, alternating red, blue and yellow......	44.	
13.	Clays, blue, gray, sandy above................	8	6
12.	Sandstone, soft, heavily bedded..............	2	6
11.	Shales, blue..................................	16	
10.	Sandstone, soft, red, gray....	3	
9.	Clays, red, blue, nodular......................	10	
8.	Limestone, clayey, four layers, clay partings, very fossiliferous...............	8	
7.	Shales, light gray...........................	5–10	
6.	Shales, calcareous............................		6–10
5.	Shales, blue and brown.......................	1–8	
4.	Limestone, impure, nodular, sometimes wanting..		8
3.	Shales, black............................1½ to	3	
2.	Panora coal		4–8
1.	Clays, blue and ash color, exposed............		3

It will be seen from the above that the massive sandstone has disappeared, and is here replaced by beds similar to those found east of the anticline at De Soto and Van Meter.

*Geol. of Iowa, Vol. II, p. 28. Des Moines, 1870.

The last exposure within the county along the Middle Raccoon is at the old mill south of Linden, in Tp. 79 N., R. XXIX W., Sec. 30, Se. qr., where the following section appears.

X. LINDEN SECTION.

		FEET.	INCHES.
12.	Drift		
11.	Sandstone, buff, shaly in part	7	
10.	Shales, gray, sandy above	8	
9.	Coal		6
8.	Shales, gray	6	
7.	Limestone, gray, very fossiliferous	1	
6.	Shales, gray	6	
5.	Limestone, buff, eighteen-inch layer below, brecciated and yellow above	4	
4.	Shales, gray	12	
3.	Sandstone, gray	2	
2.	Shales, gray	13	
1.	Clay shales, red, exposed to river	2	

From the fossiliferous limestone, No. 7 of the above section, *Productus cora*, *Productus nebrascensis*, *Productus muricatus* and *Athyris subtilita* were collected. The coal vein is forty-six feet above the river, and is the Marshall coal of White. The beds here exposed correspond closely with those in the upper part of section 9 (Nos. 14–26), and they are doubtless the same. Near the top of the hill, about one-half mile south of the above exposure, there is a second vein of coal which has been mined for several years. The seam is from sixteen to eighteen inches thick, and lies sixty feet above the coal vein of the last section. This is called by White the Lonsdale coal.

There are few exposures within the county north of the Raccoon river. Aside from several outcrops along small tributaries of the North Raccoon near Adel, and a few other exposures along the Des Moines river in Des Moines township, our knowledge of the indurated rocks beneath the drift is derived largely from the records of wells and shafts of coal mines. The following section taken from White* gives a

*Geology of Iowa, Vol. II, pp. 36-37. Des Moines, 1870.

general idea of the character of the beds as exposed near Adel, along Hickory and Miller's branches.

XI. ADEL SECTION.

		FEET.	INCHES.
14.	Limestone, buff, fragmentary, earthy		6
13.	Shales, black, carbonaceous	1	
12.	Shales, blue, arenaceous	2	
11.	Sandstone, gray and red, with arenaceous, shaly partings	8	
10.	Clays, yellow and blue, arenaceous above..2 to	4	6
9.	Coal (Marshall)		1-4
8.	Shales, blue and yellow, containing ferruginous nodules, arenaceous above.............10 to	12	
7.	Limestone, light buff, soft, contains the following species: *Rhynchonella uta*, *Derbya crassa*, *Chonetes mesoloba*, *Productus muricatus*, *Productus longispinus*, (rare) *Athyris subtilita*, *Spirifer cameratus* and others	2	
6.	Clay, variegated	12	
5.	Shales, black, carbonaceous	1	
4.	Shales, gray, with numerous fossils	1	
3.	Shales, blue	4	
2.	Limestone, rather compact, irregularly bedded, earthy, shaly above.....................4 to	5	
1.	Clays, blue, exposed	1	

Two miles south of Waukee, in section 6 of Boone township, an outcrop on Sugar creek shows the following beds.

XII. SUGAR CREEK SECTION.

		FEET.	INCHES.
9.	Drift	5	
8.	Shales, gray	4	
7.	Limestone, blue, compact, fossiliferous	1	
6.	Shale, black, carbonaceous, coaly in part	2	6
5.	Shales, gray		8
4.	Sandstone, gray, with plant stems	1	
3.	Shales, gray	4	
2.	Coal (Marshall)		3
1.	Shales, gray	1	

The above section corresponds well with the upper part (Nos. 8 to 15) of the Van Meter section. The three-inch vein of coal (No. 2) is the Marshall seam, and No. 7 is the upper limestone band. Sugar creek has cut its channel through these beds, exposing them at various points along its course. Stone has for many years been quarried at the exposure just described, Nos. 4 and 7 being used.

In the extreme northeast corner of the county the Des Moines river has cut a deep and narrow trench down into the coal measures, but the sides are now overgrown with vegetation, and outcrops are few. Just above the bridge and in the bluff on the west side of the valley the following section occurs.

XIII. HIGH BRIDGE SECTION.

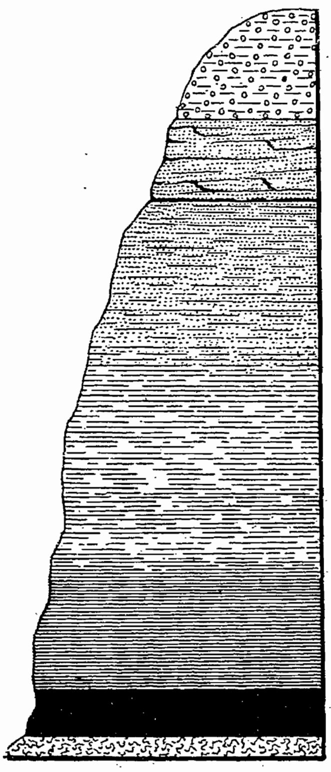


Figure 2. Bluff near Pritchard drift, High Bridge.

		FEET.	INCHES.
5.	Drift	4	
4.	Sandstone, thinly bedded	3	
3.	Shale, light colored, with sandy concretions, grading downward into bituminous	18	
2.	Coal	1	8
1.	Fire clay, exposed		4

The shaft of a coal mine at Dawson, a town on the Chicago, Milwaukee & St. Paul railway, furnished the following record of strata.

XIV. DAWSON SECTION.

		FEET.	INCHES.
11.	Soil	3	
10.	Yellow clay	13	
9.	Blue clay	64	6
8.	"Slate" gray	2	6

		FEET.	INCHES.
7.	Coal	1	10
6.	Fire clay	4	
5.	Sandstone	8	
4.	"Slate," gray	10	
3.	"Slate," black, oily	13	
2.	Coal	3	
1.	Fire clay	4	

Forty feet below the three-foot vein (No. 2) a third seam is reported with a thickness of 3½ to 4 feet.

In the southwestern corner of the county, in Union and Adams townships, the Missourian limestone is exposed at several points. The rock was at one time quarried quite extensively in section 28 of Adams township, and the section at these old quarries (Tp. 78 N., R. XXVIII W., Sec. 28, Sw. qr.) is as follows:

SECTION XV.

		FEET.	INCHES.
15.	Drift		
14.	Limestone, thin bedded, sandy, exposed	6	
13.	Unexposed	8	
12.	Limestone	4	
11.	Shales, gray, calcareous		8
10.	Limestone		9
9.	Shales, gray	4	
8.	Limestone, fragmental	2	6
7.	Shales, with nodules of iron	2	
6.	Shales, red, jointed	10	
5.	Sandstone, soft, shaly, exposed	3	
4.	Unexposed	40	
3.	Limestone	3	
2.	Shales, coaly	1	
1.	Shales, gray, exposed to stream	2	

The nine-inch ledge (No. 10) was the lowest rock removed. The quarry is located well up toward the top of the hill and the limestone does not appear to extend much farther to the east and north of this point. The base of the section (Nos. 1 to 3) is exposed along the small stream just west of the quarry.

Along the east and west road in section 32, and about one-half mile south of the above outcrops, the following beds are exposed.

SECTION XVI.

		FEET.	INCHES.
6.	Geest	1	6
5.	Limestones	11	
4.	Shale, gray	2	6
3.	Shale, coaly	2	
2.	Limestone		6
1.	Shales, gray, not well exposed	33	

The shales at the base of the above section contain several limestone bands near their lower part.

About one mile northwest of the old quarries in Tp. 78 N., R. XXVIII W., Sec. 20, Se. qr. an exposure along Bear creek showed no limestone at that point except a two-foot layer about eight feet above the creek. This section is here given for comparison with the two previous ones, and to show the change in the character of the deposits near the border of the limestone area.

SECTION XVII.

		FEET.	INCHES.
8.	Sandstone, gray	2	
7.	Shales, red and gray	8	
6.	Shales, gray, very sandy below	19	
5.	Sandstone, soft	12	
4.	Shales gray	1	
3.	Limestone, impure, earthy, gray	2	
2.	Shales, gray	2	6
1.	Shales, sandy above, exposed to creek	6	

Another exposure of the Missourian limestone is found at the quarries on Bear creek in sections 22 and 23 of Union township. At Brown's quarry (Tp. 78 N., R. XXIX W., Sec. 22, Se. qr.) the following beds were observed:

XVIII. BROWN QUARRY SECTION.

		FEET.	INCHES.
8.	Geest	1	3
7.	Limestone	10	
6.	Unexposed, probably shale	6	
5.	Shale, black, fissile		6
4.	Limestone, blue, compact, exposed		8
3.	Unexposed	25	
2.	Limestone, impure and fragmental below	3	
1.	Shale, calcareous and ferruginous, exposed	3	

The rock here quarried is No. 7, which is a blue to buff, compact and evenly bedded limestone. The individual ledges vary in thickness from eight to ten inches and are separated by marly partings three to four inches thick. At certain horizons there is an abundance of flint nodules which have a linear arrangement in rather well defined bands.

This limestone is also exposed in the southwest quarter of section 35 of Union township, just north of the Madison county line. It has a thickness at this place of twelve to fourteen feet and is underlain by blue shales. The rock has been quarried here for a number of years, the upper eight feet being removed.

WELL RECORDS.

Our knowledge of the character of the deeper strata of Dallas county is derived from the records of several wells which have been sunk through the heavy superficial deposits and penetrate to a greater or less depth the underlying coal measures.

The Marshall artesian well is located on the south bank of the South Raccoon in Tp. 78, N., R. XXIX W., Sec. 7, Se. qr. The record as given by Mr. Marshall is as follows.

		FEET.
5.	Shales, red and blue	65
4.	Sandstone	6
3.	Shale and slate, bituminous	200
2.	Sandstone, white	20
1.	Limestone (Saint Louis) penetrated	8

The well is located at the base of the bluff and no drift is here present. The well is thus entirely in the coal measures except the lower eight feet, which is in the Saint Louis limestone. The latter was reached at a depth of 291 feet.

A deep well put down in section 4 of Lincoln township furnished the following record.

		FEET.	INCHES.
6.	Yellow clay	40	
5.	Blue clay	50	
4.	Coal		8
3.	Shales, gray	60	
2.	Shales, black, carbonaceous	150	
1.	Sandstone	7	

The most noticeable feature about this record, as in the previous one, is the great thickness of the shales penetrated, 200 feet and more, without entercountering any sandstone or limestone beds or coal veins. There is a marked contrast in this respect between the records just given and that of a well drilled one mile southwest of De Soto, in section 25 of Adams township. The record of this well is as follows.

		FEET.
82.	Soil and subsoil	8
81.	Yellow clay	37
80.	Blue clay	12
79.	Clays and shales, red and yellow	7
78.	Soft rock	1
77.	Clay, red and blue	28
76.	Limestone	3
75.	Slate	2
74.	Coal	1
73.	Fire clay	4
72.	Shale, with marly partings	3
71.	Limestone, gray	3
70.	Shale	1
69.	Limestone, coarse grained	1
68.	Shale, with marly partings	4
67.	Sandstone	2
66.	Shale and clay	5
65.	"Coal roofing" (slate?)	1
64.	Sandstone	2
63.	Calcareous rock, hard, gray	4
62.	Rock, hard	6
61.	Shales and clays, red and blue	10
60.	Sandstone, gray	6
59.	Limestone	5
58.	Sandstone	4
57.	Shale, with thin layers of rock	5
56.	Sandstone, gray, flinty	5
55.	Clay and shale	6
54.	Limestone	10
53.	Clay	5
52.	Limestone	3
51.	Shale	3
50.	Sandstone	4
49.	Shale	2
48.	Limestone, gray	3
47.	Shales, very hard	2

		Feet.
46.	"Rock," hard	4
45.	Shale	4
44.	Sandstone	2
43.	"Rock," hard, white	19
42.	Slate, black	2
41.	Coal	2
40.	Fire clay	1
39.	"Rock"	7
38.	Clay	1
37.	"Rock," hard, light colored	4
36.	Slate	1½
35.	Coal	1½
34.	Fire clay	2
33.	Shale, gray	7
32.	"Rock"	1
31.	Shale	1
30.	"Rock"	1
29.	Shale, gray	3
28.	Rock	1
27.	Shale	5
26.	"Rock," gray	8
25.	Shale	1
24.	"Rock"	2
23.	Shale	3
22.	"Rock"	10
21.	Shale	4
20.	Sandstone	3
19.	Shale	1
18.	Sandstone	8
17.	Clay, red	1
16.	Sandstone	18
15.	Shale, blue	3
14.	"Rock," gray	5
13.	Shale	2
12.	"Rock"	6
11.	Shale	2
10.	Sandstone	3
9.	Shale	3
8.	Coal	3
7.	Fire clay	1
6.	Shale, dark	1
5.	Sandstone	9
4.	Shale	7
3.	Sandstone	4
2.	Shale	1
1.	Sandstone	2

The first 57 feet are through drift, and the coal measures were penetrated to a depth of 321 feet without reaching their base. Four veins of coal were encountered—namely, 1 foot at a depth of 98 feet; 2 feet at a depth of 239 feet; 1½ feet at 255 feet, and 3 feet at 350 feet below the surface.

The "rock" of this record is probably a hard shale or slate.

GEOLOGICAL FORMATIONS.

Upper Carboniferous.

DES MOINES.

The indurated rocks of Dallas county, with the exception of those occupying the small area in the southwest corner, belong entirely to the Des Moines stage of the Upper Carboniferous or Pennsylvanian series. The beds are made up of shales and sandstones, with occasional bands of limestone and veins of coal. The great bulk of the formation is composed of shales. These exhibit great variation in composition, and all varieties, from pure clay shales to sandy, calcareous, and carbonaceous shales are represented. Not infrequently the shales grow more and more sandy until they grade into a true sandstone.

The color of these shales is commonly gray or blue, though red and variegated shales may occur, as do also the black, carbonaceous varieties. The latter, as shown by well records, may reach a great thickness. There is one characteristic feature of the beds of this stage which strikes the observer at once, and that is the rapid change in the character of the rocks, both vertically and laterally. Shales are replaced by sandstones and sandstones give way to shales. Individual beds when traced any great distance are very liable to thin out and disappear entirely, or they may be found to increase in thickness from a few inches to many feet. This rapid variation in the character of the beds is well shown in two exposures, not more than twenty rods apart, found near the mouth of a small stream emptying into the Raccoon river in section

12 of Union township (Tp. 78 N., R. XXIX W., Sec. 12, Sw. qr.). The first of this section is as follows:

	FEET.	INCHES.
8. Drift	12	
7. Limestone, gray, sandy	3	
6. Clay shales, gray	6	
5. Limestone, blue		6
4. Marl, gray, fossiliferous	1	
3. Shales, bituminous, coal above	1	3
2. Limestone, very fossiliferous		4
1. Clay shales, gray, exposed to creek	2	

The second section, a short distance from the above, shows the following beds.

	FEET.	INCHES.
5. Drift	10	
4. Sandstone, yellow, ferruginous, showing cross bedding	7	
3. Clay shales, blue	4	
2. Coal		2
1. Clay shales, exposed to stream	5	

The six-inch limestone (No. 5) of the first section thins out rapidly and disappears within a distance of ten feet. It is exceptional to find the limestone bands thus pinching out, since they are as a rule quite persistent and continuous over considerable areas.

Next to the shales in abundance are the sandstones. These may be somewhat soft and shaly, when they can be considered as sandy shales, or they may occur in beds varying in thickness from four inches to many feet. Commonly the ledges are not more than four or five feet thick. Their color is usually a gray or buff, though yellow, blue and other shades are not infrequent. In the vicinity of Redfield these sandstones are especially abundant. They are exposed along the Raccoon river for some five miles, extending from half a mile below Cottonwood Mill to Redfield. At the latter town the sandstone has a thickness of nearly fifty feet. It here forms a massive bed undivided by well marked bedding planes and makes a steep escarpment for some distance along the river. The limestone bands vary in thickness from a few inches to three and four feet, though they rarely exceed two feet. As has already been stated these bands are very persistent and can be traced from one township to another or even across entire counties. They are for this reason especially valuable in correlating the beds of different sections and particularly the coal veins. Three or four well marked beds of limestone are exposed in the different outcrops within the county, separated by clay shales and sandstones.

One of these limestone bands has already been mentioned as forming a well defined horizon, not only in Dallas, but also in Madison and Guthrie counties. It is exposed along the Raccoon river at Van Meter, De Soto and at the mouth of Panther creek. At De Soto there is a thin bed of limestone about 40 feet above it. Two limestone layers occur below this horizon. This persistent limestone layer is No. 14 of the general section.

The coal veins, a number of which occur in the coal measures of the county, will be discussed elsewhere in this report.

The following general section shows the character and succession of the beds of the Des Moines stage as they appear in Dallas county:

GENERAL SECTION OF DES MOINES BEDS.

		FEET.
18.	Limestone, gray	1 to 4
17.	Shales, gray and red	2 to 8
16.	Sandstone, buff, soft, somewhat shaly	8 to 20
15.	Shales, gray, arenaceous, ferruginous below	10 to 12
14.	Limestone, blue, impure	1 to 2
13.	Shales, bituminous, coaly in part, separated from overlying limestone by gray shale band	1 to 2½
12.	Shales, gray	1 to 4
11.	Sandstone, usually hard, heavily bedded above, with lepidodendrons, imperfect plant remains, and charcoal fragments	1 to 10
10.	Shales, gray, arenaceous, above	4 to 6
9.	Coal (Marshall)	½
8.	Shales, gray, with nodular bands, ferruginous	6 to 12
7.	Limestone, fragmentary, very fossiliferous	1 to 2½
6.	Shales, blue and red variegated	6 to 15

		FEET.
5.	Limestone, gray to buff, fragmentary	2 to 4
4.	Shales, gray	12
3.	Sandstone	1 to 2
2.	Shales, gray and red in alternating bands	20 to 30
1.	Sandy shales and sandstones	60
	Redfield coal	

Thickness.—The thickness of the Des Moines beds in Dallas county can be determined with a good degree of certainty from several wells drilled in the southern part of the area. In the Marshall artesian well the Saint Louis limestone at the base of the coal measures was struck at a depth of 291 feet, or about 503 feet, A. T. As this well is located in the deep valley of the Raccoon the height of the coal measures in the uplands above must be added. This would give a thickness to the Des Moines beds of over 400 feet. The well is located only a mile or two north of the border of the Missourian limestone and the distance from the base of the latter to the Saint Louis may be placed at less than 500 feet and it probably does not exceed 450 feet.

In the Redfield well the limestone at the base of the coal measures was struck at about the same depth as in the Marshall well and would indicate a thickness of about 400 feet. The well drilled near De Soto went through 321 feet of coal measures without reaching their base, and at Van Meter coal is mined at a depth of 380 feet from the top of the coal measures at that point. At Des Moines the record of the Greenwood Park well shows that the beds have a thickness of 484 feet. At Boone they are only 260 feet thick.*

The coal measures were divided by White into the Upper, Middle and Lower, and all three divisions were mentioned† as occurring in Dallas county, the middle division being especially described from the outcrops along the Raccoon river. The present Survey has recognized only two divisions of the Upper Carboniferous, namely, the Missourian and the Des

*Iowa Geol. Surv., vol. V, p. 198.

†Geol. of Iowa, vol. II, p. 18. Des Moines, 1870.

Moines. The latter stage, or series as Keyes now regards it,* comprises the Middle and Lower subdivisions of White.

Bringing together all the knowledge of the Des Moines formation secured from well records, prospect holes and natural exposures the general succession in Dallas county is about as follows:

(1) At the base, and directly overlying the Saint Louis, there are between 100 and 200 feet of hales and sandstones. (2) These are followed by a shale and limestone member and (3) this in turn is covered by a shaly member. This last is not well developed in Dallas, but is quite well marked in Madison county, where it is 80 feet thick. In the southern part of the state a formation, probably the same as the middle limestone member, occurs and has been called the Appanoose formation.†

As suggested by Keyes‡ the succession is much the same in Iowa as in Kansas and Missouri, where we have the Cherokee shales, Henrietta limestone and Pleasanton shales.

While these divisions cannot be separated in mapping in Dallas, there appears to be the same general succession as further south and west.

MISSOURIAN.

The beds of this stage are confined, as already stated, to the southwestern part of the county, where they underlie a portion of Adams and Union townships. They are well exposed at several points where the limestone has been quarried quite extensively. The rock is blue or buff in color, very compact and non-crystalline. The individual ledges are from eight to ten inches thick, and are separated by marly partings. At certain horizons bands of flint nodules appear. From eight to twelve feet of these limestones are exposed at the quarries, and they apparently represent the base of the Missourian, and are thus the Winterset limestone of White§

*Amer. Geol., vol. XVIII, pp. 22-28, 1896.

†Bain: Iowa Geol. Surv., vol. V, p. 378.

‡Proc. Iowa Acad. Sci., 1896, vol. IV, p. 22-25, 1897.

Geol. of Iowa, White. 1870. Vol. I, p. 246, 1870.

or the Earlham beds of the Bethany limestone, as more recently defined.*

Below the quarry limestone there are shales with occasional thin bands of limestone. These shales with intercallated limestones probably represent a period of oscillation of the shore line, when shallow water conditions favorable for the deposition of the Des Moines shales were gradually changing to deep sea conditions which allowed the formation of the Missourian limestone. If this were the case, it would be difficult to tell in the field just where the one formation ends and the other begins.

The following is a general section of the Missourian beds as they occur in Dallas county.

GENERAL SECTION OF MISSOURIAN BEDS.

		FEET.	INCHES.
6.	Limestone, blue to buff, compact, evenly bedded	10 to 14	
5.	Shale	6	
4.	Shale, black, fissile		6
3.	Limestone, blue-black, compact, exposed		6
2.	Shales	25	
1.	Limestone, impure, fragmental	6	

This limestone has been traced west in southern Guthrie county to the point where it disappears under the Cretaceous.† Its eastern limits have been determined by Tilton in Madison county, and from there it has been traced south by the present writer through eastern Clarke and Decatur counties to the Missouri line. The Winterset limestone of White is the equivalent of the Bethany Falls limestone‡ of the latter state and of the Erie limestone§ of Kansas, since their continuity has been established in the field. Tilton and Bain‖ retain the name Winterset for the third limestone member of the Bethany formation.

*Geol. of Madison county, Iowa Geol. Surv., vol. VII, 514.

†Geol. of Guthrie County. Iowa Geol. Surv, vol. VII. p. 1.

‡Trans. St. Louis, Acad. Sci., vol. II, 311, 144. 1862. Mo. Geol. Surv., Iron Ore and Coal Fields, pt. ii, p. 77 *et seq.* 1873.

§ Univ. Geol. Surv. Kansas, vol. I, p. 154. 1896.

‖ Geol. of Madison County. Iowa Geol. Surv., vol. VII, 517.

Pleistocene.

The indurated rocks of Dallas county are concealed beneath a heavy covering of drift. This deposit of clay, sand and gravel, left by the ancient ice sheets, everywhere conceals from view the underlying coal measures, except at certain points along the streamways where the superficial materials have been removed.

The greater portion of the county, as already shown, lies within the limits of the Wisconsin lobe, which extended as far south as the Raccoon river.

KANSAN DRIFT.

The oldest drift exposed anywhere within the county is the Kansan. In many parts of the state a still older drift is known to occur below it. It is exposed at Afton Junction, Union county, about thirty miles south, and evidence of it has also been found in Polk county and elsewhere. It is not improbable that this older drift occurs also in Dallas county, but any evidence of such an occurrence is wanting. The Kansan drift covers the southern half of Boone, Van Meter and Adams townships, the greater portion of Union and the southwest corner of Linn. Wherever exposed in road cuts or along streams it has a dull red or brownish appearance, due to the high state of oxidation near the surface. This oxidized condition is a marked characteristic of the deposit. When a considerable thickness of the till is exposed it is noticeable that at a depth of thirty to forty feet below the surface the color changes to a dark blue. This change is well exhibited in a high bluff exposure on the south side of the Raccoon in section 14 of Adams township. The entire bluff, which is here nearly 100 feet high, is formed of Kansan drift. The upper thirty or forty feet is red and oxidized and contains quite a number of small pebbles and some sand. Below this is a compact, blue bowlder clay, quite free from pebbles, though patches of sand appear in places. Sugar creek, in the lower portion of its course, cuts into Kansan drift, and an exposure in section 15, of Boone township, showed the following varieties of bowlders: Granite, quartzite, limestone, hornblende, gneiss, diorite, diabase, gabbro and quartz. The red quartzite was especially abundant and chert was also common. The granite bowlders and pebbles were much weathered and rotted, crumbling readily in the hand. About a mile south, in section 22, several pieces of conglomerate, resembling the Cretaceous rock of Guthrie county, were found. These fragments were probably derived from a Cretaceous area to the north, which has either been carried away by erosion or else deeply buried under the drift. The nearest known outcrop of this rock is about twenty-five miles west in Guthrie county.

Surface bowlders are not as common in connection with the Kansan drift as they are with the newer Wisconsin. This is doubtless due partly to the fact that the former is in most places covered by loess, thus concealing any bowlders that may have been upon the surface. Occasionally a good sized one is found, as in section 18 of Union township, where a red granite bowlder, twenty-five feet long and half as wide, was seen.

The Kansan drift, as already pointed out, is much cut up by streams, and the surface is well drained. The valleys in this older drift have many branches and these in turn break up into smaller ravines, forming a well developed drainage system, and showing that the forces of erosion have been active for a considerable period.

The thickness of the Kansan drift varies in different places from sixty to 125 feet and more. A well drilled about five miles southeast of Redfield, in section 24 of Union township, passed through 123 feet of drift, the upper forty-three feet being yellow, oxidized till, below which was blue clay.

LOESS.

The Kansan drift is covered in most places by a sheet of loess. As this latter deposit is not found overlying the newer or Wisconsin drift, its presence or absence furnishes a ready means of determining which of the two drift sheets are present. The loess is characterized by its homogeneous structure, the fineness of its constituents, its buff color and the absence of all pebbles and bowlders. The deposit often contains numerous lime concretions, known as loess-kindchen, and fossils may be present in greater or less abundance. The loess is considerably younger than the Kansan drift, since the latter had been eroded quite extensively before the loess was deposited over it. That it is older than the Wisconsin drift is shown by its presence beneath that drift sheet. While no instances were noted in Dallas county where this was the case, buried loess with shells has been reported in wells, and Bain* mentions a number of localities in Polk county where the Wisconsin drift overlies the loess. The loess is, therefore, intermediate in age between the Kansan and Wisconsin drift sheets, and has been referred to the Iowan.† This correlation is based partly on the fact that the loess can be traced around the southern border of the Wisconsin to Marshall county, where it comes in contact with the Iowan, but chiefly on the fact that the conditions at the end of the Wisconsin invasion were not favorable to the deposition of loess, as is shown by the gravel trains. But at the end of the Iowan invasion there was a period of loess deposition. The Iowan drift sheet and the loess found along its border are known to hold an intermediate place between the Kansan and Wisconsin, and there would seem to be good reason, therefore, for considering the loess of Dallas county to be an equivalent of the Iowan. The thickness of the deposit varies widely. In places it thins out and disappears, while at other points it is known to be from ten to twenty feet thick, if not more. In

* Iowa Geol. Surv., vol. VI, pp. 444-447. 1896.
† Bain: Iowa Geol. Surv., vol. VI, p. 461. 1896.

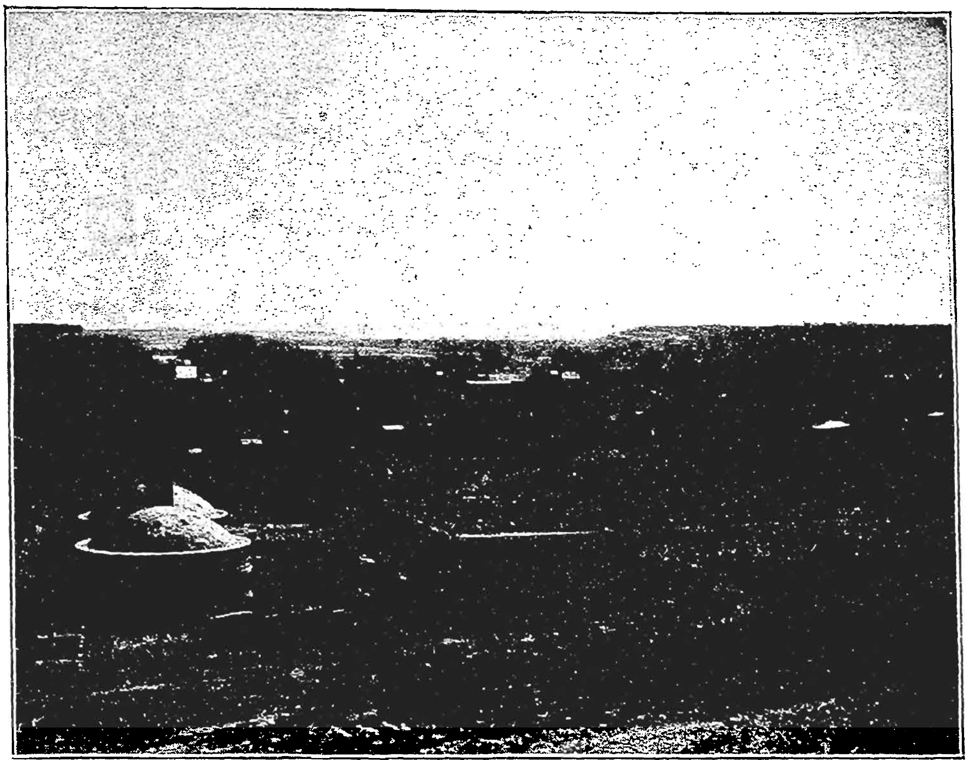


FIG. 1. Gorge of the Raccoon river cut in coal measures. Overlooking Van Meter.

FIG 2. Drift section on the Raccoon river southwest of Redfield. The open caves near the center of the picture mark the gravel horizon.

the bottom of the valley at Bear creek, in section 36 of Union township, ten feet of loess are exposed.

The best exposure, however, and one of special interest, occurs on the north side of the Raccoon, in section 7 of Union township. The section is as follows:

		FEET.	INCHES.
5.	Loess, sandy, stratified	13	
4.	Clay, with lime concretions		8
3.	Loess, sandy	6	
2.	Gravel, very ferruginous	7	
1.	Shale, gray	11	

No fossils were found in the loess. The interloessial clay contains no pebbles, but is a stiff, gray clay, similar in appearance to the clay of till. It shows little or no foreign material of any kind. The gravel underlying the loess bears evidence of considerable age, since ferrugination has gone on quite extensively and much iron is present. It contains rather a high percentage of Cretaceous material in the form of well-rounded, clear, quartz pebbles. The gravel is pre-Iowan in age, and seems to represent Kansan surface material re-worked.

The most significant feature in the above section, however, is the clay interstratified with the loess. Cases of this kind are not common. An example of interloessial till is described by Todd and Bain as occurring near Sioux City.* The bowlder clay at that place contains pebbles and bowlders and differs in this respect from the South Raccoon exposure. The presence of the till in the loess is ascribed by the above writers to icebergs which, breaking off from the ice sheet, carried the till and dropped it where now found. Subsequently it was covered by loess. This theory would hardly seem to be applicable to the Dallas county region. There is no evidence of a body of water of sufficient extent and depth to float icebergs. While the presence of the clay in the loess is not easy to account for, its occurrence there, as well as the stratified appearance of the loess itself, would seem to prove beyond a

* Iowa Acad. Sci., vol. II, pp. 20-23. 1895

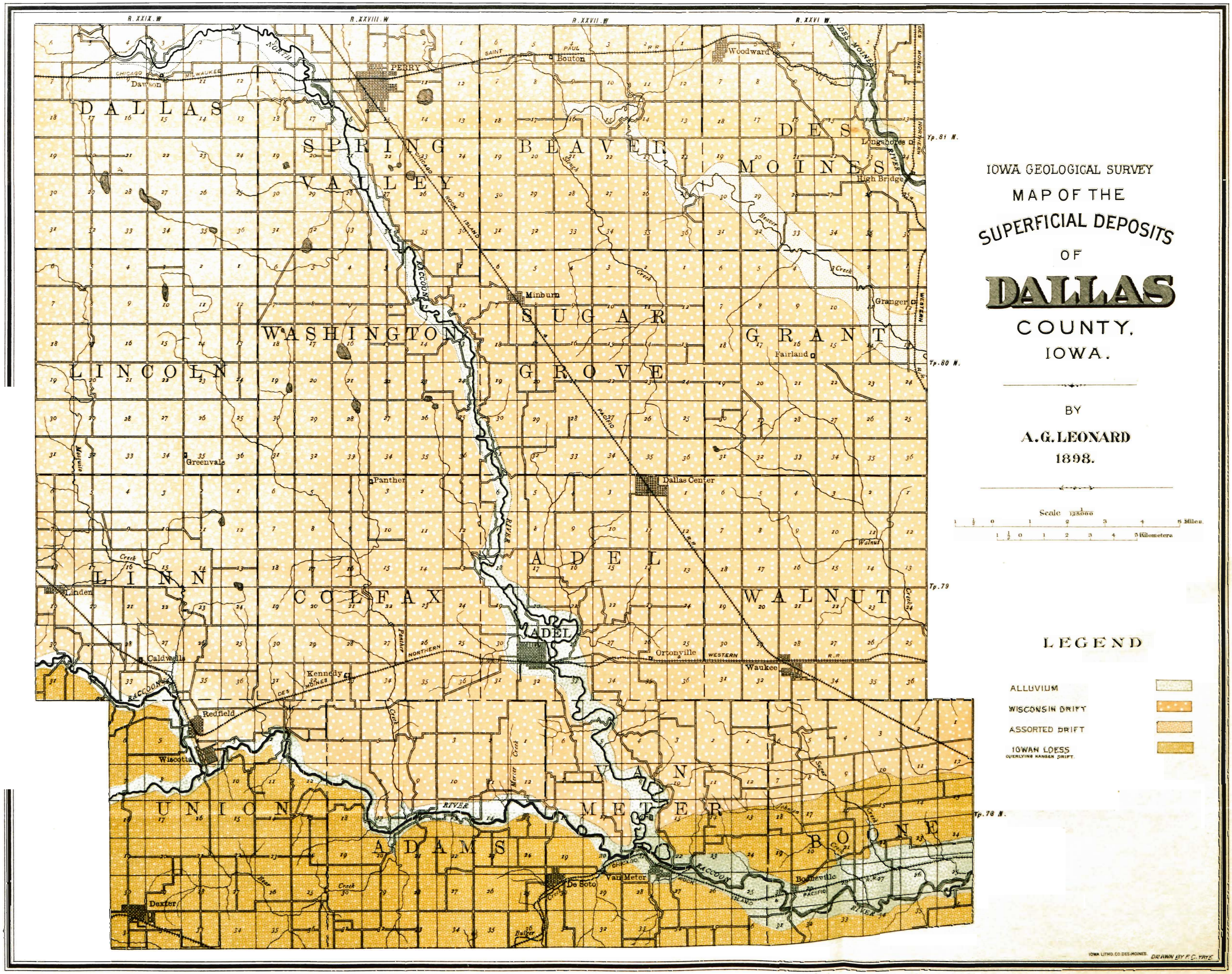
doubt that the materials were deposited in water. The most probable hypothesis is that the beds are secondary and represent the accumulations of side wash in the valley at the time that the river was ponded by the Wisconsin ice.

WISCONSIN DRIFT.

Much the larger portion of the county is covered by the newer or Wisconsin drift. As has already been pointed out this drift has undergone but slight erosion and the surface is for the most part flat and poorly drained. Wherever exposed the till has a fresher and less oxidized appearance than the Kansan. It is of a buff or light gray color, and its pebbles and bowlders do not show the extensive weathering exhibited by those in the older drift. Bowlders are also much more numerous over the surface of the Wisconsin, especially near the border. In the vicinity of Redfield bowlders are abundant both on the surface and also scattered through the gravel terrace at the mouth of Mosquito creek and below. Whereever excavations have been made in the terrace large numbers of good sized bowlders, a foot or more in diameter, are brought to light. Their abundance in the terrace at this point would seem to indicate that the borders of the Wisconsin ice sheet was not far distant, for they could not have been carried very far by the streams issuing from the ice front, but must have been soon deposited along with the gravel at no great distance from the border.

As already stated, there is no evidence of the Wisconsin ice having crossed the Raccoon river, except at a point two miles northwest of Redfield. On the south side of the Middle Raccoon, in section 6 of Union township, there is a thick bed of bowlders, and bowlders also cover the surface in large numbers. On the north side of the river the following section is exposed.

		FEET.
3.	Wisconsin drift	25
2.	Stratified sand and gravel, assorted drift	6
1.	Shale, black	4


IOWA GEOLOGICAL SURVEY
MAP OF THE
SUPERFICIAL DEPOSITS
OF
DALLAS
COUNTY,
IOWA.
BY
A. G. LEONARD
1898.
Scale
1 ½ 0 1 2 3 4 5 Miles.
1 ½ 0 1 2 3 4 5 Kilometers
LEGEND
ALLUVIUM
WISCONSIN DRIFT
ASSORTED DRIFT
IOWAN LOESS
OVERLYING KANSAN DRIFT.
R. XXIX. W.
R. XXVIII. W.
R. XXVII. W.
R. XXVI. W.
Tp. 81 N.
Tp. 80 N.
Tp. 79
Tp. 78 N.
DALLAS
SPRING VALLEY
BEAVER
DES MOINES
LINCOLN
WASHINGTON
SUGAR GROVE
GRANT
LINN
COLFAX
ADEL
WALNUT
UNION
ADAMS
VAN METER
BOONE
Dawson
Perry
Bouton
Woodward
Longshores
High Bridge
Minburn
Granger
Fairland
Greenvale
Panther
Dallas Center
Linden
Caldwell
Kennedy
Adel
Ortonville
Waukee
Redfield
Wiscotta
Dexter
De Soto
Van Meter
Booneville
IOWA LITHO. CO. DES MOINES.
DRAWN BY F. C. YATE.

Across the river, and only a short distance below the above exposure, another section showed the following section.

		FEET.
2.	Bowlder bed	15
1.	Shales, gray, exposed to river	15

No. 2 is composed almost wholly of good sized bowlders, with very little clay material. A large proportion of the rocks are limestone, but granite and gneiss is also quite common. While this bowlder bed cannot perhaps be said to form a true terminal moraine, it at least marks the limit of the Wisconsin ice and gives evidence that the Des Moines lobe crossed the river at this point. The bowlders were doubtless left by the ice where they now lie and were not transported by water or other agency. The river valley here shows evidence of being post-glacial and post-Wisconsin. The old valley was filled up with drift, and the river was forced to cut a new channel.

The thickness of the drift over the northern portion of the county, as shown by several well records, varies from 80 to 120 feet and it is not improbable that, in places, it reaches a greater depth.

ALLUVIUM AND TERRACES.

Many of the streams of the county are bordered by alluvial bottoms. Along the Raccoon river from Van Meter east to the county line an old flood plain is a marked feature of the landscape. It varies in width from one to two miles and extends up the North Raccoon for a considerable distance. It then narrows to about half a mile and again broadens out in the vicinity of Adel. Below Van Meter the South Raccoon is bordered along its entire course by a flood plain of varying width. The smaller streams of the county frequently have flood plains along the lower portions of their courses. Thus Sugar creek has well defined bottom lands, extending up more than a mile from where it enters the valley of the Raccoon.

Terraces.—Gravel terraces are found along the North, Middle and South Raccoon rivers, and also along the Des Moines. In the valley of the latter stream there is a well defined gravel terrace about twenty-five feet above the river. Just west of its bridge the Chicago, Milwaukee & St. Paul railroad has extensive gravel pits in this terrace. At various points along the sides of the gorge there are evidences of a higher terrace about seventy feet above the river. The latter is composed of drift and has been considerably eroded by small streams.

Along the North Raccoon a gravel terrace about twenty feet high is well developed. This is well shown just south of Adel, where the road runs over it for some distance. It is one-quarter of a mile wide at this point.

At Booneville, Van Meter and Redfield the terraces are well defined. Near Booneville two can be readily distinguished, the higher twenty feet and the other about twelve feet above the river. At Redfield and Van Meter the gravel terrace is about twenty feet above the river. As already noted, at Redfield there are numerous good sized bowlders mixed with the gravel.

The terraces owe their formation to the streams flowing from the melting ice sheet. These rivers were loaded with gravel and sand, which was carried some distance down stream and deposited. Terraces of aggradation, as defined by Salisbury,* would thus be built up. The high drift terrace along the Des Moines had a different origin and seems to mark a definite stage in the down cutting of the stream.

GEOLOGICAL STRUCTURE.

DEFORMATIONS.

The strata of the county have been for the most part but little disturbed from the nearly horizontal position which they occupied when deposited. They have a gentle dip to the southwest, but this is so slight that it is scarcely noticeable

* Ann. Rept. State Geol., N. J., 1892, 103-104. 1893.

in any single outcrop. The only marked deformation noted is in the southwestern corner of the county, in the vicinity of Redfield. The beds have here been forced into an anticline, whose axis appears to have a direction approximately north and south, though this could not be definitely determined.

This fold brings the deeper strata to the surface, and a massive sandstone and underlying coal seam outcrop near Redfield. The strata dip in either direction from the crest of the anticline. In following up the South Raccoon from Booneville, the same beds appear in the different outcrops until the bend at Cottonwood mill is reached, where a massive sandstone appears above the river, and the strata outcropping farther down the stream disappear. The same beds again appear a few miles above Redfield, along the Middle Raccoon, and are also found in Guthrie county. The same succession of strata thus appears on the east and west sides of the anticline.

An interesting outcrop is found in section 2 of Union township, about one mile south of the bridge. There is here exposed about twenty-five feet of rather soft blue or gray sandstone. The rock shows cross bedding, the bedding planes being inclined about 30° to the horizontal. Cutting these planes at an angle of nearly 25° are well developed cleavage planes. Since the planes of bedding are not very conspicuous, and hence are apt to be overlooked at first sight, these cleavage planes are easily mistaken for them. The forces that produced the pressure resulting in the development of this well marked cleavage were, perhaps, the same ones that produced the Redfield anticline, as these beds lie within the area of disturbance. Two sets of joints are also present. One set is nearly vertical, and at right angles to the face of the exposure; while the other set is approximately parallel to the face, and has an inclination of 75° or 80°.

ECONOMIC PRODUCTS.

Coal.

Dallas county ranks as one of the important coal producing counties of the state and for over thirty years this mineral fuel has been mined within its borders. Underlain as it is over nearly its entire area by the lower coal measure beds (Des Moines formation) with their numerous veins of coal, there is no reason why this industry should not reach even greater development than it has at present. Whereas now only surface seams are being worked in many places, it is very probable that by going deeper, other and thicker seams would be found which could be worked with good profit. At Van Meter, for example, two veins are mined at depths, respectively, of 285 and 305 feet, each one averaging three feet in thickness.

Coal occurs at a number of different horizons. Some of the veins outcrop along the streamways and others lie some considerable distance below the surface and are reached only by sinking shafts. They range in thickness from a few inches to three feet, and in several instances four-foot veins are reported.

The lowest horizon from which coal is mined within the county is at Van Meter, where the lower vein can be but little more than 100 feet above the Saint Louis limestone, and is therefore well toward the base of the Des Moines beds. The seam lies 370 feet below the heavily bedded sandstone exposed in the bluff one mile east of town. Six feet below this sandstone there is a coal horizon, but the vein—the Marshall coal—is here only six inches thick. Between fifty and sixty feet above the Marshall coal there is another coal horizon, the Lonsdale coal, which is the highest within the county. It is mined about two miles south of Linden, in section 31, Linn township, and less than a mile from the county line. Between these two extremes, the one last mentioned, or the Lonsdale seam, and that worked at Van Meter, there are a number of horizons at which coal is found. The mines on the Raccoon below Cottonwood mill are in a vein above the massive sandstone exposed along the river between that point and Redfield. The old mines along the river just south of Redfield were a few feet below the sandstone.

The coal which has been mined at several points between Redfield and the county line, along the Middle Raccoon, lies considerably above the horizon of the Redfield vein.

That deeper coal veins are present in the southern part of the county is shown by the record of the De Soto well already given. At that point four veins of coal were encountered, as follows:

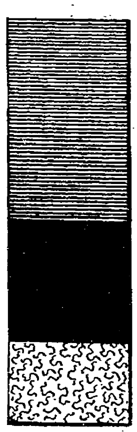
DEPTH.	THICKNESS.
98 feet	1 foot.
239 feet	2 feet.
255 feet	1½ feet.
350 feet	3 feet.

In the northern part of the county coal is mined at Dawson and on the Des Moines river. The veins worked at these points cannot be correlated with those in the southern part of the area.

In the following list of mines the attempt is not made to give all the locations where coal has been or is now being mined. It would be difficult to secure a complete list as many small local banks are abandoned and new ones opened from year to year. It is thought, however, that all those mines have been included which were in operation during the summer and fall of 1896, and also others now abandoned but of importance as showing the presence at certain points of seams of coal.

Raccoon Valley Mines.—In the vicinity of Commerce, just over the line in Polk county, there are a number of small drifts in the hillside. At one point a shaft has been sunk to a depth of 100 feet and a three-foot vein of coal worked for several years.

Van Meter is one of the important mining localities of the county. In the western part of town is located the mine of the Platt Pressed and Fire Brick Co. The shaft, which is about 300 feet deep, reaches three veins of coal. The lower vein averages three feet in thickness, and twenty feet above is the middle vein which varies considerably, ranging from eighteen inches to four feet, with an average thickness of about three feet. It is this latter that is now being mined, the lower seam having been worked out at this point. From three to seven feet above the middle vein there is a third coal horizon. This coal is nowhere more than eighteen inches thick, and in places it thins out and disappears entirely. The two upper veins are separated by fire clay, which is used in the manufacture of brick by the Platt Pressed & Fire Brick Co. whose plant is located close by the mine. The two plants are worked in co-operation.



	FEET.
3. Shale, dark, argillaceous, somewhat fassile..	5
2. Coal..........	3
1. Fire clay..........	2

Figure 3 Coal bed at Platt Pressed and Fire Brick Co.'s Mine. Van Meter.

South Raccoon Valley Mines.—Coal has been mined at numerous points along the South Raccoon, but most of the mines are abandoned. Two mines are in operation in section 12 of Union township. The vein worked here varies from fourteen to twenty-four inches in thickness, and becomes thicker toward the east. The seam dips quite rapidly to the east and a short distance from the shaft of the Caves' mine it passes below the river bed. The coal thins out to the north and west until, within a distance of about a mile, it disappears. Many mines have been opened in this vein during the past fifteen years.

Oliver Caves' Mine.—(Tp. 78 N., R. XXIX W., Sec. 12, Ne. qr., Nw. ¼.) The seam is twenty to twenty-four inches thick;

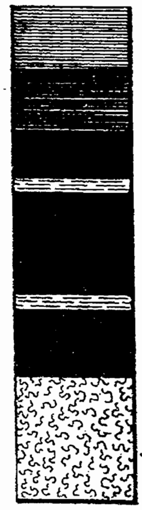
formerly worked by a slope. A new shaft has now been sunk 45 feet to the coal. The section at the shaft is as follows:

		FEET.	INCHES.
10.	Drift	25	
9.	Shale, gray	4	
8.	Limestone, blue, compact	1	
7.	Clay		6
6.	Limestone, blue, fossiliferous		10
5.	Shale, black, bituminous; "black jack"	8	
4.	Limestone, blue		10
3.	Slate, black	2	6
2.	Coal		20
1.	Fire clay	...	....

M. V. Dawson Mine.—This is located across the river and a short distance west of the Caves mine (Tp. 78 N., R. XXIX W., Sec. 12, Nw. qr., Se. ¼). The vein is the same one that is mined on the opposite side, but is here worked by a drift. It has a thickness of eighteen to twenty inches. Both of these mines are in operation only during the fall and winter and supply local trade. During the busy season each mine employs from ten to sixteen men, and the output is in good demand.

The first mines in the county were opened in the vicinity of Redfield, and south of town in the valley of the South Raccoon a number of slopes and drifts show that coal has been quite extensively mined here. At the present time these mines are not worked. The vein is three feet thick and lies about twelve feet below the massive sandstone which forms the steep escarpment known as the "Hanging Rock."

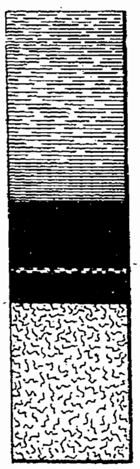
The old Leeper mine, which was operated more than twenty years ago, was a shaft sixty-five feet deep and worked a vein averaging three feet in thickness. The section at this point is as follows:



	FEET.	INCHES.
7. Shale, rather massive and compact, exposed	2	
6. Coal		8
5. Clay parting		1/4
4. Coal	1	7
3. Clay parting		3
2. Coal	1	
1. Fire clay, exposed	2	

Figure 4. Bed of old Leeper Mine. Redfield.

Not far distant is the old Redfield mine, near which the following strata are exposed:



	FEET.
3. Shale, bituminous in lower part	6
2. Coal, two benches, two feet and one foot in thickness, separated by clay parting	3
1. Fire clay, gritty	5

Figure 5. Coal vein at Redfield Mine. Redfield.

On the south side of the river, in section 12 of Union township, and near the Marshall artesian well, a one-foot vein of coal has been worked for several seasons. The seam lies forty feet above the river and has yielded considerable coal.

Middle Raccoon River Mines.—Along the Middle Raccoon, from Redfield to the county line, a large number of mines have been opened from time to time, and old drifts are frequently met with on both sides of the river. On Mosquito creek, just above its mouth, at the old Parker and Piatt mines, a thin vein of coal was early worked on a small scale.

For several years mining has been carried on at Samuel Mohr's place, in Tp. 79 N., R. XXIX W., Sec. 33, Sw. qr. The coal is about one foot thick, with a good slate roof. It has been worked at several points by means of drifts and slopes. Another vein about eighteen inches thick outcrops at various points along the hillsides bordering the small stream, in sections 28 and 29. This bank has been worked to some extent in the southeast quarter of section 29, just south of the railroad. Less than a mile west of here, on the C. C. Duck place, a twenty-inch coal seam has been mined in past years. The vein lies about seventy-five feet above the river, and it is doubtless the same one that is worked about a mile southwest, on the opposite side of the stream. It is also probable that this is the same seam that has been mined one mile to the east. Coal occurs in this neighborhood at two horizons above the river level, the upper vein lying sixty feet or more above the lower. The upper is the thicker vein of the two, and most of the mines are apparently on this seam, though a few work the lower one.

The Topping Mine (also known as Manor's coal bank), is located about two and one-half miles south of Linden (Tp. 79 N., R. XXIX W., Sec. 31, Ne. qr., Sw. ¼). It has been opened three years, and is still in operation. The vein, which is from sixteen to eighteen inches thick, is divided by two thin dirt bands. The coal has a sandstone roof, and is of good quality. It is sold quite extensively in Linden and the surrounding country. There is another mine about one-half mile south of here, just over the Guthrie county line.

		FEET.	INCHES.
3.	Sandstone (exposed)	1	
2.	Coal, 8, 4 and 6 inches, separated by thin clay partings	1	11
1.	Fire clay		6

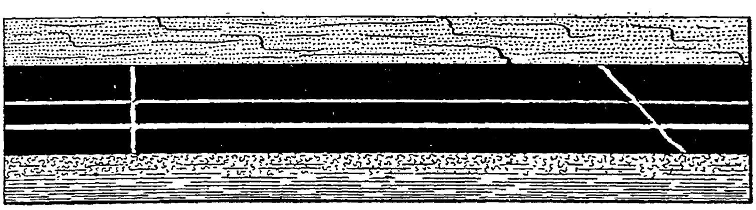


Figure 6. Clay seams in Topping Mine, south of Linden.

North Raccoon Valley Mines.—Four miles north of Adel coal has been worked for many years. Two seams about twenty feet apart are present in this vicinity. The upper one has a thickness of twelve to fifteen inches, and the lower varies from two to three feet. The Chaney mine, located in Tp. 79 N., R. XXVIII W., Sec. 12, Se. qr. Sw. ¼, is still worked to some extent for the local trade. The seam is here thirteen inches thick, and is overlain by several feet of bituminous fissile shales. In the bluff of a ravine on the Chaney place the following section is exposed.

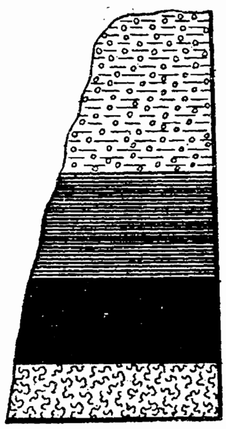


Figure 7. Section at Chaney Drift. Four miles north of Adel.

	FEET.	INCHES.
4. Drift	3	
3. Shale, bituminous	2	
2. Coal	1	6
1. Fire clay exposed	1	

A short distance east of the Chaney mine is the Pittman bank, where coal was formerly taken from the lower vein.

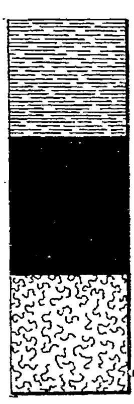
About four miles north of here, and three miles southwest of Minburn, in section 24 of Washington township, a new mine was opened in the winter of 1896-97. It is on the land of Mr. Charles Scott, and was worked by George and Thomas Bott, of Redfield. The coal outcrops near the bottom of a ravine about a mile from the Raccoon, and lies from forty to fifty feet above the river. It averages two and one-half feet in thickness, though it is three feet in places. The seam is divided by one foot of fire clay. The top vein runs from eighteen to twenty-four inches and the lower vein from twelve to thirteen inches in thickness. A good slate roof covers the coal. The vein dips to the east. The coal is of good quality, and all that was mined found a ready market.

Dawson is at present one of the important mining towns of the county. The mine of the Chicago Coal Co., is located one-half mile east of town, on the Chicago, Milwaukee & St. Paul railway. The present shaft, which has a depth of 125 feet, was put down in November of 1895. At this point there are three veins, as follows:

DEPTH.	THICKNESS.
83 feet	1 foot, 10 inches.
118 feet	3 feet.
165 feet	$3\frac{1}{2}$ to 4 feet.

The shaft at present extends only to the three-foot seam, the lower coal having been reached by boring. The record of the shaft has already been given on a previous page. The mine has a good slate roof, with fire clay beneath the coal. It is worked on the longwall plan and ventilated by a fan. Nearly all the coal taken out is used by the railroad, though some is sold to the local trade. At the old shaft, located one-quarter of a mile west, four veins of coal are reported, there being two seams below the three-foot coal worked at the new mine. These were three feet and four feet thick respectively.

The Tudor mine is located near the river at the foot of the bluff just north of Dawson (Sec. 10, Nw. qr., Ne. $\frac{1}{4}$). It is worked by means of a shaft, which reaches the same vein that is mined by the Chicago Coal Co. The vein here varies considerably in thickness, ranging from one and one-half to three and one-half feet, and thins toward the west. The mine supplies the local trade. The section shown here is:



	FEET.	INCHES.
3. Shale, bituminous	3	
2. Coal	3	6
1. Fire clay	3	

Figure 8. Coal seam at Tudor Shaft, Dawson.

Des Moines River Mines.—In the valley of the Des Moines river coal has been mined for the local trade at a number of different points, and at the present time several mines are being operated in this part of the county.

The oldest of these is the Strange mine (also known as the Tabor shaft), now operated by J. H. Watson. It is located near the wagon bridge (Tp. 81 N., R. XXVI W., Sec. 14, Sw. qr. Ne. ¼), and has been in operation twelve years. At a depth of forty feet the shaft reaches a two-foot vein. The roof is formed of a compact, impure sandrock eighteen inches thick, with black slate above. Below the coal there is four to six inches of bituminous shale underlain by fire clay. The longwall method is used in working the mine. There are several other openings in the same seam near the present shaft.

The mine of the Chestnut Valley Coal Co., operated by Ole Olsen, is about half a mile north of the Strange mine (Nw. ¼ of Nw. qr, Sec. 14). The opening is a new one, the first coal having been taken out in the fall of 1896. The shaft is 112 feet deep and passes through four veins of coal. A fifth vein is reported to have been struck by the drill at a depth of 171 feet.

The thickness and depth of the seams are as follows:

	DEPTH	THICKNESS.
1.	16 feet	12 to 14 inches.
2.	40 feet	1 foot 8 inches.
3.	87 feet	2 feet 4 inches.
4.	109 feet	2 feet.
5.	171 feet	4 feet.

The upper vein is exposed in the bed of a small stream near by. The third seam is the one being worked, though some coal has been taken from the fourth. The third vein is the same one that is mined at the Tabor shaft. Both of these mines supply the local trade.

PRODUCTION.

A majority of the mines of the county are operated by means of shafts and employ steam power. A few are fitted with gins run by horse power, and some are drifts or slopes. In 1897 the total reported production from seven mines amounted to 14,102 short tons, which, at an average price of $1.58 was valued at $22,281.16. This probably very closely approximates the true production.

Clays.

Dallas county contains an abundance of good clays. The coal measure shales and clays, which outcrop at numerous points within its borders, furnish the best of material for the manufacture of clay products. The drift clays are utilized to good advantage at several localities, as are also the alluvial deposits found along many of the streams. The loess of the southern part of the area would doubtless be found well adapted to the same purpose, as it has been used elsewhere with good success. The clays support a number of plants in different parts of the county.

Van Meter.—The Platt Pressed and Fire Brick Co. have extensive works at the foot of the bluff in the western part of town. The clay used is obtained partly from the coal mine near by and partly from near the top of the bluff above the plant. The section at the latter point is as follows:

	FEET.	INCHES.
5. Soil	1	
4. Sandstone		8
3. Shale, sandy, gray	2	
2. Sandstone, blue, compact	1	6
1. Shales, red and gray, exposed in face of pit	15	

The clay shales obtained from the bluff are used in the manufacture of red brick. The clay for the buff and fire brick is obtained from the mine at a depth of 265 feet. Between the upper and middle veins of coal there are from three to seven feet of fire clay. The entire thickness between the two seams is removed in places. The lower part of the section at the mine is as follows:

		FEET.	INCHES.
9.	Shale, argillaceous	90	
8.	Coal	1 to	1½
7.	Fire clay, impure, gray	2 to	4
6.	Fire clay, "hard clay," "Flint" fire clay		6 to 18
5.	Fire clay		6 to 18
4.	Coal	1½ to	4
3.	Sandstone	16	
2.	Shale, bituminous	1	6
1.	Coal	2 to	4

No. 7 is used for the buff brick, either alone or mixed with a small amount of No. 5. No. 6 is used for making first grade fire brick. The shale (No. 9) overlying the top coal makes a good quality of brick of a pink color. By a mixture of these several clays, a building brick of almost any desired color can be secured. Analyses of the three different grades of fire clay have been made for the company, with the following results:

	NO. 6.	NO. 5.
Silica, $Si\ O_2$	86.63	55.11
Alumina, Al_2O_3	10.92	26.71
Iron oxide, Fe_2O_3	.10	4.29
Lime	.....	.....
Sulphuric acid	.....	4.16
Water	2.32	9.69
Total	99.97	99.96

Analyses of Nos. 5 and 6 were by W. S. Robinson, chief chemist of Union Pacific railway, Omaha, Neb.

ANALYSIS OF NO. 7.

Silica, $Si\ O_2$ (combined)	29.94
Alumina, Al_2O_3	25.74
Quartz, $Si\ O_2$	23.27
Lime, $Ca\ O$	.48
Magnesia, $Mg\ O$	.98
Iron oxide, Fe_2O_3	7.07
Alkalies, K_2O, N_2O	4.30
Water and organic matter	10.19

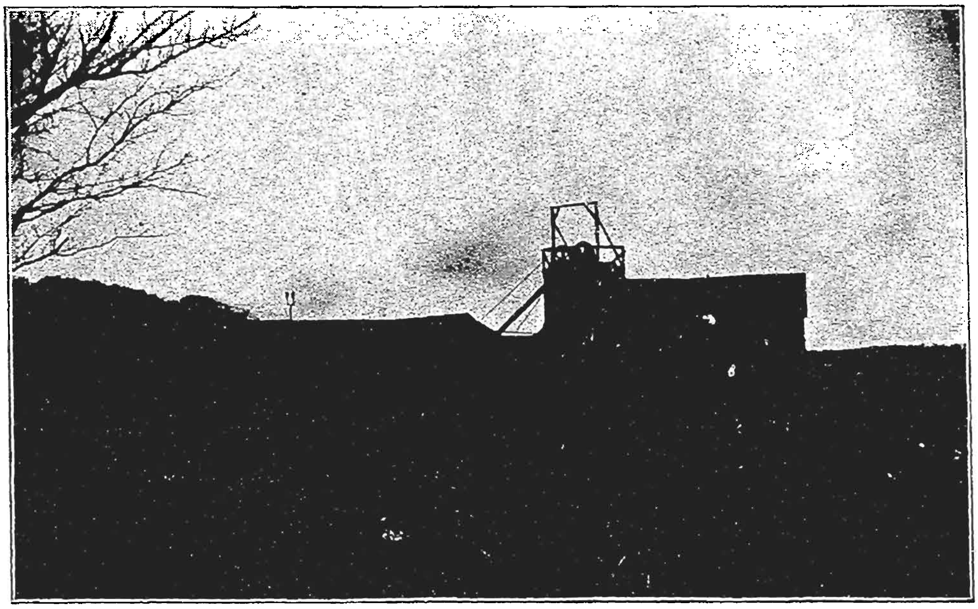


FIG. 1. Top works of the Chicago and Van Meter Coal Co.'s mine, Van Meter.

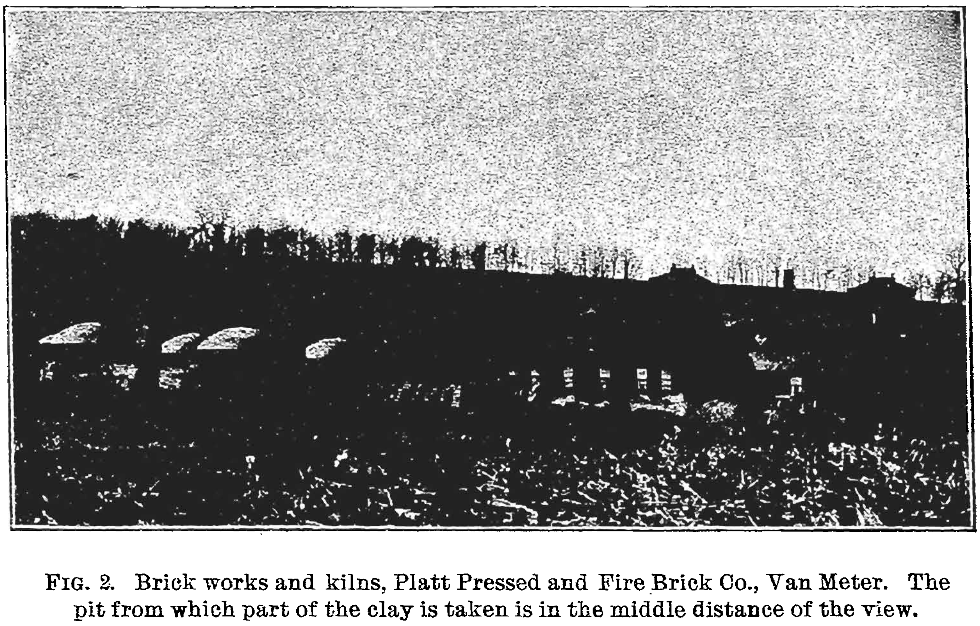


FIG. 2. Brick works and kilns, Platt Pressed and Fire Brick Co., Van Meter. The pit from which part of the clay is taken is in the middle distance of the view.

Analyzed by Charles Ferry, Troy, N. Y.

No. 6 makes a first-class fire brick, which will withstand a temperature of nearly 3,000° Fahr.

Aside from the necessary sheds and power house, the plant consists of a four-mould Simpson dry press, an E. M. Freese & Co.'s "Mammoth" stiff-mud machine, two nine-foot dry-pans made by the Des Moines Manufacturing and Supply Co., a Johnson & Cregier smooth-roller crusher and a twelve-foot pug-mill. There are two Andrews steam dry-sheds, four forty-horse-power boilers, a 150-horse-power engine and six round, down-draft kilns with a capacity of 500,000. For front brick, the Simpson press is used; for ordinary building brick, the Ohio. The works have a daily capacity of 20,000 pressed brick and 60,000 stiff-mud brick. Nearly 20,000 fire brick, which are repressed by hand, can also be produced daily.

The product consists chiefly of buff pressed brick and fire brick. Some pressed brick of terra cotta red color are also made. The output of the plant is deservedly one of the most popular in the state. So far the fire brick have been made on the dry-press, but it is proposed to hereafter to make them up as a stiff mud. The company is also arranging to manufacture Roman brick and to make some additions and improvements to its plant.

Adel.—The R. M. Kearnes & Co. Brick and Tile factory is located northwest of town, just outside the city limits. It was established fifteen years ago. The clay is obtained from a bank about half a mile west of the works. At this point the section is:

	FEET.	INCHES.
3. Shale, variegated, siliceous and micaceous, with hard, ferruginous, clayey concretions........	14	
2. Coal, impure, clayey, and with calcareous layers		4
1. Shale, light gray to white at top, variegated below, the bottom being brick red to brown, more or less micaceous.....................	??	

At the west end of the section, which is 100 feet long, drift clays rest directly upon No. 1. The bottom clay (No. 1) is the best, and the upper portion of it affords a white brick, but is not used alone. When the works were started, a "Centennial" machine was put in and used for a number of years, when a "Decatur Leader" was substituted. The latter was in turn replaced by a brick and tile mill made by Freese & Co., of Galion, Ohio. The clay needs to be thoroughly ground and pugged in order to give good results.

Drain tile from three and one-half to ten inches in diameter is the main product, only a few brick being made. The clay is dried in closed sheds with swinging doors, and burned in three round, down-draft kilns with a capacity of about 20,000 three-inch tile. These are water-smoked and burned three and one-half days.

Two miles east of Adel is the brickyard of C. Finn. Common "white oak" clay to the depth of eighteen inches is used. Sand brick have been made here and in this vicinity for a number of years. The product is burned in temporary kilns.

Redfield.—Half a mile west of town, on the west side of the Middle Raccoon river, is the yard of W. B. Cooley, who began making brick here in 1893. The yard is located at the foot of the hills that rise rather abruptly from the bottom lands along the stream. The clay used is taken to a depth of from six inches to three feet. It is a sandy wash material, derived mainly from the siliceous till which covers the upland and slopes. The brick are sand-rolled, and when burned they have a good, cherry-red color. Near the river at Redfield a plant was erected a few years ago for the manufacture of brick and tile from the coal measure shales. Owing to unwise management, rather than from lack of suitable material, the industry proved a failure.

A new plant has recently been built at Redfield, having moved here from Jefferson in the summer of 1896. This is the Goodwin & Meyer Brick and Tile works, which are located in the north part of town, near the Des Moines Northern & Western railroad. A short switch runs to the factory. When the works were visited, they had just been completed, and no brick had yet been burned. The clay is obtained from the coal measure shales which outcrop in the hillside close by the works. Here are exposed about twelve feet of blue clay shales, overlain by four feet of red clay. The entire thickness is used, and it is necessary to strip off only a few feet of soil and drift in order to reach the clay. The latter has been carefully tested and found well adapted for making a good quality of brick and tile. Both dry-press and wet mud brick are made. For the former a Frey-Sheckler brick machine is used. The plant is also provided with a dry-pan made by the Des Moines Manufacturing and Supply Co. for grinding and powdering the clay. There is a large two-story drying shed, besides buildings for machinery and boilers.

De Soto.—The De Soto Brick and Tile works, operated by McKissick & Blackman, are located in the eastern part of town, near the Chicago, Rock Island & Pacific railroad. The clay is obtained from near the top of the hill on the south side of Bulger creek, and nearly half a mile south of the plant. Fifteen feet of gray, slightly sandy coal measure shales are exposed in the clay bank. Underneath these there is a ten-inch band of blue, compact limestone. No stripping is necessary, as all the clay is used up to the grass roots. A Bennett machine is used in the production of structural brick and drain tile. The sizes of the tile range from three to eight inches in diameter. They are dried by air in ordinary sheds and burned in three round, closed kilns.

Minburn.—The Minburn Brick and Tile works, which are operated by Martin Myers, lie on the edge of the North Raccoon valley, a mile west and a little south of the station. This factory has been in operation at intervals for over seventeen years, but only on a small scale until the last few seasons. In 1893 fire destroyed the works, but they were rebuilt the following year. A "Decatur Leader" is used along with Brewer conical rollers. The product is dried in a large drying shed and burned in two down-draft kilns. The output consists mostly of tile, ranging in size from three to twelve inches.

Drift clay from near the surface is used to a depth of two to four feet. The top is ashy gray in color, and is known as "timber soil;" under this are eighteen inches of black, more or less gumbo-like clay, and the remainder is ordinary yellow bowlder clay. Some pebbles and rarely a lime concretion occur. A little sand is mixed with the clay to prevent checking. The product has a good red color and finds a ready market. In this section of the county the demand for the larger sizes of tile is constantly growing.

Perry.—About two miles northwest of town is the D. A. McBride brickyard, located in Tp. 81 N., R. XXVIII W., Sec. 5, Se. qr., Se. ¼. Alluvial clay is used to a depth of three feet and is mixed with an ashen and black clay taken from a former swampy area. These are used in the proportion of two of the former to one of the latter. The black clay is not siliceous and contains much humus. It shrinks considerably when used alone. This swamp clay also affords an excellent material for burned clay ballast.

Adjoining the McBride yard is another operated by C. McKean. In both of these yards sand-rolled brick are made. The material used at the latter place is very similar to the alluvial clay used at the adjacent plant. It is largely a redeposition of the drift clay which is found on the slopes, but the more clayey portion has been removed, to the detriment of the material. The brick are burned in temporary kilns and have a good color when not burned too hard.

Dawson.—The Omaha Brick and Tile Co. established a large plant just east of the station at Dawson, on the south side of the Chicago, Milwaukee & St. Paul railroad, and near the mine of the Chicago Coal Co. The plant is well equipped with sheds supplied with steam pipes for drying the product; tracks and cars for conveyance to and from the two capacious, rectangular, patented, down-draft kilns; a Frost dry-pan and a large Penfield brick and tile machine, with convenient apparatus for hauling the raw material. The plant was completed in the spring of 1890, and work was extensively carried on until July, 1891. Various causes have been assigned for the closing of the factory, but it was certainly not due to any defect in the clay or in the quality of the product made. Light colored structural brick and fire brick were manufactured. They are said to have been of first class quality, and found a ready market. Shales are exposed at the water level a short distance northwestward, and these might be utilized, as well as other workable beds near by.

Madrid.—Wilson Bros. have a small brickyard about a mile and a half southwest of Madrid (Tp. 91 N., R. XXVI W., Sec. 1, Sw. qr., Nw. ¼). Common brick were moulded by hand until several years ago when a "New Quaker" was put in. Arenaceous bowlder clay from the upland is used to a depth of two feet. Below, the clay is more sandy and gravelly. The brick are burned in common kilns and are of fair color.

PRODUCTION.

In 1897, according to the reports made to this office, Dallas county ranked twelfth in the production of clay goods. The items were as follows.

Common brick, number	1,033	
Common brick, value		$ 9,631
Total brick, number	2,145	
Total brick value		16,684
Total clay value		35,107

Building Stones,

Both the Missourian limestone and the sandstone and limestone beds of the Des Moines stage furnish good building material. The limestone is quarried at several points in Union and Adams townships along Bear creek and its tributaries.

Bear Creek Quarries.—In the southeast quarter of section 22 of Union township is the quarry of Charles Brown, which has been worked for forty years. The section at this place has already been given. From ten to twelve feet of limestone is exposed in the face of the quarry. The rock is of a blue or buff color and is in beds of eight to ten inches in thickness. Many of the layers are separated by marly partings three or four inches thick, and at certain horizons flint nodules are abundant. The stone is readily worked, and no blasting is necessary in its removal. It is cut vertically by joints and divided horizontally by the marly partings, so that the rock is readily broken into blocks that can be handled. The limestone is very compact and of excellent quality. It is used quite extensively in Redfield, Dexter and the surrounding country.

Stone has been quarried at other points along Bear creek in this immediate vicinity. About two miles south, in the southwest quarter of section 35, near the county line, is the quarry of James Fry. It has been worked for twenty-five years. From twelve to fourteen feet of limestone are here exposed, the beds being the same as those quarried farther north. The stone is used in Dexter and also supplies the country trade.

There were formerly extensive quarries in section 28 of Adams township, operated by Laird & Royce. A switch from the Chicago, Rock Island & Pacific railway extended to them and large quantities of stone were shipped. Most of it was used by the railroad for ballast and construction. The quarries were located on a small tributary of Bear creek, about two miles south of its confluence with the major stream. They were well up toward the top of the hill, and though not worked for a number of years, much stone has been quarried here in the past. About two miles south, and just over the line in Madison county, are the large Earlham quarries, where the Missourian limestone has been extensively worked for many years.

The sandstone of the Des Moines stage, which outcrops along the South Raccoon in the vicinity of Redfield, is quarried in the southeast quarter of section 3 of Union township.

The quarry belongs to Mr. W. F. McGuire, and has been worked for fifteen years. The section here is:

		FEET.
5.	Drift	
4.	Sandstone, soft, buff, heavily bedded	8
3.	Sandstone, blue, compact, hard	7
2.	Clay shales, sandy, blue	4
1.	Sandstone, exposed to river	8

Number 3 is the only rock quarried. At the quarry it has a thickness of seven feet, but it thins out rapidly, and about thirty rods east it is only one foot thick. The stone is of excellent quality and is scarcely affected by weathering agencies. It is used extensively in Redfield and is shipped to Fonda, Waukee and other points on the Des Moines Northern & Western railroad.

Talbot Quarry.—This quarry, which is about four miles northwest of Redfield, in the southwest quarter of section 29, Linn township, was opened in 1893. It was connected by a switch with the Des Moines Northern & Western railroad, about a mile distant. The section at this place is as follows:

		FEET.	INCHES.
11.	Soil	3	
10.	Clay, sandy, buff	8	
9.	Shale, black, fossiliferous	2	
8.	Coal, with clay parting	1	8
7.	Fire clay	3	
6.	Shale, gray, with lime concretions	4	
5.	Limestone, hard, compact, blue, fossiliferous above, mostly in solid ledges	7	
4.	Shale, light gray	21	
3.	Limestone, gray, brecciated above	1	6
2.	Shales, gray, not fully exposed	1	6
1.	Shale, black, fissile, coaly below	1	6

The rock quarried was the heavy bed of rough limestone (No. 5). Almost the entire product of the quarry was used as crushed stone. It was shipped to Des Moines and employed in the concrete foundations of the brick pavements. The crusher used was manufactured by Fraser & Chalmers, Chicago. As shown from the section, the amount of stripping that was necessary was very considerable and added greatly to the cost of quarrying. Work at this quarry has been stopped for several years. A coal seam above the limestone here has been worked at several points.

A three-foot ledge of rough gray limestone has been quarried on a small scale near the switch in section 28 of Linn township. Underlying the compact, fossiliferous limestone bed there are exposed about twenty-five feet of shales.

The limestone and sandstone bands of the coal measures have been quarried to a greater or less extent at a number of other localities in the county. At two points near Adel, in sections 21 and 28 of Adel township, a three-foot bed of sandstone has been worked and considerable stone removed. Rock has been obtained from several small quarries near Van Meter and has also been taken out along Bulger creek near De Soto. Two miles south of Waukee, in the northwest quarter of section 6, Boone township, the coal measures are exposed along Sugar creek and a ledge of sandstone has been quarried for local use.

PRODUCTION.

The stone production of Dallas county was not reported for 1897.

Road Materials.

At a time when the movement toward the improvement of country roads is beginning to assume considerable importance, the question of good road materials is one of special interest. Dallas county is well furnished with such materials. The Missourian limestone and the calcareous beds of the coal measures afford rock suitable for crushed stone, while along many of the larger streams there are terraces from which gravel may be secured in abundance.

As already stated, the limestone of the old quarries in section 28 of Adams township was used quite extensively for ballast on the railroad, and the rock from the quarry four miles northwest of Redfield was also utilized as crushed stone.

Almost any of the limestones of the county would furnish suitable material for macadamizing the roads. The gravel of the terraces can also be used for the improvement of the highways. These beds have been opened at several points in the county, and worked on an extensive scale by the railroads for ballast. The Chicago, Milwaukee & St. Paul railroad formerly had large gravel pits in section 11 of Des Moines township, only a short distance west of their bridge over the Des Moines river. The Chicago, Rock Island & Pacific railroad has for many years been making extensive excavations in the gravel beds at Van Meter, and the Des Moines, Northern & Western has also taken out large quantities of gravel from its pits about a mile northwest of Redfield.

Gravel beds are known to occur at many points along the North Raccoon, as for example at Adel and various points between Dawson and Perry. The drift in some places contains quite clean beds of gravel, though these are as a rule well toward the base, and hence difficult to reach unless the overlying till has been removed by erosion.

Natural Gas.

The presence of natural gas in the county has been known for a number of years. It was discovered near Dawson in 1888. It had been found two years before at Herndon, eight miles west of Dawson, and the wells yielded a good flow of gas. They were first mentioned in the report of the state mine inspector* for the years 1886 and 1887, and the presence of gas at Herndon was also noted by McGee in the Eleventh Annual Report of the United States Geological Survey.† In 1892, Call, in the Monthly Review of the Iowa Weather and Crop Service, also referred to the gas wells at Dawson and Herndon, and gave as the probable source the vegetable matter buried in the drift. Other localities in the state where natural gas has been found are Letts, Louisa county; Stan-

* Report State Mine Inspector, 1887, pp. 169-170.
† Eleventh Ann. Rept., 1889-1890, pt. i, p 595.

hope, Hamilton county, and in Polk county about seven miles northeast of Des Moines. From these various occurrences it will be seen that it is not an unusual thing to find gas in the drift of the state.

The Dawson wells are three-quarters of a mile south of town. Five holes have been drilled, one being put down in 1888 and the other four in 1891. They have a depth of from 110 to 115 feet, passing through drift clay into a bed of sand and gravel. The gas occurs in the gravel layers below a compact blue clay. A coal shaft just east of Dawson shows sixty-four feet of this blue clay, overlain by a yellow clay. During the summer of 1896 the first well, which had been bored eight years before, was tested to find the pressure, with the result that this was ascertained to be twenty-four to twenty-five pounds to the square inch. The gas burned with a flame fifteen to twenty feet high. It was piped into town, and for a time supplied one of the houses with fuel. It was also used in the kilns of the brick plant a short distance east of the station. Three of the wells still have a good flow, but are no longer used. An analysis of the gas from the first well shows its composition to be as follows:

Hydrocarbons and nitrogen	95.35
Carbon monoxide	2.50
Carbon dioxide	1.60
Oxygen	0.55
	100.00

In this connection mention should perhaps be made of the gas found in large quantities in the water supply of Perry, six miles east of Dawson. Perry secures its supply from four wells located in the southern part of town. These wells have a depth of 115 feet. Gravel is struck seventy feet below the surface and the lower forty-five feet is through this material. The amount of gas in the water is so great that Mr. J. W. Rodefer has for some time been experimenting for the purpose of extracting it for use in heating and lighting. He has succeeded in doing this on a comparatively small scale and the gas thus separated is used to furnish fuel and light to his office. Could it be extracted by a sufficiently inexpensive method and in large enough quantities, this natural gas contained in its water supply would furnish Perry with a convenient fuel.

There are two possible sources of the gas of the drift: (1) it may have been derived from the underlying rock and the drift then serves simply as a reservoir for its accumulation and storage, or (2) it may have been derived from the vegetable accumulations of the drift and thus have its source in the Pleistocene deposits where it is now found. The latter source is much the more common, and in most instances there is slight doubt that the gas has been derived from the decomposition of the vegetable remains in the drift. But examples of the latter serving only as a reservoir are occasionally found. Thus Orton* mentions several such instances in Ohio, and it is possible, though not probable, that the gas at Dawson may have been derived from the underlying coal measure shales. To collect gas from such a source the gas-bearing rocks must be overlain by porous beds of drift. Then during the long periods while they hold this relation the porous beds become charged with gas where the conditions of level are suitable. As already stated, the gas at Dawson is found in a stratum of sand and gravel which is apparently at the base of the drift and overlying the coal measures. It is possible, therefore, that the gas originated in these black carbonaceous shales and has passed up into, and accumulated in, the gravel and sand beds above, where it is prevented from escaping by the covering of blue clay.

But while the above source is a possible one, it is far more probable that the gas at Dawson, as elsewhere in the state, has had its source in the vegetable accumulations of the drift. It is not necessary to suppose that it has been formed directly in the place where it is now found. It may have originated from the decomposition of vegetable material some consider-

* Geol. Surv., Ohio, vol. VI, pp. 772-775.

able distance off, and later have diffused itself laterally through the gravel until reaching a place favorable for its accumulation.

An interesting and significant fact concerning the distribution of the Iowa gas wells is that they are found not far from the border of the upper or newer drift sheet of the region. Thus, for example, at Dawson and Herndon the wells are only a few miles back from the edge of the Wisconsin lobe, and at Letts, in Louisa county, the Illinois ice seems to have extended only a short distance to the west. Orton mentions the same fact concerning the distribution of the wells in Ohio, where they are found along the border of the glacial deposits, or back twenty to forty miles.

The most favorable conditions for the preservation of forest beds and like accumulations of vegetable material would seem to be near the edge of the ice, where this was the thinnest and where during its advance there would have been less disturbance of the materials beneath. During its advance a comparatively few miles of the ice sheet would pass over the drift near the border, while back fifty or seventy-five miles the ice would be considerably thicker and a vastly greater bulk of ice would pass over the surface, with the result that the underlying deposits would be greatly disturbed. The forest bed, if present, might in such cases be carried away or be mingled with the clay of the drift.

Concerning the origin of the natural gas little need be said. It is now generally admitted by all geologists and most chemists that the various bitumens, including natural gas, are genetically connected with, and are closely allied to, marsh gas, and that they are produced by the natural decomposition of organic tissue. Natural gas closely resembles in composition the inflammable marsh gas which is often observed coming from the muddy bottom of stagnant ponds. The following analysis, giving the mean results of seven analyses made for the United States Geological Survey, by Prof. C. C. Howard, shows the composition of natural gas.

Marsh gas	93.36
Nitrogen	3.28
Hydrogen	1.76
Carbon monoxide	.53
Oxygen	.29
Olefiant gas	.28
Carbon dioxide	.25
Hydrogen sulphide	.18
Total	100.03

Marsh gas, the principal constitutent, is a simple compound of carbon and hydrogen in the proportions of 75 per cent of the former to 25 per cent of the latter.

The natural gas at Dawson and other Iowa localities is then simply the product of the decomposition of the vegetable remains buried in drift.

Some years ago an effort was made to find gas at Redfield and a deep hole was bored. A record of the strata penetrated was kept and has been examined by a member of the survey force. This record differs in no essential particular from the records of other deep wells that begin in the same geological formation and reveals nothing not previously known concerning the general geological structure and stratigraphy of the state. It lends no encouragement to the belief that the underlying rocks are gas-bearing.

Water Supply.

Dallas county has an abundance of good water. The supply is derived chiefly from the sands and gravels of the drift, though in some instances water is obtained from the coal measures.

There are several artesian wells in the county. The Redfield well, which has a depth of 1,500 feet, was put down with the hope of finding gas and oil. The well is on the "picnic grounds" beside the river, just south of town. A flow of water was struck at a depth of 280 feet, and other veins were found at various depths below this. A stream now flows from the well, but it is not utilized, being allowed to run into the river near by. The water contains considerable iron, and there is quite a deposit of this mineral along the course of the small stream. Reference has already been made to the artesian well belonging to Mr. Marshall, in section 7 of Union township, and its record has been given. As in the Redfield well, water was struck at a depth of 280 feet, in a white sandstone at the base of the Des Moines shales. The sandstone was twenty feet thick, and lay upon a limestone that probably belongs to the Saint Louis. The pressure at first was sufficient to throw a one-quarter-inch stream nineteen feet high, and, though it has naturally diminished somewhat, the pressure is still strong. The four wells which supply the town of Perry, though they are no longer flowing wells, are still to be considered as true artesians. The water for a time came to the surface and flowed, but after a number of wells were sunk in the neighborhood and the water was pumped by the city, the head was lowered and now stands five or six feet below the surface. The water in this locality comes from a heavy bed of gravel lying seventy feet below the surface. This gravel layer is penetrated to a depth of forty-five feet and contains an abundance of water. There is a large area in the northwestern part of the county, including parts of Lincoln, Dallas, Spring Valley, Washington and Colfax townships, where, below the blue clay of the drift, there is a bed of sand and gravel. It averages about eight feet in thickness and carries much water. While this well-marked sand layer is absent in other parts of the county, the Pleistocene deposits nevertheless have a number of horizons where water is present in sufficient quantity to supply the needs of all, except, perhaps, in very dry seasons. The sandstones of the coal measures can usually be relied upon to furnish considerable water, but the expense of drilling wells to any very great depth in these will prevent the sinking of many such so long as the drift wells are adequate.

Soils.

The soils of the county are formed almost entirely from the two drift sheets that cover the region. Over a portion of the southern tier of townships the Kansan drift with its covering of loess has given rise to a very productive soil. Wherever the loess forms the surface the soils have a buff or light gray color and do not have the appearance of very great fertility, though as a matter of fact they are well supplied with plant foods and are well adapted for fruit raising and for corn. These loess soils have the property of absorbing moisture very readily and of retaining it for a considerable period. They are free from the pebbles and bowlders often so abundant in the drift soils.

The Wisconsin drift forms the surface material over much the larger portion of the county and gives rise to a soil of much fertility, as the prosperous appearance of the farms bears ample testimony. In many parts of the region, however, the surface is so flat and poorly drained that the land needs to be thoroughly underdrained before the soil reaches its greatest productiveness.

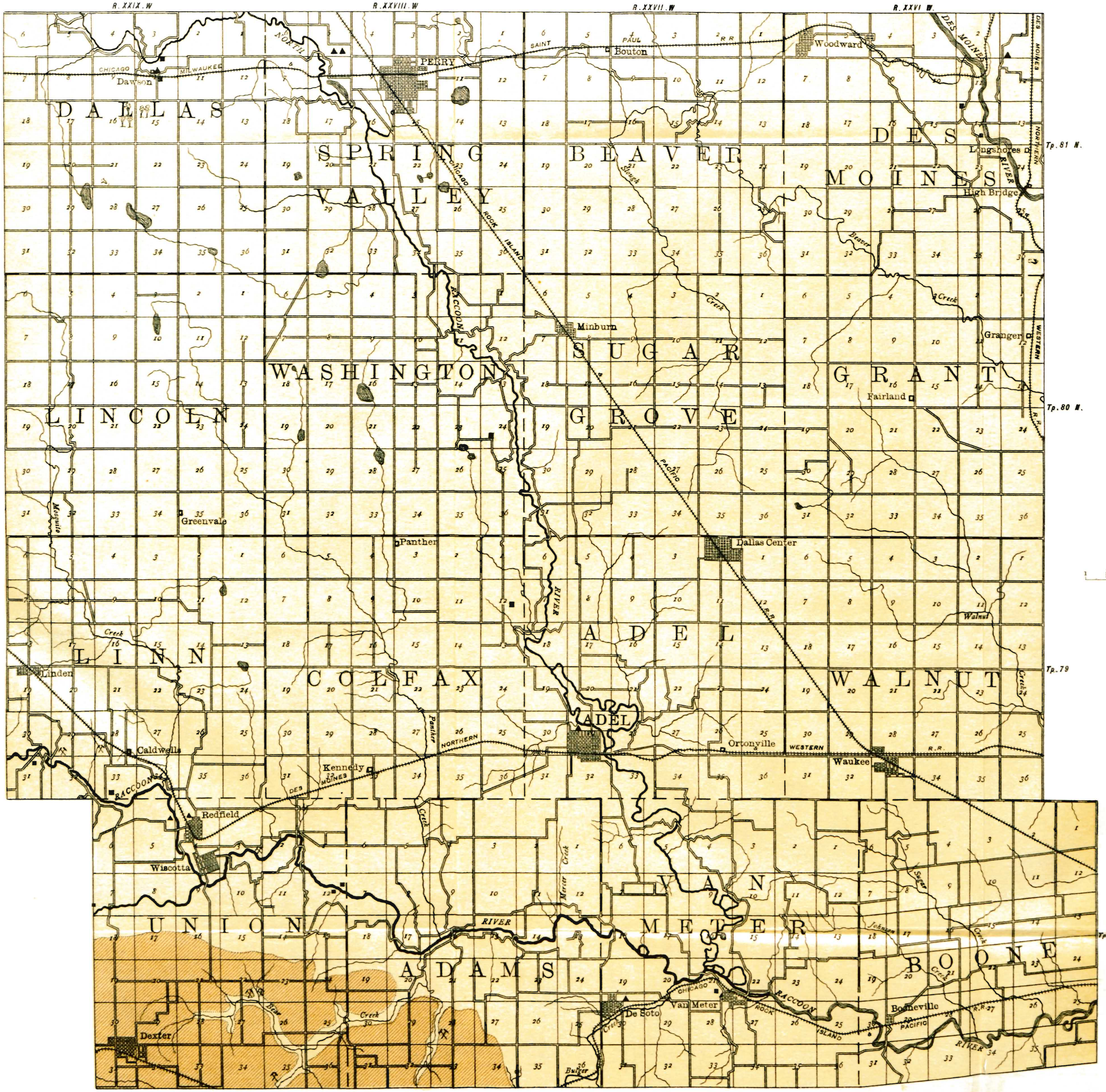
Though it covers but a comparatively small part of the area of the county the alluvium probably forms as rich a soil as any in the region. The old flood plains along the streams have been covered by the sediment carried in the waters of the rivers and deposited along their courses. In many cases these alluvial bottoms are now occupied by rich pastures that furnish grazing to numerous herds of cattle. In other instances the rich fields of waving corn give evidence of the fertility of these bottom lands.

From what precedes it will be seen that the soils of Dallas county are of three kinds, dependent upon the geological formation that forms the surface. These are (1) the soils of the Wisconsin drift, (2) the loess soils of the Kansan drift area, and (3) the alluvium.

ACKNOWLEDGMENTS.

This report would be incomplete without acknowledging our indebtedness to those who have so cheerfully furnished information and in this way materially assisted in its preparation. To Prof. Samuel Calvin and to Mr. H. F. Bain the writer is under special obligations for many valuable suggestions and for assistance freely given at all times. The writer is also indebted to Mr. J. L. Hightower, Mr. J. W. Rodefer, Mr. Marshall and the many other friends of the Survey who have shown their appreciation of the work by furnishing information as to well records, mines, etc. In the preparation of this report use was made of the notes on clay collected by Mr. E.H. Lonsdale, as also of those of Mr. A. C. Spencer on building stones, and the notes of Mr. A. J. Jones on the coal mines.

To each and all of the above persons the writer takes pleasure in making due acknowledgment.



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF DALLAS COUNTY, IOWA.

BY

A. G. LEONARD

1898.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

MISSOURIAN

DES MOINES

INDUSTRIES

MINES

CLAY PITS

GAS WELLS

QUARRIES

IOWA LITHO. CO. DES MOINES.

DRAWN BY F. C. TATE.

GEOLOGY OF DELAWARE COUNTY.

BY

SAMUEL CALVIN.

GEOLOGY OF DELAWARE COUNTY.

BY SAMUEL CALVIN.

CONTENTS.

INTRODUCTION.

Delaware county belongs to Northeastern Iowa, a region that has become noted the world over by reason of McGee's exhaustive memoir on its Pleistocene history.* Delaware lies directly west of Dubuque county and its northeast corner is only about eight or ten miles distant in a direct line from the Mississippi river. Its fertile lands early attracted the stream of settlers overflowing from the mining region around Dubuque. The main body of the county is included in the great Iowan drift plain, but in the extreme northeast it embraces some of the rugged irregularities of the Driftless Area. Delaware has Clayton county on the north, Buchanan on the west, and Jones and Linn bound it on the south. The eastern boundary of the county is twelve miles west of the Fifth Principal Meridian, the north-south line to which all the ranges of townships in the state are referred. The county is cut into approximately symmetrical north and south halves by the Second Correction line. Sixteen congressional townships are included in the area, the eight townships north of the correction line being severally somewhat larger than those south of it.

*Pleistocene History of Northeastern Iowa, Eleventh Ann. Rept. U. S. Geol. Surv., pp 189-577. Washington, 1891.

The area at present included in Delaware county was among the first regions west of the Mississippi to be studied by geologists. It was traversed in the autumn of 1839 by a party organized, under the direction of Dr. David Dale Owen, to explore the mineral lands of the United States. Each township was examined, quarter section by quarter section, and notes were made on the timber, soils and rock exposures. In the published report* of this exploration the detailed observations on the several townships are presented in short paragraphs under the following heading.

"*Description of the individual townships, showing the face of the country, proportion of prairie and timber, how watered, nature of the soil, and the kind of rocks and minerals.*"

Owen's work of that year began below Davenport and was carried, in Iowa, as far north as McGregor, and so Delaware county is only a small part of the area explored by the remarkable survey of the autumn of the year 1839. The soils are graded as first, second and third class—first class soils, in the judgment of the pioneer explorer, being rather rare, even in Delaware county. No minerals were noted in the area we are considering except some indications of iron ore. Under the head of "Fossils of the Coralline Beds of the Upper Magnesia Cliff Limestone of Iowa and Wisconsin," Dr. Owen, on plates xiii and xiv, gives excellent figures of a number of the common fossils of the Niagara limestone as it is developed in Delaware county. Many are described as new species, but for some reason Owen's specific names have not received the recognition from later students of Paleontology that they clearly deserve.

Mr. J. D. Whitney, Assistant Geologist on the Survey conducted by James Hall, notes very briefly some of the characteristic features of Delaware county.† No detailed investigations were made in the county, and the essential facts reported are embraced in the simple statements that the region is mostly

*Rept. of a Geological Exploration of Part of Iowa, Wis. and Ill., in the Autumn of the year 839. David Dale Owen, M. D. Ordered printed June 11, 1844.

† Rept. Geol. Surv. of Iowa, James Hall and J. D. Whitney, vol. I, part i, p. 295. 1858.

rolling prairie, it is drained by the Maquoketa river and its branches, the rock exposures are not satisfactory, and the rocks seen in place belong to the Niagara limestone.

The report of Dr. C. A. White* makes no reference specifically to Delaware county, but on the geological map accompanying the report the county is included in the area occupied by formations of the Upper Silurian period.

In McGee's memoir on northeastern Iowa† there are many references to geological phenomena in Delaware county. The indurated rocks and superficial deposits receive more or less attention. The Rockville conglomerate is noted for the first time in geological literature, and a new formation is thus added to the geological section of northeastern Iowa.

In Professor Norton's report‡ on the Artesian Wells of Iowa there is a detailed description of the deep well at Manchester.

Short papers relating more or less directly to the geology of Delaware county, have appeared in the *Geological Magazine*, the *American Journal of Science*, the *American Geologist* and the *Proceedings of the Iowa Academy of Sciences*, under the authorship respectively of McGee, Wilson and Calvin.

PHYSIOGRAPHY.

The topography of Delaware county includes a number of interesting and unique forms. About two-thirds of the surface is occupied by Iowan drift, and this area, with some exceptions to be noted later, presents the rather monotonous alternations of gently rounded eminences, and broad, irregularly disposed swales, or "sloughs," that, in the absence of more perfectly defined drainage channels, serve as water courses to carry the storm waters to the larger streams. In the typical Iowan drift plain the topography shows no erosional forms, the irregularities of the surface, such as they are, being

*Rept. on the Geol. Surv. of the State of Iowa, by Charles A. White, M. D., Des Moines, 1870.

†Op. Cit.

‡Artesian Wells of Iowa, by William Harmon Norton. Iowa Geol. Surv., vol. VI, pp. 113-428. Des Moines, 1897.

FIG. 1. Knob of limestone projecting through the Iowan drift plain in sw. qr. section 2, Delaware township. Delaware county.

FIG 2. A very symmetrical rounded boss of Niagara limestone rising conspicuously above the Iowan drift plain in sw. qr. sec. 12, Oneida township, Delaware county.

due mainly to the eccentricities of ice molding. The Iowan drift plain is best developed southwest of the Maquoketa river, in Adams, Hazel Green, Prairie, Milo and Coffins Grove townships. Northeast of the river the best examples of the drift plain are found in Delaware, Honey Creek, Oneida and Bremen townships. The characteristic plain of Iowan drift was, at the time of settlement of the county, a gently undulating treeless expanse, covered in summer with a luxuriant growth of prairie grass, and dotted with numerous bowlders of grayish or reddish porphyritic granite. The low lands, or sloughs, were undrained, and, except in the neighborhood of the main streams, there were practically no indications of erosion as a factor in the genesis of the topography. Since the settlement of the county many of the sloughs have been artificially drained, and many more have been drained by ditches of varying depth cut in the rich, black loam by storm waters gathered from the higher grounds and flowing along the axes of the broad, shallow depressions.

Within the area properly belonging to the Iowan drift there are a number of exceptional topographic features. One group of these is due to the fact that near the margin of the Iowan ice the materials of the drift were too scant wholly to conceal the irregularities of the pre-Iowan surface. Accordingly some of the pre-Iowan knobs and prominences project above the mantle of drift. Some of these are symmetrically rounded rocky knolls that, viewed from a short distance, bear a very striking resemblance to the tumuli of the mound builders. A very characteristic example of these pseudo-tumuli is seen in the Nw. ¼ of Sw. ¼ of section 2, Delaware township (Plate vii, Fig. 1). This stony knob rises twelve feet above the level of the drift immediately surrounding it. It is composed of very much weathered Niagara dolomite which contains silicified specimens of *Favosites favosus*, *Alveolites undosus*, Syringopora, *Amplexus shumardi*, Zaphrentis and some very obscure Stromatoporoids. Another similar knob, very striking on account of its symmetrically rounded form rising above the drift mantled plain, occurs in the Nw. ¼ of Sw. ¼ of section 12, Oneida township. The rock here is thin bedded, and much decayed on the outside (Plate vii, Fig. 2). It has been quarried to some extent for road material, and amongst the debris there occur imperfect specimens of *Favosites favosus*. These knobs bear no constant relation to surrounding altitudes. They may occur in any situation, from tops of hills of moderate height to low grounds bordering the prairie streams. The first example given above is found on a hill top, the second occurs on the border of a low plain, through which flows a branch of Plum creek.

Another feature, which is after all but a modification of the preceding, is found in the form of weathered crags and irregular rock masses that, in certain cases, occupy spaces covering some hundreds of acres. The deeply pitted, weather-beaten rocks and the absence of till suggest that some of these areas never were invaded by Iowan ice. The topography within such areas is usually very irregular and is in fact due to pre-Iowan erosion and weathering of massive Niagara dolomite. An example of the topography under consideration occurs in the region immediately adjoining the town of Earlville, particularly on the west and south. In the east half of section 21, Oneida township, is a small, nearly driftless valley bounded by weather-beaten crags. The topography is plainly pre-Iowan. The crags show effects of prolonged weathering, and the relief is wholly inconsistent with known effects of erosion since the close of the Iowan stage. Another very typical example of the same type of topography occurs in the Sw. ¼ of section 2 and Se. ¼ of section 3 in Delhi township. Drift is practically absent and the scant surface materials are wholly insufficient to cover up the jagged, weathered ledges of Niagara limestone, or to fill up the small gulches and crevices between the prominent projecting masses (Plate viii, Fig. 1). The rock here, as in all cases of the same kind elsewhere, has weathered into fantastic shapes. The surface is deeply pitted, and everything betokens exposure to the atmosphere

FIG. 1. View of a portion of the stony knob projecting through the drift in se. qr. section 3, Delhi township, Delaware county, showing the weathered, fissured and pitted condition of the limestone.

FIG. 2. Valley of Elk creek bounded by hills 220 feet high. The topography is that of the driftless area, view taken in section 10, Elk township, Delaware county.

for a much longer period than post-Iowan time. At this point the rocks are quite barren of fossils. *Favosites favosus* and a large celled variety of *Halysites catenulatus* occur very sparingly. A number of areas of the same type are scattered through North Fork township, being especially prominent in sections 10, 22 and 27, and driftless rocky ridges occur in section 36 of Bremen township. In this last case the rock ledges are rendered very conspicuous by the fact that they rise somewhat abruptly above a low and very level plain covered with a thin mantle of Iowan drift. The low plain referred to is a part of the wide preglacial valley of Bear creek. In sections 15, 16 and 22 of the last named township, there is a somewhat rounded rocky hill projecting abruptly above the plain of Iowan drift. There are some rocky points in a plain of Iowan drift near Sand Spring in South Fork township. There are also similar rocky points in sections 6, 7 and 18 of Milo township and in section 12 of Prairie.

With the exception of the cases cited in Milo and Prairie townships, all the remnants of pre-Iowan topography within the proper limits of the area belonging to the Iowan drift are found near the line which marks the extreme eastern border of the Iowan glaciers. That the Iowan ice invaded some of the areas referred to is indicated by typical bowlders lying on bare rock surfaces or on residual clays and cherts; but finer materials, such as ordinarily make up the main body of the drift sheet, seem to have been locally absent.

Other exceptional topographic forms, similarly limited to the marginal zone of Iowan drift, are found in the peculiar ridges called paha by McGee.* The typical paha are isolated, elongated hills rising above the Iowan drift plain. Superficially they are composed of loess, a fine, yellow, pebbleless clay, but the loess usually forms a relatively thin mantle over a core of rock or of Kansan drift. The paha ridges are not always isolated. A chain or series of such ridges, more or

*Pleistocene History of Northeastern Iowa, Eleventh Ann. Rept. U. S. Geol. Surv., p. 220. Washington, 1891.

less intimately connected one with another, may extend across the country for miles; and in many cases the paha are simply lobes or digit-like extensions projecting into the relatively low, drift-covered plain from a larger body of loess that may cover continuously an area of many square miles in extent. Good examples of isolated paha are seen in sections 3, 4 and 12 of Honey Creek township, and in 6, 7 and 18 of Elk. There is a very beautiful cluster of these loess-covered ridges in sections 23, 24, 25 and 26 of Oneida township, and there is another group in 9, 10 and 15 of South Fork.

Of the paha ridges connected with continuous areas of loess, mention may be made of the chain of loess hills extending from section 6 to section 10 of North Fork township. In sections 27 and 28 of Union township there is another very prominent ridge of the same type. Others are found in the northwestern sections of Union and at other points around the margins of the extensive loess-covered areas presently to be noted.

A third exceptional topographic form within the area properly belonging to the Iowan drift occurs in the form of sand ridges, or dunes, of æolian origin. While on the whole these ridges are inconspicuous features of the landscape, they occur in certain localities in such numbers as to force themselves upon the attention. One of the most definitely marked ridges of wind-blown sand is found at the "Sand corners," at and around the southeast corner of section 1, Delaware township. Wind drift sand, in places occurring in ridges and in places spread out on a comparatively level surface, is very abundant in the southeast half of North Fork township, and a moderately conspicuous sand ridge, with a definitely northwest-southeast trend similar to that of the isolated paha, occupies parts of sections 17 and 18 in South Fork township.

Besides the paha already described, there are in Delaware county continuous areas of considerable extent covered with loess. Within these larger loess-covered regions no Iowan drift was observed, and it is quite certain that, in some cases at least, they were never invaded by Iowan ice. In all these regions erosional topography prevails. The surface, as a rule, is carved into ridges and narrow valleys. There are no undrained sloughs, but everywhere the drainage is perfect and the water courses well defined. The margins of these regions, where the loess hills begin and the Iowan drift ends, are always higher than the adjacent drift plains, a fact very fully and very graphically described by McGee in the work on northeastern Iowa already cited. One of the areas in question embraces all of Colony township and parts of Elk, Oneida and Bremen. This region contains Kansan drift, covered very generally with loess. The Iowan ice seems to have reached its extreme eastern margin along a very sinuous line drawn from the northwest corner of Elk township to near the southeast corner of section 25, Bremen township. On one side of that line is a relatively low plain, on the other side are loess ridges rising from twenty to forty, or even sixty, feet higher. On one side a gently undulating plain, without trace of erosional topographic forms; on the other side sharply rounded hills and V-shaped valleys, the whole surface deeply trenched and molded by erosion. On one side Iowan drift, Iowan bowlders and black, loamy soil; on the other side nothing but Kansan drift occasionally revealed in the water-worn gullies under a heavy mantle of loess, and uneven, rough, hilly farms with a soil composed of yellow loess clay. The transition is so abrupt as to create surprise even in the mind of the experienced student of Pleistocene deposits and their attendant topographic forms.

Northeast of the line which marks the limit of the Iowan drift, two types of topography are clearly recognizable. Apart from the valleys of the main drainage streams, the loess, in general, forms a mantle resting upon an eroded surface of Kansan drift, and the loess itself has suffered much erosion since it was deposited. The present surface configuration is due, therefore, to effects produced during two periods of erosion, both post-Kansan. The first erosion period extended over the very long interval between the deposition of the Kansan drift and the deposition of the loess. During this period the drift surface was deeply carved, and when later the loess was molded over the irregularities of this surface the old pre-loessial lines of drainage were not so completely obliterated but that they controlled to a large extent the lines along which erosion attacked the new deposit. The fine silt-like loess is easily cut by surface drainage, and post-loessial erosion has in most cases tended to accentuate the irregularities of the surface on which this deposit of fine yellow clay was laid down. The particular surface configuration developed in the manner just described has sufficient individuality to deserve a distinctive name, and may be called loess-Kansan topography.

In the south-central part of Colony township, about the headwaters of the numerous branches of Bear creek, the loess-Kansan surface is more than usually level and at first sight suggests a gently undulating plain of Iowa drift. The surface, however, is covered with loess, and it requires no very close inspection to see that the irregularities, though not very pronounced, are erosional in type. The characteristics of this rather level loess-Kansan plain, embracing the initial branches of Bear creek, and differing so sharply from the rest of the loess-Kansan area, are probably related to the fact that the Iowan ice, at the time the loess was depositing, filled the valley of Bear creek as far north as sections 10 and 11 of Bremen township. During all the time the Iowan ice occupied the valley there was no drainage of the basin embracing the head water branches of the creek, except by overflow toward the northeast into the Little Turkey river. There was, therefore, no erosion of the surface of the basin so long as the Iowan ice remained stationary, and even after the retreat of this ice the flow of water down Bear creek valley was not very energetic. On the other hand, the rest of the loess-Kansan area in northeastern Delaware is drained toward the northeast, the surface waters flowing with great energy toward the deep stream channels of the Driftless area. This drainage was not checked by the Iowan ice. Erosion proceeded uninterruptedly during the whole period of the ice invasion, and the swollen streams flowing away from the margin of the ice served to intensify the effects of the erosive processes.

While loess-Kansan topography is the prevailing type in that part of Delaware county which lies beyond the margin of the Iowan drift, there is yet another type well expressed along Elk creek and its tributaries in the northern part of Elk township, and along Little Turkey river and some of its branches in the northeastern part of Colony. Here the stream valleys are from 200 to 280 feet in depth. They are not limited to erosion in drift or loess. They are gorges or canyons cut through ledge after ledge of Niagara limestone and down into the underlying Maquoketa shales. Drift and loess are absent in these deeper valleys. The work of carving them was nearly all accomplished in preglacial time. They illustrate the Driftless area topography.

Driftless area topography is illustrated along the whole course of Elk creek and its branches from sections 16 and 23 of Elk township to the north line of the county. Steep, rocky walls bound the valleys of the streams (Plate viii, Fig. 2), and for some distance on both sides of the valleys the surface materials consist of a thin mantle of loess overlying residual clays and cherts. In the Se. ¼ of the Ne. ¼ of section 10 the nearly vertical rocky bluffs rise to a height of 220 feet above the level of the stream. From the hilltop overlooking the valley in section 1 of Elk township, to the bottom of the gorge, the difference in level is 275 feet. The Little Turkey river flows in a deep, picturesque valley which traverses sections 1, 2, 11, 14 and 15 of Colony township. A small tributary of Little Turkey which begins in the northeast quarter of section 3 of the same township, has a valley characterized by even wilder grandeur than that of the main stream. Weathered cliffs, tumbled crags, and precipices over which the waters plunge when set in motion by melting snows, or following heavy rains, are some of the striking features of this charming bit of Driftless topography. The maximum depth of the driftless valleys in Colony township is 280 feet.

Inside the Iowan area, and surrounded on all sides by Iowan drift, are two anomalous regions that seem not to have been invaded by Iowan ice. One of the regions occupies the central part of Richland township and may be called the Richland highlands. The other embraces three-fourths of Delhi township and parts of Milo, North Fork, South Fork and Union townships, and may for convenience of reference be named the Delhi plateau. The regions in question seem to have been islands in the midst of the Iowan glacial sea. At all events they contain no Iowan drift. The togography is erosional, partly resembling the loess-Kansan type, partly that of the Driftless area. Except in the stream valleys the surface is on the average higher than that of the Iowan drift plain, the difference in elevation ranging from forty to more than a hundred feet. Both areas are traversed by the Maquoketa river. In each there are heavy bodies of loess exhibiting the rounded hills, steep slopes and sharp valleys that result from erosion of this peculiar deposit. In each there are spaces, free from both loess and drift, in which steep rocky cliffs, isolated towers, and all other features of Driftless area topography are characteristically developed.

The region in Richland township includes the somewhat noted locality known as the "Backbone." The "Backbone" is a high rocky ridge around which the Maquoketa forms a loop. The summit of the ridge rises from 90 to 140 feet above the stream. Its sides are in places precipitous, the rocky cliffs rising sheer for more than 80 feet. Erosion and secular decay have carved the rocks into picturesque columns, towers, castles, battlements and flying buttresses. The exposed surfaces are deeply pitted and weather worn (Plate ix, Fig. 1). Crevices, widened by protracted chemical action of air and water, are wholly or partly filled with dark-brown residual clay or geest. The stream, on each side of the ridge, flows in

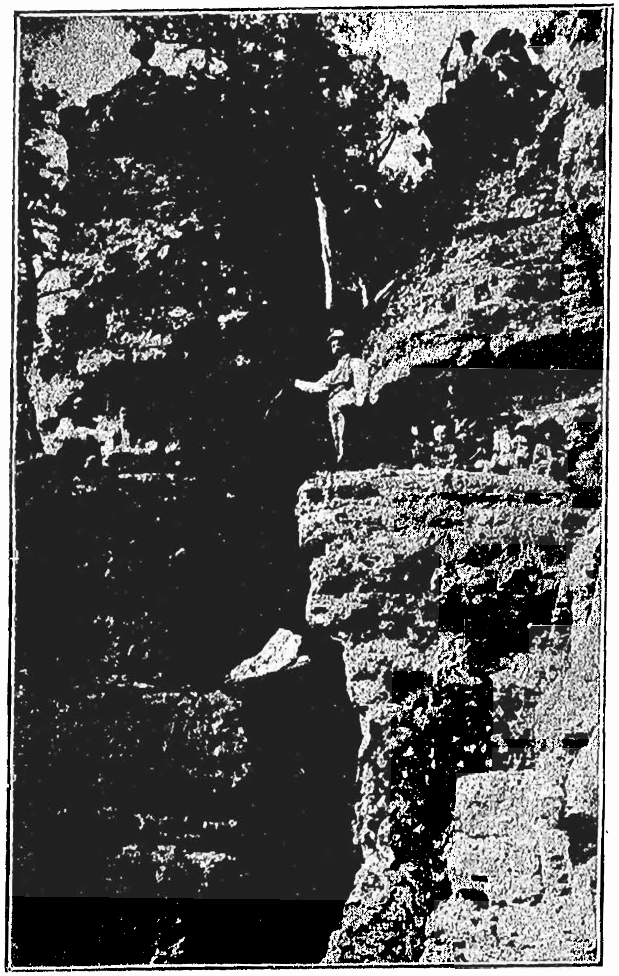


FIG. 1. The "Stairway" at the Backbone in section 16, Richland township, Delaware county. The view shows a portion of the vertical, weather-beaten cliffs.

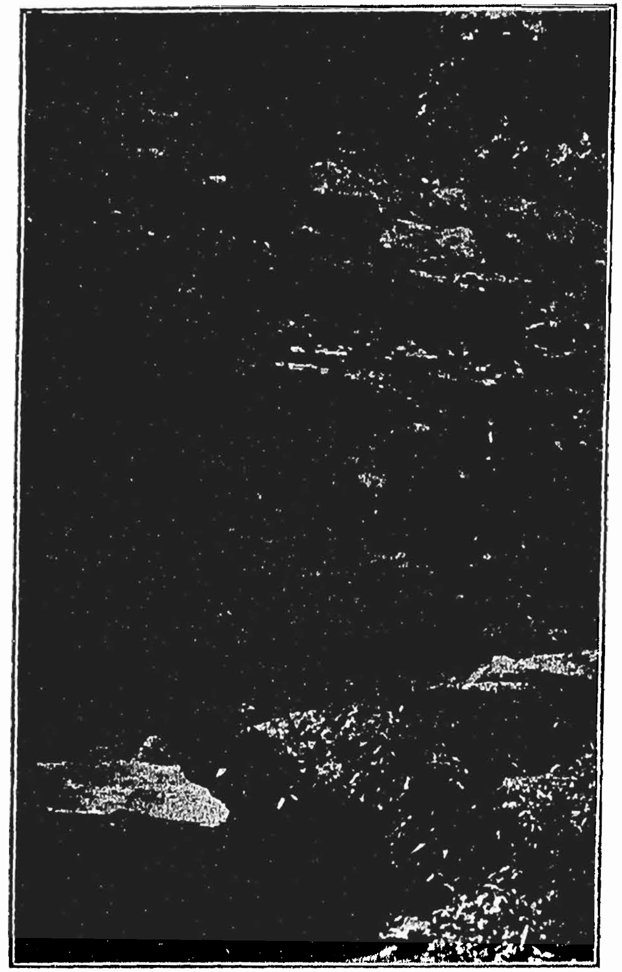


FIG. 2. Beds of passage from Maquoketa shales to Niagara limestone. The heavy ledges at the top of the view are Niagara. The thiner layers belong to the transition phase of the Maquoketa. Ne. qr. section 15, Elk township, Delaware county.

a deep valley. The "Backbone" with its valleys on the east and west is a bit of Driftless area, and the sections north of the "Backbone," namely, 3, 4, 5, 8, 9 and 10, as well as the region to the southeast between the center of section 16 and Forestville, and southward along the river to section 34, constitute a region of loess-Kansan topography.

Between the south end of the area just described and the southeast quarter of section 4 of Milo township, the Maquoketa flows through the Iowan drift plain, in a valley but little depressed below the general level of the country. In the northern part of Milo township, the river enters the second of the anomalous areas, and in doing so it turns away from a low drift-plain to cleave its way through an area that rises from 80 to 100 feet higher than that from which it turned aside. These areas of anomalous topography afford illustrations of McGee's anomalous rivers. In section 5, where the stream crosses the north line of Milo township, the river channel is but a shallow trough in Iowan drift, and the drift plain, with little change of level, extends for many miles towards the south. In the east part of section 9 of the same township the stream flows in an old rock-walled valley of erosion approximately 200 feet in depth. The gradient of the stream is not perceptibly changed, the greater depth of the valley being due to the increase in altitude of the general surface in passing from the first to the second point mentioned.

With one or two unimportant exceptions, the Maquoketa flows in a comparatively deep canyon all the way from section 9 of Milo township to the south line of Delaware county. At Hartwick, in section 30 of Delhi township, the valley is 190 feet in depth, and at Fleming's mill, a mile east of Hartwick, the depth is 215 feet. In Delhi township and in the northern part of Union the stream valley is cut through a plateau and not through a ridge, as is usual with other anomalous rivers. The plateau has an extreme width of about ten miles, extending from section 23 of Milo township to section 21 of North Fork, and embracing in its eastern margin the valley of Plum creek. Loess hills all around its border rise sixty or eighty feet above the adjacent drift plain, and throughout its entire area of about sixty-five square miles the topography is erosional. Loess hills predominate, but there are some areas covered with sand, and in some places weathered crags of Niagara limestone control the character of the topographic forms.

At Hopkinton the Maquoketa emerges from its canyon and skirts for a short distance the eastern edge of the loess-covered highlands; but, although the low plain followed by the railway to Monticello might have been traversed with a very slight amount of channel cutting, the stream turns abruptly into the hills, and has excavated a gorge 165 feet in depth in ledges of limestone. This gorge cuts longitudinally through a ridge that overlooks plains of Iowan drift both on the east and west.

The North Maquoketa flows through a high, loess-covered ridge, free from Iowan drift, in sections 1 and 12 of South Fork township, and the Iowan drift plain between this ridge and the loess hills bordering Plum creek, looking like a much depressed valley, affords an impressive illustration of McGee's paradoxical divides.*

Even the cores of the paha that are distributed near the margin of the loess-covered areas appear to have been islands in the Iowan glacial sea, for they consist usually of rock masses, or of ridges of Kansan drift, and bear no evidence of having been overtopped by Iowan ice.

Finally, there are some striking topographic forms due to the unequal distribution of Iowan drift within the limits of the Iowan drift plain. The gentler undulations, due to ice molding, which in general express the difference between the uplands and the sloughs, give place at one or two points to pronounced hills or ridges of drift resembling moraines. The

*This valley-like divide west of the ridge through which flows the North Maquoketa is very graphically described by McGee in his *Pleistocene History of Northeastern Iowa*. Eleventh Ann. Rept. U. S. Geol. Surv., pp. 218-219. Other divides of the same paradoxical type are described on other pages of the work cited.

best examples of the ridges referred to occur in the southern part of Milo township and in the southern part of Hazel Green. A ridge of Iowan drift, without loess, extends in a nearly east-west direction through the southern half of sections 21 and 22 of Milo township. Another ridge, with a southeast-northwest trend, more pronounced and more moraine-like, is found in sections 33 and 34 of the same township. This ridge is broken into many knobs and rounded hills. Its height above the plain on the north and south is ninety feet. Even more moraine-like is a complicated series of knobs and ridges occurring in sections 27 and 28 of Hazel Green township. The general trend is not well defined. The area is more than half a mile wide, and in length extends beyond the limits of the sections named. The aspect is identical with that of a terminal moraine. Areas of low, wet ground alternate with irregularly distributed knobs and ridges. The higher points rise eighty feet above the ordinary level. On the summit of some of the knobs there is a thin veneer of loess, thus forming a sort of pseudo-paha; but the main body of the ridges in question seems to be composed of Iowan drift.

DRAINAGE.

One system controls nearly all the drainage of Delaware county. The Maquoketa river enters the county in Richland township and flows nearly southeast, leaving the county finally in South Fork township. Above Forestville, in Richland township, the valley, for some distance, is a rock-walled gorge cut in Niagara limestone, and for two or three miles below Forestville the valley retains the gorge-like character as it passes through loess-covered highlands. In the southern part of Richland township, however, the stream enters the Iowan drift plain through which it flows until it passes Manchester. Two miles below Manchester it leaves the low plain of Iowan drift to follow a canyon cut in the highlands that extend from that point to the southern limits of the county. As already noted, the valley, at certain points in the highlands, is more than 200 feet in depth. The singular habit, first fully described by McGee, of streams avoiding low plains and cutting deep chasms through rocky highlands, is well illustrated at many points along the Maquoketa in Delaware and Jones counties. This puzzling behavior has not yet been fully explained.

Contrary to the view sometimes entertained, these deep valleys dissecting uplands are much older than the age of the loess, older than the Iowan drift, older than the Kansan. Undisturbed loess comes down on the side of the deep valley to the level of the water at Flemming's mill, south of Delhi. The reddish-brown Buchanan gravels, in beds undisturbed since the close of the Kansan age of the glacial epoch, lie in the lowest parts of the valley at Hartwick and Hopkinton. The erosion in the bottom of this valley, like the erosion on the drift plain itself, has been inappreciable since the disappearance of the Iowan ice.

The tributaries of the Maquoketa from the west are mostly small, unimportant prairie streams that have their headwaters in the sloughs of the Iowan drift plain. Prairie creek, or Coffins Grove creek, as it is sometimes called, begins in slough lands in the eastern part of Buchanan county and flows eastward through the southern part of Coffins Grove township to join the Maquoketa a mile above Manchester. In section 28 of Coffins Grove the channel of Prairie creek is cut through a rocky hill, timbered and covered with some loess, but elsewhere the channel of the stream is a shallow depression cut but little below the general level of the adjacent prairie.

Buck creek and its branches drain the undulating prairie land of Hazel Green township and part of Milo and Adams. The upper branches of the stream have no definitely marked channels, the drainage waters being conducted along the sags or sloughs. Near the center of Hazel Green township the channel has better definition, but is a mere shallow ditch in the prairie. In the western part of Union township Buck creek enters a gap in the loess-covered plateau and flows thence to its junction with the Maquoketa in a deep valley, sometimes between rocky walls that rise 125 feet above the level of the stream. The walls are developed into picturesque, rugged, fissured, weather beaten cliffs in section 9 of Union township.

A few streams flow into the Maquoketa from the east. Honey creek, with its principal tributary, Lindsey creek, drains the larger part of Honey creek township and the northern part of Delaware. It joins the Maquoketa above Manchester. Honey creek, together with its branches, is throughout most of its course a simple prairie stream flowing in a shallow channel through the ordinary drift plain; but in the west half of section 35, Honey creek township, the stream wanders in a broad valley bounded by rocky cliffs twenty-five feet high. The region contains some deposits of loess, but there are no signs of Iowan drift. All the drift exposed below the loess or at the surface is of Kansan type.

Plum creek is the largest affluent of the Maquoketa in Delaware county. Its ramifying branches extend to the northern part of Oneida and Bremen townships, and the southwest part of Elk township pays tribute to this stream through a system of undefined channels or sloughs. The initial branches and upper reaches of Plum creek conform to the usual type of streams flowing in an uneroded drift plain; but east of Earlville the creek enters the region of the Delhi plateau, flowing through rock gorges and among loess hills that overlook the drift plain throughout most of the remainder of its course, to its junction with the Maquoketa in section 11 of Union township. For a short distance, in sections 20, 28 and 29 of North Fork township, Plum creek follows the western margin of the low drift plain from which the Delhi plateau rises abruptly to the westward, but in section 33 of the township named it turns away from the drift plain to follow a rock-walled chasm cut through a portion of the plateau. At the top of the chasm the rock ledges are overlain by residual chert and Kansan drift, but the Iowan drift does not rise above the plain which constitutes the paradoxical divide between Plum creek and North Maquoketa river.

The North Maquoketa river flows through the eastern part of North Fork township, and through sections 1 and 12 of South Fork. The area draining into the North Maquoketa is unimportant. Above Rockville in North Fork township and in its short course in South Fork this stream flows in a deep valley, the borders of which rise conspicuously above the general level of the neighboring plains. For a few miles below Rockville the North Maquoketa has a channel in the Iowan plain, a condition that affords a feasible crossing for the Farley and Cedar Rapids branch of the Chicago, Milwaukee & St. Paul railway.

Bear creek has its origin in a number of small branches draining the central part of Colony township. It flows southward through sections 2 and 10 of Bremen, emerging from the loess-Kansan area and passing out upon the Iowan drift near the southwest corner of the last named section. During the occupation of the county by Iowan glaciers the lower part of the valley of Bear creek was choked with ice, and the valley was undrained except by overflow to the north into the valley of Little Turkey river. As a result of the conditions noted Bear creek was robbed of part of its drainage area, the waters from the northern part of this area being permanently turned into the Little Turkey. From section 10 of Bremen township, Bear creek flows near the margin of the Iowan drift, in an ancient valley that was only partially filled by glacial debris, and enters the North Maquoketa at Dyersville.

The northeastern part of Elk township and the northern part of Colony are drained by branches of Turkey river. The main drainage channels in the locations named trend toward the north. Elk creek flows in a rock bound valley that is more than 200 feet in depth, and the valley of Little Turkey river, before crossing the north line of Colony township, attains a depth of nearly 300 feet. The valleys of Elk creek and Little Turkey properly belong to the Driftless area.

Buffalo creek receives the drainage from the greater part of Adams township and from part of Prairie. With the exception of Robinson creek its affluents in Delaware county are without definite channels. Buffalo creek is a prairie stream flowing in a broad concave depression in the drift, all the erosion it has accomplished being represented by the channel a few feet in depth. The difference between the amount of erosion represented by the valley of Little Turkey river in the northeast corner of the county and the inconsiderable channel of Buffalo creek in the southwest is well nigh immeasurable.

The greater part of the surface of Prairie township does not reveal a single well-defined water course. Over most of the drift plain, indeed, there has been practically no erosion since the withdrawal of the Iowan glaciers, and even in the beds of the larger streams the post-Iowan deepening of the channels has been at most only a few feet. The deep valleys of the Richland and Delhi highlands, as well as the similar valley of the North Maquoketa, resemble canyons of preglacial origin. The highly oxidized, reddish-brown Buchanan gravels near Hopkinton and Hartwick demonstrate that, at all events, they are older than the Kansan stage of the Pleistocene.

STRATIGRAPHY.

The geological formations of Delaware county embrace representatives of at least two groups, namely, the Paleozoic and the Cenozoic. A somewhat problematic deposit near Rockville, the Rockville conglomerate, has with some doubt been referred by McGee* to the Cretaceous system, and so may represent the Mesozoic group. Keyes† thinks that the Rockville conglomerate, and other ferruginous conglomerates in northeastern Iowa are probably Carboniferous instead of Cretaceous, but the most recent evidence at hand tends to

* Pleistocene History of Northeastern Iowa, by W. J. McGee, p. 234 and pp. 304-308.
† Iowa Geol. Surv., vol. I, p. 125. Des Moines, 1893.

support McGee's conclusion, and so in the present report this deposit will be retained in the taxonomic position to which it was first assigned.

The stratigraphic relations of the several formations of this county are expressed in the following

Synoptical Table of Formations in Delaware County.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent?	Alluvial.
		Glacial.	Iowan (including Loess and Iowan drift).
			Buchanan.
			Kansan.
In process of forming during all the ages since the post-Silurian elevation of the region above sea level.			(Residual clays and chert, Geest.)
Mesozoic?	Cretaceous?	Upper Cretaceous?	Dakota? (Rockville conglomerate).
Paleozoic.	Devonian.	Middle Devonian.	Wapsipinicon.
	Silurian, or Upper Silurian.	Niagara.	Delaware.
	Ordovician, or Lower Silurian.	Trenton.	Maquoketa.

Ordovician.

MAQUOKETA SHALES.

The Maquoketa shales are the oldest of the geological formations naturally exposed in Delaware county. They are best seen in the deep, driftless valleys of Elk creek and Little Turkey river, as well as in the lateral ravines opening into the valleys mentioned. There is, however, a very interesting occurrence of these shales at the mill dam at Rockville. The east end of the dam abuts against thin beds of soft, yellowish, argillaceous limestone that, for the most part, is rather free from fossils, but contains impressions of *Orthis testudinaria* down near the level of the water. The plunge of the water over the mill dam has scooped out a deep pit on the lower side. Out of this pit there has been carried, and strewn along down the stream, a great number of very fossiliferous slabs of shaly limestone. These have all the characteristics of the fossiliferous beds of the true Hudson river or Cincinnati shales. They are very rich in monticuliporoid bryoza. *Plectambonites sericea* is exceedingly common, and *Strophomena planumbona* Hall,* *S. nutans* James, *Orthis testudinaria* Dalman, as usually recognized in this country, and *Orthis occidentalis* Hall, are not rare. Less common are *Strophomena filitexta* Hall, *Zygospira modesta* Say and *Calymene senaria* Conrad. These fossil-bearing shales, both lithologically and faunally, are identical with typical horizons of the Hudson river shales as developed in southwestern Ohio and eastern Indiana.

The thin-bedded, shaly limestone, above the level of the river, has a thickness of twenty-five feet, and is overlain by heavy ledges of dolomitic limestone that are unquestionably of the age of the Niagara. The shaly limestones, however, probably all belong to the Maquoketa stage. At least the lower layers are of this age, for they contain such typical species as *Orthis testudinaria;* and the upper portion, destitute of fossils and becoming rather more calcareous, is made up of transition beds that record the passage from the conditions of deposition which gave rise to blue shales, to those represented by the Niagara dolomite. The following section was taken at this point.

---

* In recent years, Professor Hall and some other authors have referred this species to *Strophomena rugosa* Rafinesque. See Pal. N. Y., vol. VIII, part i, and Geology of Minnesota, Final Report, vol. III, part i.

		FEET.
6.	Loess, resting on residual clays and cherts, without intervening drift......0 to	6
5.	Rather evenly bedded layers of fairly good quarry stone......	30
4.	Thin bedded limestone, with much chert......	20
3.	Heavy ledge of dolomite......	3
2.	Argillaceous, yellow limestone, with fossils of Maquoketa stage at base, and becoming more calcareous towards the top; transition beds......	25
1.	Blue and gray shales, with thin, calcareous, very fossiliferous layers below level of water. Not measured.	

The base of No. 3 in the above section may conveniently be taken as the line of junction between the Maquoketa shales and the Niagara limestone. Below that line the beds grade downward into true Ordovician or Lower Silurian; above the line the cherts and dolomites are typical of the Niagara limestone.

At the point where Elk creek crosses the north line of the county the bottom of the valley is forty feet below the top of the Maquoketa formation. In this valley the exposures of the more shaly, clayey phase of the deposit are, however, neither very numerous nor very satisfactory. In general the shale is concealed by talus material, and this in turn may be overgrown by rank vegetation, so that it is only where recent landslides have occurred that the beds are seen with any success. Even then one is not always certain that the material is in place.

Numerous good exposures of the argillaceous limestone corresponding to the transition beds, No. 2 of the Rockville section, occur at intervals along Odell's branch of Elk creek in sections 10 and 15 of Elk township. These transition beds are invariably capped with heavy ledges of Niagara limestone (Plate ix, Fig. 2.) Near the confluence of the two branches of Elk creek in the Se. ¼ of Se. ¼ of section 10 there are some exposures of the shaly beds of the Maquoketa stage, and at intervals along the valley to the north line of the county the shales are seen in the banks of the creek. Just below the calcareous transition beds, which are uniformly about twenty-five feet in thickness, there are four feet of indurated blue shale, below which the beds weather into smooth, plastic potters clay. Considering the great abundance of fossils in the bluish calcareous bands beneath the transition beds at Rockville, it is a singular fact that no fossils of any kind were seen either in the shales proper or in the yellow calcareous beds above them, at any of the exposures in Elk creek valley. The definite localization of faunas is one of the most striking facts encountered by the geologist in studying this formation in Iowa.

The best exposures of Maquoketa shales in Delaware county occur along Little Turkey river and its branches in sections 2 and 3 of Colony township. A deep lateral gorge, eroded by a small tributary of the Little Turkey in sections 2 and 3, cuts through nearly the whole thickness of the formation and affords a number of fairly satisfactory sections. At what is known as the "big spring" in the Se. ¼ of Ne. ¼ of section 3 the bottom of the gorge coincides with the base of the transition beds and the spring issues on top of the shaly portion. The section taken a few yards below the spring shows:

		FEET.
5.	Steep slopes sodded over; not measured.	...
4.	Niagara limestone in thick heavy ledges	10
3.	Transition beds; soft, yellowish argillaceous limestone, more shaly below, becoming firmer and more calcareous above, in thin layers	25
2.	Hardened shale, in layers two to four inches thick, some of the layers containing segments of crinoid stems	1
1.	Bluish shale, indurated, composed of thin laminæ, no organic remains	4

The spring is 230 feet lower than the level of the plateau on which Colesburg is built. One-fourth of a mile below the spring there is a clay pit from which a large amount of clay to supply the pottery at Colesburg has been taken. The altitude is sixty feet lower than the spring, and between the spring and clay pit there is almost a continuous section of the shales exposed. Following down the stream a short distance farther, just beyond the Delaware line, in Clayton county, the massive dolomitic beds of the Galena limestone are reached. The Maquoketa shales in this particular locality are very uniform throughout their entire thickness. Excepting the transition beds occupying the upper twenty-five feet of the formation the whole body is argillaceous. The usual calcareous fossiliferous bands are absent. If there are any fossil remains below No. 2 of the big spring section, they escaped observation. The only differences noted between different horizons had reference only to varying shades of the blues and drabs that control the color tones of the formation.

At West Dubuque, Graf and other points in Dubuque county there are very fossiliferous beds, containing a unique fauna, near the base of the Maquoketa shales. Near Wadena, in Fayette county, there are beds, rich in fossils, belonging to the Cincinnati shales fauna, in the upper part of the formation. The Cincinnati fauna, with a different proportional representation of species, occurs just below the transition beds at Rockville, Delaware county. But in Elk and Colony townships, of Delaware county, and in some ravines in Clayton county, a few miles northeast of Edgewood, the exposures of the Maquoketa shales, some of them showing the entire thickness from top to bottom, are absolutely destitute of organic remains. This peculiar localization of faunas record conditions of late Ordovican sea bottom not yet explained.

Silurian.

NIAGARA LIMESTONE.

DELAWARE STAGE.

The formation following the Maquoketa shales in ascending order was designated by Hall* the Niagara limestone; and in this correlation of a western dolomite, containing a mixed Clinton and Niagara fauna, with the Niagara shale and lime-

*Rept. on the Geol. Surv. of Iowa, by James Hall and J. D. Whitney, vol. I, part i, p. 71. 1858.

FIG. 1. Fallen masses from the basal ledges of the Niagara limestone, showing the tendency to split along parallel planes of lamination. Southwest qr. section 14, Elk township, Delaware county.

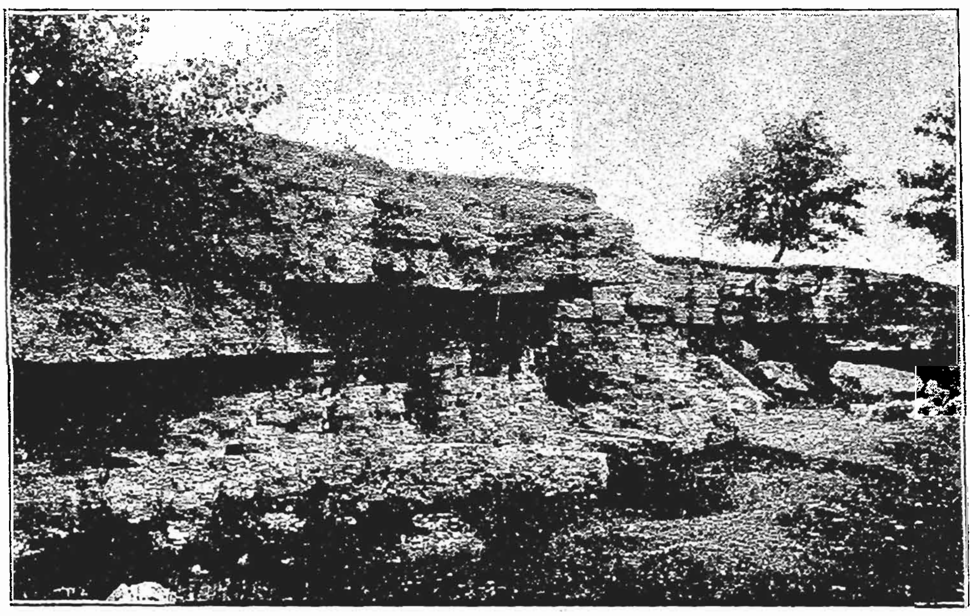


FIG. 2. Reglarly bedded prentamerus-bearing limestone in section 31, Bremen township, one mile east of Earlville.

stone of western New York, he has been followed by all geologists who subsequently have studied the formations in this part of the Mississippi valley.

The Niagara limestone begins as heavy ledges at the top of the argillaceous limestone which marks the close of the Maquoketa stage. There is much local variation in the details when sections in different parts of the county are compared, but in general the beds near the base of the formation are heavy, compact, non-fossiliferous dolomite. In some instances they are massive ledges, four to six feet in thickness, showing no indications of lamination planes. In other cases they are very distinctly laminated, and readily split along the horizontal planes of lamination into great blocks with parallel faces. This laminated condition of the lower beds is best seen in Elk and Colony townships. A typical concrete illustration of the structure described is seen in the vertical faces of cliffs of Niagara limestone that overhang the more rapidly weathering transition beds of the Maquoketa shales in the southwest quarter of section 14, Elk township. Near the southwest corner of the section named the recession of the transition beds has undermined the basal ledges of the Niagara and allowed blocks fifteen to thirty feet in diameter and ten to fifteen feet in thickness to fall down into the channel of the creek. In falling the blocks have been pitched at all angles, and some stand on edge (Plate x, Fig. 1). All have been split along some of the lamination planes so as to demonstrate very forcibly the nature of the structure that is only suggested by the weathered edges of the masses yet in place. The same structure is equally well illustrated at the big spring in section 3 of Colony township. The weathered edges of the undisturbed beds indicate horizontal lamination. Fallen blocks of great size, cleft by the force of the fall into relative thin slabs with smooth, parallel surfaces, afford a very impressive demonstration.

The laminated condition of the basal ledges of the Niagara in the northeastern part of Delaware county is the more note-worthy for the reason that at Rockville, in North Fork township, the corresponding beds are not laminated; and in the opposite direction, in Fayette and Clayton counties, the beds immediately above the Maquoketa shales are massive, homogeneous, with no more tendency to split horizontally than vertically. The Williams quarry, near the northeast corner of Fayette county, is worked in basal ledges of Niagara, which are four to six feet in thickness; and dimension stone is obtained by sawing the great blocks, after they are quarried, to the size desired. The laminated condition of the stone in Elk and Colony townships will have great economic importance if the demand for heavy dimension stone should ever make it an object to operate quarries in these localities.

The laminated basal ledges of Niagara limestone in Elk creek valley have an aggregate thickness of about twenty-five feet, and are followed by some definitely bedded dolomite, which in some places consists of thin layers with considerable chert. Along Elk creek this second member is ten feet in thickness. This is followed by a bed of quarry stone in very definite layers, which range from three to thirty inches in thickness. The stone is fine-grained, and light yellow to light drab in color. The individual layers are homogeneous, without laminæ, and sharply separated one from the other by clayey partings. Exposures of the quarry stone horizon occur at a number of points in section 16 of Elk township, and quarries are worked on the land of B. A. Baker, George Boehm and Job Odell. The quarry operated by O. Wilcox on land of Mr. Odell shows a section thirty feet in thickness. The heavier layers are toward the top of the exposure, and some of these contain numerous cherty concretions. Near the base of the quarry the stone lies in thinner layers and is free from chert. The quarry is capable of yielding good material for cut dimension stone, all kinds of ashlar work, rubble and heavy dimension stone for bridge piers. A great number of joints trending southwest-northeast cut vertically through the strata. The best material for cut stone lies about the middle of the quarry section. Here the beds are free from chert, and the surfaces of the individual layers are comparatively parallel planes. Near the base of the quarry the layers present uneven surfaces, the irregularities resembling the effects of wave action.

The Wilcox quarry is situated on the north side of a triangular ridge separating two converging valleys. Around the point of the hill, and almost opposite the exposure operated by Wilcox, another opening has been made in layers corresponding to those in the upper part of the Wilcox quarry. The stone is weathered at the top, and is overlain by dark-brown residual clay, residual chert and a thin layer of loess. There are no signs of drift. If the Kansan drift was ever laid down in this locality it was entirely removed by erosion before the deposition of the loess. All the other quarries opened at this horizon show essentially the same details as those described.

Regularly bedded limestone, apparently the same as the beds worked, continue below the base of the Wilcox quarry for at least fifteen feet, and hence there is a total thickness of forty-five feet of beds that might be quarried. Between the quarry stone and the horizontally laminated beds at the base of the Niagara there is a rather gradual transition through strata intermediate in character. No fossils were noted either in the basal beds or in the quarry stone.

Above the quarry stone in Elk creek valley the section is not very satisfactorily exposed. Forty feet higher than the top of the quarry there appears in the hillside some massive, vesicular, coarse-grained, crystalline ledges that exhibit the usual lithological characters of certain fossiliferous beds that elsewhere are known to lie at the same distance above the base of the Niagara. Here, however, the beds, so far as could be observed, are barren. In other localties they contain a fauna embracing a number of corals, the most common and most characteristic species being *Syringopora tenella* Rominger.

A short distance northeast of the center of section 20, Elk township, the roadway cuts through ledges crowded with casts of *Pentamerus oblongus* Sowerby. Altogether about thirty feet of the Pentamerus-bearing beds are exposed. The elevation is 100 feet above the top of the Wilcox quarry.

There are two gaps in the Elk creek section of the Niagara limestone. The first is forty feet in extent and occurs between the top of the Wilcox quarry and the massive crystalline ledges that represent the horizon of *Syringopora tenella*. The second, forty or fifty feet, lies between the ledges last named and the first exposures of the Pentamerus beds seen in coming up the valley. The exposures containing Pentamerus near the center of section 20, represent the top of the Pentamerus-bearing horizon. At least they are overlain by a few feet of limestone free from Pentamerus and evidently representing the next higher horizon. From what is known elsewhere of the thickness attained by the several portions of the Niagara limestone in this part of Iowa, the Elk creek section may be determined with a fair degree of approximation; and this particular section, notwithstanding certain unfilled gaps, is presented first for the reason that it affords the best and practically the only available opportunity for study of the lower members, down to contact with the Maquoketa shales. The succession of strata seen along the valley from the southeast quarter of section 10 to near the center of section 20 is as follows.

6.	Barren beds of massive dolomite much weathered....	10
5.	Pentamerus beds, with casts of the ordinary *Pentamerus oblongus* Sowerby..............................	60
4.	*Syringopora tenella* beds in heavy non-laminated ledges, usually vesicular and crystalline.....................	70
3.	Quarry stone beds of the Wilcox quarry and other quarries in same neighborhood.......................	45
2.	Intermediate beds, somewhat regularly stratified.....	10
1.	Basal ledges, horizontally laminated, with definite partings at intervals of four to eight or ten feet, resting on the thin-bedded, argillaceous limestone at top of the Maquoketa shales..........................	25

Near Hopkinton, in the southern part of the county, there are many picturesque cliffs of Niagara limestone affording opportunity for study of other portions of the complete

Niagara section. Along the Maquoketa river in sections 24, 25 and 36 of township 87, north, range 4, west of the fifth principal meridian, the cliffs rise vertically almost from the margin of the stream, to a height of 165 feet above the water. The cliffs consist at the base of massive dolomitic ledges, ranging from 6 to 15 feet in thickness, with no lamination, breaking when quarried for any purpose into shapeless blocks containing many vesicular cavities, and very coarse and granular in texture. These coarse massive ledges rise in places to the summit of the cliffs, 165 above the water, but at the Loop quarry, in Sw. ¼ of Nw. ¼ of section 25, Tp. 87, N., R. IV, W., they are capped with evenly bedded quarry stone varying from 12 to 20 feet in thickness. The section here gives the following details.

		FEET.
7.	Rock ledges, presumably of quarry stone, hidden under slope covered with loess and dark colored ferruginous residual clays; from summit of hill to uppermost beds exposed in Loop quarry	38
6.	Quarrystone in definite beds which are arched as if the quarry were located at the summit of a small anticline	12
5.	Massive beds, no definite bedding planes; fossils rare, and consisting of casts of Orthoceras and related Cephalopods, with casts of Caryocrinus and Eucalyptocrinus	20
4.	Beds similar to 2 and 4 containing *Cerionites dactylioides* and *Pentamerus pergibbosus*	10
3.	Massive bed of the usual coarse, vesicular dolomite. No fossils detected	15
2.	Massive dolomite with numerous casts of *Pentamerus oblongus*. In the lower part of this member the casts of Pentamerus are small and rather scarce; in the upper part the individuals are larger and much crowded together	25
1.	Unexposed to level of water in river	45

Near the Williamson lime kiln in the southern part of section 24, the rock ledges are exposed down to the water's edge; and at this point *Pentamerus oblongus* occurs, even in the lowest beds, in considerable numbers. The total thickness of the *Pentamerus oblongus* beds is not less than sixty feet. In general this horizon is a coarse massive dolomite that breaks up into pieces of irregular shape, but near the center of section 27, Colony township, there is an exposure of evenly bedded Pentamerus limestone in which the layers vary from eight to ten inches in thickness. The beds have been quarried for building stone, and blocks of fairly regular shape are obtained. Another exception to the general statement respecting the Pentamerus beds is seen in some quarries east of Earlville, (Plate x, Fig. 2,) where beds rich in casts of Pentamerus are separated by shaly partings into layers varying from six to thirty-six inches in thickness. In general, however, the Pentamerus beds show no very definite bedding planes. The ledges below Hopkinton may be regarded as their typical phase. The same massive phase of the Pentamerus limestone is seen near the opposite corner of the county at the Backbone in Richland township. It occurs also at the mill in Forestville. It is this phase that is exhibited in section 20 of Elk township near Greeley. It is seen again along the headwaters of Lindsey creek northeast of York. It is this same phase that occurs in the bed of Honey creek near Millheim as well as in the low cliffs along Sand creek where it traverses the Ne. ¼ of Se. ¼ of section 8, Milo township. Besides *Pentamerus oblongus* the beds of this horizon contain, locally, colonies of corals among which *Halysites catenulatus* and *Syringopora tenella* are the most characteristic. The two species named range, however, from the base of No. 4 of Elk creek valley section to the top of No. 5 of the Loop quarry section. They are most common in the horizon below the Pentamerus beds.

The presence of Cerionites at the horizon represented by No. 4 of the section at the Loop quarry is quite constant throughout this part of Iowa; and the crinoid and cephalopod fauna of the next higher member, No. 5, is also well represented over an area embracing the southeastern part of Delaware county and adjacent portions of Dubuque, Jones and

Jackson. The fauna characteristic of this horizon seems to be best developed in Cedar county.

The stone at the Loop quarry, No. 6 of the preceding section, is a fine quality of light gray to light buff dolomite, regularly bedded, easily quarried and capable of being worked into forms suitable for almost any structural purposes. The individual layers in the part now exposed range from three to ten inches in thickness. In the upper part of the quarry some of the layers include cherty concretions, but in general the stone is of excellent quality for all ordinary masonry. The lower layers contain casts of a variety of *Pentamerus oblongus* that differs from the usual form in being thin and wide, and in having the spondylium of the pedicel valve and the septal laminæ of both valves very feebly developed. The presence of these casts does not, however, impair the value of the stone for ordinary range work.

The beds represented at the Loop quarry were first worked in this neighborhood along the ravine known as Whittaker hollow, in the southeast quarter of section 23, Tp. 87 N., R. IV, W. The Merriam quarry, located a short distance southeast of the center of the section, has been operated intermittently for a great many years. The quality of the stone is the same as at the Loop quarry. A second quarry on the Merriam property has recently been opened a few rods east of the original one. It shows nothing different from those already described. The layers in both are thin at the top, and are badly shattered and weathered. Residual clays and cherts, with some loess, overlie the limestone beds, but drift is practically absent. In the bottom of these quarries are ledges two feet in thickness suitable for bridge stone.

The regularly stratified beds belonging to the horizon of the Loop and Merriam quarries is found in the Davis quarry, east of the center of section 17, in South Fork township, and at the McGlade quarry and other quarries in the same neighborhood, though here the layers are thinner than in the quarries west of the river. These exposures would produce excellent flagging stone. Among the few fossils which they have furnished are *Calymene niagarensis* Hall, *Illænus imperator* Hall and the peculiar siphuncle that has been described as *Huronia vertebrale.* An exposure of the thin-bedded quarry stone of the Davis and McGlade quarries occurs near the center of section 27, North Fork township. There are other outcrops in this same township, but they have not been quarried. In Delhi township, within the town of Delhi, are some small quarries worked in these beds, and on the south side of the river at Fleming's mill, in Sw. ¼ of Nw. ¼ of section 29, Delhi township, this upper quarry stone horizon is exposed at an elevation of ninety feet above the level of the water. One of the best quarries worked at this horizon is located near the center of section 24 of Milo township. It has layers ranging from flagging stone two or three inches in thickness up to heavy dimension stone with a thickness of two feet.

Exposures showing some departures from the typical phase of the quarry stone horizon are seen in the east part of section 9, Milo township. The beds have been quarried at a few points. The stratification is mostly regular, but the quality of the stone is much inferior to that usually seen in this position. The layers are more broken and shattered than usual, and some of them evidently yield rapidly to the effects of weather. A large amount of the rock is bluish in color; and some beds, quite worthless for ordinary uses, seem to be made up to a great extent of crystalline calcite. The face of the exposures is about twenty-five feet in height; but the stone is overlain by a heavy bed of loess resting on residual clays and chert, and the upper layers are thin, much shattered and badly weathered, necessitating a large amount of stripping.

There is no drift, at least there is none of Iowan age. The exposures occur on hills through which the Maquoketa flows in a gorge 200 feet in depth. The hills rise eighty to 100 feet above the adjacent portions of the Iowan drift plain, and the region is one of many that give very positive indications of the fact that in Delaware county the Iowan ice did not overflow eminences that rose a few score of feet above the general level.

The building stone beds noted as belonging to the horizon of the Merriam and Loop quarry stone represent the same zone as the building stone beds of the Delaware stage noted in the report on Jones county.*

At the Backbone, in section 16 of Richland township, the vertical cliffs, eighty to ninety feet in height, show the following section:

		FEET.
4.	Pentamerus beds, massive and weathering irregularly	25
3.	Band of chert, with casts of Pentamerus	1
2.	Pentamerus beds, like No. 4	43
1.	Massive beds, without Pentamerus, but containing colonies of *Halysites catenulatus* and *Syringopora tenella*.	20

Cliff-forming Beds.—The part of the Niagara limestone lying between the horizon of the Wilcox quarry, on Odell's branch of Elk creek northeast of Greeley, and the horizon of the Merriam and Loop quarries, on the Maquoketa river southeast of Hopkinton, is usually coarse in texture, and lies in heavy, massive ledges, as shown in plate ix, figure 1. It becomes very much pitted on the surface, but in the mass resists the weather admirably, and tends to stand in vertical, picturesque cliffs and towers, some of which approach 100 feet in height. At the point called Wildcat Den, southeast of Hopkinton, the vertical faces of the cliffs rise fully 100 feet, the summit being 130 feet above the stream, which here flows near the base. The weather-beaten, massive, castle-like salient, between the floor of the Loop quarry at the summit and the roadway at the foot of the bluff, rises sheer for seventy feet on its outer wall, and a number of towers and chimneys in the same neighborhood are fully its equal in vertical dimensions. Table Rock, further down stream, in the southwest quarter of the same section, is a flat-topped mass of equal height, belonging to the same horizon, and almost completely isolated by circumdendation. In the southeast quarter of section 9,

*Geology of Jones county, by Samuel Calvin, p. 75, Iowa Geol. Surv., vol. V. Des Moines 1896.

Union township, the deep valley of Buck creek is walled in, in places, by vertical cliffs, that are more than eighty feet high from the top of the talus to the summit, and the top of the cliffs has an elevation of 120 feet above the level of the stream. In sections 32 and 33, North Fork township, similar cliffs rise sheer from the water in Plum creek, and overlook the low-lying Iowan drift plain in sections 34 and 35 of the same township. It is this same limestone that forms the impressive cliffs and towers at the Backbone in section 16, Richland township (plate xi, fig. 1). All along the canyon of the Maquoketa, from section 9 of Milo township to the south line of the county, the same rugged, weathered cliffs appear at short intervals, preserving fragmentary bits of preglacial scenery. Even over the prairies, remote from streams, particularly in the southeastern part of the county, ledges of this same horizon project through the thin drift in numberless places, some of which are referred to in discussing the topography of the county. Owen appropriately referred to this part of the geological column as the Coralline and Pentamerus beds of the Upper Magnesian limestone,* in his report published in 1852. In his earlier report, which covered work done in the autumn of the year 1839, he uses a term no less felicitous when he refers to the Coralline beds of the Upper Magnesian Cliff limestone.† The coral and Pentamerus-bearing beds of the Niagara limestone in Delaware county are pre-eminently cliff-forming, and that one characteristic will readily serve to distinguish them without further inspection.

Non-dolomitized portions of the Niagara Limestone.—A very unusual phase of the Niagara limestone is seen at a few points in Union township. A fine-grained, bluish, compact limestone, not dolomitic, and resembling some portions of the Devonian, occurs in small patches a few yards in extent. These patches were supposed at first to be Devonian outliers, but their relations to the ordinary granular Niagara dolomite, into

*See map accompanying Geol. Surv. of Wis., Iowa and Minn., by D. D. Owen. 1852.

†See heading over plates xiii and xiv, Rept. Geol. Expl., etc., in the autumn of the year 1839. Ordered printed 1844.

which they grade laterally and which sometimes overlies them, preclude their reference to the Devonian. One of the best examples of the phase described occurs a short distance west of the southeast corner of section 8 in the township named. Another patch of the same kind occurs near the northeast corner of the same section. More of the same stone is found one-fourth mile north of the center of section 19, and it is shown in an instructive exposure along the north line of section 29. Masses of the blue, fine-grained limestone lie in the midst of granular dolomite and are portions of continuous layers that, except in the non-dolomitized spots, possess the characteristics of the ordinary Niagara. All the exposures named are purely local phenomena, small patches of Niagara that in some way escaped the process of dolomitization.

More extensive non-dolomitized portions of Niagara limestone occur in Coffins Grove township. All the beds through a thickness of 20 or 30 feet and over an area some miles in extent, are non-dolomitic. Some of the beds are quite fossiliferous, the fossils being chiefly corals; and while the corals elsewhere at this horizon are usually silicified, they are here unchanged except by the interstitial deposition of calcite. Typical exposures of the beds under consideration are seen near the center of section 26 in the township named, and the same beds crop out in the bluffs along Prairie creek in section 28. The beds may be satisfactorily studied in the low bank of the creek at the point where the stream is crossed by the Masonville road, in the northwest quarter of section 28. Fine-grained, unfossiliferous, non-dolomitized Niagara, near Hazelton, is discussed in the report on Buchanan county.

Fauna of the Niagara.—The Niagara limestone, at any given horizon, varies locally both as to lithological characters and fossil contents. The life of the Niagara seas was not uniformly distributed over the sea bottom, but seems rather to have been segregated in colonies. Fossils are common only in the zones that lie between the two quarry stone horizons. No indications of life were noted in the basal laminated beds, nor in any beds below the top of the lower quarry stone worked in section 16 of Elk township. Above that line, up to the base of the Merriam and Loop quarry zone, fossils abound in certain favored localities, while in other localities organic remains are rare or are wholly absent through scores of feet of the massive dolomite. In number of genera and species the corals are better represented than any other group. Usually the corals are silicified and they sometimes occur abundantly in the residual materials, mingled with reddish brown geest and shapeless fragments of chert, the beds in which they were originally embedded having been removed as a result of secular rock decay. *Halysites catenulatus* and *Syringopora tenella* range through the whole thickness of the fossil-bearing beds, but other species occur only in the Pentamerus zone or just above it. One of the best known localities in the county is that along Prairie creek, in section 28 of Coffins Grove township. Residual clays and cherts have in places a thickness of several feet, and these are rich in beautifully preserved specimens of silicified corals. Many are not described, but so far as they are now known the most common species are.

Zaphrentis stokesi Edwards & Haime.
Streptelasma patula Rominger.
Streptelasma spongaxis Rominger.
Cyathophyllum radicula Rominger.
Ptychophyllum expansum Owen.
Strombodes mamillare Owen.
Strombodes gigas Owen.
Strombodes pentagonus Goldfuss.
Cystophorolites major Rominger.
Cystophorolites minor Rominger.
Cystiphyllum niagarense Hall.
Favosites favosus Goldfuss.
Favosites niagarensis Hall.
Favosites alveolaris Goldfuss.
Favosites (*Astrocerium*) *hispidus* Rominger.
Favosites (*Astrocerium*) *hisingeri* Edwards & Haime.
Favosites obliquus Rominger.

FIG. 1. Vertical cliff of Niagara limestone on west side of "Backbone." The cliffs rise sheer for ninety feet above the talus slope at the base.

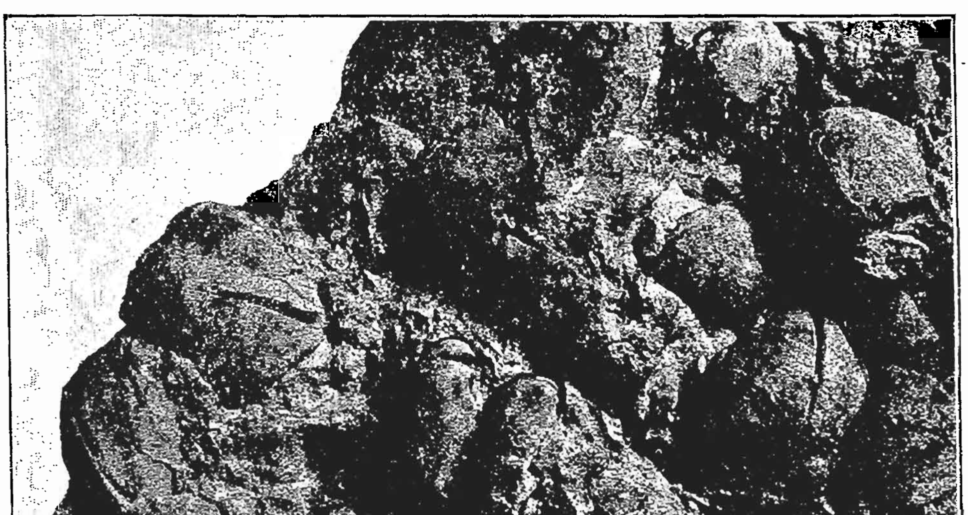


FIG. 2. Block of Niagara limestone from the Pentamerus-bearing horizon showing crowded casts of *Pentamerus oblongus.*

Alveolites undosus Miller.
Cladopora laqueata Rominger.
Thecia major Rominger.
Halysites catenulatus Linnæus.
Syringopora tenella Rominger.
Syringopora verticellata Goldfuss.
Heliolites megastoma McCoy.
Heliolites interstinctus Linnæus.
Heliolites pyriformis Hall.
Heliolites subtubulatus McCoy.
Plasmopora follis Edwards & Haime.
Lyellia americana Edwards & Haime.
Lyellia decipiens Rominger.

Besides the species enumerated in the above list there are three or four species of Zaphrentis probably undescribed, one or two of Streptelasma, and one of Ptychophyllum differing from *P. expansum* in the greater number and much smaller size of the lamellar crests. There are also some strange forms of Strombodes. There are several unknown species distributed among the genera Cladopora, Thecia and Limaria and there is at least one species of Lyellia which, when the descriptions are published, may prove to be the same as some figured by Davis in *Kentucky Fossil Corals*.

Cystideans and Crinoids in identifiable condition are very rare, and the list may be summed up in the species *Caryocrinus ornatus* and *Eucalyptocrinus crassus*.

The list of Brachiopods also is small, the forms that can be counted as at all common embracing only *Pentamerus oblongus*, *P. pergibbosus*, *Stricklandinia castellana*, *Atrypa reticularis* and *Spirifer radiatus*. The last named species is indeed rare. The *Atrypa reticularis* is most abundant in a thin cherty bed occurring in the Pentamerus zone southwest of Hopkinton. *Stricklandinia castellana* can scarcely be said to be common. In fact there is but one really common species, the *Pentamerus oblongus*. This seems in places to have occupied the sea bottom to the almost complete exclusion of everything else, (Plate xi, Fig. 2,) and to have persisted long enough for fifty or sixty feet of limestone to accumulate.

The Mollusca are only sparingly represented. The collections embrace no identifiable Pelecypods. Gastropods are represented by internal casts of *Platystoma niagarensis* Hall, a Holopea, and one or two species of Straparollus. There are several genera of Cephalopods embracing Orthoceras, Huronia, Actinoceras, Discoceras and Gomphoceras.

Trilobites are very rare. One glabella and one pygidum of *Illænus imperator* Hall, and a rather imperfect cast of *Calymene niagarensis* Hall, were observed, and that is practically the entire list. In Cedar and Jackson counties, however, this horizon furnishes quite a number of genera and species.

The building stone beds of the Merriam and Loop quarry horizon have yielded some organic remains, as already noted. The flat form of Pentamerus occurs exclusively in these beds. *Calymene niagarensis* was found only in these beds in Delaware county, but it is known from lower horizons in some contiguous counties. Illænus ranges from the lower beds up into the quarry stone, and the same is true of Huronia. Some specimens of *Favosites favosus* were found in beds of this horizon in section 9 of Milo township.

Chert beds of the Niagara.—Chert occurs extensively as concretions in the layers of Niagara limestone or as partings between them. Its distribution, however, both horizontally and vertically, is very erratic. In some localities, at certain horizons, it is present in enormous quantities, making up fully half, or much more than half, of the entire mass of rock exposed; in other localities, at the same horizon, it may be entirely absent. The quarry worked in the Nw. ¼ of the Nw. ¼ of section 2, Milo township, furnishes about as much chert as limestone. The limestone is reduced to thin, irregular layers, between which there are beds of chert equal in thickness to the beds of limestone. Both chert and limestone are broken and shattered, the chert in particular being reduced to a great number of angular fragments that vary in size from a fraction of an inch up to six or eight inches. By exposure to the weather, particularly to frost, the chert is broken up into a sort of natural macadam, and large amounts of it are used in road building.

In a low bluff in the western part of Hopkinton, beds containing a large amount of chert are worked for road material, the sandy soil of the region making road metal of some kind an absolute necessity.

While there are few rock exposures that do not show more or less of chert, the most remarkable beds of this material were seen in some of the rocky knobs protruding through the drift near the northeast corner of section 27, Bremen township. There seems to be here a solid bed of chert, and great detached blocks, eighteen inches thick and three or four feet in length and width, lie heaped on each other or scattered over the surrounding surface. The large blocks referred to showed no definite traces of fossils, but thousands of tons of silicified corals are embedded in the very thin drift and residual clay covering the adjacent fields. Vast numbers of these have been gathered and piled along the roadway into a rude stone wall, ten or twelve feet wide at base and several rods in length.

Devonian.

WAPSIPINICON STAGE.

There are no Devonian rocks naturally exposed in Delaware county. The southwest corner of the county, where these rocks should occur, if anywhere, is deeply covered with drift; but there are rock exposures on Buffalo creek, at Coggon, and even half a mile north of Coggon, within half a mile of the Delaware county line. These exposures, according to Norton,* include the Otis beds and Independence shales belonging to the Wapsipinicon stage of the Devonian. Connecting the exposures near Coggon with exposures of Devonian lying in the line of strike along Pine creek, southwest of Winthrop, in Buchanan county, the line traverses a drift covered region in

*Geology of Linn county, by William Harmon Norton, pp. 147, 148. Iowa Geol. Surv., vol. IV. 1895.

which no exposures are seen, and cuts off the hypothetical Devonian area represented on the geological map accompanying this report, in the southwest corner of the county.

Cretaceous.(?)

ROCKVILLE CONGLOMERATE.

The Rockville conglomerate was first recognized by McGee, and was fully described in his memoir on the Pleistocene History of Northeastern Iowa, previously cited. According to the author, "The formation to which this designation is applied consists either of a dark brown pudding-stone of well worn quartz pebbles in a matrix of earthy limonite, or of obscurely stratified ferruginous sandstone. It is destitute of definite bedding and other constant structural characteristics, is found in only a few scattered bodies of limited extent, is seldom seen in contact with older formations, and is not known to be fossiliferous."* This very fully describes the formation as it occurs near Rockville, in North Fork township. The exposures observed by the writer are located on sloping ground, a few yards west of the middle of the east line of the Sw. ¼ of the Nw. ¼ of section 24, about a fourth of a mile west of Rockville. The original exposure described by McGee was a short distance farther west and on higher ground. At the point where it was seen by the writer, the conglomerate projects above the thin sod over an area only a few yards in extent, and small bowlders of it lie scattered on the surface over a much larger space. The deposit is composed very largely of dark brown, ferruginous sand, which serves as a matrix in which a great number of small pebbles are embedded. Many of the pebbles seem to be quartz, but many are rolled fragments of local chert, and associated with them are angular pieces of chert ranging up to an inch or more in diameter.

Sandstone and conglomerate, probably of the same age as the Rockville conglomerate, is exposed under the loess in the

*Op. Cit., p. 304.

Ne. ¼ of the Se. ¼ of section 34, Elk township. The exposure is about six feet in thickness. While resembling the Rockville conglomerate in some respects, it differs in some important particulars. In the first place, the material is definitely stratified, and consists of fine-grained sandstone in thin layers at the base of the exposure, with coarser conglomerate layers above. In the second place, the deposit is not very ferruginous, the colors being drab and light grays, with some yellowish bands in the finer layers. A very large proportion of the fragments in the conglomerate beds is cystalline quartz. No local chert was observed. In the absence of fossils it is impossible definitely to fix the age of either the Rockville conglomerate or the light colored sandstone and conglomerate southeast of Greeley. Both are much younger than the Niagara limestone. Both probably were laid down during the same marine invasion of this part of Iowa. The reasons cogently stated by McGee in the work already mentioned make it reasonably probable that the deposits are Cretaceous in age.

Fragments of a ferruginous sandstone, resembling some phases of the Des Moines stage of the Carboniferous, are strewn somewhat thickly along the course of the intermittent stream that flows down Whittaker hollow, in section 23 of Union township. These fragments lack the conglomerate character of the exposures at Rockville and the upper part of the exposure near Greeley. Fragments of chert and silicified Niagara corals are embedded in the sandstone, but there are no coarse fragments of quartz. There are some plant impressions, but they are not identifiable. The sandstone in Union township was not seen in place, but the beds from which the scattered fragments were derived are probably not far away from the point where the fragments themselves were seen. The friable nature of the sandstone precludes the notion that it could be transported far by stream action, amid masses of chert and limestone, before being completely disintegrated. As to age, the Whittaker hollow sandstone may provisionally be correlated with the Rockville and Greeley deposits, until more definite information is at hand.

Residual Materials.

In preglacial time, the Niagara limestone suffered decay on a very large scale, and residual materials resulting from such decay are conspicuously distributed underneath the drift, especially in the eastern part of the county. These residual products, or geest, present three distinct phases. First, a dark, reddish-brown, stiff clay is one of the results of weathering of the Niagara dolomite. A small amount of argillaceous matter is present in the limestone as an impurity; and, being insoluble, it is left after decay and removal, by solution, of the calcareous portion of the deposit. With the clay is left the iron constituent that is also present as an impurity in the limestone. The dark, ferruginous clay is seen in the upper part of nearly all rock exposures. It does not, as a rule, attain any great thickness, but it fills the spaces among the bowlders of disintegration in the zone of preglacial weathering, and fills all horizontal and vertical fissures, often to a depth of many feet from the surface. It were needless to mention localities, for it occurs practically in every quarry.

Second, the Niagara dolomite varies in texture, and apparently in fundamental structure, in different localities. Typically it is hard, compact and crystalline, but there are phases of it that are soft and granular where the rock seems to be composed of partially consolidated dolomite sand. Weathering in such instances removes the cementing material, and the rock disintegrates into a yellowish or grayish mass of incoherent granules, resembling loose sand. As a typical locality where this phase of residual material may be observed to advantage, reference may be made to the rock cut on the Great Western railway northwest of Millheim. Underneath the thin bed of drift there is a body of very black, ferruginous, residual clay that belongs to the first type of residual products. Beneath this is a mass of the incoherent dolomite sand that represents the stage of decay when the cement holding the constituent grains of the dolomite together has been dissolved away. In some places this incoherent material is two or three feet in thickness. In other cases it descends along crevices to an even greater depth. Lying in it are fragments of the limestone not yet completely decayed, but so soft and friable that they may be crushed in the hand or ground to coarse powder between the fingers.

In the third type of residual material angular fragments of chert predominate. The region around Delaware Center affords typical illustrations of the chert beds that result from decay of limestone in which bands and concretions of chert are common. The road between sections 25 and 36 of Delaware township passes over some hills that have been denuded of drift, and heavy beds of residual chert, forming a natural macadam, are exposed. The interstices between the fragments of chert are filled with a small amount of reddish-brown residual clay. Similar exposures, forming natural roadways, occur very generally throughout the eastern part of the county.

At a number of points in the north half of sections 27 and 28, Coffins Grove township, the residual materials consist of beautifully preserved, silicified fossils, embedded in reddish-brown clay. The fossils represent the cherty constituent of the beds that have undergone decay, and the clayey portion of the residuum is the argillaceous constituent stained deeply with iron oxide.

The residual products, that constitute so important a part of the superficial materials in this part of Iowa, have resulted from chemical disintegration of the Niagara limestone in some or all of the geologic ages between the close of the Silurian and the beginning of the Pleistocene. Similar changes are doubtless still in progress to some extent, but it is impossible at present to assign any given portion of the residuum to any particular age.

Pleistocene Deposits.

SUB-AFTONIAN DRIFT.

No Pleistocene deposits older than the Kansan drift were recognized in any of the exposures observed, but the existence of a sub-Aftonian or pre-Kansan drift is indicated by the presence of a soil and forest bed, between bodies of bluish till, reported by well drillers from different parts of the county. Satisfactory details could not in all cases be obtained. Two wells reported by McGee* are typical and may serve as illustrations of the general phenomena. His well, numbered 44, on land of the late Mr. John S. Barry in Prairie township, gives the following section, copied from the report cited.

		FEET.
3.	Unstratified yellow clay, with pebbles and bowlders...	8
2.	Compact blue clay, with small pebbles and bowlders of greenstone	17
1.	Brownish and black earth, like surface soil, with sticks, twigs, branches and other fragments of cedar	2

"Water was obtained in forest bed and is periodically foul." Since the record reported by McGee was obtained a succession of dry seasons has necessitated the boring of deep wells all over Iowa. On the Barry farm, and on adjoining farms, the deep wells have shown the whole drift series to be from seventy to eighty feet in depth, so that below the soil and forest-bed reported above, there is a body of drift approximately fifty feet in thickness. According to recent intrepretations, this lower body of drift is beyond question sub-Aftonian. The soil and forest bed, No. 1 of the well section, is Aftonian. The blue clay, No. 2, is Kansan drift, and the unstratified yellow clay, No. 3, is Iowan.

No. 45 of McGee's well records, quoted from the work cited, gives the following section.

*Pleistocene History Northeastern Iowa, p. 520.

		FEET.
4.	Pebbly yellow clay	4
3.	Clean laminated blue clay	17
2.	Black loam, with partially decomposed logs, sticks, bark and twigs of coniferous wood	2
1.	Dense blue clay, with a few pebbles and a water bearing sand vein, depth not stated	

This last well is located at Greeley. No. 1 is very probably sub-Aftonian drift, and Nos. 2, 3 and 4 will readily be correlated with Nos. 1, 2 and 3 respectively of the Barry well.

KANSAN DRIFT.

The bed of blue clay above the soil and forest bed in the wells noted is typical of the unweathered Kansan. Nearly all excavations of any considerable depth, in the drift-covered portions of the county, reveal this same blue clay with its greenstone bowlders and pebbles. A good section showing Kansan till, weathered and unweathered, is seen in the recent railway cutting in the southwest quarter of section 6, Oneida township. The unweathered Kansan is more or less jointed, and has typical blue color, while the weathered Kansan has by oxidation been changed to reddish or yellowish-brown. The whole section here shows:

		FEET.
3.	Light yellow Iowan till	8
2.	Oxidized Kansan till, yellowish-brown	3
1.	Non-oxidized Kansan, blue	8

Narrow bands of weathering and oxidation descend along joints in the Kansan almost to the bottom of the exposure. Numerous striated greenstones occur in both the oxidized and unoxidized zones. Sub-Aftonian till is not exposed, but forest bed material was found in the bottom of the cut when trenches were dug to lay drain tile along the sides of the road bed. There are no signs of forest material between Kansan and Iowan.

Many interesting exposures of Kansan till occur in areas not occupied by Iowan. These areas have been discussed under head of Topography on account of the special topographic forms that distinguish them from the Iowan drift plain. Within these areas the Kansan drift is usually overlain by loess, and the deposition of the loess seems to have been accomplished so quietly as not to disturb in any degree the characteristics acquired by the surface of the drift in the long interglacial interval that, in this part of Iowa, followed the retreat of the Kansan ice. Accordingly, the full effects of the weathering that had taken place up to the time of the deposition of the loess are perfectly preserved. This old surface is very ferruginous, very much oxidized, and completely leached so far as calcareous matter is concerned. It is also very red or reddish-brown, and, owing to the effects of rain erosion in carrying away the finer silts, it usually contains a larger proportion of pebbles than the main body of the drift where weathering has not taken place. In the northeast corner of the county, outside the limits of the Iowan drift, reddish-brown, pebbly Kansan is exposed beneath the loess, one-fourth of a mile north of the center of section 28, Elk township. It occurs on both sides of a ravine, and its surface, underneath only a thin mantle of loess, conforms to the present slope of the hills. The slopes and contours were essentially the same as now before the loess was laid down. Another exposure, showing the same phenomena and leading to the same conclusion relative to the pre-loessian topography, occurs near the southwest corner of section 22 of the same township. These and many other similar exposures are located within less than a mile of the margin of the Iowan drift. Eight miles farther east, Kansan till appears with its usual characteristics beneath a thin veneer of loess, along the west line of section 13, Colony township. The eastern limits of the Kansan are not so sharply defined as in the case of the Iowan, but there are reasons for believing that the locality last mentioned is very near the margin of the Driftless area. In the northeast quarter of section 13, for example, there are many sink holes which are inconsistent with the presence of any considerable body of drift, and drift is certainly absent in that part of the valley of Little Turkey river that passes through sections 1 and 2 of the township named.

A considerable body of Kansan drift is well exposed for some distance both east and west of the center of section 15, Colony township, and there are indications of drift in sections 4, 5 and 6; but in sections 1 and 2 signs of drift were not observed, and the whole aspect of the country is suggestive of the Driftless area.

Buchanan Gravels.—Extensive beds of gravel were laid down during the melting and retreat of the Kansan ice. The floods that carried and deposited the gravels seem to have swept over valleys and highlands alike, for stratified deposits of the Buchanan stage occur indifferently at all elevations In the region invaded by Iowan ice these deposits are invariably overlain by Iowan drift; in the loess-Kansan area, beyond the Iowan margin, they are overlain by loess.

A good illustration of Buchanan gravels is seen at a gravel pit on the land of Mr. M. V. Newcomb, in the northern part of the southeast quarter of section 26, Oneida township, near Earlville (Plate xii, Fig. 1). The gravel bed has been worked extensively for road material, and has contributed in large degree to the improvement of the streets of Earlville. A vertical face of fifteen feet is now exposed, but test pits show that the deposit continues twenty feet below the level now worked. The deposit is a mixture of coarse sand and gravel, with occasional small bowlders ranging up to a foot in diameter. The coarse and fine materials are not arranged in definite bands, but lenses and irregular masses of coarse gravel are frequently embedded in gravel or sand of comparative fineness. There is a large amount of Niagara chert in the coarser beds, but in general the pebbles and bowlderets are of foreign origin. Some of the beds are very ferruginous and firmly cemented, and all are more or less conspicuously iron-stained. All of the present exposure shows the effects of prolonged weathering. Oxidation is complete. A large proportion of the granite pebbles and bowlders are so perfectly decayed that they crumble to fragments on the application of the slightest force. Test pits made at various points show the entire hill, which rises gradually to the north of the present working, to be underlain by gravel at a short distance beneath the surface. The rusty, weathered and oxidized deposits of the Buchanan stage are covered with a thin layer of Iowan drift containing some unweathered bowlders.

An immense bed of Buchanan gravel extends over some hundreds of acres in a low plain in sections 25 and 36 of Bremen township. The plain is covered with two or three feet of Iowan drift, and large Iowan bowlders are liberally sprinkled over its surface. The gravels lie beneath the Iowan drift. The upper zone, three or four feet in thickness, is deeply weather-stained and oxidized. The bedding is more regular than is usually seen when the gravel beds occur on higher ground, as near Earlville. The materials are also finer, ordinary quartz sand making up a larger proportion of the deposit, and the bowlders a few inches to a foot in diameter, common in the beds at greater elevations, are practically absent. Furthermore, the oxidation and weather staining, probably owing to the finer and more compact character of the deposit, do not affect the beds to so great a depth as at Earlville. Heavy beds of the same gravels, exhibiting the commoner, upland phase, occur under thin beds of loess at a number of points in Colony township, the best exposures being seen forty rods north of the center of section 9, near the northwest corner of the southwest quarter of section 4, and near the center of section 6. All of these points are from six to eight miles east of the extreme eastern margin of the Iowan drift.

Near the southeast corner of the county Buchanan gravel makes up a conspicuous ridge that begins in the southwest quarter of section 13, Tp. 87 N., R. III W. (South Fork township), and extends into the northwest quarter of section 24. The gravels here are very ferruginous, are of the coarse

FIG. 1. Buchanan gravel underneath a thin layer of Iowan drift, on land of Mr. M. V. Newcomb, north of Earlville.

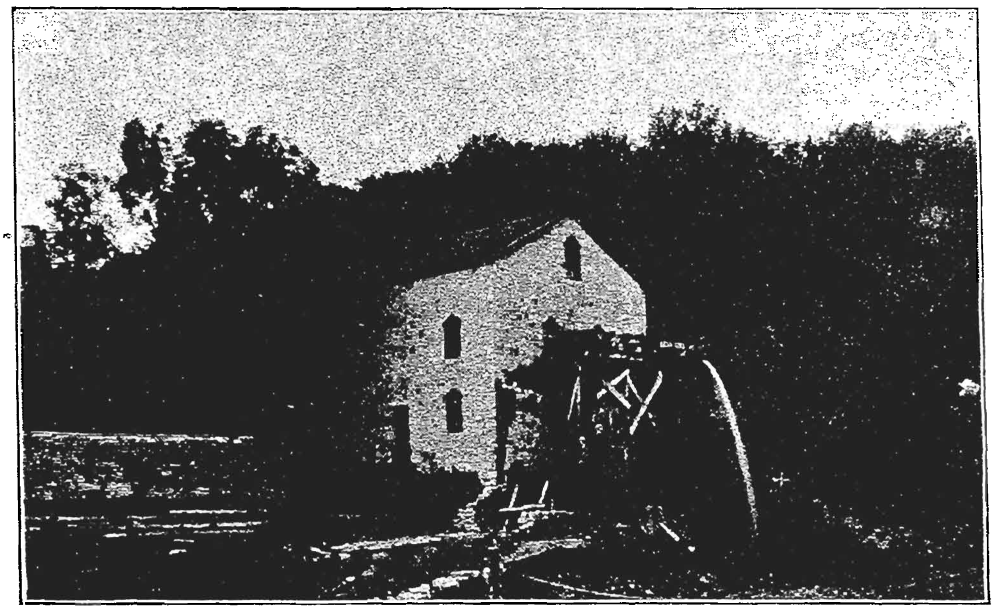


FIG. 2. Fountain Spring Mills, on Odell's branch of Elk creek. The topography of the region is that of the driftless area, and the streams are fed by springs

upland type, contain the usual decayed granites, together with striated pebbles and bowlders of Kansan age, and show a fair degree of cementation. The ridge in which they occur rises considerably above low lying drift plains to the south and southwest.

In the northwest corner of the county these gravels cover considerable areas in Richland township, the lowland phase appearing conspicuously beneath the Iowan drift along the valley of a branch of the Maquoketa, in section 19, and the upland phase occupying a ridge in the southwest quarter of section 32. In a sort of terrace at the bottom of the valley on the west side of the Backbone in section 16, weather-stained beds of the Buchanan stage occur under beds of sand and gravel of more recent origin, the contrast between the older and the newer portions of the terrace being very striking. The valley here is older than the Buchanan stage—older than the Kansan.

At Hartwick, in Delhi township, as already noted, reddish-brown deposits of this age are seen at the bottom of the gorge underneath terrace material which is probably not older than the Iowan stage, and reference has also been made to the occurrence of these gravels in the river valley near Hopkinton.

Honey Creek township is generously supplied with gravels of the Buchanan stage, particularly along the valley of Lindsey creek and Honey creek. In fact these gravels occur in almost every township of the county, affording at numerous points the very best of material for the improvement of miry roads. An outcrop deserving special mention is located west of Delaware in the southeast quarter of section 31, Oneida township. While the deposit is genetically the same as the ordinary Buchanan gravels, the material used is very largely residual Niagara chert of local origin. Reddish-brown sand and gravel is, however, interstratified with the beds of chert; and near the base of the pit, which is about eight feet in depth, the usual characteristics of the Buchanan stage are well displayed. A great amount of chert that must have been transported and deposited by strong currents of water, yet retaining to a large extent the sharp angles of the individual fragments, occurs near the top of the exposure with practically no admixture of any other material.

IOWAN DRIFT.

The Iowan drift is well displayed over the larger part of Delaware county. It overlies the Buchanan gravels at scores of points within the Iowan area, but in general it rests upon the weathered and eroded surface of the much older Kansan till. The Iowan drift is very new and fresh as compared with the Kansan. Its surface has suffered scarcely any erosion since it was laid bare by the melting and disappearance of the Iowan ice. The topography of the Iowan area is characterized by long sweeping curves, the low eminences being separated by broad, shallow, concave depressions which, at the time of settlement of the county, were marshy and supported a luxuriant growth of coarse slough grass. The irregularities of the present surface are in part controlled by the topography of the old Kansan surface upon which the mantle of Iowan drift was laid down, and in part by local variations in the amount of drift deposited by the Iowan ice.

The study of the distribution of the Iowan drift in Delaware county has revealed some unexpected phenomena and presented a number of interesting problems that are not yet fully settled. In the first place the extreme eastern margin of this drift sheet is quite sharply defined by moraine-like ridges of loess that rise conspicuously above the drift plain, and extend in a very tortuous line from the northwest corner of Elk township to Dyersville. All of Colony township, the greater part of Elk, approximately one-third of Bremen, and a small fraction of Oneida were not invaded by Iowan ice. But in addition to the extra marginal area just noted, there are island-like areas that rise out of the level sea-like plain of Iowan drift areas that were surrounded, but not invaded, by the glaciers of the Iowan stage. These anomalous areas are all higher than the ordinary drift plain by which they are surrounded. The larger ones are topographically different from the plain, resembling in this particular the Driftless area. Neither Iowan drift nor Iowan bowlders are found within their limits, but heavy beds of loess molded over a very much weathered and eroded surface is a prominent characteristic. Sometimes the loess rests on reddish-brown, oxidized Kansan drift. In other cases it rests on undisturbed residual clays and cherts.

These anomalous areas are of two kinds. First, there are small detached hills a few acres at most in extent, loess-covered, and standing prominently above the drift plain. These are the paha of McGee referred to in the section of this report devoted to togography. The paha are more or less elliptical in shape with the longer axes trending northwest-southeast. They are too numerous to be described in detail, but a concrete example occurs in the south half of section 3, Honey Creek township. The summit is fifty-five feet above the Iowan drift at the base. Gullies cut along the roadside on the southern slope show that the paha is composed of Kansan drift overlain by a cap of loess. Another paha near the northeast corner of section 27, Oneida township, has a core composed chiefly of a prominent point of limestone, but the limestone is overlain by a thin sheet of much weathered Kansan drift, and the loess, which is an essential part of all paha, forms a mantle over the whole a few feet in thickness. The paha are limited to a belt, a few miles in width, lying inside the margin of the Iowan drift. There are some interesting groups north of Earlville. There are a few rather prominent examples in the northwest corner of Elk township. They are very numerous in the northeastern half of Honey Creek township. They are in general conspicuous features of the marginal portion of the Iowan drift plain.

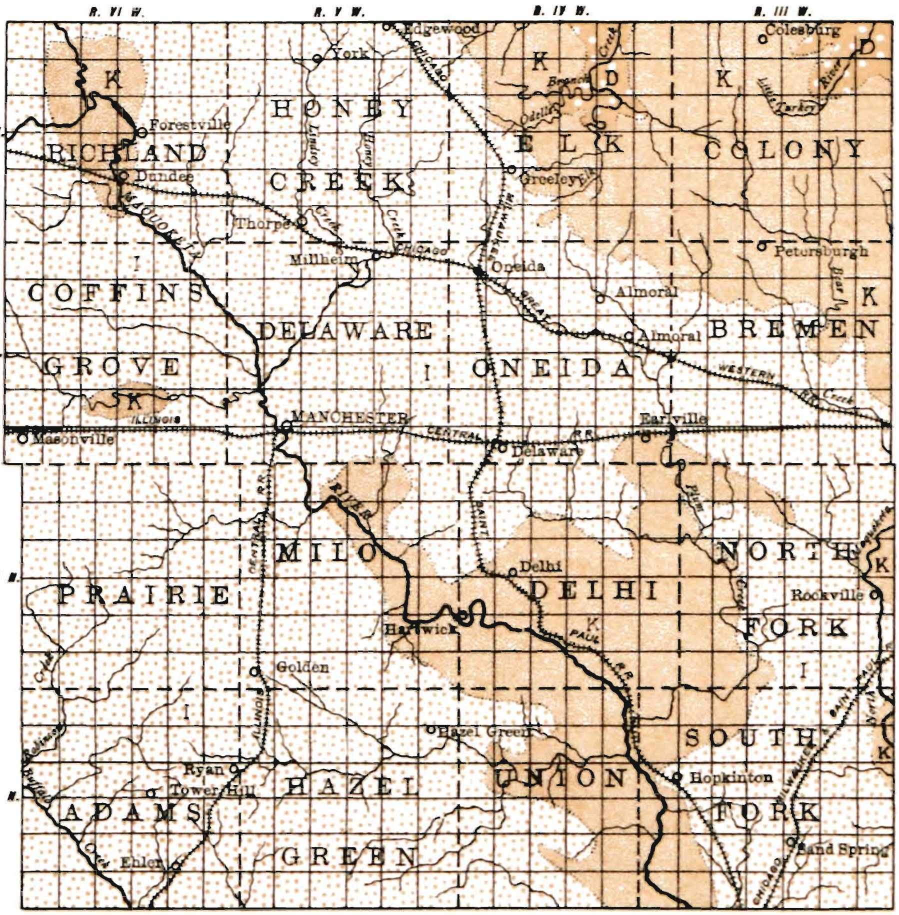
Second, there are some comparatively large areas, each embracing a number of square miles. One of these, with heavy beds of loess and Driftless area topography, stands in the midst of Iowan drift in the central part of Richland township. This area constitutes the Richland highlands. At a number of points on the high ground west of Forestville the loess is seen resting on undisturbed residual clays and cherts. The Maquoketa flows through the highlands in a comparatively deep canyon. Iowan drift is absent, and the Kansan drift is seen but rarely.

The largest area of the kind under consideration is the Delhi plateau, described at some length under the head of topography. It is surrounded by Iowan drift, but contains none within its limits. Kansan drift, weathered and oxidized as usual, occurs under the loess at numerous points. Near Hopkinton, as already noted, the loess rests on Buchanan gravels. In many places, however, there are no signs even of a Kansan invasion of the region, and loess lies on residual products. By way of explanation of these anomalous areas it can only be said that it looks as if the Iowan ice had been too thin near its margin to overflow eminences rising fifty feet or more above the general level, and so it simply flowed around them. The upper surface of the ice in general was doubtless somewhat higher than the tops of the eminences in question, so that when the flow was at its maximum these areas lay at the bottom of shallow, basin-like depressions within which fine silt or loess was deposited. The facts, however, may have been quite different from those which the peculiar phenomena, at first sight, seem to suggest.

The Iowan drift is a light yellow, highly calcareous clay, unchanged by weathering and oxidation even at the surface. It presents a strong contrast to the deeply weathered, leached and oxidized upper zone of the Kansan. Its presence, however, may be detected without special tests by the gently undulating topography free from erosion forms, and by the presence of large granite bowlders strewn over the surface. Mingled with the granites other forms of crystalline rocks occur occasionally. A fine, large quartzite bowlder, five feet long, three feet wide and fifteen inches thick is seen on the Sw. ¼ of Se. ¼ of section 16, Delaware township, and another similar in type, and probably from the same original ledge, was noticed in the southeast quarter of section 3 of the same township. Both bowlders show very perfectly the lamination planes of the original bedding, and in both the surface is beautifully ripple-marked.

Loess is the name given to the fine, silt-like clay that in general covers the area outside the margin of the Iowan drift. Loess also covers the paha, and very generally it covers the other island-like areas that seem to have been completely surrounded by Iowan ice without being overflowed by it. The composition, structure and distribution of the loess indicates that it was derived from the Iowan drift, and its deposition was in some way connected with the presence or retreat of the Iowan ice. Approximately one-third of Delaware county is loess-covered, the localities so covered having been already described. Quartz sand, to a large extent, takes the place of loess in the northern and central parts of the Delhi plateau. In many other localities the loes is underlain by stratified sand. This is particularly true along valleys that may have served as drainage courses to carry off the water from the melting Iowan ice. An interesting occurrence of sub-loessial sand was seen in Whittaker hollow, a mile or two southwest of Hopkinton. Heavy beds of loess lie on the sloping sides of the valley, and at one point in the southwest quarter of section 23, Union township, a bed of highly colored, reddish-orange, stratified sand is exposed beneath twenty-five feet of loess. The sand, six feet in thickness, rests on the bottom of the valley, showing that Whittaker hollow, as well as the rest of the drainage courses of the region, was eroded to its present depth before the sand or loess was deposited. All these valleys are in fact pre-Kansan, as shown by the presence at various points of undisturbed Buchanan gravels.

For four or five feet above the base of the loess, at the point under consideration, there are irregular pockets of the



PLEISTOCENE MAP OF DELAWARE COUNTY, IOWA,

BY

SAMUEL CALVIN

I — IOWAN DRIFT

K — NO IOWAN DRIFT. CHIEFLY LOESS RESTING ON KANSAN PARTLY DRIFTLESS

D — NO DRIFT

IOWA LITHO CO. DES MOINES

DRAWN BY F. C. TATE

bright-colored sand, not mingled with the clay, but simply enclosed in it, as if they had been deposited as frozen pellets. The sub-loessial sand is clearly an aqueous deposit, and the sand pellets included in the basal portion of the loess were certainly not transported by wind. In the upper part of the exposure, about fifteen feet above the base of the loess, a few specimens of *Succinea avara* were noted. The whole body of loess at this point is quite distinctly banded, and is more than usually arenaceous.

With reference to the areas actually invaded by Iowan ice the distribution of the loess seems to be generally, if not invariably, extra-marginal. Except at the point noted under Topography in sections 27 and 28 of Hazel Green township, it is not certain that the loess of this region ever rests on Iowan drift. The contact of the loess with Niagara limestone, with residual products such as dark-brown clays and cherts, with Kansan drift and with Buchanan gravels, may be observed at scores of points; but nowhere, except in the single instance mentioned, was it seen resting on drift of Iowan age. It may yet indeed be possible that the morainic ridges referred to in Hazel Green township are composed of Kansan drift with Iowan drift lapping up on the sides, but not reaching the top; and that after all the loess does not rest on till of Iowan age, but on Kansan, as is its almost universal habit.

ALLUVIUM.

Narrow belts of alluvium occur along the principal drainage courses in all the areas that were not invaded by Iowan drift. The Little Turkey river has in places a beautiful, flat-bottomed valley, which is covered with heavy beds of rich alluvium. Alluvial plains, but of no great width, border Elk creek and its branches; and Buck creek, Plum creek and the Maquoketa river have their flood plains covered with alluvium within the limits of the Delhi plateau. Alluvium covers the flat bottom of the valley through which the Maquoketa flows at the Backbone in Richland township, and a small amount of the same deposit is found along the

North Maquoketa, in sections 1 and 12 of South Fork township. Streams, such as Buffalo creek, that flow through the area of Iowan drift, have no flood plains, or alluvial plains, in any true sense; for the gently undulating surface of the region through which they flow, covered with drift and sprinkled with bowlders, continues without interruption to the water's edge.

TERRACES.

Well defined terraces, composed of stratified sands and gravels, occur along the streams of Delaware county, particularly in the areas inside the Iowan margin, but which are free from Iowan drift. The height to which the terraces rise above the water in the adjacent stream varies considerably in different localities. Near Hopkinton the upper surface of the terrace on the east side of the river is fifty feet above the water level. Near Millheim, in Delaware township, a terrace composed of fine stratified sand has an elevation of thirty feet above the water in Honey creek. At other points in the county the height of the terraces above the water in the nearest stream varies within limits ranging from ten to fifty feet.

At Hopkinton the terrace material is piled against the side of an ancient valley, that was bounded by rocky cliffs seventy-five to a hundred feet in height. The town is built on a platform that overlooks a rather wide bottom land, or flood plain, the platform corresponding in height to the upper surface of the terrace. The descent from the top of the terrace to the bottom land is abrupt. In the center of the town the Niagara limestone is encountered a few feet below the surface, but near the margin of the platform wells seventy-five feet in depth are made without striking rock. The same sandy terrace extends for more than a mile northwest from Hopkinton on the left side of the river. A gravel terrace begins on the west side of the stream, near the center of section 11, Union township, and continues beyond the north line of section 2.

In section 2 it is set off by an abrupt descent of fifteen feet from the narrow flood plain. Excavations show that the main body of this terrace is made up of very old, weathered, ferruginous material of the age of the Buchanan gravels. The deposit presents all the characteristics of the valley phase of this formation. The materials are finer than on the highlands. The coarser material is at the top of the deposit, with sandy beds below. The weathered zone at the top has the usual reddish-brown color.

Manchester is built on a sandy and gravelly terrace, the material showing perfect stratification when seen in fresh section. The terrace deposit extends up Honey creek for several miles, and is also well displayed at intervals, above the mouth of Honey creek, along the Maquoketa river. At the Backbone, in Richland township, a sand terrace on the left side of the stream rises thirty feet above the water. This terrace is composite, for fresh sands overlie rust-colored, oxidized gravels of Buchanan age. The contrast between the older and newer portions of the deposit is very striking. In some places, however, the old gravels seem to underlie nothing but the talus derived from adjacent slopes.

It is interesting to note that the terraces observed in this county are nearly all referable to the period of ice melting following the invasion of the Kansan glaciers. In some cases there have been some additions to the terrace deposits in times more recent than the Buchanan gravels, but the significant point is that these valleys are pre-Kansan in origin.

Soils.

Delaware county affords quite a variety of soils. The typical soil of the Iowan drift region, covering two-thirds of the surface of the county, is a deep black loam, rich in organic matter and containing an abundance of the soluble mineral constituents from which the crops of the farmer draw so large a supply of plant food. The largest continuous area of Iowan drift embraces the townships lying southwest of the Maquoketa river, and it is here that the rich, black, loamy soils of the type described are best developed. Between the Maquoketa river and the Iowan margin there are large areas, more or less interrupted, however, by the island-like paha and other patches free from Iowan drift, over which soils of the same superior quality are distributed. Every township in the county, except Colony, has some areas covered with soils derived from Iowan drift. In some parts of Oneida, Bremen, North Fork, South Fork and the other townships included between the Maquoketa river and the Iowan drift margin the soils are thin. Rock ledges and residual clays and cherts come near the surface or even become superficial by projecting through the scant materials belonging to the drift. Over an area of several miles in extent around Delaware the thin soil, in many places, is insufficient to conceal the rocks and residual cherts which form numerous stony knobs and flint hills unfit for cultivation. Angular fragments of chert mixed with ferruginous residual clay, constitute a natural macadam of excellent quality in many of the roadways. Near the margin of the Iowan ice the amount of fine clayey material transported and deposited was very small, and hence it is that thin soils characterize so much of the surface in a zone, six or eight miles in width, immediately adjacent to the margin of the Iowan drift plain. The townships of Hazel Green, Adams, Prairie and Coffins Grove, together with the southwest half of Milo, are in general covered with a heavy bed of drift upon which a soil unexcelled in the Mississippi valley has been developed since the retreat of the Iowan ice.

Around Rockville there are extensive areas covered with æolian sands and presenting a type of soil far from desirable. Sands that bear evidence of having been carried and deposited by winds occur at numerous points in the belt of thin soils inside the Iowan margin. Such sands occur abundantly near Earlville, Delaware, and generally throughout North Fork, Bremen and Oneida townships. They are lodged usually on the gentle slopes of the low hills, the broad swales or low lands being generally free from sand and covered with a heavy black loam. In a low ridge near the northwest corner of section 7, Oneida township, there are four to six feet of æolian sand resting on an old soil bed, as demonstrated by excavations made by Mr. B. F. Hoyt. Sand, derived from terrace material along the stream valley, characterizes the soils on both sides of the Maquoketa for some distance above and below Manchester.

In the portion of the county not covered with Iowan drift the soils are either loess clays, sands or residual products. Northeast of the Iowan boundary line loess is the prevailing material. The surface is hilly and uneven. Yellow loess clay, quite free from organic matter, but rich in lime carbonates and other forms of mineral plant-food, gives color and character to the fields, and presents a strong contrast to the deep, black, mellow loam which prevails over the region of Iowan drift. On steep hill slopes loess soils are not very productive. They wash badly, and the surface often presents a series of impassable ditches and gullies. In the central and southern part of Colony township there is an area more than usually level for a region covered with loess and Kansan drift. The storm waters are carried off slowly. The surface is not gashed or gullied, and the loess type of soil is here seen at its best. Such a soil is very fertile, is adapted to a great range of crops, and ranks with the best known anywhere in the great fertile northwest.

Loess covers the paha in the marginal zone of Iowan drift, and where the surface is not too steep the soil possesses many admirable qualities. Loess covers the highlands in the central and northern part of Richland township. The surface is rather hilly north and northeast of the Backbone, so that the country is better adapted to orchard culture or timber culture than to ordinary farming. The Delhi plateau is largely covered with loess, but the broken and hilly character of the surface in general indicates that the production of ordinary farm crops is not the purpose to which the region is best adapted. It should be reserved as forest land, but where this is not practicable it should be devoted to orchards, vineyards or the cultivation of small fruits. Some portions of this plateau are covered with sand, the region about Delhi being typical in this respect. The sand beds are at least ten to fourteen feet in thickness, and, near the northern margin of the plateau, seem to take the place of the loess. The sandy soils about Hopkinton seem to be derived from sand terraces that are probably as old as the close of the Kansan glacial stage.

Taking the county as a whole the average grade of its soils is high.

Deformations.

No very marked foldings of the indurated beds were observed in the county, but there are indications of a very interesting deformation affecting the strata over a large area in the northern and northwestern townships, and interfering with the normal dip toward the southwest. The Pentamerus beds, for example, are exposed in section 20 and in adjacent sections of Elk township. In place of the usual dip, however, these beds actually rise slightly toward the west and appear at the Backbone in the center of Richland township. They are found at intermediate exposures, as near Millheim and Forestville. The same reversed dip is continued westward, outcrops of Niagara occurring in townships of Buchanan county, west of Richland; and a salient angle of the Niagara area cuts a deep notch in the eastern edge of the Devonian.* Massive ledges of Niagara are exposed on the Wapsipinicon river, near Fairbank, in the southwest corner of Fayette county.

*See Geological map, Plate ii. of this volume. Note in the eastern edge of the Devonian the re-entrant angle, having its apex near the northwest corner of Buchanan county.

ECONOMIC PRODUCTS.

Building Stone.

There are at present no quarries operated on a commercial scale in Delaware county. Building stone of excellent quality occurs in abundance; outcrops of the beds capable of furnishing it are numerous and not unfavorably situated; but so far the quarries have been developed only to the extent of supplying local demands; they are worked intermittently; there are none supplied with other than the simplest machinery and appliances for getting out the stone; there are none that ship any considerable portion of their output beyond the limits of the county.

Quarries have been opened in almost every neighborhood in the northeastern half of the county. There are two horizons at which evenly-bedded, easily-quarried stone occurs, and the quality of the stone at both horizons is such as to place it among the best in Iowa. The lower quarry stone horizon begins about thirty feet above the base of the Niagara limestone and has a thickness of more than thirty feet. The other horizon occurs near the top of the Delaware stage, above the Pentamerus beds, and has about the same thickness as the lower quarry stone horizon.

The principal quarries of the lower horizon are located in Elk township. There are at least four in section 16, one in section 23, and two or three occur in section 2. All are worked more or less constantly during the summer season. The Wilcox quarry, already described in discussing the characteristics of the lower portion of the Niagara limestone, is in the southwest quarter of section 16, and is typical of all the others at this geological level. It presents a vertical face of about thirty feet. The beds range from three or four inches to thirty-six inches in thickness. The ledges, especially near the middle of the exposure, are fine-grained and suitable for use as cut stone in the best grades of masonry. Stone for all structural purposes, including bridge piers and heavy foundations, as well as the range courses and trimmings of ordinary buildings, might be obtained here with great facility if only the conditions of the market demanded it. The other quarries of this neighborhood are capable of producing stone of equally high grade.

There are quarries at the same horizon in Bremen township. One of these is located south of the center of section 13, and there are two or three in section 26. A quarry on the land of Paul Steger, in the northern part of section 26, furnishes good stone for rough masonry. The rock is granular, vesicular, much pitted by weathering where exposed, rather evenly-bedded; beds are horizontal and vary from a few inches to more than a foot in thickness. The pitted condition due to weathering is peculiar and distinguishes the rock of this locality from the equivalent beds on Elk creek. The quality is inferior when compared with stone from the Elk creek quarries. Another quarry in which the stone shows similar peculiarities of weathering occurs on land belonging to John Lappe, a short distance southwest of the center of section 26, Bremen township.

Beds of this lower quarry stone horizon, resembling those on Elk creek, are exposed at many points along the Little Turkey river and its branches in the northeastern part of Colony township.

The best exposures of the upper quarry horizon are seen in Union township, a few miles southwest of Hopkinton. The Merriam quarry, in the southeast quarter of section 23, has been worked longer than any of the rest and may serve as a general illustration. I am indebted to notes furnished by Prof. A. G. Wilson, of Lenox college, for the following description of the Merriam quarry section.

	FEET.	INCHES.
11. Layers of limestone alternating with layers of chert, each about three inches thick........	2	4
10. Single layer, with embedded concretions of chert....................................	2	

		FEET.	INCHES
9.	Three to six inch layers of limestone alternating with two to three inch layers of broken chert	5	
8.	Fair rock with little chert	1	3
7.	Even-grained rock, cleavable		10
6.	Good quarry stone in several layers	3	
5.	Compact layer with large, flat Pentamerus	2	
4.	Lowest layer worked		10
3.	Vesicular ledges below base of quarry	3	
2.	Cherty layers	4	
1.	Cherty and vesicular layers down to talus	18	

The Merriam quarry has from fifteen to twenty feet of excellent quarry stone. There are two or three other quarries worked at the same horizon in the same quarter section.

The Loop quarry is situated in the northwest quarter of section 25, Tp. 87 N., R. IV W., about one mile southeast of the Merriam quarry. This quarry has been worked only a short time, but it gives promise of furnishing a large amount of valuable building stone. The stone is fine-grained, homogeneous, easily worked and of good color. As the quarry is carried farther back into the hill the aggregate thickness of the available stone will increase to twenty-five or thirty feet. The beds now exposed furnish excellent material for rubble, range courses and dimension stone up to ten inches in thickness.

Quarry stone belonging to the Merriam quarry horizon crops out at a number of points along a small ravine in the east half of section 17, South Fork township. The bedding seems to be thinner here than on the west side of the Maquoketa in Union township. Some of the beds, however, are ten inches in thickness; and quarries worked on land of H. Davis, in the northeast quarter of section 17, and on the land of M. McGlade, in the southeast quarter of the same section, have furnished a large amount of good building stone for local use. Another small opening at this same horizon was noted in section 14 of South Fork township.

There are several quarries in the upper building stone beds in Milo township. The largest are located in the eastern part of section 9, near the north end of the highlands, called in this report the Delhi plateau. The land on which the quarrying is done is nearly 200 feet higher than the Maquoketa river at the nearest point. The rock is here less magnesian than at other exposures in the county. A large proportion of it is bluish in color, and there are many large pockets of calcite. The bedding is quite regular, but the quality of the stone is not equal to that at the Merriam and Loop quarries further south. A much better quality of stone is furnished by the quarry of T. B. Matthews, located near the center of section 4. The Matthews quarry has beds ranging from two inches up to two feet in thickness. The stone is a good color, rather fine texture and may be used for the better grades of structural work.

In Delhi township the upper quarry stone is worked to some extent at Beal's quarry, in the town of Delhi. It is exposed, and might be easily quarried, in the bluff south of Fleming's mills, in section 29, and there are a number of other exposures, though at rather inaccessible points, along the bluffs of the Maquoketa, in sections 29, 30, 33, 34 and 35. A small quarry capable of affording very excellent stone is opened on land of George H. Norris, in the northeast quarter of section 23.

The Pentamerus beds are usually massive and break on quarrying into shapeless pieces, but at a few points in the county they lie in comparatively thin, even layers that may be quarried without difficulty, and yield stone suitable for a number of purposes. The position of the Pentamerus beds is between the two quarry stone horizons already described. A small quarry is worked in the Pentamerus horizon in the northwest quarter of section 3, Colony township. In the same township there is another quarry at this horizon near the center of section 27, and still another is worked in the southwest quarter of section 35. The last mentioned has been operated more extensively than the other two. The quarry face is about eight feet in height. The beds are somewhat shattered near the top. Chert is abundant as partings between the layers, or as concretions embedded in them. The limestone is overlain by a very reddish-brown, pebbly Kansan drift. *Pentamerus oblongus* is the prevailing fossil, but along with this species there occur Receptaculites sp., Stromatoporoids undetermined, *Lyellia americana*, *Halysites catenulatus*, *Syringopora tenella*, *Strombodes pentagonus* and *Streptelasma patula*.

Some of the most important quarries worked in the Pentamerus beds are located in the southwest quarter of the northwest quarter of section 31, Bremen township. In one of these quarries (Plate x, Fig. 2) there is an exposed section, thirteen feet in thickness, which shows.

		FEET.
2.	Coarse vesicular stone in heavy ledges, ledges varying from eight to thirty inches in thickness...........	8
1.	Evenly-bedded stone in layers two to six inches in thickness. Some of the layers contain Pentamerus oblongus with shells partly preserved. Stone is soft earthy dolomite, with some chert.............	5

The massive beds of No. 2 contain Lyellia, Favosites and other corals. These thick ledges are undermined in taking out the thinner layers of No. 1, and great blocks left without support fall down on the floor of the quarry, as shown in figure 2 of plate x.

Some stone is obtained from this horizon near Sand Spring, in South Fork township. Pentamerus limestone is used for foundations and bridge piers at Forestville, in Richland township. Near the northwest corner of section 2, Milo township, there is a small quarry that with rather coarse, thin-bedded limestone furnishes an unusual amount of chert.

Lime.

With an abundance of stone of first-class grade for lime-burning it is a little surprising to find that only a small amount of lime is produced in Delaware county. There are no kilns that are operated continuously or that attempt to do more than supply some temporary local demand. There are scores of localities where the Pentamerus and coral-bearing beds, lying between the two quarry stone horizons, are massive, crystalline and free from chert. In such case, if properly managed, they will produce a superior quality of lime. Remains of abandoned limekilns are found in almost every neighborhood where the Niagara limestone outcrops, but no kilns were seen in operation. There are half a dozen or more of these old kilns in the neighborhood of Hopkinton. No better lime was ever made anywhere than that which these kilns produced when they were operated. The raw material is abundant and easily obtained. What is lacking is capital, organization and efficient management. Dubuque lime, and other limes not one whit better than the home product, but made on a large scale by improved methods, are able to supplant the home product when made by the primitive appliances adopted by the pioneer settlers of the county.

Clays.

Loess clays and drift clays suitable for brick making are widely distributed in Delaware county. The Mattox brickyard at Manchester is probably the oldest in the county. It has been operated for twenty-one years. The clay used is Iowan drift, which is here quite free from pebbles. Beneath the thin layer of Iowan there is blue Kansan till, rich in pebbles, and many of the pebbles were derived from limestone. The presence of these limestone fragments renders the Kansan till unfit for use in brick making. The brick made at the Mattox yard are hand molded. They are dried on the yard and subsequently burned in the ordinary cased kilns. There is very little loss from checking either in drying or burning. The capacity of the kilns vary from 150,000 to 300,000. The greatest output in any one year was 900,000. The brick are of good color, and individually weigh about four and one-fourth pounds.

The Williamson and Stead brickyard is located about one mile south of Hopkinton. Loess clay is used, the thickness of the bed being about fifteen feet. The brick are molded in a Martin machine, operated by horse power, and having a capacity of 15,000 per day. A re-press is used on some of the product. The clay from the pit is soaked in water and is used without mixing with sand. There is little trouble from checking. The clay, unlimited in quantity, would make good pressed brick of excellent color if there were a demand sufficient to warrant the outlay for the necessary machinery.

Brick have been made from loess clay at two points east of Colesburg. Both kilns are in section 3, Colony township. The brick were hand molded. They stood firing well, burned hard and took on a good color. No brick were made here in 1897.

A pottery at Colesburg, operated by Frank Brock, makes a good grade of earthenware from Maquoketa shales. The whole thickness of the shales is exposed in a deep gorge in sections 2 and 3 of Colony township, and the clay used at the pottery is taken from near the middle of the deposit, the pit being located in the Se. ¼ of Ne. ¼ of section 3. The shales here are non-fossiliferous, and consist throughout their whole thickness of beds that weather into smooth, fine-grained plastic clay, suitable for the manufacture of pottery and various grades of brick. The raw material is unlimited in amount.

Cement Rock.

The transition beds, twenty-five feet in thickness, between the shaly portion of the Maquoketa formation and the base of the Niagara, have the qualities of beds used in the manufacture of natural cement. No tests have yet been made to determine the quality of the product these beds would yield, but the experiment of making cement from the beds of this horizon is well worth trying.

Iron Ore.

A body of bog ore, limonite, underlies Iowan drift in some low meadow land in the south half of the southeast quarter of section 1, Delaware township. Similar ore was encountered in digging surface wells in adjacent parts of section 12. The area within which this ore is known to exist is about 100 acres.

The iron ore is quite impure, being mixed with sand and pebbles. In thickness the bed varies from a few inches to six feet, as reported by persons who had made test pits to determine the question. A small gully is in process of excavation by head-water erosion, in the lowest part of the meadow; and at the head of the excavation the ore is naturally exposed. At this point the bed is thin and the ore occurs in large flakes and irregular masses separated one from the other by ferruginous sand and clay. The iron rests on blue clay of Kansan age. The overlying Iowan drift varies from one to more than six feet in thickness.

At present this deposit possesses little economic value, its chief interest lying in the fact that it records the existence at this point of an interglacial marsh of long duration, and adds another link to the irrefutable chain of evidence that the ages of the Kansan and Iowan drift sheets are separated by long reaches of time. The bog ore is an interglacial deposit, bearing witness to the fact that the interglacial climate for many centuries favored the growth of luxuriant vegetation.

Road Materials.

Throughout the whole northeastern half of Delaware county material for the improvement of roads is abundant. Loess clay answers an excellent purpose on sandy roads, and such clay is usually plentiful within easy hauling distance of almost every point along the Maquoketa river or in the area lying northeast of that stream. Better and more permanent improvement is made by the use of chert and broken limestone. The streets of Hopkinton, which are naturally sandy, have been covered with risidual clay, chert and fragmentary limestone from a pit in the western edge of the town, and the results are very satisfactory. A stretch of road in sections 11 and 12, Tp. 87 N., R. IV W., formerly almost impassable by reason of deep sand, has been put in excellent condition by the use of the same kind of material taken from the river bluff in the northeast quarter of section 11. A quarry in the northwest quarter of section 2, Milo township, has furnished a large amount of very desirable road metal in the form of chert and limestone. Material of the same kind is generally distributed except in the prairie townships southwest of the Maquoketa.

Residual chert alone is used to a large extent in Delaware, Oneida and Delhi townships. Some stretches of road in the central part of the county are provided by nature with a macadam of residual chert in place, and beds of fragmentary chert, grading down into beds of partially decayed chert and limestone, are coextensive almost with the outcrops of indurated rocks.

In the Pleistocene formation the most important road materials are the Buchanan gravels. These have been already described. The pit near Earlville, on the land of Mr. M. V. Newcomb, has furnished more material for use on wagon roads than any other in the county, but there are other deposits equally good awaiting the enterprise that will develop them and use the material on the loamy and clayey roads that at certain seasons of the year are impassable for loaded teams. The great pit near Dyersville, in section 25 of Bremen township, is the largest in the county. The product has been used for ballast on the line of the Chicago-Great Western railway. The gravel deposits here occupy an area of several hundred acres in sections 25 and 26, and could supply material enough to improve the larger part of all the roads needing improvement in the entire county. A bed almost as extensive as that in Bremen occurs in sections 18 and 19, Richland township.

The townships of Honey Creek, Colony, Delaware, Oneida, Milo, Delhi and South Fork are also well supplied with gravels. Beds were also noted in Coffins Grove and Prairie townships. There is no county better supplied with easily-worked materials for the improvement of the ordinary prairie roads.

With an abundance of residual cherts and Pleistocene gravels ready to hand it is not likely that resort need very soon be made to stone mechanically crushed or broken for use on streets and roads, but should the demand for such a product arise, there are rock exposures in almost every neighborhood, except the southwest part of the county.

Railway Ballast.

The Buchanan gravels are already used to a large extent for railway ballast, and their use might, with small expense, be greatly extended; for deposits occur near railway lines at Earlville, as well as at numerous other points throughout the county. The gravel pit of the Chicago Great Western railway near Dyersville has been noted. A similar pit is worked by the Illinois Central a few miles south of Manchester. When broken stone ballast comes to be needed, the county can furnish it in quanities to meet any probable demand.

Water Supply.

Delaware county is well watered by streams which are in the main permanent even in seasons of drouth. Springs are numerous and bountiful, the permanence of the streams being due largely to the volume of water which the springs supply. Along Elk creek and its numerous tributaries there are many copious springs along the outcrop of the transition beds between the Maquoketa shales and the Niagara limestone. Springs also abound at the same horizon along Little Turkey river and its branches in Colony township. At the Backbone in Richland township there are a score or more of springs issuing from crevices in the shattered limestone below the horizon of *Pentamerus oblongus*. The same horizon is marked by springs, some of large volume, in Honey creek and Delaware townships, near Millheim, and in South Fork township, near Hopkinton. The splendid springs that supply Spring creek, in section 35 of Delaware township, and in sections 2, 3 and 10 of Milo, come from about the same geological level. The bountiful supply of pure spring water poured out from the rocks along the valley of this creek has afforded the opportunity for establishing here one of the largest and best equipped fish hatcheries under the control of the United States fish commission. Springs, in short, occur at intervals along all streams that cut their channels through the superficial deposits down into the indurated rocks.

Well water is obtained in streaks of sand and gravel in the Pleistocene deposits. Formerly wells twenty to forty feet in depth afforded an unfailing supply of water throughout all the prairie portion of the county; but lately it has been necessary in most cases to bore through the drift and for some distance into the underlying rock, in order to get the volume of water needed on the ordinary farm. In the southern part of Prairie township, for example, the drift series is from 80 to 120 feet in thickness, and the farm wells are bored from 70 to 100 feet, or even more, in the Niagara limestone underlying the drift. The well on the estate of John S. Barry is 285 feet deep, and on land of S. M. Shofner, near the northeast corner of section 27, a well is 300 feet in depth. On other farms in the same neighborhood the wells range in depth from 150 to 200 feet.

Near Hopkinton the deeper wells go through the Niagara limestone and for some distance into the Maquoketa shales. A typical well of this locality gives the following section, taken from notes furnished by Prof. A. G. Wilson.

		FEET.
5.	Sandy soil	2
4.	Clay subsoil	8
3.	Niagara limestone, buff	130
2.	Limestone, nearly white	20
1.	Maquoketa shales, blue	40

The well is located on land of Charles Root, in the northwest quarter of section 18, South Fork township. The well head, as reported by Professor Wilson, is about 140 feet above the level of the river. Some of the wells of the neighborhood are reported as going 100 feet into Maquoketa shales.

While supplies of water for farm and isolated household purposes may be obtained in the drift, in the Niagara limestone or in the Maquoketa shales, at depths ranging from twenty to 300 feet, supplies for cities must be drawn either from permanent streams or from the great water-bearing sandstones that, throughout the county, lie at depths of 1,500 or 2,000 feet beneath the surface. Manchester obtains its water supply from a deep well reaching to the basal portion of the Saint Croix sandstone. A summary of the record of this well, published by Norton,* gives the following.

		FEET.
10.	Niagara	225
9.	Maquoketa	205
8.	Galena-Trenton	354
7.	Saint Peter	33
6.	Upper Oneota	65
5.	New Richmond	49
4.	Lower Oneota	275
3.	Jordan	90
2.	Saint Lawrence	229
1.	Basal sandstone (penetrated)	345

The depth of this well, according to Norton's report, is 1,870 feet, and the bottom is 944 feet beneath tide level. The water, as shown by the official analyses, is of excellent quality.

Water Powers.

Water powers with head varying from eight to fourteen feet have been developed along the Maquoketa river at the following points.

1. Forestville, Richland township.
2. Quaker Mills, Delaware township.
3. Manchester, Delaware township.

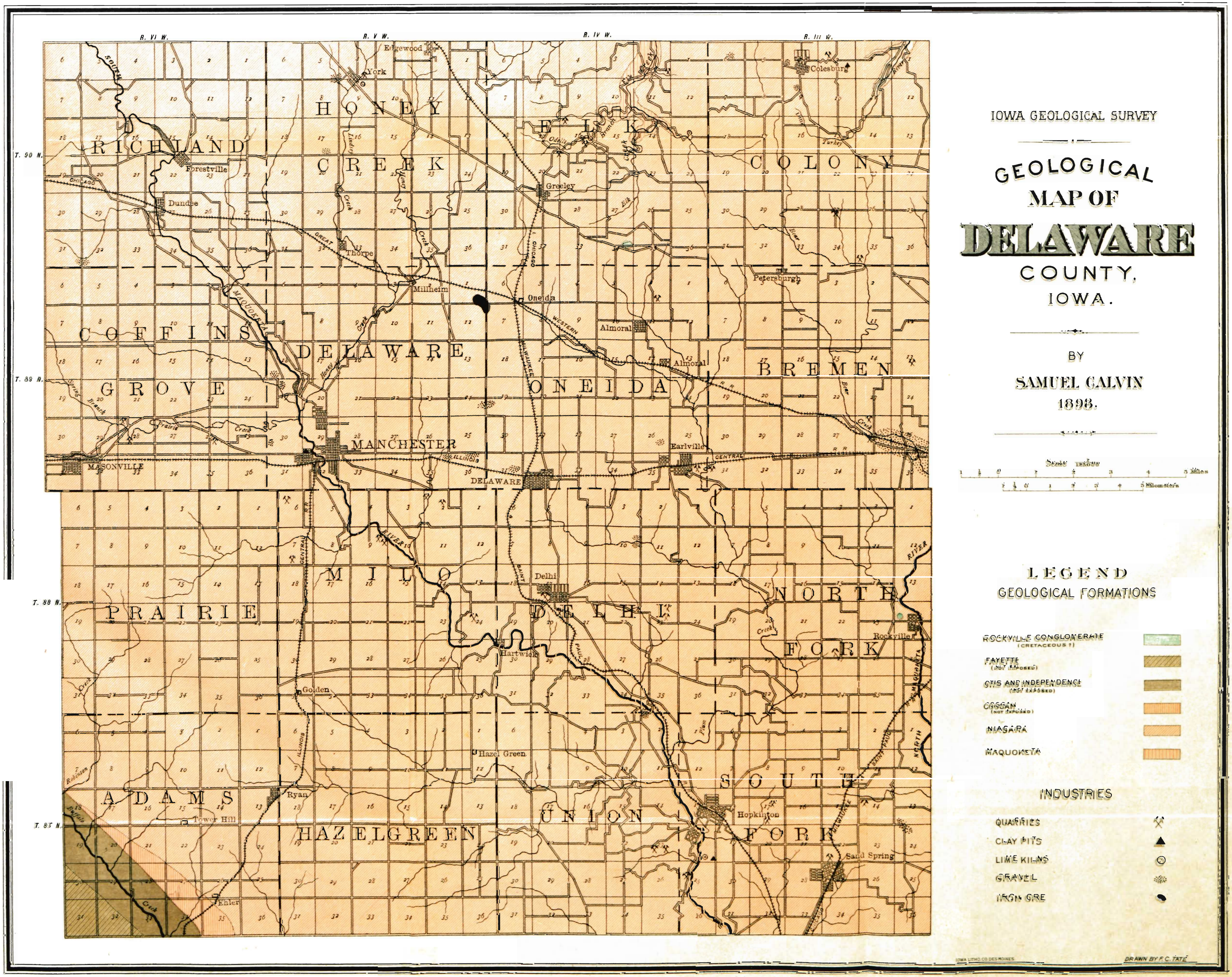
*Iowa Geol. Surv., vol. VI, p. 219. Des Moines, 1897.

4. Hartwick, Delhi township.
5. Fleming's Mills, Delhi township.
6. Hopkinton, South Fork township.

Mill sites on Honey creek are found at Millheim, in section 3, and at two points in section 20, near Manchester, Delaware township. The Fountain Spring mills (Plate xii, Fig. 2) are on Odell's branch of Elk creek, in section 16, Elk township. There is an abandoned site on Elk creek about a mile south of the Clayton county line. A sawmill was once operated near the mouth of Plum creek, and there was another on Buck creek, in section 10, Union township.

ACKNOWLEDGMENTS.

In the prosecution of the field work in Delaware county, the writer received substantial help from a large number of individuals, all deeply interested in the purposes for which the Survey is maintained. Especial acknowledgments are due to Prof. A. G. Wilson, of Lenox college, whose intimate knowledge of the geology of the county, acquired through many years of painstaking study, has been freely placed at the disposal of the Survey. Professor Wilson accompanied the writer in the field for several days, and his private note-book has been drawn upon for a number of facts embodied in this report. Mr. B. F. Hoyt, of Manchester, a careful student of natural phenomena, rendered very effective assistance, and the writer is also indebted to Judge Blair and Judge Seeds, of Manchester, for valuable assistance and information concerning the location of points of interest. To Prof. J. W. Rosser, of Greeley; Mr. Frank Grimes, of Colesburg, and Mr. Grant Crawford, of Hopkinton, thanks are due for aid rendered while work was being prosecuted in their respective localities. The Survey is indebted for many favors to Prof. T. H. Macbride, and we owe the subjoined report on the forest trees of Delaware county to the courtesy of Mr. John E. Cameron.



College - Lenox - Hopkinton

FOREST TREES OF DELAWARE COUNTY.

BY JOHN E. CAMERON.

The surface of Delaware county is divided into prairie and timber land. The timbered area occupies about one-fourth of the county and is confined to the rougher and more broken regions. The timber is well distributed, following as it does the south fork of the Maquoketa river and its branches in its diagonal course through the county. Extensive forests exist along Elk creek in the north central, and along the Little Turkey river, in the northeastern part of the county.

Most of the wood is second growth, but some large and valuable timber remains west of the Maquoketa, in Union township, and in the valley of the Little Turkey, in Colony township. The best example of the original forest is to be seen in a piece of timber owned by Dr. Hugh Livingston, located two miles south of Hopkinton, in South Fork township.

A few miles above Manchester there is a valuable strip of timber east of the Maquoketa river, which has grown up since the country was first settled. But while in a few instances the timber has extended its range, in the last few years great tracts of second growth have been cleared for farms, pastures and farming lands, so that where once stood valuable forests we find to-day the poorest farms of the county.

There is a marked difference between the forests of the drift-covered regions of the south and the Driftless area of the northern part of the county. In the former we have the woods common to this latitude, while in the latter these give place to a large extent to the chestnut oak (*Quercus muhlenbergii*), white or canoe birch (*Betula papyrifera*), rock elm (*Ulmus racemosa*), witch hazel (*Hamamelis virginiana*), leatherwood (*Dirca* *palustris*), white pine (*Pinus strobus*) and the red cedar (*Juniperus virginiana*).

The appended list of shrubs and trees of Delaware county is represented by specimens in the State university herbarium. In arrangement and synonomy Gray's Manual, sixth edition, has generally been followed.

DICOTYLEDONES.

TILIACEÆ.

Tilia americana L. Basswood. Hills and rich woods. Common.

RUTACEÆ.

Xanthoxylum americanum Mill. Prickly-ash. Frequent in moist woods.

CELASTRACEÆ.

Celastrus scandens L. Climbing bittersweet. Frequent on uplands, climbing over low shrubs.

Euonymus atropurpureus Jacq. Burning-Bush. Waahoo. Rare in moist woods.

RHAMNACEÆ.

Ceanothus americanus L. New Jersey tea. Dry woodlands and prairies. Common.

VITACEÆ.

Vitis riparia Michx. Wild grape. Common on low, rich soil.

Ampelopsis quinquefolia Michx. Virginia creeper. Common.

SAPINDACEÆ.

Acer dasycarpum Ehrh. Soft maple. Frequent on low bottoms.

A. saccharinum Wang. Sugar or rock maple. One of the commonest of the forest trees.

Negundo aceroides Moench. Box elder. Sparingly along the streams.

Staphylea trifolia L. American bladder-nut. Noted only in North Fork and Richland townships.

ANACARDIACEÆ.

Rhus typhina L. Staghorn sumach. Only in the north-eastern part of the county.

R. glabra L. Smooth sumach. Common on high, open ground.

R. toxicodendron L. Poison ivy. Frequent on dry soils. Often confounded with the Virginia creeper. The former has three leaflets; the latter has five.

R. canadensis Marsh. Sweet-scented sumach. Noted only in Union and Delhi townships.

LEGUMINOSÆ.

Amorpha fruticosa L. False indigo. Low sandy soils along streams. Frequent.

A. microphylla Pursh. On rocky soil. Rare.

Tephrosia virginiana Pers. Goat's rue. Rare. Grows in very sandy soils.

Robinia pseudacacia L. Common locust. Escaped from cultivation in places.

Gymnocladus canadensis Lam. Kentucky coffee-tree. Only a few small trees were found south of Hopkinton along the river.

Gleditschia triacanthos L. Honey locust. A few trees along the river south of Hopkinton.

ROSACEÆ.

Prunus americana Marshall. Wild plum. In clumps on low ground. Common.

P. virginiana L. Choke cherry. Common.

P. serotina Ehrh. Wild black cherry. A common forest tree.

Physocarpus opulifolius Maxim. Nine bark. Common along rocky hillsides in the northern part of the county.

Rubus strigosus Michx. Wild red raspberry. Frequent.

R. occidentalis L. Black raspberry. Rather common.

R. villosus Ait. Blackberry. This species and the two preceding were formerly quite common, but the pasturing of the timber land has killed them out to a large extent.

Rosa blanda Ait. Wild rose. Frequent in open ground.

Pyrus coronaria L. Crab apple. Common on low ground.

Cratægus coccinea L. Hawthorn. Frequent.

C. coccinea L. var. *mollis* Torr. and Gray. Rare.

C. tomentosa L. Rather common in upland woods.

C. crus-galli L. Cockspur thorn. Rare on low grounds.

Amelanchier canadensis Torr. and Gray. Service-berry; Juneberry. Found only east of Colesburg.

SAXIFRAGACEÆ.

Ribes cynosbati L. Prickly gooseberry. Reported.

R. gracile Michx. Missouri gooseberry. Common along the streams.

R. oxyacanthoides L. Frequent on the hillsides.

R. floridum L'Her. Wild black currant. Rich open ground. Rare.

HAMAMELIDEÆ.

Hamamelis virginiana L. Witch hazel. Rare, except in northeastern part of the county. It is a rather tall shrub, blossoming late in autumn, when the leaves are falling, and maturing its seeds the next summer.

CORNACEÆ.

Cornus circinata L'Her. Round-leaved cornel or dogwood. Low rich soils. Frequent.

C. stolonifera Michx. Red-osier dogwood. Common along the streams.

C. paniculata L'Her. Panicled cornel. Frequent in thickets along the streams.

C. alternifolia L. Rather common on the hillsides.

CAPRIFOLIACEÆ.

Sambucus canadensis L. Black-berried elder. Common in open, rich land.

S. racemosa L. Red-berried elder. This rare shrub is found in a deep ravine, near Pine spring, east of Colesburg. Occurs rarely in the state.

Viburnum opulus L. Cranberry tree. High cranberry bush. Only found along streams in the northern part of the county.

V. dentatum L. Arrow-wood. On low ground. Frequent.

V. lentago L. Sheep-berry. Along the streams. Rather rare.

Lonicera sullivantii Gray. Honeysuckle. Frequent on rocky bluffs.

L. glauca Hill. In the northern part of the county on rocky hillsides. Rare.

OLEACEÆ.

Fraxinus americana L. White ash. Common.

F. viridis Michx. Green or black ash. Common.

THYMELÆACEÆ.

Dirca palustris L. Leatherwood. Infrequent.

URTICACEÆ.

Ulmus fulva Michx. Slippery or red elm. Abundant in upland woods.

U. americana L. American or white elm. Common in moist, rich soils.

U. racemosa Thomas. Cork or rock elm. This valuable tree is common in the northeastern portion of the county.

Celtis occidentalis L. Hackberry. Frequent along the streams.

Morus rubra L. Mulberry. One tree noted south of Hopkinton. Others have been reported as occurring along the Maquoketa river bottom.

PLATANACEÆ.

Platanus occidentalis L. Sycamore. In the south part of the county a few small trees occur along the river. It is reported that trees six feet in diameter were cut in an early day in that vicinity.

JUGLANDACEÆ.

Juglans cinerea L. Butternut. Common.

J. nigra L. Black walnut. Very common.

Carya alba Nutt. Shell-bark hickory. Common in upland woods.

C. amara Nutt. Bitternut; Pignut. Common.

CUPULIFERAE.

Betula papyrifera Marshall. Paper or canoe birch. Frequent on the rocky hillsides in the northeastern part of the county.

B. nigra L. River or red birch. Confined to the western and southern parts of the county along the streams.

Corylus americana Walt. Hazelnut. Common.

Ostrya virginica Willd. Iron wood. Common on moist hillsides.

Carpinus caroliniana Walt. Blue or water beech. Very common along the streams.

Quercus alba L. White oak. Common.

Q. macrocarpa Michx. Bur oak. Abundant.

Q. muhlenbergii Engelm. Occurs in Union township, south of Hopkinton, and in the northern part of the county along rocky hillsides.

Q. rubra L. Red oak. Common.

Q. coccinea Wang. Scarlet oak. Common on all soils.

Q. coccinea Wang. var. *tinctoria* Gray. Occurs with the last.

SALICACEÆ.

Salix nigra Marsh. Black willow. Banks of streams, bending over the water.

S. discolor Muhl. Pussy willow. Frequent along streams.

S. humilis Marsh. Prairie willow. On dry uplands. Not common.

S. tristis Ait. Dwarf gray willow. Borders of thickets on dry hillsides.

Populus tremuloides Michx. American aspen. Frequent on low soils.

P. grandidentata Michx. Large-toothed aspen. Frequently occurs where other timber has been removed.

P. monilifera Ait. Cottonwood. Common on rich soils, in low places on the prairie and along streams. Not infrequently planted.

MONOCOTYLEDONES.

LILIACEÆ.

Smilax hispida Muhl. Greenbrier. In rich woods. Frequent.

GYMNOSPERMÆ.

CONIFERÆ.

Pinus strobus L. White pine. Only in the northern part of the county. Mostly on rocky ridges—the "Backbone."

Juniperus communis L. Common juniper. On dry hillsides. Usually taken for a young red cedar.

J. virginiana L. Red cedar. Common along the hills and bluffs in the northern part of the county.

Taxus canadensis Willd. American yew. Ground hemlock. A low, straggling evergreen, on rocky bluffs, in the northern part of the county.

GEOLOGY OF BUCHANAN COUNTY.

BY

SAMUEL CALVIN.

GEOLOGY OF BUCHANAN COUNTY.

BY SAMUEL CALVIN.

CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Buchanan is one of the important agricultural counties in the northeastern part of Iowa. Its location is so near the Mississippi river that it attracted early attention from the pioneer homeseekers. Before the advent of the railroad the great watercourse was the main highway of travel, and Dubuque was one of the points from which immigrants began the overland journey into the interior of the state. Buchanan is the third county west of the river, and its relative proximity to what was at the time the nearest market had its influence in determining the choice of many settlers; but the principal attraction was found in the beautiful expanses of undulating prairies, with soils marvelously fertile and easy of cultivation, in the groves that dotted the prairies, and in the wide stretches of woodland skirting drainage streams that ran clear and full through the whole round of seasons.

Buchanan county embraces sixteen congressional townships. The second correction line divides the county into two nearly equal parts. Delaware and Dubuque counties lie between Buchanan and the eastern boundary of the state. Fayette and Winneshiek separate this county from Minnesota. Buchanan is bounded on the west by Black Hawk, and on the south by Benton and Linn.

GEOLOGICAL WORK IN BUCHANAN COUNTY.

Previous to the inauguration of the present Survey, the geology of Buchanan county was the subject of more or less study by a number of observers. As usual, in this part of Iowa, the first geologist to enter the county was Dr. David

Dale Owen, whose parties exploring the mineral lands in the autumn of 1839, examined the townships since named Middlefield, Fremont, Madison and Buffalo. Limestone is reported at one point in Madison township,* but in general no rock was seen except granite bowlders, some of which are described as of gigantic size.

The next geologist to visit Buchanan county was Prof. J. D. Whitney, but no detailed work was undertaken, and the report† subsequently published contained only a very brief reference to the exposures along the Wapsipinicon from Independence to the south line of the county. No rocks were noted except those belonging to the Devonian period. In the same report Prof. James Hall‡ described and figured a number of interesting fossil forms from the quarries near Independence. In Hall and Whitney's report the limestones at Independence are correlated with the Hamilton formation of New York.

In 1872 Hall and Whitfield published a paper‖ on the Devonian of Iowa, referring incidentally to the limestones at Independence, and correlating them, as had been done before, with the New York Hamilton.

Certain coral-bearing beds at Waterloo, now known to lie above the limestones at Independence, were, however, referred by Hall and Whitfield, in the report cited, to the Corniferous or Upper Helderbeg, while the Lime creek shales, which carry a fauna intimately related to the fauna of shales below the Independence limestones, were correlated with the New York Chemung.

The shale beds lying below the Independence limestones were described by Calvin§ in 1878. The position and characteristics of the Independence shales were noted, and attention

*Rept. of a Geol. Expl. of part of Iowa, Wis. and Ill., in the autumn of the year 1839. By David Dale Owen, p. 112. Ordered printed June 11, 1844.

†Rept. on the Geol. Surv. of Iowa. By James Hall and J. D. Whitney. Vol. I, part I, p. 296 1858.

‡Op. cit., vol. I, part. II.

‖Des. of new Sp. of Fos. from the Dev. rocks of Iowa; 23d An. Rep. N. Y. State Cab. Nat. Hist., p. 223, *et seq.* Albany, 1873. Advance sheets of the paper were distributed in 1872.

§Bulletin of U. S. Geol. and Geog. Surv. of the Territories. Vol. IV, No. 3, pp. 725-730. Washington, July 29, 1878.

was directed to the fact that the fauna of these lower shales was very similar to that found in the shales along Lime creek, in Floyd and Cerro Gordo counties. The Independence shales, however, lie near the base of the Devonian system, as it is developed in Iowa, while the Lime creek shales lie near the summit, with at least 150 feet of limestones between the two horizons; and the practical identity of the two faunas could lead but to the conclusion that the whole Devonian of Iowa, as then known, belonged to a single series.

There are some references to the rocks of Buchanan county in the report of the Tenth census.* The statistics on the quarries and building stones of Iowa were compiled by McGee. A brief description of the quality of the stone near Independence and Quasqueton is given, and all the Devonian strata of the state are referred to the Hamilton system.

There are frequent references to the topography, drainage and rock exposures of Buchanan county in McGee's† memoir on the Pleistocene history of northeastern Iowa. The records of a number of wells‡ give the best sections so far available of the Pleistocene deposits of the county.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface of Buchanan county presents little variety in the way of topographic forms. Much the greater part of the surface is covered with drift of Iowan age, and is diversified only by the gentle swells and broad, ill-drained sloughs that everywhere mark the presence of this sheet of till. Examples of erosion are almost entirely absent over the whole area of Iowan drift, the topographic forms being due mainly to the eccentricities of ice molding. Only along the drainage courses are there any signs of erosion since the retreat of the Iowan

*Tenth Census Rept., Building Stones and the Quarry Industry; Iowa, by W J McGee. Vol. X, p. 263. Washington, 1883.

†Pleistocene Hist. of Northeastern Iowa. U. S. Geol. Surv., Eleventh An. Rept. Washington, 1891.

‡Op. cit., p. 519.

ice, and even here the process is in the incipient stage, for it is generally limited to the cutting of the shallow channel and to the carving of short, secondary trenches that extend back only a few rods from the stream. The general surface of the country remains about as it was left by the Iowan ice. The general drift surface is practically unmodified by erosive agents.

In the interval between the going of the Kansan ice and the coming of the Iowan the surface of the older drift was deeply eroded, and in many cases the present surface configuration is controlled to a greater or less extent by the inequalities thus produced. Indications of pre-Iowan topography, only partly disguised by the later drift, are seen—first, in the valley of the Maquoketa, and, second, in the gravel ridges rising forty or fifty feet above the level of the valley, in the northeast corner of Madison township. The broad, shallow depression followed by Buffalo creek, is a partly-filled pre-Iowan valley. It may indeed be preglacial. At all events it was a drainage course at the close of the Kansan, for beds of Buchanan gravels laid down during the melting and retreat of the Kansan ice, and now highly oxidized, are strewn all along its course in Buchanan county. The same is true of Pine creek and its valley in the western part of Byron township. The same is true to a greater or less extent of every stream in the county. Their valleys, if the broad depressions in which they flow deserve to be called valleys, are not products of erosion since the retreat of the Iowan ice. They were determined by the character of the surface before the Iowan drift was deposited. This later drift simply veneered, without completely disguising the old valleys. Nearly all these valleys were waterways when the Kansan ice was melting and were partly choked by trains of gravel which is now recognized as the valley phase of the Buchanan gravels.

That the Iowan drift, in certain localities, is very thin, and simply mantles a topography developed in pre-Iowan time, is illustrated at numerous points. There are ridges of weathered

Buchanan gravels over which the Iowan till is limited to a few inches of dark loam. Even in the valleys the deposit of Iowan age is not infrequently less than a foot in thickness. A rounded, rocky bluff, rising sixty-five feet above the level of the river, in the southwest quarter of section 4, Perry township, has numerous Iowan bowlders strewn over the entire surface, from the level of the water up to the summit, and stands as an example of an old topography practically unaffected by Iowan drift. Over by far the larger portion of the county, however, the Iowan drift completely conceals the characters of the pre-Kansan surface and presents a topography peculiarly its own.

Where typically developed, the Iowan drift plain exhibits a surface that is rather gently undulating. The relief curves are low, broad and sweeping, with the concave portions often longer than the convex. Drainage of the broad, gently concave lowlands is imperfect, or was so before the introduction of artificial conditions. The only evidence of erosion is found in the narrow, shallow channels of the drainage streams cut but little below the level of the otherwise unbroken plain.

Taken as a whole Fremont township has more of the typical characteristics of the Iowan drift plain than any other area of similar size in the county. The relief in general is very low, large areas being flat and imperfectly drained. This is particularly true of the broad plain which is bisected by Prairie creek. From a short distance north of the center of the township, this stream flows in a narrow, shallow, trough-like ditch; but the gradient is so low that the sluggish current is frequently brought apparently to a standstill by beds of spatter dock and other pond weeds that choke the channel. The broad, gravelly plain east of Buffalo creek, in the western part of the township, grades imperceptibly into the relatively high ridge of drift between Buffalo and Prairie creeks, a ridge that forms the watershed between the Wapsipinicon and Maquoketa systems of drainage. This ridge would, however, be inconspicuous if set in the midst of topography of pronounced erosional type.

All the other townships are cut by drainage streams of more or less importance, and these, as already noted, follow pre-Iowan valleys that give more than the usual amount of diversity to the surface. But over the greater part of every township the features that characterize Fremont are duplicated with only slight modification of details. In some instances, as over most of Newton township, the curves are slightly sharper and the amount of dry land, as compared with the sloughs or damp meadow land, is greater. Newton, on the whole, has more perfect drainage than Fremont. There is a large area of very gently undulating land between Bear creek and the Wapsipinicon river in Homer and Cono townships. Westburg is a distinctively prairie township with some moraine-like knobs and hills in sections 10 and 15, and some dry gravelly and sandy ridges in sections 5 and 6; but in general the surface has the low, monotonous undulations of uneroded drift. Buffalo township is divided, almost diagonally, by a very broad, shallow sag in the general surface, the sag being followed by the west branch of Buffalo creek; but with the exception of some sand hills and rock exposures in sections 13 and 24, the whole township is occupied by typical Iowan drift unmodified since the retreat of the Iowan glaciers. The eastern part of Fairbank township is a very level, dry plateau in which a sheet of Iowan drift varying from two or three to thirty feet in thickness overlies an extensive bed of Buchanan gravels. The plateau is a unique piece of prairie land, without the usual undulations, and without any indications of imperfect drainage. The underlying gravel seems to afford an easy means of escape for the surplus surface waters.

From section 12 of Jefferson township to the south line of the county, Lime creek flows in an old valley, forty to fifty feet in depth, with numerous rock exposures along the sides, and a very meager amount of Iowan drift coming down on the slopes to the level of the stream.

The most anomalous piece of topography in the county is seen in the high hills bordering the Wapsipinicon river, in Liberty township, northwest of Quasqueton. From the west line of this township to Quasqueton the river flows in a gorge 130 to 150 feet in depth. The highlands indeed begin, but are at first not very pronounced, in section 24 of Sumner township, and they attain their greatest height in section 29 of Liberty. The land near the river is conspicuously higher than that farther back on the drift plain. The stream, as in the case of the other anomalous rivers of McGee,* here seems to go out of its way to cleave a channel in the highest land of the whole region. This highland seems not to have been invaded by Iowan ice. Where it merges into the drift plain there are sometimes bare stony hills and channels of pre-Iowan erosion, as in the west half of section 24, Sumner township, and in sections 31, 32 and 33, Liberty township. On the flanks of the hills, a little higher than the level of the drift, there is a deep deposit of sand, but the sand, at still higher levels, gives place to true loess. There is a heavy capping of loess overlying Kansan drift on the hills north of the river gorge, in sections 29 and 30 of Liberty township. From all the data that can be gathered concerning it, this area of hills and highlands seems to have projected as an island above the surface of the Iowan ice. The region embraces an area of a number of square miles, lying on both sides of the river, beginning in the southern part of section 24, Sumner township, and extending southeastward to Quasqueton. It rises above the surface of adjacent Iowan drift to a height of 100 feet or more at the points of greatest elevation. The larger part of the area is north of the river. It was while the Iowan glaciers stood in the surrounding region that the loess was deposited over the higher summits and the beds of sand were laid down at the middle and lower levels.

A curious bit of topography breaking into the general monotony of the Iowan drift plain is seen in the south half of

*Pleistocene History of Northeastern Iowa. Eleventh An. Rept. U. S. Geol. Surv., p. 218, *et seq.* Washington, 1891.

the northeast quarter of section 28, Middlefield township. There is here a series of prominent knobs and rounded hills separated by sharp, narrow valleys, the whole arrangement and aspect recalling a fragment of the terminal moraine of the Wisconsin drift. The summit of the highest point is eighty feet above the road at the east end of the group, a road which follows, on even grade, the valley of Buffalo creek. The height above the creek is about ninety feet. The knobs are grassed over and afford no opportunity to examine their structure, but numerous large granite bowlders sprinkled in the sharp valleys suggest that they are of Iowan age. Elsewhere the broad sag constituting the valley of the Buffalo ascends very gradually in a direction at right angles to the stream and imperceptibly blends with the surface of the upland drift.

There are numerous gravel terraces along the Wapsipinicon river between Littleton and the south line of the county. The gravel is in all cases pre-Iowan, dating from the deposition of the Buchanan gravels. A well marked terrace, separated from the river by a sandy flood plain, passes through the center of section 25, Cono township. Another terrace of the same age and same structure occurs in the western half of section 3 in the same township. There are others of similar type in sections 28 and 29 of Washington township, and in sections 13 and 24 of Perry. All these terraces rise abruptly to a height of ten or twelve feet above the swampy or sandy flood plain between them and the river, the height of the slope being indicative of the amount of erosion that has taken place since the gravels were deposited.

DRAINAGE.

The drainage of Buchanan county is effected chiefly by the Wapsipinicon river and its branches. This stream flows in a general southeast direction from near the northwest corner of Perry township to near the southeast corner of Cono. It follows the southern or southwestern margin of its drainage basin. Its main branches flow in from the north, there being no affluents of any importance from the south or west. Streams flowing into the Cedar river and draining the southwestern corner of the county have pushed their sources back to within two miles of the Wapsipinicon, restricting the drainage area southwest of the stream to a comparatively narrow zone. On the other, or north side of the stream, the drainage area is much wider. The tributaries are long, and some of them originate within less than a mile of Buffalo creek, which drains a very low and narrow valley northeast of the Wapsipinicon. The law that streams in Iowa seek the south side of the valleys, with longer affluents and the wider portion of their drainage basins on the north side, is very generally, though not universally, true.

The Little Wapsipinicon enters the county at Fairbank, near the northwest corner, and drains the western half of Fairbank township. The eastern half of this township is in general a level plateau without undulations or drainage courses, the surface waters apparently escaping into a bed of Buchanan gravels which here underlies the Iowan drift. The Little Wapsipinicon joins the main stream at Littleton, in Perry township. Otter creek, which, with its branches, drains Hazelton township, is a stream of some importance, supplying valuable water power at two points, and entering the main water course in section 19 of Washington township. The eastern part of Washington township is drained by a number of small streams, among which Harter creek, that flows into the river above Independence, is probably the most important. Pine creek drains the southwestern part of Buffalo township and the greater part of Byron and Liberty. In western Byron it flows in a partly disguised pre-Iowan valley. The banks of the creek are not marshy, as is usually the case in prairie streams, for the reason that heavy beds of Buchanan gravel underlie the surface drift. In Liberty township this stream cuts into the anomalous highlands described under the head of topography. Owing to the thinness or total absence of the later drift along its lower course, Pine creek loses the character of a prairie stream in section 9 of Liberty township, and thence to its mouth runs in an old valley, whose sides present a great number of interesting rock exposures.

Buffalo creek is a typical prairie stream, flowing in a shallow channel cut in drift all the way from the north line of Buffalo township to where it crosses into Delaware county, near the middle of the east line of Newton. Its drainage basin is very narrow and all its affluents, except the east branch in Buffalo township, are short, intermittent streams, usually following mere sags or sloughs, without definite channels. Buffalo creek is in the main parallel to the Wapsipinicon, and is a part of the Wapsipinicon drainage system, the two streams coming together in Jones county, near Anamosa.

The drainage in the northeastern part of the county belongs to the Maquoketa system. The greater part of Madison township is drained by the south fork of the Maquoketa, and nearly all of Fremont township is drained by the sluggish Prairie creek that eventually joins the Maquoketa, near Manchester, in Delaware county.

Spring creek, Lime creek and Bear creek, that drain the part of the county southwest of the Wapsipinicon basin, bear tribute to the Cedar river. They are all of the ordinary type of prairie streams except Lime creek, which, in the southern half of Jefferson township, follows a pre-Iowan valley, forty or fifty feet in depth. This old valley seems not to have been filled with Iowan drift, and its walls are diversified with numerous low, rocky cliffs, or rounded, rocky prominences, covered with a scant layer of residual soil.

GEOLOGICAL FORMATIONS.

General Relations of Strata.

The geological formations of Buchanan county belong to three different systems—namely, the Silurian, Devonian and Pleistocene. The Devonian follows the Silurian in natural sequence without any considerable break; but between the Devonian and the Pleistocene there is a gap of immeasurable extent. The Silurian and Devonian systems are represented by the limestones and shales that make up the universally spread foundation rocks of the county. These are the so-called indurated rocks. They are the rocks that are worked in all the limestone quarries and are exposed in all the rocky knobs and ledges that project through the loose superficial materials or soils. All the Silurian and Devonian beds are more or less altered marine sediments. On the other hand, the Pleistocene beds are composed of loose, unconsolidated materials laid down by a number of different processes upon the surface of the land. Most of these materials were transported and spread out by glaciers. The pebble-bearing or bowlder-bearing yellow and blue clays, so generally distributed over the county and so universally recognized by well diggers and others who have occasion to make excavations to any considerable depth below the natural surface, are all of glacial origin. Glaciers transported the granite bowlders that, within the limits of this county, are such conspicuous and striking features in every prairie landscape. Torrents of water from melting glaciers transported, sorted and deposited the great beds of rust-colored Buchanan gravels that are found at numerous points in almost every township. The modern streams have built up deposits of clay and sand that are part of the Pleistocene system, and even winds have been instrumental to some extent in shifting and rearranging the loose surface material and making new deposits of Pleistocene age.

The following table shows the taxonomic relations of the strata exposed in Buchanan county.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Post-glacial deposits.
		Glacial.	Loess?
			Iowan.
			Buchanan.
			Kansan.
Paleozoic.	Devonian.	Middle Devonian.	Cedar Valley.
			Wapsipinicon.
	Silurian.	Niagara.	Delaware.

The last column in the table above, giving the names of the several stages represented in the geological formations of the county, is subject to revision. For example, for the term Buchanan, as applied to the interval of time following the age of the Kansan drift, it may be found convenient to adopt the name Yarmouth, proposed by Leverett.* But the only recognized deposits referable to the time immediately following the disappearance of the Kansan glaciers are those to which the name *Buchanan gravels* is applied, and it is for this reason that the term used in speaking of these deposits is retained. It must be borne in mind, however, that the deposition of the gravels seems to have been practically coincident with the withdrawal of the Kansan ice, and from this point of view a strict classification might require us to regard the gravels as only a phase of deposits properly belonging to the Kansan stage. Admitting all this, the fact remains that the marked structural differences between the Kansan drift and the

*JOURNAL OF GEOLOGY, Vol. vi, p. 176, et seq. Chicago, Feb.-March, 1898.

Buchanan gravels renders their separation for purposes of study and treatment a matter of very great convenience, and with this understanding the arrangement, so far as relates to this particular part of the column, may be allowed to stand.

A similar explanation seems necessary with respect to the use of the term *Loess* for the interval following the Iowan drift. The intimate genetic relation between Iowan drift and loess is such as to require us, in a rigid system of classification, to look upon the two deposits as different phases representing the same stage; and it is only as a convenient way of recognizing the differences in physical characteristics which distinguish them that the two are separated. The Buchanan gravels were certainly not laid down until the Kansan ice had retreated from the surface over which they were spread. Loess may have been deposited on the highlands northwest of Quasqueton while the Iowan ice was at its maximum, or even before the maximum was reached. Absolute contemporaneity between Iowan drift and loess is much more possible than between Kansan drift and Buchanan gravels in the same neighborhood.

Silurian System.

NIAGARA LIMESTONE.

The Niagara limestone is found in all the outcrops in the northeastern part of the county. With one or two exceptions presently to be noted, the rocks of this series are coarse, granular, vesicular dolomites, interbedded at certain localities with large quantities of chert. The beds all belong to the Delaware stage and are simply an extension of the strata exposed in the northwestern part of Delaware county.

Along the Maquoketa, near the southwest corner of section 10, Madison township, there are exposures of the coarse Niagara limestone in some low knobs bordering the stream. Excepting some casts or impressions of *Halysites catenulatus*, the beds are unfossiliferous. Niagara limestone is exposed over an area of several acres in extent in the southern part of section 18 and northern part of 19, in the western edge of Madison township, and there are exposures on the township line between section 18 of Madison township and 13 of Buffalo. The limestone here occurs in stony knobs or prominences and affords a section twelve or fifteen feet in thickness. The beds are quite regular, from two to six inches in thickness, and they have been quarried in a small way at one or two points, and in at least one locality they have been used in the manufacture of lime. The drift is very thin on all the low, rounded hills of the immediate neighborhood, so that the stone could readily be exposed and quarried over a much larger area, if the demand warranted the effort. Silicified colonies of the corals *Halysites catenulatus* and *Favosites favosus* are the principal fossils, and with these are associated a number of Stromatoporoids, silicified, and practically structureless in their present condition. Near the middle of the west line of section 16, in Madison, there is an outcrop of Niagara, covering a small area, and affording silicified corals, mostly *Syringopora tenella*.

In Buffalo township there are exposures of Niagara limestone near the southeast corner of section 13. Where the road between sections 13 and 24 of this township crosses the east branch of Buffalo creek there is a vertical ledge of Niagara which forms the west abutment of the bridge. Other exposures occur at intervals for a mile or more below the bridge. All are of the coarse, granular type, and all indicate a horizon about the middle of the Delaware stage, the equivalent of the Pentamerus and coral-bearing zone described in the report on Delaware county.

Niagara limestone is exposed at numerous points along Otter creek and its branches, in the northern part of Hazelton township. The outcrops are almost continuous along the stream courses in sections 2 and 10, north and northeast of Hazelton. In the southwest quarter of the northwest quarter of section 10 the rock appears in thin, irregular beds which furnish *Lyellia americana* and *Heliolites interstinctus*. In the southeast fourth of the same quarter section, Mr. J. O. Goff has opened a quarry that shows thin layers in the upper part of the working and thicker beds near the base. There is a large amount of chert interbedded with the limestone. The height of the vertical quarry face is about fourteen feet. The upper two or three feet is made up of soil, reddish-brown residual clays and decayed fragmentary limestone. The length of the quarry face is about 100 feet. In getting out the stone a large amount of rubbish, composed of chert and chipstone of good quality for road making, is produced. Natural exposures of the same beds, much weathered and overgrown with moss, extend along the low bluff east of the quarry for a distance of 500 feet. In the talus along the base of the bluff, and in the wash of the creek, there occur *Lyellia americana*, *Syringopora tenella*, *Favosites hispidus*, *Favosites favosus* and *Favosites alveolaris*, or a species with pores in the angles of the corallites and closely related to *F. alveolaris* and *F. aspera*.

All the exposures in section 10 of this township show the coarse, granular facies of the Niagara dolomite; but in the southwest quarter of section 2 the coarse dolomite passes beneath fine-grained non-dolomitized limestone which may possibly represent the horizon of the evenly-bedded quarry stone in the upper part of the Delaware stage in Delaware and Jones counties. This fine-grained limestone varies in color from light drab to blue. It breaks with conchoidal fracture and has the grain of lithographic limestone; but the texture is not quite uniform and all the pieces observed were still further rendered valueless as lithographic stone by numerous checks and flaws. Some quarries are worked in this horizon in the northeast quarter of the southwest quarter of section 2, the largest being known as the John Conrad quarry. The layers vary in thickness from four to ten inches. The beds are light gray in the upper part of the quarry; bluish in the lower part. Near Coytown, in the southwest quarter of the southeast quarter of section 2, the light gray facies of these upper beds is exposed in a quarry that has been worked in the manufacture of lime. Near the top of this quarry the layers seem to be brecciated, and thin beds of lithographic limestone are irregularly interbedded with a rather coarse crystalline dolomite. Neither at Coytown nor at the Conrad quarry were any fossils observed in the fine-grained limestone, nor were any found in the overlying residual clays to indicate that beds of the ordinary Niagara type, containing silicified corals and other organic remains, had ever existed above it.

In the banks of Otter creek, at Kiefer Brothers' mill, south of Hazelton, there are ledges of Niagara limestone rising above the level of the water to a height of fifteen feet, and on the hillside sloping to the west there are outcropping ledges, alternating with spaces concealed by clay or sod, up to a height of twenty-five to thirty feet farther. Near the level of the water the layers are quite regular, and free from fossils so far as noted, except for a single cast of a small individual of *Orthis biforata*, such as occurs not infrequently in certain phases of the Delaware stage, in Cedar county. Higher up, on the slope of the hill, *Lyellia americana* and the Favosites with pores in the angles of the corallites, which is referred to the species *Favosites alveolaris*, are not uncommon. These two, indeed, are the most characteristic and persistent species of the Niagara limestone in this part of Buchanan county. There is a small quarry of evenly-bedded Niagara limestone east of the creek, in the northeast quarter of section 18, Hazelton township, but the best outcrop of Niagara in this township is seen in the hill west of the west branch of Otter creek, on the road passing between sections 7 and 18. The locality is known as the Miguet hill. A section showing twenty-five to thirty feet of rock is here exposed. The stone has been quarried on a small scale, and some has been taken out to improve the grade of the road. The lower beds exposed contain *Halysites catenulatus*, *Syringopora tenella* and *Ptychophyllum expansum*. Higher up there is a larger assemblage of typical Niagara corals, including *Heliolites interstinctus*, *Lyellia americana*

Halysites catenulatus and *Favosites alveolaris*. At the summit of the hill the beds are largely made up of thin, expanded forms of Stromatopora not silicified. One-fourth mile further west the rock is again exposed, and in the residual surface materials are silicified colonies of Heliolites, Lyellia, Halysites and Favosites. A few layers of soft, earthy Niagara limestone, very much decayed by weathering, are exposed in the railway cut in the south edge of Hazelton, but they show nothing of special importance.

While no outcrops of Niagara were seen in Fairbank township, the formation underlies the drift over an undetermined area, but one of considerable extent, in the northeastern corner. On the Little Wapsipinicon river, one and one-half miles north of the town of Fairbank, the Niagara limestone forms a high bluff on the south side of the stream. The bluff rises forty feet above the level of the water, and the vertical cliffs of brownish-yellow, weathered dolomite measure sixteen feet. On the rounded slopes above the projecting ledges the soil contains masses of residual Niagara chert and silicified Niagara corals, showing that the Niagara limestone is present up to an altitude equaling that of the summit of the bluffs. This fact is of interest only when taken in connection with another fact—namely, that at Fairbank, only a mile and a half south, there are quarries opened in Devonian beds, and the level of the Devonian quarries is forty feet lower than the summit of the bluff of Niagara limestone, twenty-five feet lower than the brow of the vertical cliff of massive Niagara dolomite. The later Devonian was deposited against the side of a steep, anticlinal fold, which lifted the Niagara of northeastern Buchanan much above the position it normally would have occupied had the strata retained, relatively, the position in which they were laid down on the floor of the Silurian sea. To this upward folding of the Niagara is due the strong re-entrant angle which is made in tracing the eastern edge of the Devonian area from the central part of Fayette county to near the southeast corner of Buchanan.*

*See geological map of Iowa, this volume, Plate ii.

Devonian System.

The earlier geologists of Iowa attempted to correlate the Devonian strata of the state with certain recognized Devonian beds belonging to the geological column of New York. Owen referred a part at least of the Devonian formations he encountered west of the Mississippi to the Hamilton series,* and nearly all subsequent geologists have followed his example. The fact is, however, that the Devonian system of Iowa was deposited in an area geologically isolated from that in which the eastern Devonian was developed. The conditions of sedimentation were different in the two areas. The order and succession of faunal conditions were not the same. The eastern Devonian faunas, subjected to certain physical conditions and undergoing certain modifications, probably migrated from the northeast along the eastern border of the continental nucleus, while the western faunas of the same period seem to have come from the northwest along the western border of the Devonian continent. The conditions encountered were different and the modification of the species progressed along wholly different lines. Even in the case of species that are common to the two provinces, there is evidence that the time and order of arrival at the same latitude on opposite sides of the old continent were not the same. The Devonian fauna of Iowa is intimately related, in certain respects, to that at the Ramparts of the Mackenzie river; it bears some resemblance to the Devonian fauna of the Eureka District of Nevada; but, for purposes of minutely correlating strata, it would be misleading to compare it with the faunas of this period in the eastern province. As an illustration of the extent of the error into which even the most eminent and experienced of geologists may be led when attempting to correlate the eastern and western Devonian by means of the geological faunas, it is worth noting that some years ago the quarry stone at Raymond was referred to the Schoharie stage, the coral-bearing

*Owen's Geol. Surv. of Wis, Iowa and Minn. Explanations of figures of Devonian fossils Tables iii and iii A.

beds at Waterloo were called Corniferous, the limestones at Independence were assigned to the Hamilton, and the Lime creek shales were called Chemung. Now the Lime creek fauna is found in shales below the Independence limestones, and so, judging from the fauna, the Independence shales are also Chemung. Furthermore, the coral-bearing beds at Waterloo are younger than the limestones at Independence, for they lie above them, and the quarry stone at Raymond is still younger than the coral beds that were referred to the Corniferous. Beginning with the Independence shales, the actual order of the strata in Iowa, according to the correlation referred to, would be—(1) Chemung, (2) Hamilton, (3) Corniferous, (4) Schoharie—a complete reversal of the order observed in New York. It may be repeated, for the sake of emphasis, that the western Devonian cannot be correlated, except in a broad and very general way, with that of the east.

All the beds of this system observed in Buchanan county are referred provisionally to the "Middle Devonian," and this notwithstanding the fact that no positive evidence of an erosion interval between the Silurian and Devonian is known to exist.

INDEPENDENCE SHALES.

The Independence shales belong to the Wapsipinicon stage of Norton.* The underlying "Otis beds" are not known in Buchanan county, and the shales in question constitute the lowest recognized member of the Devonian in this part of Iowa. In the county there are no natural exposures of the shales that show well their characteristics and entire thickness. The most that is known here concerning them was learned from shafts sunk at the old Kilduff quarry, now owned by Thomas O'Toole, east of Independence. The formation was penetrated to a depth of twenty feet and was found to consist of dark-colored shales, alternating with thin beds of

*Iowa Geol. Surv., vol IV. Report on Linn county, by W. H. Norton. Professor Norton here uses the term "Kenwood beds" for the Linn county equivalent of the Independence shales.

limestone. At certain levels the shale was very dark, carbonaceous, and contained vegetable remains, some parts of which had been transformed into true coal. There are outcrops of the shales in the river bank, at the level of the water, near the center of the north line of section 10, Sumner township. There is a small exposure of the shales in the bank of the creek in the southeast quarter of the southeast quarter of section 35, Washington township; and they are seen again near the bridge at Quasqueton, in Liberty township. Running through this formation at a certain level is a bed of unfossiliferous, laminated, clayey limestone that splits into thin leaves one-fourth to one-half an inch in thickness. This phase is easily recognized, and exposures of it are seen along Harter creek, in the northwest quarter of section 27, Washington township, and along the Wapsipinicon, in the southwest quarter of section 24, Sumner township. In general, however, the natural exposures are few and unsatisfactory, the position of the beds being such that the outcropping edges are either covered with talus or are sodded over. The fauna of the shales embraces the following species.

**Pachyphyllum solitarium* Hall and Whitfield.
Romingeria umbellata Rominger.
**Stropheodonta variabilis* Calvin.
**S. canace* Hall and Whitfield.
**S. arcuata* Hall.
**S. calvini* Miller.
**Strophonella reversa* Hall.
**Productella hallana* Walcott.
**Strophalosia rockfordensis* Hall.
**Orthis impressa* Hall.
O. infera Calvin.
**Rhynchonella (Pugnax) pugnus* var. *alta*.
**Rhynchonella (?) ambigua* Calvin.
Pentamerus (Gypidula) munda Calvin.
**Atrypa reticularis* Linnæus.

**Atrypa aspera* var. *hystrix* Hall var.
Spirifer subumbona Hall?
**Cyrtina hamiltonensis* var. *recta* Hall.

The species marked with an asterisk are common to the Independence shales and Lime Creek shales, at the two extremes almost of the Devonian series. Of some of the species, however, the proportional number of individuals differ very greatly at the two horizons. For example, *Stropheodonta variabilis* is rare along Lime creek, but it is one of the most common and persistent species in the Independence shales, while *Orthis impressa*, which is represented by numerous large and well-developed individuals in the Lime Creek horizon, occurs but rarely in the shales at Independence, and the individuals are small. The *Rhynchonella (Pugnax) pugnus*, found both in Lime Creek and Independence shales, is a small acuminate variety, quite distinct from that occurring in the state quarry beds of Johnson county, Iowa, or in the unique High Point fauna of New York. The form called *Rhynchonella (?) ambigua* is of doubtful generic relationships, and that listed as *Spirifer subumbona* Hall? is probably a new species. Only a very few of the species marked as common to the two shale horizons are found in the intermediate beds.

Fayette breccia.—The widespread assemblage of brecciated beds above the Independence shales constitutes the upper part of Norton's Wapsipinicon stage. Furthermore, the breccia, as defined by Norton, embraces a number of distinct life zones, and even includes beds in which the characteristic brecciation is not very perfectly developed. In some of the exposures there are layers of limestone, unbroken and apparently undisturbed, that lie in the midst of brecciated limestone made up of fragments that, judging from the wide range of color and texture, were derived from a dozen or more different beds.

The breccia, in its lower and more typical phase, is well exposed in the bed of the river, below the bridge at Independence. It is here composed of angular fragments of limestone,

FIG. 1. View in City quarry at Independence, showing effect of crushing in the *Spirifer pennatus* beds, upper part of the brecciated zone.

FIG. 2. Small fold showing the effect of crushing in the upper part of the brecciated zone, near Brandon.

varying in character, evidently the product of many distinct layers, and all cemented together by a calcareous matrix. The fragments range from small pieces with dimensions of a fraction of an inch up to masses a yard or more in length and width and a foot in thickness. There are fine-grained, dark drab fragments which break with conchoidal fracture, and there are finely laminated fragments of the same color. There are pieces of fine-grained, light-colored, lithographic limestone, and coarser, dingy yellowish colored beds were also involved in the general destructive process, whatever it may have been, that reduced a large number of limestone layers to the brecciated condition. The fragments, large and small, of different color and of different texture, are promiscuously tumbled and heaped together, some on edge and others at all possible angles with the original position. Some of the blocks are fossiliferous, but the greater number show no traces of life. The most common fossil in the layers exposed in the bed of the stream at Independence is *Pentamerus* (*Gypidula*) *comis* Owen, the species being represented in some of the constituent blocks of the breccia by occasional perfect shells and multitudes of detached valves. In the south bank of the river, along the north side of section 10, Sumner township, the breccia is exposed, beginning near the level of the water and extending to the summit of the low bluffs. The underlying Independence shale crops out at the water level, and this is followed by the phase of the breccia in the river bed at Independence. Higher up in the bank, above the phase referred to, *Pentamerus comis* is very abundant in the large fragments of limestone that, at this horizon, make up nearly the entire deposit; and a large Gyroceras occurs in considerable numbers. Above the Gyroceras bed is a body of soft, light gray or nearly white limestone, not distinctly bedded, but very much shattered, and cut by joints that, intersecting at every possible angle, divide the bed into a great number of shapeless fragments which still retain their relative positions unchanged. (Plate xiv, Fig. 1).

In this part of Iowa the shattered limestone above the Gyroceras horizon differs very much from the true breccia below. Below the Gyroceras bed the fragments are of many different kinds, evidently displaced and promiscuously mingled; while above this bed the fragments into which the rock has been broken bear evidence of very little displacement. The phenomena of slickensides, very extensively developed on the joint walls, are indicative of tremendous crushing and shearing strains to which the rocks of this horizon have been subjected. At Troy Mills, in Linn county, and farther south, the beds at this same geological level were involved in the process that produced true breccia, and for this reason Norton includes them in the brecciated zone and recognizes them as the fourth phase of the Fayette sub-stage.* While not a true breccia in the neighborhood of Independence, these beds pass into the brecciated condition in the southern part of the county, and must be considered as a part of the Fayette division of the Wapsipinicon stage. At the point under consideration, in section 10, Sumner township, this upper member of the Fayette formation is unfossiliferous at the base, but, without apparent change in lithological characters, it passes up into beds that are exceedingly rich in a great variety of fossil forms. The fossiliferous zone furnishes a very fine ribbed *Atrypa reticularis*, robust forms of *Atrypa aspera* var. *occidentalis*, and large, typical individuals of *Spirifer pennatus*. *Spirifer bimesialis* is the only other spirifer. *Pentamerus comis* occurs, but is rare when these beds are compared with the Gyroceras horizon. Equally rare is *Cyrtina hamiltonensis*, which here assumes the true Hamilton type as seen in the Hamilton shales of western New York and western Ontario. Even more rare are *Heliophyllum halli* and an Astræaspongia related to *A. hamiltonensis* Meek and Worthen. *Orthis macfarlanei* is rare, but more common than the two species last named. Naming this life zone from its typical fossil it has been called the *Spirifer*

**Geol. of Linn County.* By W. H. Norton. Iowa Geol. Surv., vol IV, p. 161. Des Moines, 1895.

pennatus beds. To recapitulate, a section of the Fayette breccia includes the following.

		FEET.
4.	*Spirifer pennatus* beds, composed of soft, light gray limestone, intersected by numerous joints that cut the formation at every possible angle and divide it into relatively small, shapeless blocks. The most conspicuous fossils are *Spirifer pennatus* Owen, *Spirifer bimesialis* Hall, *Atrypa reticularis* Lin., *Atrypa aspera* var. *occidentalis* Hall var. *Pentamerus comis* Owen, *Orthis macfarlanei* Meek, *Orthis iowensis* Hall, *Productella alata* Hall, *Stropheodonta demissa* Con....................	8 to 12
3.	Barren beds, similar in lithological characters and physical condition to the *S. pennatus* beds, but destitute of fossils, or nearly so............	10 to 15
2.	Gyroceras beds, composed of rather large but displaced and tumbled fragments of a coarse grayish or yellowish limestone, though there are occasional small areas in which the beds show no signs of disturbance. Principal fossils, two species of unnamed Gyroceras and *Pentamerus comis* Owen. The last is exceedingly abundant in some blocks, but it is generally represented by separated valves....................	5
1.	The true brecciated beds, composed in the main of small, angular fragments, mostly unfossiliferous, many of the fragments fine-grained and dark drab in color............................	15 to 20

The principal exposures of the breccia, besides those already mentioned, are found along the valley of the river between Independence and the south line of the county. In the northwest quarter of section 14, Sumner township, Nos. 1 and 2 are both well exposed. In some ravines in the southwest quarter of 24 and northwest of 25 in the same township, the weathered edges of all the beds from the base of No. 1 to the top of No. 4, are seen at various points in the rather gently sloping and partly sodded hillsides. At Pine creek mill and in the hills west of the mill the *Spirifer pennatus* beds are well developed, the stone being somewhat harder than at Independence; and one of the most extensive exposures, including beds 1, 2, and 3, is seen in the river bed below the mill dam at Quasqueton.

The higher phases of the breccia, including beds 3 and 4, are found in all the quarries about Independence. These beds furnish nearly all of the quarry stone of local origin used in Independence and the country surrounding it. The quarries and natural outcrops are too numerous to be mentioned separately, but the constancy of the lithological and other characters of the beds fortunately makes separate description unnecessary.

A quarry worked wholly in the Barren beds, No. 3, is located south of the cemetery, in the eastern part of section 2, Tp. 88 N., R. IX W. The beds exposed in this quarry are, as usual, divided by numerous joints. The stone is soft, light colored where weathered, but bluish in the interior of the larger blocks. Fossils are conspicuously absent, at least there are no organic remains that are obviously of the same age as the beds forming the quarry. Some years ago, however, Mr. J. McMillan took from this quarry some large masses of a silicified Diphyphyllum that all showed evidence of having been worn and rounded before being embedded. The specimens obtained by Mr. McMillan are evidently mere fragments of larger coralla; and yet, while all are large, at least one was nearly four feet in its greater diameter and weighed several hundred pounds. The corals occurred in pockets in the limestone. The species is not definitely determined, but the silicified condition, the character of the matrix in which the corallites are embedded, and the evidence of weathering before being placed in the position in which the masses were found, all suggest that the coral may be Silurian, probably Niagara, in age. It would be interesting to know by what agency these great weathered masses were transported and dropped upon the sea bottom when the material making up the Barren beds of this region was in process of accumulation.

A quarry located in the eastern edge of Independence is

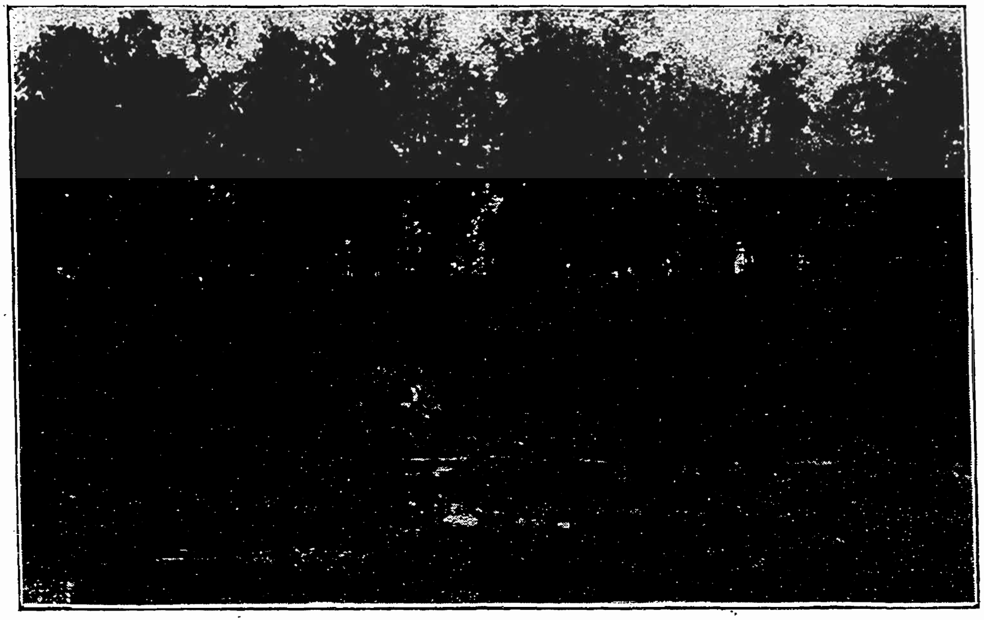


FIG. 1. Regular stratification in Cedar valley limestone, Acervularia horizon, above crushing, near Littleton.

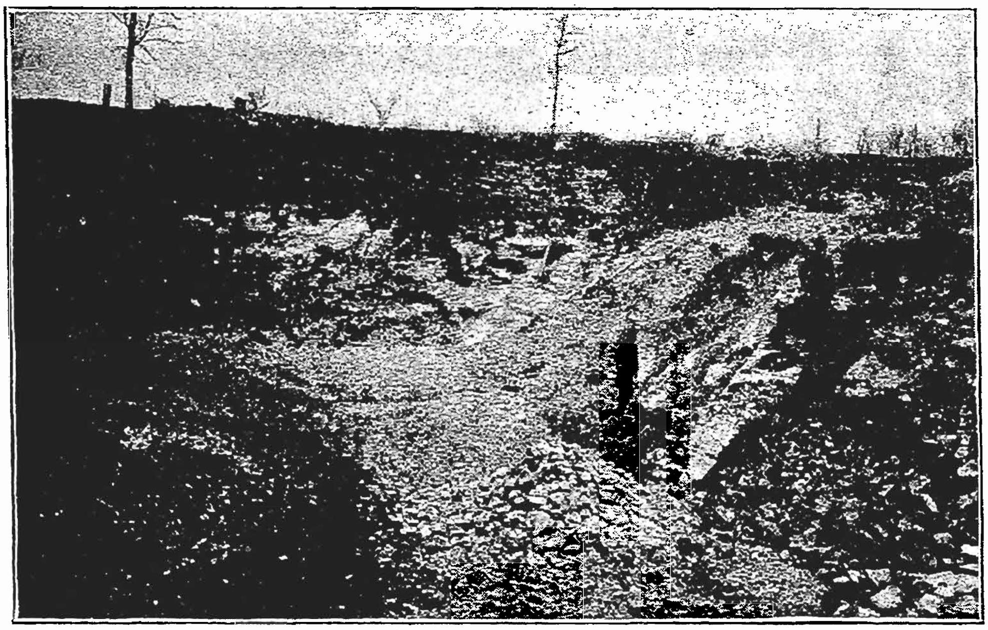


FIG. 2. View of O'Toole quarry, east of Independence. Badly weathered Cedar Valley limestone overlies the *Spirifer pennatus*.

typical of nearly all the natural or artificial exposures of this region. It shows the following section.

		FEET.
3.	Yellowish, rather hard limestone, which rings when struck with the hammer, in rather thin layers, and containing numerous corals, among which *Cystiphyllum americanum* and *Acervularia profunda* are the most characteristic species	4
2.	*Spirifer pennatus* beds showing the usual assemblage of fossil species, not definitely bedded, but intersected by a great number of joints. The phenomenon of "slickensides" developed on the joint faces on an extensive scale	8
1.	Barren beds, lithologically like the *S. pennatus* beds above	10

No. 3 of this section is the lowest member of the Cedar Valley stage of the Iowan Devonian. In this county it is everywhere rich in corals, and in some areas of limited size it becomes a crowded coral reef. From its most characteristic fossil it may be called the *Acervularia profunda* beds. The fauna of the *Svirifer pennatus* beds, No. 2, is about the same at the various outcrops throughout the county. The fine-ribbed *Atrypa reticularis* is the most abundant fossil; but this species, under a number of varietal forms, has a great vertical range, and the *S. pennatus* is therefore the most typical species of this horizon.

The quarry owned by Thomas O'Toole, near the north line of the southwest quarter of section 35, Washington township, is one of the most important of a large number of quarries that have been opened within a distance of one and one-half miles east of Independence (Plate xv, Fig. 2). There occurs here the usual succession of Barren beds at the base of the quarry pit, with very fossiliferous *Spirifer pennatus* beds occupying a middle position and coral-bearing beds of the *Acervularia profunda* zone above. It was in an abandoned pit, a few rods west of the O'Toole quarry, that the first shaft which brought to light the Independence shales of this locality was put down.

Outcrops of the *Spirifer pennatus* beds are seen at a number of points along Pine creek and the Wapsipinicon river in Liberty township. In the southeast quarter of section 32, same township, a mile and a half west of Quasqueton, are some very typical exposures which afford, among a large variety of beautifully preserved fossils, a small celled Favosites resembling in structure, though not in mode of growth, *Favosites placenta* Rominger. In the southeast quarter of section 16, Cono township, a small quarry is worked partly in beds belonging to the horizon of *Acervularia profunda* and partly in beds of the *Spirifer pennatus* zone. Beds bearing *Spirifer pennatus* and its associated species crop out along the creek in sections 31, 32 and 33, Newton township, and the same beds are again seen, a mile or more east, along the south line of section 34. North of Independence the *pennatus* beds crop out in the banks of the stream at Otterville, but the rock exposures seen along the Wapsipinicon for some distance northwest of Otterville belong to higher zones. North of Fairbank in Fayette county, the *pennatus* beds are again seen on the flanks of the Niagara anticline previously noted.

CEDAR VALLEY LIMESTONE.

The line of division between the Wapsipinicon and Cedar Valley stages of the Iowa Devonian may conveniently be drawn at the top of the *Spirifer pennatus* zone. Above this line there is a marked change in the character of the limestone and a still more marked change in the fauna. The rock is harder, at first ranging from yellow to dark gray in color, and the evidences of crushing and disturbance have almost entirely disappeared. The characteristic fauna of the lower beds ceases abruptly, and in the zone immediately following the *S. pennatus* beds corals become the predominating type. The most common species is *Acervularia profunda*, and in the beds characterized by this fine coral there occur *Favosites alpenensis* and several other species of Favosites, *Alveolites goldfussi*, *Clado-*

pora magna, *Cladopora palmata*, two or more species of Zaphrentis, *Aulocophyllum* (sp.?), more than one species of Cyathophyllum, *Ptychophyllum versiforme* and *Cystiphyllum americanum.* Besides the corals there are a number of peculiar stromatoporoids that have as yet received no attention from paleontologists. Near the base of this zone, but in a narrow band containing but few other corals, the large and beautiful *Phillipsastrea billingsi* occurs locally in considerable numbers.

Beds of the *Acervularia profunda* zone occur at the top of nearly all the quarries around Independence. The coral from which the zone is named is not infrequently found in masses a foot in thickness and two feet in diameter. At an old quarry south of the correction line road, about a mile east of Independence there were observed a number of large coralla which, when broken with the hammer, showed a tendency to separate into individual prismatic corallites as in the case of many coralla of *Cyathophyllum rugosum* from near the Falls of the Ohio. *Acervularia profunda* and nearly all the species noted above as being usually associated with it, are found in a soft, granular, easily-weathered matrix at the top of a small quarry on land belonging to Mr. Burke, in the northeastern part of Independence. All the beds worked at present in the Burke quarry belong to the *Acervularia profunda* zone.

The larger coral, *Phillipsastrea billingsi*, seems to occur in isolated patches, and while it has a wider range than *Acervularia profunda*, it is not so uniformly distributed over the area in which it is known to be present. Its place when present, is only a few feet above the base of the Cedar Valley limestone. In this position a number of coralla are seen at the top of the hill on the Winthrop road, one-half mile east of Independence. Fine specimens of this species have been taken from the upper beds of quite a number of quarries in the same vicinity. The coral is present at this same horizon in the river banks above Quasqueton. At the McPike and Elliott springs in the northeast quarter of section 33, Newton township, specimens, weathered out of the limestone, were formerly very abundant, but they have nearly all been carried away by collectors and only those firmly embedded in their original position remain. On the sides of the low, rounded hills in the southeast quarter of the southwest quarter, and southwest quarter of southeast quarter, of section 34, Newton township, specimens of Phillipsastrea in place, or freed by weathering, are still quite numerous. Phillipsastrea is also relatively abundant at Troy Mills, south of the Buchanan county line in Linn county, as well as along the river southeast of Troy Mills for a number of miles. Its position here, as well as elsewhere, is near the base of the undisturbed beds above the Fayette breccia.

At Troy Mills *Spirifer pennatus* is found ranging into beds above the Phillipsastrea horizon, a range consistent with what is known concerning this species of spirifer at a number of other localities, but which has not been observed at any of the exposures around Independence. There are specimens of *Spirifer pennatus* in the lower part of the Cedar Valley limestone at Littleton, Jesup and Gemmel's quarry, near Quasqueton; but wherever this species is found above the true *S. pennatus* beds of the disturbed and brecciated zone, the individuals are rare and are characterized by having the cardinal line longer, the cardinal area wider and flatter, and the whole aspect of the shell coarser than among the typical individuals of the lower horizon.

On the west side of the river, below the mill dam, at Littleton, there are natural exposures of Devonian limestone showing the following section (Plate xv, Fig. 1).

FEET.

8. Yellow, fossiliferous shaly limestone, breaking down, on exposure to the weather, into small flakes of limestone mingled with a large amount of calcareous clay. Fossils include a small-stemmed Cladopora related to *C. iowensis* Owen, *Megistocrinus farnsworthi* White, a large, robust form of *Stropheodonta demissa* Conrad, that is usually much wider than long, *Orthis iowensis* Hall, an extremely coarse-ribbed

		FEET.
	Atrypa reticularis Lin., a Spirifer ralated to *S. parryanus*, but differing in having a narrower cardinal area and having the mesial fold divided by a furrow, a small form of *Cyrtina hamiltonensis* Hall, and a small, thin Dielasma........................	10
7.	Heavy-bedded, yellowish limestone, unfossiliferous...	5
6.	A crowded coral reef made up chiefly of coralla of *Acervularia davidsoni* Ed. and H., with which, however, are associated *Ptychophyllum versiforme* Hall, Cyathophyllum, two or three species, *Favosites alpenensis* Win., a Favosites growing in lenticular or hemispherical masses, like *F. emmonsi*, and Cladopores of different species	1
5.	Hard, regularly-bedded, dark drab or bluish limestone in ledges six to eight inches in thickness. This number contains *Pentamerella dubia*, associated with large numbers of *Spirifer parryanus* and a coarse-ribbed *Atrypa reticularis*. There is also a large, flat form of *Stropheodonta demissa* which differs markedly from the small, very arcuate individuals of this species found with *Spirifer pennatus* at Independence..	2
4.	Soft limestone in two or three layers, carrying occasional coralla of *Acervularia profunda*.............	1
3.	Soft, yellowish limestone, with Favosites and some other corals, but best distinguished by the presence of *Newberria johannis* in moderately large numbers, with which occur *Pentamerella arata* and *Dielasma (Cranæna) romingeri*.............................	2
2.	Bed of dark grayish limestone, containing numerous small specimens of Cystiphyllum, a large Zaphrentis, large masses of Stromatopora and some coralla of *Acervularia profunda*	1
1.	Dark brown or grayish limestone, with many large specimens of *Cystiphyllum americanum* and some stromatoporoids, exposed at level of water, near the mill dam	2

Along the river bluff, a short distance above Littleton, in the southwest quarter of section 4, Perry township, there are, at the level of the water, exposures of the yellow, shaly limestone, No. 8, of the section described above. The bluff above the level of the shaly limestone is partly sodded over, but the details, as far as they can now be made out, would give.

	FEET.
2. Yellow, earthy limestone, evenly-bedded, in layers varying from two to eight inches in thickness, as indicated in a quarry breast eighteen feet in height at the top of the bluff and occasional outcrops on the hillside. Rock contains broken shells of one or more species of Spirifer, and more perfect specimens of a coarse-ribbed *Atrypa reticularis*..........	60
1. Yellow, shaly limestone, corresponding to No. 8 of the Littleton section	5

No. 2 of this section lies above the beds described in the section below the mill at Littleton. The quarry at the top of the bluff at the point described belongs to Mr. G. Jesse. It yields flagging and building stone of very fair quality. Another quarry at the same geological level, and showing the same characteristics, is located on land belonging to Mr. Lewis Schreier, in the south half of the southeast quarter of section 33, Fairbank township. It may be said in passing that this is the level of the quarry stone at Raymond, in Black Hawk county.

The beds in the upper portion of the Burke quarry, at Independence, correspond in part to Nos. 1 and 2 of the Littleton section, while all the beds at Littleton, from 1 to 4 inclusive, belong to the *Acervularia profunda* zone. About a mile east of Littleton the fauna of this zone occurs in great profusion and in a beautiful state of preservation in the wash of a small, intermittent creek. The corals are weathered out of a soft, light gray, granular matrix, resembling that at top of the Burke quarry, at Independence; and specimens of Favosites, Alveolites, Cladopora, Zaphrentis, Cyathophyllum, Ptychophyllum, Acervularia, Cystiphyllum, and other genera, including a number of stromatoporoids, all thoroughly cleaned, yet in perfect condition and ready for the museum, may be collected in large numbers.

At Fairbank there is a quarry on the west side of the river showing rather evenly-bedded, yellowish limestone, somewhat argillaceous, and the thicker beds have many cavities lined with calcite. This quarry gives the following section.

		FEET.
5.	Very dark brown, residual clay or geest, containing some complete shells of *Newberria johannis* and some very much weathered fragments of *Acervularia davidsoni*..................A few inches to	1
4.	Limestone, in thin layers, containing *Newberria johannis* and *Pentamerella arata*..................	4
3.	Bed crowded with *Newberria johannis*, mostly broken and detached valves..............................	1
2.	Yellowish, soft, evenly-bedded limestone, in layers ranging up to six or eight inches in thickness, containing many small individuals of Cystiphyllum..	5
1.	Heavy beds, not fossiliferous, exposed at base of quarry	2 to 3

The section at Fairbank shows some decided variations in character and thickness of the several members when compared with corresponding beds farther south. No. 2 is the same as No. 2 at Littleton, but it is more argillaceous and does not contain *Acervularia profunda*. Nos. 3 and 4, at Fairbank, are equivalent to No. 3 at Littleton, but together they are much thicker, and the peculiar fossil, *Newberria johannis*, is much more numerous, crowding certain layers to the total exclusion of everything else. The beds here all lie below the horizon of *Acervularia davidsoni*. This species was not seen in place at this locality, but the weathered and iron-stained specimens in the residual clays above the quarry indicate that it was once present in its normal position. About one-half mile northwest of Fairbank, in Fayette county, there are two quarries opened in beds that, at the base of the exposure, carry the fauna of the *Spirifer pennatus* beds at Independence. These beds here, however, are not crushed or brecciated, but lie in regular layers eight to ten inches in thickness. At the top of the quarries are yellowish beds, containing cavities lined with calcite, equivalent to the beds in the lower part of the section at Fairbank, and containing some small, depauperate colonies of *Acervularia profunda*. One and one-half miles north of Fairbank the Niagara dolomite, as already noted, rises in the hill overlooking the river to an altitude of forty feet above the level of the Devonian limestone in the quarries just described.

There are two quarries, one on each side of the correction line road, one-half mile southeast of Jesup. The north quarry belongs to T. F. Kenyon. The limestone beds, at this point, are somewhat contorted, and dip at an angle of 5° toward the east. The aggregate thickness of the beds exposed is about eighteen feet. The section shows:

		FEET
6.	Black loam	1 to 2
5.	Broken and decayed yellow limestone, more or less disturbed	2 to 3
4.	Yellowish limestone, not very fossiliferous, affords some good quarry stone	5
3.	Beds of soft limestone, easily affected by weather. Fossils are a coarse *Spirifer pennatus* and numerous small Pentamerids of undetermined species	2
2.	Limestone containing numerous stromatoporoids and true corals. The corals embrace the genera Acervularia, Cyathophyllum, Ptychophyllum, Cystiphyllum and Favosites. Some fair building stone	6
1.	Fissile limestone with few fossils	3

The Acervularia in the Kenyon quarry is the species *A. profunda* Hall. All the beds lie below the horizon of *A. davidsoni*. Among the stromatoporoids associated with *A. profunda* is *Stromatopora erratica* H. and W., one of the few species still retained in the genus Stromatopora as emended by Nicholson. The quarry on the south side of the road belongs to Edward Lown. The strata dip slightly toward the south. The beds worked are equivalent to Nos. 4 and 5 of the Kenyon quarry. The beds corresponding to No. 5 are, however, not broken and disturbed as they are on the north side of the road.

East of Quasqueton, on land belonging to G. E. Gemmel, an exposure of Devonian limestone has been quarried at intervals for a number of years. The limestone is quite regularly bedded, and the horizon is very clearly indicated by the fact that in the upper part of the quarry the strata carry *Acervularia davidsoni* and *Spirifer parryanus,* while lower down are *Acervularia profunda* and the usual association of corals, and still lower are *Atrypa aspera* and *Spirifer pennatus. Orthis iowensis* is very common in some of the beds. There is also a large form of *Stropheodonta demissa* characteristic of the Cedar valley beds which carry either of the two species of Acervularia found in this county. The top of the Gemmel quarry is about 80 feet higher than the brecciated beds exposed in the channel of the river below the bridge at Quasqueton.

A number of interesting outcrops of beds equivalent to those seen along the valley of the Wapsipinicon between Fairbank and Troy Mills, occur in the valley of Lime creek in Jefferson township. The *Spirifer pennatus* beds are exposed near the foot of the hill on the west side of the creek not far from the southeast corner of section 14. Farther up the hill the overlying beds of the Cedar valley stage occur. Along the creek in section 23 the beds lying above the *S. pennatus* horizon outcrop continuously for some distance. A reef of *Acervularia davidsoni* is conspicuous a short distance south of the center of the section last named. Five or six feet below the level of the reef there are beds crowded with small individuals of *Atrypa reticularis,* while above the reef the beds are softer and yellowish in color, and correspond in lithological and faunal characteristics, as well as in position, to Nos. 7 and 8 of the section at Littleton. A very good exposure of the yellow shaly limestone is seen in a road cutting along the north side of the northwest quarter of section 26. This member has here a thickness of fifteen feet, and contains the coarse-ribbed form of *Atrypa reticularis* which characterizes bed No. 8 at Littleton. Above the yellow limestone there lies a bed, fifteen feet in thickness, of whitish, compact fine-grained limestone corresponding to the white unfossiliferous beds in the upper part of the exposures in Johnson county. This white limestone is either absent at Littleton or is represented by No. 2

at the G. Jesse quarry a short distance northwest of the town mentioned.

Along Lime creek, south of Brandon, in the northwest quarter of section 34, the beds are well exposed and show the following section.

		FEET.
4.	Soft limestone grading up into yellow shale, which carries silicified individuals of the coarse-ribbed *Atrypa reticularis* and a Spirifer resembling *S. parryanus*	8
3.	Coral reef consisting of Acervularia, Favosites, Ptychophyllum and other corals	1
2.	Evenly-bedded limestone with few fossils or none	4
1.	Limestone, regularly bedded and capable of being quarried, in layers from two to six inches in thickness, the thinner beds serving well as flagging. Beds contain *Sp. pennatus*, *Atrypa aspera*, Favosites growing in hemispherical form, related in structure, though not in mode of growth, to *F. alpenensis* Winchell, and stem segments of Megistocrinus. In these beds occurs a large *Stropheodonta demissa* like the form associated with *Spirifer parryanus* at Littleton	4

In the low bluff bounding the flood plain on the south side of the creek, at Brandon, there are exposures of Devonian strata showing some unusual peculiarities. The beds are folded, buckled and displaced on a scale sufficient to produce a complex series of alternations of lithological and paleontological characters at the same level along the hillside. At one point, for example, there are beds carrying *Spirifer pennatus*. At the same level a few yards away there is a portion of the coral reef with Acervularia, Ptychophyllum, Favosites and other characteristic corals. Farther on are yellow shales corresponding to No. 8 of the Littleton section, and carrying the coarse-ribbed Atrypa and other fossils that everywhere distinguish this horizon. Some of the displacement may be due to faulting on a small scale; but the residual material resulting from extensive weathering conceals the beds over most of the hillside, and allows only occasional glimpses of the strata. The sharp fold shown in Plate xiv, Fig. 2, is seen at one of the exposures.

The yellow limestone corresponding to Nos. 7 and 8 of the Littleton section is all hard enough for building stone a short distance southwest of Brandon, and a quarry is worked at this horizon in the bluff of Cedar river, south of the county line.

There are a few unimportant exposures of the Devonian strata on Bear creek, in section 36 of Jefferson township, and another outcrop, which furnishes *Phillipsastrea billingsi*, occurs one-fourth of a mile north of the center of section 20, in Homer township.

Pleistocene.

The surface of Buchanan county is very generally covered with beds of drift or other deposits belonging to the Pleistocene system. The sub-Aftonian or pre-Kansan drift has not been recognized at the surface, but its presence is demonstrated in numerous borings and excavations by a soil and forest bed horizon underneath the blue clay of Kansan age. At Oelwein, north of Buchanan county, the forest bed and underlying drift were well exposed in the deep cut on the line of the Chicago Great Western railway, and the details of the section were described in papers read before the Iowa Academy of Sciences in December, 1896.*

KANSAN.

Kansan drift is spread almost universally over Buchanan county. In some cases it comes almost or quite to the surface; in other cases it is reached only after penetrating ten or twenty feet, or even more, of the later Iowan till, and in still other cases it is buried beneath Iowan till and Buchanan gravels. A very common relation of Pleistocene deposits is illustrated by the well section on land of J. W. Welch, in the southwest quarter of section 28, Buffalo township. The record shows,

*Prcc. Iowa Acad. Sci, vol. IV, pp. 54-68.

		FEET.
3.	Dark soil and yellow till	4
2.	Reddish ferruginous sand and gravel	23
1.	Blue clay, penetrated	1

No. 3 of this section is Kansan drift, No. 2 is Buchanan gravel, and No. 1 is Iowan till. In the same quarter section another well shows.

		FEET.
3.	Soil and yellow till	22
2.	Reddish gravel	11
1.	Blue clay, with pockets of sand	19

Although the thickness varies considerably, the members of this last section are severally the same as the corresponding numbers in the one above. In a railway cut in the south half of section 3, Buffalo township, the section shows.

		FEET.
4.	Black loam or soil	1
3.	Yellow Iowan till	5
2.	Reddish yellow, oxidized Kansan till	2
1.	Unaltered blue Kansan till	4

The Kansan till is normally a blue clay intersected by numerous joints and carrying large numbers of pebbles and bowlders of dark colored, fine grained greenstone. Fragments of limestone are not uncommon, and there are also some bowlders of light colored, porphyritic granite. The bowlders and bowlderets of various kinds are quite generally facetted and striated on one or two sides. Where the Kansan drift was not disturbed by the later Iowan ice invasion there is a zone of oxidation, varying in thickness, and recording the changes that took place in the superficial portion of the drift as a result of exposure to weather during the long interval between the retreat of the Kansan ice and the advent of the Iowan. The oxidized zone is only partly preserved in No. 2 of the section last above described. Fragments of wood, many of which are referable to the American larch, *Larix americanus*, are distributed through the entire thickness of the blue Kansan till. Wood is, however, more abundant in the lower part of the formation; and it reaches its maximum in the forest and soil bed that marks the Aftonian horizon and separates the Kansan from the sub-Aftonian drift.

BUCHANAN GRAVEL.

In the latitude of Buchanan county the disappearance of the Kansan ice was attended by strong currents of water flowing away from the ice margin. These currents were loaded with glacial debris including fragments ranging from fine silt to bowlders a foot or more in diameter. The course of the currents was marked by deposits of sand and gravel more or less sorted and stratified, and not infrequently cross-bedded on an extensive scale. It is to these particular deposits that the name Buchanan gravel has been applied. Beds of the gravel are strewn continuously for miles along the valley of Buffalo creek in Byron and Middlefield townships. They are common along Pine creek in the western part of Byron. They are conspicuous along the valley of the Wapsipinicon between Littleton and Independence. All the streams, in fact, are bordered more or less generally by trains of gravel. But the gravels are by no means confined to the stream valleys. They are found quite as frequently on the high lands, and some of the highest points in the county are marked by the presence of coarse, ferruginous stratified deposits of this age. Streams may have flowed in glacial canyons along the hilltops while the adjacent lowlands were still occupied by heavy bodies of ice.

The Buchanan gravel presents two phases, an upland phase in which the materials are relatively coarse, and a valley phase composed largely of sand and fine gravel. Bowlders, ranging to more than a foot in diameter, are not uncommon in the upland deposits; pebbles more than an inch in diameter would rank among the unusually large constituent fragments in the lowland phase.

The type exposure of Buchanan gravel occurs at the gravel pit of the Illinois Central railroad, in the northwest quarter of section 32, Byron township. Here the deposit is about twenty feet in thickness. It consists of stratified, often cross-bedded, sands and gravels, with many bowlders, six, eight, ten or twelve inches in diameter. A very large proportion of the bowlders show unabraded, glacial-planed surfaces which would indicate that if they had been transported by current action for any considerable distance, they were not rolled but probably had been carried by floating ice. In some parts of the pit the gravels are very ferruginous and weather-stained. Many of the granite bowlders are completely decayed and crumble to sand on the application of very slight force. The gravel rests on typical Kansan blue clay and is overlain by yellow Iowan till which varies from less than a foot in thickness at the western end of the exposure to more than six feet at the extreme eastern end. Two facts are at once apparent; first, the gravel is interglacial in position; second, it is very old as compared with the overlying Iowan till. The characteristics and relations of the gravels at this type locality are illustrated in Plates xvi and xvii.

A very fine exposure of Buchanan gravel is seen in a large pit worked for road material near the northeast corner of section 4, Liberty township. In some respects it is better than the type exposure east of Independence. The oblique bedding, the complete oxidation, the ferruginous characteristics, the deep red color, the decay of the granites, in short, all the distinctive features of this deposit, are exhibited in remarkable perfection. The line of division between the gravel and the overlying Iowan drift is also well shown, and at the south side of the pit there are yet remnants of the interglacial soil bed. The lower ten feet of the exposure is made up of coarse, cross-bedded sand which is sharply defined from the still coarser gravel which constitutes the upper part of the deposit. The decayed granites are most conspicuous in the gravelly portion of the bed, and associated with them are numerous planed bowlders and bowlderets. It is a general rule, illustrated at practically all the exposures of the

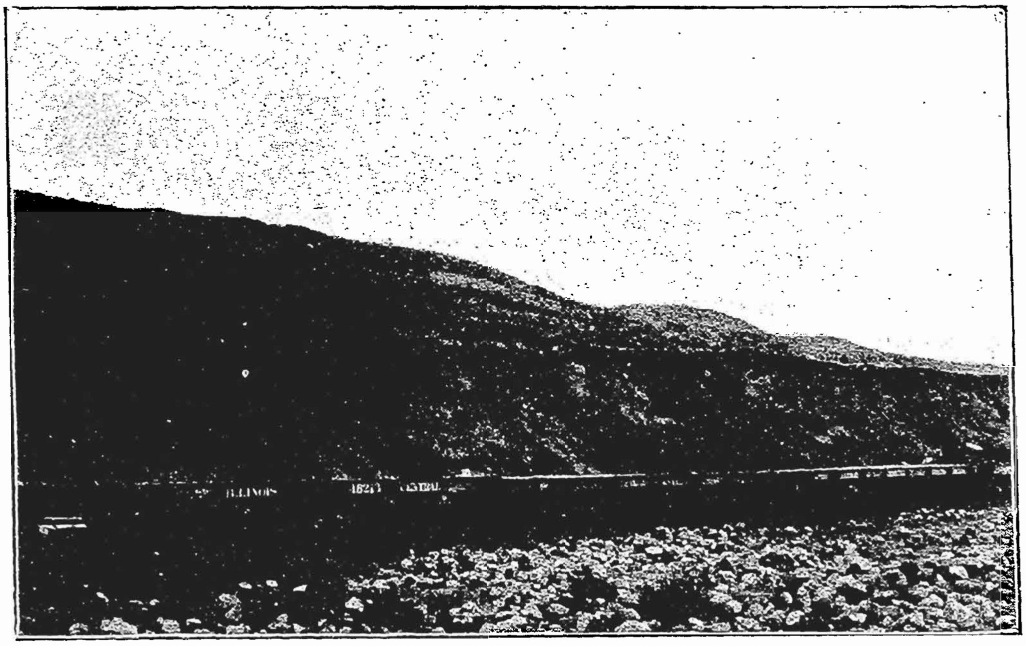


FIG. 1. General view of the typical exposure of Buchanan gravels. Illinois Central gravel pit.

FIG. 2. Nearer view of the typical exposure, showing Iowan drift above the gravel.

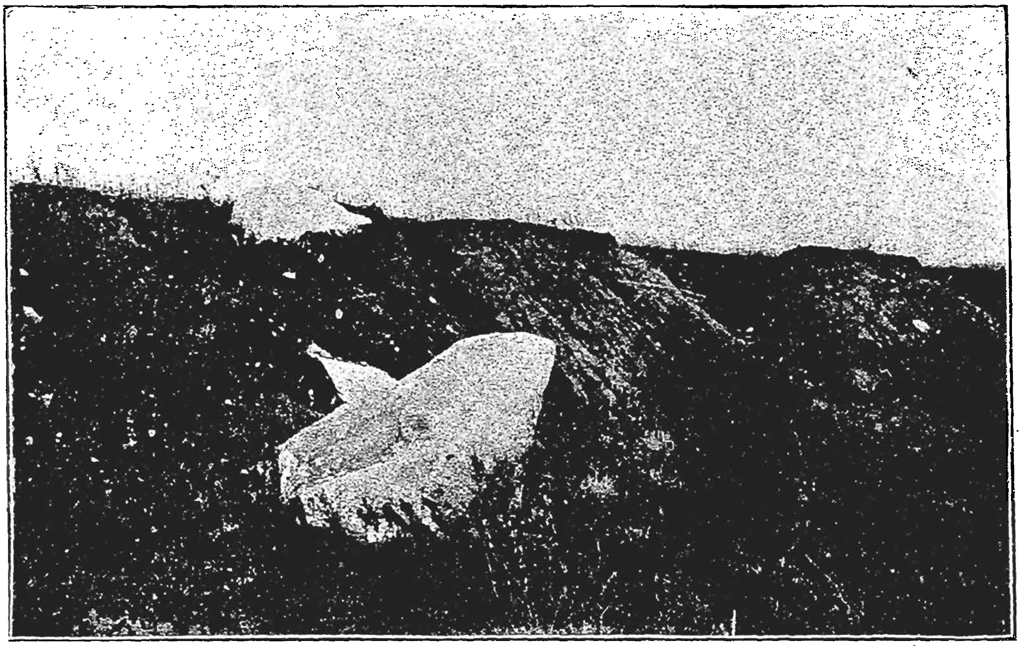


FIG 1. An abandoned part of Illinois Central gravel pit. Stratification is obscured by rain wash. A bowlder belonging to the Iowan stage is perched on the margin of the pit, and others, having been undermined, have fallen to the bottom of the excavation.

FIG. 2. Field immediately north of the Illinois Central gravel pit, showing large numbers of Iowan bowlders.

FIG. 1. Buchanan gravel overlain by Iowan drift, two miles west of Winthrop.

FIG. 2. A nearer view of part of the Winthrop gravel pit, showing coarse material above stratified sand. This is a typical exposure of the upland phase of the gravels.

beds under consideration, that the coarser material occurs in the upper part of the deposit. This exposure is illustrated in Plate xviii, Figs. 1 and 2.

Another excellent exposure of Buchanan gravel occurs west of the center of section 33, Perry township. A large pit is worked for material which is used in improving the streets of Jesup. A thickness of eighteen feet is exposed. The gravel is overlain by a very small amount of Iowan drift. The exposure shows all the usual characteristics of stratification, oblique bedding, ferrugination, oxidation and granitic decay.

About a mile east of Independence there is a heavy bed of Buchanan gravel presenting all the usual characteristics. It is overlain at one point by two and a half feet of Iowan drift. This deposit is remarkable for the fact that it occurs on the highest ground between the Wapsipinicon and the Buffalo. At one point the bed has been worked extensively for road material, but the gravel covers the whole hilltop over quite a large area. The overlying drift in general is thin, and even the Kansan drift beneath the gravel is very scant. The beds at this point illustrate well the upland phase of this formation. It is the upland gravel that occurs in the pit east of Jesup, and the same phase of the gravel forms a sharp ridge in the northeast quarter of section 11, Madison township.

The region about Rowley is well supplied with gravels belonging to the Buchanan stage, as will be seen by consulting the geological map of the county, and there is an extensive area underlain by these gravels in the eastern half of Fairbank township.

The valley phase of the Buchanan gravel is seen in terrace-like deposits that follow Buffalo creek in Byron and Madison townships, as well as the valley of Pine creek in the western part of Byron. The best illustrations of this phase, however, are found along the Wapsipinicon river between Littleton and Independence.

Gravel is found over an area from half a mile to a mile and a half in width east and southeast of Littleton, and it is continued in a belt of varying width all the way to Independence. It extends up the valley of Harter creek for at least two miles. There are a number of pits, showing well the character of the deposit, in the southwest quarter of section 27, Washington township, and there are natural exposures on Harter creek, in the northeast and northwest quarters of the same section. The deposit here, as is general in the valleys, is made up of sand and fine gravel. These valley gravels are not as ferruginous, nor are they as highly colored, as those on the highlands; but the Iowan bowlders sprinkled over the surface, and the thin layer of Iowan drift overlying the deposit, leave no doubt as to the practical contemporaneity of the upland and lowland phases. Absolute contemporaneity is not assured, for when the upland gravels were depositing, the valleys were probably filled with ice. The lowland gravels of this locality were not laid down until after the Kansan ice had left the valleys, and the general ice margin had retreated some distance to the north or northwest. The upland phase was produced by transportation and deposition in vigorous currents in close proximity to the margin of the melting ice; the valley phase shows the effect of currents that have lost much of their original impetuosity and disposed of the coarser materials with which they were at first loaded. Deposition in connection with the valley phase took place at points more remote than in the case of the upland gravels, from the edge of the retreating ice.

IOWAN DRIFT.

The Iowan drift is the superficial deposit over the greater part of Buchanan county. Since this drift was laid down the surface has been modified to only a very slight extent. The general aspect of a region covered with drift of Iowan age is typically displayed in Cono, Homer and Westburg townships, southwest of the Wapsipinicon river, and in Middlefield, Fremont and Byron, northeast of this stream. The surface is

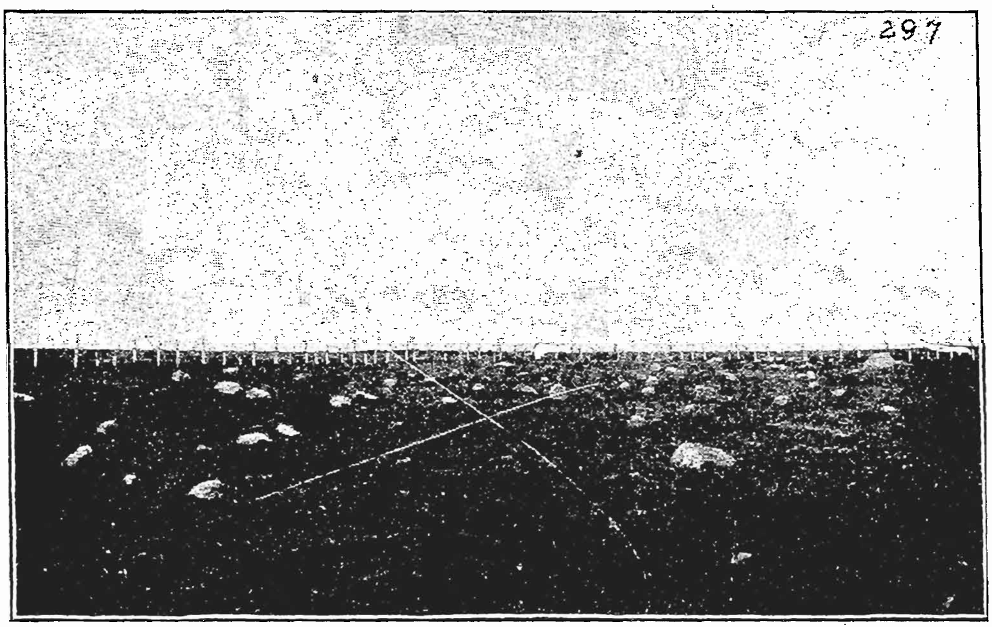


FIG. 1. A characteristic field strewn with Iowan bowlders, in the northern part of Newton township.

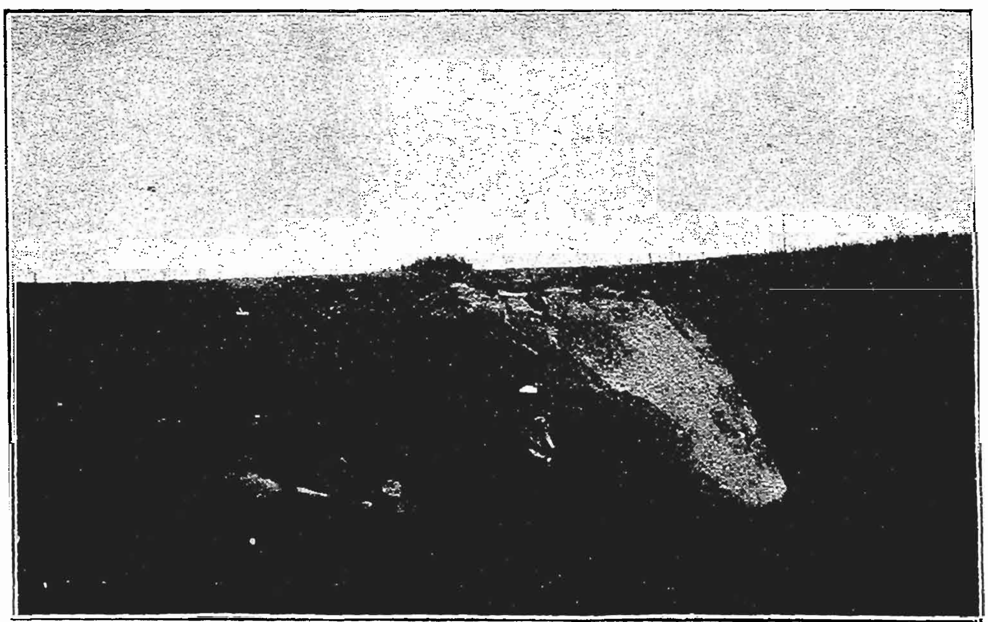


FIG. 2. An Iowan bowlder of medium size, showing effects of weathering.

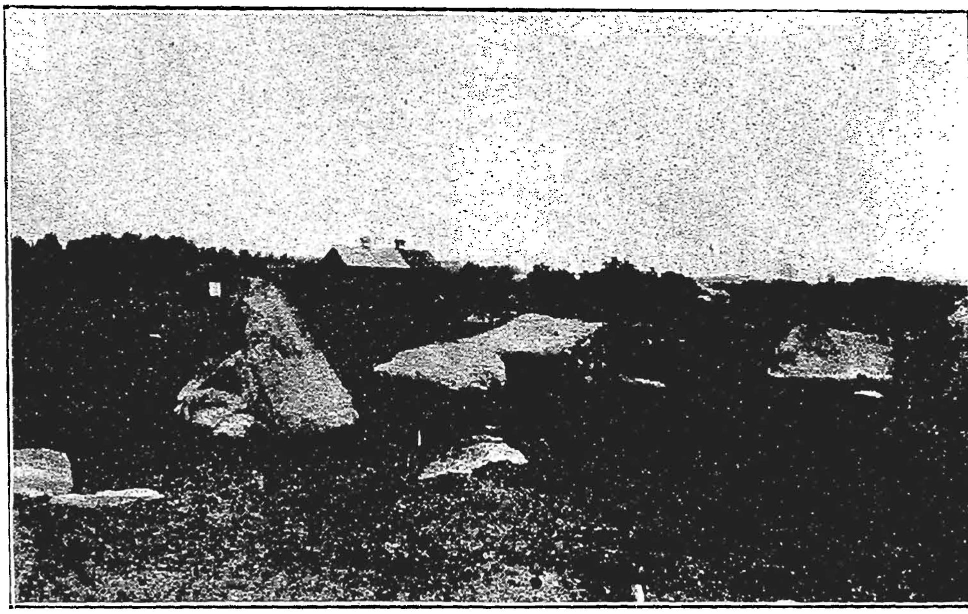


FIG. 1. Group of large Iowan bowlders, southeast of Winthrop.

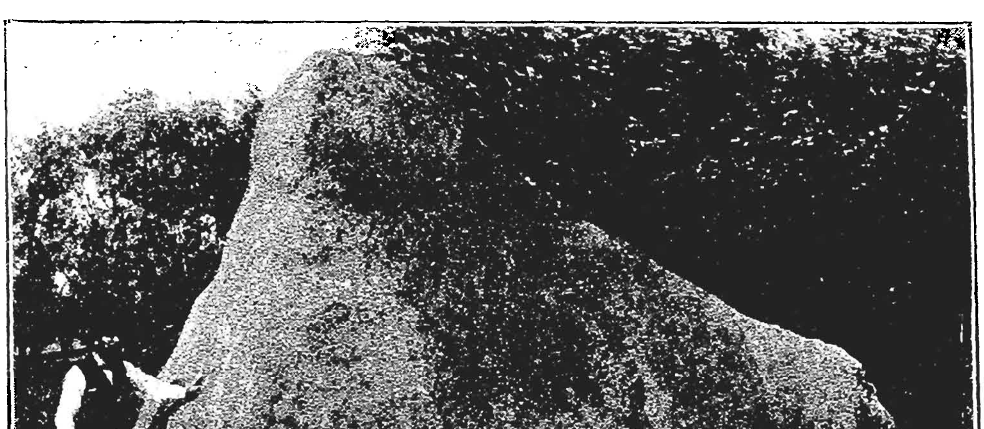


FIG. 2. Large Iowan bowlder near the center of Newton township.

very gently undulating and is liberally sprinkled with enormous granite bowlders. Bowlders ten, fifteen or twenty feet in diameter, and standing conspicuously above the general surface, are common features of the prairie landscapes, and great granite masses, thirty feet in diameter, are known at several points. Multitudes of smaller bowlders, ranging from one to two or three feet in diameter, are a serious encumbrance in many fields and pastures (Plate xix, Figs. 1 and 2).

The main body of the Iowan drift is a yellow, highly calcareous clay. It shows no such differences between the superficial and deeper portions as does the Kansan. It has remained, even at the grass roots, practically unchanged by weathering since its deposition. The great stretches of undulating prairie without marked drainage courses remain unaffected by the agents of erosion. As compared with the Kansan drift or the Buchanan gravels, the Iowan is very young, the time since its deposition being evidently only a very small fraction of the length of the interval between the disappearance of the Kansan ice and the appearance of the Iowan.

The maximum thickness of this drift sheet is unknown. It was evidently deposited on a deeply eroded surface, and it is, therefore, very thin over the pre-Iowan hilltops and deeper in the pre-Iowan valleys. Railway cuts, which of necessity are limited to the higher ridges, usually, in Buchanan and adjacent counties, show only a thin veneer of Iowan drift resting on weathered Kansan. In the big railway cut east of Oelwein in Fayette county, the Iowan stage is represented by a layer of loamy soil less than a foot in thickness, while in the eastern part of Fairbank township, Buchanan county, the farm wells show at least thirty feet of Iowan till overlying highly oxidized beds of Buchanan gravel.

LOESS.

Loess is rather rare in Buchanan county, the deposits of this material being of small importance when compared with the widely spread beds of the same material in Dubuque, Delaware and Jones counties. In Buchanan, true loess seems to be limited to some high points north of the Wapsipinicon river in sections 28, 29 and 30 of Liberty township. While the loess here is typical in character, its thickness is not very great. It mantles an irregularly eroded surface that rises from sixty to eighty feet above the level of the Iowan drift plain. Rain erosion in the fields and roads has, in places, cut through the entire thickness of the deposit and revealed the underlying Kansan drift with its peculiar bowlders and characteristically weathered surface. There is no Iowan drift on these loess-covered highlands.

A light colored sandy clay, resembling some phases of the loess, is seen in sections 27 and 34, Fairbank township, and a similar deposit occurs at a number of points in sections 26 and 27 of Liberty township. The thickness of the material at the points last named does not exceed two, or two and a half feet. The arenaceous clay appears in some localities to grade into beds of sand of varying thickness. The stretch of sandy road, on the main line of travel between Quasqueton and Independence, passing through section 20 of Liberty township, is an illustration in point. At a certain altitude there are beds of sand; a little higher the sand gives place to an arenaceous loess; and on the highest points of the region the deposit, as already described, becomes a true loess, a fact well illustrated in section 29 of Liberty township.

POST-GLACIAL DEPOSITS.

But little change has taken place in the surface of the county since the retreat of the Iowan ice, the date from which the postglacial history of the county should be reckoned. Some alluvium has doubtless been deposited along the stream valleys during times of high water, but in most cases it is too thin to be differentiated from the loam which has been developed on the surface of the Iowan drift by the numerous agents concerned in soil-making. In the deep preglacial valleys that have been mentioned as occurring at a few points along Lime creek and the Wapsipinicon river, there are some beds of alluvium, but they are thin, small and unimportant.

In the county there are a few rather anomalous peat bogs which present the unusual phenomenon of being higher than the dry ground in the immediate neighborhood. One on land of Mr. B. Stoner, in the northwest quarter of section 13, Perry township, is typical of all the beds of the kind observed. The peat is coarse and fibrous, with a total thickness of eight or ten feet. The bed occurs on a long, gently sloping hillside and in the center is several feet higher than the dry ground at the right and left. The area covered is small. The surface supports a luxuriant growth of coarse sedge or slough grass. A similar peat bog on relatively high ground was seen in the southwestern part of section 19, Newton township, and there is another in the southwest quarter of section 8, Hazelton township. The location of the peat beds has been determined by the presence of springs or "seeps" issuing from the drift on the hill slope.

Soils.

Soils, in the narrower sense which limits the term to the fine dark colored loam developed on the surface of the loose, superficial materials, are generally, throughout the county, of postglacial origin. Soils vary with the nature of the deposit from which they are derived. Drift soils are most common in the county under consideration, and practically all of the drift soils are developed on the Iowan till. This class of soils is from six inches to two or three feet in depth, dark in color on account of its wealth of organic matter, more or less sandy, warm and easily cultivated. Such soils contain a considerable amount of lime carbonate that, added to the vegetable matter with which they are so richly endowed, renders them capable of producing crops of cereals for many successive years without showing signs of exhaustion. The small area of loess soils in sections 28, 29 and 30, of Liberty township, has recently been stripped of its timber and brought under cultivation. The results are more satisfactory than in many other areas of similar soils where the slopes are steeper* and the effects of rain erosion are more pronounced. There are small areas of gravelly and sandy soils along the stream valleys, the largest being found north and northwest of Independence.

Deformations.

The anticlinal fold to which reference was made in discussing the Niagara limestone, is the principal disturbance of which there is clear record in Buchanan county. There are some slight folds, probably, however, due to inequalities of deposition, in the Devonian strata. At Brandon there is an example of a short buckling of some of the beds as shown in Plate, xiv Fig. 2.

Unconformities.

The Devonian beds are evidently unconformable on the sloping side of the Niagara anticline in the vicinity of Fairbank, and the relations of the several Pleistocene deposits to each other, and to the indurated rocks on which the lowest drift sheet lies, afford other illustrations of unconformity.

ECONOMIC PRODUCTS.

Building Stone.

Building stone is quarried in a small way at the exposures of Niagara limestone in sections 18 and 19 of Madison township and section 13 of Buffalo. The Devonian limestone is worked for building material more extensively than the Niagara, but there are no quarries in the county that attempt more than to supply local demands. The great number of small quarries around Independence has been referred to in connection with the description of the Fayette formation. The stone is rather soft, not well bedded, and a large part of

*See description of loess soils in reports on Delaware, Jones and Johnson counties.

it yields in the course of a short time to the effects of the weather. A harder, and generally better, quality of stone is found in equivalent beds along Pine creek, in section 21, Liberty township, and in sections 33 and 34, Newton township.

The Gemmel quarry near Quasqueton is operated in beds that include the horizon of *Acervularia davidsoni*, in the Cedar valley limestone. The stratification is more regular, and the stone is harder and more resistant to weather than in the quarries in the Fayette stage near Independence. It is the same horizon and essentially the same quality of stone that is represented in the Kenyon and Lown quarries southeast of Jesup. With only one or two exceptions, the many small quarries along Lime creek, near Brandon, are worked in the Cedar valley limestone, and the product is similar to that from the quarries near Quasqueton and Jesup. In the northern part of the county, at the Fairbank quarry, this horizon furnishes stone in thicker and more regular beds, and the quality on the whole is better.

The quarry stone horizon above the beds containing *Acervularia davidsoni* is represented in the Schreier quarry in the southeast quarter of section 33, Fairbank township, and in the Jesse quarry in the southwest quarter of section 4, Perry township. The formation at this horizon consists of an earthy, soft, yellowish limestone in rather regular layers which range from two to eight inches in thickness. The layers are cut by nearly vertical joints at intervals of from two to eight feet. The stone hardens on exposure, and is not easily affected by the weather. The quarries named are capable of furnishing an indefinite amount of good building stone.

Another source of building stone is found in the great number of granite bowlders sprinkled over the surface. These all belong to the Iowan drift and were transported and deposited by the Iowan ice sheet. Many of the larger bowlders have been reduced to blocks of convenient size by the methods employed in granite quarries, and many of smaller size have, one by one, been dressed into proper shape with the hammer.

All the important bridge piers of the county are constructed of heavy blocks of granite. Foundations for the great mill and other important buildings at Independence are of cut granite obtained from Pleistocene bowlders in the immediate neighborhood. Granite derived from local bowlders was used in the foundations of the hospital for the insane; small granite bowlders just as they are gathered from the fields have been used extensively on the farms as foundations for barns and dwelling houses. Granite quarried from Pleistocene bowlders was at one time exported from Independence on quite a large scale, some of the great blocks being used in the foundation of the state capitol at Des Moines. The supply of granite for building purposes is practically inexhaustible, and the quality of the material is unimpeachable. The appearance and relative size of some of the large bowlders are illustrated in Figs. 1 and 2, Plate xx.

Lime.

At present there is scarcely any lime produced in Buchanan county. Kilns have been operated at Independence, Quasqueton and other points within the area of Devonian outcrops, and in section 19 of Madison township, lime was made from the Niagara limestone. Imported lime has of late years supplanted the local product.

Brick Clays.

Clays suitable for the manufacture of brick occur at a number of points in the county; those most generally distributed belonging to the Iowan drift. The fine yellow clay of Iowan age, with proper treatment, will make brick of superior quality; the difficulty experienced in working it is due to the pebbles and small bowlders with which it is charged. There are portions of the drift, however, from which bowlders and pebbles are absent. The favorable conditions, it is true, are not always present in convenient localities, and it is to this fact that the practical abandonment of brick making in the county, of late years, is probably due.

The pebbleless, loess clay on the highlands west of the mouth of Pine creek in Liberty township, might be used advantageously, and it would make brick of excellent quality, if only enterprise and capital found sufficient encouragement to justify the construction of a plant. A fine quality of pressed brick might be made from the clay in question. So far as known no effort has been made to utilize this important deposit.

Coal.

Several times during the past years there has been more or less interest aroused over the reported discovery of coal. These reports have come from various points in the county and were all based on the fact that borings or excavations had penetrated the Independence shale. In certain localities this shale is black and carbonaceous; it even contains small particles of coal associated with pyritized stems of terrestrial plants; but nowhere does the deposit contain anything of commercial value. The people should bear in mind that the rocks of the county are all older than any productive coal measures. Furthermore, the deeper lying rocks are older than those at the surface, and so, contrary to a popular notion very generally held and expressed, the deeper the boring or excavation the more hopeless becomes the search for coal.

The Independence shale was penetrated by Mr. Kilduff in a pit near the present O'Toole quarry, east of Independence, in a well near Jesup, and again in an excavation near the mouth of Pine creek, in Liberty township.

Road Materials.

In solving the problem of good roads for Buchanan county the Buchanan gravel, with which the region is so generally and so bountifully supplied, will be recognized as a factor of the first importance. Gravel beds occur within convenient hauling distance of almost every neighborhood, and the supply is sufficient to put every foot of clayey and boggy road in the county in excellent condition. The gravels have been already used to good purpose in making street and road improvements in and around Independence, Winthrop and Jesup, and many stretches of country roads that were formerly, at times, impassable have been greatly benefited by the application of this material. But as yet the work is scarcely begun, and the splendid resources of the county in respect to materials for road improvement have scarcely been touched.

The sandy roads will require different treatment. Some of the longest and worst stretches of sand are conveniently located with reference to the loess-covered area in Liberty township, and loess clay over sand produces excellent results. There are sandy roads near Independence in proximity to a number of quarries from which crushed stone might readily be obtained. This material alone, however, would probably not last well, for the stone from the Independence quarries is rather soft and would soon be ground into fine, calcareous dust under the wheels of ordinary travel and traffic. But the region is well supplied with gravel as well as with limestone, and a foundation of stone, dressed on top with Buchanan gravel, will make a very serviceable and durable roadbed.

Water Supplies.

When the county was settled, near the middle of the present century, the streams, even of the smaller size, seldom failed throughout the year, and well water was found everywhere in the drift at depths ranging from five to forty feet. Within recent years the minor streams are dried up during midsummer, and permanent wells, as a rule, are only found after boring through the drift and from twenty to more than 200 feet into the underlying rocks. In some localities, as in the eastern half of Fairbank township, water supplies are still found at comparatively shallow depths in beds of Buchanan gravel. The city of Independence is supplied with water drawn from a bed of gravel by means of drive wells. The gravel is reached at a depth of from thirty to fifty feet. About seventy of these wells were used in 1896, and about 400,000 gallons were pumped daily to supply the demand. The pumps had a capacity of 500,000 gallons a day.

At the residence of Adelbert Smith, near the northwest corner of section 22, Buffalo township, there is a flowing well which furnishes a constant stream an inch in diameter. The well is 152 feet in depth; it ends at the rock, in a bed of gravel which lies beneath blue clay of Kansan age. Another well on the place, not flowing, however, is twenty-five feet deep and penetrates a bed of Buchanan gravel.

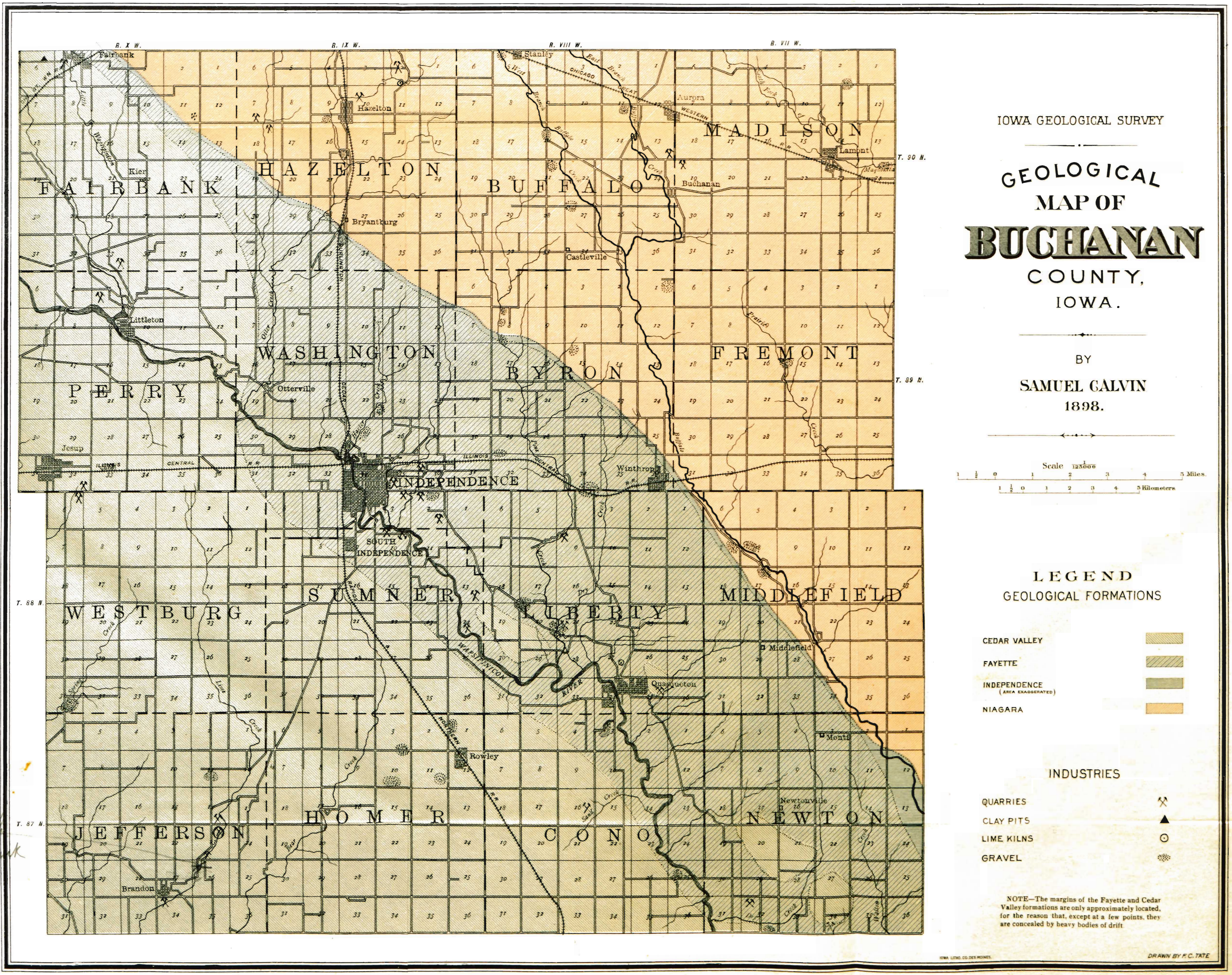
The well records show that the surface of the rock upon which the unconsolidated drift and other superficial materials lie, is very uneven. The preglacial surface had its hills and valleys, and the relief was much greater than that exhibited by the present surface. The known thickness of the Pleistocene deposits varies from zero, where the indurated rocks appear at the surface, to 215 feet in section 4 of Buffalo township.

Water Powers.

There are water powers developed along the Wapsipinicon river at Fairbank, Littleton, Independence and Quasqueton. The most important is that at Independence. There is here a large, expensively equipped flouring mill, which utilizes about 200 horse power. The Kiefer Brothers' mill near Hazelton is on Otter creek. It has a head of twelve feet and uses at times more than 100 horse power. Another mill on Otter creek is located at Otterville.

ACKNOWLEDGMENTS.

The writer acknowledges his obligations to all who generously aided in the collection of the facts embodied in the foregoing report. To D. S. Deering in particular he is very greatly indebted. He is indebted also, for many favors, to Hon. Henry J. Griswold, and Hon. Merrit Harmon. But the list is too large to name each individual separately. All requests for information or assistance met a generous and hearty response.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF BUCHANAN COUNTY, IOWA.
BY SAMUEL CALVIN 1898.
Scale 1/125000
Miles
Kilometers
LEGEND
GEOLOGICAL FORMATIONS
CEDAR VALLEY
FAYETTE
INDEPENDENCE (AREA EXAGGERATED)
NIAGARA
INDUSTRIES
QUARRIES
CLAY PITS
LIME KILNS
GRAVEL
NOTE—The margins of the Fayette and Cedar Valley formations are only approximately located, for the reason that, except at a few points, they are concealed by heavy bodies of drift.
IOWA LITHO. CO. DES MOINES.
DRAWN BY F. C. TATE
R. X W.
R. IX W.
R. VIII W.
R. VII W.
T. 90 N.
T. 89 N.
T. 88 N.
T. 87 N.
FAIRBANK
HAZELTON
BUFFALO
MADISON
WASHINGTON
BYRON
FREMONT
PERRY
WESTBURG
SUMNER
LIBERTY
MIDDLEFIELD
JEFFERSON
HOMER
CONO
NEWTON
Fairbank
Hazelton
Stanley
Aurora
Lamont
Buchanan
Kier
Bryantburg
Castleville
Littleton
Otterville
Jesup
Independence
South Independence
Winthrop
Middlefield
Quasqueton
Monti
Rowley
Newtonville
Brandon
Wapsipinicon River
Buffalo Creek
Chicago Great Western R.R.
Illinois Central R.R.

GEOLOGY OF DECATUR COUNTY.

BY

H. F. BAIN.

GEOLOGY OF DECATUR COUNTY.

BY H. F. BAIN.

CONTENTS.

INTRODUCTION.

Decatur county lies in the southern tier of counties, almost midway between the Mississippi and Missouri rivers. Ringgold bounds it on the west, Clarke on the north, Wayne on the east, and Harrison and Mercer counties, of Missouri, on the south. In area it includes 528 square miles, with some fractional pieces of land, the total being 343,910 acres. The townships run from 67 to 70 north, the southern tier being fractional, and the ranges from XXIV to XXVII west. The county is, as usual, divided into sixteen civil townships.

To the geologist Decatur county is of especial interest, because of the fact that running through it is the heavy limestone which forms the base of the Missourian series and which derives its interest to the economist from the fact that it divides the productive from the unproductive coal measures. This limestone, or assemblage of separate limestones, is known as the Bethany or Bethany Falls limestone, a name first used by Broadhead. In Iowa the exposures have been mainly studied are in the vicinity of Winterset, and to the strata at that point White gave the name of Winterset limestone. The beds outcropping at Bethany, Mo., and Winterset, Iowa, have for some time been believed to be identical, and the actual continuity of the two has, in fact, been recently proven. Between the two points mentioned, however, no detailed sections have been published, and it was mainly to supply this lack that the study of Decatur county was taken up at this time.

Previous to the present survey White seems to have been the only geologist who had worked in the county. His notes* include sections at a few points along Grand river and its tributaries, but the short time allowed for the work precluded anything like a detailed study of the area. The adjoining counties of Iowa were also described by him in the report cited. In Missouri, Harrison and Mercer counties, which

*First and Second Ann. Repts. State Geologist, pp. 42-43. 1868. Also Geology of Iowa, vol. I, pp. 318-327. 1870.

adjoin Decatur on the south, have been visited by various members of the Missouri Geological Survey. The earliest notes are those of Swallow, descriptive of certain fossils collected in Harrison county.* The coal beds of both counties are noted by Winslow.† The character of the surface deposits are noted by Todd,‡ and the altitudes and topography discussed by Marbut‖. Broadhead has also published notes on the coal measures of the region, which will be more particularly referred to in the body of this report.

PHYSIOGRAPHY.

TOPOGRAPHY.

Decatur county lies well up on the Mississippi-Missouri divide. The streams belong to the Missouri river system, but the country belongs rather to the high land between the rivers than to the Missouri valley proper. It is a broad, even, but much dissected plain, with little or no slope, and includes the northern continuations of the Warrensburgh platform and the Lathrop plain, defined by Marbut.§ In the country under discussion the two physiographic areas are not very distinct. The influence of the drift seems to have been such as to obscure the divisions which here may perhaps never have been so sharply defined as farther south. In a general way it is true that as one passes west from the Des Moines to the Missouri river the ascent is made by a series of steps. This is shown by the profile of the main line of the Chicago, Burlington & Quincy railway. This road runs across the drainage lines of the region and accordingly crosses a series of intermediate upland stretches. These bits of upland are approximately level but stand successively higher toward the west. The divide between the Des Moines and the Chariton runs from Maxon to Albia at 959 A. T. and is about 300 feet above

*Trans-St. Louis Acad. Sci., vol. II, pp. 81-101. 1863.
†Missouri Geol. Surv., vol. I, p. 99. 1896.
‡Missouri Geol. Surv., vol. X, pp. 143-181. 1896.
‖Missouri Geol. Surv., vol. VII, pp. 225-316. 1895. Ibid, vol. X, pp. 45-49. 1896.
§Missouri Geol. Surv., vol. X, pl. ii. 1896.

Ottumwa. The second upland is almost level from Russell, 1,037, to Chariton, 1,042; being 90 feet above the plain just mentioned. The third upland, from near Brush to Murray, has a slight rise to the west, being at Osceola, 1,132, and at Murray, 1,216. West of Murray the railway dips down into the valley of Grand river, just touching the level of the top of the Bethany limestone (1,051) at Afton Junction. At Creston, 1,312, it is again on an upland which extends with slight slope to Hillsdale, 1,189, not far below the crest of the Missouri river bluffs. Into this latter plain the Nishnabotna and Nodaway rivers have cut 200 to 250 feet, while the Missouri bottom land at Pacific Junction lies at 962 A. T.

From Creston west to the edge of the Missouri valley there is a long gentle slope not broken by marked escarpments. To the east the country first drops down to the Osceola platform, 1,132 A. T., and then by a further drop of about 100 feet to the Chariton platform. The Albia platform lies about 125 feet still lower and from there the slope to the Des Moines is gentle. At Chariton, Osceola and Creston there is a great thickness of drift. At Chariton, as shown by drill holes, the rock is found at 882 to 897 A. T. At Osceola the top of the limestone quarried northwest of town lies 140 feet below the railway station. At Creston there are no exposures and the drift is known to be very thick. The nearest exposures lie 260 feet below the level of the town. The rock then, rises between Chariton and Osceola from 882 to 1,092 feet, while from Osceola west present evidence seems to indicate that it maintains an approximately even surface. This would apparently indicate that in preglacial time the Bethany limestone formed in Iowa, as it does now in Missouri, a marked escarpment. The distribution of the drift, however, is such that this escarpment is almost wholly concealed.

The major portion of Decatur county, being underlain by the Missourian, would belong to Marbut's Lathrop plain. The portions of the Warrensburgh platform penetrating the county are confined to the river valleys, and hence form but an insignificant fraction of the whole. It is the general upland plain which is most obvious as one travels through the county. The valleys are all clearly erosional and the roughness encountered when one descends from the upland is indicative of the completeness with which the streams have dissected the area.

The major streams of the county have a north-south direction. Their tributaries follow the main streams and do not usually travel from far to the east or west. The result is that the original upland plain has been cut by a series of long relatively narrow river valleys with high narrow ridges between. The resulting topography was quite fittingly described by the early settlers who spoke of the region as the "devil's wash board." An east-west traveler must cross a series of alternating ridges and valleys. The north-south traveler may usually find a ridge road. From the latter, looking off over the country, the tops of the successive flat-topped ridges appear rising to an even surface and restoring the old plain in which the valleys have been carved.

By examining the following table of elevations the position of this plain can be understood. Weldon and Van Wert, 1,147, are upon the upland. Leroy, 1,107, and Garden Grove, 1,114, occupy similar positions. Lamoni, 1,126, and Tuskeego, 1,175, in the southwest are on divides which form a portion of the plain. Decatur City near the center of the county, at 1,111, is also on the plain. De Kalb, 947, Grand River, 957, and Davis City, 914, are all on flood plains. Blockley, 1,042, and Leon, 1,025, are on partially dissected land. Pleasanton, 1,173, on the extreme southern line of the county, again marks the upland. The differences in these upland levels are not important and may be to a limited extent due to errors arising from comparing different surveys. On the whole they indicate a very even surface with little, if any, slope.

For convenience of reference these elevations are put in tabular form.

Table of Elevations.

STATION.	AUTHORITY.	FEET.
Blockley	D. M. & K. C. Ry	1,042
Cainsville (Mo)	D. M. & K. C. Ry	936
Davis City	C., B. & Q. Ry	914
Decatur City	D. M. & K. C. Ry	1,111
De Kalb	H. & S. Ry	947
Garden Grove	C., B. & Q. Ry	1,115
Grand River	H. & S. Ry	957
Lamoni	C., B. & Q. Ry	1,126
Leon	D. M. & K. C. Ry	1,025
Le Roy	K. & W. Ry	1,107
Pleasanton	D. M. & K. C. Ry	1,173
Tuskeego	C., B. & Q. Ry	1,175
Van Wert	K. & W. Ry	1,147
Weldon	K. & W. Ry	1,147
Westerville	K. & W. Ry	987

DRAINAGE.

The streams of Decatur county are all tributary to Grand river, which flows into the Missouri in Chariton county, Mo. Grand river itself has two main branches coming together near Chillicothe. The eastern fork alone penetrates Decatur county, though certain of the tributaries of Big creek, which is independent of this eastern fork, tap the southwestern portion. It is the eastern branch of Grand river proper which is known in Iowa as Grand river. In Missouri, when the term is used without qualification, the western or the united stream is usually referred to. Grand river in Iowa is an important stream having its headwaters in Adair county and crossing Madison, Union, a corner of Ringgold, and the western part of Decatur county. As far south as Afton Junction in Union county there is no reason to believe that the stream is preglacial. Throughout its course in Decatur county it is quite certainly older than the Kansan drift, since the latter is found undisturbed in its valley while the rocks rise in the hillsides a considerable distance above the flood plain. It has a broad valley whose width is suggested by the outline of the Des Moines formation where the river has cut through the Bethany. From Terre Haute to Davis City the Des Moines area shown on the map outlines the bottom land. It will be noted that the river runs close along the south bluff, where it has an east-west trend. On the north the slope is long and gentle and the bottom land is broad. The south bluff is abrupt, rising in section 28 of Burrell township, 140 feet above low water. This is true again north of Westerville, where the south bank of the river is a sharp bluff, while the north side of the valley shows a long, gentle slope. Where the stream runs from north to south it shows no especial predilection towards either bank.

This tendency of east-west streams in Iowa to run along their southern bank has been noted by McGee,* Tilton† and Calvin.‡ The latter has suggested that it is due to the greater activity of weathering agencies upon a southward facing slope. McGee was evidently inclined to consider the phenomena as due to structural agencies. In Decatur county, however, there is no evidence of structural peculiarities adequate to account for the phenomena, and its almost universal presence throughout southern Iowa, regardless of the character of the rocks which the stream may be eroding, seems warrant for the conclusion that the climatic cause suggested by Calvin is a true one. The phenomena cannot be due to individual tilted blocks of strata, as suggested by McGee, and any other structural agency competent to the task could only be a prolonged uplift to the north, which would induce a migragation of the divides toward the uplift, as has been shown by Campbell.§ This would account for the larger number and longer course of the tributaries flowing from the north into an east-west stream, but would hardly account for the marked difference in the slopes of the valley sides proper. It is probable that while uplift to the north has been a potent factor in providing the phenomena, the climate factor is also to be taken into account.

*Eleventh Ann. Rept. U. S. Geol. Surv, Pleistocene Hist. N. E. Iowa, p. 412. 1891.
†Iowa Geol. Surv., vol. V, p. 307. 1896.
‡Iowa Geol. Surv., vol. VII, pp. 49-50. 1897.
§Jour. Geol., vol. IV, p. 567, 657. 1896.

That Grand river in this portion of its course is an old stream will be readily believed by anyone familiar with this valley. The size of the latter, and the fact that much of it is cut in rock, is alone convincing. The distribution and character of its tributary drainage lines afford additional proof. Still further evidence tending to prove its great age may be adduced from the great bend in the river in the northwest portion of Burrell township. (See Fig. 1, Plate xxi). This has originated as an upland meander and has been cut through the Bethany down to the Fragmental limestone. It is characteristically developed, but the tongue of rock running out into the bend has been very largely cut away. Only a low spur protrudes from a high bluff at the base of the bend. Such a spur would, in any case, be short lived, as it is exposed to vigorous erosion on three sides, but the fact that it has here been almost completely cut away, seems to be of more than usual significance. Upon Middle river, in Madison county, and Raccoon river, in Guthrie county, as well as on other rivers which cross the Bethany escarpment, upland meanders are well developed,* but in no case is the rock tongue so much eroded as in the Decatur county example. Here it has been so nearly cut away that at first it was thought to be absent. Upland meanders are developed by a long and slow process,† and where they have not only been developed, but almost destroyed, they indicate a considerable lapse of time. The meander and the stream valley are, of course, of later age than the peneplain, and they indicate that the time of stream cutting anterior to the drift was long, and that the peneplain is, relative to the drift, old. Further than that it seems impossible, at present, to fix its age.

Within the county the most important tributaries of Grand river are Elk creek from the west, and Long branch from the east. Both are important streams, cutting through the drift and into the rock. Exposures of Carboniferous are found

*Geol. Madison county, Iowa Geol. Surv., vol. VII, pp. 500-501. 1897.
†Marbut: Mo. Geol. Surv., vol. X, p. 98. 1896.

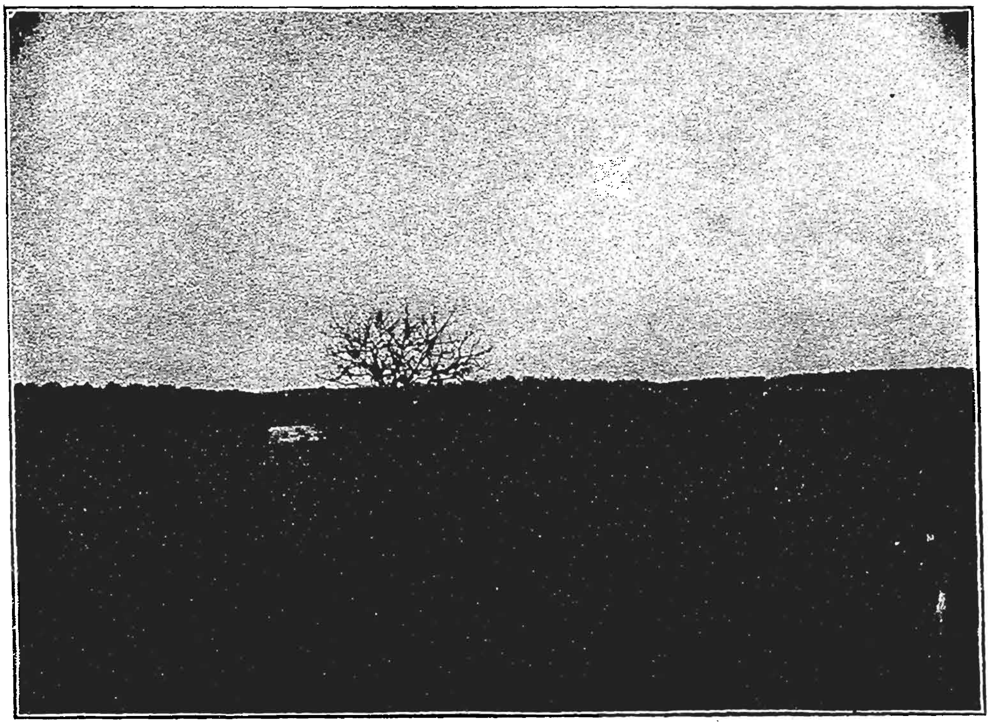


FIG. 1. View of Grand river bottom land, across the big bend in Sec 5. Burrell township, Decatur county.

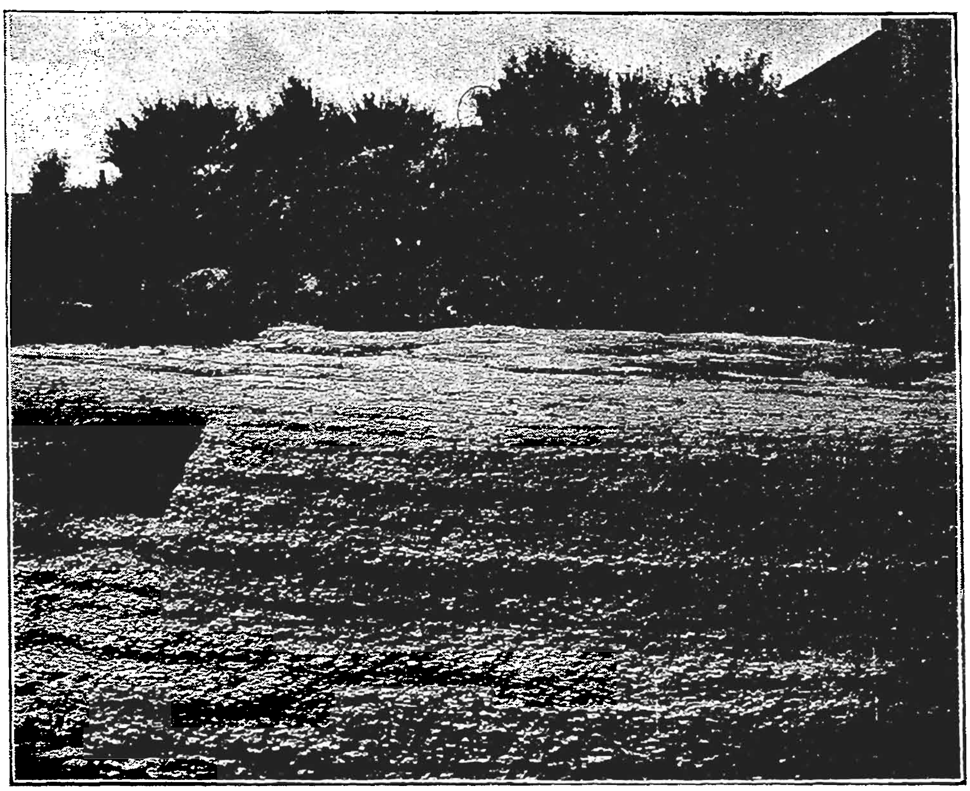


FIG. 2. Near view of Fragmental limestone, below mill, Bethany, Mo.

along the branches of Elk creek from sections 21 and 22 of Grand River township to the mouth, and along Sweet creek, a tributary, from section 23 of Bloomington township to the main stream. The minor tributaries show exposures for corresponding distances. Elk creek with its branches drains most of Bloomington and Grand River townships, but in addition to it Grand river receives from the west Sand creek near Westerville, Bad run near Grand river, Roaring branch and Russells branch between there and the north of Elk creek, Pot Hole creek or Potters branch near Terre Haute, Dickerson creek near Davis City, and some minor streams between that place and the Missouri state line. These streams with their tributaries reach out into all that portion of the county west of Grand river, except portions of Bloomington and New Buda townships and all of Fayette, which are drained by Shane and Seven Mile creeks, streams having courses through Big creek to the main branch of Grand river near Pattonsburg, Mo.

Long creek, with its tributaries, Bee and Wolf creeks, is the most important stream flowing into Grand river from the east. It receives Short creek near De Kalb, and at the latter place has cut 200 feet below the upland at Van Wert. There are rock exposures along the lower portion of its course.

Aside from Grand river there are two important rivers in the county, Weldon and Little rivers. Weldon river has its source in Franklin township and flows east through Garden Grove, and thence almost due south to the state line, receiving Jonathan, Brush and Steel creeks with Turkey run and List branch. Little river has its source near Van Wert and a course from there south past Leon, Blockley and Spring Vallay.

The streams of the county are almost entirely pre-loessial in age. Only the minor tributaries have had a later origin. The major streams, Grand river, Weldon river and probably Little river, are preglacial, or at least pre-Kansan. Some of the tributaries are perhaps as old as the main streams; but most of them are merely pre-loessial.

It seems probable that the preglacial drainage of the county was in outline quite similar to the present. In contrast with most of Iowa the present streams seem to be working on a lower level than that which obtained in preglacial times. They are cutting in the rock and usually show no important drift filling below low water. The bridges over Weldon river and Steel creek in Morgan, Woodland, and even sections 13 and 25 of High Point township, rest on rock or shale foundations. The same is true of the Little river bridges in Hamilton township and of the Grand river bridges as well as those over Long and Elk creeks. Yet in the valleys of Weldon, Little and Grand rivers there are places showing undisturbed drift down to low water level. The entire absence of great drift-filled channels in this region as compared with that farther east* would indicate that in later glacial times, and perhaps in the present, the surface of Iowa has been warped, the west rising more than that to the east. This is in accord with other observed phenomena.

The effect of the varing hardness of the underlying rocks upon present valleys is shown in the alternate widening and closing of their valleys, though the latter is probably also due in part to other agencies, as already suggested. The effect is also shown in the ponding of the streams as each of the members of the Bethany is crossed; phenomena first observed and described by White.†

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

The geological formations occurring in Decatur county fall into two series, differing widely in character, origin and age. The underlying rocks are indurated. They include principally shales and limestones, and record the time when what is now

* Proc. Iowa Acad. Sci., vol. II, pp. 23-26. 1895.
† Geol. Iowa, vol. I, pp. 318-320. 1870.

a portion of a beautiful prairie plain lay beneath the waters of the Carboniferous sea. They are the products of the destruction of an older land and were laid down by the action of marine agencies. Partially at that time and partially since, under the influence of circulating waters and slight pressure, they have been changed from relatively loose, unconsolidated sea deposits to the firm, hard rock now found.

Over these older rocks are the loose and unconsolidated gravels, sands and clays which form so common and conspicuous a feature of the surface. These are of very much later age than the indurated rocks, belonging indeed to the Pleistocene period, and have been in part deposited in present time. They are the product not of the sea, but of ice; an incursion of immense glaciers or a sheet of land ice, which spread over much of the northern hemisphere. In part these deposits were made by the ice itself, and in part by the waters from its melting. Some of the beds present were formed by the present rivers by ordinary processes, such as may even now be seen in operation. Some were laid down by waters of uncertain age and extent, and some perhaps by winds. The relations and ages of these beds are indicated in the subjoined table. Their distribution and character will be described later.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium
		Glacial.		Loess.
				Gumbo.
			Kansan	Drift.
			Pre-Kansan (?).	Drift (?).
Paleozoic.	Carboniferous.	Missourian.	Bethany.	Westerville (?).
				De Kalb.
				Winterset.
				Earlham.
				Fragmental.
		Des Moines.	Pleasanton.	

Carboniferous.

The Carboniferous of the Mississippi valley is divided into two major divisions long known respectively as the upper and lower. The latter does not occur within the county and its only importance in this connection arises from the fact that the St. Louis limestone, one of its members, forms the floor upon which the coal measures rest. In any future deep drilling for coal the St. Louis will indicate the horizon below which it is inadvisable to prospect.

The upper Carboniferous is commonly known as the coal measures, and the term Pennsylvanian series has been proposed to cover the same beds. In this immediate region it consists of two major members, known as the Des Moines and the Missourian, each divisible into subordinate groups. These correspond respectively to the lower or productive and to the upper or unproductive coal measures. Keyes has proposed* to consider each of these divisions as independent series; dividing the Carboniferous of the interior into the Mississippian, Des Moines, Missourian, and Oklahoman. While it is not certain that these different divisions are of strictly equivalent rank, and probably some include more than others, it is a great convenience in discussion and in mapping to use the terms in the sense proposed, and for these reasons they are adopted here, leaving to future critical paleontologic studies the adjudication of the rank of the divisions.

DES MOINES SERIES.

PLESANTON SHALES.

The Des Moines formation is but sparingly exposed within Decatur county. The best exposures are on Weldon river. Immediately south of the state line (Tp. 67 N., R. XXIV W., Sec. 28), at the wagon bridge over the Weldon, a thin sandy limestone is exposed about four feet above the water. The rock carries *Productus costatus*, but seems to show no specimens of *Chonetes mesoloba* which is usually found in the Des Moines strata. In physical characteristics it very closely resembles a bed found at the corresponding horizon in Madison and adjoining counties and it is confidently referred to the Des Moines formation.

At the bridge in section 15 of Morgan township, there is an exposure showing twelve feet of blue sandy shale of Des Moines character and differing from anything found in the Missourian of the region. The basal portion of the Bethany outcrops high in the hills on the west side of the river, and beds probably representing the Earlham horizon have been opened up in a small quarry. In the first ravine west of Little river

*Am. Geol., vol. XVIII, pp. 22-28. 1896.

(Sec. 16, Se. Se.) a sandy limestone corresponding in character to that found on Weldon river, near the state line, outcrops. It is here fourteen inches thick and, as usual, non-fossiliferous. About six inches above it are traces of a three-inch black shale, an unusual member of the section and perhaps only locally developed. The arenaceous limestone outcrops again about two miles west of Weldon river on Lick branch (Sw. of Se., Sec. 17, Morgan Tp.) at which point it has more of the shaly character.

Along Grand river there are few exposures of the Des Moines, the fragmental limestone of the Bethany, or the Earlham, outcropping usually at the edge of the flood plain. Near Davis City, however, the upper portion of the lower beds may been seen. Along the small ravine leading down past the old lime kilns north of town (Nw. of Se., Sec. 35, Burrell Tp.) below the base of the Bethany is the following exposure.

		FEET.
5.	Shale	3
4.	Shale, black, "slate"	1
3.	Shale, drab, sandy	4

Farther down and near the mouth of the ravine is the following.

2.	Shale, sandy, yellow	6

On the main stream near the mill, and accordingly below the above, the following beds are exposed.

1.	Shale, drab, clayey, with several thin bands of blue-black non-fossiliferous limestone	4

It is stated that before the dam was put in, limestone used to show in the bottom of the river below these beds, and it is known to extend below the bottom land as far across the valley as the trestle opposite town extends. Limestone has also been encountered in wells north of Davis City under the low platform reaching out from the hills to the west and under the bottom land (Nw. of Sw. Sec. 7, and Nw. of Nw. Sec. 12, New Buda Tp.). Since the Fragmental limestone is exposed on

Dickenson creek at a level above this bottom land (Sw. Sec. 3) this lower limestone would correspond to the arenaceous limestone exposed on Weldon river. No. 1 of the section as given would correspond to the same number in White's section* at this point. The other numbers give details of the beds comprised under No. 2 in his section. He mentions finding here specimens of *Beyrichia americana*, which he also collected from corresponding beds in Guthrie county. This would strengthen the reference of the beds to the Des Moines.

The beds here referred to the Des Moines form the top of that formation. With the exception of the arenaceous limestone already mentioned they are predominently shales. They are usually arenaceous to a noticeable degree. They correspond in general facies and in stratigraphical position to the Pleasanton shales of Kansas.† While the actual equivalence has not been proven, it has been suggested‡ and it seems quite likely to prove the correct correlation. In the interests of simplicity of nomenclature the name applied by the Kansan geologists may be used for these beds. They are not extensively exposed in Iowa though they have been described in Guthrie,‖ Dallas§ and Madison** counties, and are known at other points. It is, perhaps, significant that to the east of the Bethany limestone one finds in Wayne, Lucas and Clarke counties a broad, open prairie, such as would readily be formed over the area of outcrop of these shales by step and platform erosion.†† The actual surface is, of course, due to the drift, and the underlying step and platform is correspondingly obscured. The topography, nevertheless, serves to outline the probable outcrop of these beds and would suggest that they are of greater importance than knowledge derived from their outcrops alone would indicate. Their

*Geol. Iowa, vol. I, pp. 321-322. 1870.

†Haworth: Kansas Univ. Quart., vol. II, p. 274, 1895; Univ. Geol. Surv. Kansas, vol. I, pp. 154-155, 1896.

‡Keyes: Proc. Iowa Acad. Sci., vol. IV, pp 22-25. 1897.

‖Bain: Iowa Geol. Surv., vol VII, 443-444. 1897.

§Leonard: Ibid., vol. VIII, pp. 78-82.

**Tilton and Bain: Ibid., vol. VII, 504-509. 1897.

††Marbut: Mo. Geol. Surv., vol. X, p. 29. 1896.

probable thickness and the character of the underlying beds is discussed in connection with the subject of coal.

MISSOURIAN SERIES.

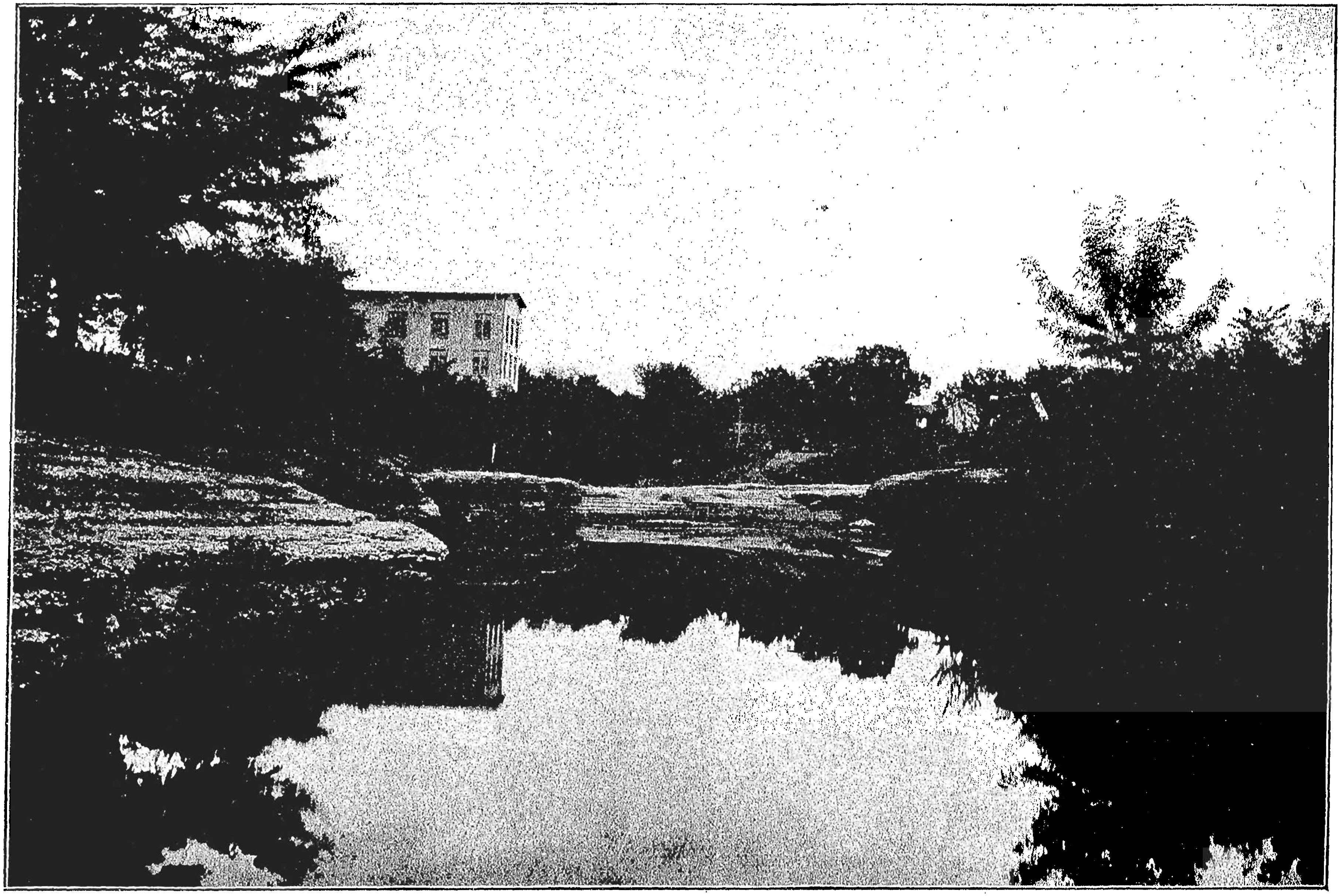
As will be seen by the maps, the major portion of the county is underlain by the Missourian, or upper coal measures. This formation, as here developed, consists of several beds of limestone separated by shales of various types. This assemblage of shales and limestones taken together constitutes the Bethany limestone, the lowermost of the several subdivisions of the Missourian. The Missourian as a whole has not yet been much studied, though the Bethany limestone and its equivalents have received considerable attention in Kansas, Missouri and Iowa.

BETHANY LIMESTONE.

At Bethany, Missouri, where the limestone was first studied by Broadhead,* the beds as now exposed yield the following sequence as shown along a small tributary of Big creek running through the town. The first exposure, which shows the top of the Bethany, is near the railway bridge north of the depot, the top of the limestone being at about 888 A. T.

	FEET.
6. Limestone, fragmental, loosely cemented, with many specimens of *Meekella striato-costata*, *Chonetes verneuilanus*, *Productus costatus*, *Athyris subtilita*, *Productus longispinus*, *Spirifer cameratus* and *Dielasma bovidens*	6
5 Shale, clayey, green to drab, with thin bands of limestone	2
4. Shale, clayey, drab to black	2
3. Limestone, dark blue, two ledges, 9 and 3 inches thick respectively	1
2. Shale, black	1
1. Shale, black to drab, with irregular nodular and thin layers of impure black limestone, carrying large, well-formed *Productus cora*, *Productus*	

*Trans. St. Louis Acad. Sci., vol. II, 311, 1862; Mo. Geol. Surv., Iron Ore and Coal Fields pt. ii, p. 77 *et seq*. 1873.



TYPICAL EXPOSURE OF BETHANY LIMESTONE AT BETHANY, MO.

	FEET.
nebrascensis, *Athyris subtilita*, *Myalina subquadrata*(?), *Schizodus* sp? In the shale itself are *Myalina subquadrata*, *Productus nebrascensis*, *Athyris subtilita*, *Rhombopora lepidendroides* and plates of *Eupachycrinus verrucosus*..........................	6

Below this exposure for some distance there are no outcrops, but in the western part of town there are some small quarries which show the following beds.

		FEET.	INCHES.
7.	Shale, clayey, drab..........................	6	
6.	Shale, calcareous, transition beds, with *Spirifer cameratus*, *Meekella striato-costata*, *Productus cora*, *Productus costatus*, *Productus nebrascensis*, *Rhombopora lepidodendroides*, *Fistulipora nodulifera*, *Myalina subquadrata*, *Athyris subtilita*, *Derbya crassa*..........	1	6
5.	Limestone, heavy ledge, many *Fusulina cylindrica*....................................	2	10
4.	Limestone, thin bedded, with many of the fossils collected above, particularly *Athyris subtilita*, *Productus cora*, *Productus costatus*, *Spirifer cameratus* and *Meekella striato-costata*	10	
2.	Unexposed....................................	8	
1.	Limestone, thin bedded, with *Productus costatus*, *Productus cora*, *Productus longispinus*, *Athyris subtilita*, *Spirifer lineatus*, *Spirifer cameratus*, *Spiriferina kentuckensis*, *Chonetes verneuilanus*, *Hustedia mormoni*, *Dielasma bovidens* and *Fusulina cylindrica*.............	12–15	

Not far from here is the mouth of the stream which enters just above the falls of Big creek. The rock forming the falls lies probably six to eight feet below the base of the limestone just described. It is about twenty feet thick, the upper eighteen feet being made up of a coarse but finely cemented limestone breccia, such as is shown in Fig. 2, Plate xxi. It is marked by long dark streaks which suggest corals, but which fail to show structure. The only fossil collected from it was *Productus cora*. Below the breccia is about two feet of fine-grained gray limestone, carrying large, well-formed *Spirifer cameratus* with

Productus cora. The brecciated character of the limestone and the absence of marked sedimentation planes has yielded, under water action, rounded forms and knob and pot hole surfaces. (See Plate xxii.)

The general sequence found here with the four bodies of limestone, separated by shales, is the same as has already been found in central Iowa. The exposures in the latter region were first studied by White* and have been more recently reviewed by the present Survey.† In many of the minute details even there is a close correspondence between the Bethany section and that of Madison and adjacent counties. The latter may be summarized as follows.

	FEET.
8. Limestone, thick and thin bedded, characterized by a particular abundance of *Fusulina cylindrica*, and hence called the Fusulina limestone	15-30
7. Shales, predominantly dark colored and argillaceous, containing several thin bands of bituminous limestone, which are usually quite fossiliferous. About midway of the shales is a horizon which is particularly fossiliferous. The more usual forms, including Athyris, Productus and Spirifer, occur in great abundance and perfection. With these forms are vast numbers of *Derbya crassa* with *Myalina subquadrata*, *Myalina kansasensis*, *Myalina swallowi*, *Aviculopecten occidentalis*, *Productus nebrascensis*, etc. Not far above this horizon is usually a thin band of limestone literally made up of *Chonetes verneuilanus*. The whole thickness of the shale is	10-20
6. Limestone, medium grained, thin to thick bedded quarry rock, with *Athyris subtilita*, *Productus cora* and *Meekella striato-cosata*. Best exposed near Winterset, and hence called the Winterset limestone	12-15
5. Shale, usually dark and including a black bituminous horizon	8-12
4. Limestone, well shown near Earlham, and hence called the Earlham limestone. Carries an abundant fauna, which will be noted later	20

*First and Second Ann. Repts State Geol., pp. 71-72. Des Moines, 1868. Geol. Iowa, vol. I, pp. 245-250. Des Moines, 1870.

†Proc. Iowa Acad. Sci., vol. I, pl. iii, pp. 26-271, 893; Iowa Geol. Surv., vol. III, p. 137, 1895; Ibid., vol. VII, pp. 446-451, 1897.

		FEET.
3.	Shale, with bituminous horizon, and at many points a thin, black limestone	3-8
2.	Shales, sandy, light colored, very variable thickness	2-16
1.	Limestone, fragmental, made up of irregular bits of lime rock, filled in with calcareous clay. In places the rock can be picked to pieces with the fingers, elsewhere it hardens up into massive, thick-bedded layers. Along a small tributary of Deer creek, in Guthrie county, it is quite fossiliferous, yielding *Spirifer lineatus*, *Spirifer cameratus*, *Athyris subtilita*, *Hustedia mormoni*, *Productus longispinus*, *Naticopsis altonensis*, *Lopophyllumn proliferum*, *Orthis pecosi*, *Bellerophon sp.*, *Straparollus sp.*, *Archæocidaris sp.*	10-15

As the Earlham limestone is particularly well shown in Decatur county and presents there many analogies to the beds at the type locality, the following details regarding the latter may be quoted.* The typical section is given below.

		FEET.	INCHES.
11.	Bed of soft, yellowish, magnesian, earthy limestone, decomposing readily when exposed to weather	4	
10.	Limestone in three heavy ledges at west end of quarry	4	
9.	Buff shale with *Chonetes verneuilanus*		4
8.	Limestone, like No. 4	2	
7.	Ashen shale with very few fragments of brachiopod shells		6
6.	Earthy limestone, decomposing readily, yellowish, carrying large individuals of *Athyris subtilita*		3
5.	Drab shale, with *Productus longispinus*, *P. costatus*, crinoid stems and fragments of other fossils		6
4.	Quarry limestone, in thin layers, irregularly bedded	8	
3.	Unexposed	20	
2.	Sandstone, in heavy layers	7	
1.	Base of sandstone to creek, unexposed	17	

At one point the quarrymen had worked down in the bottom of the quarry and exposed, below No. 4, drab and black shales

* Geol. Madison county, Iowa Geol. Surv., vol. VII, pp 514-515, 1897.

to the depth of three feet, and below the shales a ledge of limestone six inches in thickness.

Distributed through the limestone beds No. 4 are the following.

Lophophyllum proliferum McChesney.
Meekella striato-costata Cox.
Productus punctatus Martin.
P. costatus Sowerby.
P. longispinus Sowerby.
P. cora D'Orbigny—*P. prattenianus* of authors.
Athyris (*Seminula*) *subtilitia* Hall.
Hustedia mormoni Marcou.
Spirifer cameratus Morton.
Spiriferina kentuckensis Shum.
Allorisma subcuneatum M. & H.
Stem segments and body plates of crinoids.
Various species of Bryozoa.

Chonetes verneuilanus N. &. P. is somewhat common in No. 9 but is very rare in the other members of the section. *Spirifer cameratus* and *Productus longispinus* are most abundant near the base of No. 4, while *Productus costatus* and *Athyris subtilita* are more common in the upper layers. All the species enumerated, however, with the exception of *Allorisma subcuneatum*, range through all the beds making up No. 4.

The best exposures of the Bethany limestone in southern Iowa are found along Grand river and its tributaries. From the outcrops found here a complete section can be made from the Fragmental limestone at the base up to and above beds which farther north have been called the Fusulina limestone, but which, from their excellent development in that vicinity, may now perhaps be best called the De Kalb limestone.

In Union county there is an important bed of limestone which, from the fact that it is well shown on Sand creek near Westerville, may be called the Westerville limestone. It lies some little distance above the De Kalb horizon. In Jones township of Union county (section 28 and farther south along

FIG. 1. Surface of Winterset limestone, showing position of glacial striæ.

FIG. 2. Glacial striæ near Lamoni. Most of the striæ are S. 1° W., a few S. 4° W., and one or two S. 5° E. Magnetic variation, N. 7° 30° E.

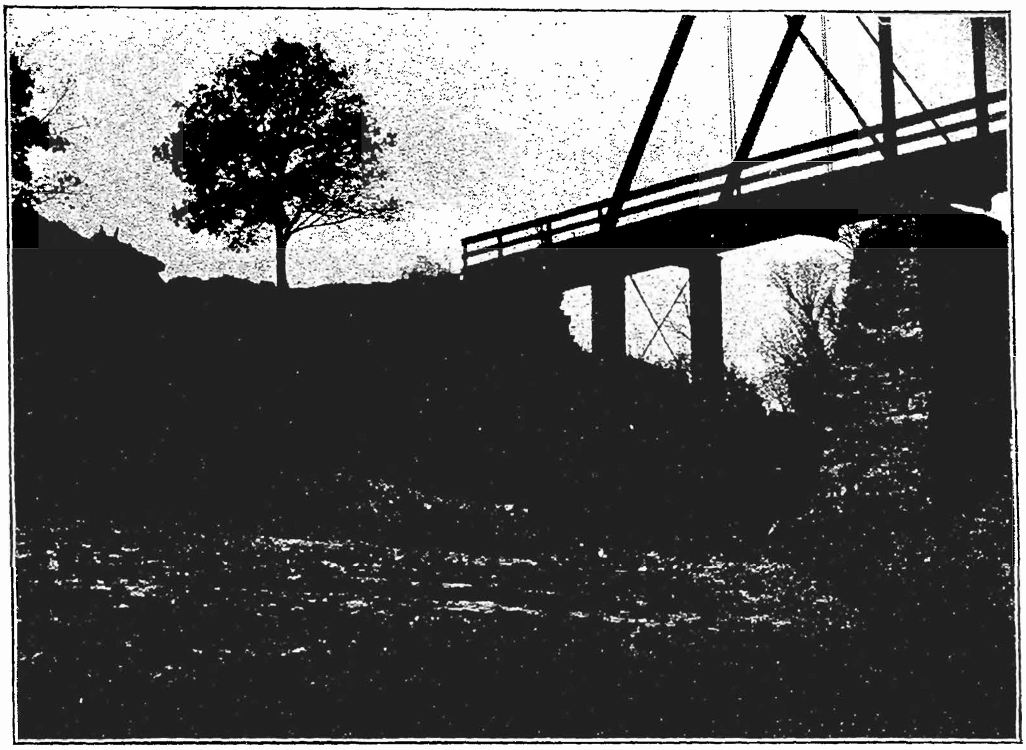


FIG. 1. Winterset limestone, west of Decatur City, with Myalina shales and Blue limestone ledge above.

FIG. 2. Winterset limestone on Potter's branch with shales below extending down to the Earlham limestone.

the river) the beds are exposed, showing the following section.

		FEET.
5.	Limestone, ash gray, fine grained, thin bedded, becoming almost shaly at the top, with *Productus cora*, *Productus costatus*, *Spirifer cameratus*, *Athyris subtilita*, *Chonetes verneuilanus* cf. *glabra*, *Lophophyllum proliferum*. *Straparollus subquadratus* and Fenestelloid bryozoa	10
4.	Shale, gray, calcareous, with thin nodular bands of limestone	4
3.	Shale, drab to black	10
2.	Limestone, impure, nodular, in two bands	2½
1.	Shale, drab to black, well exposed at Westerville	8

These beds extend into Decatur county, being seen near Westerville, on Sand creek, and on Grand river. It seems probable that the shale (No. 1) extends down to the top of the De Kalb or Fusulina limestone which is exposed near Grand river and was at one time quarried at the old Madarasz quarry. (Sec. 36, Tp. 70 N., R. XXVII W.) The best exposures of the latter limestone, and the ones which may be taken as typical, are found a short distance east of De Kalb station. (Sec. 28, Tp. 70 N., R. XXVI W.) The section at this point is given below.

		INCHES.
5.	Limestone, irregularly water worn	6
4.	Shale, hard, drab	6
3.	Limestone, irregularly bedded	8
2.	Shale, calcareous, becoming in places a poor grade of limerock	2
1.	Limestone, in thick to thin ledges	48

The limestone is quite fossiliferous, the forms collected including *Productus costatus*, *Productus longispinus*, *Athyris subtilita*, *Spirifer camerata*, *Spirifer kentuckensis*, *Dielasma bovidens*, *Derbya crassa*, *Lophophyllum proliferum* and *Fusulina cylindrica*. This fauna is more abundant than is usually found in the same beds farther north, though no exhaustive collections have been made in Madison and adjoining counties, and many of the species collected at De Kalb are known to be present, sparingly at least, in the former regions. The marked predominence of *Fusulina cylindrica* which is so striking a characteristic of these beds in Madison county, is not so noticeable at De Kalb. This is probably due as much to the greater abundance at the latter point of the other forms mentioned as to any real decrease in the numbers of the Fusulina. It is, nevertheless, true that in the earlier advent, or at least culmination, of Fusulina the Decatur county outcrops show much closer relations to the rocks as developed at Bethany, than to the Winterset section. It is for this reason, in part, that the term, De Kalb limestone, is to be preferred to Fusulina limestone, since neither the presence nor the abundance of the latter form is found to be consonant with a constant stratigraphical horizon.

The beds below the De Kalb limestone are shown near the wagon bridge just north of the railway station. The section exposed is as follows.

		FEET.
5.	Limestone, De Kalb, thin bedded, very fossiliferous.	2
4.	Shale, soft, gray	2
3.	Shale, fine black "slate"	1
2.	Shale, black, soft	2½
1.	Shale, drab	4

These shales are not particularly fossiliferous, as the section does not extend down to the Myalina horizon already noted. The latter is well shown on Grand River at the bridge about three miles west of Decatur (Tp. 69 N., R. XXVI W., Sec. 30, Sw. Sw.) The section at this point is as given below. Fig. 1, Plate xxiv.

		FEET.
5.	Limestone (De Kalb) lower ledges only	3
4.	Shales, drab to black, carrying *Derbya crassa*, *Myallina subquadrata*, *Athyris subtilita*, *Productus nebrascensis*, *Lophophyllum lepidendroides* and plates of *Eupachycrinus verrucosus*, exposed as a slope. Thin ledges of limestone found on the slope made up of *Chonetes verneuilanus*	15

		FEET.
3.	Limestone, blue to black, with *Productus cora*, *Productus nebrascensis* and *Athyris subtilita*............	3
2.	Shale, drab, clayey..................................	12
1.	Limestone (Winterset), coarse bedded, with *Athyris subtilita*, *Productus costatus* and *Meekella striata-costata*..	10

The Winterset limestone dips north here about five feet per hundred and its maximum thickness is not exposed. The dip seems to be local only. The Winterset is exposed south from the bridge as far as the abrupt turn of the river in the southeast corner of section 36, Grand river township. Within a mile the Earlham rock appears, and at the ford in section 7, of Burrell township, the Fragmental rock is seen in the bed of the river.

The Winterset rock at the Decatur bridge is quite similar to the typical beds at Winterset, both in physical characteristics and the character and relative meagreness of its fauna.

The shales between the Winterset and the De Kalb limestone form one of the most marked stratigraphic horizons in the section, and their close resemblance in all particulars to the corresponding beds at both Winterset and Bethany will be at once seen. The same fossils occur and in the same perfection and abundance.

The shales below the Winterset and extending down to the Earlham limestone are not well shown on Grand river. Elsewhere they are usually about ten feet thick and carry about their middle a one foot black slate horizon. The Earlham limestone is quite well shown near the bridge in Ne. of Nw. of section 5, Burrell township. The exposure, which is on the east side of the river just south of the bridge, shows the following beds.

		FEET.	INCHES.
6.	Limestone, coarse grained, with *Fusulina cylindrica* and *Athyris subtilita*..................	2	
5.	Shale, clayey, carrying *Athyris subtilita* and *Chonetes verneuilanus*.........................		6

		Feet.	Inches.
4.	Limestone, quarry rock, 4 to 12 inch ledges, with *Productus cora*, *Athyris subtilita*, *Hustedia mormoni*, etc	8	
3.	Shale, argillaceous, drab	1	
2.	Shale, black "slate"	1	6
1.	Shale, drab, soft	4	

The very strong resemblance of this section to the typical Earlham section as already given will be noticed at once. The partings in each case are of the same character and carry the same fossils. *Hustedia mormoni*, which is abundant wherever the Earlham is exposed, has not been collected from any of the higher beds along Grand river, although at Bethany it is found frequently at higher horizons.

The Fragmental rock is not shown at the exposure just described though it is exposed a short distance below at water level. On Pot Hole branch, south of Terre Haute (Tp. 68 N., R. XXVI W., Sec. 29, Se. of Nw.), it is present about ten feet below the base of the Earlham, being firmly cemented and non-fossiliferous. A thickness of four feet is shown in the bed of the creek and more may be present. The Fragmental rock is also below the base of the quarries opened up southwest of Davis City (Tp. 67 N., R. XXVI W., Sec. 3, Se. of Sw). Here it is also non-fossiliferous.

The exposures in and near Davis City show the Earlham beds excellently. They are the ones which have been much opened up, though the Winterset and the De Kalb are present high in the hills. From the Earlham limestone on Dickenson creek, southwest of Davis City, the following forms were obtained: *Productus longispinus*, *Productus costatus*, *Athyris subtilita*, *Spirifer cameratus*, *Chonetes verneuilanus*, *Fusulina cylindrica*, *Hustedia mormoni* and plates of Archæocidaris and Zeocrinus.

In the eastern portion of the county, on Weldon and Little rivers, it is apparently the Earlham which is exposed, though the rock has not been opened up enough to make the determination sure. The Fragmental does not show, being concealed by talus and drift, but has been encountered in bridge excavations. A short distance south of Spring Valley, limestone, apparently the Earlham, is exposed along a small stream running into Little river from the east (Se. of Se. Sec. 13). The stone is fine-grained, ash gray, breaks with irregular fracture and weathers white. One ledge as much as eighteen inches in thickness is indicated by the blocks found on the surface. The rock is said to be underlain by shales. The fossils found included *Athyris subtilita*, *Productus longispinus*, *Productus costatus*, *Chonetes verneuilanus*, and *Spirifer cameratus*.

Beds corresponding to those just described outcrop about a mile north (Nw. of Ne. Sec. 13) along a tributary of Little river, and have been in fact opened up at several points in the vicinity. At the old Cole mill (Nw. of Ne. Sec. 14) the section given below is exposed in the west bank of the river. The limestone is probably the Earlham.

		FEET.
4.	Limestone, thick bedded, with *Athyris subtilita*, very abundant corals, and plates and spines of Archæocidaris	5
3.	Shale, gray to drab	4
2.	Shale, black "slate"	1
1.	Shale, gray, sandy	6

The limestone found on Weldon river (Se. Sec. 15, Morgan Tp.) is probably also the Earlham. The only fossils collected were *Athyris subtilita* and Archæocidaris. The outcrops indicate that higher limestones occur.

In the western portion of the county there are a number of excellent exposures of the various members of the formation. Many of them will be referred to in the notes on the quarries. The exposures in the eastern portion of the county are rare and with the thick drift present it is difficult exactly to locate the eastern limits of the formation. As laid down upon the accompanying map the line is subject to some correction. The limit in the southeastern corner of the county is probably quite correct, though there may be an outlier east of Caleb creek. Farther north it is fixed by some exposures on Whitebreast creek in Clarke county. Between these points it may be found to extend a little farther to the east or west than is indicated.

Pleistocene.

In recent years the unconsolidated materials which so generally form the surface formations have attracted considerable attention. This is particularly true of those beds which were laid down by, or in connection with, the great glaciers or ice sheets which, in the period immediately preceding historic times, spread over much of North America as well as certain portions of the old world. The deposits made by the ice sheets are well displayed in Iowa and have been found to be of peculiar interest. Within the last year or two it has been shown that the drift deposits of this state have had a much more complex history than has been heretofore ascribed to them. Near Afton in Union county to the north, and again in Harrison county, Missouri, to the south, certain phenomena of more than local interest have been observed. When the study of Decatur county was taken up it was hoped that in the exposures along its deep cut valleys decisive evidence on certain mooted questions would be obtained. The result of the investigations are neither altogether satisfactory or altogether disappointing. Their value and bearing upon general questions may, however, be better estimated after a review of the evidence.

The drift deposits of Decatur county include the Kansan bowlder clay, with certain possibly older beds, the gumbo, the loess and the alluvium. The latter is the most recent deposit and is found along all the streams, occupying the lowlands. The loess is the surface formation over the upland and runs over the divides and down into the valleys in the form of a mantle. The gumbo is under it and has the same stratigraphic relations as the loess. The drift deposits proper are under the gumbo and often under the alluvium. They cover the whole of the upland region to a variable depth, averaging probably 150 to 200 feet. The drift also runs down into the preglacial valleys.

KANSAN AND OLDER DRIFT SHEETS.

The drift sheet left by the major advance of the Keewatin ice sheet and extending out from under the later Iowan and Wisconsin tills is known as the Kansan drift. It is believed to have extended on the south to the Missouri river and on the southwest across that stream into Kansas. When named* it was thought to be the oldest drift sheet in North America. Dawson† has since shown that in Canada there is an older drift, named by him the Albertan, and the evidence of two drifts in southern Iowa, long since noted by Chamberlin‡ and McGee, has been interpreted as indicating a pre-Kansan drift§ in that region.

The interpretation accords with the results obtained from a study of the Alps‖ to the extent that it postulates two old drift sheets. In the latter region there is, outside the moraine of the last glacial period, evidence of two older and widely separated invasions of the ice, the younger of the two apparently representing our Kansan. The interpretation here offered is also in harmony with numerous other phenomena. In a word it may be stated that under the Kansan drift there are traces of a still older drift, though the limits of this older drift are not known, nor is the evidence with regard to its existence everywhere as satisfactory as could be desired.

---

*Chamberlin: Gekie's Great Ice Age, pp. 773-774. 1894. Jour. Geol., vol. III, pp. 270-277. 1895.

†Dawson: Jour. Geology, vol. III, pp. 507-511. 1895.

‡Chamberlin: Loc. Cit. McGee: Pleistocene Hist. N. E. Iowa, Eleventh Ann. Rep. U. S. Geol. Surv., pp. 493-499. 1891.

§Chamberlin: Jour. Geol., vol. IV, pp. 872-876. 1896.

§Calvin: Annals of Iowa (3), vol. III, No. 1, pp. 1-22. 1897. Iowa Geol. Surv., vol. VII, pp. 18, 19. 1897. Amer. Geol., vol. XIX. pp. 270-272. 1897.

§Bain: Trans. Iowa Hort. Soc. 1896. Iowa Geol. Surv, vol. VI, pp. 463-467. 1897. Ibid., vol. VII, pp. 335-338. 1897.

‖See Le Systems Glaciaire des Alpes, guide publie, a de occasion du Congres geologique International, 6 m Session, Zurich, 1894, par M M. Penck, Brückner et du Pasquier. (With references.)

The surface drift throughout Decatur county is old. This is shown not only in the topography, but in the condition of the drift itself. Where the surface of the bowlder clay has not suffered recent erosion it is uniformily highly colored. The iron content has been oxidized until a reddish-brown surface corresponding to the "ferretto" of Italian geologists has been produced. This reddish-brown grades through orange to yellow below, and the yellow in turn gives place to blue, which is the fundamental color of the Kansan bowlder clay. Often the yellow is seen following down into the blue along cracks and fading out from their edges. All the evidences indicate that here, as elsewhere, the blue and yellow clays belong together. The change in color is a matter of oxidation, and is most marked when the oxidation has been most active.

The blue bowlder clay and much of the yellow contains a large amount of calcium carbonate, fine limestone dust. This causes it to give a vigorous reaction when tested with acid. The upper surface of the bowlder clay gives no reaction, and the strength of the reaction, increasing from nothing at the surface to full vigor at a depth of seven to nine feet, is proportional to the amount of leaching which the clay has suffered, which in turn is approximately proportional to the depth below the surface. The bowlder clay contains a considerable variety of pebbles and bowlders, they being in most cases flattened and planed, and often showing striations.

In a cut on the Humeston & Shenandoah railway, near De Kalb, the following kinds of rock were observed in the till: gray and red granite, red porphyry, Sioux quartzite coarse and fine-grained, quartzite with pebbles of clean quartz and red jasper, gabbro, fine-grained greenstones, iron concretions, bits of clear, white quartz, small pieces of limestone, chert, and very small bits of sandstone. The sandstone and limestone doubtless come from the coal measures of the adjacent region. The quartzite, including that with the quartz and jasper pebbles, probably came from the Sioux Falls region. The granites and greenstones came from farther north.

Many of the granite cobbles, both large and small, are so badly weathered that they may be easily picked to pieces with the fingers. This is particularly true of those near the top of the formation and becomes less noticeable toward the bottom. It is not confined to particular kinds of rock which might be supposed to weather easily, such, for example, as coarse-grained granites with large feldspars, but is true of a wide variety of stones.

It is believed that the weathering of the granites, the oxidation of the iron and the decalcification of the bowlder clay, in view of their obvious relationships to the original surface of the latter, are to be interpreted as evidence of a long period of subærial decay after the bowlder clay was deposited. The ferretto surface maintains itself under the loess and outlines the present topography, so that this period of exposure, which the advanced stage of the topography indicates must have been a long one, occurred after the bowlder clay was laid down, and before the overlying gumbo and loess were deposited. It is this drift which forms the bulk of the Pleistocene deposits of the county and which has been called the Kansan. Relative to the question of a possible pre-Kansan there are certain exposures of interest.

In section 36, Pleasant township of Union county, the following exposure is seen in the bank of Grand river near the ford. This is within a mile of the northwest corner of Decatur county.

		FEET.
4.	Loess-like top soil	1
3.	Sand, fine to coarse, with some gravel below	6
2.	Gravel, sandy, much weathered material	10
1.	Bowlder clay, blue-black, in physical character resembling the older bowlder clay at Afton Junction	12

The sand and gravel are evidently waterlaid beds and belong together. They graduate laterally into a reddish clay and these into a drab to blue bowlder clay. This shading off of the gravels into a bowlder clay is true as well of the gravels at Afton Junction. The gravel found at this exposure is similar in every regard to that found farther up the river. It wants only the bowlder clay over the gravel to make the exposure complete, and as the exposure is some distance below the high land, there can be little doubt of a higher bowlder clay. Between the two exposures there are traces of the same beds, and it is evident that what explains one exposure must serve also to explain the other.

About three miles northwest of Davis City (center of Sec. 28, Burrell Tp.) a bluff at another ford across Grand river shows an interesting drift exposure. The hills here on the south are close to the river. A spur runs out a little from the bluffs as indicated on the sketch map.

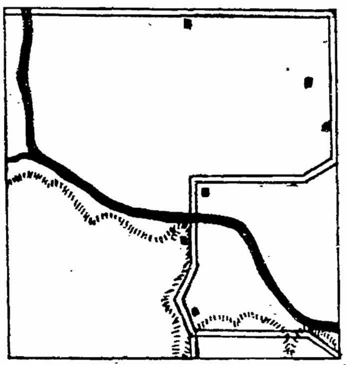


Fig. 9. Sketch map of section 28, Burrell Township.

The nose of this spur has been cut across by the river, making the exposure. At the water's edge stratified sands are exposed. Fifteen feet above the water is a well marked soil horizon buried beneath thirty feet of yellow bowlder clay sloping up to the bluff 150 feet high. The bowlder clay is evidently Kansan. From the fact, however, that it shows a certain amount of rude stratification, as well as the fact that the soil horizon is about on a level with the present flood plain, the exposure may perhaps be thought to represent side filling in over the bottom land. The absence of direct evidence favoring this, and the fact that so large an amount of bowlder clay could hardly slip down without leaving direct evidence of the fact except by a remarkably slow and uniform movement, while the bottom land is evidently young, seems sufficient reason for rejecting this hypothesis.

There is another exposure of interest found in the east bluff of the river near the bridge, about four miles southeast of Davis City (Sw. of Nw. Sec. 18, Hamilton township). Above the bridge there is a small ravine coming in from the east and cutting in two what was once apparently a continuous exposure. The portion of this exposure south of the ravine shows at the base a blue-black bowlder clay with many pebbles. This clay has the typical characteristics of the pre-Kansan. Its blackness here is quite noticeable and leads one on first view to expect a Carboniferous shale. It does not extend along the entire base of the exposure and seems to be separated from the remainder of the latter by a zone of weathering. Over it where first seen are beds of stratified sand, gravel, and loess with at least one pretty well marked zone of weathering. North of the ravine is a blue bowlder clay, not so dark in color, breaking cubically rather than in flakes, and passing upward into a yellow bowlder clay containing masses of highly weathered gravels of Aftonian aspect. Then yellowing, resultant on oxidation, here follows the cracks well down into the blue clay. In the adjoining region the usual succession of loess, gumbo, yellow and blue bowlder clay is seen. The compact black flaky bowlder clay is unusual. At the exposure itself the facts are not altogether clear, but this much may be stated definitely, that there is here a bowlder clay of a type uncommon for this region but of physical character very like that of the older drift at Afton Junction.

Directly west of Leon, on the main road to Decatur City (Sw. Sw. Sec. 29, Center Tp.), a long westward facing slope shows the exposure sketched below.

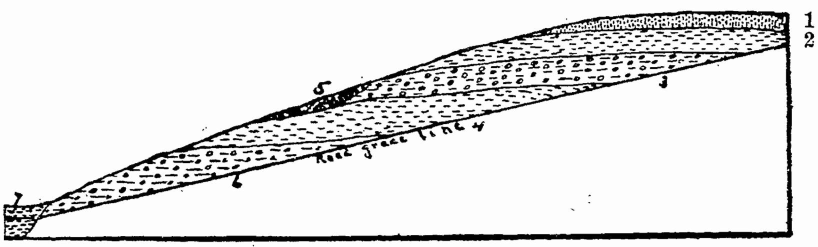


Fig 10 Drift exposure west of Leon.

On the top of the hill is the usual upland loess (1) running down over the edge of the rather steep slope. Below it is the normal gumbo deposit (2) eight to ten feet thick. Under this is a yellow bowlder clay (3) with all the usual characteristics. So far the section is exactly the same as occurs throughout the county. The bowlder clay is, however, only about fifteen feet thick, and below it is found a second gumbo about twelve feet thick. This is a dark blue-drab clay. At its upper limit it contains humus and a distinct soil three to five inches thick. The soil is quite black and well marked, though thin. It contains some roots which do not seem to come down from the bowlder clay. The latter shows slight evidence of water action for as much as a foot above the gumbo, but above that is the normal unstratified bowlder clay. Under the gumbo is a second yellow bowlder clay (6) not differing in any known particular from that above. It carries cherts, red and gray granites, limestones, greenstones, iron concretions and quartzites. The same sorts of rocks are found in the clay above. Both show evidence of age and carry much weathered material. At the foot of the slope is the alluvium of the bottom-land.

The ravines at the side of the road have cut back far enough to show that the beds lie directly under each other as indicated. The upper bowlder clay (3) where it rests upon the lower gumbo (4) is not the hillside wash or the result of creep. The material brought down by these processes is shown at 5 and is quite distinct. It includes smaller pebbles, is sandier, very gravelly, and distinctly waterlaid. It can be distinguished at a glance. No hypothesis of slipping seems able to account for the arrangement of the beds and they seem to indicate true and original superposition. This is the more probable from the fact that exactly similar exposures, except that the relations are even clearer, may be seen about one and a half miles east of Osceola in Clarke county. At several points in the ravines north of Weldon the same phenomena seem to be present though the exposures are not good. Only at the Leon exposure was the soil on top the lower gumbo noted. It has here the appearance of a buried soil with the upper portion removed, leaving only a little of the soil proper over the subsoil. There is no sufficient evidence of erosion at any point in the section lower than the top of the upper bowlder clay.

In regions where the superimposed drift sheets occur, buried forests are not uncommonly encountered. This is particularly true in regions near the edge of an upper drift, where, probably as a result of the fact that but little ice passed over the forest, it is better preserved. Buried forests are not of equal significance. They may readily occur as a result of temporary retreats and advances of the ice where only one drift sheet is present. It is only when they throw light upon the climate or physical conditions obtaining during the interrum that they have important bearing. It should always be remembered, however, that the simplest explanation is not necessarily the true one, and that where the facts are capable of explanation equally well by the hypothesis of one or of two ice sheets, it is by no means necessarily true that the former hypothesis is to be preferred.

There are evidences of a buried forest in Decatur county, and in the adjoining region. Indeed, such evidence is found at a number of points in southern Iowa, and has been reviewed at another place.* In Decatur county the forest bed is best known in the vicinity of Lamoni, where it has been encountered in several wells. In the elevator well at that place it was struck at a depth of 85 feet, and below it there was a thickness of 100 feet of bowlder clay. It is clear that this forest bed is far below the base of the loess and is in the bowlder clay. There are no specimens of wood at hand, though the material examined by Prof. T. J. Fitzpatrick was found to be coniferous. The climatic bearing of the find is unimportant. The significant facts are that the bed is of some thickness, occurs commonly in the deep wells over quite a wide region, and is in the bowlder clay. It evidently neither represents adventitious wood in the latter, nor any post-Kansan accumulations.

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

In Harrison county, Mo., Dr. C. R. Keyes* reports a nine-foot forest bed struck at a depth of about 120 feet and in the drift. The evidence here would seem to be of the same nature as at Lamoni, but the thickness of the bed makes more impossible any reference of the deposits to adventitions sources, and indicates some little time of accumulation.

These two cases represent the better examples of buried forests in Decatur and its immediate vicinity. Other cases are reported, but do not seem so reliable. In Union county good specimens of peat have been obtained from wells near Afton, but the horizon is not well fixed and may be of later age. Setting aside for the present the buried gumbo near Leon, it will be noted that there are in this county or its immediate vicinity the following evidences of two drifts.

1. Waterlaid deposits between tills.
2. Buried forests and soil horizons.
3. Traces of an underlying till of peculiar and marked physical character.

In considering the first of these it will at once suggest itself that the large amount of ice necessitates considerable water-action (though not necessarily "great floods"), and that accordingly waterlaid beds may be expected to occur at various horizons in and about the drift. It is possible, however, that the deposits should be of such a nature as clearly interdict any reference to ice-derived floods in their formation, or their distribution might be such as to show that they followed a considerable period of erosion. Neither is exactly true in this case, but it is true that the gravels found above Westerville are of the same character and occupy the same position as those found at Afton, and there are some reasons for believing that the latter accumulated during a considerable period of erosion.

Regarding the evidence derived from buried soils and forest beds but little can be added to what has already been said. It is manifestly uncertain and of slight independent value.

*Private communication.

The third point is one hard to estimate. It is true, however, that whatever one may think of correlations based upon the color and physical characteristic of bowlder clays, there is certainly some significance in the fact that at every known exposure in Iowa, of bowlder clays which for various reasons are considered as probably older than the Kansan, the physical character of the bowlder clay is the same, and that it is markedly different from that of the Kansan.

This is true not only of such clays in southwestern Iowa but of the exposures at Albion in Marshall county, Oelwein in Fayette, and at Muscatine. It is certainly a fact of some significance. Probably none of these classes of evidence at this point would independently prove the presence of a pre-Kansan drift, but it must be remembered the facts have a cumulative value. If, for example, a single exposure showed a forest bed, a soil and waterlaid deposits between drift sheets of markedly different physical characters, and there were no opposing phenomena in the surrounding region, but one inference could be drawn. In the same way when the three classes of phenomena occur not in the same, but in contiguous exposures, they gather weight from the association. For this reason it is believed that the evidence from Decatur county, meager though it admittedly is, supports the hypothesis that there are traces of a pre-Kansan drift sheet in the region, separated from the Kansan by an unknown but probably important interval.

The exposures near Leon, it is believed, are best interpreted as results of changes in the front of the Kansan ice sheet. The gumbo alone proves only that there was a period when fine sedimentation such as is characteristic of still waters could go on for some time. The soil has been so nearly removed that its original thickness can only be guessed, and it is recognized that soils alone do not necessarily indicate an especially long lapse of time. The thickness of the overlying till and the total lack of distinguishing marks between it and that below the gumbo throws the exposure out of harmony with those of the Aftonian and pre-Kansan beds. The apparently local nature of the phenomena, confined as they are to a relative narrow belt stretching from Osceola to Leon, suggests a local cause.

In the recent railway cuts of the D. M. & K. C. railway there are, at a few points, gravels suggestive of the Buchanan. The gravel consists of small well rounded pebbles, is highly stained, carries weathered material, and occurs apparently in pockets in the top of the Kansan and under the gumbo. It has the appearance at times of local hillside wash; but its occurrence at such widely scattered points as Leon, New Virginia, and Truro, together with the fact that in eastern Iowa the Buchanan gravels often occur some miles out from the edge of the later Iowan drift, suggests the advisability of keeping in mind the alternative hypothesis.

Glacial striæ.—The limestone on Pot Hole creek at one point shows striæ as indicated in Plate xxiii. As measured by Prof. T. J. Fitzpatrick these have a direction of s. 1° w. magnetic. They are upon the Winterset limestone and below the Kansan drift.

LOESS AND GUMBO.

The only general deposits occurring throughout the county and later than the drift are the loess and the gumbo clay. They are of the general type familiar throughout southern Iowa and northern Missouri. The loess is of the older or white clay phase, and as compared with that found along the Mississippi and Missouri rivers as well as inland farther north, is less porous, more plastic, and non-fossiliferous. It carries lime nodules but is free from pebbles. It graduates upward into the black loam which forms the prairie soil.

The gumbo belongs stratigraphically with the loess. It occurs below the latter, and has a blue to drab color. It is even more plastic and less porous than the loess. When damp but not wet, it has a mealy appearance which is quite deceptive as to its real character. It rarely carries pebbles though a few have been found in it. It often contains small lime balls but these are neither so large nor so numerous as in the loess. It has the appearance of being finer grained than the latter and suggests a quiet water deposit which has since been compacted or puddled by water. In general the gumbo is about ten feet thick and rests on the ferretto horizon of the Kansan. The loess is from ten to as much as twenty feet thick. Both deposits passed down the flanks of the hills into the larger valleys.

ALLUVIUM.

The alluvial deposits of Decatur county while extensive have little that is peculiar. They cover the broad bottoms of Grand, Weldon and Little rivers, and occur along many of the minor streams. As a rule the alluvium is not of any remarkable thickness. Along Grand river the flood plain is usually about fifteen feet above ordinary water stages. The alluvium is necessarily made up in the main of material derived from the loess and gumbo. South of Davis City, however, along Dickerson creek, it contains large bodies of sand and gravel, derived apparently from beds of the same age as the gravels above Westerville. Inasmuch as the river does not show this material in the region between Westerville and Davis City, it is highly probable that the beds which formed the source of the Dickerson creek deposits are concealed below the drift in the hills west of Davis City.

STRUCTURE.

The rocks of the county have been subjected to very little disturbance. The dip noted west of Decatur (see Plate xxiv) is the most pronounced in the county. It is entirely local and throughout the area the rocks lie very nearly horizontal. Apparently the general dip to the southwest which characterizes the rocks of so much of the state is here almost entirely absent. There are no data which warrant considering it here to be more than one or two feet per mile. The base of the Bethany, so far as Decatur county is concerned, seems to occupy a practically horizontal plane.

ECONOMIC PRODUCTS.

Coal.

That Decatur county lies within the limits of the coal measures has long been known. The exposures of black shale outcropping along the streams in various portions of the county, and already discussed, have led to considerable exploration in a small way, and have been the basis of various local coal excitements. As has already been stated the shale seen along the ravines belongs almost exclusively to the Upper or barren coal measures. In a few cases it carries with it a little coal. Along Weldon river in early days some coal was taken from the horizon below the Earlham limestone. Near the Cole mill (Sec. 14, Hamilton Twp.), in excavating for the bridge, it is stated that as much as eight inches of coal was found at this horizon. This thickness is quite exceptional. At no place in the county does coal of workable thickness outcrop. Any supplies which may be obtained must come from lower horizons. As has already been stated the Des Moines formation extends under the Missourian. The dip is such as to bring the various coal horizons worked in the counties northeast of Decatur some distance below the base of the limestone here.

The Des Moines formation in southern Iowa is composed of three members. (1) The lowermost beds of shales, sandstones and coal exposed along the Des Moines river, and from there west to the Chariton, and probably the equivalent of the Cherokee shales of Kansas;* (2) the Appanoose formation consisting of a series of limestones and shales, and carrying the Mystic coal outcropping west of the Chariton river in Appanoose county† and extending under the eastern portion

*Haworth and Kirk: Kansas Univ. Quart., vol. II, p. 105. 1894. Haworth: Univ. Geol. Surv., Kansas, vol. I, pp. 150-151. 1896.

†Geol. Appanoose county, Iowa Geol. Surv., vol. V, 378, *et seq.* 1896.

at least, of Wayne county; (3) a shale sequence, as yet but little studied and infrequently exposed, extending over western Wayne county, and outcropping immediately below the base of the Bethany in Decatur and adjoining counties. It is probable, but as yet unproven, that this formation is to be correlated with the Pleasanton shales of Kansas*. The Pleasanton shales in this region, at least, are not coal-bearing. Their thickness is not certainly known, but is probably not less than seventy-five feet.

The Appanoose formation carries a much worked and valuable coal bed, thirty inches thick. This coal thins, however, to the west; being at Harvard in Wayne county but twenty-two inches in thickness. The dip of the bed if persistent is such as to bring the Mystic coal horizon about 100-150 below the base of the Bethany limestone in Decatur county. It is not certain, however, that the Appanoose formation maintains itself so far to the west. Toward the north in Lucas, Warren, Madison, Guthrie and Dallas counties, its equivalents take on a character somewhat different from that of the typical exposures. The general facies, however, of the formation remains the same; *i. e.*, it consists of argillaceous shales, thin limestones and thin but persistent coal beds. Its normal thickness is usually about eighty feet. Its base should be about 160 feet below the Bethany.

The coal output of Iowa, with the exception of that derived from the Mystic bed, comes almost entirely from thick coal beds of the Cherokee shales. The workable coal occurs in this formation along certain fairly persistent horizons marked in general by the presence of bituminous matter in some form, but varying much and rapidly in the thickness of actual coal. The better horizons are uniformly near the base of the formation. The best perhaps, may be called the Wapello horizon from its considerable development in the county of that name.

The Wapello horizon has been proven through much of Keokuk, Mahaska, Marion, Wapello, Monroe and Lucas coun-

*Haworth: Kansas Univ. Quart., III, 274, 1895; Univ. Geol. Surv., Kansas, I, 152-153. 1896. Keyes: Proc. Iowa Acad. Sci., vol. IV, 24-25. 1897.

ties. The old Whitebreast mines at Cleveland in the last county mentioned, were the farthest west of any mines which have worked this horizon. From its proven extent and general richness it is the horizon most likely to yield returns to prospectors. Near Chariton, it occurs at about 675-700 feet above sea level and approximately 200 feet below the base of the beds corresponding to the Appanoose formation. At Centerville it should be at approximately 525 feet above sea level or 400 feet below the base of the Appanoose. Making the proper allowance for dip, the horizon should occur at a depth of approximately 500 feet below the base of the Bethany in Decatur county.

Whether or not it would carry workable coal so far to the west can not be foretold and can only be determined by careful work with the diamond drill. In the region where the horizon has so far been opened up it has been found to be generally rich but to be often entirely or practically barren. Even where the field is best known and has been most largely developed it requires careful and extensive drilling to locate the coal accurately enough to warrant opening a mine. The coal is not evenly distributed along this horizon but lies in a series of partially or wholly disconnected basins. Within the limits of a single square mile it varies in thickness from nothing to seven feet. In a recent set of twenty diamond drill holes through this horizon only ten showed coal of more than three feet in thickness and seven showed no coal at all.

The attempts so far made to locate coal, in or near Decatur county, have not been entirely successful. At Davis City a boring was put down about twenty years ago. Starting near the base of the Bethany limestone it was carried to a depth of 212 feet and is said to have shown only two seams of coal four inches and six inches thick respectively. Near De Kalb a hole was sometime since put down without success. This started at the base of the De Kalb limestone and ended apparently in the Pleasanton shales. An examination of such of the drillings as have been preserved shows the usual limestone and shale sequence.

At Bethany, Missouri, a hole was drilled in 1895, starting at the base of the Bethany limestone. It was carried down to 650 feet and should accordingly have reached the Wapello horizon. No coal more than nine inches thick was reported. Winslow* who reports the drillings, casts some doubts on its accuracy.

In 1897 Mr. C. Woodruff of High Point, in drilling for water reported three beds of coal respectively one foot, three feet and four inches in thickness. The hole was located upon the highland and started accordingly approximately 1125 feet above sea level. It was carried to a depth of 412 feet and seems to have stopped in the Cherokee shales.

So far as known all drilling mentioned was done with the churn or jump drill. In the last case at least, coal was not sought, so that no special preparations were made for the accurate determination of its thickness. As is easily understood, results, particularly at such depths, based upon churn drill records have very small value. The method does not permit, except under the most favorable circumstances of fine discrimination. Results of real value are only to be obtained by means of the core drill.

There has been some recent discussion in the county as to the advisability of direct prospecting for coal, and because of this fact, as well as the further facts that the conditions here are very similar to those obtaining over a considerable portion of southwestern Iowa, it may be advisable to say a little as to the cost of such work. From what has been said it will be readily understood that there is no coal to be obtained in the surface formations. Also that below these is a thickness of seventy feet of shales which are practically, if not entirely, barren. Below these in turn is a thickness of 150–200 feet which from all previous experience may be expected to carry thin coal, but no thick seams; probably no coal as much as two feet

* Mo. Geol. Surv., vol. I, p. 99. 1891.

thick. There is accordingly a thickness of at least 200 feet under the lowland or 400 feet under the high table land which for practical purposes may be expected to prove barren. Below this is a thickness of 300–400 feet in which coal may be found; the chances of thick coal increasing toward the bottom. To explore the strata thoroughly a hole running from 500 to 600 feet in depth would have to be drilled even if one could so locate the work as always to drill from the lowland. If the prospecting company owned its own drill and were not unfortunate in the loss of diamonds, the cost would probably average $1 to $1.25 per foot provided 5,000 to 10,000 feet were drilled. To locate 400 to 600 acres of workable coal, provided the strata prove as rich as farther east, a matter unproven, once could hardly count on less than twenty and might need 100 drill holes. The work would accordingly cost $10,000 to $40,000 or more. In the end it might prove that the money would be lost, though on the whole it seems probable that some coal at least would be located, though perhaps not enough to warrant a large mine. In some exploratory work in Iowa where the holes are about half as deep as they would need to be here about $7,000 was spent and work was carried on for nearly two years before a good coal basin was located. If a suitable coal basin were located the cost of working it would probably not be prohibitive. It would depend more upon the amount of railway track necessary than the depth to the coal, and if it should chance that the shaft could be located near a present railway the mine might even cost less than some now operated. The amount of capital invested would depend largely upon whether the mineral rights were leased or purchased, and upon the equipment of the mine. It might perhaps be as low as $60,000 under very favorable circumstances, or as much as $150,000. A large percentage of this would necessarily be invested before any return could be expected.

It will hardly be seriously thought that the present local market, or any probable local market of the immediate future, would warrant such an investment. It remains to examine the chance for a shipping mine. A mine in Decatur county would have the theoretical advantage in competition of nearness to Missouri river points. Practically this advantage would not be entirely realized. The C., B. & Q. railway would furnish a direct line to St. Joseph and when the D. M. & K. C. railway is extended, a short line to Kansas City would be open. Both of these markets are, however, well supplied, and competition is so keen as to offer few attractions to prospective investors. Coal would not, of course, be sold north or east to advantage. In reaching the Omaha, Sioux City and Nebraska markets, a local railway tariff would always tend to destroy any slight advantage which the location gives.

Under present circumstances it will be seen that the opening of the Decatur county coal field would be too hazardous to be a legitimate business venture. One might put down one hole and strike workable coal, and open up on such slender prospects. Such things have been done occasionally with profit, often with loss; but the undertaking would be a gambler's chance, not a business proposition. For the present it is probably better not even to put down random search holes. If good coal were found in such a hole it probably would not serve to interest capital and if no coal were found it would discourage future work, even though such a result is entirely unwarranted by the conditions of the field. Some time in the years to come when the demand for coal is greater, southwestern Iowa will be prospected and then the Grand river valley will prove the most inviting field, not so much because of any better prospect of coal occurring there rather than under the hills or in other valleys, but because the depth to which the river has cut will make the prospecting cheaper and easier. Until that time Decatur county's wealth must come, as in the present and past from its other resources.

Clays.

The clays so far developed in Decatur county have come entirely from the surface formations. The loess present throughout the county, is of the older type common in southern Iowa. It has become somewhat changed for a depth of twelve to eighteen inches from the surface, losing some of the finer and more soluble constituents and acquiring a considerable proportion of humus. The soil resulting is admirably adapted to the production of hand brick, having all the usual characteristics of alluvium. It is now used at Garden Grove and Leon. The main body of the loess below the soil, and the gumbo clays below the loess have not so far been worked. The gumbo clays are not of any value for manufacturing except in the production of clay ballast. For this purpose they are unexcelled, their plasticity and high tensile strength causing them to shrink considerably in burning and so by cracking, open up the pieces of clay to thorough interior burning. These very properties make them unavailable for use in ordinary clay works. The gumbo clays are widely distributed throughout the county and their ready accessibility makes them a valuable source of burned clay. So far they have been used only by the C., B. & Q. railway, for which several kilns have been burned at Davis City. The material here is obtained from lowland forming a long gentle slope on the west side of Grand river. It may represent, in part at least, redeposited gumbo worked over by the river. The earliest kilns here were burned by hand and required a large force of men. Ballast is now being hauled out which, however, was burned about five years ago with the aid of machines.

The material is light, porous and yet strong. It seems probable that in the future it will become an important source of road metal and be applied to the improvement of the wagon roads. The wide distribution of the clays, the ease with which it can be obtained and the cheapness with which it can be burned, all render it worthy of serious investigation.

The shale clays occurring in the county have never been utilized. From the point of view of accessibility the shales at Davis City and De Kalb are the only ones at present worthy of consideration. In each case the thickness is not great, and the shales carry limestone nodules. At De Kalb an important portion of the section (p. 278) consists of bituminous shale or slate, which would need to be thrown aside. The clays would in all probability yield a good hard brick, and possibly pavers could also be made. They could not, however, be worked by open pits, but would need to be mined. This would impose no especial burdens at De Kalb as there is a good limestone roof and a fair thickness of clay above water level. It would, however, make the work more expensive than at many competing plants.

The brick made at present are the common salmon brick. bringing about $6 per thousand. The Foster Mullinix yard is located in the northeastern portion of Leon. The brick are hand made from the surface loam and burned with wood in a cased kiln. South of Leon (Tp. 68 N., R. XXV W., Sec. 9, Sw. of Se.) W. H. Mills has burned brick of the same character. None were burned here in 1897. W. H. Jenkins runs two kilns having a capacity of 100,000 each, in the northern part of Leon, and Mr. G. C. Dilsaber burns brick of the usual character at Garden Grove. Mr. Dilsaber has recently installed a brick machine and intends to work the loess under the surface loam. The loess here should make a good hard brick of cherry red color if properly handled. It will doubtless, as usual, require extra care in drying, but there is no reason to doubt that here, as at other upland points in the county, a considerable and profitable industry in the manufacture of standard building brick can be built up.

Building Stones.

The great limestone formation which underlies so considerable a portion of the county has been opened up and quarried at a number of widely distributed points. In the main, the quarries are located in the western half of the county. In the southeastern townships a little stone has been taken out, but none of the openings there are extensive enough to be called quarries in a commercial sense. Indeed nowhere in the county is stone quarried upon an extensive scale. A majority of the openings are for local and temporary purposes. Few enjoy a regular trade and all are worked intermittently. Nevertheless the aggregate amount of stone taken out in any one year is fairly considerable. For the most part it is used rough for foundations and for well rock. A considerable amount is used in the county bridge work. Some is sold as dimension stone and some has been dressed and used for monumental purposes.

The quarry appliances are of the simplest. In general the stripping is removed by hand and wheelbarrow; occasionally scrapers are employed. The rock is pried loose by wedges and crow-bars, or where these means are ineffectual, the jump drill and blasting powder are called into requisition. In most instances perhaps, the quarries are worked on short leases; royalties being paid to the fee holder, and the quarryman deserting the opening so soon as the stripping becomes heavy or the bedding too massive for his tools. For these reasons the stone has not been opened up enough to allow its real value and character to be positively determined. That which has so far been placed upon the market has been almost entirely obtained from the croppings.

So far as shown by the natural outcrops and the quarries now open, the stone is predominantly thin-bedded. Ledges of over 12 inches are rare, though stone of 14 and 18 inches may be found. The majority of courses, however, show 4, 6 and 8 inch stone. In this particular there seems to be but little difference between the various members of the formation, except that in general the Winterset seems to include heavier courses than either the De Kalb or the Earlham, which are the main quarry rocks. In physical characteristics there is considerable uniformity. The rock is fine-grained and usually ash-grey to buff in color. It breaks with a conchoidal fracture showing smooth surfaces set with inclosures of clear calcite. It is a non-magnesian stone of great purity and contains little or no pyrites. So far as its mineralogical constitution is concerned it is well adapted to withstand weathering agencies. As a matter of fact the stone so far quarried does not usually withstand weathering so well as its general appearance would lead one to expect. It splits and cracks under frost action, the fault apparently being in the physical structure of the rock. It is cut by minute cracks which allow the absorption of water, while the close texture prevents this from freezing out, so that the full force of the expansion, which has been calculated to be as much as 138 tons per square foot, is expended upon the rock. Since this rock has a crushing strength only of about 4,500 lbs. per square inch, a good deal of it gives way before this strain. Some of the ledges naturally withstand frost action better than others, but it is doubtful whether it would be practicable to quarry them separately with a profit. For the purposes to which the stone is now applied it answers well enough, but its use in large and important structures or in bridge work, except after careful selection, can not be recommended.

It is quite probable that the Winterset rock would yield an average stone of better quality than that now marketed; but so far it has been but little quarried.

The Westerville limestone occurring in the hills along Sand creek, has not been quarried to any great extent. In general it is very similar to the De Kalb in character. A thickness of about ten feet is present and the stone is readily accessible. The rock showing near the water at the mill is the same as is exposed at Reynold's ford. It is a thin bed of impure nodular rock and has only a slight value.

In the vicinity of Grand river station there are numerous quarries working the De Kalb limestone. Among them are the quarries of S. C. Jennings, Blair Brenneman and C. Miles. The Miles quarry is east of the town near the railway bridge over Grand river. The total thickness of the stone is about three feet, the ledge yielding rock six and eight inches thick. It is a hard blue stone somewhat similar to the Reynolds' Ford rock and may represent the same horizon, though apparently at Grand river it is not far above the De Kalb proper. The most pretentious attempt to quarry the De Kalb limestone was at the old Madarasz quarry, now abandoned. This quarry is located on the river about three miles northeast of town, in section 36. It was opened near the Humeston & Shenandoah railway and at one time had a switch from that road. It is said that considerable rock was taken from the quarry for railway construction. Nothing can now be seen of the quarry face, which is said to have shown ten feet of stone with the base five feet above the river.

East of De Kalb station are the typical exposures of the De Kalb rock. A section has already been given but the following details from a neighboring quarry will show the thickness of the individual ledges.

		FEET	INCHES.
6.	Stripping, bowlder clay	6	
5.	Limestone, irregular and waterworn		6
4.	Shale, hard		6
3.	Limestone, irregularly bedded		8
2.	Shale or bastard rock	2	
1.	Limestone in five ledges that are respectively 9, 12, 6, 13 and 8 inches in thickness	4	

The upper courses yield little of value and the main output is of stone from the lower ledges. There are two quarries here, the south one being owned by Mr. B. D. De Kalb and the north one by Martha Fry. A short distance west of De Kalb station the stone has also been opened up on Short creek (Ne. of Nw. Sec. 32, Long Creek Tp.). In the quarries here the following section was observed.

		FEET.	INCHES.
10.	Shale, gray to green	2	6
9.	Limestone, shaly		6
8.	Limestone, solid		9
7.	Shale, drab to yellow	2	

		FEET.	INCHES.
6.	Limestone, thin, shaly		4
5.	Clay parting		2
4	Limestone	1	
3.	Limestone		5
2	Limestone		4
1.	Limestone		6

The rock is the usual character and carries *Productus nebrascensis*, *Productus cora*, *Productus costatus*, *Meekella striato-costata* and *Chonetes verneuilanus.*

Along Hall run and Elk creek, in Grand River and Bloomington townships, there are numerous exposures of the De Kalb and Winterset, and, near the mouth of Elk creek, the Earlham limestones. The exposure shown in Fig. 2, Plate xxiv, is one of the best and shows the Winterset limestone to a thickness of fifteen feet with the shales below it and extending down to the Earlham. This exposure is almost five miles northeast of Lamoni on Pot Hole or Potters' branch. The section at this point includes the following beds.

		FEET.	INCHES.
6.	Limestone (Winterset) with *Spirifer camerata*, *Productus punctatus*, *Productus costatus*, *Athyris subtilita*, etc	15	
5.	Shale, gray to drab	3	6
4.	Shale bitmuinous	2	6
3.	Coal		1½
2.	Shale, gray	6	
1.	Limestone (Earlham) in bed of creek.		

A few miles north of here at the Millsap quarries (Sec. 34, Grand river Tp.) the base of the De Kalb limestone shows again with some ledges of rock thirty-six inches thick. Below the limestone is a drab to gray shale carrying *Athyris subtilita* and *Productus longispinus*. About five feet below the base of the limestone, and in the shale, is a third band of limestone very full of *Chonetes verneuilanus* and overlying an irregular ledge of nodular blue limestone carrying large well formed *Productus cora*. The exposure does not seem deep enough to expose the Myalina horizon though *Derbya crassa* is present.

In the southeast corner of the same section the blue limestone shows again and a short distance farther down the Winterset is exposed.

In the northwestern portion of Burrell township the Fragmental, Earlham and Winterset limestones and associated shales are exposed on the west side of the river (Sec. 7, W. ½ Ne. ¼). On the east side of the river the Earlham has been quarried on the Anton Rauch land. This quarry has not recently been worked but the stock pile shows some excellent eighteen-inch rock. The stone from the quarry has been dressed and sold for monumental work.

South of Terre Haute on Pot Hole branch, near the exposure of Winterset figured above, there are the S. A. Ferguson, N. N. Hazelton, and Isaac Toney quarries, all in the Earlham rock. The section here is as follows:

		Feet.
3.	Limestone, ash gray to brown, fine-grained, thin-bedded, with courses up to 1 foot in thickness and shale partings	6–10
2.	Shale, drab, imperfectly exposed, but showing 1 foot of black slate	10
1.	Limestone, brecciated or fragmental type, firmly cemented and apparently non-fossiliferous	4

It is the upper rock which is quarried and which carries *Athyris subtilita* (abundant) *Productus cora*, *Productus cameratus*, *Productus costatus*, *Rhynchonella uta*, *Hustedia mormoni* (rare) and the usual stems and spines of crinoids. The rock dips to the west, and the Winterset present in the hills above is exposed farther up the stream.

Near Davis City there are quarries both north and southwest of town. The main quarry north of town is the S. Radnick, which is opened in the Earlham. The quarries southwest of town are along Dickerson branch and include the W. Rickards, Hugh Sutherland, Jos. Boswell, and C. Noble openings. These are all small openings in the Earlham.

As seen at the Boswell quarry the section is as given below.

		FEET.	INCHES.
6.	Stripping, loess-loam	2-4	
5.	Limestone	1	
4.	Rotten stone and shale	2	
3.	Limestone, 14-inch ledge carrying a 3-inch ledge below	1	5
2.	Shale and rotten stone	1	
1.	Limestone, with wavy bedding, ledges running from 3 to 16 inches	6	

The bedding in the lower stone is quite irregular. The courses are persistent but vary rapidly in thickness so that the surface lines are wavy. In the roadway, about ten feet below the stone, are traces of a black slate; and in the stream, about twenty feet below the quarry, the Fragmental rock outcrops. It is unfossiliferous except for the presence of *Productus cora*, is loosely cemented and crumbles so readily that it does not form a ledge. The Winterset limestone is present higher in the hills and possibly also the De Kalb.

The location of the various outcrops in the southeastern portion of the county and the character of the stone has already been sufficiently indicated.

Lime.

In the earlier years of the settlement of the county lime was burned at several points. The rock is not, however, adapted to the manufacture of the best grade of lime, owing to its non-magnesian character, and with the better transportation facilities now enjoyed by the region the trade has passed into the hands of producers in other sections of the country. The non-magnesian rocks burn to a clear white lime of good appearance, but which really affords a weaker bond than that furnished by the magnesian lime. It is also difficult to handle and can only be worked by exercising great care in slacking and by using an abundance of water. For these reasons it would compete upon unequal terms with the lime now on the market, and except in especial instances the old industry is not apt to be revived. The purity of the stone suggests that it would be an excellent source of lime for cement production whenever it becomes economical to grind limestone for that purpose. For the present the chalks and marls shut it out of that field.

A partial analysis made for the survey by Dr. J. B. Weems gave the following results.

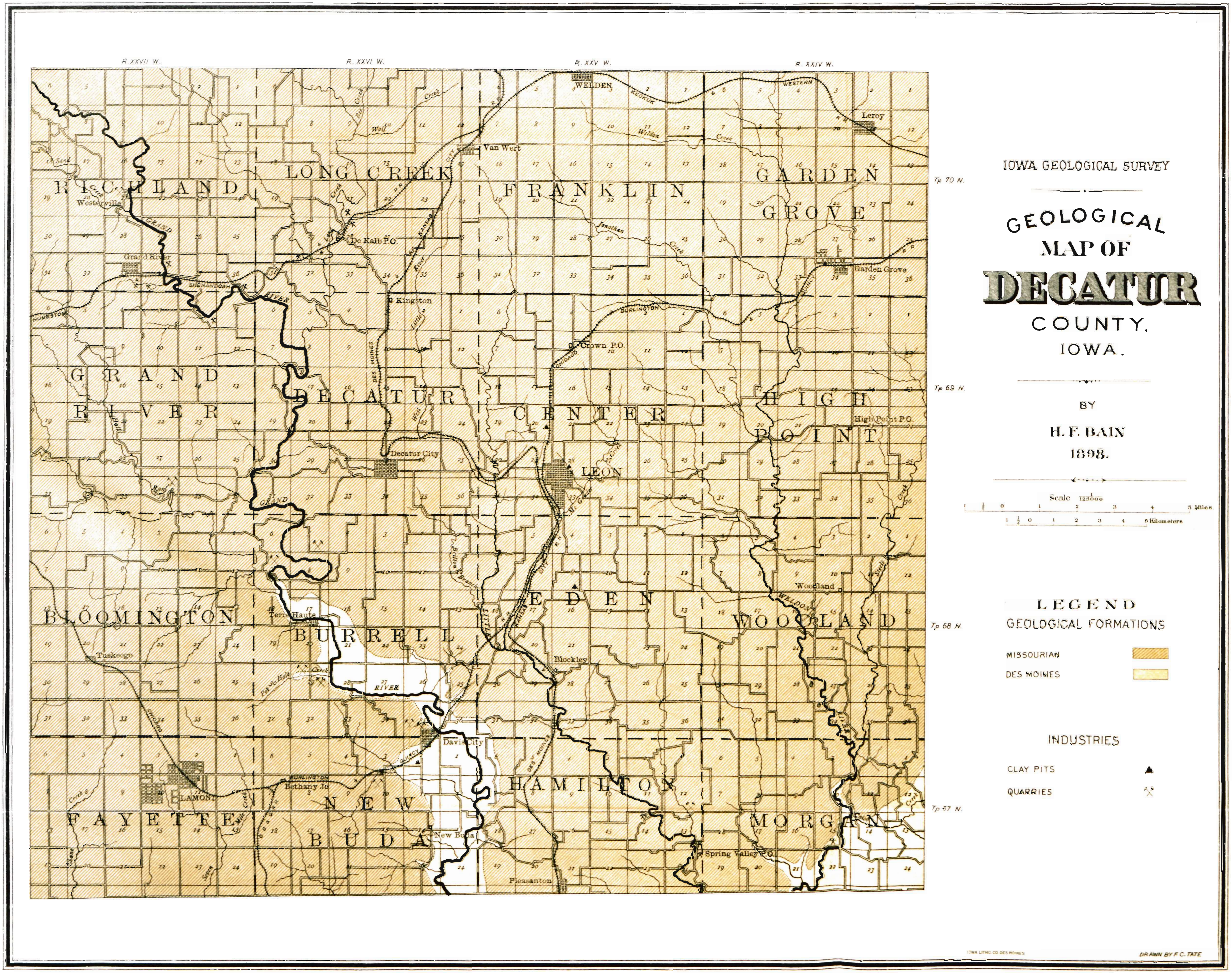
Ca CO_2	91.96
Mg CO_3	1.99
H_2O	.07

This sample was from the De Kalb limestone as shown at the type locality. It emphasizes the fact of the purity of the stone which is essentially calcium carbonate and would yield 51.25 per cent of lime (Ca O). While, as has been stated, this would be a non-magnesian lime, it may be remembered that the St. Louis and other Missouri limes, which enjoy a large trade, are of this character. Analyses of several of these are given below.*

	I	II.	III.	IV.
Carbonate of lime	99.815	92.75	97.76	98.80
Magnesia	Tr.	3.26	.12	.02
Oxide of magnesia	Tr.	....	....	....
Alumna	.054	.48	.... }	.40
Oxide of Iron	.011	.40	.20 }	
Silicic and insol	.12	.495	.26	.08
Phosphoric acid	None.	....	....	....
Sulphuric acid	Tr.	....	....	....
Calcium sulphate	....	Tr	....	....
Water	....	.675	....	....
Alkalis and loss	....	1.94	....	....
Total	100.00	100.00	98.34	99.30

I. Ash Grove white lime.
II. Champion white limestone, Ash Grove, Mo.
III. Limestone from St. Louis county.
IV. Limestone from Marion county, Mo.

* Minn. Res. U. S., 1889-90, pp. 406-407.



IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF DECATUR COUNTY, IOWA.
BY H. F. BAIN
1898.
Scale 1/125000
Miles
Kilometers
LEGEND
GEOLOGICAL FORMATIONS
MISSOURIAN
DES MOINES
INDUSTRIES
CLAY PITS
QUARRIES
R. XXVII W.
R. XXVI W.
R. XXV W.
R. XXIV W.
Tp 70 N.
Tp 69 N.
Tp 68 N.
Tp 67 N.
RICHLAND
LONG CREEK
FRANKLIN
GARDEN GROVE
GRAND RIVER
DECATUR
CENTER
HIGH POINT
BLOOMINGTON
BURRELL
EDEN
WOODLAND
FAYETTE
NEW BUDA
HAMILTON
MORGAN
Welden
Van Wert
Leroy
Westerville
De Kalb P.O.
Grand River
Garden Grove
Kingston
Crown P.O.
High Point P.O.
Decatur City
LEON
Woodland
Terre Haute
Tuskeego
Blockley
Davis City
LAMONI
Bethany Jc
New Buda
Pleasanton
Spring Valley P.O.
IOWA LITHO. CO. DES MOINES
DRAWN BY F. C. TATE

ACKNOWLEDGMENTS.

In the preparation of this report the author has received information and other courtesies from a large number of persons both within and without the county. It is impossible to mention everyone but especial reference must be made to Prof. T. J. Fitzpatrick of Graceland college who furnished the list of forest trees appended and to Mr. F. M. Smith with him for the photographs from which Plate xxiii and Fig. 2, Plate xxiv, were prepared. To Prof. Calvin is due the determination of the fossils and to Mr. William Haven of Ottumwa, is due certain valuable suggestions used in discussing the coal. To Mr. Morgan G. Thomas, state mine inspector, the author is particularly indebted for reviewing the latter section of the report and checking the cost estimates there made.

FOREST TREES AND SHRUBS OF DECATUR COUNTY.

BY T. J. FITZPATRICK.

Decatur county is essentially an expanse of prairie with narrow sinuous belts of timber stretched along Grand river and its tributaries. Unbroken prairie is being slowly occupied by forests. In such places the hazelnut, ground oak, laurel oak, red oak, bur oak, white oak, and the elms are slowly establishing themselves. Many of these embryo forests exist and are annually drawn upon for fencing material and firewood. While perhaps the larger number of such forests are being reduced in size or destroyed, in order to increase the area of tillable soil or of pasture, yet these forests, if carefully husbanded, would be sufficient for future needs. The older forests are confined to the main water courses and are of limited extent. Here the soft timber predominates. The white oak, hard maple and other trees of like character are too few in number to be of consequence in the manufacture of lumber. A few saw mills are located in the county and produce annually a small amount chiefly of soft lumber which is used locally.

The nomenclature of the following list of trees and shrubs is that of the sixth edition of Gray's Manual.

TILIACEÆ.

Tilia americana L. Basswood, Linden or Linn. Common in river bottoms and frequent in rich uplands.

RUTACEÆ.

Xanthoxylum americana Mill. Northern Prickly Ash. Frequent in woods.

CELASTRACEÆ.

Celastrus scandens L. Climbing Bitter Sweet. Frequent in upland woods.

Euonymus atropurpureus Jacq. Burning-Bush. Rich woods, infrequent.

RHAMNACEÆ.

Rhamnus lanceolata Pursh. Buckthorn. Common along fence rows bordering woods; frequent in thickets along highways.

Ceanothus americanus L. New Jersey Tea. Prairies and upland woods, rather rare.

C. ovatus Desf. Prairies and roadsides, common.

VITACEÆ.

Vitis riparia Mx. Wild Grape. Rich woods, common.

V. cinerea Englm. Downy Grape. Waste places, rare.

Ampelopsis quinquefolia Mx. Virginian Creeper. Rich woods, frequent.

SAPINDACEÆ.

Æsculus glabra Willd. Ohio or Fetid Buckeye. Rich woods, common but less so than formerly.

Acer saccharinum Wang. Hard or Sugar Maple. Frequent along Grand river but disappearing. Frequent in cultivation.

A. dasycarpum Ehrh. Soft Maple. Common in river bottoms, a frequent grove tree.

Negundo aceroides Moench. Box-Elder. Rich woods, common. Frequent in cultivation.

ANACARDIACEÆ.

Rhus glabra L. Smooth Sumach. Upland open woods, common.

R. toxicodendron L. Poison Ivy. Fence rows, woods; frequent.

LEGUMINOSÆ.

Amorpha canescens Nutt. Lead-Plant. Prairies and open woods, common.

A. fruticosa L. False Indigo. Rich soil in sloughs and low places, common.

Robinia pseudacacia L. Common Locust. A frequent tree along roadsides and in waste places.

Cercis canadensis L. Red-bud. Wooded bluffs. Frequent along Grand river below Woodmansee bridge.

Gymnocladus canadensis Lam. Kentucky Coffee-tree. A few in low woods below Woodmansee bridge.

Gleditschia triacanthos L. Honey-Locust. River bottoms and rich uplands, frequent.

ROSACEÆ.

Prunus americana Marsh. Wild Plum. Upland woods, common.

P. serotina Ehrh. Wild Black Cherry. Upland woods, frequent.

P. virginiana L. Choke-cherry. Rich woods, common.

Physocarpus opulifolius Max. Nine-bark. Rocky banks; infrequent.

Rubus occidentalis L. Raspberry. Fence rows, thickets, not common.

R. villosus Ait. Blackberry. Uplands, not common.

Rosa arkansana Porter. Common Wild Rose. Prairies, common. Determined by Mo. Bot. Gar.

Pyrus coronaria L. Crab-Apple. Thickets, common.

P. malus L. Apple. A frequent escape into fields and waste places.

Cratægus coccinea L. Red Hawthorn. Thickets, common.

C. tomentosa L. Scarlet Thorn. Thickets, frequent.

C. crus-galli L. Cockspur Thorn. Thickets, common.

Amelanchier canadensis T. & G. Service-berry. Wooded bluffs, frequent.

SAXIFRAGACEÆ.

Ribes gracile Mx. Missouri Gooseberry. Open low woods, frequent.

CORNACEÆ.

Cornus sericea L. Silky Cornel. Rich soil, frequent. This and the following were determined by the Mo. Bot. Gar.

C. paniculata L'Her. Panicled Cornel. Waysides, thickets, frequent.

CAPRIFOLIACEÆ.

Sambucus canadensis L. Elder. Rich soil, frequent.

Symphoricarpos vulgaris Mx. Coral-berry. Rich open woods, common.

RUBIACEÆ.

Cephalanthus occidentalis L. Button-bush. Swampy soil, frequent.

OLEACEÆ.

Fraxinus viridis Mx. Green Ash. A frequent tree in low or rich upland woods. Determined by the Mo. Bot. Gar.

F. americana L. This species is undoubtedly present but has not been observed.

BIGNONIACEÆ.

Catalpa speciosa Warder. Catalpa. A frequent tree in cultivation, rarely an escape.

URTICACEÆ.

Ulmus fulva Mx. Red or Slippery Elm. Rich woods, frequent.

U. americana L. White Elm. Rich woods, common.

Celtis occidentalis L. Hackberry. Low woods, frequent.

Maclura aurantiaca Nutt. Osage Orange. Formerly cultivated for hedge fences, frequently spontaneous.

Morus rubra L. Red Mulberry. Wooded bluffs and low woods, frequent.

PLATANACEÆ.

Platanus occidentalis L. Sycamore, Buttonwood. An infrequent tree along Grand river and its tributaries.

JUGLANDACEÆ.

Juglans nigra L. Black Walnut. Rich woods, frequent.

Carya alba Nutt. White Hickory. Upland woods, common.

C. sulcata Nutt. Shell-bark Hickory. Low woods along Grand river, once frequent but disappearing.

C. amara Nutt. Bitter-nut or Pignut Hickory. Rich woods, common.

CUPULIFERÆ.

Corylus americana Walt. Hazelnut. Uplands, common.

Ostrya virginica Willd. Ironwood, Hop-hornbeam. Wooded bluffs, frequent.

Carpinus caroliniana Walt. Ironwood, American Hornbeam. Wooded bluffs, frequent.

Quercus alba L. White Oak. Uplands, frequent.

Q. macrocarpa Mx. Bur Oak. A large tree in rich woods, shrubby on the prairies; common.

Q. bicolor Willd. Swamp White Oak. Bottom woods, common near Woodmansee bridge and elsewhere.

Q. muhlenbergii Englm. Chestnut Oak. Upland woods, infrequent.

Q. prinoides Willd. Ground Oak. Uplands, common.

Q. rubra L. Red Oak. Upland woods, frequent.

Q. coccinea Wang. Scarlet Oak. Upland woods, common.

Q. palustris Du Roi. Pin Oak. Low woods, frequent.

Q. imbricaria Mx. Laurel Oak, Shingle Oak. Upland woods, common.

Q. nigra L. Black Jack or Barren Oak. Uplands, frequent.

SALICACEÆ.

Populus tremuloides Mx. Quaking Asp. Upland woods.

P. monilifera Ait. Cottonwood. Low woods, frequent.

P. alba L. White Poplar. A cultivated variety of this is becoming a frequent escape.

Salix humilis Marsh. Prairie Willow. Prairies, common. Determined by the Mo. Bot. Gar.

GEOLOGY OF PLYMOUTH COUNTY

BY

H. F. BAIN.

GEOLOGY OF PLYMOUTH COUNTY.

BY H. F. BAIN.

CONTENTS.

INTRODUCTION.

Plymouth county lies on the western border of the state and is the third south of Minnesota, Sioux and Lyon counties intervening. To the east is Cherokee county and to the south is Woodbury. On the west it is separated by the Big Sioux river from Union county, South Dakota. The western boundary of the county, being formed by the river is an irregular north-south line. The remaining boundaries are simple land lines. The area extends twenty-four miles from north to south and from thirty-four to forty-one miles east and west. It includes townships 90 to 93 north and portions of ranges 43 to 49 west. The total area is 860 square miles or 490,400 acres.

To the fact that the county nowhere touches the Missouri river, the great highway of early commerce, is due the further fact that the exposures within its limits were not much studied by the various geologists who in earlier years visited Sioux City and contributed to our knowledge of Woodbury county.* The exposures along the Sioux as far north as the mouth of Broken Kettle were probably visited by several of these earlier explorers, but our knowledge of the geology of the county begins with the visit made to it by White and St. John.† Subsequently Todd published notes on the geology of the region‡ and has more recently published two valuable papers covering adjacent portions of South Dakota.** Soon after the organization of the present Survey the county was visited by Prof. Calvin and certain preliminary results have been published.§ Later a section along the Big Sioux was made by the present writer,‖ and the neighboring county to the southward was reported on in detail.†† In the course of this preliminary

*See Geology of Woodbury county, Iowa Geol. Surv., vol. V, pp. 265-et seq. 1896.

†Geol. Iowa (White), 1870, pp. 229-232.

§ Proc. Iowa Acad. Sci., vol. I, pt. iii, pp. 13-16. 1893.

**South Dakota Geol. Surv. Bul. No. 1; Bul. U. S. Geol. Surv., No. 144.

‡Iowa Geol. Surv., vol. I, pp. 145-161. 1893; Ibid, vol. III, pp. 210-236 1895; Proc. Iowa Acad. Sci., vol. I, pt. iii, pp. 7-12. 1893; Amer. Geol., vol. XI, pp. 300-307. 1893; vol. XIV, pp. 140-161. 1894; Proc. Amer. As Adv. Sci., vol. XVIII. 1894.

‖ Iowa Geol. Surv., vol. III, pp. 98-114. 1895.

†† Geology of Woodbury county, Iowa Geol. Surv., vol. V, pp. 241-299. 1896.

work and some later excursions through portions of the county a number of notes were accumulated and within the last summer some weeks were spent in a further study of the area as a whole; the present report being the result.

In the earlier work of the present Survey, as well as in that of its predecessors, the problems of the drift and surface formations were dealt with but cursorily. The immediate interest was centered in the indurated rocks. In the work of the past field season it was the drift which was especially studied. The present is a report on the first area studied by the Survey with especial reference to the drift problems of northwestern Iowa. As such it necessarily is incomplete. Certain generalizations which present knowledge indicates to be correct may, when the neighboring areas are studied, need modification. Many points must remain unsettled and many phenomena, for the present, unexplained. It has been thought better in writing the present paper to adopt as a working hypothesis that which seems at present most probably correct; the points of doubt being indicated from time to time in the discussion. It is hoped that in this way doubtful points may not be too much neglected and yet a useful report be made.

PHYSIOGRAPHY.

TOPOGRAPHY.

The area under discussion lies on the western or Missouri side of the great watershed which divides Iowa into two unequal portions. Its streams flow into the Missouri, directly or through tributary drainage. Its surface as a whole slopes to that great waterway. The county forms a partially dissected plain with the main towns located in the valleys.

The elevation of the more important points in the county is shown in the following table, prepared from railway levels. Since the development of the drainage has been controlled by the Missouri at Sioux City the elevation of the flood plain and of low water at that point is given for comparison.

STATION.	FEET.	AUTHORITY.
Akron	1,155	C., M. & St. P. Ry.
Chatsworth	1,152	C., M. & St. P. Ry.
Dalton	1,212	S. C. & N. Ry.
James	1,120	I. C. Ry.
Kingsley	1,241	C & N. W. Ry.
Le Mars	1,224	I. C. Ry.
Merrill	1,167	I. C. Ry.
Oyens	1,263	I. C. Ry.
Remsen	1,314	I. C. Ry.
Seney	1,223	C., M., St. P. & O. Ry.
Struble	1,271	S. C. & N. Ry.
Westfield	1,131	C., M. & St. P. Ry.
Sioux City (railway station)	1,104	C., M. & St. P. Ry.
Low water	1,076	Mo. Riv. Com.

Taking the elevation of a series of towns from east to west a general slope toward the west is indicated.

	FEET.
Remsen	1,314
Oyens	1,263
Le Mars	1,224
Dalton	1,212
Akron	1,155

Compare also Struble, 1,271, and Chatsworth, 1,152; Merrill, 1,167, and Westfield, 1,131; Kingsley, 1,241, and James, 1,120. Such comparisons are confessedly inaccurate, since the various towns do not bear equivalent relations to streamways and valleys. They, however, indicate at least approximately the true relations as may be seen by a comparison of upland surfaces, calculated from barometer readings tied to railway levels.

	FEET.
Highland near Remsen	1,404
Le Mars	1,334
Dalton	1,312
Akron	1,275

This comparison, however, neglects the divide between the Floyd and the Big Sioux which was found in Preston township by barometer readings to be approximately 300 feet above Chatsworth.

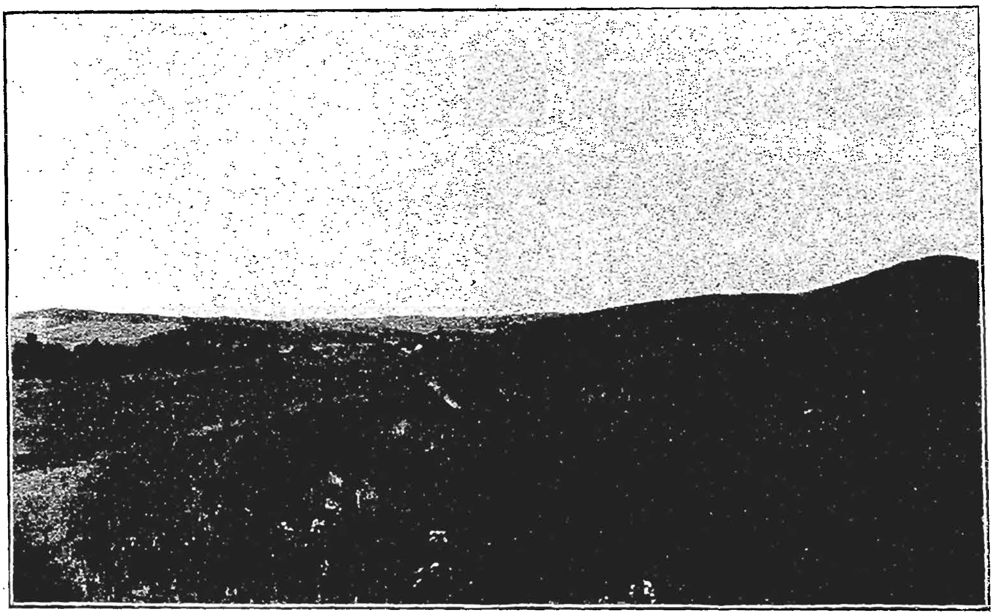


FIG. 1. Loess slopes along Broken Kettle creek, immediately above the "shut in" at Milleneryville.

FIG. 2. Loess slopes of the upland region, Plymouth county.

The slope to the south may be readily seen by following any given line in that direction. For example, Chatsworth, 1,152, Westfield, 1,131, Struble, 1,271, Dalton, 1,212, Merrill, 1,167, James, 1,120, Remsen, 1,314, Kingsley, 1,241. The last comparison is the most significant, since it is between two points located upon different water courses. Chatsworth and Westfield are both in the valley of the Big Sioux; Struble and Dalton, Merrill and James lie in the Floyd valley. The base level of erosion in these two valleys is in each case controlled by low water mark at Sioux City, 1,076. Remsen, however, lies in the valley of Deep creek, a tributary of the Floyd, while Kingsley is in the valley of the west fork of Little Sioux.

In general these elevations indicate an upland, lying at an elevation of about 1,400 feet, with a series of river valleys cut from 100 to 300 feet below it. The depth of most of these valleys is controlled by low water mark at Sioux City and is proportional at any point to the area drained by the stream above that point and to the distance from Sioux City. Along any stream the altitude increases with the distance (compare Merrill, Dalton, Struble), while with the same distance the altitude is inversely proportional to the size of the stream, or dependent upon the area of the valley above (compare Struble and Chatsworth).

Topographically Plymouth county is divisible into two rather sharply contrasted areas; the major occupying much the larger portion of the county and the minor being found in the southwestern part. Over the main portion of the county the topography shows characteristic erosion curves and surfaces. The land forms are manifestly the result of river and stream erosion and the general plain, which is so characteristic and striking a feature of the landscape, breaks up into a series of wide, shallow valleys. These digitate, and while in cross-section and general appearance they seem to be poorly developed, a close study shows that they really control the drainage of the county quite exactly. The land is all drained and upland sloughs are almost unknown. The valleys have long and gentle side-slopes, eighty feet per mile seeming to represent quite closely the average. Steeper slopes are only found at points of recent erosion. For example, along a small tributary of Clear creek, joining that stream near Kingsley (Secs. 24, 13 and 14, Elkhorn Tp.), the bluffs on the southwest side are quite abrupt and show slopes considerably steeper than are common in the region. Such phenomena are, however, due merely to local accidents of erosion. In general the slopes are long, gentle and unbroken. Wherever one looks he sees the same gentle rolling plain with a sky line which is almost, but not quite, even; a slightly sinuous or wavy line. The surface is uniformly covered with loess and while, as will be later shown, the latter is quite thin, perhaps not averaging more than six feet in thickness, there has been so little erosion since its deposition that it has been quite rarely cut through. One may drive forty miles or more in almost any direction and see nothing but loess and alluvium, and in the whole of the eastern portion of the county exposures of the sub-loessial beds are so rare that they may be counted upon the fingers.

The valleys in this region are well developed. They have flat, and often relatively wide, bottom lands. The amount of alluvium may be important. In the perfection of the drainage system and the development of the bottom lands the valleys seem to require that one should allow a considerable period for their development. There are, however, certain other facts which must be taken into account, but which are best discussed in connection with the drift. It is perhaps sufficient to say here that the erosion was manifestly accomplished before the deposition of the loess. Since that period there has been almost no erosion.

In the southwestern portion of the county there is a limited area which is topographically distinct from that just described. In a general way it may be defined as lying southwest of a line drawn from Westfield to James. In this area the predominant land forms are still those of erosion, but a very different type of erosion from that of the other parts of the county. The slopes are much steeper, and abrupt bluffs abound. Indeed the inter-stream areas stand up like peaks and spires, and the streams seem to wander between them where they may, rather than where they will. This region shows the characteristic and often described loess landscape with its bewildering complex of pointed, semi-detached hills, and winding, tortuous yard-wide divides. It marks young and vigorous erosion upon easily cut beds, which, though they can if need be, stand abrupt without grass covering, yet usually are beneath a surface of coarse prairie grass. The hills, with slopes often too steep for sod, hint to man of Nature's plan by developing a series of one-foot terraces, all but concealed below the grass. In this maze of hills, stream courses are erratic. One climbs a hill to get a synthetic view of the country and discovers instead but a larger and more complex maze of hills similar to that on which he stands. To the west is the broad bottom land of the Big Sioux and the Missouri, and out on the edge of the bottom land the hills push with frowning bluffs and steep slopes, which rise altogether 280 to 300 feet from the water. At the base are exposures of Cretaceous, and above these rocks, drift occasionally shows. Where the earlier formations are not actually exposed their presence is often indicated by the sharply moulded terrace of the Niobrara or scattered surface bowlders from the bowlder clay.

Along its inner border this topographic region is not always sharply defined. At points it fades away, shading off into the normal drift-plain erosion forms, losing its identity so gradually that one can not, save arbitrarily, put down a line to limit it. At other points the line is very sharp. For example, if one drives southeast from Westfield along the road which leads over the hills towards Millineryville, he will see spread out to the east the broad, open valleys and gently rounded slopes characteristic of the eastern portion of the county. To the west, and rising above this eastern upland plain, are the jumbled peaks and narrow, closed-in valleys of the loess region. Again, if one drives down Broken Kettle creek, he finds at first the smooth, gentle slopes and the wide, flat-bottomed valley of a drift-loess region. In section 23, of Tp. 91 N., R. XLVIII W., this valley closes in sharply. (Plate xxv.) The bluffs rise abruptly, gaining an additional height of nearly fifty feet, and the bottom land disappears. For a valley to take on such characteristics towards its mouth, rather than towards its source, is certainly anomalous. Its explanation seems to lie in the fact that the loess of the southwestern part of the county, as defined above, is later than that overlying most of the region; that it is a wind deposit and has been whipped up on the hills and poured down into these older valleys.

These two topographic regions, then, tell the story of an earlier period of river erosion and a later period in which the action of the wind was dominant.

DRAINAGE.

The streams of Plymouth county are all directly or indirectly tributary to the Missouri. Much the major portion of the area is drained by the Big Sioux and the Floyd with their various tributaries. The Big Sioux is the more important stream. It rises in South Dakota and for about seventy-five miles forms the western boundary of the state. Along Plymouth county it has a valley from one to three miles broad and with long gentle slopes rising 120 to 165 feet above the bottom land, the river itself cutting thirty-five feet into the latter and approximately 300 feet below the divide lying between it and the Floyd. The stream has a fall of about 1.4 feet per mile. Its tributary drainage is mainly from the east, the nearness of the moraine limiting it on the west. Its most important tributary within the county is Broken Kettle creek, which has its headwaters well to the northern line of the county and a course approximately parallel to the Big Sioux till the latter makes the bend to the southeastward at Westfield. The two streams meet in Hancock township within about five miles of the southwestern corner of the county. Indian creek, with its headwaters in part near Ireton in Sioux county, and in part near the headwaters of Broken Kettle, flows west to the Sioux near Chatsworth. It has a well developed valley cut, however, almost entirely in the drift. Between Indian and Broken Kettle creeks are a number of pretty little streams including Beaver, Westfield, French and Rock creeks, which divide the narrow territory between the Broken Kettle and the Sioux.

Between the Floyd and Broken Kettle is Perry creek, an important stream with a deep, though narrow, valley. The Floyd includes the east branch rising in Osceola county and receiving within Plymouth county Deep and Plymouth creeks, and the west branch or Beaver creek rising in Sioux county and receiving Mink creek from the west. These two branches unite near Merrill. In the southeastern portion of the county is the West Fork of Little Sioux, receiving Deer and Clear creeks. Between the Floyd and West Fork of Little Sioux are the upper branches of Elliott and Whisky creeks. The streams of the county seem to have had their origin in the glacial period. There is no known evidence that any of them are pre-glacial. It is quite possible that this portion of the Big Sioux antedated the coming of the ice but there is no sufficient evidence yet in hand proving that the stream is so old. It is certainly, however, older than the Wisconsin, since its valley is filled with a gravel train from that ice. The other streams of the county afford no such data for fixing their age. They are older than the loess and their valleys are cut in the drift. The relative breadth and shallowness of the valleys would seem to indicate that the process of their erosion was a slow one. There are other phenomena, however, which make it doubtful whether such an interpretation is allowable.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

In Plymouth, as in the remaining counties of Iowa outside the driftless region, there are two great classes of rocks. These are widely different in age and usually show considerable differences in character. In a broad way they may be spoken of as the consolidated and the unconsolidated formations, and yet a division on this basis does not always place the same things together. In general the two divisions are spoken of as the surface formations and the underlying rocks, but even this terminology is apt to lead to confusion; perhaps is more apt to do so here than elsewhere. In still more general and more popular speech the classes are distinguished by restricting to the one the term rock; the looser beds being spoken of as dirt, sand, clay, gravel, etc. This is the poorest classification of all since the state of aggregation does not control either the chemical or mineralogical constitution of the mass, and hence both classes of beds equally include rock. In the region under immediate consideration the underlying rocks include sandstones, clays, shales, chalk and limestone. The overlying series include deposits of alluvium, loess, gravel and bowlder clay or till. One group is composed of marine sediments, the other includes terrestrial deposits. The former belongs to the remote and the latter to the immediate past. The older series is known to the geologists as the Cretaceous; the younger the Pleistocene. That is, the one was formed at approximately the same time as the Cretaceous or chalk cliffs of England; the other was formed in most recent time.

Between the Cretaceous and the recognized Pleistocene beds there is a series of sand deposits whose age is not certainly known. Some of the beds along this horizon probably belong to the Pleistocene itself. Others seem to represent an intermediate period known as the Tertiary, and to have been formed in great bodies of fresh water; lakes which stretched from western Iowa to the foot of the Rocky mountains.

The lowest rocks of the region of which we have any knowledge either from exposure or from drill records, are much older than the Cretaceous. These include the Sioux quartzite, popularly known as the "Sioux Falls granite," and certain beds of granite, schist and old lavas which, in Plymouth county now lie buried beneath several hundred feet of later material. These older beds belong probably to the Algonkian formation, and they, doubtless, form a part of a long arm of similar material stretching out to the southwest from the Lake Superior region. The only portion of the series now to be seen is the quartzite itself and certain associated slates and diabase dikes, all found near Sioux Falls.* The surface of these older beds, which at Sioux Falls lie 1,400 feet above sea level, dips to the southeast so that at Hull the old lava beds, which seem to belong to the same formation, occur at 878 A. T. At Le Mars it is 215 A. T. and at Sioux City 135 feet below sea level. These older rocks formed the floor upon which the limestones and associated beds of the Paleozoic were deposited and over the truncated edges of the Paleozoic the Cretaceous beds were laid down. With the Cretaceous begins the portion of the history of the region which it is possible to read with approximate accuracy from the deposits now exposed. The classification of the exposed strata is shown in the table given below.

*See Beyer: Iowa Geol. Surv., vol. VI, pp. 67-112 1896.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUBSTAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.	Wisconsin.	Gravel trains.
			Iowan?	Loess.
				Drift.
	?			Riverside sands.
Mesozoic.	Cretaceous.	Upper.	Colorado.	Niobrara chalk.
				Benton shales.
			Dakota.	

GEOLOGICAL FORMATIONS.

Cretaceous.

The sandstones and associated deposits in the vicinity of Sioux City were among those which were first studied by American geologists, and fossils were collected from them before the Cretaceous, as such, had been recognized in America. The deposits of this region are accordingly intimately connected with some of the most interesting chapters in the development of the science in America. Certain crucial points were first raised because of studies carried on, in part at least, within the limits of this county.* The exposures along the Big Sioux and in the vicinity of the mouth of the Broken Kettle have long been famous, and they show much that is interesting to students of geology. Probably the best single exposure in the county is near the site of the old Crill mill (Sec. 32, Tp. 91 N., R. XLVIII W.). At this point the river

*See, with references, Geol. Woodbury Co., Iowa Geol. Surv., vol. V, pp. 241-299. 1896.

has swung in against the base of the bluff so as to cut away the gravel plain and expose the rocks. Below the loess and drift on the hilltops the following beds may be seen.

		FEET.
6.	Limestone, thin leafy texture, full of specimens of *Inoceramus labiatus;* the individual leaves of rock separated by 4 to 10 inches of chalk; exposed at several points along the slope, total thickness indicated.......	90
5.	Shale, buff, sandy, with thin layers of sandstone and ferruginous concretions	30
4.	Shale, dark blue to drab, fine-grained, argillaceous	10
3.	Sandstone, fine-grained, calcareous, light buff to white............................	15
2.	Lignite	1½
1.	Fire clay, white to light gray, only slightly exposed, found in digging................	6

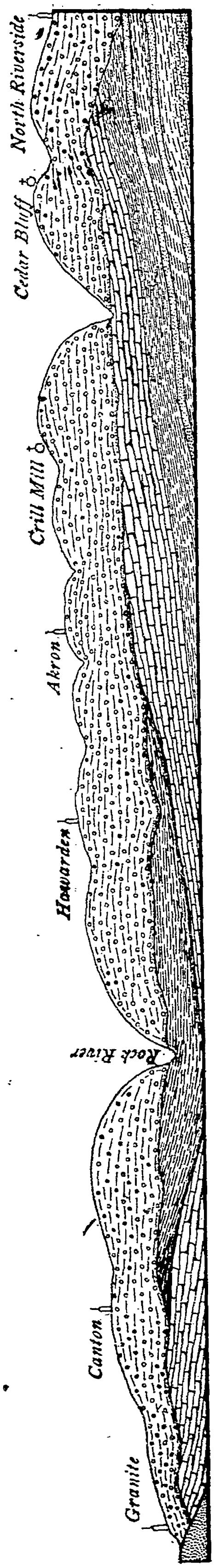


Figure 11. Geological Section along the Sioux River.

The sandstone seen in this section and the beds below represent the Dakota. The shales between it and the overlying chalk belong to the Benton formation. The Dakota and the Benton are shown in Plate xxvi. The chalk of the Niobrara is shown in Plate xxvii. Ordinarily the Benton and the Niobrara are grouped together under the name Colorado. The beds seen at this point are also exposed not far south in the famous Cedar Bluff* and at intervals between the two exposures. To the north they dip beneath the river, the uppermost beds being last exposed on the Iowa side, between Chatsworth and Hawarden, as shown in Figure 11.

DAKOTA.

The Dakota is one of the more important divisions of the Cretaceous of the interior

*Geol. Woodbury Co, Op. Cit., p. 231.

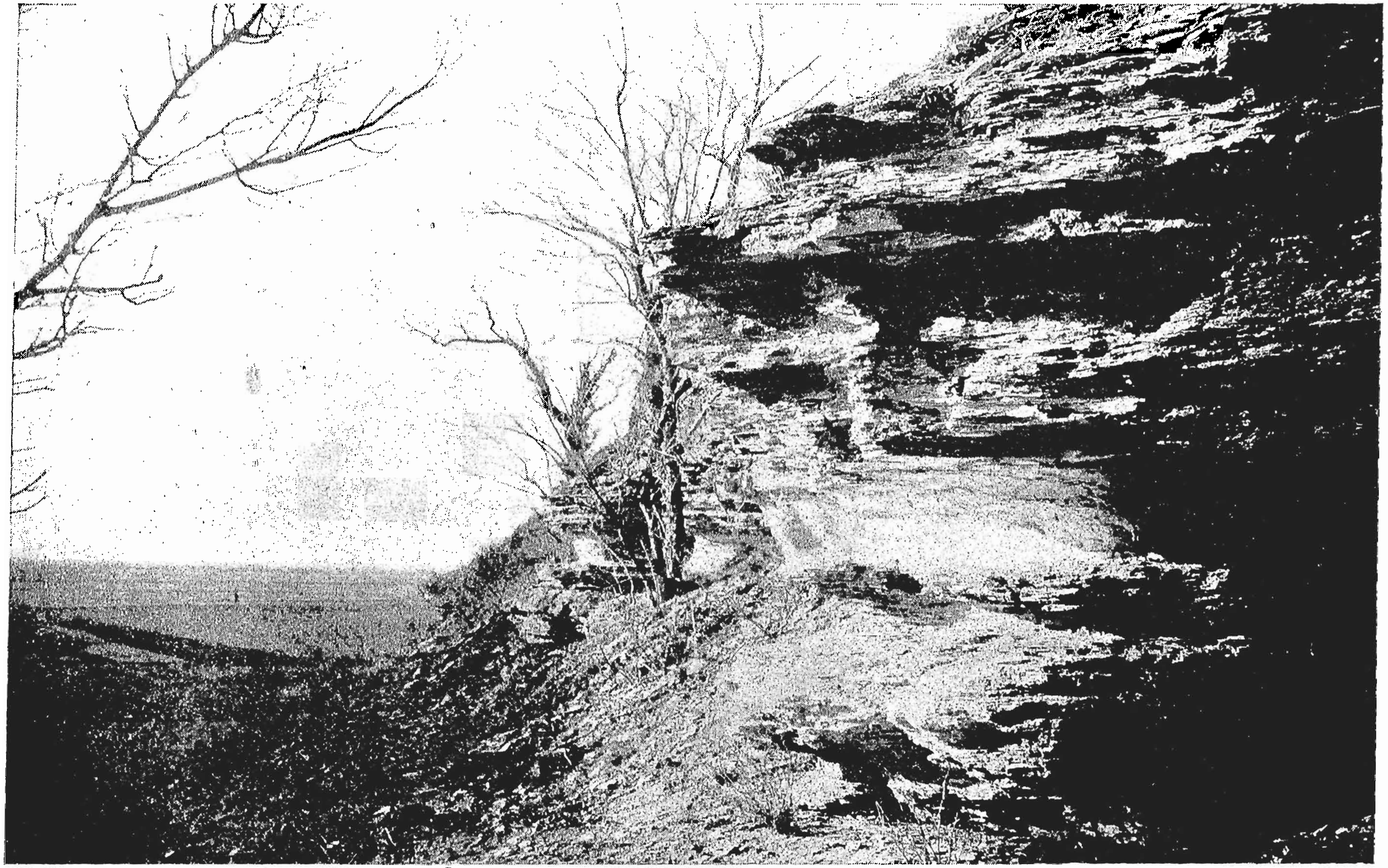
both from its areal extent, stratigraphic significance, and economic value. It outcrops over only a limited portion of Plymouth county, being confined entirely to the lower portion of the Big Sioux valley. As it is found again to the east in Sac, Greene and Guthrie counties and is encountered in well drillings at many intervening points, it is known to extend under the whole county. Over the great plains as a whole the Dakota is essentially a sandstone formation. That portion found near the mouth of the Big Sioux, however, contains a considerable percentage of shale. These shales are well exposed in the clay pits at Sargents Bluff in Woodbury county* and they also occur in the lower portion of the bluffs at North Riverside. The sandstone found at the Crill mill exposure is shown at intervals down the river and forms the top of the formation in this region. It, together with the associated shale, is believed to represent a shore formation while the overlying beds record a period of deepening waters and the deposition of off-shore sediments. It is from the Dakota sandstone that the leaves of the willow and other species of deciduous trees which caused the formation to be originally classified as Tertiary, were collected.† So far no important collections have been made from the Plymouth county exposures, though a careful search would probably be rewarded by numerous specimens.

COLORADO.

The Colorado formation doubtless underlies almost the whole of this county. Its outcrops are, however, confined to the valley of the Big Sioux and the lower course of its tributaries. The only known exception is an outcrop on Deep creek near Le Mars, now reported for the first time. The formation consists, as already stated, of a loose shale member, the Benton, and an upper chalk and limestone member, the Niobrara. The appearance of the latter is excellently

* Geol. Woodbury Co., Op. Cit., p. 260.
† Geology of Woodbury Co., p. 267.

DAKOTA AND BENTON FORMATIONS ON THE SIOUX RIVER.



CHALK CLIFF ON THE SIOUX RIVER.

shown in Plate xxvii, which is from a photograph of a portion of the Crill mill exposure. The thin lamellar character of the limestone is especially characteristic. The proportion of chalk and its purity varies greatly. At Yankton, S. D., and St. Helena, Neb., there are great bluffs of quite pure material. Farther north in the region surrounding Sioux Falls the beds, while not so thick, seem equally pure. Calvin* has interpreted this as meaning that the Sioux City exposures were nearer the shore line, so that the conditions of food supply and growth were not so favorable to the strictly marine chalk-forming types of life, such as Foraminifera. Analyses of the chalk from near Hawarden bear this out, in that they indicate a notable percentage of clay and other impurities. It is also true that toward the southeast the field relations show a transition into hard crystalline limestone and that the chalk beds proper become thinner and thinner.

The thickness of the Niobrara, as a whole, is somewhat variable since its top is a surface of erosion. From the top of the exposed Benton, at Crill mill exposure, to the top of the exposed chalk beds, is ninety feet. It is possible, however, that fifteen to twenty feet of this interval is to be assigned to the Benton. At the Otis mill, in South Dakota, opposite Chatsworth, thirty-five feet of Niobrara strata are exposed between the Benton and an overlying sandstone. Near Westfield, about twenty-five feet is exposed. In general, less than fifty feet of the Niobrara remains in western Plymouth county, though there can be but little doubt that much has been removed through erosion.

From Crill mill north to Westfield, the Niobrara forms a very sharply defined terrace in the hillsides. This terrace slopes gradually to the north with a dip of about six feet per mile. This does not seem to be the true dip of the strata, since, taking the top of the Benton as a guide, the latter is found to be a little less than two feet per mile. The top of the terrace marks, so far as can be determined, the upper surface of the

*Composition and Origin of Iowa Chalk. Iowa Geol. Surv., vol. III. pp. 211-236. 1895.

Niobrara. It seems to be a very even erosion surface and the figures would indicate that, since the Niobrara was cut down to that level, the strata have been given a northward tilt of about four feet per mile. To the north, in Sioux county, the Niobrara is covered by a series of blue-black shales which have been referred to the Pierre*. These are exposed about four miles below Hawarden (Tp. 94 N., R. XLVIII W., Sec. 15), where the following sections may be seen below the drift.

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

If the plane formed by the top of the terrace mentioned be projected, it would just about touch the top of this exposure. The erosion accordingly which developed the plane was probably later than the Pierre shales. At the Otis mill, however, there is a sandstone, to be later described, which rests upon this plane, and the period of erosion which developed the latter may accordingly be fixed as between the deposition of the Pierre shales and the Otis mill sandstone.

The exposure of Niobrara near Le Mars is found, on the Koons farm (W. ½ of Sw. ¼, Sec. 2. Tp. 92 N., R. XLV W.), on the west side of Deep creek. A thickness of about twelve feet is shown and the outcroppings occur along the stream for about 100 yards. It is possible that the Niobrara thickens under the hill, but there are no data bearing on this point. Both chalk and soft thin-bedded limestone occur. *Inocermanus labiatus* is very abundant. The base of the Niobrara is about 1,225 A. T. and is marked by a magnificent spring. Below the Niobrara, at a bend in the creek, about four feet of the Benton is exposed. It is here a blue-black, apparently unfossiliferous, clay shale with large septarian nodules. This is the only known natural exposure of rock in Plymouth county east of the Sioux valley, though the rock is known through wells and

*Iowa Geol. Surv., vol. III, pp. 112-114. 1894.

borings at several points, and other exposures may be expected to be found. The deeper streamways, both of this and Woodbury county, have been cut below the level of the upper surface of the rock. The lack of exposures is due to the drift filling of the valleys. The rock, however, is near the surface, as is shown by a well near Seney which was put down on the Kent land (Tp. 93 N., R. XLV W., Sec. 28, Se. ¼) and started at about 1,230 A. T. The well was begun with a three-foot auger and carried down with this into the Benton shale so that there can be no doubt as to the identification.

		FEET.	INCHES.
8.	Black soil	5	
7.	Yellow clay (drift)	20	
6.	Black clay shale (Benton)	85	
5.	Sandstone		1½
4.	Light clay shale	10	
3.	Sandstone		1½
2.	Pink clay	10	
1.	White sand		

Probably all the beds below the black clay shale are to be referred to the Dakota.

The usual character of the Benton is shown in the Crill mill section (see Plate xxvi). There are two divisions, an upper sandy shale and a lower, more argillaceous portion. These are well marked at the exposures down the river and may be seen at North Riverside. In the opposite direction these divisions seem to lose their identity. Near Westfield on one of the Van Vlyck farms (Nw. ¼ Sec. 13, Tp. 92 N., R. XLVIII W.) in making an excavation for a barn, the drab clay shale was found immediately below the Niobrara, as shown in the section given below.

		FEET.
2.	Limestone soft, thin-bedded, with chalky layers	25
1.	Shale, drab dark, argillaceous, with ferruginous nodules and some sandy portions	10

There was some slight evidence of disturbance here but at the Otis mill, opposite Chatsworth, the same relations were found with no evidence of movement. The section at this point, which is interesting from several points of view, is given below.

		FEET.
6.	Loess, sandy, with many lime concretions, rising over the bluffs	20
5.	Drift, new, fresh pebbles, yellow color, and with slight traces of a soil at top	30
4.	Old soil, black to drab, sandy	2
3.	Sands, white to lemon yellow, very fine-grained above, becoming coarser and orange-colored below	10
2.	Niobrara, principally thin shelly limestone with a few chalky streaks	35
1.	Shale, black to drab, with poorly developed laminations	20

The hill rises here to a total height of 190 feet, the added thickening being probably in the drift and loess. Excepting the Pierre shale already mentioned the sands and old soil seen here are the only beds, other than the drift, found above the Niobrara in this immediate region. Whether the Pierre shale extends over any portion of Plymouth county is wholly unknown. There are no exposures showing it, but there are considerable areas in the northwestern townships where it may be concealed beneath the drift.

The Otis mill sands or sandstones are of considerable interest. As has been seen they are probably separated from the known Cretaceous by a considerable interval of erosion. The presence of a marked soil separates them sharply from the known drift. In stratigraphic position they are akin to certain problematic sands already known in the region, and first noted by Todd* who has also noted their probable presence beneath the drift at Le Mars.† Fossils have been found in the beds‡ but their age can not be definitely stated. They may be anything from late Tertiary to early Pleistocene. In the present instance there is even wider latitude of interpre-

*Proc. Amer. As. Adv., Sci., vol. XXXVII, pp. 202-203. 1889.
† Proc. Iowa Acad. Sci., vol. I, pt. ii, pp. 14-15. 1892.
‡ Geol. Woodbury Co., pp. 275-279. 1896.

tation since the beds may belong anywhere between the Cretaceous and a late drift, probably Iowan. In appearance the sands differ somewhat from those found at Riverside. They are more highly colored and remind one of river deposits. They contain fragile and much rotted bivalve molluskoid fossils, which are not sufficiently preserved to allow specific determination. They seem to be Unios. The Riverside sands in their usual character are seen southeast of Akron (Ne. Sec. 7, Tp. 92 N., R. XLVIII W.), below waterlaid beds probably of the same age as the drift of the region.

Pleistocene.

GENERAL DESCRIPTION.

There are two important series of deposits in the county, which had their origin in Pleistocene time. These are the drift and the loess. The former is rarely exposed; the latter is widespread, forming the surface material over almost the entire county. Over the bottom lands there is a third formation, the alluvium, which, however, is largely derived from the loess. The modern streams are usually cutting in the alluvium, and as a result it is only occasionally that a cut along stream or railway is deep enough to expose the drift. One of the best of these exposures is on the Illinois Central railway, immediately east of Remsen. It is shown in Fig. 12. In this exposure there is a core of drift, having the shape of the present hill. It is composed of yellow bowlder clay,

Fig. 12. Section on Illinois Central Railway east of Remsen.

carrying many flattened and striated erratics, fresh and hard. There are little or no signs of weathering. There is no ferretto zone, and little sign of leaching or oxidation. The bowlders and pebbles include granite, coarse with red feldspar, and fine-grained gray, together with limestone chert, greenstone and diorite. Over the drift is a covering of loess of the usual open texture, and buff color. It is a little sandy, carries lime concretions and no fossils. It is about six feet thick. This exposure shows the normal section for the region, except that there no stratified beds are shown. Such beds, however, occur in the vicinity. Exposures of bowlder clay are really unusual, the stratified drift being more frequently seen. Bowlder clay is, however, found frequently enough to establish its presence and reveal its character.

Immediately west of Dalton (Se. Sec. 11, Washington Tp.), there is an exposure which shows certain phenomena additional to those at Remsen. Dalton itself is situated in the broad valley of West Floyd, shown in Fig. 1, Plate xxviii. The hills on the west rise 100 feet above the railway station on the bottom land. In a wagon road cut in one of these hills is the exposure in question. Fig. 2, Plate xxviii.

The drift here is, as usual, fresh and the bowlders are hard. They indicate the usual materials, quartzites, granites, greenish sandstone, limestone and chert. The pebbles are flattened and striated as usual. The drift is, however, a little more pronounced in color towards the top, the yellow being more intense and less buff. Acid tests show that it has been leached quite thoroughly to a depth of one and one-half to two feet, and less thoroughly to a distance of three feet. On the north

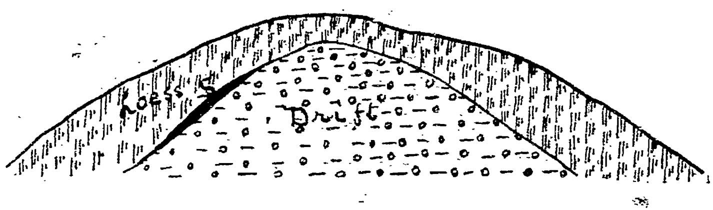


Fig. 13. Drift, loess and old soil west of Dalton

flank of the hill there is a bit of old soil, drab to black in color, and twelve to eighteen inches thick. (Fig. 13.) The slopes of the drift hill were steeper than those at present existing, as is shown by the contours of the two surfaces. The loess, however, thickens on the flanks of the hill. The loess itself is of the ordinary character, being unfossiliferous, not par-

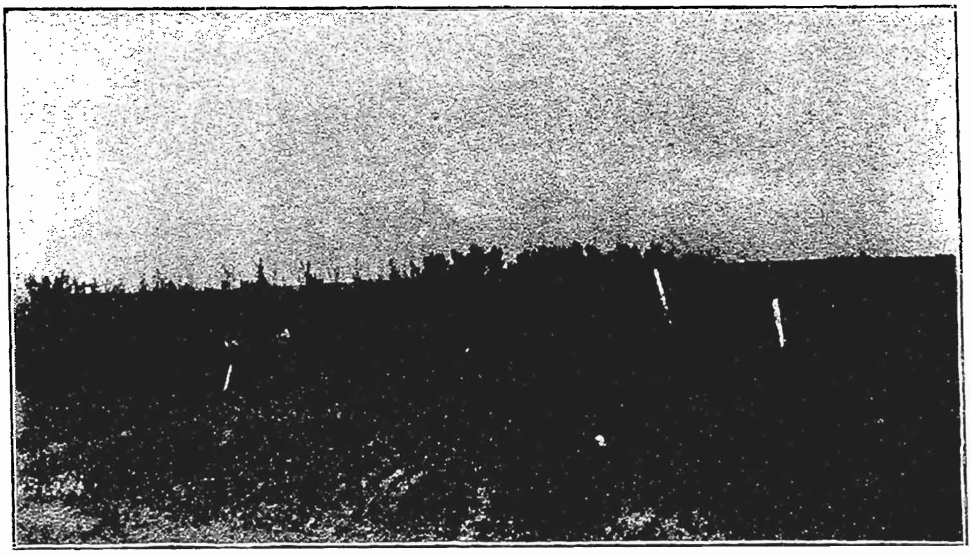


FIG. 1 Valley of Floyd at Dalton, Plymouth county.

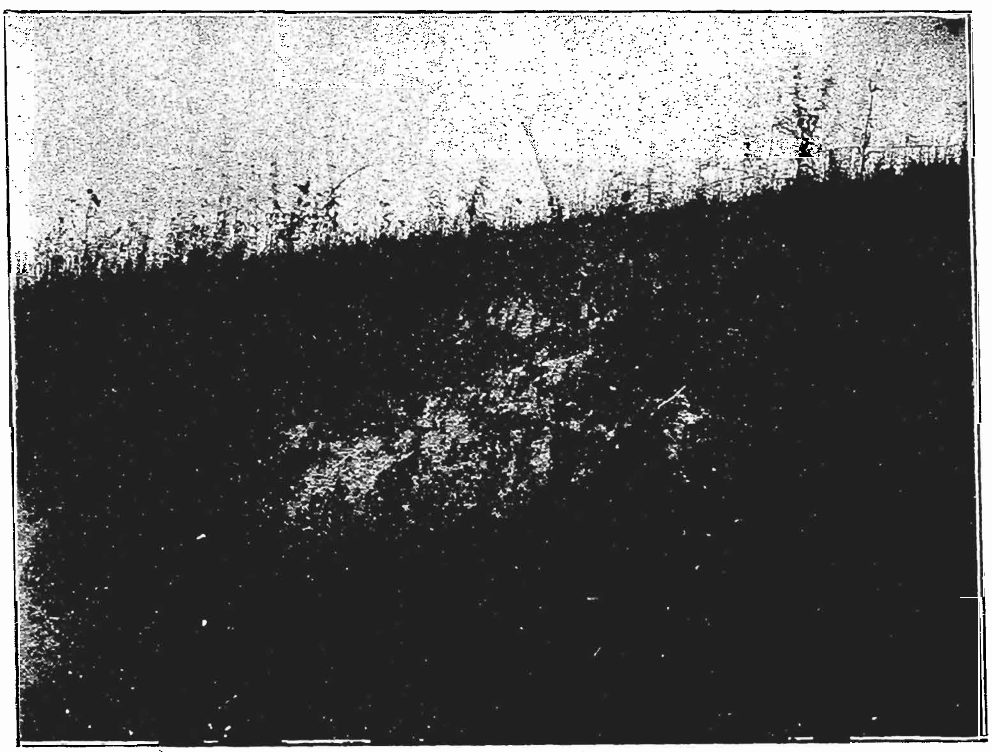


FIG. 2. Loess over drift, near view of section shown in figure 1.

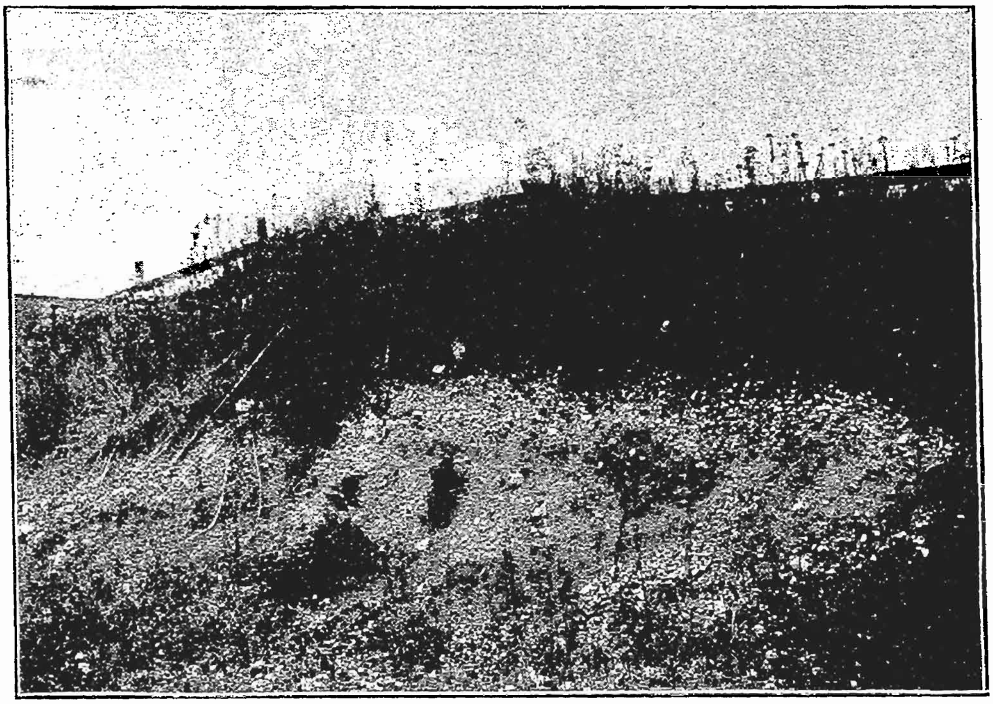


FIG. 1. Loess over drift near Akron, Plymouth county.

FIG. 2. Loess and stratified drift in the pit of the Le Mars Brick and Tile company, Le Mars, Plymouth county.

ticularly sandy, and carrying loess kindchen. These two exposures illustrate well the drift of the region. Along the Big Sioux, in the southwestern portion of the county, there are exposures showing a greater thickness, but the character of the material is the same. See Fig. 1, Plate xxix. In the northwestern portion of the county the loess is occasionally thin or entirely removed, and the hillsides are then bowlder-studded. Slopes, showing bowlders as thickly strewn as in the Iowan drift regions in eastern Iowa, may be seen in Portland township (Sw. Sw. Sec. 1, Nw. Nw. Sec. 12). Not very far from this locality (Sec. 7, Preston Tp.), there is a surface bowlder of grey granite, measuring 7x3 feet, and projecting two feet from the ground. Its surface shows a fine wind polish. In the counties to the north, notably, near Hawarden, in Sioux county, there are some remarkably large surface bowlders, and in Cherokee county, a few miles south of the town of the same name, is Pilot Rock, a Sioux quartzite bowlder, measuring 50x35x12 feet, as now exposed.

Stratified beds occur in the vicinity of Remsen and may be seen near the city dump (Ne. of Ne., Sec. 6, Tp. 92 N., R. XLIII W.). The beds exposed here are on the bottom land where the stream has been thrown against the side of the valley in such a manner as to cut away the alluvium. The exposure shows about six feet of rudely stratified coarse gravel. The material includes numerous bits of granite, Sioux quartzite, white quartzite, limestone, diorite and greenstone. The bowlders are, without exception, fresh and unweathered. Many are flattened, and some show half-effaced striations. With the gravel is a little clean white sand.

Stratified beds similar to these are found at several points in the county, being the beds most usually seen when the loess is cut through. They are found southwest of Remsen (Sec. 2, Marion Tp.), near Kingsley, in the valley of Little Sioux in Elkhorn township (Sec. 30 Sw. Sw.), at Le Mars, on Indian creek near Chatsworth, southeast of Akron and at several other points. At the Kingsley exposure the loess is at its base interstratified with the sand, and pebbles are found in it up to a distance of four feet from its base. At Le Mars the Brick and Tile Co. operate pits located on the bottom land of the Floyd. The loess is five to eight feet thick and is somewhat plastic but usually quite friable. In color it is mainly buff, but there are some horizontal bandings of yellow and blue-drab. It carries a few lime balls which are usually in distinct bands. It rests on stratified gravels and is in its lower portion quite distinctly stratified. Fig. 2, Plate xxix. The gravel bed under the loess is about three and one-half feet thick. The material is fresh, hard, and well rounded. It carries the common drift pebbles, white quartz, pink quartzite, gray and red granite, red porphyry, greenstones, gabbros, cherts, etc. At one point there is a Sioux quartzite bowlder a foot in diameter in the midst of the gravel. Cross-bedding is common. Under and with the gravel is fine, sharp-grained white sand as much as five feet thick. There are also thin streaks of blue clay free from pebbles. The material shows the action of rather strong currents and, with the but half-effaced striations on the pebbles, suggests that it is not a secondary deposit.

On Indian creek near Chatsworth (Se. of Ne. Sec. 10, Portland Tp.), in connection with a limited exposure of Niobrara, there are white and orange-colored sands interbanded with about four feet of a drab plastic clay, resembling in some particulars the gumbo of the southern portion of the state, Southeast of Akron (Secs. 7 and 8, Tp. 92 N., R. XLVIII W.). is an exposure of similar beds. The overlying material seems at first glance to be loess, but a close study shows that it is really a sand coarser in grain than is found elsewhere at the loess horizon. Below the sand and clay is a bed of sand of different constitution, already described as possibly of Tertiary age.

Throughout most of the county the stratified drift is found in the valleys only. In the Akron exposure and at some other points it is seen well up above the river. At Dalton the stratified beds occur some considerable distance above the station. When allowance is made for differences in altitude, it seems not unlikely that these water-laid beds found below the loess were laid down at a fairly uniform horizon and that they represent general conditions and not local accumulations. The material was evidently derived from the drift of the region and in many cases the large number of bowlders still showing striations indicate that it was not much, if any, reworked. The stratified beds may be a little younger than the drift but it is believed that there is not very much difference in age. It is, of course, possible that some of the beds really represent local accumulations of material gathered from the surface of the drift. This is especially apt to be true of some of the valley deposits of the eastern portion of the county. The upper gravels of the western portion are. however, quite certainly older than the major erosion of that region, and there seems no sufficient reason for assigning the erosion of the two parts of the county to different periods. Despite the fact that the loess and stratified drift are occasionally interbedded, it is believed that they are of somewhat different ages. This is held because the underlying beds are apparently independent of the present topography, while the loess is manifestly later. The two deposits are separated by whatever interval was necessary for the erosion of the valleys of the region and for the leaching of the drift with the development of the soil. That the beds should be occasionally interbedded seems not unnatural in view of the loose nature of both deposits.

Later than the loess just described, which represents the general sheet already mentioned as spreading over the major portion of the county, is the Wisconsin gravel train, occupying the valley of the Big Sioux and affording the fertile bottom land upon which Hawarden, Chatsworth, Akron, Westfield and the other valley towns are built. The railway runs along this terrace so that the elevation of the stations mentioned gives the elevation of its surface. At Hawarden and elsewhere the bottom land has been cut into, and the underlying sands and gravels may be seen. At this point the river is about twenty-five feet below the town and has a newer and narrower terrace barely ten feet above its waters. Near the mouth of Broken Kettle creek there is a higher terrace very faintly cut in the loess. Its upper surface is marked by the presence of Unios forty-five feet above low water in the Sioux. This level corresponds to the flat and well-marked bottom land found in the upper portion of Broken Kettle creek as already noted. The terrace, then, marks a stage in the waters later than the deposition of the ordinary upland loess, but earlier than the thick loess near the river which bears the marks of wind action. The Unios occur in little groups or colonies, nested together along this horizon, and at the same horizon ordinary loess fossils also occur. The same phenomena are found in Woodbury county at North Riverside, though at a lower horizon relative to present water level. In Monona county near Castana and Turin there is a very well-marked loess terrace, about seventy feet above the river and similar terraces are common in the region. These terraces must be interpreted as meaning various changes of a water level, over an area of more than local extent.

There is only very uncertain evidence of a drift older than the one exposed. Within the county there are no exposures showing glacial deposits older than the surface drift. Owing to the presence of the soft blue shales of the Cretaceous immediately below the drift it is not always possible satisfactorily to interpret such well records as are available. Forest beds have been reported from time to time throughout the northern and eastern portion of the county. In the H. Dethoff well (Se. Sec. 17, Elgin Tp.), one is said to have been encountered at a depth of ninety feet, after passing through a blue clay. Lighter, colored clays were found beneath. One mile west and two south of Marcus in Cherokee county a yellow pebble clay was reported between two blue clays. Such a succession is also reported occasionally in Plymouth county and would find its best explanation in the assumption of two drifts. The drift as reported from wells is quite thick. Near Carnes in Sioux county it is said to be 190 feet, near Orange City about the same, at Kingsley 150 to 250, and at Marcus, which is on a high divide, 400 feet of drift is reported. It is very probable that these figures include the shales of the Benton and Dakota and are really depths to the Dakota sandstone, though in the case of the Marcus well indubitable drift pebbles, said to have come from the bottom of the well, were shown. Until, however, we have the record of a well put down under the supervision of a geologist or a very careful set of samples, our interpertation of these facts must wait.

SUMMARY.

The drift series of Plymouth county, then, consist of the following members: *First*, a possible older till sheet; *second*, a well developed till with associated stratified beds, the whole relatively fresh and young, and yet having an upper surface which, occasionally at least, shows leaching and the development of the soil; *third*, a general but thin sheet of loess spread over the whole county and largely concealing the underlying beds; *fourth*, the Unio terrace of Broken Kettle creek; *fifth*, the heavy loess of the Missouri bluffs, beginning at this time, but still being deposited; *sixth*, the Wisconsin gravel terrace of the Big Sioux valley.

AGE OF THE BOWLDER CLAY.

In order to properly appreciate the significance of the Plymouth county exposures, it will be necessary to recall certain general facts as to the drift sheets of Iowa. Of the earliest of these, the pre-Kansan, so little is known that for present purposes it may be altogether neglected. If it ever existed in the region under discussion, all traces have doubtless been swept away by the later ice invasions. The second, or Kansan, is the drift sheet which covers so large a portion of southern Iowa, and adjacent portions of other states. It is a very old till and its upper surface is marked by much leaching, oxidation and ferrugination. It is covered by a mantle of loess which is normally of the older or white clay phase, being more plastic and less porus than the loess seen in northwestern Iowa. Towards the central portion of the state, however, the loess, overlying the Kansan, takes on a more friable character. Between the deposition of the Kansan drift and the loess which covered it, was a very long period of erosion, as is shown by the topography and the ferrugination, leaching etc., already mentioned. Sometime within this period, an ice sheet crossed Illinois from the northeast, and invaded the southeastern portion of Iowa. This ice sheet (Illinoian) is presumed to have come from the Laurentian center of dispersion, while the preceding Kansan invasion came from the northwest, and represented the Keewatin ice sheet. Succeeding the Illinoian invasion, after a considerable interval, was the Iowan, in which the ice covering Iowa came again from the northwest. The drift laid down by this ice sheet is well developed in northeastern Iowa, and in that region it was first studied. In northeastern Iowa it is intimately associated with the loess, the latter occasionally lapping up over, but being more commonly spread out from the edge, occupying in fact the position of an outwash. Indeed there can be but little doubt that the bulk of the loess of eastern and southern Iowa is of Iowan age. It is important to note, however, that in the type locality the loess does not cover the Iowan drift, and that throughout the extent of the latter in the northeastern portion of the state, instances of such a relationship are rare, if not entirely absent. Later than the Iowan was the Wisconsin. One arm of this ice ran down in the form of a long tongue from the Iowa-Minnesota boundary, covering the area between Spirit and Clear lakes, and extending to Des Moines. Another lobe occupied that portion of South Dakota lying between the Big Sioux and the Missouri rivers. The moraine, bounding these two lobes, is known as the Altamont and its two branches join not far north of Sioux Falls. Plymouth county is accordingly outside the Altamont moraine. whose nearest point due east is Storm Lake. On the west the moraine comes to Beresford and Brush creek, about twelve to fifteen miles west of the Big Sioux.

The Altamont moraine has been considered to mark the limit of the Wisconsin drift, and in the region to the east of the Des Moines lobe the extra-morainic drift is Iowan. At the southern end of this lobe there is an overlap and the Wisconsin rests upon the Kansan with the loess lying unconformably between. In Iowa no Illinoian has been recognized except in the southeastern portion of the state. It is possible, however, that when the ice advanced from the northeast there was a corresponding advance from the Keewatin area. At least, it is difficult to conceive of climatic or other changes which would bring about glaciation in the Laurentian region without affecting to some degree, at least, the western region. In considering, then, the age of the Plymouth county drift, there are three possibilities.

a. The drift may be Kansan.

b. It may be Illinoian.

c. It may be Iowan.

In view of the peculiar position of the area, in a notch between two lobes of the Wisconsin, it is a question whether we are justified in considering it demonstrated that the Wisconsin is everywhere terminated by a definite moraine so that a fourth possibility remains to be considered, viz:

d. Is the drift an older extra-moranic Wisconsin?

It is probably impossible with the data now at hand to fix absolutely the age of the drift. Much can, however, be done to solve the problem and some factors of doubt may be eliminated.

In the correlation of the different drift sheets there are four main sets of phenomena which may be used. These are *a*, topographic development; *b*, physical character; *c*, alteration, and *d*, stratigraphic relationship. These are not all of equal value, perhaps, and their value also varies in individual cases.

Topographic Development.—Considering first the topography of the region it may be stated at once that the relationship is strongest with the Iowan. The completeness of the drainage and the absence of sloughs, when one considers the extent of country of which this is true, sets it off from the typical Wisconsin. Indeed, judged by this factor alone, the drift of northwestern Iowa might be even older than the Iowan, and apparently approaches the Illinoian. Apparently the drainage basins are not quite so well developed as is common in areas covered by the latter drift, but this may be only apparently true, or may be due to special causes.

As compared with the Kansan the topography is much younger. The valleys are not so deep nor are the bottom lands so extensive. The Floyd at Dalton has cut only 100 feet below the upland, though at Sioux City, twenty-five miles away, the water level is 136 feet below Dalton station, or at least 120 feet below the present river level. It is true that the presence of the Unio terrace indicates that for a time, at least, the water level at Sioux City was somewhat higher than it is now, so that the cutting power the Floyd has probably not been always the same. Nevertheless in view of the favorable conditions for erosion, the shallowness of the valleys as compared with those of the Kansan region can not be considered as other than an indication of a shorter period of erosion.

Alteration.—The amount of alteration which the material of a drift sheet has suffered, when it can be shown that this alteration has taken place since the deposition of the drift, is an important index to the length of time that the drift has been exposed. The alteration of the Kansan drift material is one of its most prominent characteristics, while Wisconsin has suffered no alteration, and the Iowan usually none, but occasionally a little. The drift of northwestern Iowa is much too young and fresh to be Kansan. There is an entire absence of the ferretto horizon, and of the soft, badly-weathered bowlders. The granites are almost without exception fresh and hard. Indeed the drift contains less old material than is found in the typical Iowan of northeastern Iowa. This may, however, be due to the fact that the latter is apparently much thinner, and accordingly material derived from the old drift and incorporated in the new would have more opportunity to be exposed than in northwestern Iowa. In the latter region only a very few instances of decay of bowlders *in situ* have been noted and in these cases the amount of decay was much less than is customary in Kansan regions.

In the matter of leaching, the northwestern drift seems on the whole to have suffered more than that in northeastern Iowa, and to resemble most closely in that particular the Illinoian. A really valuable generalization on this point can not, however, be drawn without wider studies, since it is not known how extensive the leaching phenomena may prove to be. It is certainly true, however, that the leaching is greater than that suffered by the Wisconsin, and in so far these facts would suggest that the drift is older than the latter. It is also true, as already shown, that the leaching took place in the interval between the deposition of the drift and the loess.

Physical Character.—Nothing distinctive in physical character been observed to be true of the northwestern drift. Possibly its color is a trifle yellower than the Wisconsin, it approaching in that matter the Iowan. At Storm Lake, and again near Carroll it was observed that the Altamont moraine and the country inside it showed abundant large surface blocks of limestone, presumably Winnipeg. These blocks are not so abundant upon the outer drift, and to that extent there seems to be reason for believing that there was some difference in the source of the material as well as in the direction of ice flow. It may be noted in passing that all that is known of the Iowan in northeastern Iowa and much of that known of the drift in northwestern Iowa indicates that the ice had an important movement toward the east. The Wisconsin, however, as evidenced by the Des Moines lobe, and to a less extent by the Dakota lobe, had an essentially southern movement, deploying about equally to the east and west. These facts would agree with the evidence derived from the Winnipeg limestone and strengthen the argument for separating the extra-morainic drift from the Wisconsin.

Stratigraphic Relationship.—The relations of the Iowan to the loess have heretofore afforded great aid in working out the stratigraphy of the drift series. In the regions so far studied the Iowan has been found practically, if not wholly, free from a loess covering. The drift of northwestern Iowa is, however, buried beneath a well developed loess sheet and furthermore the loess is separated from the drift by the interval, whatever the time value of the latter may have been, in which the erosion, leaching and soil-making noted in the description of the deposits, occurred. Now, if the loess represents a single period of deposition, the northwestern drift is probably much older than the typical Iowan and might be, judged by this standard, either Illinoian or Kansan. Few, probably, would care to maintain that the loess is all contemporaneous. It has, however, been urged, and with good reason, that the bulk of the loess was contemporaneous with the Iowan. That the period of retreat, probably, of the Iowan ice was a period in which the general conditions favored loess deposition. It has been at the same time urged that the Wisconsin as a whole was marked by fringing and outwash deposits notably coarser; gravel trains and similar phenomena which, it may be remarked in passing, are quite characteristically developed in the region under study. These differences between fine and coarse outwash deposits have, furthermore, been considered to be due to general conditions of the altitude of the land and the changes to hinge on earth movements of some extent. The probabilities, then, in the case of a broad area covered by a uniform mantle of loess and cut by valleys filled with later Wisconsin gravel trains, certainly favor the idea that the loess is of Iowan age and the underlying drift, in this case, older. Furthermore, in the case in question, the loess may be traced south to where it overlies an undoubted

Kansan till; and so far the data for drawing a border line between the loess sheets are not altogether satisfactory. If, then, the underlying drift in the present case be Iowan, as many of the phenomena suggest, the loess is evidently a very exceptional body and requires a special explanation.

The difficulty would be readily solved if one were to accept the hypothesis that the loess were a wind deposit; but that hypothesis seems less applicable to the deposits in question than to almost any other loess of the Mississippi valley. The hypothesis must face the serious difficulties (1) that the Minnesota geologists have found it to be practically limited by the 1,500-foot contour,* and (2) the fact that the most probably wind-deposited loess of the Missouri bluffs exhibits a totally different behavior, as already noted. It is true that the character and topography of a wind deposit is largely influenced by the nature of the vegetation. The sand dunes at the southern end of Lake Michigan take the ridge form around groups of small pine trees, and in general an evenly spread grass, such as covers our prairies, seems to induce a sheet-like deposition of wind materials. The Dutch engineers understand this so thoroughly that they use grass to make the sea winds build dykes wherever they will, and they manipulate it so as to get any desired forms.† In the present case, however, both the contrasted areas have the same vegetation and there is no reason to believe that there have been differences in this regard. For the sheet-loess covering northwestern Iowa, the hypothesis of water action in some form seems on the whole best.

It would seem evident from the facts of the erosion and leaching of the underlying drift as already mentioned that the loess is much younger than the latter. This would, if the drift be considered to be Iowan, require the presence of a considerable body of water in the region at a period long subsequent to the retreat of the Iowan ice. The most ready

*Winchell: Final Rept., vol. I. Minn. Geol. Nat. Hist. Surv., pp. 543-545.
†Corthell, E. L., Eng. Mag., 409, Dec., 1897.

suggestion is obviously that this occurred when the Wisconsin ice occupied the Altamont moraine. It is true that the loess sheet maintains itself on the east up to the Altamont moraine. It is characteristically displayed west of the latter at Storm Lake, and as far south as Carnarvon, in Sac county. To the north, as has been said, it is limitedly approximately by the 1,500 feet contour, and does not reach quite to the moraine. On the west it extends up to the moraine* along Brule creek. At Storm Lake there is at one point slight evidence that the moraine is younger than, and rests on, the loess, though it has so far proven impossible to get any general or clear evidence bearing in this direction. It should be recalled that at the southern end of the Des Moines lobe, where the Wisconsin rests on the Kansan, there is clear evidence of the loess passing under the former drift. It is also to be remembered that along the eastern side of the Des Moines lobe there are no extensive loess deposits and that in general loess is not found in connection with the Wisconsin. Under exceptional circumstances it has, however, been noted in Wisconsin by Salisbury† and in Peoria county, Illinois, by Leverett.‡ In the present case the topographic distribution of the loess would certainly seem to favor the idea of an age relationship between it and the Wisconsin, and would indicate that this loess belongs in the exceptional category. Such a reference, however, meets the difficulty that the loess, a fine material requiring quiet water for its deposition can not be easily believed to have been deposited over so broad an area in connection with an ice sheet which everywhere else is fringed by gravel and running water deposits, and which even here, shows the usual gravel trains.

The character of the deposits made by the streams flowing from a melting ice sheet would be largely a matter of the competency§ of the streams. This, in turn, is dependent upon

*Todd: Private communication.
†Salisbury: Jour. Geol., vol. IV, pp. 929-937. 1896.
‡Private communication.
§Gilbert: Geol. Henry, Mts., p. 110. 1877.

their velocity and volume, and these are factors of the rate of melting and the declivity. The attempt has heretofore been made* to explain the phenomena mainly as due to differences in the declivity of the stream courses, and the rate of melting, which would at any given time condition the volume of water present (the declivity remaining the same), has been thought to be a minor factor. If one is to accept the correlation suggested and assign the loess in question to the Wisconsin, it may be needful to take the rate of melting more into account. It is obvious that with a smaller volume of water, the declivity remaining the same, the competency, as well as the capacity, of the stream becomes limited. If, on the other hand, the volume of water is augmented so greatly as to produce a pounded condition, the same result is reached. It seems possible that the latter may have been the true condition in the present case though nothing more than the suggestion can at present be made. The matter is one of such grave difficulty that the determination of the nature of the process may well wait on conclusive evidence as to the facts.

All the classes of evidence noted united in showing that the drift can not be Kansan. The limited amount of erosion which it has suffered, the general absence of weathered materials, and the small amount and possibly local character of the leaching, all set it off from the deeply eroded, much weathered and highly colored drift of southern Iowa, which is universally leached, often to depths of nine or ten feet. In stratigraphic position alone does the drift seem to correspond with the Kansan and its correspondence in this particular is no closer than with the Illinoian. With regard to the latter it is by no means certain that, when isolated, patches of Illinoian drift can as yet be discriminated. The drift of northwestern Iowa corresponds to the Illinoian in position, in relation to the overlying loess, and so far as tested, in the amount of leaching which it has suffered. Topographically the area seems younger than a typical Illinoian region. The streams have

*Iowa Geol. Surv., vol. VI, p. 462.

not reached grade nor are they apparently so near it as in Illinoian regions. Since the controlling stream level, the Missouri at Sioux City, has cut some distance below the general plane upon which the Plymouth county streams are working and the latter have high grades it is difficult to suppose that the time of their activity has been long. It is also true that the general appearance of the drift is fresher than the Illinoian of southern Iowa. It is conspicuously less highly colored.

If the drift be considered to be Iowan one would expect to find in conformity with its behavior elsewhere, extensive loess deposits contemporaneous with its maximum development. In Woodbury county near North Riverside, there are phenomena bearing on this question.* It consists of an interbedding of loess and till in such manner as to leave no doubt that the two deposits are of the same age. When first seen, because of the distance of the exposure from any other known young drift, the deposit was referred to berg action at a period when the ice stood in the Altamont moraine. Later visits to the exposure in company with R. D. Salisbury has led the writer to the belief that the deposits was made by land ice and work of the past field season, by showing the presence of the young till in Prospect Hill Sioux City, and in Ida and other counties far south of what was at first considered its probable southern boundary,† offers a ready explanation of the phenomena.

The balance of evidence would seem to indicate that the drift is either Illinoian or Iowan, and since it has already been provisionally referred to the latter it may for the present rest in that category. Clearly it is not Kansan, and while certain illusive evidence not yet well enough in hand to discuss, seems at times to link it with the Wisconsin, the bulk of the phenomena seems to indicate an earlier age.

There are traces of Kansan drift at several points in the region discussed. At Sioux City there are certain old gravels

*Todd and Bain: Proc. Iowa Acad. Sci., vol. II, pp. 20-23. 1895; Bain: Geology Woodbury county, pp. 283-284. , 1895.

†Iowa Geol. Surv., vol. VI, pl., xxviii.

which can hardly be referred to anything younger. Near Sioux Falls similar old material has been noted, and at Correctionville, the drift deposits locally include patches which must have been derived from an older till. Well to the north of Crawford county, the Kansan outcrops with all its characteristic features. In southern Carroll county the Kansan is also well shown. In this county, by the way, the three drifts are present and well displayed. The Kansan and Iowan (?) are sometimes confused along the border between the two, and the scarcity of exposures and the thickness of the loess renders it impossible to trace the border line as readily as in eastern Iowa. Without considerable detailed work it can only be outlined as running from Carroll northwest through the northern tier of townships in Crawford county.

ECONOMIC PRODUCTS.

Clay.

Plymouth county is excellently supplied with raw material for many lines of clay goods. The brick clays include material suitable for several grades of building and fire brick, and possibly by combination pavers could be made. One of the beds of clay present could, perhaps, be used for stoneware, and by other combinations sewer pipe and drain tile may be manufactured. Both the surface and the underlying formations are clay-bearing. The Dakota and the Benton divisions of the Colorado contain fine clay beds yet unused. The loess, the most valuable clay bed of the drift series, is widely distributed, and is now in use at Le Mars. At present the county produces building brick only.

The bed of fire clay noted in the Crill mill section is of very good quality. It is of a white to gray color, contains very little grit, is quite plastic and would apparently be easily worked. It lies immediately below a thin bed of lignite which, in turn, as shown by the section previously given, is below a heavy sandstone. At most stages of the water the clay could be mined by simple drifting, the sandstone forming a good roof. Some exploration in the vicinity shows that the bed is at least six feet thick. The exposures are not on a railway line, though there is an excellent wagon road from them to Westfield. The same clay could probably be obtained by sinking a shaft to it at some point along the valley north of the outcrops. It rises in the hills to the south, and has been mined at North Riverside in Woodbury county.

The following analysis, made by Prof. G. E. Patrick, shows the quality of the clay. For comparison analyses of certain standard fire clays are also given.

	I.	II.	III.	IV.	V.	VI.	VII.
Silica SiO_2	67.42	86.63	55.11	65.10	58.76	54.65	56.01
Alumina Al_2O_3	19.93	10.92	26.71	22.22	25.10	30.74	31.68
Iron Fe_2O_3	2 39	.10	4.29	......	......	.07	1.13
Iron FeO	......	......	......	1.92	2.50	......	......
Lime CaO	.55	......	......	.14	Trace.	.16	1.17
Magnesia MgO	.25	......	......	.18	......	.10	.21
Soda Na_2O	.58	......	......	......	Trace.	.12	.09
Potash K_2O	.70	......	......	.18	Trace.		
Sulphurous Acid	......	......	4.16	......	......	......	......
Phosphorous P_2O_5	......	......	......	.06	......	......	......
Hygroscopic water	2 98	2.32	9.69	2.18	1.45		
Combined water	5.59			7.10	11.05	14.05	9 71
Organic matter	......	......	......	.58	......		
Total	100.11	97.97	99.96	99.66	98 86	100.00	100.00

I. Clay from Crill mill site; G. E. Patrick, analyst. Iron Oxide calculated as Fe_2O_3.

II. Van Meter, Iowa; W. S. Robinson, analyst.

III. Van Meter, Iowa; W. S. Robinson, analyst.

IV. Stourbridge, England; C. Tookey, analyst (Percy, Met. Fuels, p. 98).

V. Savanas (Ardèche) France; Salvétat, analyst (Percy, Met. Fuels, p. 101)

VI. Mt. Savage, Md. (Tables of analyses of clays, Alfred Crossley, p. 20.)

VII. St. Louis, Mo. (Crossley.)

The Van Meter clays are the ones used by the Platt Pressed and Fire Brick Co., in the manufacture of standard fire brick. The Stourbridge and Mt. Savage clays are famous for the fire brick made from them, and the Savanas clay is used for crucibles in which cast steel is melted, at St. Etienne. For all refractory purposes it is important that the clay be as free as possible from the alkalis and other fluxing agents. The Crill mill clay contains small amounts of each of these substances, but their total is not greater than the total of several clays of excellent repute, and no one element is present to marked excess. To a certain extent, it seems that the fluxing agents counteract each other, so that the amounts found in this case do not necessarily injure the clay very greatly. With proper care in treatment, it should be possible to make a very good grade of fire brick—one amply refractory for all ordinary demands. By very especial care the clay might even be used in the manufacture of refractory materials of still higher grade.

In the Benton beds, not far above the fire clay, one finds abundant clay shale suitable for hard brick and pavers. The fire clay itself is too low in fluxing materials to allow it to be made up into paving brick economically. The Benton shales are not so pure and are accordingly better adapted to this work. A mixture of the two would probably give excellent results. For making sewer pipe, loess could be mixed with the clays to increase the percentage of silica.

Aside from the Cretaceous clays just described, and which outcrop only in the southwestern portion of the county, the loess affords the most important source of material for the brick industry. It is abundant, widely distributed, easily manipulated and yields an excellent brick. It can be made up by hand, worked as a stiff mud, or manufactured by the dry-press process. The latter seems to be the best treatment from the phase of the loess found here. It is light, open and porous and, when put through the dry-press, should yield a hard, smooth-surfaced brick. However moulded, it may be burned to an excellent, and even cherry, color at moderate heat. There is probably no widely distributed material which can be so cheaply manipulated, and is capable of yielding such an excellent finish brick, as the loess. In Plymouth county, the material is of as good quality as any found in the state. The only restrictions on its use are the necessity of importing fuel and the presence in much of it of lime balls. The latter can usually be avoided in digging.

The Le Mars Brick and Tile Co. have works in the northern part of that town. The present company has only been in operation since 1892, though brick had been made at Le Mars before that date by other firms. The pit shows a thickness of about eight feet of loess, somewhat plastic but rather friable, overlying certain sand and gravel beds also worked by the company. In color the clay is in the main buff, but it shows horizontal bandings of yellow and blue drab. It carries a few lime balls which are usually in distinct bands. There are also occasional thin streaks of fine gravel well up into the loess. The clay is tempered in a pit, moulded on a Martin horse-power machine, dried under sheds on pallets and burned in up-draft kilns. They are of good weight and color and meet a ready sale.

At present this the only plant operating in Plymouth county. At Sioux City, to the south, there are extensive works, using both the loess and the Cretaceous clays and in Sioux county, to the north, there are brick works at Orange City and Hawarden. The works at the latter point use the Pierre shale to good effect. They have been recently burned, but will doubtless be rebuilt.

Cement.

The manufacture of Portland cement is a rapidly expanding industry. In 1897 the production has been estimated* at 2,100,000 barrels with a value of $3,570,000. The production and imports for the preceding four years as given in the Eighteenth Annual Report of the United States Geological Survey are noted below.

* Eng. Min. Jour., p. 3. Jan. 1, 1898.

TABLE I.

	1891. BARRELS.	1893. BARRELS.	1895. BARRELS	1896. BARRELS.
Production in the United States	454,813	590,652	990,324	1,543,023
Imports	2,988,313	2,674,149	2,997,395	2,989,597
Total	3,443,126	3,264,801	3,987,719	4,532,620
Exports	....	14,276	83,682	85,486
Total consumption	3,443,126	3,250,525	3,904,087	4,447,134
Percentage of total consumption produced in the United States	13.2	18.2	25.3	34.7

It will be noted that while the consumption has in that time increased about thirty per cent the imports have remained stationary. The large consumption has been met by domestic manufacturing. New factories have been built and old ones enlarged until practically a new industry has been created. In 1896 Portland cement was made in eleven states, as is shown by the table given below.

PRODUCTION OF PORTLAND CEMENT IN 1896.*

STATE.	NO. OF WORKS.	BARRELS.	VALUE NOT INCLUDING PACKAGES.
California	1	9,000	$ 18,000
South Dakota	1	24,000	48,000
Illinois	1	3,000	5,250
Indiana	1	9,000	15,750
Michigan	1	4,000	7,000
New York	7	260,787	443,175
New Jersey	2	247,100	370,650
Ohio	4	153,082	267,892
Pennsylvania	7	825,054	1,224,294
Texas	1	8,000	24,000
Utah	....	....	....
Total	26	1,543,023	$ 2,424,011

In addition to the plants in operation at that time there are several others since built or now building. This remarkable growth is the result of a largely increased demand. Not only is cement being applied to a large number of new uses but larger quantities are being used in old lines of work. For

*Eighteenth Ann. Rept. U. S. Geol. Surv., pt. v, p. 1170.

example, while it has long been extensively used in the manufacture of concrete, there is now a much large amount of concrete used. In our own state the recent wide use of brick paving has absorbed a large amount of cement; concrete is also being more and more used in river improvement work for locks and dams, and the railways are using large amounts far making culverts and bridge abutments. This great expansion of the cement industry in the face of the general business depression of recent years has been a very striking event. If the erection of new mills continues at the present rate, production must soon inevitably catch up with the demand and prices be lowered. As will be seen from the figures already given there is still room for a considerable expansion so long as so large an amount of foreign cement is absorbed by the local market. It is now conceded that American cements are fully the equal of any foreign brand and in the local market they must always have the advantages of not having to undergo a long sea voyage. In the future when competition becomes keen, the mills which are best equipped or best located, or those which have materials most cheaply prepared, will be the ones to command the trade.

In the manufacture of cements the essentials are calcium, silica and alumina. The two latter are usually obtained from clay. The former may be derived from limestone, chalk or marl. As a matter of fact a large amount of cement is made from argillaceous limestone which furnishes the calcium and a portion of the alumina and silica. In some foreign mills a very pure limestone is used, but in general American manufacturers have prefered to handle softer materials so as to avoid the expense of crushing and grinding. Of these soft materials both chalk and marl have been used and each has its advantages and disadvantages. The former is in use at the Yankton works not far west of Plymouth county and is also the basis for the cement made at White Cliffs, Ark. Marl has been used principally in New Jersey, Ohio and Michigan. While marls similar to that in use in the latter states is known to occur in Iowa, so far no beds have been located which are extensive enough to warrant the establishment of a cement mill. The chalk then seems to be the most available material and the most extensive exposures of chalk occur along the Big Sioux, mainly in Plymouth county. The distribution of the beds and sections showing their thickness have already been given. It is obvious that the quantity present is sufficient to warrant investment. It remains to examine the quality and to inquire as to the trade conditions.

Messrs. S. B. and W. B. Newberry, as the result of a series of careful experiments, summarize the chemical features of cement making as follows.*

"The conclusions to which the writers are led by the above experiments may be briefly stated as follows:

"1. The essential constituents of Portland cement are tri-calcium silicate with varying proportions of di-calcium aluminate. This composition may therefore be expressed by the formula

$$X\,(3\,CaO\,SiO_2) + Y\,(2\,CaO\,Al_2\,O_3).$$

"From this formula it may be calculated that the correct proportion of lime, by weight, in Portland cement, is 2.8 times the silica plus 1.1 times the alumina.

"2. Iron oxide combines with lime at a high heat, and acts like alumina in promoting the combination of silica and lime. For practical purposes, however, the presence of iron oxide in a clay need not be considered in calculating the proportion of lime required.

"3. Alkalies, so far as indicated by the behavior of soda, are of no value in promoting the combination of lime and silica, and probably play no part in the formation of cement.

"4. Magnesia, though possessing marked hydraulic properties when ignited alone, yields no hydraulic products when heated with silica, alumina or clay, and probably plays no part in the formation of cement. It is incapable of replacing

*Cement and Eng. News., vol. IV, No 1, p. 5. 1898 lime in cement mixtures, the composition of which should be calculated on the basis of the lime only, without regard to the magnesia present."

Using the formula given X (3 CaO Si O_2) + Y (2 CaO Al_2O_3) they made up and tested cements as indicated below,* from which the theoretical composition of pure cement may be seen.

FORMULA X (3 CaO SiO) + Y (2 CaO Al O).

	R. Lime to Silicate.	CaO.	SiO_2.	Al_2O_3.	PAT TEST.	HOT TEST.	Tensile str'ngth ¼ sq. inch in section.	
							7 days.	28 days.
Silicate ....95.8 / Aluminate. 4.2	2.67	72.79	25.21	2.00	Set hard, sound, on glass.	Sound, off glass, hard.	154	173
Silicate ...91.6 / Aluminate .4	2.57	71.90	24.10	4.00	Set hard, sound, on glass.	Sound, off glass, hard.	148	227
Silicate ....85.3 / Aluminate 14.7	2.39	70.55	22.45	7.00	Set hard, sound, off glass.	Sound, on glass, hard.	180	205
Silicate ....74.8 / Aluminate 25.2	2.15	68.31	19.69	12.00	Set quick, sound, off glass.	Sound, on glass, hard.	105	84

The actual compostion of the leading cements on the market is given below† the figures being taken from the paper quoted.

CALCIUM SILICATES.

FORMULA.	R. CaO to Silica.	CaO.	SiO_2.	PAT TEST.	HOT TEST.
2 Ca SiO	1.85	65.11	34.89	Set hard, hard 7 days, hard 6 weeks.	Sound, on glass, hard.
2½ CaO SiO_2	2.33	70.00	30.00	Set soft, fairly hard 7 days, hard 6 weeks.	Sound, on glass, hard.
3 CaO SiO_2	2.80	73.68	26.32	Set soft, fairly hard 7 days, hard 6 weeks.	Sound, on glass, hard.
3½ CaO SiO_2	3.27	76.56	23.44	Cracked soft, 1 day, hard 6 weeks.	Sound, on glass, hard.

An analysis made by Mr. W. B. Newberry of the chalk as exposed at Hawarden is given below.

* Cement and Eng. News, vol. III, No. 6, p. 85. 1897.
† Cement and Eng. News, vol. III, No. 5, p. 76. 1897.

Insoluble	21.95
Silica	.75
Iron and Alumina (oxides)	6.68
Calcium carbonate	64.30
Magnesium carbonate	5.38
Total	99.03

This shows that the material while in other regards suitable for use, is too low in calcium carbonate. To manufacture cement from it, it would be necessary to mix in purer material. Partial analyses of material from the region, made for the Survey by Dr. J. B. Weems, give the following results.

	I.	II.
Calcium carbonate	83.70	94.39
Magnesium carbonate	2.48	.70
Water	.03	.06

I. Chalk rock from old quarries on Big Sioux river south of Westfield.
II. Chalk rock from Deep creek northeast of Le Mars, Sw. Sec. 2, American Tp.

These samples show an abundance of calcium carbonate and suitable freedom from magnesia. While some of the material would probably not run so pure, the samples analyzed stand for a very large portion of it and indicate that by suitable selection an excellent cement mixture could be made up. Chemically then the material is suitable.

In its physical character the chalk rock is well adapted to the work. It is homogeneous, easily quarried and easily crushed. It could be manipulated by simple machinery as has been proven at Yankton. It is well adapted to the ordinary wet process. Suitable clay is found near the chalk both at Le Mars and Westfield. Railway facilities at Le Mars are good and the Westfield deposits could be connected with the Chicago, Milwaukee & St. Paul railway by an inexpensive track along the river bottom on an old grade still in fair preservation. In the matter of fuel the plant would be at the disadvantage of having to ship in its coal but with the new Arlborg kiln as adapted to this work fuel at $2 per ton amounts to only five cents per barrel of cement.*

*Newberry: Cement and Eng. News, p. 53. Oct, 1897; Eighteenth Ann. Rept. U. S. Geol. Surv.

To summarize it may be stated that the cement industry is rapidly expanding and is meeting a growing market. There are opportunities for the manufacture of Portland cement near Le Mars and Westfield; each site would have the advantage of excellent material easily worked, and of ready railway connection. The plant would be prepared to supply an important district with no neighboring competition except from Yankton. With the exception of the fuel cost, which is relatively unimportant, the plant would be well prepared to compete with eastern factories.

In a choice between the two sites it should be remembered that the Westfield locality would offer the advantages of certain abundance of material, and would allow of the simultaneous opening and use of an excellent fire clay. It would require a longer railway spur. At Le Mars it is uncertain, in the absence of test pits, that the chalk beds are extensive enough to warrant investment. The site would, however, have the advantage of ready competition in railway connection. If either site is to be utilized it should be done without delay so that the new mill may be established before the impending period of close competition. The mill should also be built with a view of the greater economy in operation, rather than in first cost, and should be placed in experienced hands; otherwise it would probably soon prove to be a bad investment.

Lime.

In the early days the chalk rock was burned at a number of localities for lime, but in recent years the magnesian limes of the eastern portion of the state and elsewhere have driven the local product out of the market. As is shown by the analyses already given the chalk rock would only yield a non-magnesian or white lime. This is more difficult to handle and to use, and is less satisfactory than the darker colored magnesian limes, and it is doubtful whether a local plant could be made to pay. There is, however, in some quarters a large market for the white limes and the matter would be worthy of investigation, particularly in event of the establishment of cement or other works for utilizing the chalk in other ways.

Coal.

At various times in the past prospecting for coal has been undertaken within the limits of the county. The active work has been confined to two localities, one on the Big Sioux river near Westfield, and the other at Le Mars. Some diamond drill work has also been done not far north of Chatsworth, in Sioux county. At the Westfield locality, more specifically at the Crill mill site, the lignite vein already mentioned outcrops near the water level. In 1894 the Plymouth Mining Co. undertook to explore this vein, and a drift was driven in at the water's edge. It was found that, while the bed thickened somewhat under the hill, the quality remained poor, and that the amount of clay mixed with the lignite was so great as to render the whole of no value. A shaft sunk to the vein back some distance from the river confirmed the opinion derived from the bed as shown in the drift, and the work was wisely abandoned.

In the course of the drilling between Chatsworth and Hawarden a number of thin veins of lignite were developed, but nothing which in quality or extent would warrant investment. These results are particularly trustworthy, as the work was carried on with the best machinery and under the direction of experienced and reliable men. They fully confirmed the conclusions derived from a geological study of the region that the lignite veins of the region are valueless, and that the Cretaceous will, in this state, never be an important coal producer.

The question whether underlying the Cretaceous there may be outlying pockets of coal measures involves some broader questions. Between the close of the Carboniferous and the opening of the Cretaceous, there was a long period in which the Iowa was a land surface and was exposed to vigorous erosion. In this period broad areas of coal measures were undoubtedly cut to pieces and the material carried away by the streams. In eastern Iowa there are outliers of coal measures which are now separated from the main field by wide stretches of barren country. The connecting strata were doubtless cut away, in part, before the Cretaceous, and it seems probable that if from northwestern Iowa the overlying drift and Cretaceous beds could be cleared away a similar state of affairs would be found. It is by no means certain that when the coal measures were being deposited the sea extended over much of northwestern Iowa, and it is well known the coal is not co-extensive with the coal measures. In view of these facts the probability of striking valuable beds of coal in the region is seen to be very slight.

Several deep holes have been put down in the region. At Sioux City, Ponca, Neb., Hull, Sanborn and Cherokee, wells or exploratory holes have been sunk far below the level of any possible coal with negative results. At Le Mars, three holes, of which we have complete or partial records, have been put down. The drillings from one of these was examined by Todd.* The second well, so far as a record of it is obtainable, confirms the first. The two apparently indicate that Cretaceous strata of the usual character continue down to the underlying gneiss. It would not be impossible, however, that some of the beds referred to the Cretaceous should really belong to the coal measures. As Norton suggests, however, the former hypothesis finds support in the records of the Sanborn and Cherokee wells.

The third drill hole was put down southeast of the town (Tp. 92 N., R. XLV W., Sec. 15), by C. P. Woodward, who has furnished the following careful record.

*Proc. Iowa Acad. Sci., vol. I, pt. ii, p. 14; see also Norton, Iowa Geol. Surv., vol. VI, pp. 232-233. 1897.

		FEET THICKNESS.	DEPTH.
59.	Drift	25	25
58.	Bluish-black clay, with bituminous matter and gypsum	25	50
57.	Bituminous matter and gypsum	10	60
56.	Soapstone and clay, organic matter, colored by iron oxide and carbonate of lime and magnesia	19	79
55.	Bed rock, very hard, ferruginous sandstone, slightly calcareous	3⅜	83
54.	Calcareous sandstone, iron oxide, first seam of lignite, one inch; also sulphate of magnesia	2½	85½
53.	Arenaceous, chalky, and calcareous stone, with marly partings containing nearly pure calcium carbonate	7½	93
52.	Calcareous marl	1	94
51.	Calcareous fragments	1	95
50.	Slate, rotten, bituminous, calcareous	6	101
49.	Slate, slightly calcareous	11	112
48.	Shale, calcareous	1	113
47.	Slate, rotten, bituminous, and shale	12	125
46.	Soapstone and slate	6	131
45.	Shale, calcareous	1	132
44.	Shale, calcareous and siliceous, mineral-bearing	5	137
43.	Shale	8	145
42.	Shale, very hard	1	146
41.	Limestone, in bands, hard, bituminous	12	158
40.	Slate, bituminous, and shale, with streaks of coal and limestone	4	162
39.	Shale, hard slate and shale, wind veins blowing sand out of top of well at 175 feet	13	175
38.	Slate and shale, with limestone bands and openings	4	179
37.	Conglomerate, hard	2	181
36.	Sandstone, hard, ferruginous, calcareous, with slate streaks	6	187
35.	Sandstone, reddish-brown, ferruginous	8	195
34.	Rotten siliceous rocks, slate and blackjack	6	201
33.	Slate and fire clay, with streaks of hard coal	4	205
32.	Sandstone, micaceous, with streaks of fine clay	6	211
31.	Fire clay and slate	4	215
30.	Sandstone, hard, micaceous	5	220
29.	Slate, bituminous	2	222

		FEET THICKNESS.	DEPTH.
28.	Upper coal basin	2½	224½
27.	Fire clay, 6 feet; sandstone, 1 foot	1½	226
26.	Sandstone, dark, organic	5	231
25.	Shale, bituminous	3⅓	234¾
24.	Coal	1¼	236
23.	Fire clay, fine coal	1	237
22.	Soapstone and slate, limestone and coal streaks	5	242
21.	Shale, arenaceous, coal in streaks	⅔	242⅔
20.	Black oxide of iron (magnetic) hard, solid.	6	248⅔
19.	Same with soapstone	6	252⅔
18.	Gypsum and soapstone	6	258⅔
17.	Soapstone, hard ferruginous, with gypsum.	4½	263⅙
16.	Coal and slate	½	263⅔
15.	Slate and fire clay, pyrite	4⅓	268
14.	Soapstone	15	283
13.	Chert	½	283½
12.	Soapstone	6½	300
11.	Slate, bituminous, with pyrite	6	306
10.	Slate, bituminous, siliceous with pyrite	9	315
9.	Slate, fine-grained with pyrite	8	323
8.	Sandstone, brown, ferruginous, with streaks of coal and slate	11	334
7.	Sandstone, brown, ferruginous with heavy spar	....	....
6.	Shales, quartz crystals	6	340
5.	Shale, ferruginous, calcareous	10	350
4.	Quartz rock and spar	14	364
3.	Sandstone, ferruginous, with fluor spar	6	370
2.	Shales, siliceous, with streaks of carbon	6	376
1.	Coal, solid vein	5	381

This work was done with a churn drill, but seems to have been very carefully executed. The coal drillings do not differ in appearance from those obtained in ordinary work at various points in the Iowa field. Proximate analyses showed that the percentages of fixed carbon, ash and volatile matter, were not higher than usual with Iowa coal, and would, to that extent, indicate that the coal was Carboniferous, rather than Cretaceous. The assemblage of strata with the coal, is such as might come from either formation, so that while there is no decisive evidence, it is quite possible that the drill here tapped a coal measure outlier.

If this be true, it is quite probable that the coal is valuable. The matter can only be authoritatively determined, however, by further drill holes, so placed as to outline the limits of the bed.

Water Supply.

The streams of Plymouth county furnish a large amount of water which is available for stock and steam purposes. The area enjoys a good annual rainfall. At Smithland, not far south of the county limits, observations show the average rainfall for nine years to have been 24.45 inches.* Owing to the fact that the surface is covered with loess, the larger portion of this precipitation becomes available for agricultural purposes, and droughts are infrequent and slight.

The great thickness and wide variety in composition of the surface formations, makes it usually easy to obtain a good well at slight expense. The Dakota sandstone, which farther west affords such an abundant supply of artesian water, underlies the county and apparently constitutes largely the supply of ground water. Artesian wells are, however, the exception, though they are not unknown. In general the water does not rise high enough to overflow. At Oyens, in a well 190 feet deep, the water comes up over 100 feet. It is of good quality and is abundant in quantity. The fact that the Missouri and the Big Sioux have cut down deep into the Dakota, prevents it from being so important a source of water supplies as farther west. Much of the water which it carries is drained out by these streams and their tributaries.

Soils.

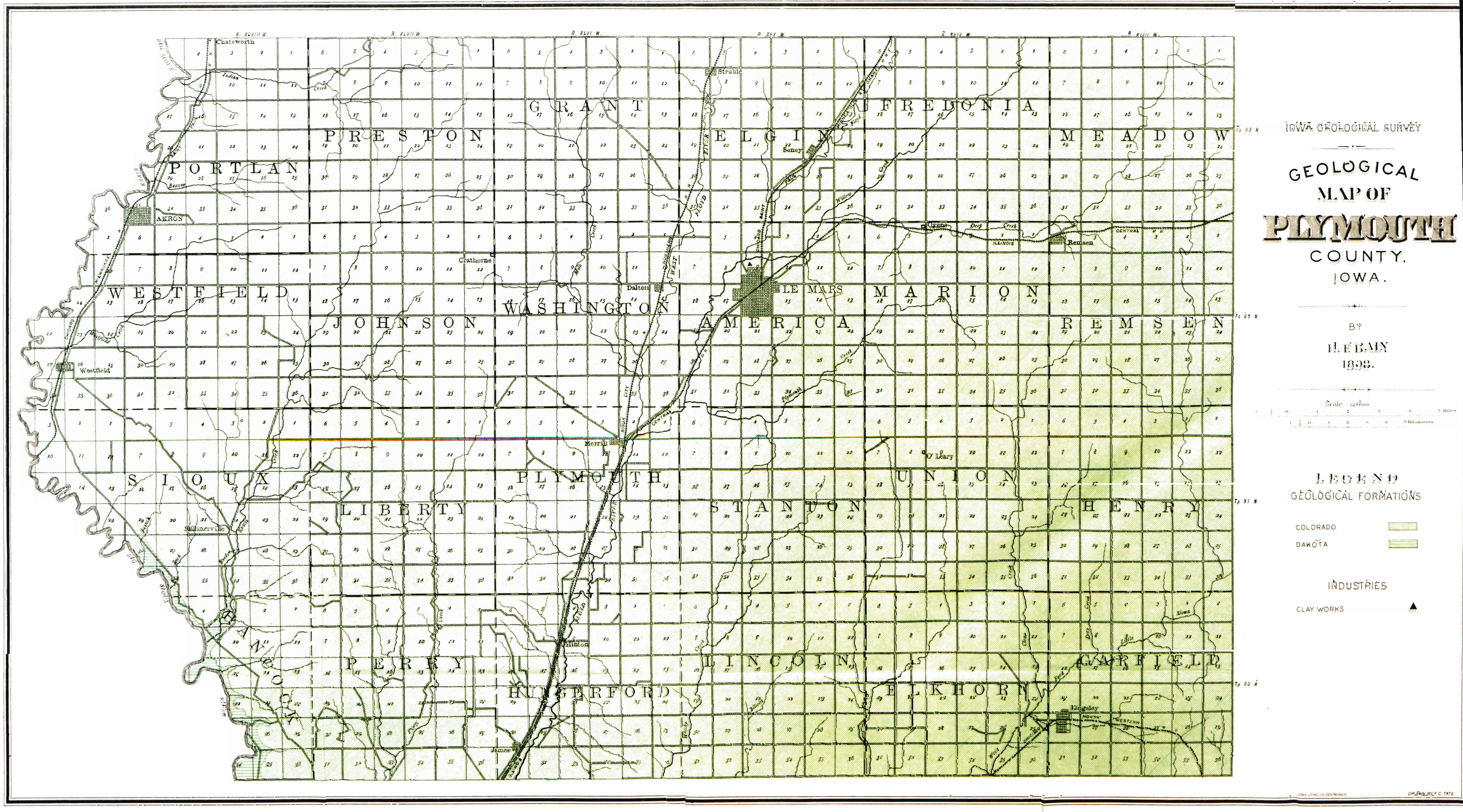
Plymouth county is essentially an agricultural county. Its wide, gently rolling prairies are closely cultivated. The loess, which forms the surface formation, affords a soil of great fertility which is easily cultivated. Over most of the county there are no stumps, stone or other hindrances to cultivation, and, except along the western border in the immediate

*Ann. Rept. Iowa Weather Serv., 1896, p. 55.

vicinity of the streams, the ground is not broken enough to interfere with farming operations. As has already been suggested, the texture of the soil is such as to prevent it from suffering much in dry seasons, and yet it has good underdrainage.

ACKNOWLEDGMENTS.

The Survey has received much assistance in the course of its work from various parties, both within and without the county. Particular obligations are felt to Judge G. W. Wakefield, Hon. Ed. M. Chassell, Mr. W. J. Wermli and Mr. Gus Pech for advice and assistance in the field work, to Mr. S. B. Newberry, of Sandusky, Ohio, for tests of cement material, and Professors Calvin, Chamberlin, Salisbury and Todd for assistance in the study of the Pleistocene. To these and to the many others who have freely given their time and services to the work, the author's most grateful acknowledgments are tendered.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF PLYMOUTH COUNTY, IOWA.
BY H. F. BAIN 1898.
Scale 1:125000
LEGEND
GEOLOGICAL FORMATIONS
COLORADO
DAKOTA
INDUSTRIES
CLAY WORKS
R. XLVIII W.
R. XLVII W.
R. XLVI W.
R. XLV W.
R. XLIV W.
R. XLIII W.
Tp 93 N
Tp 92 N
Tp 91 N
Tp 90 N
GRANT
FREDONIA
PRESTON
ELGIN
MEADOW
PORTLAND
WESTFIELD
JOHNSON
WASHINGTON
AMERICA
MARION
REMSEN
SIOUX
LIBERTY
PLYMOUTH
STANTON
UNION
HENRY
HANCOCK
PERRY
HUNGERFORD
LINCOLN
ELKHORN
GARFIELD
Chatsworth
Strubie
Seney
Akron
Westfield
Crathorne
Dalton
Le Mars
Oyens
Remsen
Merrill
O'Leary
Millnerville
Kingsley
Hinton
James
Big Sioux River
Floyd River
Plymouth Creek
Willow Creek
Deep Creek
Indian Creek
Broken Kettle Creek
Perry Creek
West Fork
ILLINOIS CENTRAL R.R.
IOWA LITHO CO DES MOINES
DRAWN BY F. C. TATE

PROPERTIES AND TESTS OF IOWA BUILDING STONES.

BY

H. F. BAIN.

PROPERTIES AND TESTS OF IOWA BUILDING STONES.

BY H. F. BAIN.

CONTENTS.

INTRODUCTION.

At the organization of the present Survey it was planned to issue a series of special reports, each devoted to one subject and covering the general features of occurrence, properties, testing and use of a particular mineral product. In pursuance of that plan the report on coal deposits, forming the second volume of the present series of reports, was issued in 1893. Since that time the energies of the Survey have been principally devoted to areal work. In the course of the latter considerable material relating to building stones has accumulated. Some of the most important quarry regions in the state have been visited and notes on them printed in connection with the county reports. The need has been felt for a more general discussion of the properties of building stones and of the best methods by which they might be readily determined. It is not thought best at this time to publish a complete report on the subject, particularly in view of the uncertainty which prevails as to the methods and value of testing stone. The present paper is accordingly preliminary in its nature and designed to meet a local and immediate want. A portion of it was some time since published in the Monthly Review of the Iowa Weather Service, and certain of the analyses and tests have been printed in the Survey reports. A few have been added, for purposes of comparison, from outside sources and some are now published for the first time. In the work of testing the Survey has had the invaluable aid of the professors at the Iowa Agricultural College and at Drake University, as noted herein.

USE OF STONE IN BUILDING.

In all times and in all countries when man would raise a great and enduring work, stone has been employed whenever it could be obtained, and in our time and country if we would erect a great public building, a noble university or a stately church, we rightly choose the same material. For the smaller buildings, where economy of money is more essential, and the total life of the building of less consequence, cheaper and less durable materials are rightly used. There are also in our country, regions where stone is so rare or of such poor quality that building rock if used at all must be shipped in. Here the cost of transportation will always place it at a disadvantage in competition with other materials, and preclude its use for any but the most expensive structures. In such areas wood and clay goods become its rivals even within its own proper sphere, but as a rule there is but little competion. Each building material is within its own sphere supreme. For cottages and individual buildings of small size wood must always be most largely used even though equally good effects might be produced with either stone or brick; for city residence blocks and store and office buildings, clay goods are usually to be preferred; but for the larger and more massive individual buildings, where dignity and permanence are valued, stone must always stand supreme, the best building material.

In the selection of the best stone for an individual piece of work our architects and engineers have a wide range of choice. There is hardly a state in the union which does not produce a considerable variety. All the different sedimentary and crystalline rocks are available in the markets of any of our larger cities. To choose wisely from this wealth of material is often a perplexing task. This is true because of the vast interests concerned. Works in which stone is used are rarely those in which small amounts of money are involved. A single contract may make the difference between success and failure in the development of a property. In any event a large contract will keep the whole quarry force busy for some time. Thus large personal and economic interests are involved.

Our engineers have before them a more difficult problem than that faced by the Egyptains and other early workers, in the matter of climate. Not only is our climate in itself more trying than that of the semi-tropical southern countries in which the earlier builders worked, but the great size of our country and the modern development of transportation facilities results in a given stone being far more widely used than was any from the ancient quarries. We no longer build from stone quarried within a few miles of our building site and hence can not argue that the rock having stood for untold centuries in the quarry may well be expected to stand in the building. Our stone may be shipped so far as to be used under totally different climatic conditions from those affecting it in its native exposures.

Again, modern conditions of life are producing a marked effect on our climate. Particularly is this true in our cities where under present conditions so much of the stone must be used. Our universal use of steam, the great amount and often poor quality of the coal burned, the imperfect combustion obtained, the large number of industries which, in the production of their wares, use chemical processes of some nature, all exert a marked influence on the purity of the air. It is doubtful if any stone used by the older builders was ever called upon to stand the insidious influence of so tainted an atmosphere as that to which our stones are exposed as a result of purely artificial conditions alone. This, coupled with the many trying natural conditions of humidity, variation in temperature, wind action and unequal settling, all make the wise selection of stone a matter requiring much thought and a wide range of information.

The very variety of material is in itself confusing. Such wide differences exist in the nature of different rocks that choice between them is not always simple. The property which, in one stone or in one position, may be an advantage, becomes under other circumstances a positive disadvantage.

A rock is not a simple substance. It is not even a definite chemical compound and is very rarely a simple mineral substance. It is rather an aggregate of minerals which may or may not be themselves simple substances, and which, in fact very rarely, are simple in composition. In strict scientific sense rock is defined by Geike as follows:* "A mass of matter composed of one or more simple minerals, having usually a variable chemical composition, with no necessarily symmetrical external form, and ranging in cohesion from loose debris up to the most compact stone." It is in this sense that the word rock is used in geology. In common usage, however, the term is restricted to consolidated beds. It is also true that the word rock is more commonly used in speaking of large masses while still in the ground; while to smaller pieces and to the quarried and dressed product, the corresponding term stone is applied.

There is an immense number of varieties of rock. The classification of these varieties may be upon a number of different bases. It may be (1) a classification based upon composition, either chemical or mineralogical, yielding such names as calcareous and plagioclase rocks; (2) it may be structural and lead to such terms as stratified and unstratified; (3) it may be genetic, and so we have volcanic and organic deposits or rocks.

Without attempting a complete or thoroughly scientific classification it will be sufficient for present purposes to consider rocks as either (1) Crystalline or (2) Clastic.

Crystalline rocks.—In this class may be placed all those rocks in which the constituents exhibit wholly, or to a marked degree, a crystalline nature. It includes such rocks as granite, gneiss, syenite and other similar forms. The granite bowlders and related rocks found in the drift and sometimes utilized in Iowa, belong to this group. It is not, however, in this state an important class, most of the stone belonging to it and used here being imported.

Clastic rocks.—This series includes the major portion of the rocks of Iowa. A clastic rock is one which is made up of small fragments of pre-existing rocks newly cemented together. It may, in time, become so changed through metamorphism that it is indistinguishable from a rock which was

* Geike: Text-book of Geology, p. 61, third Ed., London. 1893.

originally crystalline. A very great number of rocks which are usually classed with the crystallines and studied with them belong in origin to this group. An example of this occurs in our state in the Sioux quartzite. This rock is known to the trade as the "Sioux Falls granite," though it is in reality not a granite, either in composition or origin, but rather a sandstone which has been changed by the secondary growth of the quartz grains into a very hard, closely compacted crystalline.

Similar examples may be found in the limestone series. Marble is but limestone which has been re-crystallized through metamorphism. We have in Iowa no extensive deposits of true marble. There are, however, small areas which show the beginning of the change and frequently bodies of rocks of quite thoroughly crystalline type are found. In order to distinguish these phasal developments from crystallines in the ordinary usage of the term they may be called sub-crystalline. The clastic rocks of this state form two main series; (1) sandstones, (2) limestones. The quartzites may be considered as a subordinate group under sandstones, and the gypsum, while not a limestone, may, because of its closely related origin and small importance as a building stone, be classed with them. The clays, gravels, shales, and similar beds, while as truly rocks as any of the foregoing, are not usually considered as building stones.

ESSENTIAL PROPERTIES OF BUILDING STONES.

Stones vary greatly in their properties. Some are strong while others are weak. Hard and soft varieties are found. Their composition also varies. As stones are not all alike it follows that all stones are not equally adapted to use for building purposes. A given bed may produce excellent material for lime or cement, and yet the stone may be of no value at all when cut and laid in the wall. It can not be said that the conditions which govern the value of stones for building are thoroughly understood, and yet they have been studied by many investigators. The factors which condition the value of a quarry stone, or the properties which are essential in a building stone, may be conveniently considered under five heads: (1) strength, (2) durability, (3) color, (4) workability, (5) availability.

Strength.

In common with all building materials, the value of stone for building purposes is very largely dependent upon its strength. Indeed, this factor is in stone most fundamental, as the material is the one invariably chosen where the demands upon it are to be most severe.

Strength may be defined as the power of resistance to strain; the latter being any change of form or dimensions due to stress. There are in all five kinds of strain to which bodies may be subjected; tensile, crushing, shearing, transverse and torsional. For present purposes the latter may be entirely neglected.

Tensile strain is the deformation of a body resulting from stress due to pulling. It is the measure of the expansion which a body may undergo, and is usually expressed in terms of the amount of force necessary to pull it apart, or to expand it in a certain definite amount. The amount commonly chosen is that necessary to double the length of a unit rod, and is called the modulus of elasticity, or simply Young's modulus. The crushing strain is the deformation of a body due to compression. It is measured in terms of pounds-pressure per square inch necessary to rupture the stone. A shearing strain is the deformation which a homogeneous body undergoes, without change in volume, by the application of some external force. Transverse strain is that produced in a beam by a force at right angles to its length.

Stones used in building are exposed to all these strains and the value of a stone must, to a certain extent, depend upon its power to resist them. Whenever there is a change of temperature, the stone must and does contract or expand, and thus tensile strain is induced. The amount of expansion and contraction per degree of temperature has been measured for various kinds of stones. Adie* found that one inch of granite expands .00000438 inches per degree of increase of temperature, and that the corresponding increase for marble is .00000613 inches. Bartlett† reports as a result of measurements made in 1830-1831, under the direction of Colonel Trotter, the following corresponding figures.

	INCHES.
Granite	.000004825
Marble	.000005668
Sandstone	.000009532

Accepting the latter figures, it will be seen that in Des Moines, where in 1893, the maximum difference in temperature was 111°,‡ there is a total difference in the height of a granite shaft 100 feet high of .6426 inches at these extremes; and that in a granite wall 300 feet long there would be a lateral give and take of 1.9280 inches. For marble, the figures would be respectively .7549 and 2.2649 inches. While measurements on common limestone are not available, its rate of expansion may be safely assumed to be at least as great as for marble. The expansion of sandstone is still greater, and in the case mentioned would be 1.2696 and 3.8089 inches.

Such a strain will be readily seen to cause considerable wear and tear in stones. It has been shown to be sufficient cause for the pulling of the stones away from the cement, and so opens the way for decay. An examination of the seams along the sandstone courses of the Capitol building at Des Moines, in January, 1895, showed that there was at points an appreciable space between the stone and the cement. An examination of the same seams in the following July showed that they were tightly closed. It seems not improbable that in large constructions where different kinds of stone are used

*Trans. Roy. Soc., Edinburgh, vol. XIII, p. 366.
†Amer. Jour. Sci., (1), vol. XXII, pp. 136-140. 1832.
‡Ann. Rep. Iowa Weather Ser., p. 59. 1893.

in separate courses, there may be an actual movement of one course on the other.

It is also to be remembered that when one face of a structure is exposed to the hot rays of the sun, the other may be receiving a cool breeze, so that an important difference in temperature may be noticed at opposite ends of a long building, and that in winter there may often be a difference of 70° or more between the temperatures inside and outside of a building. This, of course, causes unequal expansion. It is well known that Bunker Hill monument follows the sun around each day, so that a pendulum suspended from the center of its top, described an ellipse with a major diameter of nearly half an inch. Probably the most severe tensile strain to which stones in a building are subjected is that produced by the freezing of water in its crevices. This pressure is as much as 138 tons to the square foot.

There is, perhaps, no strain the presence of which is more instinctively recognized than the crushing strain. It is at once evident that if one stone be placed upon another the lower stone will be compelled to support the weight of the overlying mass. Taking the weight of granite at 165 pounds, sandstone at 140 pounds and limestone at 150 pounds per cubic foot, it will be seen that in a column 100 feet high, there is a pressure at the base of 16,500, 14,000 and 15,000 pounds respectively. This seems, at a glance, to be large, but is in reality only 114, 97 and 104 pounds per square inch respectively, while the crushing strength of these stones is usually not far from one hundred times these amounts. As long since pointed out by Gilmore,* however, the influence of superincumbent weight is not felt so much in vertical lines of strain, but must always be resolved into oblique strains, and a stone which would easily withstand a great crushing force may readily yield to the same force, resolved into transverse and shearing strains. This accords well with the results

*Rept. on Building Stones, p. 23, Van Nostrand, New York. 1876.

of practice, in that stones rarely yield to direct crushing, but rather fail, when they do fail, through cracking or being pushed out of line.

Stone usually yields but slightly to shearing strains. The elasticity of such rock as is used for building purposes is low, while its tensile strength is high. It follows that when a shearing strain is present it usually leads to rupture rather than bending. It is, however, a mistake to consider stones as altogether lacking in elasticity. To a limited degree it is present and often exhibits itself in a marked manner. Hodgkinson experimented* on the elasticity of stone by supporting slabs at the ends and applying horizontal force. It was found that the defect of elasticity is nearly as the square of the weight. Geikie† has called attention to evidences of the elasticity of marble slabs as seen in the Scottish cemeteries. More recently Winslow‡ has noted similar phenomena as exhibited at Jefferson City. From measurements on certain marble slabs seen in the cemetery there he has calculated that a long piece of this marble two inches thick could, under continued stress for a period of twenty-five years, be bent to the form of a circle having a diameter of less than eighty feet.

This tendency of stone to warp often leads to considerable trouble and expense. During the work of the Capitol improvement at Des Moines, Mr. E. W. Crellin, the engineer in charge, found that in a few months the heavy granite blocks used for steps frequently became so bent out of shape that it was necessary to redress portions of them before they could be set. In mountainous regions nothing is more often seen than flexed strata. It is usually assumed that at the time these beds were bent they must have been under heavy pressure, and probably were, at the same time, more plastic. It seems possible that the element of time has not been sufficiently taken into account. If a granite block, simply from its own

* Athenaeum, No. 1353, p. 1165, London. 1853; Jour. Franklin Inst. (3), vol. XXVII, pp. 35-36. 1854.

† Geol. Sketches, pp. 170-172.

‡ Amer. Jour. Sci., (3), vol. XLIII, pp. 133-134. 1892.

weight and because of unequal support, will bend so as to necessitate re-surfacing before use, it seems not improbable that very slight pressure, if long continued, might lead to very important shearing.

The strains to which stones are most commonly subjected, and under which they frequently fail, are transverse strains. It is very rare indeed that one sees a crushed stone, but cracked stones are more frequent. The cracking is the expression of the transverse strain. If a stone be overloaded at one end, or if it be insufficiently supported at any point, it is subjected to transverse strain. With the low limit of elasticity of this material it can rarely accommodate itself to the unequal pressure, and so gives way. It will be readily seen that if for any cause a stone, when used in a large construction be in part unsupported, there will be an enormous pressure upon the unsupported part. To resist this pressure it has nothing except its own tensile strength. The most frequent cause of such inequality is the failure of the foundation to settle equally. If in any massive construction the foundation goes down more rapidly at one point than another, the best of stones will fail unless the factor of safety has been taken very high. More rarely the fault is in the construction of the wall, the stones being imperfectly laid. These are matters which rest entirely with the judgment and ability of the supervising architect.

The tendency of all strain is ultimately to tear apart the component particles of a substance. The abilty to resist this tendency is the measure of the strength of a substance. In stone this ability may be due to a number of different properties. In general it is dependent upon the strength of the individual particles or crystals and upon the strength of the bond.

The different particles of a rock may be bound together by several means: chemical, mineralogical, by simple contact or by means of a cement or bond. The first two means of union are not usually affected by stress but are more subject to the influence of decay. As a general rule the average crushing strength of granites and similar rocks having a mineralogical union, as contrasted with the clastics which have a true cement or bond union between the particles, is greater. This is not, however, always true. In certain cases clastic rocks are firmer than crystallines.

When the particles of a substance cohere through simple contact, the force necessary to separate them increases with the surface of contact. This is, in the case of grains of sand or clay, most largely dependent on the size of the particles. If the particles are small the interspaces are correspondingly diminished and the different pieces of mineral touch at a greater number of points. Thus it follows that, other things being equal, fine-grained rocks should show greater strength. In practice the range of variation in the size of the particles is usually so small as compared with the variation in other regards that this is rarely important. It has, however, been noted by Hatfield* that in the case of crystalline rocks the coarsely crystallized specimens crush more easily, and, while the conditions are somewhat different, it is not impossible that if the other factors could be eliminated, similar results might be obtained from experiments on clastics.

The direct controlling factor in the strength of a clastic stone is usually the nature of the bond material. In general the cementing substance found in the Iowa clastic is either argillaceous, calcareous, ferruginous or siliceous. Other cements are occasionally found and still other materials may act as such. One of the most common substances which may be a bond material is water. Its value as such is well recognized in the clay industry and it may be readily tested by trying to mould dry and wet sands. The influence of water is at once apparent in the ease with which the wet sand may be made to hold form. Water as a bond material is of small value, since it soon evaporates and the molded form crumbles. Of the cementing materials occurring in nature, argillaceous

* Jour. Franklin Inst., (3), vol. XXXV, p. 169. 1858.

cement is probably the most common. It rarely, however, occurs alone, but is usually mixed to a greater or less extent with calcareous or ferruginous matter. Calcareous bond material is universal in limestones and not uncommon in sandstones. When a calcareous cement binds calcareous material it is unsurpassed; where it joins argillaceous material it is still good; but where it joins arenaceous particles there are other substances better. Ferruginous cement is rarely found in limestone beds of sufficient extent to be of importance as building material. It is, however, a common cement in sandstones, and here its strength giving ability seems to depend very largely on its purity and the completeness with which it fills the interstitial spaces of the rock.

Siliceous cement occurs both in limestones and sandstones, and in either case contributes greatly to the value of the rock. Indeed it may well be doubted if any rock, crystalline or clastic, has greater strength than a quartzite, which is merely a sandstone with a siliceous cement.

A comparison of the crushing strength of the usual building rocks shows that as a rule their strength will run in the following order, though the exceptions are many: (1) Quartzite; (2) Granite, and a major portion of the crystallines in use; (3) Limestones and marbles; (4) Sandstones with ferruginous and calcareous bond. Siliceous limestone will rank usually at the head of the limestones and occasionally higher.

Durability.

A property of stone which is equally important with strength, and which is more difficult to estimate, is that of durability. Remembering that stone is rarely used except in buildings where permanence is an important disideratum, it will be at once apparent that whatever properties a building stone may lack, it must be durable. A stone may be ever so accessible, may be easily worked, may have a pleasing color and even a high degree of strength, and yet if it will not last when put in the wall it has no value as a building stone.

The estimate of the durability of a stone is all the more perplexing because it depends on such a variety of factors both internal and external. It can not be said that these essential factors are well understood and there is probably no material which the architect uses, about which he knows less than stone. Testing the strength of a stone may be done in accordance with well established rules; but estimates of durability can not as yet be made on any well formulated system. It is notorious that some of the worst failures of stone have been in cases where material of excellent appearance has been used. The problem is so large and so complex, and the factors which enter into it are so various, that no single method of testing will apply.

Any estimate of the durability of a stone must take into account a wide range of factors, both external and internal. Both the nature of the stone itself and the conditions under which it is used influence the degree with which it may respond to its environment without destructive effects. Both series of phenomena must be considered and the rejection of the stone may be necessary as a result of either of the two sets of conditions being unfavorable.

EXTERNAL FACTORS AFFECTING DURABILITY.

There are probably few laws better established in modern science than that organisms are influenced by their environment. This is a law which so far as we know is fundamental. It applies alike to organic and inorganic bodies. Just as surely is it true that as the heavy furred animals of the north come to inhabit a warmer climate they shed their heavier coverings, so granites and other crystalline rocks formed under one condition, upon being transferred to other conditions, slowly but surely adjust themselves to their new environment. It is well established that under the peculiar conditions present beneath the earth, silicic acid tends to drive out and replace carbonic acid, and that the reverse is true in rocks at or near the surface. The forms and combinations which were stable in granite when it was formed as a deep-seated rock, became unstable and tend to break down when it is exposed. The same is true to a greater or less extent of all rocks. A deposit which was in a stable condition at the bottom of the sea becomes unstable when forming a portion of the land surface. Hence arises the widespread decay of rocks exposed at the surface; a process which if continued long enough must inevitably cause them to break down into loose beds of gravel, sand and clay.

The processes by which this change takes place are known collectively as weathering, which is not a simple process, but a series of processes. Stones when cut, dressed and used in a building are exposed to these processes for the same reasons and to the same extent that they are when in their native ledge. Often indeed they are subjected in an even greater degree to deleterious influences. Weathering effects are due to both mechanical and chemical processes.

Mechanical effects.—The mechanical processes may be considered as due to three agencies: wind, moisture and heat.

The mechanical effects of the wind are not usually important in the consideration of building stones. That wind when loaded with sand, as it must always be to a greater or less extent, has an abrasive action is a well known fact. Endlich* has called attention to some of the more striking results of such action in Colorado. Merrill† has noted the action of storm winds on the exposed glass of lighthouses. More recently Udden‡ has reviewed the whole subject of wind erosion. Where buildings are exposed to the same conditions the action of the wind on the stone in the wall can not but be the same as in the native ledge. Egleston§ noted the fact that in many of the New York churchyards, tombstones may be found which are worn nearly smooth by this agent alone. It very rarely happens, however, that stones in buildings are so

*Bul. U. S. Surv. Ter, vol. iv, pp. 831-864. 1878.
†Smithsonian Report, 1886, pt. ii, p. 335. 1889.
‡Jour. Geol., vol. II, p. 315, 1894.
§Amer. Arch., p. 13, Sept. 5, 1885.

exposed. They are usually protected from the direct action of the wind so that its influence is less in the work of abrasion and more in bringing in contact with the stone certain injurious gases or large amounts of moisture which may be present in the air. The action of the gases is chemical and will be later considered. The erosive action of water is one of the most familiar effects seen in nature. The deep channels worn by the rivers and the general wearing away of the exposed land surface are marks of its power. It is not often, however, important from the present point of view. Except when used in bridge piers, dams and similar constructions, building stones are seldom exposed to erosive action. In large buildings certain cornice stones frequently serve for gutters, but in such cases they are usually protected by a metal surface; preferably copper.

The principal mechanical effect of water is accomplished by the aid of temperature changes in what is known as frost action. All rocks are more or less porous and hence are capable of absorbing a greater or less amount of water. This amount has been measured for a considerable number of rocks by Merrill, Hopkins, Winchell, Cutting, Heinreich, and others. In general the absorption is, for granites, from the merest traces up to $\frac{1}{140}$; for limestones the amount varies between $\frac{1}{18}$ and $\frac{1}{678}$; for sandstone from $\frac{1}{8}$ to $\frac{1}{37}$; dolomite shows about the same absorption as limestones, and quartzites average with the granites. When water freezes it expands with a force which at 30° F. is over 1,900 pounds per square foot. For lower temperature this force is greater. If the water be inclosed the force becomes sufficient to break most stone. Indeed frost is probably the principal agent in breaking down large rock masses. Jordan speaks of the Matterhorn as but a wreck—"the core of a far greater mountain whose rocks have been hurled down the valley,"* and again says: "The whole outer coat of the mountain is loose, scarcely a rock anywhere on the Swiss side being firmly attached."†

* Sciences Sketches, p. 212. 1888.
† Ibid., p. 218.

Water penetrates all the cracks of a rock and upon being frozen rends it apart. Certain of our building stones seem particularly susceptible to this action. Usually a fine-grained, compact stone will absorb less moisture and suffer less from frost than a more open textured stone. As pointed out by Merrill* this is not always true. In the case of the open textured stone, though it takes up water rather readily, it parts with it equally readily and at the same time the whole force of the expansion need not necessarily be expended in pushing apart the particles of the stone. Instances of this may be seen in our own quarries. Certain portions of the Saint Louis limestone occasionally quarried in the central portion of the state are particularly unable to withstand frost action. Yet the stone is to all appearance a very fine-grained, compact rock. In neighboring quarries a coarser textured Augusta stone stands the frost better.

The action of the frost is usually beneficial to the quarryman. In granite regions quarries are often worked for years merely in the overlying scattered boulders before the solid rock is reached. It would be impossible profitably to quarry the Sioux quartzite were it not for the aid of the frost and the joint cracks.

The principal effect of changes of temperature on stone is doubtless the frost effect just noted. Aside from any such subsidiary action temperature changes may have themselves important effects on the life of the stone. The expansion and contraction due to temperature changes have already been noticed. It is obvious that the frequent repetition of these changes in volume must affect the durability of the material. A strain which may be easily met once, if repeated often enough will cause rupture. The expansion of the different components of stone differ and thus they crowd unequally against each other. The different portions of a stone may be unequally heated, as when the outside temperature is 24° below and the inside temperature of a building 70° above.

* Op. cit, p. 333.

In all such cases the stone must be weakened. If stones be heated and then suddenly cooled they will break. Livingston found that in Africa stones heated during the daytime cooled so rapidly at night as to throw off sharp angular fragments, and Stanley states that a cool rain falling upon the sun-heated rocks caused them to split.* An interesting instance of the effect of heat was shown at the old North Avenue viaduct in Baltimore. In 1892 an oil car burned at the foot of one of the abutments. The effect of the heat was to bring out in a few hours upon the masonry the characteristic spherical weathering shown on long exposed rock faces. Julien† has called attention to the greater weathering on the face of a building which is exposed to the greatest ranges of temperature and Merrill‡ has made similar observations.

Chemical effects.—With the exception of frost action the most important agencies in the weathering of stone are chemical. The air is at all times charged with various gases some of which are destructive to stone. When the stone is exposed to water a larger number of chemical agents may be at the same time brought into play because of the substances which it may carry in solution. The attacks of these chemical agents are the most insidious because unseen, and yet they form a most important factor in the life of a stone.

The various chemical processes which take place during the weathering or decay of a stone may be summarized as follows: (1) Solution; (2) Oxidation; (3) De-oxidation; (4) Hydration; (5) Carbonization.

Solution is one of the most familiar chemical processes and one which is constantly taking place wherever rocks are exposed to rain water or moist air. Gypsum, which has been used at Fort Dodge to a very limited extent as a building stone, is readily soluble in a ratio of about 1 to 400 in water and is soon worn away. Of the stones ordinarily used for building purposes limestone suffers most from this process.

* Cit. by Gekie, Text-book, 3rd Ed., p. 329. 1893.
† Tenth Census, vol. X, Rep. on Building Stones, p. 380. 1889.
‡ Op. Cit., p. 332.

It is soluble to the extent of about 1 to 1,000 parts in water charged with carbonic acid gas.

The air at all times contains more or less moisture and some carbonic acid. In cities the percentage of the latter may become relatively high. Pfaff* has carried on experiments on the rate of weathering of limestone. The material used was the Solenhofen lithographic stone which is very similar in texture and appearance to white limestone found in the Pella beds of the Saint Louis. A plate of this rock was exposed to weathering influences for two years and from the loss in weight it was calculated that such stone weathered away at a rate of one meter in 72,000 years, or about one foot in 21,300 years. Observations made on dressed stones in England, place the rate at from one foot in 240 years to one foot in 500 years. The rate evidently varies rapidly and is apparently dependent more upon the evironment than the composition of the stone. The latter is, however, more or less to be taken into account. Dolomite is less soluble than limestone, which is one of the reasons why it usually gives better satisfaction as a building stone.

Sandstones are only very slightly soluble. The principal constituent, quartz, is not affected by any of the solutions to which building stones are ordinarily exposed. The bond material may, however, suffer from a number of them. The great durability of quartzites and of siliceous limestones is perhaps due more to the insoluble nature of the bond than to any other one factor. On the other hand, an argillaceous sandstone may break down readily, and it is a very common thing to find around a sandstone bowlder a little heap of loose sand grains which are the result of such weathering.

Oxidation is one of the most common and most active chemical processes. Oxygen is present in the atmosphere and is also a very common constituent of rain water. It is a very active chemical substance and has a great affinity for many of the minerals commonly occurring in rocks. In the crysta

*Zeit., D. D. Geol., Ges., bd. XXIV, p. 405. 1872.

line rocks the ferro-magnesian compounds especially tend to break down in its presence and to form new substances. In the clastic rocks its influence is also often felt. One of the most frequent impurities of limestones, for instance, is iron pyrites or sulphide of iron. The action of the oxygen upon this substance is first to form the sulphate of iron. In the presence of water this gives rise to iron-oxide and sulphuric acid. The former disagreeably stains the stone while the latter is an active solvent of limestone. Even in so impervious a stone as quartzite the action of oxygen upon the iron present may be detected.

De-oxidation may, under certain circumstances, result from rain water charged with reducing agents. These usually come from the decay of organic matter. The tendency of these reducing agents is to take away the oxygen present; particularly from the iron oxides. This results in discoloration. If a limestone contains magnesia, it will tend, in the presence of sulphuric acid, which may be present in the air as a result of the combustion of impure coal, to form a magnesian sulphate. This will manifest itself usually in the form of efflorescence. De-oxidation is an action not often seen on building stones, though frequently observed on native ledges.

Hydration, while occasionally observed in quarry rocks, is not important in the consideration of building stones.

Carbonization is a common form of alteration among crystalline rocks. A familiar example is seen in the alteration of feldspar to kaolin. It is the expression of the general law that under surface conditions carbonic acid tends to drive out silicic acid. It is not usually an important factor in the alteration of sedimentary rocks, as they rarely contain any great quantity of material subject to such action. In limestones the carbonization of the material has already taken place before the stone was formed. Sandstones rarely contain sufficient alkaline matter to be subject to attack, though certain arkose sandstones might suffer from this action. Such stones as are commonly found in Iowa will suffer most chemically from solution and oxidation.

The influence of organic matter in hastening the decay of stone has been very frequently insisted upon. Robert* has called attention in Le Monde to the action of *Lepra antiquitatis*, a small cryptogamic plant, in promoting decay of rocks. While it is undoubtedly true that the decay of lichens or other plant forms gives rise to organic acids which aid in breaking down a rock and reducing it to a soil, it is also true, as has been suggested, that the lichens and similar plants often form a covering which preserves the rock by protecting it from undue temperature changes. On the whole it seems not improbable that the deleterious effects of plants on building stones have in the past been too strongly insisted upon.

INTERNAL FACTORS AFFECTING DURABILITY.

The life of a stone is as much dependent upon internal conditions as upon its environment. The selection of a stone whose internal structure is such as to enable it to withstand the unfavorable conditions of modern city life is the problem which confronts our engineers and architects. The internal conditions of a stone which affect its life are mainly the nature of the constituent minerals and the state of aggregation.

While the total number of mineral species is quite large, the number which commonly occur as rock forming minerals is relatively small. The number which occur in rocks, such as are found in Iowa, is smaller still. Among those present and most important are quartz, calcite, aragonite, dolomite, gypsum, pyrite and hematite. In addition to these a number of others are found as impurities in the clastic rocks. In the crystallines, which as has been said are occasionally quarried from the drift bowlders, the whole series of feldspars, micas, pyroxenes, etc., are present.

The most common constituent of Iowa stones is calcite or calcium carbonate. This is an original constituent of the

*Cited: Van Nost. Eng. Mag., vol. II, p. 112.

limestones and is found mixed with various proportions of argillaceous impurity. It also occurs as a secondary product in veins running through certain stones. A good example of this may be seen in the Mount Vernon quarries, where the buff dolomite is cut by white veins of calcite. In this instance the calcite resists the weathering influences better than the country rock and so stands out on a weathered surface. Aragonite, a different form of calcium carbonate, also occurs.

Dolomite is a very common constituent of Iowa stone, the great ledges quarried in the Niagara being very largely dolomitic. The Galena limestone is also dolomitic, as is indeed a very large portion of Iowa limestones. There is a belief, borne out by practice, that dolomitic stones are better for lime burning purposes than pure limestones. They are also preferred for use as building stones. Magnesian carbonate is less soluble than calcium carbonate and hence there would appear to be a good reason for preferring it. In opposition to this view C. L. Dresser* points out that in cities where a great deal of coal is burned, such as Leeds where his observations were made, the sulphuric acid in the air unites with the magnesia to form magnesian sulphate. This is in wet weather absorbed by the brick or stone and in dry weather crystallizes and splits off the face of the rock.

Quartz is the major constituent of sandstones. It is a most durable material though by no means fire-proof. Gypsum is not important as a building stone. Pyrite is frequently present as an impurity and may seriously affect the durability of stone. Hematite is present as a cementing material in sandstones, though limonite is probably more common.

A second important factor in the durability of a stone is the state of aggregation. The influence of various kinds of bond upon the strength of a stone has already been pointed out; their influences upon its life are no less important. It is stated† that the air changes the cement of certain sandstones from an insoluble to a soluble condition and that practice

*London Builder, No. 863; Cit. Jour. Franklin Inst., (3), vol. XV, p. 56. 1860.

†Van Nost. Eng. Mag., vol. III, p. 296. 1872.

shows* that, in certain cases on the ground level, porous limestones decay more readily than porous sandstones as a result of the difference in composition. It will be recognized that if a 9-inch cube of stone absorbs three pints of water in forty-eight hours, as has been noted‡, the stone is exposed to far greater damage from both temperature changes and chemical action, than one in which the absorption is practically nothing. Texture is thus an important factor in the problem. General experience seems to have proven that as a rule fine-grained rocks are most durable. A fine, even texture does not allow the various injurious gases and solutions so readily to penetrate the stone and hence it is better prepared to withstand their attack. Homogeneous rocks will weather most evenly. This is a decided advantage, as unequal weathering, by weakening certain portions of a stone, may induce strain both in it and superincumbent blocks, thus impairing the strength and shortening the life of the rock.

Color.

Among the minor properties of building stones which are essential factors in their popularity and value, few are more important than color. The red sandstones are not always of greater durability or strength than similar stone of other color, and yet the reddish-brown stone was for many years most popular. This was probably due to no small extent to the fact that the stone harmonizes so well with the usual tints of brick. The choice of stone, so far as color is concerned, is in the main a matter of taste alone. Recently the light colored stones have been most popular. The darker hues give a gloomy and massive effect, while lighter tones or combinations of colors break this up. It is not always a mere matter of choice, however, since certain colors are more apt to change than others The chief coloring matter in rocks is iron, and it depends upon the form in which this occurs whether the color will prove

*Ibid., vol. XXXIII, pp. 487-488. 1885.
‡Ibid., vol. II, p. 596. 1870.

lasting. If the iron be in the form of sulphide, carbonate or protoxide, it is subject to oxidation, and the bluish or gray color changes to a brownish or reddish. This is often seen in the red surface of weathered limestone and other rocks. The deep red rocks thus have a permanence in color not possessed by the others, which is another good reason for their use.

Uniformity is important in color as in other properties, the more so as it is usually an indication of uniformity in composition and properties.

Workability.

The workability of a stone is dependent mainly upon its rift and grain. Nearly all rocks break more readily along certain planes than others. The whole art of quarrying is based upon this fact and consists in taking advantage of these planes. Only a very small portion of the stone which now reaches the market could ever be profitably taken out of it were it not for this fact. The cheapness and ease with which the Sioux quartzite can be broken up into paving blocks is due to the presence of these planes.

In unaltered clastic rocks the bedding or stratification planes are usually most prominent. These are planes of sedimentation and are due to variations in that process. In the stone as quarried, this division plane is known as the "rift" as Merrill uses the term. At right angles to this is the "grain." There may be more than one set of planes shown by the grain so that the stone may tend to break in more than one plane. If a third direction of easy splitting is present it is sometimes referred to as the "head." Thus a rift or bedding surface may be marked off by the grain in squares, triangles, diamonds or irregular polygons. It is not unusual to find the grain running along two sets of planes at right angles, or nearly so. When this is true, by a little care the stone is readily quarried out in blocks ready for use. In some cases the rift is so marked and the rift-planes so even that the stone requires no further surfacing.

The origin of the grain of a stone is a matter not clearly understood. In a more general sense the planes of grain are known as joint planes. To account for them a number of theories have been proposed. It is more usual to regard them as being simply the result of the tendency of stone to contract either when cooling from a molten condition in the case of crystallines, or, in clastics, when losing a considerable portion of their water content. Crystalline and magnetic forces as well as torsion and earthquake shocks have been called in to aid in the explanation. Very probably they are due to a considerable extent to stresses resulting from dynamic action. In regions of disturbed strata the whole series of phenomena known as cleavage, fissillity, foliation, etc., have been shown by Van Hise* to be dependent upon common causes and to afford accurate means of discriminating the structure of the strata. The extent to which a stone has been altered by these forces conditions at once its use and the methods by which the quarry may be worked. A soft stone, but little altered and in massive condition, is, for example, best worked by channelers, and is particularly subject to injury in blasting.

Availability.

The final factor in the value of stone, as in all other material, is its availability. It may be ever so excellent in every regard and still if it exists in insufficient quantity, or does not enjoy good transportation facilities, it can not be used.

One important thing to be borne in mind in selecting a quarry site is that it must afford, as far as possible, a uniform material. All stones vary slightly from ledge to ledge, or in different parts of the same ledge. It is impossible to attain absolute uniformity, yet by careful selection a practically uniform grade of stone can be placed on the market. In an industry such as this, where so much depends on capturing and holding the popular fancy, uniformity of product is of more than usual

*Sixteenth Ann. Rep. U. S. Geol. Surv.

importance. In this regard the heavy sandstone beds of the coal measures have an important advantage. They frequently show very slight bedding only, and are practically massive. They may be worked with channelers and sawmill in the same manner that marble is usually quarried.

Transportation facilities are not less important to the stone industry than to others. The presence or absence of a railway is often the controlling factor in the value of a quarry site. In our own state, the railways have been mainly built to accommodate through traffic. As the cities grow in size and wealth, and larger and more massive buildings are erected, there must be an increased demand for building stone. This will create a better local market and result in the steady development of the local stone industry. With the steadier demand it will be possible to build the long switches and local lines which are necessary in order to open up the many good ledges now untouched, and enlarge the output of the quarries already in operation.

TESTING OF BUILDING STONES.

It has been shown that the properties of stone which are to be considered in construction work are various, and that the life of the stone will depend, not only upon its own inherent characteristics, but upon the conditions under which it is used. Neither of these sets of factors is under the control of the engineer, so it becomes his problem to select the right stone for given conditions. As an aid in this selection, various tests have been formulated. In general, the tests have been made mainly with reference to strength and durability, and have included the determination of the crushing strength, absorption ratio, resistance to fire and abrasion, chemical analyses and microscopic examinations. Frost tests, both natural and artificial, have been widely applied and many special tests have occasionally been made.

It has been proposed to combine the results of these various tests, working out a formula for the value of a stone and comparing them by means of this.* While this is doubtless the end to be aimed at, it is exceedingly doubtful whether we yet know enough of the real conditions of the problem and whether our special tests are not too clumsy to make such attempts of final value.

For example, probably the best stone can be torn to pieces by prolonged frost action, either natural or artificial, and yet the same stone may give excellent results in practice. We do not know the ratio existing between the action under natural conditions and that obtained during the test, because the time element must, of necessity, differ and it is not known how much the intensity must be increased in order to counterbalance the time. It is also a question whether intense frost action, for short and rapidly succeeding periods, produces exactly the same results as the milder natural action extending through longer time. So, too, in the matter of strength, probably no stone of sufficiently sound appearance to warrant its use in a wall, ever failed by simple crushing. Many stones, however, of moderately high crushing strength, have, from various causes, failed in practice. As a rule the failure is not in strength but in durability. When a stone cracks it is almost always true that it has been improperly placed and is not equally supported. It should be remembered that the factor of safety is always taken high in stone construction, though this is to some extent an expression of our ignorance of the nature of stone. The whole matter of the testing of stone is in dispute and no general series of tests has yet been formulated. The value of many of the special tests is seriously questioned†, and much uncertainty surrounds the subject. A considerable amount of careful experimentation is yet to be done before definite conclusions can be drawn as to the value of most of the tests.

*Winchell: Geol. Nat. Hist. Surv. Minnesota, vol. I, pp. 184-191.
†Garrison: Trans. Amer. Soc. C. E., vol. XXXII, p. 88. 1894.

Tests of Strength.

Tests of the strength of materials are among the most common tests engineers are called on to make. Resistance to the various stresses, tensile, crushing, shearing, transverse and torsional, may all be measured by well known methods and formulas. Some, or all, of these tests are very commonly made upon all materials entering into building. In stone work, the crushing test alone is usually attempted, though occasionally shearing and transverse strain tests are also made.‡ It is very doubtful whether crushing tests are in themselves of much value. As has been suggested stones are rarely subjected to high crushing stresses. The test, however, gives at least a rough approximation to the power of the stone to resist other stresses. It also, to some extent, indicates the power of the stone to resist the splitting action of frost, since that is largely a matter of the tensile strength of the stone. The importance of the test is probably in most cases overestimated and the significance attached to it is an expression of our helplessness before the problem of accurately testing a stone.

The conditions to be observed in testing building stones have been formulated by Gillmore.§ It may be stated that his work, since confirmed by other investigators, shows that the crushing strength per square inch increases in cubes with the area of cross-section, that in prisms of equivalent cross-section the resistance decreases with the height and that the resistance varies also with the nature of the compressing surfaces. In all ordinary construction stone is laid in mortar so that the latter forms the surface which transmits pressure to the stone. In experimental tests smooth steel plates usually form the contact surfaces. It is obvious that the results with steel plates may be quite different from those with mortar, since there may be a greater or less degree of resistance to lateral spread in one case than in the other. Gillmore experimented upon the use of steel, wood, lead and leather surfaces

‡Johnson: Indiana Geol. Surv., 1881.
§Building Stones of U. S., Van Nostrand. 1876.

and found that with the same stone there was a marked difference in the crushing strength. Vermont marble, which has about the crushing strength of Anamosa limestone, gave the following percentages.

Steel	100
Wood	82
Lead	69.4
Leather	61.6

The differences seem to be due to the fact that the smooth steel plates, forming a good contact, resist the tendency of the stone to spread. The wood, having a tendency to spread sideways, induces a tensile strain in the stone. The lead and leather, flowing at low pressures, are driven into the interstices of the stone, acting, Gilmore conceives, as wedges and splitting the stone into numerous vertical prisms. Where, then, a rigid body forms the contact surface, the strain is a simple shearing strain. When the contact surfaces are of material which either flows or splits under smaller stress than that which seems to rupture the stone, a tensile strain is induced. The crushing tests may accordingly be varied so as to give some clue to the power of resistance which the stone may be expected to show the more important stresses.

In some tests made for the Survey at the Agricultural College in April, 1896, experiments were made upon the influence of cardboard cushions upon the crushing strength of the certain stones. The tests were made upon an Olsen testing machine, fitted with adjustable steel plates. The upper plate was fixed but the lower was free to move on a hemispherical protuberance which was accurately fitted into a well lubricated socket. By this device the pressure was equally distributed when the parallelism of the cube faces was imperfect. In the case of the specimens tested with steel bearing surfaces, the tops and bottoms were rubbed down to true planes. Where strawboard bearings were used, this was not done and the surfaces were those left by the saw.

Two stones were tested, one the Anamosa limestone, and the other the Monroe red sandstone. The former is one of the leading building stones of the state, and is quarried from certain beds of the Niagara. It is a fine-grained, light buff dolomite, very minutely laminated and quite free from impurities. Under the microscope, a section perpendicular to the bedding shows a mass of very fine crystalline grains of dolomite with a very few scattered, iron-stained points. The lamination planes are seen to be formed by the crowding together of the grains of dolomite. There is no difference in material, nor is there any observable difference in the size of the particles. Apparently the laminations here are not indicative of heterogenity of constitution. They are clearly not due to any secondary action, and probably mark only the result of various compacting influences operating in the intervals between the deposition of the individual layers. With the exception of the laminations the stone is absolutely homogeneous, and one portion of a block should be as strong as any other portion.

The Monroe red sandstone is from the coal measures, being taken from the lower portion of the Des Moines beds. It is a moderately coarse-grained stone, with some range of color and texture and corresponds in general with the Red Rock stone which has been more widely marketed. The Monroe stone has never been really opened up, as only trial lots and small shipments have been made. As will be seen from the tests, it is an excellent stone and might be used to advantage in all structures similar to those in which brown stone has been so extensively used in the east. Under the microscope it is seen to be made up of rather coarse and rounded grains of quartz cemented by a matrix of red-brown, iron-stained material which, judging from the analysis, is largely ferric oxides, but contains also some aluminous material. The sand grains are rarely in contact; the interstitial areas being usually as large as the cross-section of the individual grains.

These tests were made on the Monroe sandstone, two being with steel bearing surfaces and one with strawboard bearings, $3\frac{1}{2}x2\frac{1}{2}x\frac{3}{32}$ inches. A number of tests were made on the Anamosa stone, as given in the general tables. Several of these, made on stone from the Champion quarries, are important in this connection.

TABLE I.

Crushing Strength with Strawboard Bearings.

NO.	STONE.	HEIGHT — INCHES.	CROSS-SECTION, LBS. PER SQ. IN.	BREAKING STRESS.	
				SPALLING, LBS. PER SQ. IN.	FAILURE PER SQ IN.
20	Anamosa limestone......	2.04	4.02	4,000	4,100
21	Anamosa limestone......	2.00	4.08	5,400	5,400
22	Anamosa limestone......	2.00	4.12	5,300	5,700
23	Anamosa limestone......	2.00	4.02	4,500	5,000
19	Monroe sandstone........	1.99	4.28	2,500	2,800

All of these specimens were placed on bed except No. 23, which was placed on edge.

TABLE II.

Crushing Strength with Steel Bearings.

NO.	STONE.	HEIGHT—INCHES.	CROSS-SECTION, LBS. PER SQ. IN	BREAKING STRESS.	
				SPALLING, LBS. PER SQ. IN.	FAILURE PER SQ. IN.
11	Anamosa limestone......	2.01	4.12	4,100	6,600
12	Anamosa limestone......	2.01	4.06	6,100	7,400
13	Anamosa limestone......	1.98	4.08	5,600	7,500
4	Monroe sandstone........	1.96	4.36	3,600	3,600
5	Monroe sandstone........	1.97	4.51	3,700	3,700

From these tables it will be seen that the average crushing strength of three specimens of the Anamosa stone tested with steel bearings, was 7,188 pounds per square inch, and of the same number with strawboard, rejecting the specimens set on edge, was 5,100, or that the latter method developed 71.17 per cent the strength shown by the former. In the case of the sandstone, the per cent is

73.99, and the average for the whole is 72.58. The number of experiments was so limited that the possibility of accidental concordance of variation is not altogether eliminated, but the fact that the phenomena all point in the same direction and that the results accord with what would be expected from Gilmore's tests, give one some confidence in their substantial correctness. It is interesting to note that the specimen of the Anamosa stone set on edge stood approximately the same pressure as those set on bed and tested in the same manner. This is rather surprising and indicates apparently that the difference in the strength of this stone on edge and on bed is less than the difference in the result obtained by testing with steel and strawboard; that is, less than 30 per cent.* This confirms the results of the microscopic study which indicate that the lamination planes of the stone are not planes of weakness except as they may allow more ready penetration of moisture. It may be, though, that under frost action they would lead to the splitting of the stone. If, however, we are to take the test with the strawboard as roughly measuring the tensile strength of the stone, it would appear that in this case, frost action would probably not be important. In the case of so fine-grained a stone as the specimen tested, this may be assumed to be true and, as a matter of fact, in this case is true. This indicates one method of varying the crushing test, which is simple and easily applied, so as to yield important information other than that relative to the mere strength of the stone.

The various Iowa building stones have been, from time to time, tested to determine their crushing strength. For convenience of reference the results of these tests, so far as they are known, have been brought together in Table III.

The tests at the Agricultural College were made on the Olsen testing machine with adjustable bearings and with steel surfaces unless otherwise indicated. All specimens were sawed, and rubbed to a smooth surface, and were approximately 2x2x2 inches.

*This difference was found by Dodge to be 13 per cent. (Geol. Nat. Hist. Surv. Minn., vol. I, p. 200.)

TABLE III.

CRUSHING TESTS OF IOWA BUILIDING STONE.

	STONE.	Height—inches.	Cross section—square inches.	BREAKING STRESS—LBS. PER SQ. IN.		REMARKS.	AUTHORITY.
				Spalling.	Failure.		
	Le Grande Limestone.						
1.	Oolite, fine grained, northe'st quarry	2.03	3.94	....	11,600	Failure accomp'd by much shattering	Nos. 1–19—Tested at the Iowa Agricultural College, under the direction of Prof. A. Marston for the Survey. (See Beyer, Iowa Geol. Surv., vol. VII, pp. 247-251, 1897.)
2.	do heavy bedded	2.02	4.00	11,875	13,450	do	
3.	do do	1.97	3.96	13,636	14,900	do	
4.	do thinly bedded	1.96	3.84	10,260	10,260	do	
5.	Oolite, light, southeast quarry	2.05	4.08	10,280	12,740	do	
6.	do	1.97	4.00	14,250	14,250	do	
7.	do heavy bedded	2.00	4.00	9,500	13,250	do	
8.	Iowa marble, plain, west quarry	1.98	3.90	....	12,080	All samples of the Iowa marble broke in such a way as to show much elasticity.	
9.	do do do do	2.00	4.12	14,685	15,120		
10.	do do colored	2.00	4.06	....	9,128		
11.	Blue limestone, northeast quarry	2.00	4.08	....	....	63,000 lbs. applied, no effect.	
12.	do do do do	1.99	4.04	....	....	63,000 lbs. applied, no effect.	
13.	Fossiliferous limestone, ne. quarry	2.00	4.00	10,500	....	Sustained 65,800 lbs. without further rupture.	
14.	do do do	2.00	4.00	1,582	....	Beyond capacity of machine to crush.	
15.	do do se. quarry	1.99	4.00	10,925	....	Sustained 65,800 lbs. without further rupture.	
16.	do do do	2.00	4.04	14,430	16,435		
17.	do do w. quarry	1.97	3.96	9,773	9,773		
18.	Blue limestone, Timber creek	1.98	3.96	7,070	8,712		
19.	do do do	2.00	3.96	7,320	8,383		
20.	Burlington limestone	1.71	3.01	6,500	6,600	Stone from the quarry of Mr. John Loftus, Burlington, Iowa.	Nos. 20-48—Tested at the Iowa Agricultural College, under the direction of Prof. A. Marston, April and May, 1896.
21.	do do white	1.97	4.00	6,800	8,500		
22.	do do gray	1.95	4.28	6,700	13,100		
23.	do do blue	1.85	3.50	6,700	11,400		

TABLE III—CONTINUED.

STONE.	Height—inches.	Cross section—square inches.	BREAKING STRESS—LBS. PER SQ. IN. Spalling.	Failure.	REMARKS.	AUTHORITY.
24. Coal measure, sandstone..........	1.96	4.36	3,600	3,600	Monroe red sandstone from quarry of E. G. Kemper, Monroe, Iowa.	
25. do do	1.97	4.57	3,700	3,700		
26. do do	1.99	4.28	2,500	2,800	No. 26, strawbd bearings.	
27. Le Claire limestone................	2.02	4.16	11,100	....	Specimen stood 12,000 lbs. per sq. in. without crushing,	
28. do do	2.05	4.22	9,900	....	Specimen stood 13,300 lbs. per sq. in. without crushing.*	
29. St. Louis limestone..............	2.05	3.82	5,500	6,200	From Mastin & Sternes, Humboldt, Iowa.	
30. do do	1.85	3.70	8,500	12,500	From F. Castle, Givin, Iowa.	
31. do do	1.95	4.12	7,300	9,500	Steele Quarry Co., Tracy, Iowa.	
32. do do	2.00	4.20	5,200	9,900	Steele Quarry Co., Tracy, Iowa.	
33. Coal measure sandstone..........	1.97	4.14	10,800	11,700	(Seamy) Van Meter, Iowa.	
34. do do do	2.04	4.04	12,200	13,900	(Seamy) Van Meter, Iowa.	
35. Anamosa limestone...............	2.02	4.04	5,300	6,400	F. S. Brown & Co., a small chip broke off one corner at 2,100 lbs. per sq. in.	
36. do do	2.01	4.12	4,100	6,600	F. S. Brown & Co.	
37. do do	2.01	4.06	6,100	7,400	Champion Quarry, a small chip broke off one corner at 4,300 lbs. per sq. in	
38. do do	1.98	4.08	5,600	7,500	Champion Quarry, strawbd.	
39. do do	2.04	4.02	4,000	4,100	Champion Quarry, strawbd.	
40. do do	2.00	4.08	5,400	5,400	Champion Quarry, strawbd.	
41. do do	2.00	4.12	5,300	5,700	Champion Quarry, strawbd.	
42. do do	2.00	4.02	4,500	5,000	Champion, on edge, strawbd.	
43. do do	2.01	3.92	4,800	4,800	Champion Quarry, strawbd.	
44. do do	1.99	4.06	12,500	13,400	H. Dearborn & Sons, "Upper White."	
45. do do	2.02	3.98	10,600	11,600	H. Dearborn & Sons, "8-inch bed."	
46. do do	2.01	4.16	6,700	6,700	H. Dearborn & Sons, "Flagging layer"	

*Nos. 27 and 28 from F. H. Thielman, Le Claire, Iowa.

47.	Anamosa limestone................	1.98	4.10	12,200	13,200	H. Dearborn & Sons, dimension stone	
48.	do do	2.01	4.20	6,500	6,500	H. Dearborn & Sons, bridge stone..	
49.	Coal measure sandstone, red.......	......	......	....	4,434	Red Rock (Marion Co.)............	L. Higgins (Drake Technic, No. 2, 1894).
50.	Marshalltown, oolite...............	......	......	....	13,200	Results furnished by the company..	Howe, Rose Polytechnic.
51.	Anamosa limestone................	......	......	....	7,625	Champion Quarry furnished by J. A. Green.	Lieut. W. P. Butler.
52.	do do	......	......	....	5,917	Stone City quarries furnished by Dearborn & Sons.	Col. D. W. Flagler.
53.	Winterset limestone (Bethany)	......	......	....	4,588	Bevington Quarry..................	Rock Island arsenal.
54.	Anamosa limestone on bed.........	......	......	....	11,250	Champion Quarry.	Dodge, Minn., Geol. Nat. Hist. Surv., vol. I, p. 200.
55.	do do on edge........	......	......	....	6,750	Champion Quarry..................	do
56.	Dolomite, Joliet, Ill...............	......	......	....	14,775	Average of 3 tests.	Gillmore.
57.	Limestone, Lemont, Ill............	......	......	....	12,000	....	Gillmore.
58.	Dolomite, Winona, Minn...........	......	......	....	16,250	....	Winchell.
59.	Dolomitic limestone, Kasota, Minn.	......	......	....	18,500	....	Winchell.
60.	Sandstone, Portland, Conn.........	......	......	....	4,945	....	Gillmore.
61.	Sandstone, Berea, Ohio...........	......	......	....	8,222	Average of 4 trials................	Gillmore.
62.	Oolite, Bedford, Ind..............	......	......	....	5,600	Average 3 specimens...	Hopkins, Ind. Geol. Surv. 1896, p. 315.
63.	Quartzite, Pipestone, Minn.........	......	......	....	27,750	....	Gillmore.
64.	Granite, Vinalhaven, Me.	......	......	....	15,698	Average 6 specimens............	Gillmore.

The Le Grand stone is often known as the Marshalltown stone, since the quarries are both south and east of the latter place. It and the Anamosa stones probably have a wider sale than any other Iowa stones. The Joliet, Lemont, Kasota and Winona stones are the nearest competitors of the Iowa product. The Portland sandstone, No. 60, is representative of the eastern brownstones, and may be compared with the Red Rock and Monroe stones. The Berea stone has been used to some extent in Iowa, but does not give good satisfaction here. The Bedford stone is quite extensively sold in Iowa. The quartzite is of the same character as that occasionally quarried in Lyon county. In selecting the foreign stones for comparison, the attempt has been made to take the stones which reach our market, and so far as possible, to get fair tests.

Tests of Durability.

As has been suggested, there is no single test which may be applied to a stone to determine its durability. There are a number of special tests designed to determine the resistance of stone to certain disintegrating influences, but the value to be attached to these tests is in dispute. It is also true that there are no fixed standards to be observed in their application. In each test there is a large variation in results, due to the method of the operator. It has been suggested that the crushing strength per square inch varies with the size of the specimen tested, position in the machine, nature of bearing surfaces and method of dressing the cube. In the same way, the manipulation of freezing and absorption tests may be varied so as to produce diverse results in identical stone. In the end there are no absolute standards for comparison, and the best that can be done is to compare the results with those obtained by testing certain stones known to be good. Such comparisons are difficult and usually small value, since the difference in results due to difference in the methods of various engineers is often greater than the true difference between the stones compared. Until, however, a thorough system of tests be formulated, the method suggested is the best at hand.

Durability tests are usually intended to discover the resistance of the stone to certain mechanical and chemical effects. The more usual tests include absorption, freezing, chemical analysis and microscopic examinations. The ratio of absorption is, to some extent, indicative of the power of the stone to resist the mechanical action of frost, since the latter is manifestly due largely to the amount of water in the stone at the time of freezing. It also affords an index to the various chemical actions of solution, oxidation, etc., since the chemical elements which produce these changes are mainly carried into the stone by the water absorbed. It is a simple test, easily applied, and seems likely to be developed into something of real value.

Freezing tests are either natural or artificial. In the former the stones are alternately frozen and thawed, usually in cold storage rooms, at a rate and at temperatures which suit the convenience and fancy of the operator. In the artificial test the stone is saturated with a boiling solution of some soluble salt and then hung up to dry. The crystallization of the absorbed salt produces stresses more or less similar to those induced by frost action. The methods and value of freezing tests have been discussed by Luquer* who gives a brief bibliography of the subject. His paper is followed by an interesting discussion by Owen, Gerber, Phillips and others.

Chemical analyses are directed to the end of discovering the composition of the rock. By their means it should be possible to discover whether or not the constituents are readily soluble, subject to easy oxidation, carbonization or other changes to which the stone is apt to be exposed. A chemical analysis does not, however, always show the form in which the elements are combined, and this is often of supreme importance. From the analysis alone it is not always pos-

*Trans. Amer. Soc. C. E., vol. XXXIII, pp. 234-247.

sible to tell just what variety or varieties of feldspar are present in a rock, and yet certain feldspars weather much more easily than others. Again, pyrites is usually a very undesirable constituent in light-colored limestones, and yet in certain cases may be present in considerable quantity without injuring the latter. For example, it may be disseminated through the densest portions only, and so may be protected from oxidation by the surrounding impervious material. To discover such facts, as well as to learn the state of aggregation, the character of the cement, the presence of interval stresses due to gas bubbles in the minerals (an important factor in resistance of the stone to heat) and similar points, a microscopic examination is useful. So far microscopic tests have been applied mainly to crystalline rocks. The methods do not seem so well adapted to the study of clastics for the reason that in the latter the bond material, which is the portion concerning which it is most desirable to have information, is usually amorphous. So far most of the microscopic tests are applicable only to crystalline bodies. It remains to be seen whether new tests can be devised to meet these conditions, and in the meantime microscopic examinations of the common clastic building stones is of doubtful utility.

In the tables below (Tables iv-vi) the results of such durability tests as have been made on Iowa stones are given. For comparison similar results upon well known building stones outside this state are quoted.

TABLE IV.

FREEZING TESTS ON MARSHALLTOWN STONE.

Number.	KIND OF STONE.	Height of cube.	Surface dimensions.	Area.	BREAKING LOAD IN LBS — Spalling began.	BREAKING LOAD IN LBS — Failure.	LOAD PER SQUARE INCH — Spalling began.	LOAD PER SQUARE INCH — Failure.	Loss in weight in per cent.*	REMARKS.
1	Oolite, fine-grained, northeast quarry	2.05	2.00x2.08	4.16	55,700	56,400	13,390	13,558	0.0014	Loud report.
1	do	2.08	2.00x2.08	4.16	26,000	....	6,250	14,280	0.0013	Sustained 59,400 lbs. Very slight spall at 26,000 lbs.
5	Oolite, fine-grained, southeast quarry	1.99	1.97x2.00	3.94	50,000	60,000	12,690	15,230	......	Loud report, cube much shattered.
5	do	2.00	2.00x1.96	3.92	34,000	55,700	8,673	14,210	....	do
5	do	2.02	1.97x1.97	3.88	50,000	56,500	12,890	14,560	....	do
8	Iowa marble, west quarry	1.96	3.02x2.02	4.08	50,000	56,500	12,255	13,850	0.0007	Broke with a loud report.
8	do.	1.92	2.00x2.00	4.00	42,600	52,700	10,650	13,175	0.0008	do
8	do.	2.00	2.04x2.02	4.12	38,000	51,700	9,225	12,550	0.0009	do
11	Blue limestone, northeast quarry ...	2.00	1.98x1.97	3.90	....	....	....	15,360†	.....	59,400 lbs. applied without effect.
13	Fossiliferous limestone, northeast qr.	2.00	2.00x2.02	4.08	....	....	....	14,560†	....	59,400 lbs. applied without effect.
13	do	1.98	1.97x2.00	3.94	55,600	....	14,035	14,900†	....	59,400 lbs. sustained.
17	Fossiliferous limestone, west quarry	1.98	2.04x2.02	4.12	35,900	40,000	8,715	9,710	....	Weak report.
17	do	1 97	1.99x1.96	3.91	30,500	35,000	7,800	8,950	....	do
18	Blue limestone, Timber creek	2.00	2.04x2.01	4.10	28,000	36,300	6,830	8,850	....	Slight report.‡
18	do	1.96	1.98x1.96	3.88	32,700	32,700	....	8,430	....	

*The cubes were placed in distilled water until completely saturated, after which the specimens were encased in cotton batting saturated with distilled water and placed in wooden trays, eight by eight inches and two inches deep, provided with wire bottoms. The trays after being securely packed were placed in the refrigerator and kept at a temperature of from 17° to 19° F. for forty-eight hours. Then they were removed from the refrigerator and subjected to a temperature of 70° F. for twenty-four hours. This process was repeated six times. The specimens were afterwards subjected to refrigeration and thawing ten times, but the conditions were less constant than in the first six. In the latter series the minimum temperature ranged from 21° to 32° F.

†The above table shows that the blocks suffered no appreciable loss in weight or strength during the investigation. It is highly probable that lower temperature would have given very different results.

‡In spite of the apparent weakness, low specific gravity and rather high percentage of absorption, the quarry face along natural fissures shows this stone to be one of the most durable quarried in the county.

The results given in Table IV were obtained at the Iowa Agricultural college under the direction of Prof. A. Marston, the work being done by Messrs. G. W. Zorn and J. W. Elliott. They are a portion of a complete series of tests of the Marshalltown stone* made to some extent with a view of testing the tests. It will be noted that the Blue limestone, which is known to be very durable, stood the tests very poorly. It is easy to correlate the high absorption, low specific gravity and loss by freezing, as they manifestly indicate a stone of relatively open texture. In the chemical analysis the same thing is perhaps indicated by the slightly larger amount of water contained (Table VII). Despite the open texture, however, the stone stands well and is of good quality so that, in this case at least, the results of the tests are misleading.

The results given in Table V are from the same series of tests. Those given in Table VI were obtained by Mr. H. B. Murray at Drake university. The same stones were crushed at Ames, under the direction of Professor Marston, by Mr. Murray and the author, and the results are given in Table III under corresponding numbers. A few absorption tests from various sources are added.

*Beyer: Iowa Geol. Surv., vol. VII, pp. 242-251. 1897.

TABLE V.

ABSORPTION AND SPECIFIC GRAVITY TESTS OF MARSHALLTOWN STONE.

Number.	NAME OF STONE—MARSHALLTOWN.	LOSS OF QUARRY WATER THROUGH DRYING—WT IN GS.			WATER ABSORBED AFTER IMMERSION, EXPRESSED IN PERCENTAGES, OVER DRY WEIGHTS.				Specific gravity.	Weight per cubic foot in lbs.	REMARKS.
		0 hours.	1 hour.	5 hours.	1 hour.	3 hours.	24 hours.	144 hours.			
1	Oolite, fine-grained, northeast quarry....	350.90	350.70	350.58	0.85	1.59	2.66	2.75	Average, 2.57 lbs.	160.5 lbs.	
	do..............	348.91	348.79	348.63	1.56	3.26	3.95	4.05			
	Oolite, south quarry	335.03	334.99	334.97	1.20	1.50	2.50	2.61			
	do....................................	333.90	333.79	333.63	0.71	1.85	2.11	2.20			
	do....................................	326.90	326.30	325.63	1.50	1.96	2.55	2.64			
8	Iowa marble, west quarry...............	323.10	327.70	322.47	2.33	3.02	3.60	3.87	2.54	153.2	Average.
8	do....................................	309.40	309.00	308.01	1.81	2.43	3.31	3.57	......	......	
8	do....................................	320.90	319.20	318.20	2.31	3.06	3.97	4.37	......	......	
11	Blue limestone, northeast quarry.........	348.70	348.21	348.19	0.48	0.86	1.86	2.02	2.77	173.0	
13	Fossiliferous limestone, northeast quarry.	344.00	343.78	343.52	0.72	1.01	1.72	1.79	2.60	162.5	
12	do..............................	353.86	353.40	353.20	0.22	0.50	0.70	0.77	......	......	
17	Fossiliferous limestone, west quarry......	311.00	310.90	310.87	0.06	0.84	1.65	1.79	......	......	
17	do....................................	340.91	340.46	340.38	0.22	0.84	1.64	1.79	......	......	
18	Blue limestone, Timber creek...........	320.76	320.36	320.00	2.03	3.01	3.17	3.36	2.30	144.0	
18	do....................................	285.74	285.36	285.15	4.00	4.67	5.41	5.65	......	......	

TABLE VI.

ABSORPTION TESTS OF VARIOUS STONES.

Number.	STONE.	PER CENT OF INCREASE. 24 hours.	Week.	Total.	QUARRY.	AUTHORITY.	REMARKS.
22	Burlington gray	1.10	.77	1.87	Loftus, Burlington	Murray.	
21	do white	.39	.35	.74	do do	do	
24	Coal measure sandstone	6.90	1.74	8.64	Kemper, Monroe, Ia	do	
27	Le Claire limestone	3.11	1.21	4.32	Le Claire, Iowa	do	
29	St. Louis limestone	3.09	1.22	4.31	Mastin & Sterns, Humboldt	do	
31	do do	2.28	.99	3.27	Steel, Tracy, Iowa	do	A broken piece.
33	Coal measure sandstone	2.88	1.27	4.15	Van Meter, Iowa	do	
...	Anamosa limestone	5.66	1.82	7.48	Champion, Stone City	do	Spalls from crushing machine.
...	do do	7.61	1.76	9.37	do	do	
...	do do	4.94	1.97	6.91	do	do	Dressed cube.
...	Coal measure sandstone	8.71	2.11	10.82	Red Rock, Dunreith	do	Buff stone corresponds to No. 49
...	do do	8.00	2.82	10.82	do do	do	do do
...	St. Louis limestone	2.71	.63	3.34	Oskaloosa	do	
...	Granite	.11	.19	.30		do	From drift bowlder.
...	Anamosa limestone			5.45	Champion	G. S. Morrison	Length of test unknown
...	Winterset do			.42	Bevington	Rock Island Arsenal.	do do
...	Dolomite, Joliet, Ill			$\frac{1}{93}$			Gillmore.
...	Limestone, Lemont, Ill.			$\frac{1}{89}$			do
...	Dolomite, Winona, Min.			$\frac{1}{21}$			Winchell.
...	Dolomite, Kasota, Minn.			$\frac{1}{28}$			do
...	Quartzite, Pipestone, Minn.			$\frac{1}{368}$			Gillmore.
...	Sandstone, Berea, Ohio			$\frac{1}{21}$			do
...	Oolite, Bedford			$\frac{1}{23}$			Hopkins.

TABLE VII.

CHEMICAL ANALYSES OF MARSHALLTOWN STONE.

CONSTITUENTS.	Fine-grained oolite.	Blue lime-stone.	Iowa caen stone.	Iowa marble, plain.	Iowa marble, colored.	Stratified limestone.
Hygroscopic water (loss at 100° C.)	0 03	0.09	0.06	0.04	0.06	0.04
Combined water (expelled by ignition)	0.13	0.21	0.15	0.19	0.12	0.12
Silica and insoluble	0.77	0.96	1.24	0.80	0.89	1.22
Carbonic acid, CO_2	43.6[illegible]	43.30	43.79	44.85	44.76	43.85
Alumina, $Al_2\ O_3$	0.05	0.07	0.18	0.14	0.15	0.14
Iron, $Fe_2\ O_3$	None	None	0.15	0.15	0.31	0.26
Iron, Fe O	0.09	0.27	0.09	0.19	0.10	0.09
Lime, Ca O	55.05	54.85	50.56	45.42	45.39	50.42
Magnesia, Mg O	0.28	0.28	3.70	8.21	8.28	3.96
Manganese oxide (Calc. as Mn O.)	......	0.08	......	......	......	Trace
Phosphoric acid	......	......	Trace	Trace	......	......
Totals	100.02	100.11	99.92	99.99	100.06	100.10

PROBABLE COMBINATIONS.

Water	0.16	0.30	0.21	0.23	0.18	0.16
Calcium carbonate, $Ca\ Co_3$	98.30	97.95	90.28	81.11	81.05	90.04
Magnesium carbonate, $Mg\ Co_2$	0.59	0.38	7.77	17.24	17.39	8.08
Silica and silicates; Alumina, iron, oxide, etc.	0.95	1.37	1.74	1.42	1.38	1.72
Totals	100.00	100.00	100.00	100.00	100.00	100.00

The analyses given above were made in the Survey laboratory, by Prof. G. E. Patrick. Those quoted below were made at Drake university, by Prof. Harry McCormick. They are followed by miscellaneous analyses from various sources.

TABLE VIII.

CHEMICAL ANALYSES OF VARIOUS STONES.

STONE.	$CaCO_3$.	Ca O.	$MgCO_3$.	Mg O.	SiO_2.	Al_2O_3.	$FeO+Fe_2O_3$.	Ins.	H_2O+loss.	Alkalies.	CHEMIST.	AUTHORITY.
St. Louis limestone, Oskaloosa	95.30	......	......	......	......	.13	.46	4.01	......	......	Murray.	
St. Louis limestone, Humboldt	97.98	......	......	......	......	.48	.73	.91	......	......	do	
Anamosa limestone, Champion quarry	55.17	.....	42.79	......	......	.19	.42	1.43	......	......	do	
Burlington limestone (gray), Loftus quarry	93 61	......	......	......	......	.87	1.27	4.25	......	......	do	
Coal measure sandstone, Monroe	......	.88	......	......	84.35	8.62	5.59	......	.43	......	do	
St. Louis limestone, Tracy	94.60	......	......	3.17	......	.49	.17	1.57	......	......	do	
Coal measure sandstone, Van Meter	......	4.95	......	3.19	84.27	.62	4.74	......	2.07	......	do	
Le Claire limestone, Le Claire	57.54	......	41.57	......	......	.26	.23	.46	......	......	do	
Coal measure sandstone (red), Dunreith	......	Tr.	......	......	94.02	1.76	2.65	......	1.39	......	do	
Coal measure sandstone (buff), Dunreith	......	.41	......	......	94.40	3.03	.94	......	1.09	......	do	
Kinderhook magnesian, Marshalltown	74.10	.....	23.35	.....	.95	1 20		......	.40	......	C.G.A. Mariner	Le Grand Quarry Co.
Sandstone, Berea, Ohio	......	.74	......	2.11	44.40	7.49	3.87	......	......	.90	....	Winchell.
Dolomitic limestone, Kasota, Minn	47.90	......	35.20	......	......	......	1.49	13.85	.31	......	....	do
Oolite, Bedford, Ind	98.30	......	......	......	......	.84	.15	.64	......	......		

Microscopical Examinations.

But few of the Iowa building stones have been studied under the microscope. The difficulties in the way of the accurate determination of the minerals in unaltered sedimentary rocks are so great as to be discouraging. The particles are small, the material is largely amorphous, and many of the important minerals, calcite, dolomite, limonite, etc., are those which are not of much importance in crystalline rocks. As the latter have attracted the major attention of petrographers, the criteria for the recognition of certain of the minerals named are quite imperfect. In addition the particles under investigation are in most cases impure. For these reasons the microscope has never been the aid in the study of sedimentary rocks that it has in the crystallines. This is unfortunate, since so large a number of the building stones belong to the sedimentary series, and the range of information yielded by the microscope is, in most cases, peculiarly valuable in the study of building stones. The investigation of thin sections should allow the ready determination of the constituents of the stone, which may also indeed be learned by means of a chemical analysis. Microscopic examinations should, however, in addition show the form of combination and the freshness of the materials; both facts of special interest in estimating the durability of the stone. Something as to the state of aggregation, presence or absence of internal stresses and of fine cracks, the nature of the matrix and the hardness of the rock, may all be learned, as has been suggested, in the course of a microscopic study.

No such thorough investigation of Iowa building stones has been yet attempted. A few of the typical and better known rocks have been sectioned, and micro-photographs are shown in plates xl-xlii. The stones examined were those of which chemical analyses were made, and which were also crushed. By comparing the results in the various tables, the value of the stone as indicated by the tests may be estimated. Below is a brief description of the appearance of the stones under the microscope.

Monroe Red Sandstone (*x45*) (Fig. 1, pl. xxx). Matrix, ferruginous matter apparently including both hematite and limonite, with a little earthy material. The clear white particles are quartz; a few being rounded and water-worn, but most of the pieces having sharp fracture edges. There are no signs of internal stress, such as would be indicated by undulatory extinction.

Van Meter Sandstone (*x45*) (Fig. 2, pl. xxx). The rock consists mainly of small, sharp-cornered bits of quartz fitted close together, and with a sparing matrix of calcite and ferruginous material. The calcite is occasionally stained and clouded by ferruginous matter, in colors from green to brown.

Burlington Limestone (*x45*) (Fig. 1, pl. xxxi). The large striated crystals are calcite, showing the usual cleavage lines. There is no matrix, as the material has been wholly re-crystallized and is now a coarse marble. It is of the type called here sub-crystalline. No impurities are shown.

Burlington Limestone (*x38*) (Fig. 2, pl. xxxi). A different portion of the same section with smaller magnification.

Anamosa Limestone (*x80*) (Fig. 1, pl. xxxii). The section is cut across the bedding planes and shows the small sharp-cornered bits of dolomite, and the alternate compact and open structure which corresponds to the latter. The rock shows occasional bits of iron-stained material, a few being indicated in the photo.

Anamosa Limestone (*x80*) (Fig. 2, pl. xxxii). Section cut parallel to bedding showing the uniform size and regular distribution of the dolomitic grains. It will be noted, that the texture is the same along this plane, though varying from plane to plane as shown in the previous section. The grains are sharp-cornered and little worn, but their relations to bedding planes indicate that the rock was deposited as a dolomite.

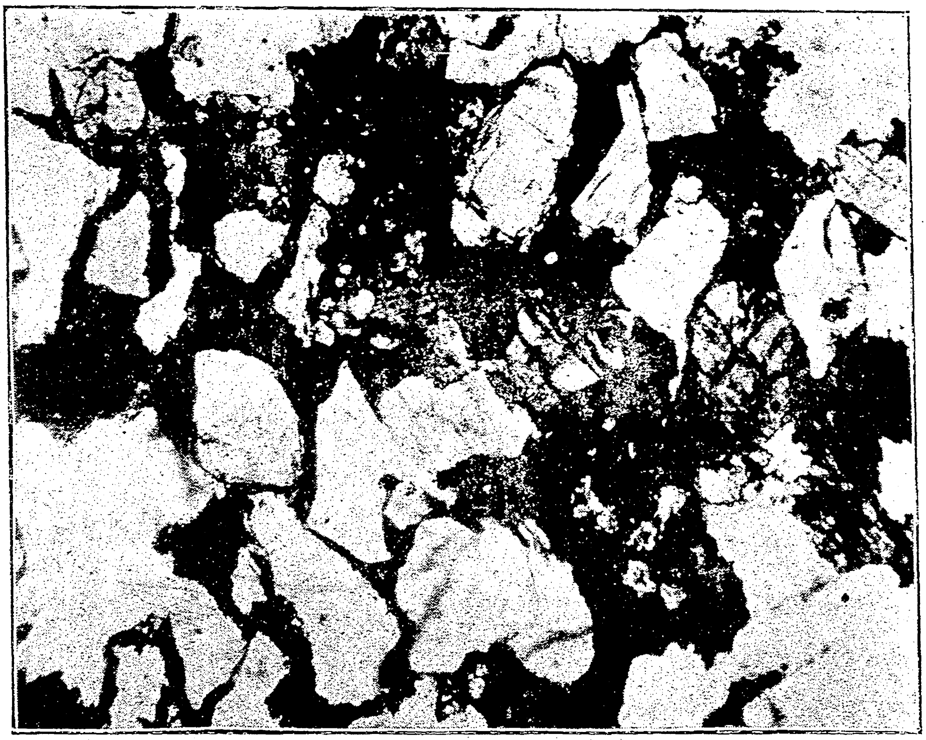


FIG. 1. Microphotograph (x 45), Monroe red sandstone, natural light.

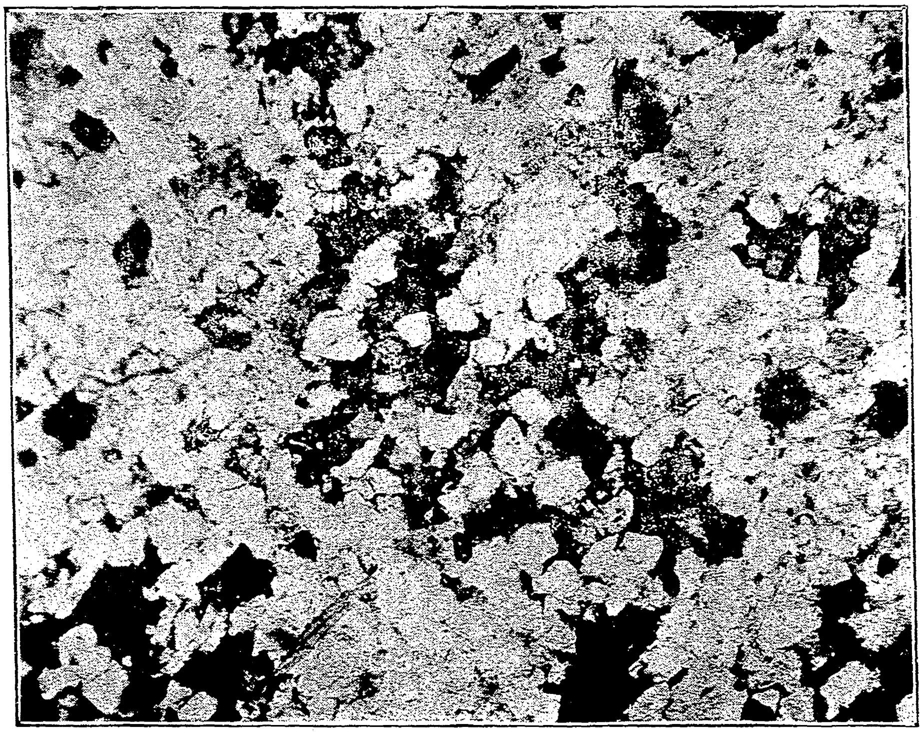


FIG 2. Microphotograph (x 45), Van Meter sandstone, natural light.

GENERAL CONCLUSIONS.

The results of the various tests so far made on Iowa building stones, indicate that the latter do not suffer by comparison with stones of the same class from elsewhere. These results have been amply confirmed by practice in the case of the stones now on the market. In the end the latter must prove the final arbiter. In the present confused condition of affairs the value to be assigned to most of the tests and the utility of many of them may be well doubted. The appearance of the stone in the quarry, so long as it is used under essentially similar climatic conditions as would be true anywhere in Iowa or neighboring states, is probably a more important guide than any series of tests yet formulated.

Below is a summary of the quarry production for 1897 taken from the tables published elsewhere in this volume.* The sandstones have not been separated from the limestone, as they form a very inconsiderable portion of the output. The sandstone output usually credited to Iowa is made up largely of dolomite, which is frequently classed in the local markets as sandstone.

Production for 1897.

Rough and rubble	$ 130,005.69
Dimension stone	66,792.30
Crushed for concrete and road use	74,862.95
Lime	123,193.65
Miscellaneous	156,531.74
Unspecified	33,758.25
Total	$ 585,144.58
Estimated addition	2,000.00
Total	$ 587,144.58

The stones now marketed are mainly dolomites and limestones belonging to the Silurian and Devonian. The Marshalltown and Burlington stones are the most important representatives of the Carboniferous. Above the Augusta

*Pp. 45-48.

good stone is rare. The sandstones of the Des Moines will probably in time become important sources of quarry products, but for the present they attract but little attention. The Cretaceous yields nothing of more than local importance to the building trade. The use of gypsum as a building stone at Fort Dodge is now uncommon, and the sandstones found lower in the formation are rarely quarried. The great bulk of the quarry products of the state come from the Cedar Valley limestone of the Devonian and the various members of the Niagara. The Galena yields an important amount of stone, but the Oneota, which includes a buff dolomite second to none in quality, is, for lack of transportation facilities, shut out of the market.

FIG. 1 Microphotograph (x 45), Burlington limestone, natural light.

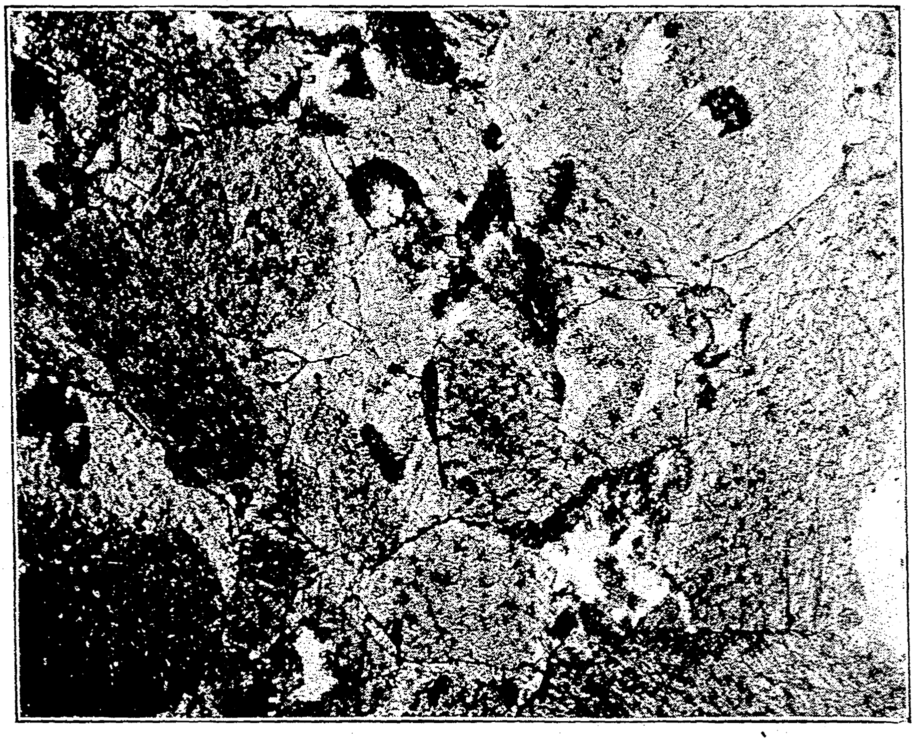


FIG. 2. Microphotograph (x 38), Burlington limestone, natural light.

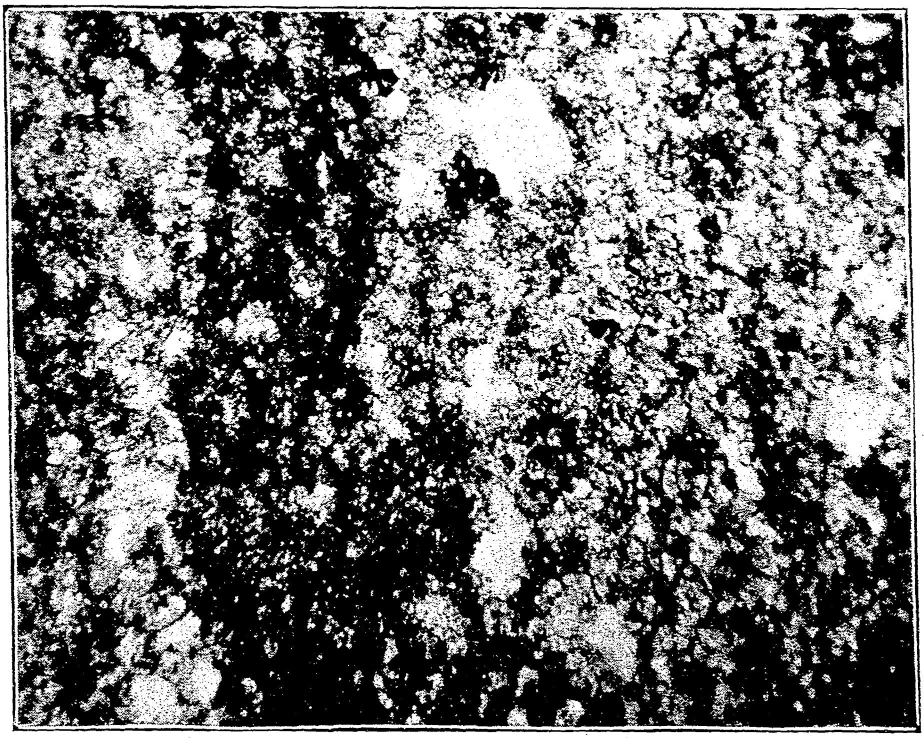


FIG 1 Microphotograph (x 80 , Anamosa limestone, section cut across the bedding. Bedding planes run across the figure from top to bottom, natural light.

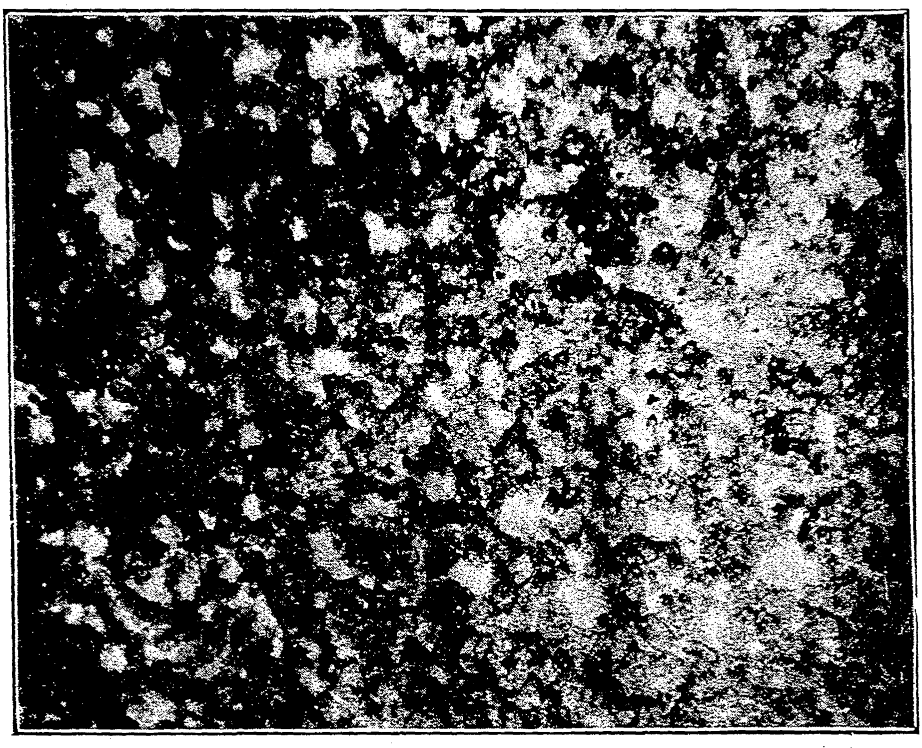


FIG 2 Microphotograph (x 80), Burlington limestone, section cut parallel to bedding plane, natural light.

INDEX.