IOWA

GEOLOGICAL SURVEY

VOLUME XI.

ADMINISTRATIVE REPORTS

SAMUEL CALVIN, A. M, PH. D., STATE GEOLOGIST

A. G. LEONARD, ASSISTANT STATE GEOLOGIST

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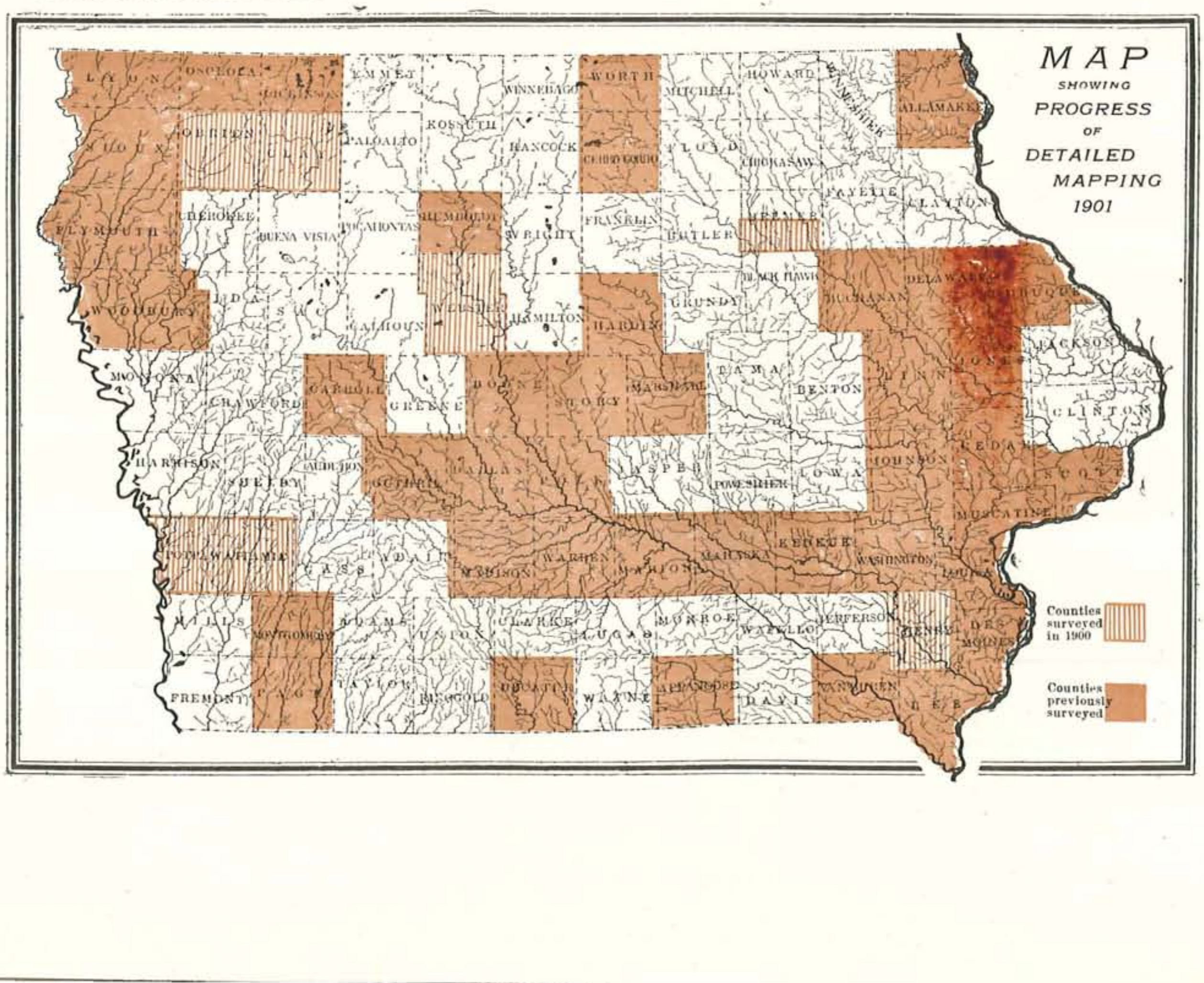
ADMINISTRATIVE REPORTS.


MAP
SHOWING
PROGRESS
OF
DETAILED
MAPPING
1901
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
BLACK HAWK
BUCHANAN
DELAWARE
DUBUQUE
WOODBURY
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SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
JACKSON
MONONA
CRAWFORD
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GREENE
BOONE
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TAMA
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LINN
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IOWA
JOHNSON
CEDAR
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MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
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MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
Counties surveyed in 1900
Counties previously surveyed

NINTH ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1900.

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

GENTLEMEN: In accordance with custom and the requirement of law I have the honor to submit, for your consideration, a brief account of the operations of the Iowa Geological Survey for the year 1900. During this year the Survey has been prosecuted along much the same lines as heretofore. This means that, so far as field work is concerned, the greater part of the energies of the Survey has been expended in the direction of areal investigation and mapping, the object being to make a detailed examination of the entire state as rapidly as possible. Examination of the geological formations in the several counties and their detailed mapping are necessary pre-requisites to the correct determination of the geological resources of the state. While, however, areal work has absorbed the larger part of the attention of those responsible for the direction of the Survey, from its organization till the present time, special subjects have not been entirely neglected. Early in the history of the Survey there was published a special report on coal giving all the information in relation to the distribution of this important mineral which could be secured up to the date of publication. The sixth volume of the present series of reports was devoted exclusively to special studies, that on the artesian wells of Iowa being the most extensive and in some respects the most important. Since the date of that publication Professor Norton has continued to collect data relating to the artesian supplies of the state as new wells have been bored. He has personally visited localities while the work of boring was in progress. He has frequently been called on for professional advice concerning the advisability of stopping the work at a certain stage or of proceeding to greater depths. His services have resulted, in some cases, in saving much unnecessary expense to the communities interested; in other cases his advice has resulted in giving communities a larger and better water supply than would have been secured if their original plans had been carried out. A supplementary report on artesian wells, giving the information collected since the publication of volume VI, will appear at an early date. The economic value and importance of such statistics become greater with every increase in the number of wells studied. The interpretation of the data becomes more precise and reliable, and the information collected can be applied to new cases with greater certainty.

A paper giving the results of careful studies on the lead and zinc ores of the Dubuque region, by Professor A. G. Leonard, also appeared in the sixth volume. The subject of lead and zinc was again taken up in connection with the geological survey of Dubuque county. Mr. Bain, who had this particular part of the work in hand, reviewed the subject exhaustively, availed himself of all the information which had been previously collected, personally examined all the old workings to which he could gain access and studied thoroughly the newer developments, devoted much attention to the genesis of the ore bodies and the conditions which led to their accumulation, and thus was able to present a report treating with great fulness all the historical, scientific, economic and practical phases of the subject. The Geology of

Dubuque County, including a discussion of the minerals and mining problems referred to, appears as a part of volume X.

Dr. Beyer, with the hearty co-operation of all the clay workers of the state and using an expensively equipped laboratory provided by the State College of Agriculture, is preparing a Monograph of Iowa clays, their geological and geographical distribution, their qualities, the uses to which they are best adapted, and the methods of treatment required in each particular case. He has had the work in hand for two years or more, and such are the extent and nature of the problems involved that it will take some time yet before the investigations can be satisfactorily completed. Studies of materials suitable for the manufacture of Portland cement were continued by Bain and Wilder, but we have not yet had reports on all the samples collected and submitted to experts for examination.

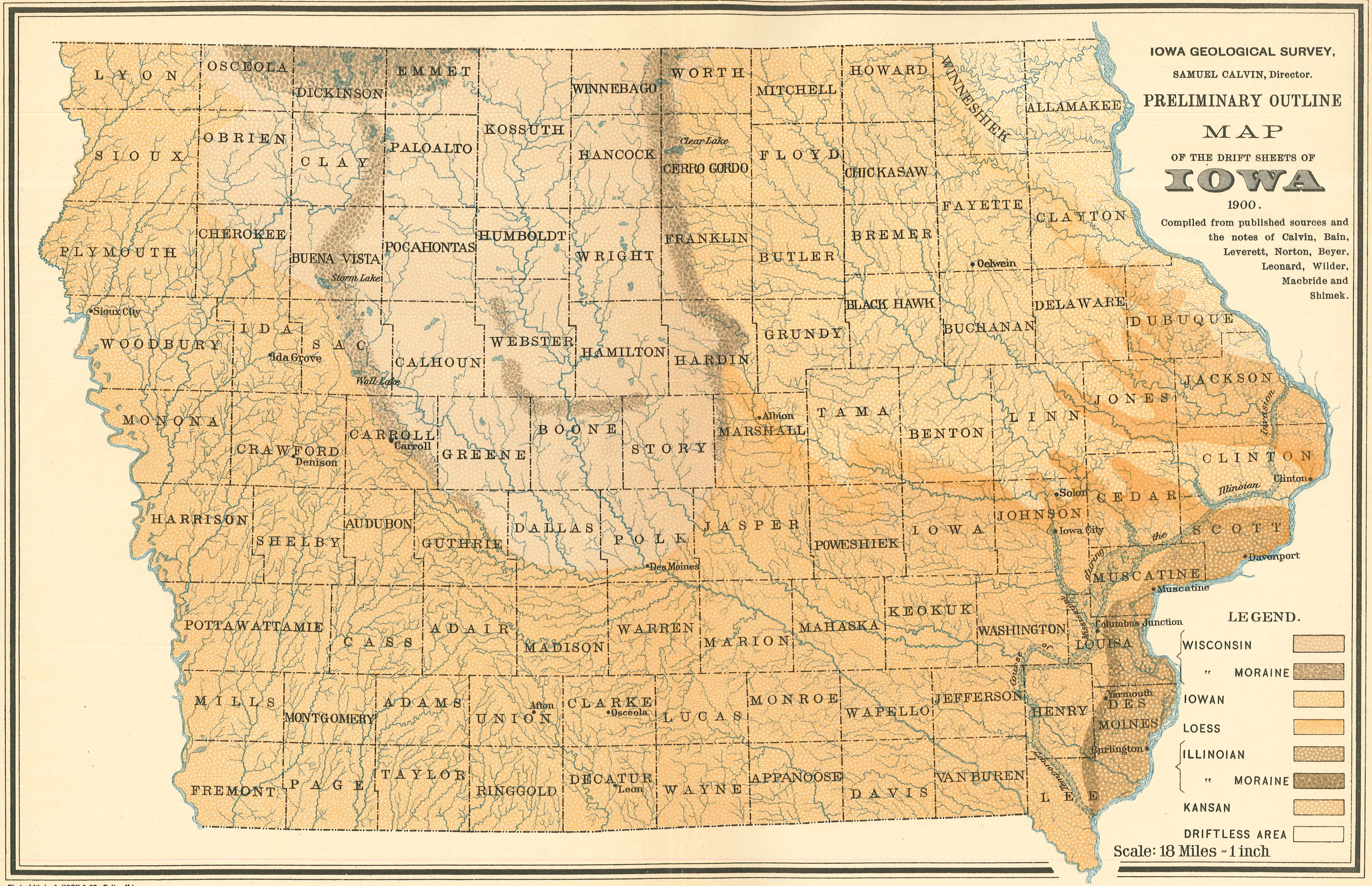
The corps of investigators employed during the past season in areal work included Calvin, Wilder, Norton, Udden Macbride, Savage and Miller. Besides the persons named, two volunteer assistants have taken up special work in connection with the soils and drift deposits of certain areas. Mr. H. R. Mosnat, whose volunteer work on the artesian wells of the Belle Plaine area made an acceptable and valuable contribution to volume IX of the Survey reports, has been studying and mapping the Iowan drift margin in Tama and Benton counties, and Mr. George L. Schoonover has undertaken the thorough investigation of the Pleistocene deposits of Jones county. Owing to the withdrawal of Mr. Bain, to whom a large share of the work of supervision had formerly been assigned, I found it necessary to spend the greater portion of the working season in field conferences with other members of the corps. Webster, Tama, Benton, Linn, Pottawattamie, Montgomery, Clay, O'Brien and Jones counties were visited and some time spent in each ; and the remainder of the field season was devoted to a review of Page county and efforts to correlate the beds exposed in Page with those of adjoining areas.

Mr. Wilder completed the field work in Webster county and submitted manuscript maps and report. It is his wish, however, that the publication of the report be deferred for the present in order that he may avail himself of the opportunities offered by a year's residence and study in Europe to visit the great gypsum mills of Germany and France and learn methods of handling and manufacturing which may prove serviceable to those interested in the gypsum industry in Iowa. The possible gain in the value and completeness of the report more than justifies the short delay, and Mr. Wilder's wishes in this respect may well be granted. Professor Norton has completed the manuscript and map for his report on Cedar county, Mr. Miller has finished Marion county, Professor Udden prepared the map and manuscript relating to Louisa county for the engraver and printer respectively, and took up field work in Pottawattamie county. This work he completed early in the season and will have the report on Pottawattamie ready for publication in the present volume. Professor Macbride's work of last year in Osceola and Dickinson counties was extended in 1900 to Clay and O'Brien. The field work was finished in September, and the manuscript report is about ready for the printer. The work last year dealt chiefly with problems relating to the Wisconsin drift; and the characteristics assumed by this drift sheet in its southward extension have been the special subject of Professor Macbride's investigations during the past season. The erratically distributed moraines, the saucer-like kettle holes, and the beautiful lake basins of the Wisconsin area are features of a topography at once unique and interesting; the Wisconsin drift soil, with its unusually large lime constituent adapting it to the cultivation of a great variety of crops, possesses economic interest which renders the region over which it is distributed well worthy of study and careful mapping. The work of Professor Savage was to finish the survey of Henry county, which he began last year, and to prepare his notes for publication. The preparation of the report is already well advanced. There was not much field work left to be done by Mr. Miller in Marion county, but the data relating to the few unfinished details were collected and his report is now in hand. The new areal work taken up during the year covered the counties of Webster, Pottawattamie, Clay and O'Brien.

The work of the office has included the usual large correspondence with persons, in and out of the state, interested in the resources of Iowa. The proof reading and other work incident to the publication and distribution of Volume X consumed a great deal of time. Volume X is the largest, and is probably one of the most valuable of the publications so far issued by the Survey. The printing of the volume began late and extended well into the summer, a fact that prevented the accomplishment of as much field work by some members of the corps as might otherwise have been done. The printing of Professor Pammel's monograph of the grasses of Iowa, which the Board ordered published fully two years ago, was taken up by the State Printer after Volume X was off the press, and there is now good reason to hope that it will soon be in the hands of the public, for whom it was prepared.

Two changes in the position of Assistant State Geologist have been made during the year. On the first of March Mr. Bain was given six months' leave of absence without pay in order that he might carry into effect at Dubuque, some plans which seemed to promise much for the advancement of the mining interests of the region. Mr. Frank A. Wilder, a man of fine training and marked administrative ability, was chosen to fill the place from March 1 till September 1, when it was expected that Mr. Bain would be ready to renew his work in the office. Before the expiration of his leave of absence, however, Mr. Bain received offers of larger pay with opportunities for experience and growth in different fields, which it would have been unwise for him to reject; and so much to the regret of all who had learned to appreciate his splendid qualities as an administrative officer and as a man, he resigned his connection with the Iowa Survey. Mr. Wilder's work was in the highest degree satisfactory, but he had planned to go abroad about the first of September for advanced study in the universities of Germany; and it again became necessary to choose a man for the position. We were especially fortunate in securing the services of Mr. A. G. Leonard who had been connected with the Survey in previous years and had had experience in conducting the affairs of the office during a former leave of absence to Mr. Bain. Miss Newman has continued to fill, with characteristic energy and ability, the position of Secretary which she has held since the organization of the Survey.

The demand for the publications of the Survey exceeds the supply. The tenth volume is about the only one of which there are copies left available for distribution, and if all requests for copies of this had been granted, the edition would have been immediately exhausted. Libraries of colleges, academies and high schools, and all public libraries in the state are supplied with the reports in accordance with the rules relating to the distribution of the volumes; while beyond the limits of the state exchanges are made with state and national surveys, and with scientific associations which regularly publish proceedings. The volumes are also sent to geologists of acknowledged standing and reputation in America and Europe; but by far the larger part of every edition goes to the citizens of Iowa. Each member of the Legislature receives a number of copies for distribution among those of his constituents who may be interested in the subjects treated, and private persons making application for reports are asked to get their requests indorsed by members of the Legislature in their respective localities. The object is to insure as far as possible the placing of the volumes in the hands of persons who will intelligently use them. The in-



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creasing use of the separate county reports in connection with the study of Physiography and Geology in high schools is an encouraging fact, since, if the practice could become universal, the men and women into whose keeping the control of affairs must soon pass, will be able to look upon the geological resources of the state with intelligent judgment as to what lines of development may be entered upon with fair prospects of success, and what propositions looking to the discovery of desirable geological products are hopelessly absurd.

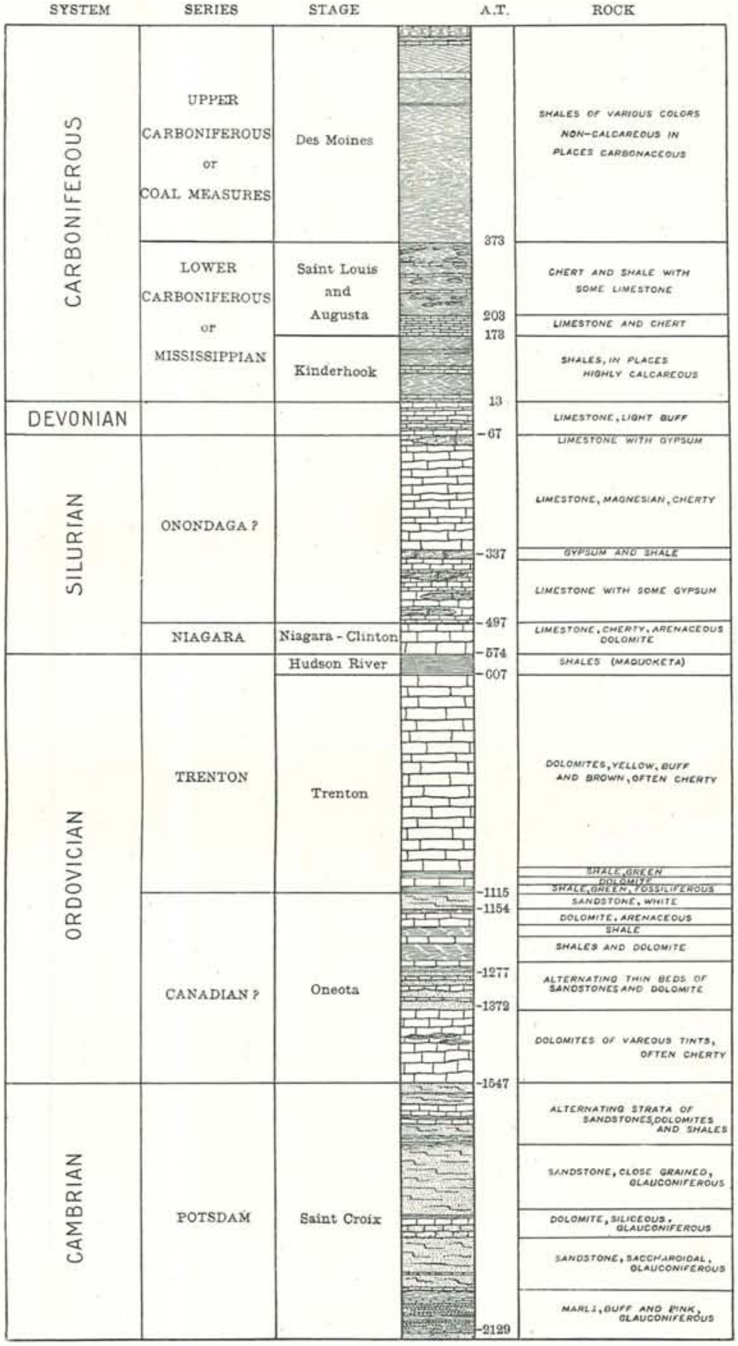
It is a source of constant wonder and surprise that, notwithstanding all that has been said and written, there are yet persons of influence, intelligent beyond the average in all other respects, who entertain the crudest conceivable notions concerning the geology of the state and the distribution of its mineral resources. The highest natural gifts and the broadest scholarly training and busines experience seem to be altogether ineffectual, in the absence of some training in the principles of geology, to protect men from the most amazing fallacies as to what may or may not be found below the surface of the ground. Samples of yellow mica from decayed Kansan bowlders, or iron pyrites from shales or limestones, are received almost weekly from persons who imagine they have discovered gold in Iowa. Small flakes of brass worn from the working parts of pumps or other farm machinery, are among the causes which have led to repeated reports of discoveries of gold in a region where not a single condition favorable to the presence of the precious metal exists. Probably the most wild and unjustifiable of all the crude beliefs respecting geological resources is that which holds to the conviction that by going deep enough the drill is sure to find something of value, no matter at what point the work of boring is commenced. There are numerous wise persons in every community, estimable, influential and in the highest degree public spirited, who are fully convinced that the question, for example, of finding coal in their special locality is simply a matter of the depth to which the explorations are carried. Rock oil and natural gas are recognized as desirable products in every progressive community, and every such community contains persons, in other respects intelligent, who are ready to stake their own fortune and that of their nearest friends on the belief that oil and gas are everywhere underneath the surface, and that their sources can be tapped with the drill, provided only there is sufficient capital to keep up the process of drilling long enough.

But is there no gold in Iowa? Men certainly have found some. Coal occurs in certain localities in the state, why are the chances not equally good for finding it in all other localities? Why is it not a good business venture in Iowa to explore the depths of the earth for gas and oil, when fortunes are made and cities are boomed by the discovery of these desirable products in other states? Why is it not a proper function of the Geological Survey to bore test holes in different localities in order to settle the question of the presence of oil and gas beneath the surface? To answer these questions fully would require much space and would involve a discussion of some of the most elementary principles of geology. Let me try as briefly as possible to present the facts necessary to an understanding of these subjects for the benefit of the non-geological reader.

Native gold, metallic gold, free gold—by whatever name it may be designated—occurs chiefly under two conditions. First, it is found in veins in the crystalline rocks. Such rocks are generally very old; they are fundamental; they occur at the surface in a broad belt around Hudson Bay—none of the newer or later formed rocks being present in that locality—and they extend down into northern Michigan, northern Wisconsin and northern Minnesota. They have been forced up near the surface and have been subsequently exposed by erosion in all mountain regions. As a rule, it is in mountain regions that gold is associated with them, for it is here that they have been fissured by the strains and movements which gave rise to the mountains. Various minerals have been concentrated in the fissures by circulating waters —the waters being more efficient if warm and alkaline—and among the minerals so concentrated we sometimes find gold. Gold-bearing veins in the crystalline rocks are the basis of all the lode mining; but it must be kept in mind that only a very small proportion of all the veins referred to carry gold. Now there are no true crystalline rocks anywhere near the surface in Iowa. All such rocks here are deeply covered with newer rocks of sedimentary origin. These sediments were laid down, one on the other, in slow and orderly succession, on ancient sea bottoms, in precisely the same way, and of precisely the same materials as the beds of mud and sand and limy ooze which are today accumulating on the marginal bottoms of the modern seas. Such rocks contain no gold-bearing veins, and hence it must be obvious that there can be no lode mining for gold in Iowa. In the second place, free gold occurs in placer mines. Placer mines are simply sheets of disintegrated rock material which has been strewn over the surface, usually along river valleys, by the action of flowing water. The rocks of mountains decay and are worn away by air, storm waters, frosts and other agents; the gold-bearing veins, if there are any, decay with the rest; the gold is freed from the matrix in which it was embedded, and the loose materials, gold and all, are gradually washed down to lower levels. The placer miner simply separates—by some convenient device—the gold from the loose clay and sand and gravel with which it is accidentally associated. It must again be obvious that, except in regions where there are gold-bearing veins, there can be no placer mines worth considering. From all this it will be easy for anyone to estimate the probability of finding gold in such a state as Iowa.

In apparent contradiction of all that has just been said it must be acknowledged that gold is occasionally washed out of the sand banks and river gravels within the limits of our state. Spread over the sedimentary rocks and forming our soils and subsoils, are sheets of drift which were transported and distributed by glaciers coming from the north. Some of the materials forming the drift at any given point were carried long distances, from away beyond the national boundary. In northern Minnesota and on the other side of the boundary line, in the Rainy Lake region, are quartz lodes carrying free gold. The ice sheets brought disintergrated materials from this region, as they did from all others over which they passed, and spread them out as part of the drift of Iowa. Some particles of gold came with the rest, and it is possible occasionally to discover some of them by panning carefully the loose surface materials. A resolute, industrious man, working persistently year by year, might possibly accumulate one or two dollars' worth in the course of a lifetime; but the business cannot be recommended as a profitable means of employing one's time. The resident of Iowa who imagines he has discovered a gold mine on his home farm is certainly basing his judgment on deceptive appearances of some kind.

To understand the situation in respect to coal a few things must be kept in mind. First, as every miner knows, the coal is interbedded with sedimentary rocks, usually with sandstones and shales. Second, sedimentary rocks were laid down, one on the other, one after the other, in slow succession; and so the history of rock deposition in Iowa embraces a very long period of time. This history is almost complete from a period earlier than the introduction of life on the globe to times when land plants and animals were well developed. Third, coal was formed from land plants of certain types, the plants being preserved so as to be transformed into coal only under peculiar and favoring conditions. Fourth, coal plants did not come into existence until long after the beginning of the record preserved in the geological strata of Iowa. The older rocks, therefore, can contain no coal, because they were laid down long before any coal plants grew. All the rocks indicated on the geological map, Plate II, in Volume X, as Algonkian, Cambrian, Ordovician, Silurian, Devonian, and



GREENWOOD PARK (DES MOINES) WELL SECTION.

Mississippian, are older than any coal. The coal of Iowa occurs chiefly in the Des Moines formation; a little is found in the Missourian. It was while these two formations were in process of accumulation, not before, that coal plants of sufficiently luxuriant growth to count for anything existed in Iowa; and though these plants were abundant, it was only in certain favored and comparatively limited localities that the preservation of the plants took place so as to form coal. The geological formations of Iowa lie one on the other somewhat like the shingles on a roof, except that the oldest and first laid formations extend underneath the rest all the way across the state. The older formations appear successively from beneath the later in going from the southwest toward the northeast. The Cambrian sandstones that are found in the sides of the valleys near Lansing, lie far below the surface at Des Moines. A well bored at Des Moines would pass, in the reverse order of their formation, through all the older beds, and would finally reach the Cambrian at a depth of about 1,600 feet. All these older beds, and all the individual layers of them, are seen in order, one after the other, between Des Moines and Lansing; and so a drill hole at Des Moines could reveal nothing of consequence that might not be learned by careful investigation of the natural surface exposures in the region between Des Moines and the northeast corner of the state.* Explorations for coal in the Mississippian, Devonian, Silurian, or older systems of rocks are foredoomed to failure for the simple reason that these rocks were all completed before a single workable coal seam was deposited, some of them before a single coal plant, or any terrestrial forms of vegetation from which coal might be formed, had come into existence. These formations all lie geologically below the coal as may be seen by consultiag

*The Greenwood Park well at Des Moines has penetrated to the Cambrian and has put to actual test the statements which any competent geologist would have made in advance. All the broad details of that boring could have been written out beforehand. The full record of the well, to the minutest details. is given in Norton's *Artesian Wells of Iowa*, Iowa Geol. Sur., Vol. VI, p. 294 *et seq*. Scores of other deep wells scattered throughout Iowa and confirming all that would be inferred from studies of the superficial exposures, are described in the same volume.

Plate III, in which their relations to each other and to the coal-bearing Des Moines formation are correctly indicated. If one could begin in the Mississippian or lower formations underneath Des Moines or in that vicinity, and bore upwards, he might have some chance of striking coal. But boring downwards in any of the formations referred to, whether under Des Moines or at points where the older beds come to the surface in the eastern part of the state, is going in the wrong direction; and the farther the boring is carried, the more hopeless becomes the search. There is positively no coal in any parts of Iowa, which have formations older than the Des Moines shales and sandstones as the surface rock. The finding of coal is not a question of deep drill holes, but is one of intelligent and thorough prospecting of geological deposits of a particular age. If the operation is begun in any formation older than the Des Moines, the drill may go through to Australia or anywhere else without finding a speck of coal.

Petroleum and natural gas are like coal in one particular—they are derived from organic products. They are known to have their origin in dark bituminous shale, in limestones, which are in general of organic origin, in quantities of vegetable matter included in sandstones, in remains of forests buried in the drift, in any accumulations of organic matter which have undergone or are undergoing decay while hermatically sealed from the atmosphere. The marsh gas, which is annually produced by the decay of vegetation at the bottom of ponds, affords an illustration of the origin of one of the products we are considering, familiar to almost every observant person. It need scarcely be said, therefore, that rocks which are older than the introduction of life on the globe can furnish neither gas nor oil; and the fact that such rocks may be reached in Iowa at no great depth makes it possible to explore the whole of the possibly productive series with comparative ease. Owing to their low specific gravity, oil and gas are displaced by descending waters and tend to rise toward the surface. They may, therefore, be found at some distance above the beds in which they are generated, but it would be very unusual to find them lower down.

The seas were practically destitute of life when the Algonkian quartzites at the base of the Iowa geological column were laid down, and all rocks older than the quartzites were formed under conditions even less favorable. It may be very positively affirmed that explorations for oil or gas below the top of the Algonkian are certain to be fruitless. Above the Algonkian lies a body of Cambrian sediments—mostly sandstones—1,000 feet in thickness. Life was far from abundant in Iowa during the deposition of the Cambrian, though even if it had been never so prolific, it would have counted for little, since sandstone is not a good conservator of the organic matter present in the seas at the time of its accumulation. Sandstones are good reservoirs for the storage of gas and oil after these products have been generated from some underlying productive rock. But there is nothing below our Cambrian from which gas or oil could be derived, and so the probability of finding either below the top of the Cambrian sandstones is so small as to be unworthy of consideration. Overlying the Cambrian are two formations, the Oneota and the Saint Peter, equally as barren as anything below them. When the drill reaches the top of the Saint Peter sandstone, it has practically passed through and beyond all formations in which there is any possible hope of finding the products under discussion. Next in ascending order comes the Trenton limestone, a formation that was laid down on a sea bottom fairly crowded with swarming forms of life. This limestone is impure; it contains a large amount of clay mixed either with the materials forming the layers of stone or laid down as beds of shale between the more stony layers. The Trenton formation was deposited under exceedingly favorable conditions for making it a productive source of gas and oil. It still contains large quantities of bituminous matter which by the slow distillation always going on must yield annually considerable volumes of gaseous or liquid hydrocarbons. At all the exposures of the lower

Trenton, from Dubuque northward, the dry shaly partings between the ledges of limestone afford material so rich in bitumen that it is easily lighted with a match; it burns freely and emits a strong oily odor. Bituminous shale, precisely like that seen in the natural exposures, was brought up from the horizon of the Trenton in the deep well at Washington, Iowa; it has been recognized in other deep wells; the same shale, rich in bitumen, probably underlies the greater part of the state.

If then a great amount of bitumen is stored up in the Trenton limestone and is constantly evolving gas and oil by slow distillation, why are not gas and oil wells as common in Iowa as in the productive regions of Ohio and Indiana? Let it be answered that something more than petroleum-bearing rock is needed in order that oil may be obtained in quantities of commercial importance. It has been estimated by Professor Orton that the rocks beneath the surface over a very large part of Ohio contain at least 3,000,000 barrels of oil to the square mile, and yet not one gallon of this can be secured by the drill without the concurrence of at least two other conditions: (1) There must be a porous reservoir—sandstone or porous limestone--in which the oil or gas may accumulate, and this must be covered with shale or other impervious deposit to prevent the hydrocarbons from escaping to the surface and becoming lost as fast as they are generated. But reservoir and cover alone will not insure a supply. So long as the rocks lie flat or have a uniform dip there will be no accumulations of any importance. (2) The reservoir and cover must present a series of folds beneath the arches of which the oil and gas are entrapped and accumulated under high pressure. Three conditions, therefore, must exist conjointly—the source of supply in some form of organic matter, the porous reservoir and impervious cover, and the arched or folded condition of the beds. It is the last of these conditions that is wanting in Iowa. Our stratified rocks are not folded to any noteworthy extent. The compression and crushing which gave rise to the Appalachian mountains produced folds as far west as Indiana, and then the effects fade out. Iowa is too for away from other centers of crustal disturbance, such as the Ozark region of Missouri or the great mountain axes of the west; and so the rocks are without the folds which are so essential to the accumulation of the fluent hydrocarbons. Besides the Trenton limestone there are petroleum-bearing rocks in other formations in Iowa, notably in the Carboniferous; but so far as discovery has gone, some of the conditions on which accumulation in commercial quantities depends, are always absent. Usable quantities of gas have been found at a few places in Iowa in the drift. This gas has its origin in the buried forests; beds of sand and gravel constitute the reservoir; and overlying bowlder clay is the impervious layer. Near Herndon and Letts are wells of this kind. The volume of gas is small; its source is near the surface; nothing would be gained, but much might be lost, by deeper borings. If either oil or gas is ever found in Iowa in usable quantities, outside the drift, it will be found either in or above the Trenton. There is no possibility of its occurring below that formation. Now, remember that deep wells which have penetrated the whole thickness of the Trenton and gone hundreds of feet below it, are scattered all over Iowa. Every one of these wells, no matter for what purpose it was made, is, in effect, a test hole for gas and oil; and every one of them answers the question of the occurrence of these products in a way that might be inferred from what is known of the geological structure—namely, in the negative. The state has been very thoroughly explored beyond the deepest point at which there is the slightest hope of success, and a thousand other test holes would not make the situation any clearer or the results more decisive. There is always the very remote possibility that there may be a small arch somewhere which has not been pierced by the drill, but the chances of its existence are so few, that if the object is simply to test for gas or oil, it would be an unjustifiable waste of money to search for it even if holes could be bored everywhere down into the Trenton limestone at the rate of one dollar apiece. The geological structure of the state, in its broader features, is now thoroughly known. The records of the many deep wells, so fully and accurately described by Norton in Volvme VI of the Iowa Reports, reveal that structure in scores of places down to the Algonkian; and from the base of the Algonkian to the earth's center, there is nothing but barren, igneous rocks in which drills might be worked eternally without the remotest prospect of finding even so much as a trace of gas or oil.

There is another fallacy which should be disposed of, if it is ever possible to dispose of any of the popular and deep-rooted fallacies concerning what is hidden from ordinary observation beneath the surface of the ground. However it has arisen, there is a wide-spread belief that experts in some way are able to judge of the presence or absence of valuable products by an examination of the topography and general characteristics of the surface of any given region. Unscrupulous persons, taking advantage of this belief, have robbed some Iowa communities unmercifully. Such persons usually own an elaborate outfit for drilling, and naturally they want to keep themselves and their machines employed. The community to be victimized is easily selected. With specious claims of expert knowledge and glib assurance that this hill and that ravine and the relations of the level plain all bear unmistakable evidence of underlying wealth of the very kind that the community for the moment most desires, the requisite amount of money is quickly coaxed from the pockets of public spirited subscribers, the hole is bored, the driller gets his pay, and the community is left to repent its folly at its leisure. Not infrequently it is the public spirited men of the community who take the initative, and, without knowledge of their own and asking no advice, but firm in the belief that the earth will yield anything desired if we only go deep enough, they proceed with the drilling of test holes on a scale involving the expenditure of thousands of dollars. The end is inevitable. It is that which invariably follows every ill-advised enterprise in which ascertained facts are ignored. The disappointment may be all the keener when the promoters realize that the facts bearing on the case were easily ascertainable.

The highest living authority on the distribution of oil and gas, the man who has done more than any one else for the successful and profitable development of all the interests related to these two products, declares that the most valuable service which science has been able to render in this connection has been the determination of the fields wherein exploration is hopeless. Iowans will do well to remember that, even in a state as munificently endowed as theirs, there are some things and some favoring conditions which Nature has failed to provide, there are some drafts on Nature's apparently limitless bounty which must go unhonored, there are some enterprises looking to the development of natural resources which in the very condition and structure of things are absolutely hopeless. Let them rather reserve all of their capital and energies for the development of the splendid resources which do exist and not waste any in the useless search for geological products which all enlightened experience shows could not, by any known possibility, be developed in the state.

It is a pleasure here to acknowledge the obligations of the Iowa Survey to the Director and officers of the United States Geological Survey. The national survey has practically finished the topographic work in northeastern Iowa and has thus rendered a service to the geological work in our state, of value more than can be easily estimated. The correct mapping of the geological formations in the driftless area would be altogether impossible without topographic base maps, and the preparation of such maps by the Iowa Survey would mean the expenditure of large sums of money and long periods of delay before work in any part of the driftless area could be undertaken. It is therefore to the generous co-operation of the national survey that we are indebted for the timely appearance of the Dubuque county report. The mapping of the geology and the presentation of the report in intelligible and acceptable form became possible only through the use we were permitted to make of the United States topographic sheets.

For some years we have been in correspondence with the Soil Division of the Department of Agriculture at Washington, looking to the organization of Soil Surveys in Iowa, but heretofore, owing to the limited congressional appropriations for such work, it has not been possible to send a party into this state. There is now a fair prospect that this work can be begun here and that typical areas of Iowa soils may be surveyed under the direction of the Chief of the Division, Mr. Milton Whitney, during the coming summer. The work will be of the highest practical advantage to the farming interests of the state.

While the museum collections have grown to some extent, there has been no systematic effort during the year to make additions simply for the sake of building up a museum, and this for two reasons. First, we have no space in which to make a display of material, and if it were collected, it would merely remain stored in the packing boxes. Second, the making of collections of any considerable size in the field involves expense of time and money, neither of which can well be spared. Small specimens, when necessary, are taken for study in the office and the laboratory; but making collections on any large scale means extra time in the field, the employment of teams to bring the material to the railway, as well as careful packing before the material can be shipped, and some extra force to care for it when it reaches the office.

Without much expense or effort we are accumulating a reference library of the highest importance. Our exchanges with working geologists and scientific societies and organizations of various kinds have brought a large volume of literature of great value, without which research work in many lines could not be undertaken. The scope of the ground covered by the regular exchanges may be inferred from the following list:

Anales del Miseo Nacional de Buenos Aires. (Buenos Aires.)

Atti della Societä Italiana di Scienze Naturali e del Museo Civico do Storia Naturale in Milano. (Milano.)

Annals of the S uth African Museum. (London.)

Annals of the New York Academy of Sciences.

American Mining News. (New York.)

Bulletin de la Société Belge de Geologie. (Bruxelles.)

Bulletin de la Société Geologique de Normandie. (Havre.)

Bulletin de la Commission Geologique de Findlande. (Helsingfors.)

Bulletin du Muséum D'Historie Naturelle. (Paris.)

Bulletin of the Geological Institute of the University of Upsala. (Upsala.)

Bulletin Societe Neuchateloise des Sciences Naturelles. (Neuchatel.)

Bulletin of the Buffalo Society of Natural Sciences. (Buffalo.)

Bulletin of the Chicago Academy of Sciences. (Chicago.)

Bericht über die Thätigkeit der St. Gallischen Naturwissenschaftlichen Gesellschaft. (St. Gallen.)

Bergens Museums Aarbog. (Bergen.)

Beiträge zur Geographie des Mittleren Duetschland. (Leipzig.)

Black Diamond. (Chicago.)

Brick. (Chicago.)

Corso di Geologia di Antonio Stoppani. (Milano.)

Communicacoes da Direccao Dos Trabalhos Geologicos de Portugal. (Lisbon .

Coal Trade Journal. (New York.)

Clay Worker. (Indianapolis.)

Cement and Engineering News. (Chicago.)

Clay Worker. (Chicago.)

Geognostische Jahreshefte. (München.)

Jahresbericht der königl. Bömischen Gesellschaft der Wissenschaften. (Prag.)

Le Globe. (Geneva.)

Memoirs and proceedings of the Manchester Literary and Philosophical Society (Manchester).

Mittheilungen des Naturwissenschaftlichen Vereines fur Steiermark. (Graz.)

Memorias y Revista de la Sociedad Cientifica. (Mexico.)

Materialien zur Geologie Russlands. (St. Petersburg.)

Mines and Minerals. (Scranton.)

Mining and Metallurgy. (New York.)

Mining, (Spokane.)

North of England Institute of Mining and Mechanical Engineers. (Newcastle-upon-Tyne.)

Proceedings of the Royal Society of Edinburgh. (Edinburgh.)

Proceedings of the Geologists' Association. (London.)

Proceedings of the Royal Society of Victoria. (Melbourne.)

Proceedings of the U. S. National Museum. (Washington.)

Proceedings of the Indiana Academy of Sciences. (Indianapolis.)

Proceedings and Collections of the Wyoming Historical and Geological Society. (Wilkes-Barre.)

Proceedings of the Rochester Academy of Sciences. (Rochester.)

Proceedings of the California Academy of Sciences. (San Francisco.)

Proceedings of the Philosophical Society of Glasgow. (Glasgow.)

Societa Geografica Italiana Bollettino. (Roma.)

Sammlungen des Geologischen Reichsmuseums in Leiden. (Leiden.)

Sitzungsberichte der königl bömischen Gesellschaft der Wissenschaften. (Prag.)

Stone. (New York.)

Transactions of the Royal Geological Society of Cornwall. (Penzance.)

Transactions of the Edinburgh Geological Society. (Edinburgh.)

Transactions of the Australasian Institute of Mining Engineers. (Melbourne.)

Transactions of the Connecticut Academy of Arts and Sciences. (New Haven.)

Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich. (Zürich.)

Verhandlunge der Russisch-Kaiserlichen Mineralogischen Gesellschaft. (St. Petersburg.)

Zeitschrift der Deutschen geologischen Gesellschaft. (Berlin.)

Publications are received from the following countries:

England, Scotland, Germany, Austria, Hungary, Bohemia, Switzerland, Belgium, France, Italy, Portugal, Russia, Sweden, Finland, Mexico, Argentine Republic, South Africa, Victoria and New South Wales, Australia.

During the past year the following Geological Survey reports have been received:

Maryland Geological Survey, Allegany County.

West Virginia Geological Survey. Volume I.

Geological Survey of Alabama. Bulletin No. 68.

Geological Survey of Alabama. Report on the Warrior Coal Basin.

The Geological and Natural History Survey of Minnesota. Volume V.

20th Annual Report of the U. S. Geological Survey. Parts I-VII.

Western Australia Geological Survey. Bulletin No. 4.

Records of the Geological Survey of New South Wales.

Jahrbuch der Königl Preussischen geologischen Landesanstalt und Bergakademie. Vols. XII-XIX.

Your attention is invited to the Reports of other officers of the Survey having the charge and administration of special lines of work.

I have the honor to remain, gentlemen,

Yours very respectfully,

SAMUEL CALVIN.

REPORT OF ASSISTANT STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY.
DES MOINES, December 30, 1900.

MY DEAR SIR—I have the honor to submit the following report for the period since I entered upon my duties the first of August. During that month I shared with Mr. Wilder the work of the office including the task of getting Volume X. through the press. Since his departure I have had charge of the office and my time has been devoted to the regular duties of the place.

Early in September the printing of the Bulletin on the Grasses of Iowa was commenced and has gone forward as rapidly as possible.

As in past years numerous letters have been received by the Survey asking for information regarding the mineral resources of the state. There have also been inquiries as to whether or not conditions in certain localities were favorable for finding coal, artesian water and other minerals. Not a few of these letters come from outside the state from those who are looking for favorable opportunities of investment. The work of the Survey in furnishing this information regarding the mineral resources of Iowa is an important one and that it is appreciated is shown by the letters received.

The demand for the reports of the Survey continues and has been so great that the supply of all the earlier volumes is now nearly exhausted and they are to be had only by purchase. In order to show to whom the reports go it may be stated that during the last few months entire or partial sets have been furnished to several large New York smelting and mining companies; a public library in New Jersey; Mining School in Ontario, Canada, and School of Mines in a western state.

Very respectfully,

A. G. LEONARD,

TO PROFESSOR SAMUEL CALVIN,

State Geologist.

REPORT OF PROF W. H. NORTON, IN CHARGE OF ARTESIAN WELLS.

Dr. Samuel Calvin, Director, Iowa Geological Survey.

DEAR SIR—I have the honor to make you the following report of the work done at this office during the year now ending. With the wider knowledge of the work of the Survey there is an increasing number of applications for information in the department of deep wells and water supply. Our correspondents are artesian well contractors, city councils, railway superintendents, the owners of large farms and industrial plants. To answer these inquiries as to the depth at which water may be found in all parts of Iowa, its probable quality and quantity, would require far more time than is at our disposal were it not for the large amount of information at hand, gathered in the previous work of the Survey. While the maps and charts that have already been prepared are of the greatest value, they do not take away the need of a careful investigation of each individual case presented.

The following is a nearly complete list of those who have consulted the office this year, together with the locality, whose artesian conditions were asked for:

Chicago and Great Western Ry.	Shannon City.
State Board of Control	Cherokee.
Keokuk Canning Co.	Keokuk.
M. E. Squire	Osceola.
Chas. E. Bigham	Cambria.
J. F. McCarthy, Artesian Well Cont'r, Minneapolis	Sumner.
J. P. Miller & Co. " " " Chicago	Waukon.
U. S. Geological Survey, Washington	General.
City Council	Mount Ayr.
" "	West Liberty.

City Council	Hampton.
" "	Bloomfield.
" "	Mason City.
" "	Sumner.

Information was obtained by correspondence or personal visit with regard to wells sunk recently in Dubuque, Tipton, Anamosa, Iowa Falls, Newton, Sioux City and Burlington, besides a number of the towns noted in the list of correspondents.

In two instances it was thought necessary by city councils to have an investigation of the problem on the spot. I was thus called during the year to Hampton, to consult as to the advisability of continuing the boring of the city artesian to greater depths; and to Mason City to advise as to best methods of increasing their water supply in order to meet the increasing population. In all instances we have met the most hearty appreciation of the work and service of the Survey.

I have the honor to remain, your most obedient servant.

WILLIAM HARMON NORTON.

Cornell College, December 31, 1900.

REPORT OF DR. S. W. BEYER.

DES MOINES, Iowa, December 31, 1900.

MY DEAR SIR—I have the honor to report the following work carried on under my direction during the year ending December 31, 1900. During the spring months my time was largely devoted to compiling the Mineral Statistics of the State. This work, as in former years, was carried on in conjunction with the Division of Mining and Mineral Resources, of the United States Geological Survey. The statistics for Clay were collected by the Federal Census Bureau and could not be collated and reduced in time for publication in Volume X.

The summer field season and such other time as could be spared from my College duties was devoted to work on the geology and technology of the clays of the state. In this work I was ably assisted by Mr. I. A. Williams on the methods of clay-working and clay-working machinery; by Professor A. Marston on the testing of clays and clay products; and Professor J. B. Weems on the Chemistry of clays. The geological work is well along and could be completed at an early date. The same is true of the tests of clay products. The chemical work is progressing rapidly and satisfactorily, while the testing of clays is little more than begun owing to lack of ways and means. It is the hope of those intrusted with the work on clays to bring it to completion during the current year so that the report will be ready for publication in Volume XII. Respectfully submitted,

Your obedient servant,

S. W. BEYER.

TO PROFESSOR SAMUEL CALVIN, *State Geologist.*

REPORT OF DR. J. B. WEEMS.

AMES, Iowa, January 3, 1901.

Professor Samuel Calvin, Director, Iowa Geological Survey, Des Moines, Iowa:

MY DEAR SIR—I have the honor of presenting the following report for the chemical work of the Survey during the past year. The analytical work is shown by the following outline:

Clay, chemical and rational analysis	4 samples
Limestone	2 samples
Coal	1 sample
Water, determination of calcium sulphate	1 sample
Gypsum	1 sample
Minerals, qualitative tests	1 sample
Minerals, determination of iron	1 sample

At present we have under investigation fifteen samples of clays. These samples are connected with the Clay investigation of the Survey. The prospect for the chemical work in the clay investigation during the coming year promises well.

It is also hoped that during the coming year, it will be possible to begin the work on the Soil investigation, which will be of special interest in many respects besides its chemical relations. Another investigation which I hope will be completed during the year is a comparison of the methods which are at present used for the "rational analysis" of clays.

Respectfully submitted,

J. B. WEEMS,
Chemist.

MINERAL PRODUCTION OF IOWA.

IN 1900

BY

S. W. BEYER.

VALUE OF MINERAL PRODUCTION.

1899.

Coal	$6,137,576
Clay (Federal census)	
Stone	809,924
Gypsum	600,000
Lead and zinc	50,542
Iron ore	3,465
Total value	$

1900.

Coal	$ 6,977,466
Clay	2,395,488
Stone	604,886
Gypsum	393,750
Lead and zinc	22,194
Iron ore	5,877
Total value	$10,401,661

MINERAL PRODUCTION IN IOWA FOR 1900.

BY S. W. BEYER.

The great industrial activity inaugurated early in 1899 in the mineral industries continued unabated throughout 1900 save in the development of lead and zinc properties. The output of stone also shows a marked falling off due almost wholly to the lull in Mississippi river improvements. Des Moines county produced scarcely 20 per cent in 1900 of the amount of stone marketed by her in 1899. The gypsum market was not quite as brisk as during the preceding year. Most of the mills were able to fill their orders by running a single shift. while during 1899 double shifts were quite the rule.

As during preceding years the gathering of mineral statistics was carried on jointly by the State and Federal Surveys. Most of the original requests were sent out from Washington, while the task of looking up the delinquents devolved largely upon the local office.

TOTAL PRODUCTION.

The value of the mineral production in 1900 was $10,401,661, distributed as follows:

MINERALS.	Value.	No. of producers.
Coal	$ 6,977,466	231
Clay	2,395,488	381
Stone	604,886	170
Gypsum	393,750	7
Lead and zinc	22,194	6
Iron ore	5,877	1
Total	$ 10,401,661	796

According to the best information available the production for 1899 was:

MINERALS.	Value.	No. of producers.
Coal	$ 6,137,576	203
Clay (estimated)*	2,275,000	360
Stone	809,924	175
Gypsum (estimated)	600,000	6
Lead and zinc	50,542	9
Iron ore	3,465	1
Total	$ 9,976,507	754

The total mineral production is shown by counties in table I.

*The returns for 1900 show that the estimate for clay published in the Tenth Annual Report was too high.

TABLE I.

Total mineral production by counties.

COUNTIES.	Total coal.	Total clay.	Total stone.	Miscellaneous.	Total.
Adair		$ 9,560			$ 9,560
Adams	$ 22,522	10,518	$ 1,250		34,040
Allamakee		19,590		$ 5,877	34,389
Appanoose	1,129.881	8,480			1,138.491
Benton		17 076	4,285		21,361
Black Hawk		15,850	15,231		31,081
Boone	485,081	33,472			518,553
Bremer		4,100			4,100
Buchanan					
Buena Vista		14,813			14,813
Butler					
Calhoun		11,000			11,000
Cass		5,275			5,275
Carroll					
Cedar		8,141	89.824		97,965
Cerro Gordo		88,135	15,330		103,465
Cherokee					
Chickasaw					
Clarke		170,580			170,580
Clay					
Clayton		8,050			8,050
Clinton		22,980	1,829		24,809
Crawford		7,925			7,925
Dallas	30.532	68,132			98,664
Davis	795	1,090			1.885
Decatur		8,760	1,358		10.118
Delaware		5,430	1,300		6,730
Des Moines		19,950	27,972		47,922
Dubuque		32,650	35,375	22,194	90,219
Fayette		12,380	11,118		23,498
Floyd		6,715	2,200		8,915
Franklin		2,240			2,240
Fremont		13,957			13,957
Greene	30,009	16,770			46,779
Grundy		3.100			3,100
Guthrie		33.895			33,895
Hamilton		62,114	1,874		63,988
Hancock					
Hardin		25.458	7,925		35,383
Harrison		14.838			14,838
Henry		23,089			23,089
Howard			1,821		1,821
Humboldt			5,400		5,400
Ida					
Iowa		29,102			29,102
Jackson			60,525		60,525
Jasper	135 412	22,125			157,537
Jefferson	6,063	16,272			22,485

TABLE I.—CONTINUED.

Total mineral production by counties.

COUNTIES.	Total coal.	Total clay.	Total stone.	Miscellaneous.	Total.
Johnson	....	$ 24,425	$ 3,780	....	$ 28,205
Jones	....	12,295	84,718	....	97,013
Keokuk	$ 306,887	28,264	2,196	....	337 347
Kossuth	....	1,950	....	....	1,950
Lee	1,600	8,510	40,652	....	50,762
Linn	....	41,595	27,676	....	69.271
Louisa	....	10,220	2,196	....	12.416
Lucas	292,090	5,300	....	....	297.390
Madison	....	3,600	4.409	....	8 009
Mahaska	1,337,548	52,705	1,165	....	1,391.418
Marion	233,597	16,375	6,755	....	256.727
Marshall	....	33,236	44,185	....	77 421
Mills	....	19,550	....	....	19.550
Mitchell	....	....	....	....	3,663
Monona	....	....	....	....	....
Monroe	851,252	3,575	3 950	....	858.777
Montgomery	....	28.795	1.125	....	29,920
Muscatine	....	28,228	....	....	28.228
O'Brien	....	....	....	....	....
Page	1,450	23,000	....	....	24.450
Plymouth	....	....	....	....	....
Pocahontas	....	....	....	....	....
Polk	1,300,636	373.486	....	....	1 674,122
Pottawattamie	....	70,965	....	....	70,965
Poweshiek	....	13,140	....	....	13,140
Ringgold	....	7,700	....	....	7.700
Sac	....	....	....	....	....
Scott	48,932	57,010	49,425	....	155,367
Shelby	....	16,950	....	....	16,950
Sioux	....	6,400	....	....	6,400
Story	8,600	23,656	....	....	23,656
Tama	....	56,350	230	....	56,580
Taylor	35,658	11,075	....	....	46,733
Union	....	12,570	....	....	12,570
Van Buren	14,393	18,319	445	....	33.157
Wapello	349,651	42,280	14,286	....	406,217
Warren	37,857	1,990	....	....	39.847
Washington	....	24,456	3,006	....	27,462
Wayne	83,558	10,080	....	....	93 638
Webster	233,462	155,492	5,175	393,750	787,879
Winnebago	....	....	....	....	....
Winneshiek	....	5,300	....	....	5.300
Woodbury	....	146,293	....	....	146,293
Wright	....	15,953	....	....	15,953
Single producers	(2) 2,395	(16) 81,958	(16) 22,919	....	....
Estimate	....	(7) 45,000	....	....	....
Total	$ 6,977,466	$ 2,395,488	$ 604,886	$ 421,821	$ 10.401.661

COAL.

The coal trade continued brisk notwithstanding the mild winter of 1900, and the price increased throughout the year. The operators were able to benefit from the good times which they were not fully able to enjoy because of early contracts during the preceding year. This prosperity was not monopolized by the operators but was shared with the miners. The wage scale was higher than for any year in the last decade.

The average price per ton was nearly 10 per cent higher than for 1899 and the total tonnage increased nearly 3 per cent. There was a notable increase in the number of men employed and the average number of days worked was not very different from the preceding year. Prospecting and exploration in several of the old districts and many new fields were vigorously prosecuted throughout the year. The most important results were obtained in Polk, Jasper and Monroe counties.

Table II gives the total tonnage, average price per ton, total value, number of mines producing, average number of days worked and number of men employed, arranged by counties. No attempt was made to keep separately the various sizes of coal put upon the market. Mine run, nut and steam coal are included in the total. This fact must be kept in mind if an analysis by counties be attempted. The Centerville district produces almost no slack and the average price given would be for lump coal, while the Des Moines-Oskaloosa district puts upon the market about 30 per cent "steam coal."

TABLE II.

Coal output by counties.

COUNTIES.	No. of producers.	Tonnage.	Value.	Average price per ton.	Average No. of men employed.	Average No. days worked.
Adams	12	12,146	$ 22,522	$ 1.85	170	99
Appanoose	49	734,698	1,130,762	1.54	190	2,561
Boone	12	288,742	485,081	1.68	206	856
Dallas	4	16,521	30,532	1.85	200	64
Davis*	1	....	....	.....	.....	.....
Greene	5	17,044	30,0C9	1.75	165	67
Jasper	8	100,256	135,412	1.35	238	221
Jefferson	2	3,650	6,063	1.66	15(	12
Keokuk	7	227,727	306,887	1.35	270	388
Lee*	1	....	....	.....	.....	.....
Lucas	2	221,922	292,090	1.32	240	378
Mahaska	22	1,098,617	1,337,548	1.22	254	2,016
Marion	20	209,223	233,597	1.12	231	462
Monroe	10	772,457	871,252	1.12	256	1,596
Page	2	600	1,450	2.42	120	7
Polk	21	851,667	1,300,636	1.53	226	1,566
Scott	7	28,728	48,932	1.70	182	97
Story	2	3,200	8,600	2.68	100	18
Taylor	3	17,829	35,658	2.06	245	60
Wapello	13	270,330	349,651	1.29	266	529
Warren	8	27,824	37,857	1.36	202	68
Wayne	3	54,503	85,558	1.53	190	182
Webster	19	135,661	233,462	1.72	210	333
Total	231	5,105,151	$ 6,977,466	$ 1.37	228	11,601

The average number of days worked and the number of men employed during the past nine years, according to the best information available, was as follows:

YEARS.	Average number of days worked.	Number of men employed.
1892	236	8,170
1893	204	8,863
1894	170	9,995
1895	189	10,066
1896	178	9,672
1897	201	10,703
1898	218	10,256
1899	229	10,268
1900	228	11,601

*Single producer.

The United States Geological Survey has not yet made public the Mineral Statistics for 1899 and it is impossible to give Iowa's rank as a coal producer for that year. In 1898 the state ranked eighth in tonnage and fifth according to value of output. These figures would scarcely be changed for 1899 and 1900.

Table III compares the output for 1900 with the output for the six preceding years:

TABLE III.

YEARS.	Short tons.	Price.	Value.	AUTHORITY.
1894	3,967,253	$ 1.26	$ 4,999,939	U. S. Geol. Survey
1895	4,156,074	1.20	4,982,102	U. S. Geol. Survey
1896	3,954,028	1.17	4,628,022	U. S. Geol. Survey
1897	4,611,865	1.13	5,219,503	U. S. Geol. Survey
1898	4,618,842	1.14	5,260,716	U. S. Geol. Survey
1899	4,928,477	1.25	6,137,576	Iowa Geol. Survey
1900	5,105,151	1.37	6,977,466	Iowa Geol. Survey

CLAY OUTPUT FOR IOWA 1900.

The clay output for Iowa for 1900 shows a healthy increase over preceding years. Every department of the industry shows an increase save paving brick and burnt clay ballast. In the manufacture and sale of paving brick there is a marked falling off, probably due to our defective paving laws and the activity of the asphalt people. The total value of clay goods marketed during 1900 approximates $2,400,000, distributed as follows:

	THOUSANDS.	VALUES.
Common brick	226,156	$1,462,395
Front brick	10,013	91 682
Vitrified paving brick	14,870	129,677
Ornamental brick		1,950
Fire brick		2,795
Stove linings		175
Drain tile		379,140
Sewer pipe		52,452
Sidewalk block		2,155

	THOUSANDS.	VALUES.
Fire proofing		31,850
Tile		300
Pottery		42,727
Burnt clay ballast		198,080
Raw clay		110
		$2,395,488

The most remarkable increase was in the production of common building brick, which faithfully reflects the building revival. The average price per thousand for common brick increased from $5.90 per thousand, in 1898, to $6.47, for 1900. A similar increase may be noted in the value of the other products. The distribution of clay products by counties is contained in table IV, herewith appended.

TABLE IV.

Clay production by counties.

COUNTIES.	No. of producers.	Common brick in thousands.	*Total brick in thousands.	Value of common brick.	*Valne of total brick.	Value of total clay.
Adair	6	1,506	1,506	$ 9,435	$ 9,435	$ 9,560
Adams	5	1,745	1,745	10,268	10,268	10,518
Appanoose	5	2,380	2,905	15,090	19,590	19,590
Audubon	2	1,300	1,300	8,300	8,300	8,480
Benton	4	1,983	2,083	12,481	13,681	17,076
Black Hawk	2	2,800	2,800	15,850	17,050	15,850
Boone	8	2,913	3,963	18,297	27,672	33,472
Bremer	3	600	600	4,100	4,100	4,100
Buchanan	1	....	....	....	....	....
Buena Vista	3	849	5,919	5,919	5,919	14,813
Butler	1	....	....	....	....	....
Calhoun	3	700	765	5,400	5,950	11,000
Cass	3	895	895	5,275	5,275	5,275
Carroll	1	....	....	....	....	....
Cedar	2	663	663	4,641	4,641	8,141
Cerro Gordo	3	4,950	4,950	30,600	30,600	88,135
Cherokee	1	....	....	....	....	....
Chickasaw	1	....	....	....	....	....
Clarke	2	400	400	2,500	2,500	170,580
Clay	1	....	....	....	....	....
Clayton	4	1,355	1,355	7,740	7,740	8,050
Clinton	4	2,035	2,935	12,380	21,380	22,980

* Not including fancy and fire brick.

TABLE IV.—CONTINUED.

Clay production by counties.

COUNTIES.	No. of producesr.	Common brick in thousands.	*Total brick in thousands.	Value of common brick.	*Value of total brick.	Value of total clay.
Crawford	3	1,150	1,200	$ 7,375	$ 7,925	$ 7.925
Dallas	10	3,292	4,482	21,740	32,836	68,132
Davis	3	173	173	1.090	1,090	1,090
Decatur	5	1,155	1,175	7,800	8,000	8,760
Delaware	3	670	720	3,980	4,330	5,430
Des Moines	3	1,450	2,068	7,500	17,950	19,950
Dubuque	6	6,365	6,365	32,650	32,650	32,655
Fayette	4	1,870	1,870	11,880	11,880	12,380
Floyd	2	850	857	6,375	6,461	6,710
Franklin	2	313	313	2,100	2,100	2,240
Fremont	7	2,070	2,070	13,942	13,942	13,957
Greene	1	....	....	....	....	....
Grundy	2	500	500	3,100	3,100	3,100
Guthrie	7	2,981	2,981	21,164	21,164	33,895
Hamilton	3	5,075	5,075	30,525	30.525	62 114
Hardin	4	445	520	2,988	3.588	25,458
Harrison	7	2,155	2,155	14,838	14,838	14,838
Henry	7	1,733	1.733	11,043	11.043	23,089
Howard	1	....	....	....	....	....
Humboldt	1	....	....	....	....	....
Ida	1	....	....	....	....	....
Iowa	6	3.940	3,940	24,102	24,102	29,102
Jasper	7	3,150	3,270	18,675	19,825	22,125
Jefferson	3	910	910	6.470	6,470	16,272
Johnson	6	3,260	3,260	17,075	17,075	24,425
Jones	3	820	820	5,380	5,380	12.295
Keokuk	7	1,548	1,548	11.040	11,040	28.264
Kossuth	2	325	325	1,950	1,950	1.950
Lee	4	1,645	1.715	7,760	8,510	8,510
Linn	9	5,510	5 510	35,535	35,535	41.595
Louisa	4	1,280	1,280	8.420	8,420	10,220
Lucas	3	800	800	5,300	5,300	5,300
Madison	2	550	550	3,600	3 600	3,600
Mahaska	5	3,700	5 700	27,555	45.555	52,705
Marion	3	1.700	1,700	14,275	14,275	16,375
Marshall	6	4,800	4 800	28,400	28,400	33,236
Mills	4	2,800	2,800	19,550	19,550	19,550
Monona	1	....	....	....	....	....
Monroe	3	575	575	3 575	3,575	3,575
Montgomery	6	3,620	3.620	24,265	24,265	28,795
Muscatine	11	4.140	4,140	23,228	23,228	28,228
O'Brien	1	....	....	....	....	....
Page	2	4,000	4,000	23,000	23,000	23,000
Plymouth	1	....	....	....	....	....
Pocahontas	1	....	....	....	....	....
Polk	18	29,454	38,877	211,224	300.786	373,486
Pottawattamie	12	11,790	11,790	68,565	70,965	70,965

* Not including fancy and tile brick.

TABLE IV.—CONTINUED.

Clay production by counties.

COUNTIES.	No. of producers.	Common brick in thousands.	*Total brick in thousands.	Value of common brick.	*Value of total brick.	Value of total clay.
Poweshiek	3	875	875	$ 6,310	$ 6,310	$ 13,140
Ringgold	4	975	975	6,700	6,700	7,700
Sac	1	......	......	......	......	......
Scott	7	8,717	8,717	50 425	52,175	57,010
Shelby	3	2,550	2,550	16,950	16,950	16,950
Sioux	2	900	980	5,600	6.400	6,400
Story	6	1,621	1,621	12,439	12,439	23,6[illegible]6
Tama	7	4,045	5 941	26,050	52,350	56 350
Taylor	4	1,655	1,655	11,075	11.075	11,075
Union	2	1,730	1,730	12,110	12,110	12.570
Van Buren	4	950	950	5,875	5,875	18,319
Wapello	5	5 053	6,154	21,880	39,130	42,280
Warren	2	260	260	1,790	1,790	1,990
Washington	5	3,483	3,547	19,254	19,766	24 456
Wayne	6	1,490	1,490	9,680	9,680	10,080
Webster	7	12,600	14,375	75,100	104,565	155,492
Winnebago	1	......	......	......	......	......
Winneshiek	2	1,000	1,000	5,300	5,300	5,300
Woodbury	6	22,883	25,383	67,355	67,355	146,293
Wright	4	150	150	1,230	1,230	15,953
Single Producers	16	7,047	7,287	45,300	47,640	81,958
Estimate	7	......	......	......	......	45,000
Total	381	226,156	251,039	$ 1.462,395	$ 1,683,754	$ 2,395.488

* Not including fancy and fire brick.

1900 was characterized by the opening of a considerable number of new plants, some of which were of large capacity, and the number of idle plants was the smallest in the history of the industry. Plants which had stood idle for years were rejuvenated and made to become revenue producers. Two new up-to-date plants were opened at Mason City during the year. While as in former years the clays and silts of the Pleistocene are used very widely over the state, there is a growing tendency to use more and more of the shales, particularly those of the Ordovician (Maquoketa shales), Devonian (Lime Creek shales), and Coal Measures.

In 1899 the Federal Census Bureau collected the clay statistics and their report has not been made public so that it is impossible to give the production for that year. In compiling the statistics for 1899, the clay production was estimated at $2,500,000 which is now known to have been too high. This over estimate was brought about by the greatly increased production of common building brick, while due allowance was not made for the falling off in the production of paving brick. In 1898 the state ranked fourth in the production of paving brick and eighth in total clay products. During the past two years the rank of the state in total clay products probably remains unchanged while she has undoubtedly fallen far to the rear in her vitrified products.

STONE.

The production of dimension and building stone shows a decline, owing, in part at least, to the increasing popularity of brick for structural purposes, while natural and Portland cements are displacing lime in the more important structures. Jackson county is still the leading lime producer. The output of lime for 1900 slightly exceeds that for 1899, owing chiefly to the renewal of the industry on Sugar creek in Cedar county. The stone put upon the market includes limestone, dolomite and sandstone. The returns show an output of $604,886, against $809,924 for the preceding year. The production was distributed as follows:

LIMESTONE—USED FOR:

Building purposes	$257,133
Paving or road making	154,149
Riprap	58,490
Lime	111,169
Other purposes	14,566
Sandstone	9,379
Total	$604,886

Table V shows the production by counties and specifies the various grades of stone put upon the market.

TABLE V.

Production of limestone in Iowa in 1900 by counties.

COUNTIES.	Total.	Building purposes.	Paving or road making.	Riprap.	Made into lime.	Stone sold to lime burners.	Other purposes.
Adams (two producers)	$ 1,250	$ 1,180	$ 70	....	....	....	....
Allamakee	....	....	....	....	....	....	....
Appanoose	....	....	....	....	....	....	....
Benton	4,285	4,000	....	$ 5	....	$280	....
Black Hawk	15,231	14,060	541	....	....	....	$ 630
Buchanan	....	....	....	....	....	....	....
*Cedar (three firms)	89,824	8,864	58,242	552	$ 22,166	....	....
Cerro Gordo	15,330	9,925	237	....	5,168	....	....
Clarke	....	....	....	....	....	....	....
Clayton	6,286	4,706	....	....	1,580	....	....
Clinton	1,829	1,581	55	193	....	....	....
Decatur	1,358	1,194	24	40	....	....	100
Delaware (two producers)	1,300	1,300	....	....	....	....	....
Des Moines	27,667	11,762	4,236	11 669	....	....	....
Dubuque	35,375	19,972	2,775	3,508	9,120	....	....
Fayette	10,743	8,543	....	100	....	....	....
Floyd (two firms)	2,200	2,200	....	....	....	....	....
Grundy	....	....	....	....	....	....	....
Hamilton (two firms)	1,874	1,874	....	....	....	....	....
Hancock	....	....	....	....	....	....	....
Harden	7,925	7,125	250	300	....	....	250
Henry	....	....	....	....	....	....	....
Howard (two firms)	1,821	1,805	16	....	....	....	....
Humboldt	5,400	5,400	....	....	....	....	....
Jackson	60,525	475	850	....	59,200	....	....
Johnson	3,780	2,050	1,344	370	....	....	16
Jones	84,718	49,962	24,467	1 262	....	....	9,027
Keokuk	2,052	1,735	210	107	....	....	....
Lee	38,737	7,009	18,496	....	....	....	45
Linn	27,676	5,035	8,884	5,757	8 000	....	....
Louisa	2,196	1,624	512	60	....	....	....
Madison	4,409	4,109	....	....	180	....	120
Mahaska	1,165	1,101	64	....	....	....	....
Marion	6,755	5,259	1,152	274	....	....	70
Marshall (two firms)	44,185	23,745	11,568	4,672	....	....	4,200
Mitchell	....	....	....	....	....	....	....
Monroe	3,950	3,575	375	....	....	....	....
Montgomery	1,125	1,125	....	....	....	....	....
Scott	48 405	24,087	9,735	14 150	125	300	8
Tama	230	230	....	....	....	....	....
Van Buren	400	320	....	....	....	....	80
Wapello	14,286	12,244	892	1,150	....	....	....
Washington	3,006	2,527	279	200	....	....	....
Webster	225	225	....	....	....	....	....
Single producers	18,209	5,430	9,809	....	2,950	....	20
Total	$586,410	$248,866	$153,949	$ 58,490	$110,589	$580	$ 13,936

* E. J. C. Bealer; King & Co.; Sugar Creek Lime Co.

PRODUCTION OF SANDSTONE IN IOWA IN 1900 BY COUNTIES.

COUNTIES.	Total.	Rough.	Building Purposes.	Curbing and Flagstone.	Other Purposes.
Keokuk	475	125	350	......	......
Webster	4,950	1,200	3,750	......	......
Single producers	4,285	1,103	2,517	515	150
Total	9,710	2,428	6,617	515	150

In 1898 the state ranked nineteenth among the stone producers and eighth in the value of its limestone. No later figures are at hand.

The value of the stone produced in Iowa during 1900 and the eight years preceding, was as follows:

TABLE VI.

YEAR.	Sandstone.	Limestone.	Total.
1892	$25,000	$705,000	$730,000
1893	18,347	547,000	565,347
1894	11,639	616,630	628,269
1895	5,575	449,501	455,076
1896	12,351	410,037	422,388
1897	14,771	480,572	495,343
1898	6,562	557,024	563,586
1899	17,239	792,685	809,924
1900	9,379	595,507	604,886

GYPSUM.

The gypsum trade continued brisk during 1900 but double shifts at the mills were not found to be necessary to fill orders as during the preceding year. Early in the season, owing to the installation of new plants, stucco sold as low as $5.00 per ton on board the cars at Fort Dodge and Corbin station. The average price for the year would be considerably higher, perhaps $5.25 per ton would be a conservative figure. The output for 1900 would exceed 75,000 tons. This includes stucco and all grades of plaster.

THE ZINC INDUSTRY OF THE DUBUQUE REGION FOR 1900.

The mining operations in and about Dubuque were carried on less vigorously during 1900 than for the two years preceding. This was in part due to falling prices and in part due to writs of injunction; two of the leading companies were engaged in litigation during the greater portion of the year, and active operations were at a standstill in their respective properties. About 2,000 tons of crude zinc ore was produced, selling at from $6.50 to $12 per ton, according to quality. The average price being not far from $8, or a total of $16,000 was received for the output of the district. A portion of the ore was milled by the Dubuque Ore Concentrating Company, and all of the ore was sold to the Mineral Point Zinc Company, of Mineral Point, Wis. The ore, as in 1899, consisted principally of zinc carbonate, "dry-bone," with disseminated particles of zinc sulphide, "jack." Prospecting was carried on quite extensively during the year, but chiefly for lead. The outlook for 1901 is not specially encouraging, although the amount produced will probably exceed that for 1900.

The price of lead continued better than for zinc, yet the output was not visibly affected. The Waters' smelter reduced 1,132,226 pounds of galena which was obtained in great part from the mines across the river in Illinois.

The output of lead and zinc may be summarized as follows:

Zinc, (carbonate and sulphide,) 2,000 tons	$16,000
Lead, (sulphide), 495,000 pounds	6,194
Total	$22,194

IRON.

The production of iron ore, inaugurated in 1899, shows a healthy growth for 1900. New crushing and washing machinery has been installed and plans are being matured to carry on mining operations on a larger scale. Shipments were made during the year to Omaha, Milwaukee and Chicago. At the present time the Waukon Iron Company is the only producer.

GEOLOGY OF LOUISA COUNTY

BY

J. A. UDDEN.

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INTRODUCTION.

LOCATION AND AREA.

Louisa county has an area of 360 square miles. It forms a broken rectangle extending from township seventy-four to township seventy-six north, and over ranges one to five west. The eastern boundary is formed by the Mississippi river while the others consist of the lines of the land survey. In range five the southernmost township is cut out and instead township seventy-six is added on the north. Counting from the south the county is the third abutting on the Mississippi river. Its river front is slightly more than twenty-two miles in length, forming a convex line with its greatest curvature to the south. The Iowa river crosses the county diagonally from northwest to southeast, receiving the Cedar river as a tributary from the northeast.

EARLIER INVESTIGATIONS.

The earlier geologists in the west neglected Louisa county to some extent. The cause for this is quite evident: there are no good outcrops of the indurated rocks along any of the larger water courses in the region, and before the land was brought under cultivation a greater part of the present lowlands were swampy tracts over which it was very difficult to travel. Dr. D. D. Owen* in his report of 1852 relates the fact that Mr. B. C. Macy "in tracing the confines of the Carboniferous formation between the Iowa and Cedar rivers, penetrated a region of ponds and swamps through which he waded for many days, and contracted an obstinate and dangerous intermittent fever." On the map accompanying this report the lower and the upper series of the Carboniferous limestones are represented as underlying the drift of this region, and on page 509 mention is made that this limestone appears near the mouth of the Iowa river. Hall† mentions the occurrence of the Burlington crinoidal limestone in the vicinity of Columbus Junction. The reports of C. A. White contain no reference to this county. In the reports of the Geological Surveys of Illinois several fish teeth are described that were collected from the Burlington limestone in Buffington creek by Frank Springer and O. T. St. John. In later years the drift has been studied by Mr. Frank Leverett, of the United States Geological Survey.‡ He has traced the outer margin of the Illinoian drift plain from its north to its south boundary and has mapped an old stream valley extending south and

* Rep. on Geol. Wisc., Iowa, Minn., 1852.

† Geology of Iowa, Vol. I, p 203, 1858.

‡ The lower rapids of the Mississippi river. Journal of Geology, vol. VII, No. i, also Monograph U S. Geol. Surv., No. xxxviii.

west from Columbus Junction. Several references bearing on the rocks of the county are made by H. E. Bain in his report on the Geology of Washington county.§ Finally, Prof. F. M. Witter, of Muscatine, published some years ago an account of the first gas wells in the drift in the northern part of the county.‖

PHYSIOGRAPHY.

TOPOGRAPHY.

The main topographical features of the county consist of two uplands and two lowlands; the bottom lands along the Mississippi, the low prairie and bottom lands of the Iowa, an upland drift plain east of the Iowa river, and an upland drift plain to the west.

The Mississippi Bottoms.—Along the northern boundary of the county these Mississippi bottoms are five miles wide. They occupy all of the north end of Port Louisa township and a strip on the east edge of Grandview, narrowing toward the south end of the township from which point it maintains an average width of less than two miles as far as the mouth of the Iowa river, in Jefferson township. From here it widens until along the southern boundary of the county it again has a width of five miles. In its northern part this bottom land has an average elevation of 552 feet above sea level and there is a slight general slope to the south of only a fraction of a foot to the mile until the Iowa river is reached. South of here the land is a little higher again. The main topographic features are the Muscatine slough, which follows the western border for the greater part of the distance north of the Iowa river, and the Great Sand Mound in the northeastern corner of Port Louisa township. This is a remnant of an old terrace rising thirty feet above the bottom land and occupping an area of a little more than a square mile, which extends north

§ Iowa Geol. Surv., vol. V, pp. 113-174.

‖ Proc. Iowa Acad. Sci., pp. 68-70. 1890-1891. American Geologist, vol. IX, p. 319.

into Muscatine county. Lake Klim is a lagoon connecting with Muscatine slough in the southeastern corner of Grandview township.

The Iowa River Lowlands.—The lowlands along the Iowa river vary from two to six miles in width and extend from the northwestern to the southeastern corner of the county. They present two expansions along their course which are separated by an encroachment of the highlands on either side. The average gradient of this plain is about one and one-sixth feet per mile, or from 615 feet above sea level in the northwestern corner to 580 feet in the southeastern corner of the county. The northernmost expansion constitutes the south end of the West Liberty Plain, the greater part of which lies along the Cedar river in Muscatine county. It here merges into the lowlands along the Iowa river. It occupies Oakland township and forms a level plain, averaging 610 feet above sea level. The Iowa river valley follows the southwestern border, varying from one-half to two miles in width and making several extensive detours to the northeast. One of these is occupied by Horseshoe lake, Hills lake, and Prairie creek and possibly marks an earlier course of Cedar river. In sections 3, 4 and 10 the plain rises occassionally to an elevation of about 650 feet above sea level, and becomes rolling and broken by low knolls and small, shallow, undrained basins. In the north half of the first two sections above mentioned there are a few dune-like hills. The Iowa bottom lands maintain a level about thirty feet below these lowlands. Toward the junction of the Cedar and Iowa rivers the upland bluffs converge and for six miles run a nearly parallel course about three miles apart, as far as Bard station. From here they diverge and enclose a lowland, usually known as Wapello prairie, which is about thirteen miles long and six miles wide. It is a level plain with an average elevation of about 590 feet above sea level. A few low sandy ridges follow in some places the shallow valleys which have been cut into its west and south border by Long and Otter creeks. Several low hills fringe the bluff line of its southern border, appearing as if partially submerged under its sediments. The largest of the latter is in Sec. 10, Tp. 73, N. R. III W. Others are seen in sections 8, 14 and 15. In Jefferson and Elliott townships the two bluff lines again approach each other to within less than two miles. The bottom lands of the Iowa river valley which follows the northeast side of these lowlands are on an average thirty feet below the latter with a width of two miles. Its southeast extension is characterized by frequent bayous, such as Warstoff's slough, Stone lake, Keever slough, Spitznogle lake, and Parson's lake, indicating frequent recent changes in the river channel. The smaller valleys of Long creek and Otter creek are cut to a slight depth on the west and south border of this plain.

The East Drift Plain.—This upland is a southern extension of the Illinoian drift plain in Muscatine county. It has an average elevation of about 100 feet above the lowlands. It is about nine miles wide on the northern border of the county. From there it rapidly tapers until its entire width northeast of Wapello is only two miles. From this point a tongue extends southeast eight miles farther. The surface of this upland is that of a moderately dissected plain, with a general slope to the west. Except near the center of Concord township it is sharply marked off from the bordering lowlands by bluff lines. On the east side this bluff line varies from 100 to 150 feet in height, and is very steep. It is only broken by two small creeks, one of which runs out on the Mississippi bottoms in the northeast and one in the southeast corner of Grandview township. On the west side the bluffs as as a rule have a longer and gentler slope and range in height from forty to ninety feet. This is always the case where the sand prairie beyond it has not recently been cut away. In sections 10 and 15 of Tp. 75 N., R. IV W., the upland in some places merges into the lowland, and no bluffs are present. In sections 4, 5, 23, 24 and 25, Tp. 75 N., R. IV W., in the northwest corner of Concord Tp., and in sections 9, 10 and 15, Tp. 74 N., R. III W., the border of the upland is elevated into an interrupted dune-like marginal ridge rising from ten to thirty feet above the low uplands. This is invariably associated with a few small, shallow, undrained basins on the upland next the ridge and is apparently the result of wind action. In the northeastern half of Grandview township there are some flat, ill-defined swells with a northwest-southeast elongation, rising thirty feet above the general upland level, while in Jefferson township several shallow and wide loess-covered valleys with a northeast-southwest trend slightly indent the surface. The most conspicuous of these is in sections 1, 3 and 9 in Tp. 73 N., R. II W.

The West Drift Plain.—The southwestern part of the county is occupied by a drift plain varying in height from 650 feet to 875 feet above sea level. Its highest point, which is also the highest in the county, appears to be in the west end of Morning Sun township. The bluffs terminating this upland plain on the east and extending from Sec. 6, Tp. 76 N., R. V W., to Sec. 35, Tp. 73 N., R. II W., are everywhere well marked and range from a height of 125 feet in Union and Columbus City townships to less than seventy-five feet in Marshall township, along the west side of Wapello Prairie. The surface of the plain has a general slope to the northeast. In Union, Columbus City, and Grove townships, and in the southeastern part of Marshall township, the creeks have open valleys with slopes on either side sometimes half a mile in length, that merge into the upland plain. In Morning Sun, in the south end of Wapello, and in Elliott townships the slopes of the small drainage valleys are usually sharply marked off from the upland plain, and the creek valleys are more narrow. In nearly all the streams which run from west to east, the south slope of the valleys are more steep and bluff-like than the north slopes. This is a noticeable feature of Goose, Short, Long and Buffington creeks and of that part of Otter creek which runs from west to east. Two features of this upland deserve special notice. There is a long depression resembling a shallow drainage valley extending from the Iowa river border of the upland, just north of Columbus Junction, southwest and then south, to the southeast corner of Elm Grove township and thence into Henry county. The average width of this depression is one and one-fourth miles, and where best defined its bottom lies about forty feet below the upland and about 710 feet above sea level. Where it crosses Long creek its banks on either side become indistinct. A smaller branch leaves it and follows the south tributary of Long creek from the northeast corner of Long Grove township to the southwest corner, where it becomes confluent with the main depression again. This channel was first observed and described by Mr. Frank Leverett of the U. S. Geological Survey*.

Another noticeable feature is a line of high level traversing this upland and following the valley just described on the east. In Columbus City township it is not well defined, but just south of Long creek it forms two parallel, well marked swells extending south through Marshall township into Des Moines county. In the vicinity of Cairo these swells reach in places an altitude of 770 feet, while farther south they rise nearly a hundred feet higher. Each swell is about a mile wide and the two are half a mile apart. A minor feature in the topography of the county which deserves mention are some sink holes occurring on the upland in the northeast quarter of Sec. 18, Tp. 73 N., R. III W., near the Concord schoolhouse. These sink holes, which are about twenty feet deep and from five to eight rods wide, are due to subterranean caverns in the lower Burlington limestone which forms the underlying rock in this section.

TABLE OF ELEVATIONS.

Below is given a table of elevations containing all the railroad stations in the county and a few other places. It appears that of the four roads represented each has a datum of its own, the difference between two of these data exceeding

*Monograph. U. S. Geol. Surv., No. xxxviii.

100 feet. As the railroads intersect, connections were easily made and the elevations here given have been reduced to a common datum, the one adopted for the C. R. I. & P. R. R. in Gannett's Dictionary of Altitudes in the United States.

STATION.	ALTITUDE.	AUTHORITY.
Bard	599	B., C., R. & N. Ry
Clifton	621	C., R. I. & P. Ry.
Columbus Junction	599	C., R. I. & P. Ry.
Cotter	708	C., R. I. & P. Ry.
Elrick Junction	568	I. C. Ry.
Fredonia	606	C., R. I. & P. Ry.
Grandview	706	M. N. & S. Ry.
Highest point on R.R. 2 miles W. of Morning Sun	846	I. C. Ry.
Highest point on R. R. 2 miles E. of Letts	710	C., R. I. & P. Ry.
Letts	663	C., R. I. & P. Ry.
Levee east of Oakville	549	I. C. Ry.
Marsh	760	I. C. Ry.
Mississippi river, opposite Keithsburg, L. W.	523	
Morning Sun, B., C., R. & N. depot	745	B., C., R. & N. Ry
Morning Sun, I. C. depot	760	I. C. Ry.
Morning Sun R. R. crossing	752	B., C., R. & N. Ry
Newport	731	I. C. Ry.
Oakville	552	I. C. Ry.
Port Louisa, L. W.	526	
Wapello	588	B., C., R. & N. Ry

DRAINAGE.

The greater part of the land in the county drains into the Iowa river which follows in its course an earlier drainage line established long before the deposition of the drift. The rains on the flat lowlands along the rivers sink for the most part into the ground, which is naturally drained to some extent by seepage through the sand in which the water is quite free to move. Natural superficial drainage lines on the surface are almost wholly absent here. Since these lands were brought under cultivation the natural drainage has been aided by ditching, and some of the bottom lands have been protected from overflows by the construction of levees.

With the exception of a dozen sections of land the east drift plain drains into the Iowa river. The divide between the Mississippi and the Iowa follows closely the crest of the

Mississippi bluffs in Port Louisa and Jefferson townships. North of this it turns west and runs a little more than two miles west of the bluffs. The drainage of the eastern slope of this divide at the south end is therefore for the most part effected by very short and deep gullies or ravines with steep sides, evidently the result of very recent erosion, while the somewhat longer ravines in Grandview township appear to be the upper portions of older creeks whose lower ends have been cut away by the westward recession of the bluff line. Except in the northern part of this county, where it is less, the slope of the highland to the west is quite uniformly twenty feet permile. The creeks flow in general toward the southwest. They are quite wide and rather shallow in their upper courses and sometimes have a poorly drained alluvial bottom. A considerable part of the land surface is still flat and undissected by these ravines.

The drainage of the western drift plain in the southern tier of townships is mostly to the north but otherwise resembles somewhat that of the east drift plain. Honey and Smith creeks come across the county line from the south and have alluvial valleys along their lower courses which widen out in places to almost a quarter of a mile. Farther up stream, where they cut the underlying limestone, their valleys are narrow. It is evident that these creeks follow old drainage lines which have a considerably higher gradient than the present stream. All of the streams in this region are fed by springs coming from the base of the limestone. More than half a dozen creeks running north are tributarties of Otter creek, which follows the south side of the preglacial excavation under Wapello prairie. Part of its water evidently escapes into the sand of the lowlands, for the increase down the stream is not always proportionate to the water it receives from the uplands. Its tributaries from the north side are small and few, owing to underground seepage. In the southeast part of Marshall township it occupies a broad valley with a high bottom land. Long creek has a general course from west to east and collects the run-off from most of Elm Grove and Columbus City townships and from the north half of Marshall township. In Marshall township its valley varies from one-fourth to half a mile in width and is largely occupied by a terrace which rises from twenty to thirty feet above its own alluvial bottom. This terrace is seen with interruptions as far west as the northeast corner of Elm Grove township. In this basin the upland is less flat than in the tracts previously described and the drainage is more mature. There are some indications that that part of Long creek which lies in Tp. 75 N., R. V. W., and in the two north tiers of sections in Tp. 74 N., R. V. W., has been captured by the lower creek and taken across a rocky ridge in sections 12 and 13, Tp. 75, N. R. V. W. At this point its valley is rock bound on both sides and very narrow and it is cut in an upland that gives no indications of the presence of a drainage line before one is on the very border of its valley. The wide, well matured slopes of the valley of Johnny creek, which comes from the east and meets the upper part of Long creek just before it enters the rock bound channel, suggests that its course may run to an earlier mouth of the upper part of Long creek.

Decisive evidence of such a change seems to be lacking, however. Short and Goose creeks are very much like Long creek. For four miles northwest of Columbus Junction the watershed between the Iowa river and Short creek follows the brink of the bluff and the narrow tongue of upland between them drains into the creek. Some of its small tributaries formerly extended beyond the present bluff line and have recently been cut short by the recession of the latter. This divide is at present rapidly shifting to the west. In the southwest corner of Morning Sun township, where the surface is flat and only gently trenched by drainage lines, the run-off is collected into the head of Crooked creek and carried west. The southwest corner of Elm Grove township is drained in the same direction.

On the West Liberty Plain and Wapello prairie lowlands the rains readily soak into the sandy ground except in some low and swampy draws where the soil is black and deep. The upper thirty or forty feet of filling on these lands consist of sandy material which allows a free seepage of the water. Under this superficial sand there is a blue clay more impervious to water. In many places, and for long distances on either side of the Iowa and the Cedar rivers, springs issue from the base of the overlying sand. The bottoms of the Iowa river are more or less subject to annual overflows above its junction with the Cedar. The Iowa river has a number of meanders with curvatures having a radius of from .14 to .46 of a mile, averaging .23 of a mile, and separated by straight races a mile or more in length. Recently, some of these meanders have been vacated by the main current and the channel has been straightened, owing perhaps to the greater violence of the floods produced by the removal of the natural vegetation in the drainage basin of the river. Below Columbus Junction the meanders of the Iowa have a mean radius of .55 of a mile, ranging from .28 to .92. A considerable part of the bottom has been reclaimed for tillage by ditches and levees.

STRATIGRAPHY.

General Relations of Strata.

The northeast half of Louisa county is covered with a heavy deposit of drift from one to three hundred feet in thickness. East of the bluff line which follows the west side of the Iowa river, no bed rock is known to outcrop, and its presence has been reported from only a single well not far from the mouth of the Iowa river. Several wells have reached a depth of less than 400 feet above sea level. Previous to the deposition of the drift this part of the county was excavated to this depth by some stream whose valley extends north and east under Muscantine and Scott counties. The extensive erosion of the bed rock over this wide area is due to its softness. It was a shale or clay more than 200 feet in thickness. Part of this formation may yet be left under the drift or it may have been removed, exposing the Devonian limestone underneath. In the southwestern part of this county the drift is thinner, being seldom more than 100, and frequently less than fifty feet. It rests on the Burlington limestone, which is about fifty feet thick. This in turn overlies the soft, shaly beds that have been removed from the area to the north and east.

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

GROUP.	SYSTEM	SERIES.	STAGE.
Cenozoic	Pleistocene	Recent	Alluvial
		Glacial	Sangamon
			Illinoian
			Yarmouth
			Kansan
			Aftonian
			Pre-Kansan
			Geest
Paleozoic	Carboniferous	Upper Carboniferous	Des Moines
		Mississippian	St. Louis ?
			Augusta
			Kinderhook

UNDERLYING FORMATIONS.

The lowest rock which comes into view in this county is a blue shale. Several wells have penetrated this to a depth of more than 200 feet. One of these was sunk by Mr. P. A. Yohe at the Concord schoolhouse in Sec. 18, Tp. 73 N, R. III W. He reports 148 feet of "soapstone of a light blue color," beginning at a depth of twenty-three feet below the curb. Then there was thirty feet of black material of about the same composition as the "soapstone." Under this again there was ninety feet of "soapstone of the same kind as that above." In another well near the center of the west line of Sec. 12, Tp. 73 N., R. IV W., the same upper blue shale and the dark shale below it were again found, but the well was not sunk to quite the same depth as the previous one. In the northwest quarter of Sec. 22, Tp. 73 N., R. III W., 210 feet of shale was penetrated below ninety feet of drift. There was some dark material about fifty feet above the bottom. At Linton, in Des Moines county, about three miles south of Morning Sun, Mr. S. C. Petterson drilled a well to the depth of 365 feet. He found ninety feet of drift, below which which were 275 feet of shale. About fifty feet above the bottom there was some ten feet of dark brown material which was reported by the driller as "resembling coal." The close correspondence of the strata reported from these wells by different parties leaves no doubt that a heavy shale underlies the south and west part of the county as a continuous formation. Some wells in the northwestern part of the county give less conclusive evidence to the same effect. It is doubtless the same shale which has been found at the same horizon in several wells in the city of Burlington. Data obtained in the surrounding counties and elsewhere in the state, indicate that the downward succession of formations below the shale just described is about as follows:

THICKNESS OF FORMATIONS BELOW THE SHALE.

	FEET.
Devonian limestone	150
Niagara limestone	280
Maquoketa shale	180
Galena and Trenton limestone	300
St. Peter sandstone	150
Lower Magnesian series	700
Potsdam sandstone	100

The Mississippian Series.

The rocks which come under this heading are so intimately associated with each other in their outcrops that the details of the several subdivisions are best presented together. Briefly told, they consist of soft and easily eroded clays, sandstones and impure limestones below, usually called the Kinderhook, and of more durable limestones above, known as the Burlington. They appear to the best advantage for study in the bluffs west of the Mississippi and south of the Iowa in Elliott, Wapello, and Morning Sun townships, rising to the greatest height near the southern boundary of the county, and becoming less and less conspicuous as we follow the bluff line to the north and west. West of Elrick Junction the edge of the Burlington limestone recedes from the bluffs and seldom appears in the slope, but it can always be found in the creeks farther to the south. North of Otter creek it is not found within two miles of the Iowa river bluffs. The following typical sections are arranged in order from southeast to northwest. They describe the several rock ledges in each exposure in numerical order from below upward. Each ledge or seam is also marked by a separate number in brackets. These latter figures refer to the several divisions in the general section (Fig. 1) to which it has been referred and which will be found described after the presentation of the local details.

SECTIONS IN THE BLUFFS AND CREEKS NORTH AND EAST OF MORNING SUN.

1. SECTION ON THE FIRST CREEK IN THE MISSISSIPPI BLUFFS NORTH OF THE COUNTY LINE SOUTHWEST OF OAKVILLE, IN THE Sw. ¼ OF SEC. 35. Tp. 73. N., R. II W.

		Feet.
11.	(9) Disintegrated crinoidal limestone	6
10.	(9) Chert	1
9.	(9) Disintegrated crinoidal limestone	3
8.	(9) Blue shale	1
7.	(9) Hard, white, criniodal limestone with chert in upper layers	8
6.	(6, 7 and 8 ?) Beds changing from a disintegrated, yellow, shaly residue below, to a somewhat crumbling crinoidal limestone with much chert above	20
5.	(6) Yellow magnesian limestone with irregular bedding above and occasional quartzose concretions	7
4.	(5) Oolitic, yellow or brown, fossiliferous, disintegrated limestone	2
3.	(4) Fine sandstone, like number 1	1½
2.	(3) Compact, dark gray limestone, somewhat weathered, showing small cavities and veins filled with calcite	3
1.	(2) Bluish white, fine sandstone, weathering yellow, with casts of gasteropods and lamellibranchs	8

2 SECTION ON THE MISSISSIPPI RIVER BLUFFS ON THE SECOND CREEK NORTH OF THE COUNTV LINE IN THE EAST HALF OF SEC. 34, Tp. 73 N., R. II W.

		FEET.
15.	(11) Blue shaly beds, weathering yellow, with some calcareous and cherty bands above	15 ?
14.	Concealed	?
13.	(10) Chert	1
12.	(10) Brown limestone and chert	2½
11.	(10) Brown limestone, disintegrated	1
10.	(10) Bluish shaly material, with quartz geodes below	2
9.	(9) White crinoidal limestone, with quartz geodes in a shaly seam near base	8
8.	Concealed	?
7.	(9) White crinoidal limestone	4
6.	Concealed	?
5.	(9) Hard, white and yellow crinoidal limestone, moderately fine grained, with layers of chert	10
4.	(6) Yellow, rather fine-grained dolomitic crinoidal limestone, broken with many joints in upper part	10
3.	(5) Oolitic limestone with *Spirifer marionensis* Shum., *Productella concentrica*, Hall, *Spirifer* (undescr. sp), *Athyris*, sp., *Zaphrentis*, sp., and *Orthoceras*, sp.	3

		FEET.
2.	(3 and 4) Yellow or rusty brownish, weathered, compact limestone, with arenaceous rock above	5
1.	(2) Bluish fine sandstone, weathering yellow, with teeth of *Helodus* and casts of brachiopods in upper part. *Syringothyris extenuatus* Hall occurs near the top of the lowest number; also *Spirifer biplicatus* Hall and *Productus*, sp	9

3 SECTION IN THE WEST BANK OF A CREEK NORTH OF THE CENTER OF THE SOUTH LINE OF THE Nw. ¼ OF SEC. 23, Tp. 73 N., R. II W.

		FEET.
5.	(9) Chert bands in decayed limestone	4 ?
4.	(9) Bluish white or white crinoidal limestone, mostly in 8 to 10 inch ledges. Contains *Eutrochocrinus lovei* W. & S., *Spirifer plenus* Hall, also *Chonetes logani* Hall. *Schinophoria swallowi* Hall, and *Actinocrinus multiradiatus* Shum. in the upper part	15
3.	(7) Irregularly bedded, coarse, crinoidal limestone	6
2.	Concealed	5 ?
1.	(6) Buff shaly material, disintegrated	3

4. SECTION ON A CREEK ONE MILE SOUTHEAST OF ELRICK JUNCTION, IN THE SOUTH PART OF SEC. 29, Tp. 73 N., R. II W.

		FEET.
5.	(5 and 6) Yellow limestone, exhibiting oolitic structure below	10
4.	(4) Blue, evenly bedded, argillaceous sandstone	2
3.	(3) Fine grained, concretionary, yellow or brown limestone, disintegrated	4
2.	(2) Soft, fine grained sandstone, with *Helodus* teeth at base	2½
1.	(2) Blue, soft, sandy material, with wavy yellow stained bands containing *Chonopectus fisheri* N. & P., above.	6

5. SECTION ON THE EAST BANK OF SMITH CREEK JUST SOUTH OF ELRICK JUNCTION, IN THE Sw. ¼ OF SEC. 29, Tp. 73 N., R. II W

		FEET.
6.	(6) Irregularly bedded and leached limestone	?
5.	Concealed	10
4.	(2) Fine grained, soft, arenaceous rock	3
3.	(1) Soft, blue, unctuous shale	9
2.	(1) Carbonaceous shale	1
1.	(1) Blue unctuous shale with thin seams of calcareous material	6

6. SECTION IN AND NEAR ANDERSON'S QUARRY ON THE EAST BANK OF SMITH CREEK WEST OF THE CENTER OF THE Sw. ¼ OF SEC. 29, Tp. 73 N., R. II W.

		FEET.
9.	(9) Crinoidal white limestone (quarry rock)............	5
8.	(6 and 7) Apparently weathered crinoidal, cherty limestone, mostly concealed..............	13
7.	(6) Brown limestone, with scant crinoidal fragments in a single ledge.......................................	7
6.	(6) Seam of chert and shale...........................	1
5.	(5 and 6) Single ledge of yellowish, hard limestone, with geodes of calcite, sparse crinoidal fragments above and two ten inch bands of oolite below	8
4.	(4) Arenaceous soft rock	3
3.	(3) Irregularly bedded, leached brown limestone.......	3½
2.	(2) Bluish gray, arenaceous, soft rock with *Deltodus occidentalis*, Leidy, *Cladodus* and *Chomatodus* and fragments of brachiopods and lamellibranchs, such as *Grammysia plena* Hall, *Pugnax striatocostata* M. & W. and *Loxonema* sp..................................	4
1.	(1 and 2) Soft gray beds above, and shaly beds below, mostly concealed under the quarry rock but appear a few rods south, containing *Orthoceras (indianensis?)* and other fossils near the middle....................	20

7. SECTION ON THE EAST BANK OF SMITH CREEK NEAR THE BRIDGE IN THE Nw. ¼ OF SEC, 31, Tp. 73 N., R. II W

		FEET.
9.	(9) White or bluish crinoidal limestone with *Productus burlingtonensis* Hall, and a *Pentremites*..............	8
8.	(8) Chert	1
7.	(7) Irregularly bedded, knotty limestone with chert above......................	5
6.	(6) Mostly thin bedded, shaly limestone with crinoid stem fragments	3
5.	(6) White crinoidal limestone above, more irregularly bedded and cherty below............................	10
4.	(6) Brownish, fine granular limestone in two ledges with small fragments of crinoid seams...............	6
3.	(5) Oolitic limestone with fossils: *Spirifer marionensis* Shum. *Athyris crassicardinalis* White, *Rhipidomella burlingtonensis* Hall, *Straparollus obtusus* Hall, *Chonetes logani* N. & P., *Athyris* sp., *Zaphrentis* sp........	2½
2.	(4) Bluish, fine grained arenaceous rock with brachiopods. A thin seam of shale above and near middle..	3½
1.	(3) Compact, fine grained limestone, thin bedded (bituminous smell)..	1½

8. SECTION IN A QUARRY BELONGING TO JAMES ELRICK NEAR THE SOUTH COUNTY LINE ON THE LEFT BANK OF SMITH CREEK.

		FEET
12.	(?) Weathered limestone	22
11.	(10?) Chert	½
10.	(9?) Crinoidal limestone with fish teeth near top	2
9.	(9) Soft limestone	1
8.	(9) Blue shale with some chert below	2
7.	(9) Fine grained, yellowish limestone with *Productus semireticulatus* (Martin) *Spirifer plenus* Hall, a *Pentremites*, in straight even ledges with fish teeth above.	2
6.	(9) Blue shale	¼
5.	(9) Bluish, rather fine grained limestone	2
4.	(9) Chert layers, interrupted	1
3.	(9) Coarse grained, yellowish or white crinoidal limestone	4½
2.	(9) Bluish white crinoidal limestone, upper ledges very evenly bedded, lower ledges somewhat fine grained with *Dielasma rowlei*, Worthen	8
1.	(8?) Softer limestone with some quartz geodes	1

9. SECTION IN J. H. SPRINGSTEEN'S QUARRY ON THE SOUTH BANK OF SMITH CREEK, IN THE Sw. ¼ OF THE Sw. ¼ OF SEC. 36, Tp. 73 N., R. III W

		FEET
2.	(10?) Blue shaly beds	3
1.	(9) White crinoidal limestone in very regular ledges near middle, and with some chert in the upper part	7

10. SECTION SEEN IN SOME QUARRIES ON GOSPEL RUN, NEAR THE NORTH LINE OF SEC. 27, Tp. 73 N., R. III W.

		FEET.
8.	(9) Chert and disintegrated limestone with *Eutrochocrinus lovei* W. and S.	3
7.	(9) Crinoidal limestone, somewhat thin-bedded, with a *Pentremites*	9
6.	(9) Thin bedded, criniodal limestone	2
5.	(8) Chert	¾
4.	(7) Yellow, irregularly bedded limestone	4
3.	(6) Yellow, disintegrated crinoidal limestone	3½
2.	(6) Coarsely aggregated crinoidal limestone with *Lobocrinus pyriformis* Shum	2
1.	(6?) Shaly disintegrated material	1

11. SECTION ON THE NORTH BANK OF A TUIBUTARY TO HONEY CREEK, IN THE Ne. ¼ OF THE Nw. ¼ OF SEC. 21, Tp. 73 N., R. III W.

		FEET.
4.	(9) Crinoidal limestone with some chert	5
3.	Concealed	25

		FEET.
2.	(?) Yellow disintegrated limestone with cast of a large *Aviculopecten*..	2
1.	(4?) Bluish, arenaceous rock of fine texture............	4

12. GENERAL SECTION IN THE QUARRIES ON HONEY CREEK, NEAR THE NORTH LINE OF THE Sw. ¼ OF SEC. 28, Tp. 73 N., III W.

		FEET.
18.	(10) Yellow limestone and chert, alternating.....	4
17.	(10) Crinoidal limestone................................	1$\frac{3}{4}$
16.	(10?) Blue shale....................	2
15.	(10?) Shaly and cherty limestone........................	1$\frac{1}{2}$
14.	(9?) Chert..	1
13.	(9) Blue shale..	$\frac{1}{2}$
12.	(9) Disintegrated crinoidal limestone...................	3
11.	(9) Disintegrated crinoidal limestone, brown or yellow, with *Deltodus spatulatus* N. & W., *Venustodus robustus* St. J. and W., and *Ctenacanthus* spine........	$\frac{1}{4}$
10.	(9) Yellow weathered crinoidal limestone with some chert..	2$\frac{5}{6}$
9.	(9) White chert...	$\frac{1}{4}$
8.	(9) Yellowish crinoidal limestone with chert above and containing *Teleiocrinus umbrosus* Hall, *Dorycrinus quinquelobus* Hall, *Actinocrinus multiradiatus* Shumard, *Batocrinus pistillus* M. & W., *Dichocrinus striatus*. Ow., and Sh., *Eutrochocrinus christyi* Shum., *Spirifer logani* Hall, *S. grimesi* Hall, *Productus burlingtonensis* Hall, *Zaphrentis centralis* E. and H., and a *Syringopora*......................................	4
7.	(9) Yellowish, fine grained limestone with small open pockets...........	1
6.	(9) Bluish white crinoidal limestone in ledges from one to three feet in thickness, without chert, containing some of the fossils of number 8, and also *Platycrinus nodostriatus* W. and Sp., and *P. glyptus* M. and W....	6
5.	(8) Crinoidal limestone with much chert................	3
4.	(7) Very irregularly bedded yellow limestone...........	7
3.	(6) Chert in large masses.............................	$\frac{1}{4}$
2.	(6) Yellow, weathered crinoidal limestone with scattered irregular layers of more solid limestone and chert....	9
1.	(6?) Yellow shaly material resembling leached, disintegrated limestone, with occasional cavities lined with crystals..............	3

Numbers 1 to 5 are seen in the creek bank, just below the main quarry; numbers 6 to 12 appear in the face on the main quarry on the west side of the ravine; and numbers 6 to 18 appear on the opposite side of the creek, in following it one-fifth of a mile up stream. *Rhipidomella burlingtonensis* Hall was seen in one of the beds numbered 5, 6 or 7.

13. SECTION ON THE RIGHT BANK OF HONEY CREEK, BELOW THE RAILROAD BRIDGE IN THE SOUTHWEST CORNER OF SEC. 28, Tp. 73 N., R III W.

	FEET.
6. (9 & 10) Yellow, very much weathered limestone, with cherty layers and fish teeth near the middle	10
5. (9) Grayish yellow, crinoidal limestone with some seams of chert	5½
4. (9) Grayish yellow, crinoidal limestone without chert (main quarry ledges)	6½
3. (8) Chert in small irregular nodules	2½
2. (7) Disintegrated brown rock, almost shaly, with a more solid layer near middle	7
1. (7) Chert	1

14. SECTION ON THE EAST BANK OF A RAILROAD CUT AT THE EDGE OF THE UPLAND, THREE MILES NORTH OF MORNING SUN.

	FEET.
5. (6?) Disintegrated brownish magnesian limestone with *Athyris incrassatus* Hall and *Chonetes illinoiensis* W.	3
4. (2 & 4?) Yellow, weathered, fine sandstone, with *Edmondia burlingtonensis* M & W., *Spirifer biplicatus* Hall, *Chonopectus fisheri*, N & P.: *Pugnax striatocostata* M. & W. (var) *Orthothetes inequalis* (?) Hall, *Chonetes* sp., *Fenestella*	3
3. (2) Fine blue sandstone with few fossils	10
2. (2) Fine grained blue sandstone with casts of *Productus laevicostatus* White, *Productus cooperensis* Swallow, *Athyris corpulenta* Winch., *Orthothetes inegalis* (?) Hall, and other lamellibranchs in abundance	2
1. Blue shale	1

15. SECTIONS IN A RAVINE FOLLOWING THE WEST BANK OF THE RAILROAD ONE AND A HALF MILES NORTH OF MORNING SUN, IN THE NORTH-EAST CORNER OF SEC. 19, Tp. 73 N., R III W.

	FEET.	INCHES
4. (9) Chert layers		10
3. (9) White or yellowish crinoidal limestone, with teeth of *Orodus*, *Deltodus* and *Cladodus*	2½	
2. (9) Greenish white crinoidal limestone with *Lobocrinus pyriformis* Shum., *Dizygocrinus rodundus* Yand and Shum., *Dorycrinus quinquelobus* Hall, *Eutrochocrinus lovei* W. and S., *Pentremites elongatus* Shumard, *Actinocrinus scitulus* M. and W	1½	

1. (9) White crinoidal limestone with *Rhipidomella burlingtonensis* Hall, and *Spirifer plenus* Hall............ 4

16. SECTION IN DELZELL'S QUARRY, NEAR CONCORD SCHOOLHOUSE, IN THE Ne. ¼ OF THE Ne. ¼ OF SEC. 18. Tp. 73 N., R. III W.

		FEET
2.	(6) Yellow limestone, rather fine grained, with fragments of crinoid stems, in heavy ledges..............	7
1.	(6) Disintegrated and soft yellow limestone............	4

It will be noticed that in nearly all the sections in the bluffs bordering the river lowlands the lower soft Kinderhook beds appear. They have evidently been protected from destruction by the overlying Burlington limestones. West of Honey creek these bluffs seldom show anything but drift. Along that branch of Otter creek which runs through the north tier of sections in Tp. 73 N., R. IV W., nothing but drift is seen, and explorations in several wells show that these beds have been deeply eroded. The drift is at least one hundred feet deep. In Sections 11, 13, 14, 23 and 24 the Burlington limestone is, however, frequently in evidence along the watercourses, and it appears even as far north as near the center of the Sw. ¼ of Sec. 3 in Tp. 73 N., R. IV W. But these exposures have a limited vertical range, as is evident from the following instances.

SECTIONS IN OTTER CREEK BASIN.

17. SECTIONS IN AND NEAR AN OLD QUARRY ON THE EAST BANK OF OTTER CREEK, IN THE Ne. ¼ OF THE Ne. ¼ OF SEC. 14, Tp. 73 N., R. IV W.

		FEET.
4.	(9) White crinoidal limestone	8
3.	(9) Blue shale...	1 ?
2.	Concealed..	8 ?
1.	(7) Crinoidal limestone and shaly material with some quartz geodes (exposed farther up in the creek)	5

18. SECTION ON THE WEST BANK OF OTTER CREEK, NEAR THE CENTER OF THE WEST LINE OF SEC. 24, Tp 73 N., R. IV W

		FEET.
1.	(9 & 10?) Somewhat disintegrated limestone, yellow or brown, with frequent bands of chert.	17

19. SECTION IN CHURCHMAN'S QUARRY IN THE WEST BANK OF OTTER CREEK NEAR THE SOUTHWEST CORNER OF SEC. 14, Tp. 73 N., R. IV W

		FEET.	INCHES
3.	(9) Crinoidal limestone	1	
2.	(9) Chert		10
1.	(9) Bluish white crinoidal limestone in ledges from 6 to 12 inches in thickness	8	

SECTIONS IN LONG CREEK BASIN.

Following Long Creek west we find bed rock for the first time near the east line of Sec. 13, Tp. 74 N., R. V W. From this point the exposures are almost continuous along the south fork for two miles, but have a limited vertical range. The Kinderhook beds gradually disappear under the overlying limestones. The Buffington fork is rocky a mile from its mouth and has a few scattered exposures farther west. The north or main branch runs through a valley in which the Burlington limestone is frequently exposed in the bluffs or on the small tributaries. But with few exceptions these rocky cliffs are less than twenty feet in height.

20. SECTION ON A SMALL TRIBUTARY OF LONG CREEK, SOUTH OF THE CENTER OF THE Se. ¼ OF SEC. 13, Tp. 74 N., R. V W.

		FEET.
4.	(?) Brownish gray, compact, siliceous rock, possibly changed locally from a dolomitic limestone by infiltration	8
3.	(?) Not exposed	2
2.	(2) Blue, soft, fine sandstone with *Orthothetes inequalis*, *Chonopectus fisheri* Hall, *Aviculopecten caroli* W., *Productus levicostus* White, *Rhipidomella burlingtonensis* Hall, *Macrodon cochleris* Winch., *Orthoceras whitei* Winch , *Conularia* (*micronema ?*), *Edmondia* sp.	4
1.	(1) Soft shale (seen farther east)	?

21. SECTION IN THE WEST BLUFF OF LONG CREEK, SOUTH OF THE CENTER OF THE Nw. ¼ OF SEC. 13, Tp. 74 N., R. V W.

		FEET.
5.	(6) Irregularly bedded, compact, brown or gray dolomite; some brachiopods, with a few crinoid fragments	10
4.	(3 & 4) Rather harder than that below, brown earthy stone	2
3.	(2) Soft, rather uniform, bluish gray, light colored fine sandstone, with lamellibranchs and teeth of *Helodus* near top	5

		FEET.
2.	(2) Alternating layers of fine loose sandstone...........	5
1.	(1) Green clayey shale	3

22 SECTION IN J. H. WASSON'S QUARRY IN THE SOUTH BANK OF THE SOUTH BRANCH OF LONG CREEK IN THE NORTHWEST CORNER OF SEC. 23, Tp. 74 N., R. V W.

		FEET.
6.	(10) Disintegrated limestone with bands of chert.......	3
5.	(?) Yellow disintegrated limestone	3
4.	(9) Blue shale...	1
3	(9) Yellow, slightly disintegrated crinoidal limestone with small hollows filled with calcite crystals (also zinc blende)..	4
2.	(9) Yellowish, partially disintegrated limestone with fish teeth such as *Deltodus spatulatus* N. & W., *Psammodus glyptus* St. J. & W., *Cladodus* sp., *Helodus* sp., and *Orodus* sp.......................................	1½
1.	(9) Crinoidal white limestone in ledges from 6 to 10 inches in thickness with *Eutrochocrinus lovei* W. & S., *Batocrinus laura var. sinuosus* Hall, *Batocrinus laura* Hall, *Dizygocrinus rotundus* Yand and Shum...	4½

23. SECTION IN GRAY'S QUARRY NEAR THE NORTH BANK OF THE NORTH BRANCH OF LONG CREEK IN THE Ne. ¼ OF THE Nw. ¼ OF SEC. 3, Tp. 74 N., R. V W.

		FEET.	INCHES.
5.	(9) Yellow, disintegrated encrinital limestone with fish teeth near the base and with *Schizophoria swallowi* Hall, *Eutrochocrinus christyi* Shum., *Batocrinus laura* Hall, *Dizygocrinus rotundus* Yand and Shum., and teeth of *Deltodus*	5	
4.	(9) Ecrinital white limestone in heavy ledges with *Productus semireticulatus* Martin, *Productus burlingtonensis* Hall, *Spirifer grimesi* Hall....	3	
3.	(9) Chert..		10
2.	(9) Brownish yellow, porous, disintegrated limestone..	3	
1	(9) Bluish white crinoidal limestone with occasional crinoids near top......................................	5	

24. SECTION ON THE WEST BANK OF LONG CREEK ONE-FOURTH MILE SOUTH OF THE MOUTH OF JOHNNY CREEK NEAR THE CENTER OF THE SOUTH LINE OF SEC. 12, Tp. 74, R. V W.

		FEET.
5.	(6 or 7) Gray compact limestone........................	8
4.	Concealed..	13
4.	(3 or 4) Brownish gray gritty rock.....................	3
2	(2) Blue, soft, fine sandstone with casts of *Bellerophon bilabiatus* M. & W., *Straparollus macromphalus* W., *Spirifer subrotundatus* H., *Orthoceras whitei* Winch.,	

	FEET
Glossites elliptica, Straparollus, Modimorpha (?) Bellerophon (two species)	3
1. (1 & 2) Blue arenaceous soft rock with shale below	12

25. SECTION ALONG LONG CREEK IN THE SOUTHEAST CORNER OF SEC. 33, Tp. 75 N., R. V W.

	FEET.
2. (10 & 11) Weathered shaly limestone and shale with cherty layers	15
1. (9) Sound, bluish white or gray, crinoidal fossiliferous limestone	15

26. SECTION IN F. J. MOORE'S QUARRY ON THE EAST BANK OF LONG CREEK IN THE Sw. ¼ OF THE Ne. ¼ OF SEC. 33, Tp. 75 N., R. V W.

	FEET
6. (9?) Bands of chert	1
5. (9?) Yellowish shaly material or disintegrated limestone	2
4. (9) Yellow, partially disintegrated limestone with chert bands and fish teeth in the upper part, containing *Deltodopsis bialveatus* St. J. & W., *Deltodopsis convexus* St. J. & W., *Deltodus spatulatus* N. & W., *Cladotus*, fragments of spines	2
3. (9) Bluish white crinoidal limestone in ledges from 6 to 10 inches in thickness with *Productus burlingtonensis* Hall	2
2. (9) Shelly limestone with many brachiopods and *Igoceras capulus* Hall	1
1. (9) Crinoidal white limestone	2

27. SECTION ON THE SOUTH BANK OF LONG CREEK NEAR THE WEST LINE IN THE Nw. ¼ OF SEC. 32, Tp. 75 N., R. V W.

	FEET.
3. (11) Shaly limestone	5
2. (11) Blue shale	1
1. (11) Yellow limestone, somewhat fine grained	8

SECTIONS ON CLIFTON CREEK AND IOWA RIVER.

North of Long creek basin the drift rapidly increases in thickness and the bed rock is rarely exposed. It has been observed only in sections 22 and 27, Tp. 75 N., R. V., W., and in and near the bluffs of the Iowa river in sections 16 and 17, Tp. 76 N., R. V. W. At this latter place the blue Kinderhook shale is exposed in the bank of the river, rising some five or six feet above the water for a distance of a few rods.

It is covered by the shale and sandstone of the coal measures. Over most of this northern territory the Burlington limestone has been removed and the unprotected Kinderhook beds have been deeply eroded.

28. SECTION IN A TRIBUTARY OF CLIFTON CREEK IN THE Ne. ¼ OF THE Ne. ¼ OF SEC. 27, Tp. 75 N., R. V W.

	FEET.
7. (6) Crinoidal fossiliferous limestone, with chert seams (exposed farther up in the creek)	10
6. Concealed	4?
5. (?) Chert of oolitic aspect and with fragments of fossils	½
4. (?) Yellow decayed limestone, with sparse crinoid joints	2
3. (?) Chert of oolitic appearance and containing small fragments of fossils	½
2. (?) Yellow disintegrated limestone with scattered joints of crinoids, a productus, and various gasteropods	½
1. (2) Bluish gray arenaceous rock with fish teeth near the top and various gasteropods; also *Athyris corpulenta* W., *Productus curtirostra* Winch., *Productella nummularis* Winchell, *Orthoceras inequalis* Hall, *Edmondia burlingtonensis* M. & W., *Eumetria altirostris* White, *Porcellia obliquinoda* White, *Grammysia plena* M. & W. *Bellerophon* (undescr?) and a *Platyschisma*	4

29. SECTION ON THE SOUTH BANK OF CLIFTON CREEK NEAR THE CENTER OF SEC. 22, Tp. 75 N., R. V W.

	FEET.
2. (6?) Yellow decayed limestone	3
1. (2) Arenaceous blue material	5

30. SECTION ON THE SOUTH BANK OF A SMALL CREEK IN THE SOUTH BLUFF OF THE IOWA RIVER, IN THE SOUTHWEST CORNER OF SEC. 16, Tp. 76 N., R. V W.

	FEET.
1. (1) Bluish green shale cut up by joints into small rhomboidal blocks	4

General Section of the Subcarboniferous Rocks.—In comparing the sections above described with each other and with many others seen in the field, and on noting theirrelative positions, it becomes evident that they form a conformable succession of beds approaching a depth of one hundred feet. Certain parts of this section are much affected by weathering or else are quite generally concealed under the drift. At such

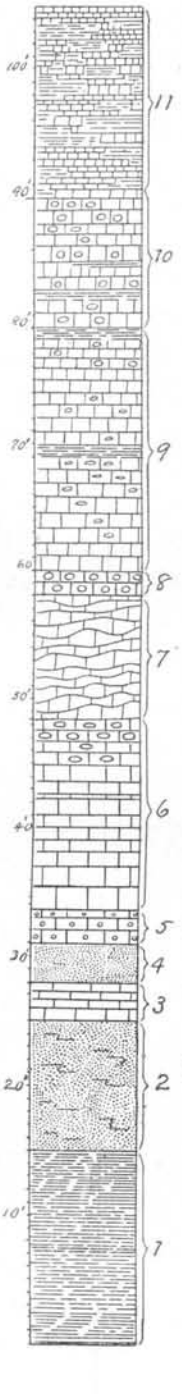


Fig. 1. General Section of the Lower Carboniferous (Mississippian) Rocks in Louisa County.

horizons it has been impracticable to make close comparisons or exact correlations, either on the basis of fossil remains or of lithologic characters. Both of these characters seem otherwise quite constant for each horizon, and doubtless much smaller subdivisions than those here attempted might be identified in different places with a closer examination of the rock and in a region where disintegration were less far advanced. As it is, eleven different divisions appear sufficiently constant to be capable of identification in this county. These will here be described in succession from below upward. See general section, Fig. 1.

(1) Maple Mill Shale:—The lowest member consists of a greenish, unctuous shale. In one place this has a dark band containing carbonaceous material some five or six feet below its upper limit. At another place it is cut up by two sets of joints into small and quite regular rhomboidal blocks. No fossils have been found by the author in this shale in Louisa county but at Burlington, where it is exposed deeper down, it contains several brachiopods, some decapods and a dictyospongia. In Louisa county only some fifteen feet are exposed, but several wells have, as already stated, penetrated it to a depth of at least 180 feet.

(2) English River Gritstone (Chonopectus Sandstone of Weller):—The Maple Mill shale changes somewhat gradually upward into a soft bluish gray, fine grained sandstone with intervening thin seams of shaly

material. It consists of rather angular quartz fragments of very uniform size, averaging one-sixteenth of a millimeter in diameter. By boiling in acid about eight per cent in weight is dissolved, consisting mostly of carbonate of iron and carbonate of magnesia. In weathering this rock turns a dull yellow color. In this condition the upper layers frequently exhibit fine, parallel curving, concentric, red or rusty lines on the surface. These are seemingly the result of some kind of progressive oxidation and concentration of the ferruginous material which it contains. A few inches below its upper surface there is a thin layer which contains imbedded fish teeth. A species of *Helodus* is almost invariably present and other observed forms are *Deltodus occidentalis* Leidy, *Cladodus* and *Chomatodus.** In the upper as well as in the lower part of this rock casts of various other fossils, mostly brachiopods and lamellibranchs, are quite frequent and ocasionally abundant. The following have been identified by Dr. Stewart Weller in a collection made by the author:

Fenestella, sp.
Athyris corpulenta Winch.
Syringothyris extenuatus Hall.
Pugnax striatocostata M. & W.
Orthothetes inequalis Hall (?)
Rhipidomella burlingtonensis Hall.
Eumetria altirostra White.
Productus curtirostra Winch.
P. cooperensis Swallow.
P. levicostatus White.
Productella nummularis Winch.
Chonetes, sp.
Chonopectus fisheri Hall.
Spirifer biplicatus, Hall.
S. subrotundatus Hall.
Modiomorpha, sp.
Grammysia plena Hall.

*The identification of these fossils were kindly made by Dr. C. R. Eastman.

Macrodon cochlearis Winch.
Aviculopecten caroli W.
Glossites elliptica Hall.
Edmondia burlingtonensis M. & W.
Bellerophon bilabiatus M. & W.
Bellerophon (two other species).
Porcellia obliquinoda White.
Platyschisma, sp.
Straparollus macromphalus W.
Loxonema, sp.
Orthoceras (*indianensis* ? Hall.)
O. whitei Winch.
O. inequalis Hall.
Conularia micronema Meek (?)

The thickness of this sandstone is about ten feet.

(3) "Lithographic Limestone:"—The next number is sharply marked off from the other beds both above and below. It consists of a compact gray limestone of fine texture and pure composition containing less than two per cent of insoluble material. A ground and polished surface has the appearance of lithographic rock. A part of the residue from a dissolved specimen is siliceous, but it also contained some dark carbonaceous substance. Specimens taken south of Oakville and Elrick Junction and also from Des Moines county are impregnated with bituminous material. This rock has been observed only in the southeastern part of the county and is sometimes absent here also, apparently having been dissolved and carried away by underground water. In Long creek basin, where the terranes are most thoroughly weathered and leached, it has not been definitely identified at any locality. In some of the sections where it appears it has been changed to an earthy brownish layer and is shrunk in thickness. No fossils have been secured from it in this county. Where not leached or altered its thickness is from three to four feet.

(4) Upper Gritstone:—The succeeding member consists of a soft blue or yellow, arenaceous rock quite similar to the English river gritstone in texture and composition, consisting of quartz grains of small and very uniform size. Fossils have not been observed. Where the underlying limestone is absent it rests upon the lower sandstone from which it is usually separated by a yellow or brown rusty seam. The thickness is three feet.

(5) Oolite ledges:—Above the upper gritstone there is a ledge of white or yellowish oolitic limestone. It is distinctly marked off from the bed below but somewhat continuous with that above it. The oolitic spherules are small and imbedded in a matrix of calcareous material which resembles in texture the limestone above it. This ledge is often greatly affected by leaching, being either wholly removed or else appearing as a yellow porous rock. The calcareous spherules have been dissolved, leaving imperfectly rounded vesicles testifying to their former presence. Where not affected in this way it usually contains numerous fossils, the following forms having been recognized.

Zaphrentis, sp.
Athyris crassicardinalis White.
Rhipidomella burlingtonensis Hall.
Productella concentrica Hall.
Spirifer marionensis Shum.
Chonetes logani, N. & P.
Straparollus obtusus Hall.
Orthoceras, sp.

Its thickness is from two to three feet.

(6) Wassonville Limestone:—This limestone is separated from the previous one by no other sharply defined lithological character than the disappearance of the oolitic structure. It consists of variable, usually moderately fine-grained limestone, normally in very thick ledges below. It contains

sparse fragments of crinoid stems, but seldom any entire fossils. Sometimes there are layers of a gray chert and in the lower ledges this chert sometimes has an oolite structure. Elsewhere it is mostly filled with traces of small fossil fragments. The upper part of these ledges are sometimes characterized by well marked close joints, which cut the rock into small blocks. Overlying as it does the less pervious aud less soluble beds of fine sandstones and shales this limestone has served as a highway for percolation of underground water Everywhere along the creeks it marks a horizon where springs issue, some of which are small streams. Except in a few places the rock is so thoroughly changed by leaching, solution and weathering as to be quite unrecognizable, frequently appearing as a brown, earthy, crumbling mass. Sometimes it is wholly absent, only a few cherty layers remaining. *Athyris incrassatus* Hall and *Chonetes illinoiensis* Worthen have been observed. The thickness of these ledges is perhaps as much as fifteen feet. Possibly a part of them should rather be referred to the next division.

(7) Lower Burlington Limestone:—Above the rock just described there is a horizon of limestone with layers that have a peculiar wavy, curving or sometimes twisted and knotty appearance. On one of the ledges which was seen in the bed of Gospel Run, some giant ripple marks six inches high and from four to six feet apart from crest to crest, extended in a direction a little north of east. Occasionally this rock is quite fine-grained and of a whitish gray color, but in most of the outcrops it is filled with crinoidal fragments. There are also frequent seams of chert. At one place a specimen of *Lobocrinus pyriformis* Schum. was observed. The thickness does not much exceed eight or ten feet.

(8) Main Lower Chert:—A persistent layer of chert usually overlies the irregularly bedded limestone. Occasionally it consists of a single seam, measuring a foot or more in thickness, while at other places there are several thinner layers, measuring in all two or three feet.

(9) Upper Burlington Limestone:—The most conspicuous rock in this region consists of a white, or greenish or yellowish white, typical crinoidal limestone in ledges from six inches to almost two feet in thickness. The lower ten feet are usually quite free from chert, but in the upper part chert seams are frequent and there are also some seams of green shale. One of the upper ledges contains teeth and spines of fishes such as *Ctenacanthus*, *Deltodus*, *Cladodus*, *Venustodus robustus* St. J. & W., *Psammodus glyptus* St. J. & W., *Detodopsis bialveatus* St. J.& W., D. *convexus* St. J. & W., *Deltodus spatulatus* M. & W., and *Orodus*.* Occasional fish remains are also seen in some of the ledges above and below this one. Many other fossils were observed by the writer in this rock, namely:

Syringopora, sp.
Zaphrentis centralis E. & H.
Glyptopora, sp.
Pentremites elongatus Schum.
Actinocrinus multiradiatus Schum.
A. scitulus M. & W.
Batocrinus laura Hall.
B. laura var sinuosus Hall.
B. pistillus M. & W.
Dorycrinus quinquelobus Hall.
Platycrinus glyptus M. & W.
P. nodostriatus W. & Sp.
Teleiocrinus umbrosus Hall.
Dizygocrinus rotundus Yand & Schum.
Lobocrinus pyriformis Schum.
Eutrochocrinus lovei W. & Sp.
E. christyi Schum.
Dichocrinus striatus Ow. & Schum.
Schizophoria swallowi Hall.
Rhipidomella burlingtonensis Hall.

*The identifications were kindly made by Dr. C. R. Eastman.

Dielasma rowlei W.
Productus burlingtonensis Hall.
P. semireticulatus Martin.
Spirifer plenus Hall.
S. grimesi Hall.
S. logani Hall.
Chonetes logani Hall.
Igoceras capulus Hall.
Orthoceras, sp.

The thickness of this division is about eighteen or twenty feet.

(10) Montrose Cherts:—The Upper Burlington limestone runs into a more cherty and impure rock with somewhat fewer crinoidal fragments and more frequent seams of green shale. Good exposures of this part of the section are not frequent for it is much affected by weathering. Fossils are scarce. Round quartz geodes occur in it near the upper limit, ranging from two inches to half a foot in diameter. Otherwise the character of the ledges appears quite variable. Their whole thickness is about ten feet.

(11) The Upper Shales and Limestones:—The uppermost beds consist of soft and fine grained limestone ledges alternating with, or imbedded in, softer yellow or bluish gray beds of shale and shaly limestone. This is only rarely seen in exposures, being usually concealed under the drift. No fossils have been noticed. The greatest thickness exposed does not exceed fifteen feet.

Correlations.—The five lower numbers in this general section together with at least the lower half of the sixth number constitute the upper part of what is generally known as the Kinderhook group. It is a most perfect parallel to the Kinderhook section at Burlington. On examining the section at the latter locality for the first time, I knowing the succession in Louisa county, the writer had no difficulty in placing his hammer on that thin seam in the second member containing fish teeth and in promptly finding some specimens of *Helodus*. It is equally evident that the upper part of number 6 and all of number 7 are the northward extension of the Lower Burlington; that number 9 corresponds to the Upper Burlington, and at least a part of number 10 to the Montrose chert as described by Keyes in Des Moines county. But it is uncertain whether the upper part of number 10 and the shaly beds above this should also be regarded as a part of the Upper Burlington, or as a thin and modified representative of the Keokuk group. It resembles the latter in having a geode horizon and in containing much shaly material. In the absence of fossils and of an opportunity to compare the lithological characters in the field the question must be left unanswered for the present.

Comparing the series with the section described by Bain in Washington county number 1 is evidently equivalent to the Maple Mill shale and number 2 to the English River gritstone. The lower part of number 6 is the Wassonville limestone. Dr. Bain has himself verified this correlation in the field.

It appears likely that the shales at the base of this section and below it, are the upward continuation of the Sweetland creek shale of Muscatine county. With the general dip of the terranes to the south the dark main body of the latter should come in at the level where the deep wells in this region have gone into a black shale. In the lowest exposure of this same shale at Burlington, the author has lately found a *Dictyospongia*. This gives its fauna a resemblance to that of the Waverly and the Genesee, to which the fauna of the Sweetland creek beds is also related.

These shales were deposited at no great distance from the shore, for they contain remains of vegetation. The overlying gritstones seem to consist of such fine sand as has been observed to be sometimes laid down farther out by off-shore submarine currents. It is not a littoral sand and is free from the fine mud common in shore deposits of the same fineness. This indicates a deepening and a clearing of the waters. Progressive though oscillating changes toward such conditions are indicated by the succession of muddy clay, fine clear sand, a calcareous precipitate, fine clear sand again, an oolitic calcareous precipitate, and then organic calcareous sediments. In these last calcareous sediments there is at first a rapid increase in the organic ingredient, as if a new fauna were establishing itself under the new and favorable environment of a clearer medium. The upper divisions of the Kinderhook may thus represent a period of return from this region to the deep sea conditions existing in the Middle Devonian. The uppermost beds of the last mentioned age are known to indicate a change in the opposite direction.

Geographic Conditions.—A comparison of the development of the Kinderhook and the Burlington rocks in Des Moines and Louisa counties throws an interesting sidelight on the geographical conditions of the period to which they belong, and corroborates some conclusions drawn from other evi dence. The thickness of these formations is greatly reduced in their northern outcrops. Leaving out those parts in each of the two sections of which the measurements are somewhat uncertain the thickness of the formations in the two counties is as given in the following table. The measurements for Des Moines county has been taken from the report of Keyes.*

Parts of the Section Compared.	Thickness in Louisa County, in feet.	Thickness in Des Moines County, in feet.
Number 10. (Montrose cherts)	10	30
Numbers 6, 7, 8 and 9 (Upper and Lower Burlington)	40	95
Number 5. (Oolitic rock)....................	2	3
Number 4. (Upper "yellow sandstone") ..	3	6
Number 3. (Lithographic limestone)......	4	18
Number 2. (Lower "yellow sandstone")...	10	25
Total of measured parts of section.......	69	117

It is well known that the nearest shore of the Mississippian

*Iowa Geol. Surv., vol. iii, p. 422, 1893 sea lay somewhat to the north. This has caused the diminished development of these sediments in the same direction. The thinning may to some extent be due to a reduction by leaching and solution of later date, but even after making all allowances for such changes the full original thickness of these beds thirty miles north of Burlington can not have been much more than one half of what it was at the latter place. The shore of the Mississippian sea was evidently not very far distant and may have been less than fifty miles away. But the thinning was perhaps not uniform beyond the present northernmost extension of the terranes. The presence of Subcarboniferous pebbles in the basal conglomerate of the coal measures suggests a greater northern extension of the lower beds than is indicated by this thinning in Louisa county.

The Saint Louis Limestone.

On the left bank of Honey creek, in the Se. ¼ of the Sw. ¼ of Sec. 32, Tp. 73 N., R. III W., some twenty rods north of the boundary of the county, there is a limestone breccia of greenish gray color composed of fragments of varying sizes, imbedded in a calcareous matrix of the same color. Some of the limestone blocks contain fragments of crinoid stems and other unrecognizable fossils. There are also seen in them some small cavities filled with a bright green clay. The breccia is only three or four feet high in the bank and rests on an uneven surface of the lower formation, which is yellow and weathered. An unconformability is here indicated. The rock extends only a few rods along the stream. A little farther down some reddish shaly beds appear on the same side of the creek. These are apparently continuous with the geode-bearing horizon of the Augusta, exposed nearby. The limestone breccia on this creek is entirely unlike anything else seen in the county. Dr. Bain, who visited the locality in company with the author, inclines to the opinion that it represents the Saint Louis stage. If such is the case there are possibly some more outliers of the same formation under the drift in the southwest part of the county, where the bed rock occurs in wells at a considerably higher level than that of Burlington limestone in the nearest outcrops.

The Des Moines.

After the deposition of the Subcarboniferous sediments in this region the bottom of the sea in which they were laid down was raised and new land formed. The deposits were then subjected to considerable erosion. There is no doubt that the Burlington limestone originally extended beyond its present northern border. The marginal remnant of the Burlington often has cavernous tunnels and crevices filled by the deposits of the next succeeding period and the base of these later deposits are found frequently to contain Subcarboniferous chert farther to the north. It is quite evident that the erosion preceding the next submergence cut this limestone down almost to its present condition. Accompanying this erosion there was a tilting of the land to the south. Following the erosion and tilting of the land it was again submerged and the Coal Measures were laid down in the marginal waters of a sea advancing an unknown distance to the north.

Only a small part of these deposits are left in the area included within the limits of this county, and they occur as small isolated outliers. The largest of these is less than half a mile in visible extent. It appears in the west bluff of the Iowa river near the adjoining corners of sections 16, 17 and 21 in Union township. A few rods up a ravine known as "Coal Hollow" there lies on the north bank a dark shale containing lumps of Kinderhook shale. The latter appears in an undisturbed condition in the same ravine near the river. This debris contains the characteristic concretions of clay ironstone of the Coal Measures. A short distance farther up there outcrops four feet of grayish white sandstone alternating with black shale and a few inches of coal. The sandstone shows several imprints of *Stigmaria*. In the base of the river bluff one-third of a mile above this ravine several similar outcrops occur resting on the bluish green Kinderhook shale. Worn pieces of Burlington and Kinderhook chert are imbedded, as if worked into the upper surface of the older shale, which is capped by a foot or two of black Coal Measure shale. Close by to the south a Coal Measure sandstone forms the river bank. It was found to contain impressions of Lepidodendrons and rises several feet above the water. The greatest thickness observed was about fifteen feet. Most of the exposures are at the present time partly covered by talus. It seems probable that this outlier may for some distance underlie the deep drift to the southwest. Fragments of the sandstone are frequently seen in the bowlder clay exposed in the opposite bank of the river. About forty rods south of Long creek and north of the center of the south line of the Se. ¼ of Sec. 13, Tp. 74 N., R. V W., a yellowish gray sandstone appears in several places under the drift along a small ravine, and a pit sunk in the left banks of the ravine some years ago went through a few feet of Coal Measure shale with some thin seams of coal. Bowlders of sandstone are frequent in the drift at this place and also for two miles to the east and a mile to the south. In Secs. 20, 21 and 28 in Tp. 74 N., R. V W., three wells have been sunk into a sandstone some twenty feet in thickness. Pieces thrown up from an open well were found to consist of Coal Measure sandstone. Rock of this kind has also been reported as encountered in wells under the drift in Sec. 27, Tp. 75 N., R. V W., at Cotter Station, and at Newport.

Some interesting occurrences of the same sandstones are found in dike-like fillings which occupy crevices in the Burlington limestone. The end of one of these runs out in the south bluff of Long creek, where this takes an abrupt turn to the north in the Se. ¼ of the Sw. ¼ of Sec. 13, Tp. 74 N., R. V W. This "dike" is sixty feet in width and fifteen feet high, lying with vertical walls against the limestone on both sides and forming an almost homogeneous mass of rock without marked bedding. It apparently extends for some distance back into the bluff. About one-fourth of a mile east another deposit of the same rock follows for several rods, the west slope of a ravine coming in from the south. Still other masses in similar situations occur south of the old Delzell quarry in the west bluff of the creek which runs through the Ne. ¼ of Sec. 17, Tp. 73 N., R. III W., and near the base of the east bluff of Honey creek east of the center of the Ne. ¼ of Sec. 32, Tp. 73 N., R. III W. Near this last place the channel of the creek for a short distance follows a crevice which is filled with the same sandstone. No doubt other "dikes" of this same rock are to be found in the county. All those here described appear to run in a north and south direction. The sandstone forming them has a particularly sharp grittiness, due to what must be a secondary enlargment of the grains. The grains are more or less perfect small quartz crystals with regular faces and edges. All of of the "dikes" have doubtless been formed as fillings in old caverns in the eroded limestone. The enlargement of the sand-grains may have been brought about by percolating water which has followed the drainage of the ancient caverns.

Subsequent History.—Over how large an area the Coal Measures were laid down it is impossible to say, but there must have been a considerable thickness here and they must have extended a considerable distance north. The land was then again elevated and subsequent erosion removed all but these few remnants of the basal part of the beds. As far as known there is no evidence within this county that it has been submerged since that time. During most of Mesozoic and Cenozoic time the land has undergone erosion. This finally resulted in the development of the topography now presented by the surface of the bed rock under the drift. This topography is the only record left of what occurred here during the long period of erosion already mentioned.

THE OZARKIAN AND THE GEEST.

Since the old land surface has been covered with drift a knowledge of it can only be secured from records of wells that have penetrated the drift and the underlying formations. Eighty-four records from such wells, mostly on the uplands, have been obtained for this purpose. The facts thus gleaned are here presented in tabular form and also on a map. This map shows, in fifty-foot contour lines, the elevation of the old land surface above the sea level. (Plate IV)

WELL RECORDS IN LOUISA COUNTY.*

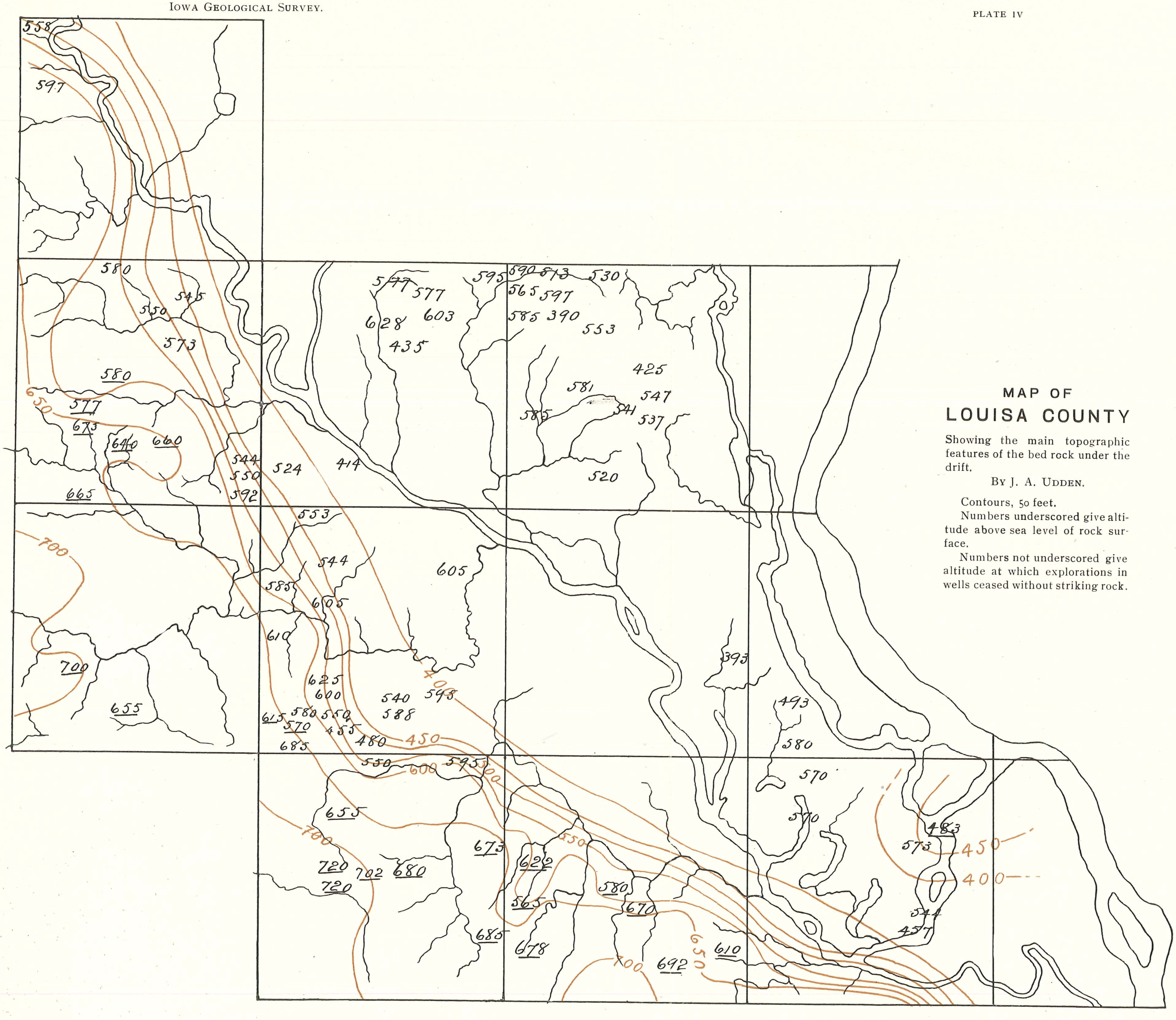
TOWNSHIP 73 NORTH, RANGE II WEST.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation of curb.	Depth.	NOTES.	Bed rock above sea level.
1	Sec. 5	Upland	66.	90	All drift	570
2	W. Clark, Sec. 8.	On bluff slope	630	60	Yellow clay 30 ft, sand 30 ft	570
3	John Hays, center south line, Sec. 11.	Upland	700	127	Yellow clay 40 ft, blue clay 80 ft, sand	573
4	J. Parson, Sec. 11	Upland	695	212	Yellow clay 30 ft, sand 6 ft, blue clay 80 ft, sand 14 ft, blue clay 25 ft, sand with timber 25 ft, blue clay. Rock at bottom	*483*
5	Dr. Parsons, Sw ¼ Sec. 23.	Second bottom	575	118	Sand, gravel and loam 31 ft, blue clay 61 ft, wood and black loam 10 ft, sand with water, 6 ft	457
6	T. M. Parsons, Sec. 23.	Upland	630	86	All drift	544

TOWNSHIP 73 NORTH, RANGE III WEST.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation of curb.	Depth.	NOTES.	Bed rock above sea level.
7	Concord School, Ne. ¼ Sec. 18.	Upland ravine	630	300	Drift 8 ft, limestone 15 ft, "soapstone" 148 ft, dark shale 30 ft, "soapstone" 99 ft	*622*
8	H. Harris, Ne. ¼ Sec. 20.	Upland	700	140	Drift 135 ft, Kinderbrook shale 5 ft	*565*
9	J. G. Keck, Sec. 22.	Upland	700	130	Clay 30 ft, rock 90 ft, "soapstone" 10 ft	*670*
10	W. D. Jamison, Nw. ¼ Sec. 22.	Near bluff	670	300	Drift 90 ft, shale 210 ft, carbonaceous material 50 ft above bottom	*580*
11	Sw. ¼ Sec. 25	......	....	......	......	*610*
12	Dobson & Jamison, Se. ¼ Sec. 27.	Upland	731	......	Drift 39 ft, soft sandstone 11 ft, then limestone	*692*
13	Cyrus Hewitt, Nw. ¼ Sec. 29.	Upland	750	76	Drift 72 ft, limestone 3 ft	*678*

*Where the elevation of the surface of the bed rock is known, it is given in italics in the last column of the table. Other figures in this column give the elevation of the bottom of the well when explorations stopped in drift.



MAP OF LOUISA COUNTY

Showing the main topographic features of the bed rock under the drift.

BY J. A. UDDEN.

Contours, 50 feet.

Numbers underscored give altitude above sea level of rock surface.

Numbers not underscored give altitude at which explorations in wells ceased without striking rock.

TOWNSHIP 73 NORTH, RANGE IV WEST.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation of curb.	Depth.	NOTES	Bed rock above sea level.
14	Thomas Harris............... Sw ¼ Sec. 1.	Bluff..........	670	75	Rock at bottom,.....................	595
15	Wm. Miller.................... Ne. cor. Sec. 4.	Slope	670	120	All drift	550
16	D. C. Marshall .... Nw. ¼ Sec. 9.	Upland........	750	126	Drift 95 ft., limestone 31 ft.	655
17	E. W. Sniverly .... South line Sec. 12.	Slope	690	87	Drift 17 ft., rock 70 ft..................	673
18	John S. Curran .... Sec. 15.	High upland ..	844	202	Drift 160 ft., shaly rock 42 ft.	680
19	J. K. Brown.................... Se. cor Sec. 16.	High upland ..	820	141	Drift 118 ft., limestone rock 23 ft	702
20	R. C. Dryden .... Center east line, Sec. 17.	High upland ..	840	160	Drift 120 ft., rock 40 ft.	720
21	James Chilson .... Sw. ¼ Sec. 20.	Level upland ..	760	126	Drift 40 ft., rock 86 ft..................	720
22	Morning Sun.................. Town Well.	Upland........	750	162	Drift 65 ft., limestone with some shale 97 ft	685

TOWNSHIP 74 NORTH, RANGE II WEST.

23	Fred Weiderecht .... Center So. line, Sec. 29.	Upland..	670	177	Rotten wood, sand and mud at 125 ft.	493
24	F. B. Stetson.................. Center E. line, Sec. 31.	Edge of upland.........	650	70	Yellow clay 8 ft., blue clay 10 ft., rotten wood, blue clay 12 ft, rotten wood, blue clay 20 ft., wood and sand 5 ft., blue clay 10 ft., wood and sand	580

TOWNSHIP 74 NORTH, RANGE II WEST.

25	Joseph Schofield .... Center Sec. 24.	Low upland ...	640	247	Yellow clay 10 5t., blue clay 8 ft., old soil 3 ft., blue clay, sand at 70 ft., old soil at 160 ft., white cemented sand at bottom......................	393
26	Average of several wells......	Low upland ...	640	123	Soil 4 ft., loess and yellow clay 40 ft., blue clay 76 ft., sand 3 ft	517

TOWNSHIP 74 NORTH, RANGE IV WEST.

27	John Hanft...................... Center W. line Sec. 5	Upland........	718	165	All drift..................................	553
28	Lyman Huff. .... Se. ¼ Sec. 8	Upland........	720	176	All drift..................................	544
29	Geo. Harrison .... Center Sec. 17	Low upland...	690	85	No rock	605
30	Geo. Boulton .... Ne. ¼ Sec. 18	Upland........	710	125	All drift..................................	585
31	James Dalton .... Se. ¼ Sec. 19.	Upland slope..	730	120	All drift..................................	610

TOWNSHIP 74 NORTH, RANGE IV WEST—CONTINUED.

Number.	LOCATION AND OWNER	SITUATION.	Elevation of curb.	Depth.	NOTES.	Bed rock above sea level.
32	Patrick Cetter, Sw cor. Sec. 26.	Upland	700	160	All drift	540
33	Unknown, Sw. cor. Sec. 26.	Upland	700	245	Blue clay with boulders at 150 ft., timber at 125 ft	455
34	Jesse Van Horn, Sw. cor. Sec. 27.	Upland	720	180	All drift	540
35	Cornelius Murphy, So. ½ Sec. 27.	Upland	700	105	Yellow clay and gravel 60 ft., blue clay 40 ft., water sand 5 ft	595
36	Wilson Sellers, Cairo, Sec. 28.	High upland	750	125	All drift	625
37	Cairo Village.	High upland	750	150	Black soil 8 ft., yellow clay 25 ft., blue clay 83 ft., gravel 8 ft	600
38	James Mullen, Se. ¼ Sec 29.	High upland	745	165	All drift	580
39	Henry Freeman, Sw. ¼ Sec. 29.	Upland	720	180	Drift 150 ft., sand at 120 ft., shale 30 ft	570
40	Skinner Bros, Sw. ¼, Sec. 30.	Low upland	705	70?	Mostly drift, rock at bottom	645
41	R. S. Cummings, Sw. ½ Sec. 32.	Upland	730	120	Drift 45 ft., limestone 75 ft.	685
42	Jos. Bates, Center of E. line, Sec. 33.	Upland	690	209	Yellow clay 70 ft., blue clay 68 ft. sand 1 ft., blue clay 25 ft., sand and clay 23 ft., dark drift 22 ft	480
43	E. S. Briggs, Nw. ¼ Sec. 33.	Upland	710	122	All drift	588

TOWNSHIP 74 NORTH, RANGE V WEST.

Number.	LOCATION AND OWNER	SITUATION.	Elevation of curb.	Depth.	NOTES.	Bed rock above sea level.
44	L. M. Samson, Se. cor. Sec 20.	High upland	760	60	Loess 10 ft., boulder clay 40 ft., sand 3 ft., rock below	700
45	Evan Davis, Ne. ¼ Sec. 28.	Upland	750	115	Drift 95 ft., sandstone 20 ft	655

TOWNSHIP 75 NORTH, RANGE III WEST.

Number.	LOCATION AND OWNER	SITUATION.	Elevation of curb.	Depth.	NOTES.	Bed rock above sea level.
46	Dan'l Westbrook, Se. ¼ Sec. 4.	High upland	710	180	Sand at 150 ft	530
47	John Sneider, near Letts.	Upland	690	300	Yellow clay 18 ft., quicksand 3 ft., blue clay 70 ft., yellow clay and gravel 20 ft., blue clay and gravel 30 (?) ft., sand to bottom	390
48	Letts	Low upland	683	170	All drift	513
49	Joseph Wagner, Sec. 6.	Upland	703	135	Yellow clay and sand 15 ft., blue clay 60 ft., coarse gravel 2 ft., sticky blue clay with wood below 47 feet, sand 13 ft	565
50	P. M. Reisch, Letts, Sec. 6.	Low upland	685	100	All drift	585

TOWNSHIP 75 NORTH, RANGE III WEST—CONTINUED.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation of curb.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
51	C. Vincent ... Se. cor. Sec. 6.	Low upland...	685	106	All drift ...	597
52	W. W. Wagner... Center S. line, Sec. 6.	Upland ...	700	110	All drift ...	590
53	Charles Wabintz... Center W. line, Sec. 9.	Upland ...	713	160	All drift ...	553
54	Peter Hass (?) ... W. ½ Sec. 13.	In bluff...	615	180	All drift ...	435
55	Fay Letts ... Se. cor. Sec. 19.	Low upland..	665	80	All drift ...	585
56	Noah Letts .. Ne. cor. Sec. 20.	Low upland...	675	94	All drift...	581
57	Martin A. Gray ... N. ½ Sec. 22.	Upland ...	720	173	Soil 6 ft, yellow clay 50 ft, quick sand 40 ft, white and blue clay, mixed, down to 170 ft. then sand with gas, which would not burn ...	547
58	George Young ... N. of Grandv. Sec. 22.	Upland. ...	710	173	Yellow clay 38 ft, black mucky soil 6 ft, sand 1 ft, blue clay 104 ft, sand 20 ft, clay 4 ft ...	537
59	John Bike. ... Sec. 22.	Upland ...	706	165	Drift at 165 ...	541
60	John Schafer. ... Center Sec. 28.	Upland.	690	170	Sand at 80, 136 170 ft, rest mostly boulder clay	520

TOWNSHIP 75 NORTH, RANGE IV WEST;

Number.	LOCATION AND OWNER.	SITUATION.	Elevation of curb.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
61	I. Idle ... Sec. 1.	Upland. ...	710	115	All drift...	595
62	B. Littner ... Nw. ¼ Sec. 2.	Upland ...	718	115	All drift...	603
63	R. W. Lee ... Center east line, Sec. 3.	Upland ...	680	103	All drift ...	577
64	Charles Estle. ... Ne. ¼ Sec. 3.	Upland ...	680	120	All drift ...	560
65	M. Lee... Center west line, Sec 3.	Upland ...	690	113	All drift...	577
66	M. A. Turkington Center south line, Sec 10	Low upland...	650	215	Loess, 5 feet; yellow boulder clay, 16 feet; yellow sand, 3 feet; blue sand 26 feet; white sand, 80 feet; dark bluish hard sand, 45 feet; light soft sand, 40 feet...	435
67	Etta Littrell ... Ne. ¼ Sec. 10.	Upland ...	728	100.	All drift...	628
68	Danl Overholt ... Se. ¼ Sec. 29.	Bottom land..	580	164	Alluvium, 8 feet; blue pebbly clay 72 ft, sand, 2 feet; blue clay, 14 ft; sand 68 feet...	416
69	Robert Owens ... Sw. ¼ Sec. 30.	Upland ...	700	176	All drift...	524

TOWNSHIP 75 NORTH, RANGE V WEST.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation of curb.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
70	H. E. Orr, Center Sw. ¼ Sec. 3.	Upland	720	175	All drift	545
71	Nels Spurgeon, Ne. ¼. Sec. 5.	Upland	720	140	All drift	580
72	Jane S. McKay, Nw. ¼ Sec. 10.	Upland	720	147	All drift	573
73	F. M. Duncan, Sec. 10.	Upland slope	710	160	All drift	550
74	Ruben Stapp, Sec. 16	Upland	730	400	Drift 150 feet, shale 250 feet	580
75	E. Robinson, Se. Cor Sec 20.	High upland.	740	65	Rock at bottom	675
76	Cotter Station, Sec. 20.	Upland	710	136	Drift, 133 feet; sandstone, 3 feet	577
77	J. W. Garner, Columbus City.	Upland	720	170	Loess, 13 feet; blue till, 157 feet; sand.	550
78	D. W. Overholt, Se. ¼. Sec. 25.	Upland	710	166	Loess and yellow till, 35 feet; blue till, 125 feet; sand and gravel, 6 feet	544
79	Martin Schaum, Center Sec. 27.	Upland	725	68	Drift, 65 feet; sandstone, 3 feet	660
80	F. J. Moore, S. line Sec 28	Upland	730	90	Rock at bottom	640
81	Humphrey Jones, Se. ¼ Sec. 32.	Upland	745	80	Rock at bottom	665
82	L. Williams, Columbus City.	Upland	720	128	Loess, 20 feet; blue till 108 feet; sand.	592

TOWNSHIP 76 NORTH, RANGE V WEST.

83	Edward Murdock, Nw. ¼ Sec. 6.	Upland	710	152	All drift	558
84	Josh Lucky, Nw. ¼. Sec. 18.	Upland	730	133	All drift	597

It will be observed that the main features of the ancient topography consist of an upland plain in the southwestern part of the county having an average elevation of 650 feet above the sea and of a wide lowland under the two rivers and under the east drift plain. By following the lowlands into the adjacent counties on the north we find that it is a local widening of some deep drainage valley. Its great width here is due to the presence of the soft Kinderhook beds which have been more easily removed than the overlying limestones.

The deep trenching of the ancient water-courses into the general prairie peneplain indicates that a general rising of the land took place some time before the end of the long erosion period. This elevation resulted in a rejuvenation of the drainage. The period when this occured has been called the Ozarkian or Sierran, from the fact that a like elevation took place at the same time in the region of the Ozarks and in the Sierra Nevadas. Before erosion had brought the land surface down to a new base level glacial conditions set in and covered the land with drift.

Very little is left of the products of disintegration from the Ozarkian period. During a time of rejuvenated drainage its surface accumulations would be promptly removed. Perhaps much of what remained was removed at the time of the first ice invasion. The only undoubted occurrence in this county of geest, as this old surface material has been called, appears on top of the bed rock in the limestone quarry in the west bank of Honey creek northwest of the center of Sec. 28, Tp. 73 N., R. III W. It fills a small depression in the surface of the ledges to the depth of three or four feet and may be described as a stiff, brownish yellow clay-like material, mingled with fragments of chert from the disintegrated limestone. A lower extension of the same cavernous hollow contained several pockets of a black, earthy oxide of manganese. On the top of the geest there are indistinctly stratified layers of a fine yellow sand or clay, containing occasional fragments of Archaean rocks. Above this there is typical bowlder clay.

The Pleistocene.

The bowlder clays and other drift materials of the glacial age have a greater development in this county than in most other parts of the state. Over the townships east of the Iowa river it probably averages three hundred feet in depth and on the west side it ranges from twenty to more than 200 feet. Three distinct sheets of bowlder clay are believed to have been brought here by three different ice fields at three successive epochs. These have been named the Albertan or pre-Kansan, the Kansan and the Illinoian, enumerated in the order of their sequence in time and from below upward. The base of the Albertan is everywhere beyond the reach of direct observation in surface exposures. Several well records indicate that it is underlain in the old lowlands by deposits of gravel, sand and silts, containing remains of preglacial vegetation. These deposits are probably a filling laid down in front of the first advancing ice sheet. Neither at that time nor since does there seem to have been any active plaining of the uplands by the ice. No scorings have been observed anywhere on the bed rock in this county. The general result of glaciation has been a filling up of the lowlands.

THE ALBERTAN OR PRE-KANSAN.

This till is dark gray or almost grayish black in color and of a rather soft and mealy texture. On being exposed to the action of the atmosphere this color rapidly changes to dirty yellow or brown. It invariably contains pieces of wood of gymnospermous trees. The fragments are mostly small, less than three inches in length, and are either broken off branches or splinters of larger pieces. Occasionally entire small logs are seen. Another constant feature is the presence of small fragments of coal averaging two or three grains in weight. A study of the pebbles contained in this drift shows that in comparison with the overlying tills this contains about twice as many fragments of local rocks. There is also a greater representation of rocks whose outcrops lie to the northwest, such as fragments of the Kinderhook and of the Burlington beds. In the north as well as in the south part of the county this till occasionally contains good sized bowlders of the latter rock, something which is never the case in the other two tills north of the northern margin of these formations. Of the crystalline rocks there is more greenstone, hornblende rock and schists than in either of the other drift sheets. On the other hand there is a smaller proportion of dolomitic limestone and rocks common in the Kewenawan. The largest exposures of this till do not disclose more than ten or fifteen feet and well records do not indicate a greater thickness than twenty-five feet. Over the uplands it is almost absent except in situations where the preglacial surface was low. The most important localities for this drift which were noted are as follows: (1) On the right bank of Honey creek near the south line of Sec. 21, Tp. 73 N., R. III W. (2) On the south bank of Smith creek near the center of the Se. ¼ of Sec. 35, Tp. 73 N., R. III W. (3) In a well on the upper slope of the bottom land in the Nw. ¼ of Sec. 6, Tp. 76 N., R. V W. (4) In the southwest bank of Smith creek near the southeast corner of Sec. 30, Tp. 73 N., R. II W. (5) In the south bank of Long creek near the center of Sec. 22, Tp. 74 N., R. IV W. (6) In the bank of the Muscatine North and South railroad cut, in the east bluff of the Iowa river, in the Se. ¼ of Sec. 9, Tp. 74 N., R. III W. (7) Oh the west bank of the Iowa river at Wapello. (8) On the west bank of the Iowa river one mile north of Columbus Junction and farther north. (9) In the west bank of the Cedar river two miles north of Columbus Junction. (10) In the railroad cuts in the bluffs of the Mississippi river in Sec. 2, Tp. 75 N., R. III W.

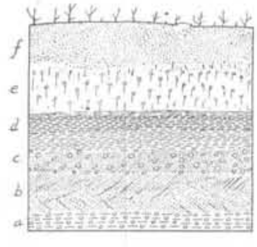


FIG. 2. General relation of the drift layers in the north bluff of the Iowa river in Nw. ¼ of Sec. 15, Tp. 74 N., R. III W.; *a* Albertan till (seen to the Nw. along railroad); *b* Aftonian sand, cross-bedded; *c* dark leached till and sandy boulder clay; *d* dark peat with a forest bed above and a diatomacious earth below; *e* typical loess, becoming sandy above; *f* fine wind-blown sand. Note: The Illinoian till is apparently absent.

This oldest till apparently underlies most if not all of the lowlands, and wells on the eastern upland indicate that it underlies the main water sand as a continuous sheet. Its upper surface in this territory approximates a level plain with an elevation of from ten to thirty feet above the bottom lands. This plain is particularly well shown in the cuts along the Muscatine North and South railroad in the Se. ¼ of Sec. 9, Tp. 74 N., R. III W., three miles south of Wapello. It follows the roadbed for about a quarter of a mile and finally disappears, as the latter rises above it, near the wagon road bridge on

Indian creek (Fig. 2, *a*). This locality suggests that the plain may have been the main shearing plain under the Kansan ice. On such a supposition it seems difficult to account for the presence of the sand which intervenes between this till and that next above. In one instance there seems to be a soil horizon on its upper surface. This is at the foot of the west bluff of the Iowa river, along the wagon road in the Se. ¼ of Sec. 21, Tp. 76 N., R. V W. (Fig. 4 *a*.) At one or two points it appears partly replaced by a dark blue laminated silt with indurated, thin concretionary laminæ of calcerous material. This phase is to be seen in the east bank of the Iowa, on both sides of the north line of Sec. 16, Tp. 76 N., R. V W.

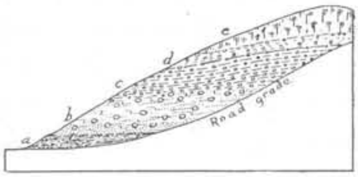


FIG. 3 Relations of strata of drift seen on the south side of the road leading down the Iowa river bluff in the Se. ¼ of Sec. 21, Tp. 76 N., R. V W. *a* Black, tough, leached silty soil (top of Albertan till ?) *b* tough boulder clay with ferruginous joints, yellow above, grayish blue below (Kansan); *c* somewhat stratified and sandy, yellow till; *d* leached horizon (Sangamon); *e* loess.

THE AFTONIAN.

The till just described is almost invariably overlain in this county by sand and gravel, varying in thickness from two to ten feet. This is occasionally cemented into a mortar rock. The prevailing color of the deposit is yellow. A peculiar relation which it maintains to the till below is that pockets of the sand extend down in the otherwise level surface of the latter. These pockets are from one to several feet in width and of equal depth. (Fig. 4, *e e e*.) Occasionally they form filled tunnels in the drift. This stratum is the main water sand in all the deep wells of the upland. Along the level of its outcrops in the bluffs there are a number of springs. Typical exposures of a similar sand

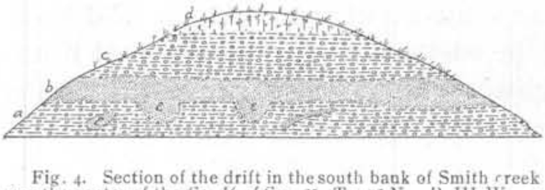


Fig. 4. Section of the drift in the south bank of Smith creek near the center of the Se. ¼ of Sec. 35, Tp. 73 N., R. III W. *a* Albertan till; *b* Aftonian sand; *c* Kansan till; *d* Loess; *e e e* pockets of Albertan sand extending into Albertan till.

in the drift near Afton Junction have been described by Bain* and the name is taken from that locality.

THE KANSAN.

The till which lies above this sand constitutes the bulk of the upland drift in the county. In its unweathered state it has a gray or yellow color and is tough and hard when dry. (Figs. 2–7.) It is generally cut by an irregular set of joints along which some oxidation has taken place. When thoroughly weathered it usually acquires a deep ferruginous stain. In comparison with the other tills there is among its pebbles a greater proportion of diabase and other Kewenawan rocks and of granite. Limestone and dolomite pebbles have about the same relative frequency as they do in the Albertan till. In respect to other rocks it seems to have an intermediate character between the till above and below. In the west tier of townships it directly underlies the loess and the topography of its surface presents a state of comparatively well advanced maturity, as already stated. In the eastern part of the county the inequalities of its surface seem to have been evened up by a later deposit of glacial detritus.

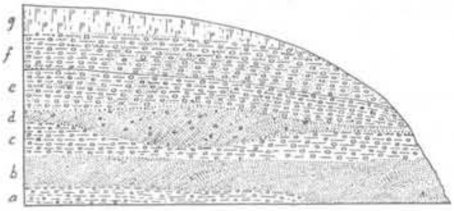


Fig. 5 Section of the drift in the north bank of the cut of the Muscatine North and South railroad in the bluff of the Mississippi river in the Se. ¼ of Sec. 2, Tp. 75 N., R. III W. *a* Silt associated with Albertan till; *b* Aftonian sand; *c* Kansan till; *d* Buchanan gravel and cand?; *e*, *f* Illinoian till with sand; *g* Loess.

*Iowa Geol. Surv., Vol. vi, p. 464, 1896.

THE BUCHANAN GRAVELS AND THE YARMOUTH SOIL.

Above that part of the Kansan till which is east of the Iowa river there often lies another sand which has the same relation to the Kansan as the Aftonian has to the Albertan. This is seen in several places along the Muscatine North and South railroad particularly in Sec. 10, Tp. 75 N., R. III W.

In the Ne. ¼ of the Ne. ¼ of this section it rests on an almost horizontal plane surface (Fig. 6, *b*) on the Kansan bowlder clay. This plane is sharply marked and can be seen for a quarter of a mile. The sand is evidently a glacial product. It is somewhat gravelly, contains occasional striated pebbles, and is rather imperfectly assorted. Here or there it has a long slanting or curving oblique lamination, and is also seen to run into silt. Occasional pockets extend into the underlying drift. In the Sw. ¼ of the Sw. ¼ of Sec. 11, Tp. 75 N., R. III W., it is ochreous from the infiltration of ferruginous material. In other places it is leached to a gray color. Sometimes its upper part changes into a soil-like stratum, either directly overlain by loess or plainly covered by another till.

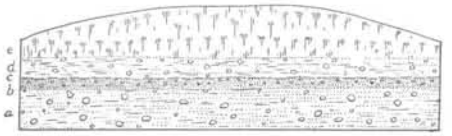


Fig. 6. Section of the drift in the southeast bank of the Muscatine North and South railroad in the Ne. ¼ of Ne. ¼ of Sec. 10, Tp. 75 N., R. III W. *a* Kansan bowlder clay; *b* gravelly sand; (Aftonian); *c* trace of leached horizon; *d* silty bowlder clay (Illinoian); *e* loess.

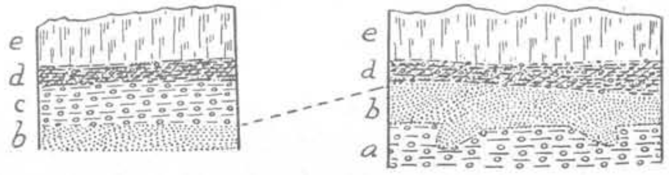


Fig. 7. Relations of different drift sheets as seen in the exposures in the banks of the Muscatine North and South railroad along Indian creek in the Ne. ¼ of Ne. ¼ of Sec. 4, and Nw. ¼ of Nw. ¼ of Sec. 3, Tp. 74 N., R. III W. I Sec. 4, II Sec. 3. a Kansan till; *b* Buchanan sand;? *c* Illinoian drift; *d* Sangamon soil; *e* loess.

A soil evidently occupying the same position in the drift series but not associated with any sandy deposits is seen in a ravine near the south line of the Sw. ¼ of the Sw. ¼ of Sec. 32, Tp. 73 N., R. III W., and again in the wagon road near the top of the east bluff of Honey creek, near the northwest corner of section 33. There rests on this soil a pebbly, sandy, leached till several feet deep. The Kansan till which continues downward from this soil is deeply leached. The soil at these places has the same relation to the tills above and below as the Yarmouth soil, studied by Mr. Leverett in the county to the south, has in the latter locality.

THE ILLINOIAN.

The till above the gravel and soil just described has been shown by Mr. Leverett to belong to another extensive sheet and to have been laid down at a time considerably later than the Kansan drift, after the latter had been extensively eroded and leached.* He has shown that it is the result of an ice invasion from the northeast and that it pushed westward over this county to within about six miles of Washington county. Along the outer edge of the ice field a terminal moraine accumulated which appears as an interrupted broad belt of high upland, already described, extending from north to south through range IV. It is well marked in Secs. 3 and 4, Tp. 75 N., R. IV W. South of this point there is a broad interruption caused by the lowlands along the Iowa river. South of Columbus Junction it appears again somewhat indistinctly in the eastern part of Columbus City township. South of Long creek it rises to a greater height, in places as much as fifty feet above the general upland level. It is here a double belt, one flat ridge lying on the east and another on the west of an intervening sag. Its general trend is a little east of south and it crosses the south boundary of the county almost three miles west of Morning Sun. In Secs. 3 and 4, Tp. 73 N., R. IV W., the westernmost branch of Otter creek cuts across the east ridge and thus drains the sag between the two parallel ridges of the moraine. It is evident that the upper course of this branch has been fixed by these two ridges. At the time the ice had withdrawn to the inner moraine this sag drained away from the ice field through two wide and well marked valleys that cross the outer moraine. One of these is an extension of the main course of Otter

*Monograph U. S. Geol. Surv. XXXVIII.

creek and extends west from the bend of the latter, following the south line of Secs. 5 and 6, Tp. 73 N., R. IV W. The other crosses the same ridge in the north half of Secs. 20 and 21, two miles farther south and is now occupied by a small tributary to Crooked creek. Both of these transverse valleys in the moraine are much too large to have been made by the present streams, but they are readily accounted for as incident to the marginal drainage on the Illinoian ice field. The cluster of low knolls on the uplands in the vicinity of Grandview were no doubt also made by the Illinoian ice. Its area is characterized by a similar topography in Illinois as noted by Leverett.

In its best development along the terminal moraine the Illinoian drift is of a yellowish or grayish color and of slightly less compact texture than the Kansan. It is probably more than fifty feet thick. Inside of the moraine, where it is thinner, it is usually more sandy. In places it is apparently absent or represented by a stratum of sand. Along old drainage lines this till is sometimes associated with a fine, calcareous, laminated silt which contains striated pebbles. Such a silt is exposed in the bank of Muscatine North and South railroad in Sec. 2, Tp. 75 N., R. III W., where it has at times slid down over the road bed. It is evidently a marginal glacial wash. As to the rocks represented by the pebbles of the Illinoian drift, the most notable difference between them and those of the two other drifts is that the former contains a greater proportion of magnesian limestone and a smaller proportion of calcareous limestone and of crytalline rocks. Both of these features are in accordance with Leverett's conclusion that the Illinoian drift came from the northeast, for the principal country rock in northern Illinois and southeastern Wisconsin consists of dolomitic limestone.

While the Illinoian ice field was building up the terminal moraine which traverses this county from north to south, the Mississippi river was forced to take a course west of the margin of the ice. It then occupied the broad, shallow valley already described in discussing the topography. The significance of this valley was first made clear by Mr. Leverett, who has traced its course as it is marked on the map of the surface deposits. It should, perhaps, be noted as a singular fact that within this county no deposits of river sand or stream silt have been observed in this ancient channel on top of the Kansan drift.

THE SANGAMON.

The upper surface of the Illinoian till is usually leached to a depth of several feet and is either a ferretto zone or a leached gray soil, occasionally overlain by a peaty material. This soil phase is particularly conspicuous in Sangamon county, Illinois, where it has been studied by Leverett, and from which locality it takes its name. The red and oxidized condition of the Illinoian surface is most frequently seen where the old Illinoian land surface lies on well drained slopes. It is common in the country east of Morning Sun and also along the lower course of Long creek. Between the two ridges of the double Illinoian moraine west and northwest of Morning Sun there is almost always a dark soil at the base of the loess in the ravines forming the headwaters of the west branch of Otter creek. The uplands east of the Iowa river usually have a soil intervening between the loess and the uppermost till. This is particularly conspicuous on the lowest part of this upland and where its general slope to the west is least, as in the basin of Indian creek and in the country north and south of Grandview. In the Sw. ¼ of the Sw. ¼ of Sec. 11, Tp. 75 N., R. III W., it is black and peaty and deeper than usual. This peaty phase becomes most pronounced in the east bluffs along the Iowa river northeast of Wapello. Along the wagon road leading up to the old townsite of Harrison, near the center of Sec. 23, Tp. 74 N., R. III W., the peat is quite pure and rests on a leached soil with dark curving cylinders extending down from the bottom of the peat and resembling filled animals' burrows. At a place locally known as the "Hog Back," just east of the Muscatine North and South railroad bridge, in the Nw. ¼ of the Nw. ¼ of Sec. 15, Tp. 74 N., R. III W., this peat is in part replaced by a thick tangle of decayed gymnospermous wood (Fig. 2 d). At the present time the peat is not well exposed here owing to its having been burnt out during a dry season some years ago, causing a landslide in the face of the bluff. The peat is associated with small pockets of a pink colored diatom-bearing earth, and among the vegetable rubbish there were seen some small pine seeds and a fragment of the elytra of a beetle. In the judgment of the writer it is in this same Sangamon soil that the remains of elephants have been found at two other points in the county. A tooth was once taken out in digging a shallow well in a small tributary to Indian creek in Sec. 28, Tp. 75 N., R. III W. Some years ago there were dug out from the bed of Otter creek, near the center of the Nw. ¼ of Sec. 25, Tp. 73 N., R. IV W., a tooth, lower jaw, part of the pelvis, several ribs, and a large piece of a tusk of an elephant. At the locality where these bones occurred the bank of the creek consists of materials resembling the soil of the Sangamon horizon. It should be mentioned also that Mr. Geo. Gresham reports the finding of a deer's antler in the same soil layer in the Nw. ¼ of Sec. 14, Tp. 74 N., R. III W.

The old Sangamon land surface frequently runs down with the slope in the ravines. This is nearly always the case where these slopes are gentle and give no evidence of recent cutting. As we find it now it evidently represents a time when the Illinoian till had already become deeply leached and extensively dissected by the present drainage. These conditions correspond with those which doubtless prevailed at the time of the advent of the Iowan ice field, for the Illinoian drift had then long been subjected to erosion and presented a well dissected plain. The southern border of this ice was only some forty or fifty miles off to the north, for it reached as far south as Scott county. At that time, or just before it, this region was covered with gymnospermous trees and a boreal climate no doubt prevailed.

THE LOESS.

Subsequently the Sangamon land surface was covered over by a yellow dust-like, sometimes sandy, deposit known as loess. This is the common upland "clay," which is really no clay at all, being composed of uniformly much coarser particles than those making up the bulk of true clay. Nor does it have the laminated and stratified structure seen in water deposited clays. On the contrary, the loess has a marked vertical structure with an irregular horizontal bedding, if any. Its real origin is yet in doubt, but there seems to be good reason to believe that it is a deposit of terrestrial dust.

In this county the loess is heaviest over the western upland, averaging nearly twenty feet along the bluffs of the Mississippi river. From these bluffs there is a general thinning westward. South of Elrick Junction there are places where it is fifteen feet thick. Along the west bluffs of the Iowa river it is occasionally as much as fifteen feet, but averages somewhat less. From a mile west of this bluff over the west upland it rarely attains this thickness and appears to average less than eight feet. In the territory of the Kansan drift it usually extends down over the gentle north slopes to the small streams with a somewhat attenuated fringe. In all recently cut steep slopes it comes out over a more horizontal surface, and its edge is plainly bevelled with the rest of the bluff. Frequently there is a perceptible thickening of the loess along the edge of the bluffs adjoining larger valleys. This is most common where the bluffs face to the west. Sometimes this feature is pronounced and the edge of the upland consists of a bordering ridge which may be composed of fine sand. Such is the "Hog Back" north of Wapello, and some sandy ridges along the same bluffs to the northwest. Shallow ponds may lie back of these ridges, which are evidently blown up by the wind. Otherwise the loess never appears to have modified the drainage. Only a few very shallow and small undrained depressions are noticeable along some of the high divides.

The loess, or at least a deposit exactly like it in texture, also covers extensively the lowlands of the Iowa and the Cedar rivers, excepting of course the present flood plain. On these lowlands its thickness is, however, much less than on the uplands, usually only three or four feet.

A singular structural feature was noticed in the loess where the wagon road leads down the bluff in the Ne. ¼ of Sec. 1, Tp. 74 N., R. III W. It here rests on a ferruginous sand and is only some twelve feet thick. Near the base the loess is cut up by some scarcely visible joints into irregular spheroidal blocks of uniform size, which become apparent on digging into the bank. Going up from the base of the deposit the blocks deminish in size from nearly an inch in diameter at the base to less than the size of a pea four feet higher up. On close inspection it was found that these joints are partly filled with some bright sand grains. From the relation of the different sizes of the blocks to different levels in the deposit it can be inferred that this peculiar brecciation, as it may be called, is not due to any very recent or superficial cause.

The author has collected loess fossils from only two localities in the county. From the bottom of a well twelve feet deep at Grandview the following shells were taken in loess of blotched yellow and gray color:

Succinea avara Say.
S. grosvenorii Lea.
Linnaea caperata Say.
L. humilia Say.

Grandview lies on the main divide between the Mississippi and the Iowa.

Another lot was collected in the bank of the wagon road near the centre of the west line of Sec. 13, Tp. 75 N., R. V

W., about a mile north of Columbus Junction. The loess at this place is about twelve feet thick and has a faint yellow band half way up from the base. As explained before, the bluff here occupies the line of what at some earlier time was a divide. The fossils occur in the lower part of the loess, which here has an ashen gray color. The species collected were as follows:

Polygyra multilineata (Say) Pils.
Pyramidula strigosa iowensis Pils.
P. perspectiva (Say) Pils.
P. striatella (Auth) Pils.
Zonitoides arboreus (Say) St.
Z. shimeki (Pils) P. & J.
Conulus fulvus (Draph) Mull.
Vallonia gracilicosta Reink.
Sphyradium edentulum alticola (Ingers) P.
Bifidaria pentodon (Say) St.
Helicina occulta Say.
Succinea avara Say.
S. obliqua Say.
S. grosvenorii Lea.
Limnæa humilis Say.*

Terrace and Alluvium. The greater part of the higher low lands along the Iowa and the Cedar rivers lie from thirty to forty feet above the flood plains. This higher lowland, usually known as the "second bottom," is an ancient terrace which probably was built up, in part at least, at the time of the Iowan ice invasion. It consists of sand and some gravel with a thin veneer of loess. In many places the surface materials have been drifted by the wind into sandy ridges. The depth of the terrace sand is not certainly known, except at some points along the river. Around Wapello and north of Columbus Junction it is seen to rest on the Albertan till

*The identifications in this list, as well as in the previous one, were made by Professor B. Shimek.

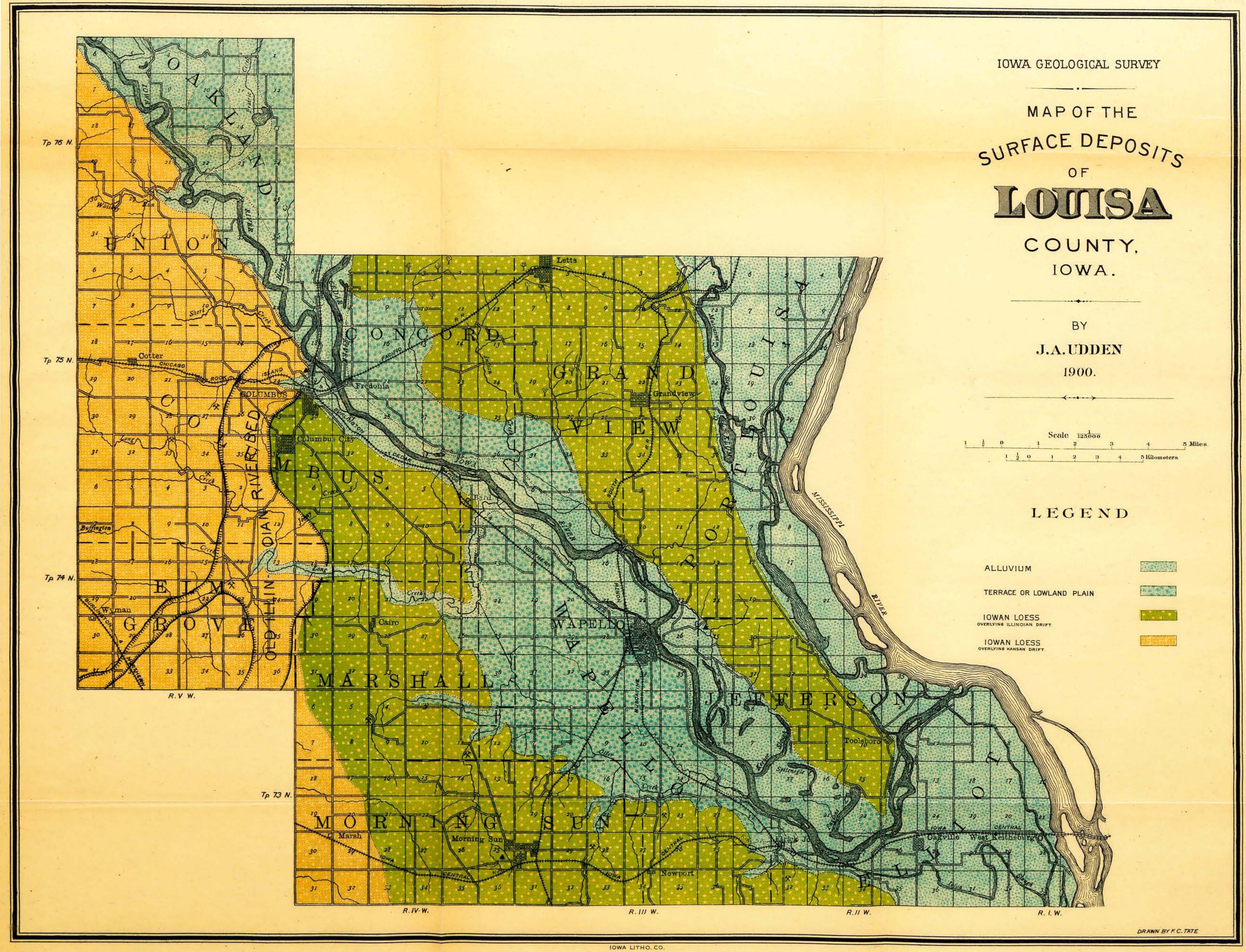
and is some thirty or thirty-five feet deep. This same terrace is continued up the valley of Long creek as far as to Sec. 13, Tp. 75 N., R, V W. It is also present along the lower courses of some of the other tributaries coming from the uplands. Along Long creek the terrace sand is sometimes overlain by a few feet of a fine, laminated, grayish blue silt, above which there is the usual loess capping. Along Otter creek in Secs. 1 and 2, Tp. 73, R. IV W., this loess capping with a soil layer on top has been covered over by a few feet of more recent alluvium.

On the bottoms of the Mississippi river a similar terrace extends south from Muscatine county in Secs. 4 and 9, Tp. 75 N., R. II W. This is probably a remnant of an extensive terrace built up over these lowlands by the drainage of the Wisconsin ice.

The most recent deposits are represented by the alluvium from the present streams now laid down over their flood plains during high water. This consists in the main of dark sandy silt and gray sand. The most extensive alluvial tracts are along the Mississippi river, where only a few vestiges remain of the earlier terraces.

Geological Structure.

The only structural feature which can be made out with certainty in this area is a slight general dip to the south. West of Columbus Junction the English river gritstone lies at a level of about twenty feet above that which it has in the bluffs north and northeast of Morning Sun. The distance between these two localities is about a dozen miles. The dip is therefore one or two feet per mile. This probably accurately represents the attitude of the formations in the southern part of the county. In the city of Burlington the English river gritstone is still forty feet above the river level. In the northern part of the county the dip should be considerably greater than this in order to make room for the 200 feet of the Kinderhook shales. In Muscatine county,



IOWA LITHO. CO.

which abuts on the north, the dip is much greater. It may hence be inferred that the northern part of Louisa county marks a line of change in dip to the south—the line of a slight synclinal flexure, as it were.

Joints.

In the course of the survey of this region some observations were made with a three-inch hand compass on the direction of joints in the country rock. Usually several sets of joints are to be seen and the direction of two or three of the most prominent ones are noted. The recorded directions are given in a table below and plotted in Fig. 8. It will be noticed that these trend in nearly all directions. This is no doubt due to the fact already noted that there is no apprecia-

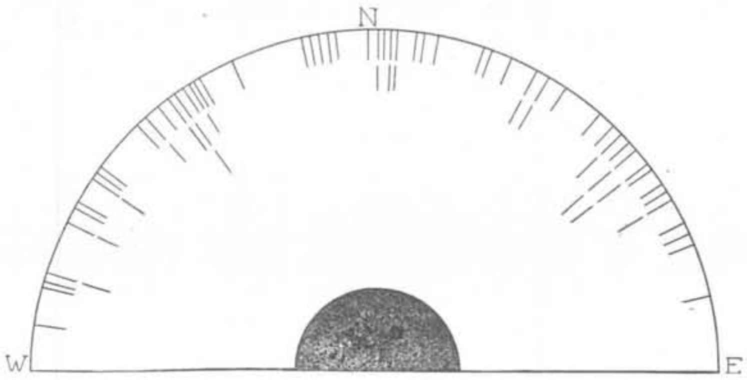


Fig 8. Diagram showing trend of joint planes in the bed rock.

ble dip to the strata in the southern part of the county, where most of these joints were observed. It may probably also be the result, to some extent, of insignificant local fractures caused by the settling of the cavernous Burlington limestone. There is, however, a slight clustering of the joints in three chief directions, namely: approximately N. 35° W., N. 52° E., and N.-S. The joints approximating to the northeast and northwest directions were no doubt produced in connection with the general southwest tilting of the surrounding region and the other main set may have been formed during a tilting to the south. The data seem too few and uncertain for further discussion.

TABLE SHOWING BEARINGS OF JOINTS IN THE COUNTRY ROCK IN LOUISA COUNTY.

In the Kinderhook Beds.

Tp. 73 N., R 2 W.	N. 25° W.	N. 84° W.	....	....	....
Tp. 73 N., R 3 W.	N. 28° E.	N. 57° W.	....	....	....
Tp. 74 N., R 4 W..	N. 48° E.	N 54° W.	N. 73° W.	....	....
Tp. 75 N, R 5 W..	N. 57° E.	N. 12° W.	N. 7° E	N. 3° E.	....
Tp. 76 N., R 5 W.	....	N. 55° W.	....	....	....

In the Burlington Limestone.

Tp 73 N., R 2 W.	N 53° E.	N. 60° E	N. 53° W.	N. 34° W.	....
Tp. 73 N, R. 2 W.	N. 68° F.	N. 22° E.	N. 61° W.	N. 54° E.	....
Tp 73 N., R. 2 W	N 87° F.	N 13° W.	N 75° W.	....	....
Tp 73 N, R 3 W	N 41° E.	N. 10° E.	N. 31° W.	....	....
Tp. 73 N., R. 3 W.	N 58° E.	N 68° W.	N. 50° E.	N. 68° W.	....
Tp 73 N, R. 3 W	N. 50° E.	N. 11° W.	N. 10° W.	....	....
Tp 73 N., R 3 W	N. 18° E.	N. 42° W.	N. 60° W.	N. 10° W.	....
Tp 73 N., R. 3 W	N. 2° E.	N. 19° E.	....	....	....
Tp. 73 N, R. 3 W.	N. 3° E.	N. 5[illegible]° W.	N 66° E.	....	....
Tp. 73 N. R 3 W.	N 30° E.	N. 42° W.	N.-S.	....	....
Tp. 73 N., R. 4 W	N. 46° E.	N.-S.	N. 9° W.	....	....
Tp. 74 N., R. 5 W	N. 53° E.	N 44° W.	N. 36° W.	....	....
Tp 74 N, R 5 W.	N. 64° E.	N. 34° E.	N. 2° E.	N. 46° E.	N 36° W.
Tp 74 N., R. 5 W.	N. 28° F.	N. 50° E.	N. 36° W.	N. 6° E.	N. 30° E.
Tp. 74 N., R. 5 W.	N. 54° E.	N. 87° W.	....	....	....
Tp. 75 N., R. 5 W	N. 66° E.	N. 33° W.	....	....	....
Tp. 75 N., R. 5 W	N. 39° W.	N. 37° W.	N. 82° W.	N. 2° W	....
Tp. 75 N., R 5 W	N 53° E.	N. 64° W	N. 82° W.	N. 1° E	

Minerals.

Large crystals of calcite are frequently found in the Burlington limestone. Calcite in the form of stalactite is occasionally seen in caverns in the same rock. Pyrites occurs in concretions and small crystals in the Kinderhook shales and sandstone and in the Burlington limestone. On the surface of the Kinderhook beds incrustations of epsomite sometimes accumulate. A black sphalerite occasionally fills little irregular hollows in the quarry ledges of the Burlington limestone. In larger caverns in the same rock small deposits of wad have been noticed and in its upper shaly ledges there are geodes lined inside with quartz crystals or with amorphous chalcedony. A bowlder of native copper was found by Mr. John F. Marshall in a ravine a mile east of Cairo some years ago. It weighed thirty-five pounds and was about the size of a brick.

ECONOMIC PRODUCTS.

Building Stones.

The Burlington limestone is quarried in a great number of places along its line of outcrop south and west of the Iowa river. Dalzell's old quarry, now abandoned, near the center of the north line of Sec. 17, Tp. 73 N., R. III W., and about two miles north of Morning Sun, is in the ledges of the Lower Burlington. The same ledges have also been quarried on John D. Anderson's property just south of Elrick Junction on Sec. 27, Tp. 75 N., R. V W. This rock is usually too much weathered to furnish durable building material. On Anderson's property the Upper Burlington is now quarried and good rock is obtained. Nearly all of the small quarries throughout the county are in the same beds. The largest output is from the quarries east of Morning Sun, on Honey creek, where Mr. Wm. Turner is now (1899) taking out rock on land belonging to Mr. Charles Wilson. About 2,000 perch are annually quarried and bring an average price of seventy-five cents a perch. The local market is supplied and some of the product is shipped to Mediapolis, Weyland, Olds, Winfield and other neighboring towns. Most of the rock is of excellent quality. It is used for foundations and for bridge piers. Some has been dressed at the quarry as finishing stone and has brought thirty-one cents a square foot. The total thickness of the ledges which are used is about eight feet, and the different beds vary from four to eighteen inches. The quarry gives employment to from four to eight men. Some of the rubbish has been sold to the city of Morning Sun, crushed, and used in macadamizing the streets. The quarry next in importance is worked by Mr. J. H. Wasson in the south bank of Long creek near the northwest corner of

Sec. 23, Tp. 74 N., R. III W. The ledges are the same as those in the Morning Sun quarries, and the rock is of about the same quality. An extensive drift covered country lies to the west of this place and there is a large local market, which for many years has been supplied from this point, as may be seen from the many old quarry pits. Three men are usually employed, and the price of the rock varies from 58 cents to $1.25 a perch according to quality.

A tabulated statement of the quarry industry in this county is given below.

STONE QUARRIES IN LOUISA COUNTY.

OPERATOR.	LOCATION.	Number of men employed	Average price per perch.	Number of perches of rock quarried in a season.
Wm Turner.........	Sec 27, Tp 73 N , R III, W.......	6	$ .75	2,000
J. H. Wasson........	Sec 23, Tp 74 N., R V, W........	3	1.00	900
J Gray	Sec. 3, Tp. 74 N., R. V, W.........	2	1.00	550
F. J. Moore	Sec. 33, Tp. 75 N , R V, W.........	2	......	300
W. C Bryant........	Sec. 22, Tp 73 N., R III, W......	3	.80	400
....	Sec 4, Tp. 73 N , R. IV, W........	4	.80	500
John D Anderson...	Sec. 31, Tp 73 N., R II, W.........	2	......	300
J. H. Springston.....	Sec. 36, Tp. 73 N , R. III, W........	1	......	....

Very litte sandstone is found in this region and none has been quarried except in the old Dalzell quarry near the center of the north line of Sec. 17, in Tp. 73 N., R. III W. Here some sandstone is found as an outlier in an old cavern in the Subcarboniferous limestone. Some of the rock is still left but explorations with the drill have shown that it is of limited extent. More of it is seen near the forks of Long creek in Sec. 13, Tp. 74 N., R. V W., but this has not yet been utilized. The rock is massive, almost without bedding, and very difficult to quarry. It would without doubt prove a durable and strong stone for foundations.

Clay Industries.

The clay industry in Louisa county is carried on by three firms which are engaged in making brick and tile, one in Columbus Junction, one in Morning Sun, and one near Wapello. These employ about twenty men and their total product is 1,050,000 common brick and about 500,000 tile.

McClurkin, Ockletree & Company own and operate a brickyard located in the Sw. ¼ of the Se. ¼ of Sec. 25, Tp. 73 N., R. 4 W., just outside the city limits of Morning Sun. The average annual product is 300,000 common brick and 200,000 3-inch tile. The principal market is in Morning Sun, but some brick is also sold in Wapello and Oakville. The bricks bring $6.50 per 1,000, and the 3-inch tile is sold for $10 per 1,000. Some larger tile is also made. Six men are employed. The bricks are made by a Mackenzie machine, run by steam power. The burning is done mostly in two down-draft kilns. Some of the hardest brick have been used for sidewalks. Most of the clay is an upland loess, thoroughly weathered and free from lime. In making the largest tile this clay is mixed with a leached bowlder clay, quite free from pebbles. The latter is found close by on a branch of Otter creek, and seems to be from an outcrop of an ancient drift under the Kansan bowlder clay.

At Columbus Junction the only brick factory now running is Oaks Brothers' brick and tile works in the north part of the city. This factory uses the Acme brick and tile machine with a capacity of about 25,000 brick per day. Steam power is used. The brick is dried under cover and burnt in open covered kilns. The tile is burnt in a down-draft kiln. Eleven men are employed and the average product for a season is 600,000 brick and 150,000 tile. The brick is sold at $6.50 per 1,000 and the 3-inch tile at $10.00 per 1,000. Most of the tile is sold at home. The brick is red, fine in texture, hard, and makes a good building brick. About one-half of the output is shipped to the surrounding towns, Nickols, Letts, Lone Tree, Wapello, Cotter and Washington and the rest supplies the home market. The clay used in this factory is a loess, from eight to twelve feet in thickness, which covers a low terrace-like extension of the upland lying between the Iowa river and Clifton creek. The lower part of this loess has a grayish blue color and is slightly calcareous. This portion of the deposit burns to a lighter shade and the bricks made from it have a specially fine texture.

A mile and a half east of Wapello, near the northwest corner of Sec. 25, Tp. 74 N., R. III W., Mr. O. M. Zerber has been operating a brick yard for the last five years. He manufacturers about 150,000 brick each season, supplying the home market in Wapello and the surrounding country. The average price of the products has been $6.00 per 1,000. The brick is made from the surface material of the loess on the upland adjoining the Iowa river bottom. The clay pit covers an acre and is only two feet deep. The surface mould, which is six inches in thickness, is not used. The brick is hand made, sun dried, and burnt in open kilns. A summary of the clay industries in the county is given in tabular form below:

CLAY WORKS IN LOUISA COUNTY.

NAME OF FIRM	No. of men employed.	Price of brick per 1,000.	Price of tile (3-inch).	Quantity of brick made in one season	Quantity of tile made in one season.
Oaks Bros., Columbus Junction	11	$6.50	$10.00	600,000	150,000
McClurkin, Ockletree & Co., Morning Sun	6	6.50	10.00	300,000	200,000
O. M. Zerber, Wapello	3	6.00	....	150,000	....

Coal.

Though there is no doubt that the Coal Measures at one time covered the county, it is equally certain that all of the workable coal occurring in these strata has been removed with them. Nevertheless two attempts have been made at coal mining, both of them in the small outliers of the black

Coal Measure shale already described. If any larger outliers of this formation remain under the drift they are more apt to be found along the west boundary of the county, where the bed rock is least affected by preglacial erosion. Some well drillers have supposed that coal might be found in the lower dark Kinderhook shale which has been explored by some of the deeper wells in the southern part of the county. It is well known that this supposition has no foundation whatever, since these shales are barren elsewhere. Money expended in prospecting for coal in this county can bring no return.

Natural Gas.

Twelve years ago natural gas was discovered in Louisa county. It occurs in quantities large enough to be utilized. The gas appears to come from the fine sand or silt that lies under the Kansan till. The overlying bowlder clay evidently serves as an impervious capping under which the gas collects as it is distilled from the bituminous material in the pre-Kansan drift. It has been shown that there is an old soil horizon at this level. This in all likelihood is the chief source of the gas, though the lowest till itself contains bituminous material. Possibly some of this bituminous matter was originally derived from the Sweetland Creek shale, which has doubtless been worked into the lower till in considerable quantity. Gas has been found in more than a score of wells in larger or smaller quantity and it is quite likely that it might have been found in many more places if properly searched for. It occurs in the upper part of the fine sand already referred to and may sometimes be overlooked as the tubing is sunk in a new well. This may reach and enter the sheet water which usually is present in the same sand farther down. If the tubing be raised gas may escape. There have been several instances of this kind in the experience of the well drillers of the region. It has also happened that a well which has just reached the gas-bearing sand has at first given no indications of gas but after having been left standing over night it has begun to blow gas.

In such cases the pressure was evidently too small at first to overcome the weight of the water in the casing. When this water is left to settle into the dry sand its head is lowered until its pressure is balanced and overcome by the gas pressure. There should then be a more or less sudden outburst of the gas and such instances are actually on record. A whole family was in one case awakened in the middle of the night by a loud roar from a new well which at the close of the previous day showed no sign of gas. Some of the well drillers fully understand this principle and have of late been successful in sinking gas wells where others have failed. To stop the tubing at the right level requires good judgment and experience. Sometimes it has proved profitable to test for gas in this way at different levels in the same well. Even a few feet may make a difference between failure and success.

The oldest productive well was sunk eleven years ago and is yet giving a good supply. Three or four wells have ceased furnishing gas after having been productive for some time. One of these is said to have become clogged. It seems probable that in the other instances the supply was really exhausted. Most of the wells are less than three years old. In a few cases the supply has been unsteady and apparently changes with the weather, as if affected by barometric pressure. At times one or two wells have furnished a wave like flow, the gas coming in puffs at intervals of a few minutes. The supply is not always proportionate to the pressure. When escape is shut off the pressure may rise comparatively high in wells where the yield is otherwise small.

To make any predictions as to the life of the wells in this region would perhaps be unsafe. The history of other small fields of drift gas will probably be repeated here. Some new wells will now and then be found, while many of the old wells will cease to yield. The gas is evidently held in many small and irregular reservoirs under the till which probably correspond with upward bends of the silty and sandy stratum in which it is held. It is not likely that all of these reservoirs have yet been tapped. A few of them may have been emptied in the case of wells which have ceased to flow. Possibly the gas is still slowly being formed and this may help to lengthen the life of some of the wells. In any case the first supply must represent an accumulated quantity which when once withdrawn never quite returns as long as there is escape.

The pressure of the gas has been measured in fifteen different wells and was found to vary from four to ten and one-half pounds. These measurements were made with a small steam guage adapted for low pressure. In general the highest pressure is found in the deepest wells and these are mostly located on the highest ground. Possibly the head of the ground water is the principal factor which determines pressure. Apparently the gas can escape naturally only against the head of this water.

The principal uses of the gas have been for lighting, cooking, and heating. In a few cases it has been used for fuel in small steam engines. It is piped into the farm houses by means of small iron tubing. Regulators are used to make the pressure more steady. Where the gas is plentiful the farmers cook the feed for their hogs and this has proved to be of considerable advantage in pork production.

At one time there was considerable talk of exploring for gas in the older rocks underlying the drift at Letts. While there is not the least reason to believe that gas will be found by deep borings here, the undertaking would very likely result in procuring a good water supply for this village and would therefore be a commendable enterprise.

Below I give in tabulated form such data as were secured during the survey concerning the gas in this region up to the month of November, 1899.

TABLE OF DATA ON GAS WELLS NEAR LETTS.

OWNER'S NAME.	LOCATION.	USES.			Elevation in feet.	Pressure in pounds	Depth in feet.	AGE. (NOV. 1899.)	
		Engines.	Stoves.	Light.				Years.	Months.
Joseph Wagner	Nw. ¼, Sec. 6, Tp. 75 N., R. III W.	...	3	4	700	9	122	1	...
Mrs. Amelia Hadley	Se. ¼, Sec. 36, Tp. 76 N., R. IV W. (Muscatine county)	1	3	5	735	10	126	2	...
I. Idle	Nw. ¼, Sec. 1, Tp. 75 N., R. IV W.	...	...	...	710	6	114	...	6*
B. B. Lintner	Nw. ¼, of Nw. ¼, Sec. 2, Tp. 75 N., R. IV W.	...	2	4	718	$10\frac{1}{2}$	115	1	...
H. H. Westbrook	S. ½, Sec. 36, Tp. 76 N., R. IV W. (Muscatine county)	...	2	4	723	Unsteady	117	1	...
Wm. Griffin	Se. ¼, Sec. 35, Tp. 76 N., R. IV W. (Muscatine county	...	2	4	700	$6\frac{1}{4}$	120	...	...
John Idle	Sw. ¼, Sec. 35, Tp. 76 N., R. IV W. (Muscatine county)	...	2	5	690	6	98	...	...
R. W. Lee	Ne. ¼, Sec. 3, Tp. 75, N., R. IV W.	...	...	...	680	$9\frac{1}{2}$	103	...	2
Charles Estel	Nw. ¼, Sec. 3, Tp. 75 N., R. IV W.	...	4	5	680	4	86	...	8
R. M. Lee	Sw. ¼, Sec. 3, Tp. 75 N., R. IV W.	1	8	10	690	4	113	11	...
Etta Littrell	Ne. ¼, Sec. 10, Tp. 75 N., R. IV W.	...	3	3	728	7	100	...	2
Robert Wilson	Ne. ¼, Sec. 10, Tp. 75 N., R. IV W.	...	...	...	710	?	90	...	Recent.
Fay Letts	Se. ¼, Sec. 19, Tp. 75 N., R. III W.	..	2	3	665	4	80	...	1
Noah Letts	Ne. ¼, Sec. 20, Tp. 75 N., R. III W.	1	...	...	675	4	94	4	...
Two wells in Letts	Letts	...	2	5	685	5	100	1	...
C. Vincent	Se. ¼, Sec. 6, Tp. 75 N., R. III W.	...	2	2	685	7	106	2	...
Wm. Wagner	Sw. ¼, Sec. 6, Tp. 75 N., R. III W.	...	3	4	700	7	110	3	...

*Well made in 1892, and gas was observed then, but was shut off until 1899.

Gravel and Sand.

Glacial sand and gravel are infrequent in this region where they lie deeply buried near the base of the drift. Some sand deposits of apparently limited extent have been exposed in the cuts along the Muscatine North & South railroad, as in a curve in the Nw. ¼ of Sec. 14, Tp. 75 N., R. III W., and in Sec. 2 in the same township and range, but these have not been utilized to any extent. Plastering sand is taken from the banks of the principal rivers and creeks and is frequently hauled many miles.

Soils.

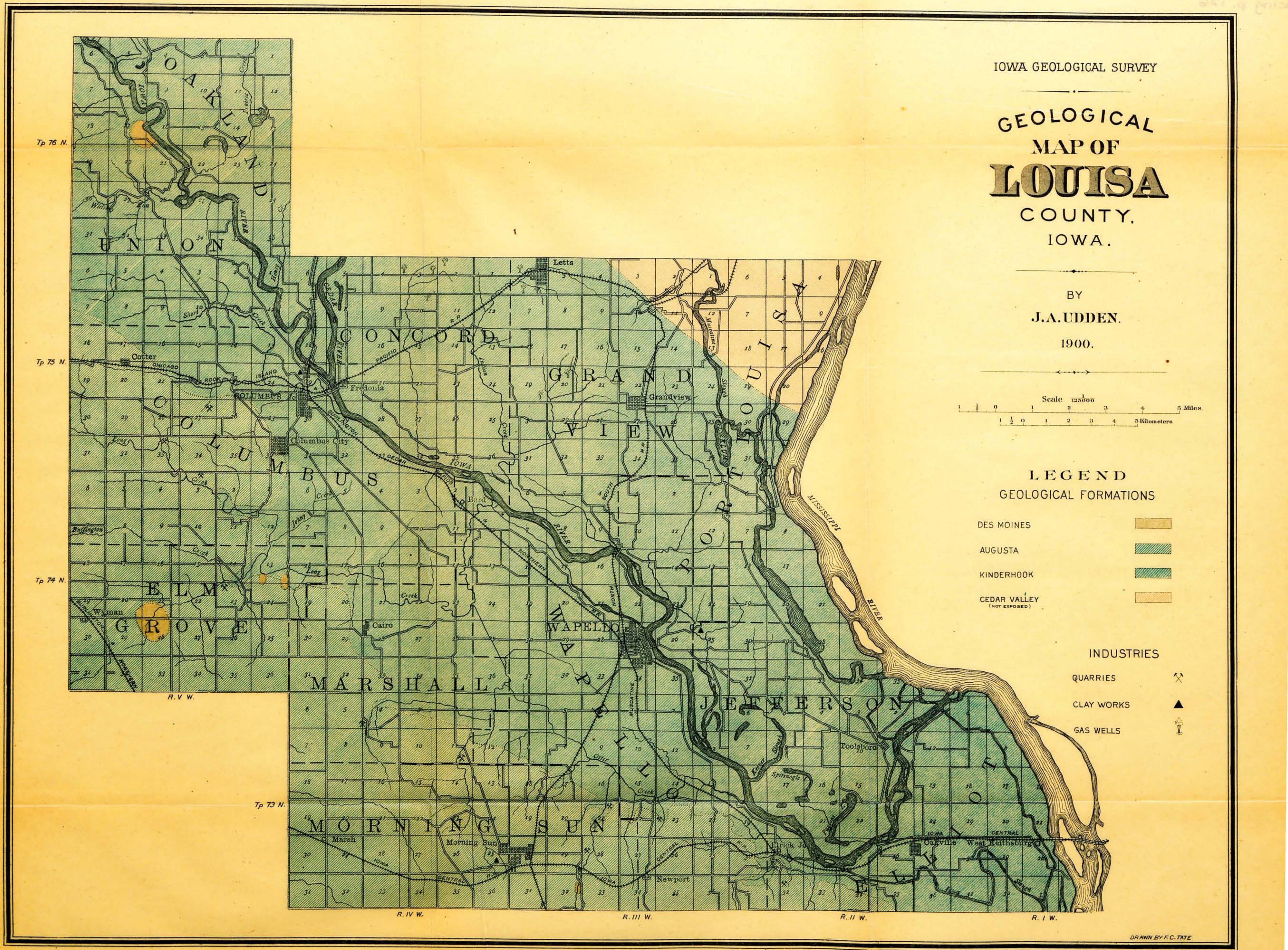
The soil on the loess-covered uplands has an open, loose texture of the kind usually found in this part of the state. It is an excellent corn soil. A large part of the Iowa river lowlands has a thin veneer of the same material and the soil in some places does not differ much from that on the upland farms, though there are apt to be frequent sandy patches. As a rule the soil is somewhat sandy on these lowlands, and, in places, it is almost all sand. Some of these sandy lands are used for melon crops in Oakland township and in the vicicity of Wapello they are used for other vegetables. In the northern part of Louisa county the Mississippi bottoms are quite sandy, and, in places, gravelly, and a considerable part of the ground is used for growing watermelons.

Water Supply.

This county has no artesian wells. Should it p rove desirable, a copious flow may be found anywhere on the lowlands at a depth of from 1,200 to 1,400 feet. On the uplands where the drift is deep, water is usually obtained in drift gravel at depths varying from seventy to three hundred feet. The supply in the shallow wells, which go down to the bottom of the loess only, is now frequently unreliable, except on flat lands which are not well drained. Along the outcrop of the Subcarboniferous west of the Iowa river there are many copious springs in the ravines. In almost every case these springs come from the transition beds between the upper Burlington and the Kinderhook shales. On the lowlands water is everywhere plentiful in the sand which underlies the surface silt and driven wells are universal. The city of Wapello uses a system of such wells placed at regular intervals along the streets for fire protection. A steam pump can be attached to them as to so many hydrants.

Acknowledgments.

The author has received most valuable aid in his studies in this county from the following gentlemen: Dr. Samuel Calvin, State Geologist, Dr. H. F. Bain, Assistant State Geologist, M. Frank Leverett, Dr. C. R. Eastman, Prof. C. M. Clarke, Prof. B. Shimek, Prof. P. F. Meyers, Mr. Wm. Wagner, of Letts, Mr. J. A. Nelson, of Muscatine, and Mr. W. H. Davisson, of Davenport.



IOWA LITHO. CO.

GEOLOGY OF MARION COUNTY.

BY

B. L. MILLER.

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INTRODUCTION.

LOCATION AND AREA.

Marion county lies slightly east of a north and south line drawn through the center of the state, and is in the third tier of counties from the southern boundary. It corners with Polk county on the northwest, is bounded by Jasper on the north, Mahaska on the east, Monroe and Lucas on the south, and Warren on the west. It is regular in outline, being a square each side of which measures twenty-four miles. It includes sixteen congressional townships with an area of 516 square miles.

PREVIOUS GEOLOGICAL WORK.

The navigation of the Des Moines river in the early history of the state led geologists to study the formations outcropping along that stream. In 1849 Dr. D. D. Owen conducted a geological survey of the Des Moines river and adjacent territory for the U. S. Treasury Department.* He described several exposures of the Coal Measure rocks at various points in the county, noting particularly those which show to such good

*Geol. Surv., Wis., Iowa and Minn., pp. 115-119, with plates. Philadelphia, 1852.

advantage at Elk Bluff and Red Rock. In 1856 A. H. Worthen, at that time an assistant on the Iowa Geological Survey and later State Geologist of Illinois, made a more detailed study of the Des Moines valley.† He included in his report several sections at different places along the river. The next geologist to publish anything concerning the geology of Marion county was Dr. C. A. White, who, in his report of 1870, briefly described the coals of the county and gave some analyses of the same.‡

In the course of the work carried on by the present geological survey, the county has been visited at various times by several of the geologists connected with it. Among these was Dr. C. R. Keyes, who, in his report on the coal deposits of Iowa, describes these deposits in Marion county§. Until the publication of this report only that part of the district lying along the Des Moines river had been studied, but in it the entire county is considered in reference to its coal mines.

PHYSIOGRAPHY.

TOPOGRAPHY.

Marion county may be considered as a broad, rolling plateau into which the Des Moines and South Skunk rivers, with their tributaries, have cut their valleys. This plateau gradually rises to the southwest, as is indicated by a difference of over thirty feet between Pella and Knoxville. Beyond the latter place the rise continues, though it has not been accurately measured. The Des Moines and Skunk rivers, which are approximately parallel to each other, cut across the northern part of the county, flowing in a southeasterly direction, while their tributaries join them at a slightly acute angle. The main tributaries run parallel to each other and in a northeasterly direction. Thus, there are two systems of divides, the main divide between the two rivers running northwest

†Geology of Iowa, Hall, vol. I, pt. I, pp. 167-170, Albany, 1858.
‡Geology of Iowa, White vol. II, pp. 263-264, 364-365. Des Moines, 1870.
§Iowa Geol. Surv., vol. II, pp 317-340. Des Moines, 1894.

and southeast, and those between the tributaries running southwest and northeast. These divides rise to almost the same altitude in every part of the county, about 900 feet, and are very similar in appearance. They are followed entirely across the county by diagonal roads which encounter few hills. The uplands display no prominent topographic features but everywhere present gentle rolling surfaces with just enough slope to secure good drainage. The well improved farms occupying the uplands present a most pleasing appearance and are good evidence of the fertility of the soil. In the northern part of the county the plateau-like character is better preserved than in the southern, on account of the smaller number of streams.

The present surface features of Marion county are due almost entirely to stream erosion, most of which is post-glacial. The whole county having been covered with Kansan drift and loess, the erosion topography is essentially different from that of a driftless area. Steep hills and bluffs are seldom found except in immediate proximity to the streams.

In the eastern part of the county the underlying rocks are mainly limestones, while in the middle and western portion they are shales, with occasional beds of sandstone. In the limestone and shale regions the streams have eroded valleys to about the same extent, the flood-plains of the larger streams being well developed and the slopes gentle, especially on the northern side of eastward flowing streams. Where the streams have cut through sandstone, the valleys are much narrower and the sides steeper; this results from the cementing material of the sandstone being almost insoluble in river water. Where the Des Moines river cuts through the Red Rock sandstone the valley is narrower than in any other part of its course in Marion county; it is less than a quarter of a mile wide, while usually it is from half a mile to two miles in width. The rocks which have been cut through by the streams in eroding their valleys are so homogeneous in character that the slopes of the hills are the same from top to bottom. In no place can terraces, due to the alternation of harder and softer layers of rock, be traced for more than a few rods and seldom are they present at all. Thus, the entire region presents a smooth, rolling, featureless surface, although considerably rougher than some of the prairie counties of the state.

All of the five principal streams of the county have developed flood plains throughout nearly their entire courses. Of these Cedar and English creeks have narrow flood plains in comparison with South Skunk and Des Moines rivers and White Breast creek. As is true of all the rivers in this part of the state, where the streams have an easterly direction, they flow near the south side of the valleys, thus permitting the development of flood plains on the north side with very gentle slopes connecting them with the uplands. On the south the bluffs are much steeper. In places the stream may not flow near this side of the valley, but even in such instances the south bluff is much steeper than the north one.

Two explanations have been offered to account for these features. The first is that they are due to the deflection of streams to the right banks, caused by the rotation of the earth. G. K. Gilbert, in a paper* read before the National Academy of Sciences in 1884, shows that "all streams in the northern hemisphere are by terrestrial rotation pressed against their right banks and all in the southern are pressed against their left banks, the degree of pressure being independent of the direction of the flow." He considers this force to be sufficient for the deflection of the water to the right bank of the stream, and consequently the formation of cliffs on that side, with gentle slopes on the left. Deflections of this kind are certainly partly accountable for the steep bluffs on the right of the streams of this district, but not primarily, since, if this were the only cause, the steepest bluffs would be found on the right side of those streams flowing nearly straight north or south. On the contrary, it is found that the most

*Memoirs of the Nat. Acad. Sciences, vol. III, First Memoir, Washington, 1884 noticeable differences in the steepness of the bluffs on the two sides occur where the streams flow southeast.

The second explanation accounts for this phenomenon by the different rates of decomposition of the rocks on the two sides of the streams. Where all the rock strata yield to weathering influences with equal readiness, the more rapid the decomposition the more gentle will be the slopes. In this state frost is one of the greatest destructive agents of rocks. With each successive freezing the cohesion of the particles is overcome and they are forced farther apart. On those slopes facing northward the rocks remain frozen during the entire winter, while on the opposite side there may be many alternate thawings and freezings during the same space of time. Thus, in the spring, far more material is found ready to be removed by erosion on the north side of the streams than on the south. This latter cause is the most effective in this region. Were the streams very swift the former might be more effective. Where the streams flow southeast, as in the case of all the larger ones of this part of the state, we have the combined action of the two causes and there is the greatest variation in the steepness of the bluffs on the two sides.

Table of Elevations.

LOCALITY.	Elevation above sea level.	Authority.
Bussey	876.2	C. B. & Q.
Cedar creek bridge at crossing C., B. & Q., north of Bussey.	704.7	C, B. & Q.
Cedar creek, bed of stream at crossing C., B. & Q., north of Bussey	673.2	C. B. & Q.
Cordova	745.5	Wabash.
Donley	759.6	C. B & Q.
Dunreath	747	Wabash.
Dunham	744.7	C. B. & Q.
English creek bridge at crossing C. B. & Q., about one mile east of Flagler	728 8	C. B. & Q.
English creek, bed of stream at crossing C., B. & Q., about one mile east of Flagler	704.7	C. B. & Q.
Fifield	732 3	·Wabash.
Flagler	745 5	C. B. & Q.
Hamilton	905 5	C B. & Q.
Harvey	718	C., R. I. & P.
Howell	724.5	Wabash.
Knoxville	910	C., R. I. & P.
Knoxville	911.7	C. B. & Q.
Lovilla (Monroe county)	932.3	C B. & Q.
Marysville, at bridge	760.5	Survey.
Monroe (Jasper county)	924	C., R I. & P.
Morgan Valley	759 5	Wabash.
Otley	893	C., R I. & P.
Pella	878	C., R I. & P.
Percy	759	Wabash
Pleasantville	925.7	C. B. & Q.
South river bridge at crossing C., B. & Q. west of Swan, (Warren county)	763.24	C. B. & B.
South river, bed of stream at crossing west of Swan, (Warren county)	735.7	C. B. & Q.
Summit of divide, north of Pleasantville	936 7	C. B. & Q.
Swan	761.7	C, B & Q.
Tracy	716.7	C. B. & Q.
Walnut creek bridge at crossing C., B. & Q., south of Tracy.	703.7	C. B. & Q.
Walnut creek, bed of stream at crossing C, B. & Q., south of Tracy	680.7	C. B. & Q.
White Breast creek bridge, crossing C., B. & Q., northwest of Knoxville	761.7	C. B. & Q.
White Breast creek, bed of stream at crossing C., B. & Q., northwest of Knoxville	723.7	C. B. & Q.

DRAINAGE.

Marion county is drained by the Des Moines and South Skunk rivers and their tributaries. The South Skunk river flows across the northeastern corner and drains an area of about forty square miles. The remainder of the county is drained by the Des Moines river, which enters the northwestern corner and flows southeast, leaving the county along the eastern border a little south of the center. The two rivers flow approximately parallel to each other. They are marked by broad ox-bow loops and wind about considerably in their flood plains, showing that they have cut nearly to grade and have ceased to erode their channels. The South Skunk river has a length within the county, measured with the stream, of somewhat more than eight miles, while a straight line from where it enters to where it leaves is only five miles in length. In the same manner the Des Moines river flows thirty-four miles within the county, while it is only twenty-four miles from the point it enters to where it leaves. This river has frequently changed its course over the flood plain, leaving cut-offs, and at present is much straighter than it was a few years ago.

The drainage systems are completely developed and hence there are no lakes on the uplands. The only bodies of standing water are on the flood plains, and these are usually the remnants of former cut-offs.

The glacial material of the Kansan ice sheet was apparently spread quite evenly over the surface, leaving no depressions of any considerable size, into which the surface water might be drained to form lakes. Neither are there any terminal moraines which serve as dams to interfere with the drainage. No evidence has been found indicating the former existence of such lakes. Yet it is probable that at the close of the glacial period the surface water was not drained off as quickly as it is at the present time, since the valleys of nearly all the tributaries of the main streams are post-glacial in their origin.

The three chief tributaries of the Des Moines river, White Breast, English and Cedar creeks, all have northeasterly courses. They rise in adjoining counties lying to the west and south, and flow within the county approximately parallel to each other. Besides these, the lower course of South river lies within Swan township, emptying into the Des Moines river less than a mile from the western border. This latter river drains directly only a very limited region, but through Coal creek a considerable area is drained in Franklin and Pleasant Grove townships. Besides the streams just mentioned the Des Moines river receives several small tributaries, such as Sugar, Ballard and Teter creeks from the south and Walnut, Prairie, Calhoun and Brush creeks from the north.

The only tributary of any importance emptying into the South Skunk river is Thunder creek, which has its source on the Pella divide.

Knoxville is located on the divide between White Breast and English creeks. These streams are from two to six miles apart, with an average distance of about four miles. Because of the narrowness of the divide there are no large tributaries flowing from it into either stream.

History of the Drainage.—There is evidence to show that the Des Moines and Skunk rivers, through part of their courses in the county, if not the entire distance, flow in preglacial valleys. The best evidence of this is the fact that the loess and drift cover the sides of the valley in the same manner that they do the uplands. If the streams were post-glacial, these sheets would have been cut through as the valley deepened. The same evidence would show that the streams had about reached their base-level before the ice age, as there has been no appreciable deepening of either valley since. Further, it indicates that there have been no elevations or depressions or general warping of the earth's crust in this region within comparatively recent times. Another evidence of the preglacial origin of these two river valleys is found in their width and in the character of the limiting bluffs. Along these bluffs there are few outcrops of rock and the slopes are very gentle. This is probably due to the great amount of weathering which has taken place, together with the smoothing of the rougher rock contours by the later filling in of drift and loess.

All of the other streams of the county seem to be post-glacial, unless perhaps it be the lower part of White Breast creek, but there is no conclusive evidence of this. However, the streams do not all seem to be of the same age. White Breast and English creeks flow about the same distance through similar material and carry about equal amounts of water. Notwithstanding these points of similarity, White Breast creek throughout the greater part of its course has a well developed flood plain, a feature which is almost altogether lacking along English creek. The former stream also has a meandering course, and in several places has formed cut-offs, most of which are of small size. Thus it would seem that White Breast creek is much older than English. It has the best developed flood plain of any of the secondary streams. Cedar creek, in the southeastern part of the county, is the only other stream that has one worthy of mention. The two principal rivers of the county do not now carry as much water as they did a few decades ago, when it was possible for small steamboats to pass up the larger stream as far as Des Moines. This is now out of the question, since at places there are bars extending entirely across the river where the water is only a few inches in depth, except during times of high water. This decrease in the size of the streams is due not so much to the decrease in the amount of rainfall as to the cultivation of their drainage basins, thus causing a larger amount of the water which falls upon the land to penetrate the soil instead of being drained off the surface.

It is the popular opinion that in former geological times those streams which now have flood plains were so much larger than at present that they filled their valleys from bluff to bluff. Because of the prevalence of this idea it seems best to offer a few words in refutation. When the ice melted, the streams were probably very much swollen in size and may perhaps have entirely filled their valleys, but this was only temporary, the conditions not lasting long enough to accomplish much in valley erosion. Instead of this the valleys have reached their great width by the process of lateral corrosion, meandering from side to side after having ceased to cut at the bottom. The result seems to have been accomplished in part, also, by tributary streams and the weathering agents wearing back the bluff lines.

The amount of fall of the Skunk and Des Moines rivers has been determined by Mr. Dwight Porter, whose results were published in the Tenth Census Report on Water Power of the United States.* The following tables are taken from his report:

ELEVATION AND SLOPES OF THE SOUTH SKUNK AND DES MOINES RIVERS.

LOCALITY.	Elevation above sea—Feet.	Fall between points—Feet	Distance be-tw'n points.—Miles.	Fall between points—Feet per mile.
South Skunk River—				
Vowell's, Jasper county	759	....	....	....
Rome, Henry county	550	209	108	1.94
Des Moines River—				
Des Moines, Polk county	786	150	111	1.35
Ottumwa, Wapello county	636	....	....	....

ESTIMATED VOLUME AND HORSE POWER OF THE SKUNK AND DES MOINES RIVERS.

LOCALITY.	DRAINAGE AREA—SQUARE MILES.	LOW WATER ORDINARY DRY YEAR.		LOW WATER AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume cubic feet per second.	Theoretical horse power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse power, 10 feet head.	Volume cubic feet per second.	Theoretical horse power, 10 feet head.
Skunk River—							
Vowell's (Jasper Co)	1,275	80	91	100	114	150	170
Farmersville (Mahaska Co.)	1,654	100	114	130	148	200	227
Des Moines River							
Bennington.	11,822	900	1,022	1,050	1,193	1,580	1,795
Ottumwa (Wapello Co)	13,465	1,040	1,181	1,210	1,375	1,820	2,068

*Tenth Census of the United States Water Power, pt. II., pp. 381-389

Since the towns of Vowell's and Farmersvills are no longer given on the maps it is necessary to locate them. Vowell's was on the South Skunk river in Tp. 79 N., R. 20 W., Nw. ¼ of Sec. 11, while Farmersville was in Tp. 76 N., R. 16 W., Ne. ¼ of Sec. 23.

From the above table it seems that the two main streams might well be made to yield considerable power if suitable dams were erected.

STRATIGRAPHY.

Geological Formations.

The surface geological formations represented in the county are very widely separated in age, since they belong to the Carboniferous and Pleistocene systems. The absence of rocks of intervening periods indicates either that the region has been land from the close of the Carboniferous to the present time; or else, if under water since, the deposits have been removed by erosion. If the latter supposition were true, it is highly probable that there would be occasional fragments of the rocks of intervening periods, as the strata are seldom removed entirely by erosion over any considerable area. But no such evidence has, as yet, been reported.

The Carboniferous has been divided into the Lower and Upper, or the Subcarboniferous and the Coal Measures. The upper part of the Lower Carboniferous, known as the Saint Louis, and the lower part of the Coal Measures, known as the Des Moines, are the sole representatives of the system in Marion county. The Pleistocene deposits consist of the Kansan drift, the loess, which was probably contemporaneous in origin with the Iowan ice sheet, and the more recent alluvium of the river valleys.

Unconformability between the formations of the different epochs is plainly indicated in various places. The Coal Measures lie unconformably upon the Saint Louis, and the loess is in turn unconformable with the drift. Furthermore, within the Des Moines formation there are several local unconformabilities. One of the most interesting occurs in Red Rock bluff, shown in the geological section along the Des Moines river. Here a bed of coal and shale occupies a depression cut in the massive sandstone.

The Saint Louis strata appear at the surface only in the eastern part of the county and there only along the streams. The Des Moines and South Skunk rivers, with a few of their tributaries, such as Cedar, English and Thunder creeks, by the erosion of their valleys, have exposed these beds to view. Westward they dip under the Coal Measures, but their presence has been determined by deep drilling. The surface of the Saint Louis formation is quite irregular, there being numerous anticlines and synclines, most of them, however, of very limited extent. These are plainly seen at several places along the Des Moines river. That the bending preceded the deposition of the Coal Measure rocks is shown by the unconformability existing between the two formations. Pella is situated upon the crest of one of the largest of these anticlines, since the Pella beds rise very close to the surface and have an elevation of slightly less than 900 feet, while the same strata are found along the Skunk and Des Moines rivers at an altitude of 100 feet less.

The taxonomic relations of the strata of the county are shown in the following synoptical table:

GROUP.	SYSTEM.	SERIES	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.	Iowan.	Loess.
			Kansan.	Drift.
Paleozoic.	Carboniferous.	Upper Carboniferous or Pennsylvian.	Des Moines.	Red Rock Sandstone.
		Lower Carboniferous or Mississippian.	Saint Louis.	

Underlying Formations—Rocks older than the Carboniferous are not exposed within the county but were encountered in sinking a deep well at Pella. The detailed record of this well is published in the report on the artesian wells of the state* but the following summary of Professor Norton's study of it may be of interest here.

SUMMARY OF THE DEEP WELL AT PELLA.†

Nos.	Formation.	Thickness—feet.	Depth—feet.	A. T—feet.
59–62	Pleistocene	135	135	733
53–58	Des Moines	195	330	538
42–52	Mississippian	270	600	268
40–41	Kinderhook	125	725	143
32–39	Devonian	165	890	– 22
18–31	Silurian	255	1,145	–277
16–17	Maquoketa	190	1,335	–467
4–15	Trenton	350	1,685	–817
3	St. Peter	15	1,700	–832
1–2	Oneota (penetrated)	60	1,760	–892

Carboniferous System

SAINT LOUIS.

The strata of this period consist so largely of limestones that the formation is frequently known as the Saint Louis limestone. These are the oldest surface rocks found within the county. Besides limestone, they consist of marl, sandstone and shale.

The following section from Tp. 75 N., R. 18 W., Ne. ¼ of Se. ¼ of Sec. 35, gives a fairly good idea of the lithology of the formation. All below the first three members belong to the Saint Louis, the upper two being Pleistocene, while the third belongs to the Coal Measures. The upper members are exposed in a quarry, while the lower ones have been reached by drilling.

*Iowa Geol. Surv., vol. VI, pp. 310-315.

†It is suggested by Mr. Bain that the local stratigraphy favors the reference of Nos. 56-58 to the Pleistocene. It is possible that the Coal Measure material of the sample belongs to a till usually rich in such fragments. The glacial materials of the samples, which we have taken to have fallen in from above, may belong to till at the horizons stated.

		Feet.	Inches.
15.	Loess	2	
14.	Drift	2	
13.	Black carbonaceous shale	3	6
12.	Fossiliferous marl	8	
11.	Limestone	1	4
10.	Limestone, thin bedded	5	
9.	Thick ledge of limestone	1	7
8.	Compact limestone	1	5
7.	Flagging stone, fine grained		4
6.	White limestone	1	
5.	Shale, carbonaceous, black, friable		1
4.	"Soapstone," drab		7
3.	Limestone, hard, cherty	1	
2.	Shale	5	
1.	Sandstone	20	

Nos. 6 to 12, inclusive, have been called the Pella beds while 1 to 5 are known as the Verdi.

Since other sections of the Pella beds are given under the head of stone quarries it does not seem advisable to give more here. The following are characteristic sections of the Verdi beds in the northeastern part of the county.

Tp. 77 N., R. XVIII W., Se. ¼ OF Sw. ¼ SEC. 24.

		Feet.
4.	Sandstone, buff, cross-bedded, lower part very soft	5
3.	Limestone, massive, cherty, breaks irregularly, has been quarried for foundation purposes.	4
2.	Sandstone, gray, soft	3
1.	Limestone, cherty (exposed)	2

The above section is exposed in the bluff of Thunder creek. The bluff is here much higher than indicated above, but the lower portions are concealed by talus.

Tp. 77 N., R. XVIII W., Se. ¼ OF Ne. ¼ SEC. 26.

		Feet.
4.	Drift and loess at edge of bluff (thicker farther back)	3
3.	Limestone, cherty	2
2.	Shale, argillaceous, buff	5

1. Sandstone massive, yellow, with arenaceous interbedded limestone bands one-half inch to four inches in thickness. These bands are very hard, compact, fine grained, and resist weathering to greater extent than sandstone so that layers stand out from sandstone on weathered surface. Occasional irregular fragments of this limestone 1 to 2 inches in diameter are found in the sandstone (exposed)	20	

This section occurs on the south bank of Thunder creek, rising from the water's edge.

Tp. 77 N., R. XVIII W., Ne. ¼ OF SEC. 23.

	FEET.	INCHES
5. Loess and drift, gradually thickening back in hill	10	
4. Sandstone thinly laminated, quartzitic	1	
3 Shale, bluish gray, argillaceous		6–8
2 Limestone, hard, cherty	2	4
1. Sandstone, soft, variable in color, yellow, buff	6	

Exposed on south side of Skunk river at bridge.

The Saint Louis limestone is of fairly good quality and consequently is used very extensively for building purposes throughout the region in which it is found. The individual ledges vary little in thickness, and, because of the regularity of the fissures, can be quarried to good advantage. The stone is usually very white in appearance and fine grained. Some of it when first exposed to the air is blue, but soon turns white. The limestone is comparatively free from impurities and was formerly used for the production of lime. Most of the rock is very fossiliferous, the principal fossils being brachiopods.

The marl is highly calcareous, effervescing freely when treated with acid. Several layers of this marl are found intercalated between the limestone ledges in the upper part of the formation, sometimes forming the upper member as in the section given. On an unweathered surface the marl is very compact so that in quarrying it is removed in large blocks which, when exposed to the atmosphere, soon fall to pieces. The weathered marl resembles the clay resulting from the decomposition of drab argillaceous shale. The marl is highly argillaceous and possesses little or no grit. This deposit is the most fruitful source of fossils of all the Saint Louis beds. Scarcely a cubic inch can be found that does not contain one or more fossils, most of which are in an excellent state of preservation. Many different species occur, including brachiopods, corals, crinoids, pentremites, etc. On the weathered surface of a heap of this material thrown out from a quarry near Pella, hundreds of fossils were picked up in a very short time. Thus far no use has been made of the marl, but it seems not improbable that it may prove valuable as one of the ingredients in the manufacture of cement.

The shale of the Saint Louis is principally argillaceous and is commonly called "soapstone." It is gray, drab, or blue in color and is very soft. Occasionally the cleavage planes are not well developed, so that it appears not unlike mere beds of clay. The shale is found principally in the lower part of the Pella beds or in the upper part of the Verdi.

There is within this county usually a thin layer of black, friable, carbonaceous shale, found immediately under one of the thick layers of limestone of the Pella beds. This shale varies in thickness from one to four inches. It is the nearest representative of coal thus far found within the lower carboniferous of the state, and its presense seems quite unusual. It is prominently exposed in four different places in the county near the Des Moines river.

The sandstones of the Saint Louis differ markedly from the sandstones of the Coal Measures in that they are always intercalated with thin layers of limestone or sandstone possessing a calcareous cement. All the layers are massed together, appearing as a single massive ledge. Frequently these intercalated layers of limestone are somewhat cherty in appearance, so that on a weathered surface they stand out prominently. The limestone layers are usually from one to three inches in thickness, and are found from six to twelve inches apart. Occasionally they attain a thickness of from one to three feet, but even then there is no marked bedding plane between the limestone and the sandstone. In a few places the sandstone of the Saint Louis, together with the intercalated limestone ledges, has been quarried for foundation purposes. Its characters, however, are such as to make it quite undesirable because of the irregularity with which it breaks. In these respects it is quite unlike the indurated rocks of the Pella beds.

While no attempt was made to secure a complete list of the fossils found in the Saint Louis of the county, the following were frequently observed. Most of them occur in the marl of the Pella beds, previously noted.

Allorisma marionensis, White.
Spirifer keokuk, Hall. (*S. litttori*, Swallow).
Rhynchonella (pugnax) ottumwa, White.
Athyris (seminula) subquadrata, Hall.
Productus marginicinctus, Prout.
Terebratula (dielasma) turgida, Hall.
Orthis keokuk, Hall.
Zaphrentis pellaensis, Worthen.
Pentremites koninekana, Hall.
Trilobite, (fragments undetermined.)
Chaetetes, sp. undescribed.
Crinoid stems.
Bryozoa, (specimens not identified.)

DES MOINES.

The Coal Measures form the surface rocks of the entire county, except where they have been removed in the eastern part in the valleys of the streams. On the uplands they are concealed by the drift and loess but every large stream cuts down into them. The Coal Measures generally have a slight dip to the southwest and gradually increase in thickness as one proceeds from the northeastern to the southwestern part of the county.

The rocks of the Coal Measures consist of shale, coal, sandstone, limestone and conglomerate. The maximum thickness is probably about 600 feet. These beds have been deposited upon the eroded surface of the Saint Louis and are consequently everywhere unconformable with them. At one place a short distance south of Pella, a block of Saint Louis limestone was found included in the Coal Measure shales. Beds of coal frequently occur at a lower level than the Saint Louis limestone at neighboring outcrops. In these respects the Coal Measures of Iowa agree with those of Kansas. At the close of the Lower Carboniforous the rocks just formed were uplifted to form land, and a period of active erosion prevailed. Strange to say the Pella beds, consisting largely of marl which is so easily worn away, were in some places left at the surface. The base of the Coal Measures frequently rests upon this marl. At other points it has been worn away and they rest immediately upon the lower limestone layers of the Pella beds, while in one place along the South Skunk river the latter are entirely wanting, so that the Coal Measures are found immediately overlying the Verdi beds. These facts seem to indicate a considerable period of erosion between the deposition of the Lower Carboniferous and the Des Moines rocks. In this county the maximum erosion was about thirty feet; in an adjoining county it was very much greater.

The rocks of the Coal Measures vary rapidly in longitudinal as well as in vertical extent, thus making it exceedingly difficult to definitely correlate the different horizons. Very few strata can be traced more than two or three miles. Sandstones gradually pass into arenaceous shale, from that into bituminous shale, and then into coal. When changes such as these occur, if the intermediate steps cannot be seen, it becomes exceedingly difficult to make general sections with any degree of accuracy. Wells sunk in the Coal Measures, sometimes only a few rods apart, pass through quite different materials. At times this is due to contemporaneous erosion, which will be discussed later in connection with the Red Rock sandstone, but more frequently is due to the different kinds of deposits formed contemporaneously in adjoining regions.

The following sections taken from various parts of the county are characteristic of the Coal Measures.

ENGLISH CREEK, Tp., 75 N., R. 19 W., Sw. ¼ OF Ne. ¼ OF SEC. 2.

		FEET	INCHES
10.	Loess	1	
9.	Drift	3	
8.	Shale, gray, argillaceous	2	
7	Sandstone massive, yellow, and buff	10	
6.	Shale, arenaceous, light yellow	2	1
5.	Shale, black, containing large concretions	18	
4.	Limestone, extremely hard, black, containing iron pyrites	1	6
3.	Shale, arenaceous	10	6
2.	Limestone, hard, black, called hydraulic rock	1	6
1.	Shale, black to water's edge (exposed)	13	

This section is near the base of the Coal Measures, the Saint Louis appearing a very short distance down the stream. Presumably the black shale rests upon the upper member of the Saint Louis.

CEDAR CREEK Tp. 74 N. R., XVIII W., Sw. ¼ OF Se. ¼ OF SEC. 2.

		FEET.
6.	Shale, white, argillaceous	8
5.	Sandstone, yellowish brown, variable hardness, formerly quarried	8
4.	Shale, yellow	*
3.	Shale, bituminous	*
2.	Shale, arenaceous, gray, at times sandstone proper; numerous plant fossils	*
1.	Sandstone, in bed of creek, extremely hard, brown, containing some $Ca\,CO_3$, exposed	2

WHITE BREAST CREEK Tp. 75 N., R. XX W., Se. ¼ OF Se. ¼ OF SEC. 19.

		FEET.	INCHES.
10.	Clay, yellow, derived from decayed shale	5	
9.	Shale, bituminous	5	
8.	Coal, very soft	1	6
7.	Fireclay, arenaceous, extremely hard, much fractured, filled with lepidodendron roots	2	
6.	Sandstone, gray, thinly laminated, soft	4	
5.	Sandstone, gray, massive, has been quarried	8	

*Numbers 2, 3 and 4 are poorly exposed and thickness could not be determined.

		FEET.	INCHES.
4.	Shale, arenaceous	1	4
3.	Sandstone, gray, soft	2	6
2.	Shale, arenaceous	5	9
1.	Sandstone, massive, buff to gray, displays very irregular cross-bedding, exposed to water's edge	25	

The coal mentioned in the above section has been mined near here for home use. In one mine it is almost two feet in thickness but on account of its poor quality is of little value.

WHITE BREAST CREEK Tp. 74 N., R. XXI W., Ne. ¼ OF Ne. ¼ OF SEC. 4.

		FEET.	INCHES.
11.	Drift and loess	10	
10.	Shale, yellow, argillaceous	5	
9.	Shale, bituminous	3	
8.	Coal, very soft	1	2
7.	Fire clay	2	3
6.	Coal, soft		4
5.	Fire clay	2	6
4.	Sandstone, thinly laminated, white	1	
3.	Sandstone, massive, buff, yellow; is quarried	4	
2.	Shale, gray, arenaceous	3	
1.	Shale, bituminous (exposed)	10	

A third bed of coal which averages about three feet in thickness is said to be reached a short distance below this section.

Over most of the county the Coal Measures are represented by thick beds of shale with intercalated coals. The shales are principally bituminous, although the argillaceous and arenaceous varieties are not infrequent. They are of such a motley character that no general statements can be given which will apply to all of them. In color they vary from white to black with the gray, drab, red and blue well represented. Nearly all the Coal Measure shales seem to have been deposited in small basins and hence have very little lateral extent and vary greatly in thickness. The only positive characters which might distinguish the Coal Measures from the Lower Carboniferous shales are the greater abundance in the former of bituminous matter and of fire clay filled with the roots of the coal plants underlying the beds of coal. Selenite crystals of a diamond shape are frequently found in the argillaceous variety in considerable abundance.

The limestones of the Coal Measures are limited in amount and are usually of very poor quality. They are quite impure owing to the considerable percentage of silica present, but yet at one time lime was burned from a ledge of this rock. This lime was used in building the foundation of the old court house and, notwithstanding the impurities, seems to have been very durable. The limestones are heterogeneous in character and consequently break irregularly. For the same reason the weathered surfaces are very rough. Fossils of marine invertebrates are frequently present, but not in such large quantities as in the Saint Louis limestones. Still, the weathered surface of almost every ledge of this limestone will show some crinoid stems standing out from the matrix. The rock is either white or yellow, except in those cases where it is found in contact with the coal. It then belongs to another class which has been described by Mr. Bain in his report on Polk county.* It is called clay-ironstone, which is merely an impure form of limestone. In one of the mines near Flagler a ledge varying in thickness from eight to twelve inches is found near the upper part of the coal vein. The stone when removed from the mine is of an intense black color and usually very hard. When exposed to the weather the surface becomes whitened until it does not appear unlike ordinary limestone. Besides calcium carbonate and the calcareous material whose presence can be easily detected by the color of the weathered and unweathered stone, analyses show the presence of both iron and sulphur. The following analyses of specimens of this stone from Mahaska county illustrate this:

*Iowa Geol. Surv., vol. VII, p. 297. Des Moines, 1897.

ANALYSIS OF IRONSTONE BOWLDERS FROM COAL SEAM IN MINE OF AMERICAN COAL CO., EVANS, MAHASKA COUNTY, IOWA.

Hygroscopic water (loss at 100 degrees C)	.25
Carbonic acid, CO_2	39.67
Other volatile and combustible matter	7.78
Silica and insoluble	.10
Sulphur (in $Fe\,S_2$)	.64
Iron (in $Fe\,S_2$)	.56
Iron protoxide, $Fe\,O$	.38
Alumina, $Al_2\,O_3$	.34
Manganese oxide, calculated as MnO	.38
Lime, Ca O	49.62
	99.32
Loss and undetermined	.68
	100.00

PROBABLE COMBINATIONS.

Hygroscopic water	.25
Organic matter and combined water	7.78
Pyrite. $Fe\,S_2$	1.20
Calcium carbonate, $Ca\,CO_3$	87.89
Silica and silicates of alumina	2.88
Carbonates and oxides of Fe.Mn., etc	....
	100.00

ANALYSIS OF ROCK FROM TOP OF ROOM, COREY'S MINE, ROSE HILL, MAHASKA COUNTY.

Water expelled at 100°C	.25
Carbonic acid, CO_3	25.10
Silica and insoluble matter	.30
Sulphur (as FeS_2)	18.30
Iron (as FeS_2)	16.00
Sulphuric acid, SO_3	1.27
Sulphur, free or otherwise combined*	1.30
Lime, CaO	32.94
Alumina, Al_2O_3	.54
Organic matter and water expelled by ignition (mostly organic matter) by difference*	4.00
	100.00

APPROXIMATE COMBINATIONS.

Hygroscopic water	.25
Calcium carbonate, $Ca\,Co_3$	57.04
Pyrite, $Fe\,S_2$	34.30

*Uncertainty here. Needs further investigation.

Silicates, sulphates and sulphur in some form ?........	4.41
Organic matter, water and loss by difference	4.00
	100.00

It is very seldom in this region that these impure limestones are found in the form of a continuous stratum; they usually occur as loose bowlders lenticular in shape and of various sizes. The long diameter of the bowlders is always parallel to the planes of stratification. At times these bowlders occur in such large numbers that they seriously interfere with the process of mining and some mines have been abandoned merely because of their presence. They occur in largest numbers in the overlying black shale or in the upper part of the coal bed although occasionally some are found near the base. In a few places bowlders of such large size have been encountered lying within the seam that the coal was almost entirely cut out. At one place a shaft was sunk upon one of these bowlders and no coal at all was struck, but it was found by drifting off to either side.

The conglomerates of the Coal Measures of this county are not well developed, there being only two places where they are prominently exposed. These are in Moose's quarry, a few miles northwest of Knoxville. and Feight's quarry, in the southwestern part of the county, near Newbern. Both of these conglomerates are calcareous. While they are of considerable thickness they seem to have but small lateral extension and to occupy small basins in earlier Coal Measure deposits. Neither one can be traced far, either by exposures or by well records. They do not seem to be contemporaneous and the former is much the older. In the first mentioned outcrop fossils of calamites are abundant, while in the latter fragments of marine organisms are present in large numbers. In Moose's quarry the limestone conglomerate alternates with sandstone. The following section is taken from this locality:

Cross Bedding in Coal Measure Sandstone, Red Rock Quarry.

MOOSE QUARRY SECTION

		FEET.	INCHES.
14.	Sandstone		6
13.	Limestone conglomerate, marked cross bedding	2	6
12.	Sandstone		8
11.	Shale, white, argillaceous		6-24
10.	Limestone conglomerate		22-32
9.	Sandstone, thin bedded		20
8.	Limestone conglomerate, breaks into pieces eight to ten inches in thickness	2	6
7.	Sandstone, hard, coarse, brown	1	
6.	Sandstone, brown, soft	3	6
5.	Sandstone, gray, hard	2	
4.	No exposure	50	
3.	Coal		28
2.	Fire clay	1	
1.	Coal		24

The quarry is located near the top of a hill while the coal outcrops in the ravine at its base. The limestone conglomerate spoken of in the above section is by the quarrymen usually known as "bastard" limestone.

The sandstones of the Coal Measures are very well represented in the northern part of the county and are found in other parts also. They contain considerable iron, and, at times, are very highly colored. They differ from the Verdi sandstones in these respects and also in being more highly micaceous. (See plate V.)

RED ROCK SANDSTONE.

This sandstone, belonging to the Des Moines formation, is in many respects the most interesting deposit of the county. It has been noted and described by every one who has done any geological work in this region. It outcrops along the Des Moines river a short distance below and above the town of Red Rock. Its greatest thickness at these places is slightly over 100 feet. It is interesting because of its great thickness and the very small area over which it is found. On either side, to the east and the west, it ends abruptly and no further traces are found of it in either direction. Owen, who passed up the Des Moines river in 1849, supposed that its disappearance was due to great faults on either side with a vertical displacement of at least 100 feet. It seems, however, on closer study that this disappearance is due, not to faulting, but to contemporaneous erosion. Since this term may not be generally understood I quote from Scott* in explanation of it. Contemporaneous erosion "is produced when a current of water excavates channels for itself in the still soft and submerged mass of sediment. . After the current has ceased to flow renewed deposition fills up the hollow with the same or a different kind of material than was thrown down before. This structure requires only a short pause in deposition, not a long unrecorded break, and does not necessarily involve movements of elevation and depression. Furthermore, contemporaneous erosion is a local phenomenon, and though in a limited section it may not always be easy to distinguish it from an unconformity, the difference becomes apparent when a wider area is examined. If the structure be one of contemporaneous erosion the two series of strata will be conformable except along the line of the channel or channels."

The reason for believing that contemporaneous erosion is the correct explanation rather than faulting is that the sandstone occurs in a region where faults are infrequent and, when present, have a very small vertical displacement. Furthermore, Coal Measure shales are found lying against the sandstone and unconformable with it. Thus it seems that the area now occupied by the Red Rock sandstone was originally a place of great deposition of sand which certainly had a much greater lateral extent than at present, but streams during the Coal Measure period eroded it on either side and left this small isolated mass. It is probable that this mass was once also thicker than at present and was considerably reduced in thickness during the erosion of its borders. During the Coal Measure period the sediments had not yet become so thoroughly consolidated as at the present time so that the removal itself

*Scott, Introduction to Geology, pp. 272-273, Macmillans, 1897.

was much easier. Possibly the erosion took place while it was a mere loose mass of sand.

While detailed study has not been made to connect this area with the massive sandstones along the Des Moines river in Mahaska county, from their position near the base of the Des Moines formation it seems probable that they were at least contemporaneous in origin if not actually connected at one time, the intervening area having been removed by stream erosion. The rock of the two outcrops is quite different in character, but sandstone is so variable that it would be unusual to find the same characters at the two places, especially as regards composition and color, separated as they are by a distance of about fifteen miles.

This sandstone has its greatest extent in a south-west-northeast direction, the southernmost point being Eagle Rock, located directly south of the most eastern outcrop along the river. Northward it was traced by well records to connect with the large sandstone quarries located about four miles northeast of Monroe, in Jasper county. Here it again comes to the surface along the south bluff of the South Skunk river and is extensively quarried.

It is not improbable that it extends even farther northward as there are outcrops of similar stone at Lynnville and Kellogg in Jasper county, though these may belong to an entirely distinct formation. The sandstone has an extent north and south of at least eleven miles with a maximum width of about three miles. But within this area it has been removed in several places. Eagle Rock is an isolated portion separated from the larger area on the north by a small ravine; northward one deep well record was obtained which did not pass through any thick layer of sandstone at all comparable to the Red Rock sandstone, while wells in the immediate neighborhood were sunk into this sandstone a great distance, but failed to penetrate it. The isolation of Eagle Rock illustrates recent stream erosion while the absence of the sandstone in the well is due to erosion during the Coal Measure period.

Eagle Rock is a small hill extending east and west for a distance of about one quarter of a mile with a width slightly less. It forms a part of the north bluff line of White Breast creek, and where it has recently been washed by the waters of this stream it presents a vertical face of fifty-three feet of massive sandstone. The ridge rises fifty feet above this, but the rock is not exposed. No trace of this ledge is found south of the creek but instead, at the same level, thick beds of Coal Measure shale occur. Its former westward extent from Eagle Rock is indicated by the sand ridge occurring between the Des Moines river and Teter creek, the sand of which has undoubtedly been derived from this sandstone which itself has been removed by the latter stream.

The color, composition and hardness of this rock varies considerably in the area described. That of Eagle Rock is gray or buff in color and firmly consolidated throughout the greater part. In places, however, the cementing material seems to have been very insufficient, thus leaving pockets, as it were, of loose sand. In the exposed face of the rock these appear as holes of variable size. Within one of these it is said that an eagle formerly built its nest for several seasons, thus giving the name to the rock.

As it outcrops along the Des Moines river the sandstone resembles that of Eagle Rock in that the sand grains are chiefly quartz with the principal cementing material iron oxide. It also varies in hardness in the same way. Unlike the Eagle Rock sandstone, however, the predominant color is brick red, although large masses are gray or buff in color. The two most notable exposures are Elk Cliff in Tp. 76 N., R. XIX W., Ne. $\frac{1}{4}$ of Ne. $\frac{1}{4}$ of Sec. 7, and Sw. $\frac{1}{4}$ of Sw. $\frac{1}{4}$ of Sec. 5 and the Red Rock stone quarry in Tp. 77 N., R. XX W., Sw. $\frac{1}{4}$ of Ne. $\frac{1}{4}$ of Sec. 35. In the quarry the distribution of the red coloring matter is not in layers but occurs in irregular blotches throughout the mass. In places the color of the stone changes very rapidly so that a deep red may be next to a white mass.

The line of contact is usually a sinuous one although at times nearly straight. The color is due to the presence of iron oxides, since analyses shows that the buff rock carries .94 per cent of these while the red contains 2.65 per cent. The question arises whether the coloring of the stone was contemporaneous with its deposition or not. That it has not been caused by exposure to the atmosphere, thus allowing the oxidation

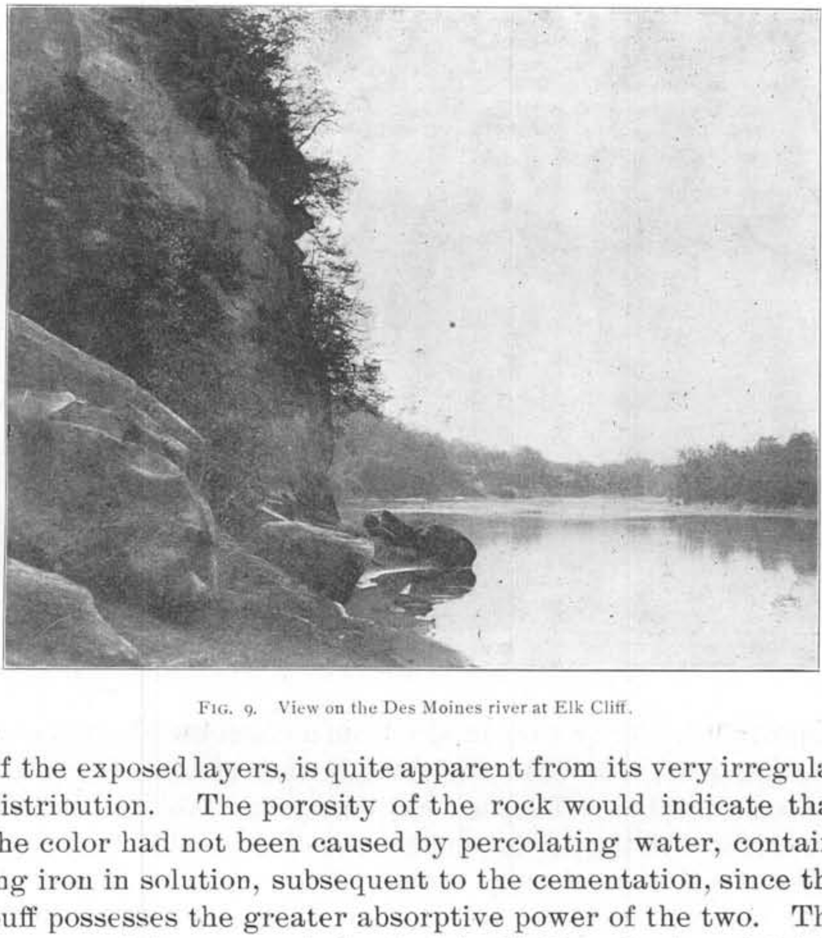


FIG. 9. View on the Des Moines river at Elk Cliff.

of the exposed layers, is quite apparent from its very irregular distribution. The porosity of the rock would indicate that the color had not been caused by percolating water, containing iron in solution, subsequent to the cementation, since the buff possesses the greater absorptive power of the two. The percent of increase of the buff is 10.82 and of red 8.64.* The hardness of the stone seems, in general, to correspond

*Bain. Iowa Geol. Surv., vol. viii, pp. 410-412 to the color, the darker colored stone being harder than the buff. Thus we may say with a considerable degree of certainty that the color is contemporaneous with the cementation process. The irregular distribution is similar to the segregation of nodules of iron pyrites in shale and coal beds, and to the collection of the calcareous matter of the loess in the formation of the loess-kindchen.

In this same quarry large spherical concretions are occasionally found composed of material not unlike quartzite in

FIG. 10. Red Rock Quarry, showing quartzitic concretions in the Red Rock Sandstone at the top.

appearance. They vary in size from a diameter of six inches to three feet. A slight flattening in the vertical direction is quite noticeable. They are extremely hard and so interfere seriously with the sawing of the stone. In color they vary from a white to a gray, never being highly colored. At first thought it might seem that they were deposited as bowlders at the time the enclosing mass of sandstone was formed. But careful observations disprove this, since a very gradual transition from the quartzitic mass to the softer sandstone can be noticed. Microscopic studies show that these masses have been rendered quartzitic through the secondary enlargement of the sand grains by additions of silica.

Northward from the Des Moines river no outcrop of the Red Rock sandstone is found until the quarry near Monroe is reached. Here the stone is of a much more compact nature and the cementing materials, especially at the base, seem to have been much greater in amount. It is also somewhat coarser grained, while the coloring matter is more evenly distributed. The lower layers are very dark red while the upper ones are gray. The sandstone at this point shows a vertical exposure of thirty-five feet.

The Red Rock sandstone is unconformable with the underlying Coal Measures and also with the Saint Louis. Although not the basal member of the Coal Measures this sandstone immediately overlies the Saint Louis a short distance above Elk Cliff. Here the upper members of the Pella beds rise in a low anticline about fifteen feet above the river with a lateral extent of a few rods. Elsewhere shale beds including coal are found between the Saint Louis and the Red Rock sandstone. Keyes* estimates that these shales are at least seventy-five feet in thickness as exposed along the Des Moines river. Where the sandstone is the thickest no well records have been obtained in which this stone has been penetrated to the underlying formations because very few wells, if any, go through it, sufficient water being obtained within the sandstone.

In Missouri a sandstone deposit, nearly 200 feet in thickness, is found in the Coal Measures which is similar to the Red Rock sandstone in occupying only a small area. It is, however, more recent in origin. It is known as the Warrensburg sandstone.†

The lower part of the Coal Measures of Iowa seems to be equivalent to the Cherokee shales of Kansas, described by

* Iowa Geol. Surv., vol. II. p. 146, Des Moines, 1894.

† Winslow: Mo. Geol. Surv., vol. IX, pp. 45-54, Jefferson City, 1896.

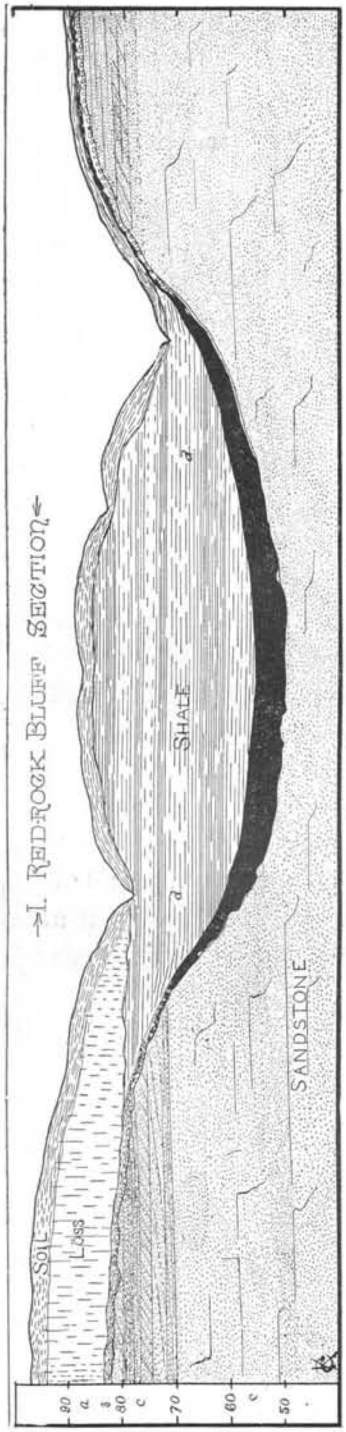


FIG. 11. Unconformability shown in Red Rock quarry.

Haworth.* There are naturally many minor differences, there being no development of sandstone in Kansas comparable to the Red Rock formation. The conglomerate previously spoken of as occuring a short distance north of Knoxville seems to be of later origin than the Red Rock sandstone. It is, perhaps, best correlated with the conglomerate described by Shepherd in his account of the Coal Measures of Greene county, Missouri.† This rock occupies depressions in a basal sandstone known as the Graydon sandstone. These can be compared with each other only in their position and not from any characters possessed by the strata themselves.

In the Red Rock quarry a very good example of local unconformity occurs. This is a small basin formed in the upper part of the sandstone which has been filled by Coal Measure shales and a bed of soft coal. This has been described by Keyes in former reports of the survey‡ and is shown in the section along the Des Moines.

From the different kinds of deposits found within the Coal Measures of this county and their comparatively local extent it would seem that the conditions existing during their formation were un-

* Univ. Geol. Surv. Kansas, vol. I, pp. 150-151, 221-224, Topeka, 1896.

† Mo. Geol. Surv., vol. XII, pp. 123-138. Jefferson City, 1898.

‡ Iowa Geol. Surv., vol. I, pp. 100, 108; vol. II, p. 52.

favorable for any extended deposit. While the Red Rock sandstone was being formed in the northern part of the area, shales of various kinds were being deposited in the southern; it is not unlikely that during the time the coal was being deposited in the basin above the sandstone, thin ledges of sandstone were being formed in other parts of the county. Indeed it is highly probable that other sandstones found within the county owe their origin to the deposition of sand removed by streams from the former extensions of the Red Rock formation. Some of the arenaceous shales may have had a similar origin.

Fossils of the Coal Measures.—The fossils of the strata of this period include the remains of both animals and plants, but more particularly the latter. Fossil plants in great numbers and almost perfectly preserved are found in many places in the shales and sandstones. On White Breast creek, directly north of Knoxville, and on the Des Moines river south of Pella, literally wagon loads of plant remains could be obtained with very little effort. They occur either in arenaceous shales or fire clay. These fossils are the remains of coal plants, lepidodendrons, sigillaria, calamites, and ferns. The fire clay underlying the coal beds is usually well filled with the fossilized roots of the coal plants, while the shales above contain many leaf impressions.

The fossil plants above mentioned occur in layers and so are unlike the ones described by A. C. Spencer* in the fellowing article quoted in its entirety: "The wide celebrity of the fern-bearing concretions from the Carboniferous beds of Mazon creek, Illinois, attaches more than passing interest to the occurrence of similar structures in the Coal Measures of Iowa.

"These concretions are found in a small ravine near the Des Moines river north of Dunreath, in Marion county. Careful search for similar concretions in the gullies of the neighboring streams has not been successful, from which it seems that

*Proc. Ia. Acad. Sci. Vol. 1, pt. IV p 55, Des Moines, 1894.

the strata, which are cut by the streams in question, lie above their general level on a slight anticline. The other alternative is that the concretions are limited to a very small area, but from the relations of the overlying beds the first explanation seems to be correct.

"The plant remains are found in nodules or concretions, scattered through beds of drab shale. These, when broken open, often display very perfect forms. Plant remains are not, however, present in all the concretions. Others are like small septarial masses and are filled with zinc blende.*

"The nodule-bearing shale is from three to perhaps ten feet in thickness, and of a light drab color. It rests upon an irregular layer of large septarial masses, which, exposed in the dry bed of the stream, resemble roches-moutonnees of a small scale. Above are shales, in part bituminous and in part arenaceous. Four inches of compact gray limestone, bearing fern impressions, follow, above which is more sandy shale and a thin seam of coal which has been mined near by. The coal is about fifteen feet above the concretionary bed.

"Many of the concretions have been washed out and are found already opened, but the best specimens are those recently exposed, which afford very perfect leaflets of several ferns. Among the forms identified were *Neuropteris hirsuta*, *N. augustifolia* and *Annularia longifolia*. Others will undoubtedly be found when more material is examined."

The animal remains of the Coal Measure rocks of the county, while not so abundant as the plants, are much more varied. Two localities deserve especial mention: These are Ruckman's coal mine, Tp. 75 N., R. XIX W., Sec. 20, and Feight's stone quarry, Tp. 74 N., R. XXI W., Nw. ¼ of Nw. ¼ of Sec. 28. At the former place, in the roof material of the mine, so plentiful are the fossils, and so perfectly preserved, that not even the Pella beds marl of the Saint Louis surpasses it as a collecting ground.

*Mr. Spencer here seems to have made the error, so common in this region, of mistaking siderite for zinc blende.

The stone in which they occur is an impure limestone, containing so much bituminous matter that it is as black as coal when taken out. On exposure, however, it whitens similar to the clay ironstone previously described. The other place mentioned is of interest because of the presence of an unusually large number of crinoid stems and scutes of the fish known as *Petrodus*. The stone containing them is a massive

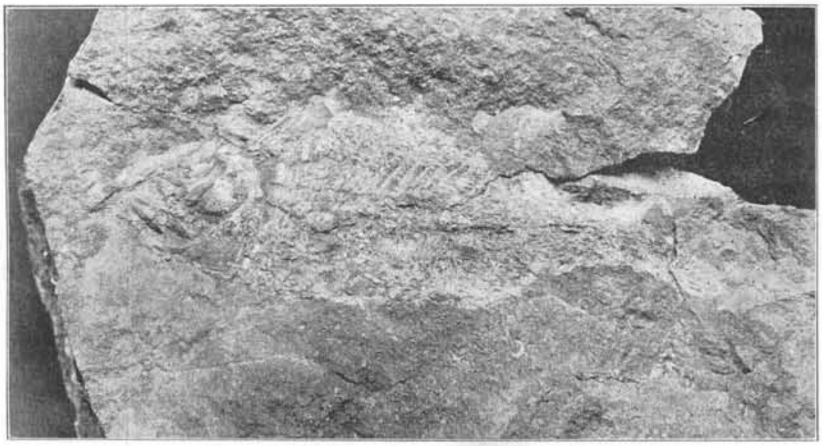


Fig. 12. Fossil fish found in old coal mine in the south part of Knoxville.

ledge of limestone conglomerate, varying in thickness from eight to twelve feet. The fossils appear very prominently on the weathered surface.

Pleistocene.

THE KANSAN DRIFT.

The drift of Marion county is that formed by the Kansan ice invasion. None of the other ice sheets, with the possible exception of the pre-Kansan, are represented here. This mantle of drift originally covered the entire county and was probably quite evenly distributed. Since the glacial period, stream erosion has been very active and all of the streams of any importance have cut down through it. The drift is prominently exposed on almost all hillsides, but is covered on the bottoms by alluvium and on the uplands by the loess. Its thickness varies considerably, being seldom less than five or more than one hundred feet.

The drift consists chiefly of bowlder clay of a blue or yellowish color, containing many glaciated pebbles. Large bowlders are frequently met with in the bottom of the ravines and streams, but are seldom seen in other localities. Occasionally a ravine will be fairly filled with these bowlders as is notably the case with one in Tp. 75 N., R. XX W., Se. ¼ of Se. ¼ of Sec. 20. Here one of considerable size was found which measured three feet two inches by two feet four inches by two feet six inches. This was the largest one observed, most of them being little more than a foot in diameter. These glacial bowlders represent various kinds of igneous and sedimentary rocks and are of many different colors. The most common variety is red granite. Many of them are greatly striated and polished, sometimes only on one side, but frequently on two sides almost parallel to each other.

That the ice had great force as it moved over the country is evidenced by the position of the rocks in a stone quarry located a few rods south of Marion county, in Lucas. Here in a ravine a great thickness of Coal Measure limestone outcrops, the rock being quarried in several places. By action of the ice this stone was broken into large and small masses which were shifted about somewhat, but not removed. The rocks appear as they might had they been fractured and disturbed by a great earthquake. Most of these blocks have later been loosely joined together by deposits of calcareous matter from percolating water. Some of the fragments are many feet in diameter, while others are only a few inches.

That a considerable length of time elapsed between the periods of deposition of the drift and the overlying loess is indicated by the color of the upper portion of the drift sheet. In that part exposed to air previous to the deposition of the loess the iron has been oxidized to a red color. This zone of weathered drift has recently been designated by the term ferretto.*

*Proc. Iowa Acad. Sci., Vol. V, 1897, pp. 90.

It varies in thickness from six to twenty inches, but has perhaps an average of about fourteen. The porosity of the till seems to have been an important factor in determining the extent of the oxidation.

In the Saint Louis limestone quarry near Durham, Tp 75. N., R. XVIII W., Nw. ¼ of Sw. ¼ of Sec. 4, an old forest bed is found.

The section here is as follows:

		FEET.
5.	Black soil	2
4.	Loess	10
3.	Black soil, with numerous small stems and roots	2
2.	Water worn gravels and fine sand	8
1.	Saint Louis limestone	6

This section is briefly described and figured by McGee in his report on the geology of northeastern Iowa*

The forest bed seems to be post-Kansan and probably is of the same general age as the Buchanan gravels. The color of the old soil indicates the presence of a large quantity of vegetable material. It also shows vertical jointing, with the joints very numerous. The deposit seems to be quite local as it appears only in the east end of the quarry.

The bowlder clay is quite homogeneous in character, considering the number of different kinds of material entering into its composition. This material has been derived from many sources, picked up as the ice advanced, and finely pulverized and intimately mixed together. Some grit can usually be detected even in the most finely divided clay.

LOESS.

The loess of this district possesses no character to distinguish it from that of the other counties of the state. It is a fine, dull gray, homogeneous deposit found everywhere over the uplands and occasionally extending down the slopes of the valleys and connecting with the alluvium. This is always true in the preglacial valleys, and may be found in post-glacial

*Eleventh Ann. Report U. S. Geol. Surv., pp. 494, 511.

valleys, where it has been washed down over the drift. In passing down a steep hillside from the uplands, one passes successively over exposed layers of loess, drift, country rock, and alluvium. The loess deposits range in thickness from a few feet to seventeen feet. Small, irregular concretions of lime, sometimes two inches in the longest diameter, are very abundant in certain localities. These are known as loess-kindchen. While no special effort was made to collect fossils from the loess a few were found. In the main, however, the loess deposits of this county are sparingly fossiliferous. The loess displays the characteristic vertical jointing. It contains small quantities of sand, the individual grains being so fine as to be invisible to the naked eye.

ALLUVIUM.

The alluvial deposits are the most recent ones and are represented by the black alluvial soils of the river valleys. They have been derived principally from the loess of the uplands. A large amount of vegetable material is present, thus rendering these soils very productive. The alluvium, as a general rule, is evenly distributed over the flood plains of the larger streams, and the bottom lands are so level that they are drained with difficulty. White Breast creek, in Tp. 76 N., R. XIX. W., Sec. 19, has built up one bank slightly higher than the surrounding flood plain so that there is a noticeable slope from the bank of the creek back to the bluff line, similar to the Mississippi in its lower course. This is produced in times of flood when the creek overflows. The greatest deposit of sediment is made just at the bank, where the first loss of velocity of the overflow water occurs, and the carrying power is correspondingly decreased.

The alluvium that is continually being carried down into these river valleys in time fills up the lakes or ponds which represent former cut offs. Thus, these bodies of water are only temporary.

Sand Ridges.—At three localities, as shown on the map, sand covered areas of considerable extent are found. These ridges could scarcely be called sand dunes, since they do not possess the dune-like form, neither are they composed entirely of sand. The term ridge is also a misnomer, since they are not true ridges, but common usage is followed in designating them thus. They are sand covered uplands of limited area and topographically scarcely unlike other uplands. The largest area is about one and one-half miles in length with a maximum width of one mile. They are all located near streams, the distance from the latter seldom being over three-fourths of a mile.

The Coal Measures of this county include several thick, though local, deposits of sandstone of which the Red Rock deposit previously described is the most remarkable. In some places the cementation process has consolidated them into firm, resisting rock; in others, the cementing material has been insufficient, so that the stone readily crumbles into loose sand. Near each of the three ridges, sandstone ledges of loosely cemented sand have been cut through by streams when just about at their base level. In each case the sandstone is now seen outcropping on either side of the valley immediately above the level of the flood plain. Furthermore, in each instance, the valley has attained a considerable width, showing that a large amount of sandstone has been removed by erosion. It is thus evident that the sandstone has been worn away by streams meandering through their valleys from bluff to bluff. The streams had about the same slope and velocity as at the present time, and so were not able to transport the sand resulting from the disintegration of the strata. It was deposited on the flood plain near the place from which it was obtained.

The next step in the process of formation of the ridges occurred when the sand was taken up by the wind and blown to the uplands, where it was spread out as a mantle over the loess. A casual observer could scarcely fail to see that the sand has been brought to these places from the valleys and that the wind has been the motive force. That this action took place very recently, geologically, is evidenced by the fact that, though the surface may be very level, the thickness of the sand will vary greatly, showing that there was considerable erosion between the time of the deposition of the loess and that of the sand. It is apparent that this action is not in progress at the present time, since there is no sand connection between the flood plains of the streams and the sand ridges. Yet conditions may again become such that sand will be blown from the flood plains upon the uplands.

The three ridges of Marion county resemble each other in their location, all of them being northeast of the place where the sandstone ledges have been cut through. This is to be accounted for in the prevalence of southwest winds during the summer, the season when the sand is blown. Where it is not held firmly by vegetation the sand is being slowly, though gradually, moved toward the northeast. Were it not for the frozen condition of the ground in the winter the strong northwest winds then common might cause a shifting of the sand toward the southeast.

Since only the finest materials are taken up by the wind and carried in this way the sand is usually too fine to be of any use, particularly as it is seldom pure, but is mixed with considerable loess. The color is a dull gray, instead of white or buff, as is that of the sandstone. In one place, however, an excavation by the roadside revealed a thickness of several feet of almost pure sand and from this place the material had been removed for plastering purposes.

The character of these sand ridges can perhaps be made clearer by selecting a single one for description. The largest one lies in the extreme northeastern corner of the county, just north of the Skunk river. The sand covering this area is of unequal depth, ranging from three to eighteen feet. The area is very irregular in outline on account of the streams heading in this divide having cut through it in many places.

The water supply is interesting and somewhat unusual. Although the difference in elevation of any two points on the divide is not more than ten feet, yet a spring is found in the head of a ravine just at the divide which never fails entirely, even in droughts. In other places, also, a good supply of water is reached at a depth of ten to sixteen feet or just at the base of the sand. These wells can be used only for a short time on account of the sand gradually filling them up, even when cased. The sand is evidently a very good water bearing stratum, but the supply from this source is limited in amount and varies from season to season; nevertheless, it is greater and less variable than one might expect.

The roads in this area are very poor since the sand is readily ground up by vehicles into a loose mass, at times six to eight inches in depth. It is sometimes almost impossible to haul heavy loads over these roads.

On account of the large amount of loess mixed with the sand, the soils of this ridge support some kinds of vegetation nearly as well as those of the surrounding country. The entire ridge is under cultivation. Those plants which thrive in sandy soils, such as watermelons and potatoes, grow luxuriantly here, while other crops, such as corn, do poorly. In some places there is so much sand that the corn will scarcely mature.

ECONOMIC PRODUCTS.

Coal.

Mr. Park C. Wilson, who was state mine inspector from 1880 to 1886, speaks of Marion county coal as follows:* "In regard to Marion county as a coal county I will say that while visiting the different coal counties in the state for almost four years in the capacity of mine inspector, I have made a careful study, so far as possible, of their deposits to determine their extent and I am now firmly of the opinion that Marion county has the largest deposits of coal of any county in the state.

*Marion County Coal Company, its Property and Prospects, 1889.

"In my opinion the greatest difference there is in Iowa coal is in the hardness of the coal, as the softer it is the more it is damaged by being handled, and in a practical point of view I consider that the most important question in regard to the condition of the Iowa coal in different localities, and one which can be readily answered by those who are shipping. The harder the coal, the better condition it is in when delivered to the consumer, and the better price it will bring in the market, and the hardness of the coal does not add to the cost of production, but on the contrary, lessens the cost of mining, does not require the care in handling, stands exposure better, and is better for steam purposes than softer coal, and, in the above particulars, Marion county stands second to none in the state."

As previously described, the Coal Measures extend over nearly the entire county, only small areas in the eastern part having the Lower Carboniferous as the surface rocks, immediately underlying the Pleistocene deposits. The Coal Measures contain numerous beds of coal so that it may be said that almost the entire county is underlain by coal.

Notwithstanding these abundant deposits mining has not been carried on nearly so extensively as in some of the adjoining counties, particularly Mahaska. The reason for this non-development of the mining industry in this region has been neither the character of the coal nor the thickness of the seams, but the lack of railway facilities for the transportation of the product. Mahaska county, while not possessing any better coal or thicker beds has had the advantage in a larger number of railroads. Without the latter it is impossible for large mines to be operated. For many years the chief fuel of this region has been coal, practically all of which, with the exception of small quantities of anthracite, has been mined at home. Marion county is not very well supplied with railroads and they are not located where they will best serve the coal interests. The three which do cross it are located in the northern and eastern parts. These roads, however, have been very serviceable and several extensive mines have been opened near them from which considerable coal has been shipped. But in other parts of the county only country mines have been opened. Recent drillings seem to indicate the presence of numerous workable beds in the southern and southwestern portion of this area which rival if not surpass those already being worked.

The Coal Measures dip toward the southwest, gradually increasing in thickness from the surface contact with the Saint Louis in the northeastern corner to a thickness of at least three hundred feet in the southwest. Near Newbern drill holes slightly over three hundred feet in depth have failed to reach the Saint Louis limestone.

Owing to their very local character it is impossible to say how many beds of coal there are within the county. Instead of the coal underlying the entire region in continuous beds, it is found in lenticular masses which seldom extend more than a few miles in their greatest diameter. As these masses are traced outward from the center the coal is found to gradually decrease in thickness and finally to pass by numerous gradations into bituminous shale or, occasionally, even into arenaceous or argillaceous shale. Numerous attempts have been made to trace coal beds from one region to another, perhaps many miles distant, and to correlate different seams but on account of the rapid changes in the strata of the Coal Measures such attempts have always been unsatisfactory. No great degree of accuracy is possible so that the results of such work are of little or no value.

So common is the presence of coal that where Coal Measure strata are present a drilling seventy-five or one hundred feet rarely fails to penetrate at least one coal bed, and frequently several. Four different seams have been passed through in a single drilling. Many of the veins are so thin that it has not been deemed expedient to work them at the present time, but not a few seams ranging in thickness from three to thirteen feet have been located. Of these latter, some are now being operated but others have never been opened.

From the local nature of the various beds it is always advisable to drill a number of prospect holes before sinking a shaft, since the deposits may be too limited in extent to repay any great expenditure of money. Again, it must not be considered positive proof that coal is absent underneath a certain tract of land if a single drill record fails to record its presence. Another hole drilled only a few hundred yards away may disclose a good layer of workable coal.

Since the Coal Measures form the surface rocks of the county, disregarding the Pleistocene deposits, all of the mines are comparatively shallow. Indeed, most of them are worked from slopes extending in from outcrops along the sides of the hills or bluffs of the creeks. The deepest shaft thus far opened is somewhat less than 200 feet in depth. Coal is in some places found at a greater depth, so that when the supply lying near the surface is exhausted a profitable supply can be reached by going deeper.

The coal of the county is all bituminous but varies considerably in hardness, ranging from a very soft to a medium hard variety. As a general rule it is quite pure, although small quantities of iron pyrites, called sulphur balls by the miners, are not infrequent. Occasionally the mining of a thick bed of coal is interfered with by the presence of clay ironstone nodules or bowlders which are sometimes four or five feet in diameter. In a mine near Flagler, there is a layer of this stone occurring within the coal bed. A few mines have been abandoned because of the large amount of this stone encountered. Faults and rolls are seldom met with in the region. When they are present the faults have so small vertical displacement that the coal is seldom entirely cut off. Their presence is indicated by the fractured condition of the coal and the smooth, glazed surfaces known as slickensides. The presence of rolls, while more important than faults, may be said to cause very little interference in mining. In a few exceptional cases a four or five foot vein of coal has been so narrowed by a roll as to be only one or two feet in thickness.

The coal of this county is underlain in almost every case by beds of fire clay varying in thickness from a few inches to fifteen feet. This fire clay is filled with the roots of coal plants, especially those of lepidodendrids and sigillarids. Though very little use has been made of this clay, it seems to possess the qualities which would make it of value in the manufacture of fire brick. In some places when the coal is removed the fire clay heaves, that is it rises in the entries on account of the removal of the overlying pressure, until it becomes necessary to remove it to prevent the passage way from being closed. The heaving, however, has seldom been sufficient to seriously interfere with the development of the mine.

In the great majority of mines the roof material is a black bituminous shale, or "slate" of the miners. On account of the very small number of faults throughout this region the shale forms a very substantial roof. But occasionally numerous faults, all of them slight in amount of thrust, will be found in a mine, so that the roof will be composed of much broken shale forming a very dangerous roof. In other mines the shale immediately over the vein frequently falls soon after the removal of the coal. This is known as the draw slate. Above this, firmer slate forming a very safe roof is found. In several mines sandstone occurs in immediate contact with the coal. In such cases, on account of the excellent quality of this rock as a roofing material, it is not necessary to use any timber. In a few instances an impure limestone overlies the coal and forms a stable roof.

The coal mines of the county may be divided into two classes with respect to their owners, namely, those owned and operated by corporate coal companies and those controlled by individuals, usually the owners of the land. There are several large coal companies operating in this district and others have extensive options on coal leases. In fact, almost every piece of land is at present or has been in the past optioned or leased by coal companies. The method of procedure is to secure an option upon a certain tract for a stated length of time with the privilege of buying the coal if desired at any period within the specified limit. For such an option a small sum of money is paid. The option entitles the company to drill prospect holes at any place on the property. In this way considerable areas have been prospected and large bodies of coal have been located, which, but for this method might have long remained unknown.

The mines operated by companies are worked principally by shafts. They are located along the lines of railroad and the entire output is shipped. The mines operated by individuals are usually worked by slopes which extend into the hills only short distances. These latter, called country mines, are generally operated only during the winter and certain periods in the summer when there is little work to be done on the farm. Many are worked just enough to secure fuel for one or two families; others are worked enough to supply the neighborhood and the small towns near by.

A few mines located several miles from the railroads ship some coal, hauling it by wagon to the shipping point. This is not very profitable on account of the large supply located nearer these points and the low price of the output. Thus, because of the insufficiency of railroad lines, the coal resources of the county have not been properly developed.

At various times there have been projects for building a line across the southern part of the county but as yet the work has progressed no further than to make the survey. Such a line of railroad would cause a great impetus to the mining industry of the county sufficient to place it in the foremost ranks of the coal producers.

For convenience the coal deposits may be divided into three districts: (1) the district north of the Des Moines river; (2) the district between the Des Moines river and English creek; and (3) the district south and east of English creek.

DISTRICT NORTH OF DES MOINES RIVER.

In the first district coal is mined at several localities, the most important being near the towns of Pella, Otley, Dunreath, and Morgan Valley.

Pella Mines.--Near Pella a number of mines have been opened at various times, several of which are now in operation and supply the town with fuel. The coal is here found near the base of the Coal Measures, only a short distance above the Saint Louis limestone. The largest of these is the Buwalda mine, located in Tp. 77 N., R. XVIII W., Se. ¼ of Ne. ¼ of Sec. 32, on the divide between the Des Moines and Skunk rivers. The shaft is 115 feet in depth and the coal varies in thickness from four feet six inches to four feet nine inches. In sinking the shaft about eighty feet of sandstone was passed through, most of which was massive, with thin beds of shale intercalated in some portions. From the foot of the shaft the coal rises in every direction at the rate of about one foot in every twenty. The roof near the shaft is formed of a very hard sandstone, but only a short distance away the sandstone roof is replaced by shale, which gradually increases in thickness until about fifteen feet of shale separates the coal and sandstone. From four to fifteen men are employed here. It is estimated that this bed of coal is something more than 200 acres in extent, about twenty-five acres of which have already been worked out. The product is a good grade of bituminous coal. The upper two inches of the bed is called cannel, and has many resemblances to true cannel coal.

Otley Mines.—There are several mines now in operation in Summit township, the most important of which are located in Secs. 21, 27, and 28, Tp. 77 N., R. XIX W. The largest is the one owned by the Otley Coal company and operated by them until the shaft was destroyed by fire in December, 1898. They contemplate soon rebuilding, as they own the coal underlying a considerable area in that region. The old shaft, located in the Nw. ¼ of Nw. ¼ of Sec. 27, was 112 feet in depth. The coal varies in thickness from five to six feet. It was worked by the room and pillar method, the rooms being driven 150 feet, with a width of twenty-five to thirty-five feet and pillars five feet in thickness. In sinking the shaft a seam of coal about eighteen inches was passed through at a depth of thirty feet. About forty men were employed in the mine. A switch connected it with the Rock Island railroad at Otley and the entire output was shipped. The mine was dry and possessed a gray shale roof.

The Roberts and McCloskey mines in Sec. 28, and the Vriezelaar and Smith mines in Sec. 21 are very similar to the one just described. They are all slope mines and employ from four to twenty men each. The coal from them supplies all the local trade, while some is hauled to Otley and shipped.

Dunreath Mines.—The most extensive mining operations of any in the county have been carried on near Dunreath, but at the present time almost no coal is being mined at that place. In the absence of a topographic sheet it is impossible to give the elevation of the different coal beds with any degree of accuracy or to correlate deposits several miles apart. As nearly as can be determined it seems that there are four beds of coal represented in this region. At no one place, however, are all four present. The upper one has a thickness of about two and one-half feet and lies about forty-five feet above the level of water in the river. This was not worked except just at the outcrop in the sides of the hill south of Dunreath. Fifteen feet lower is the seam that was extensively worked. This bed is correlated with the one that has previously been mentioned as occupying a depression in the Red Rock sandstone in the quarry near Red Rock. The Black Diamond and the Success were the principal mines operating in this bed. The first was located in Tp. 77 N., R. XX W., Nw. ¼ of Sw. ¼ of Sec. 26. The coal was from four to seven feet thick, with an average of about five and one-half feet. A large number of men were employed, and altogether the coal was removed from about seventy acres. The Success mine was located in Tp. 77 N., R. XX W., Sw. ¼ of Nw. ¼ of Sec. 27. The coal here averaged four and one-half feet in thickness and some forty acres were worked out. About twenty feet below the seam just described is another layer twenty inches in thickness, and a short distance below this is a fourth which is sometimes seen in the bed of the river in dry seasons.

The Dunreath coal supply has certainly not been exhausted and we may expect that at some future time paying mines may again be located in this region, although probably at a greater distance from the town. The quality of the coal and the character of the roof material were both said to be good.

Morgan Valley Mines.—In this area, in the northwest corner of the county, several mines have been worked at different times, but altogether only a small amount of coal has been removed. At the present time one mine, located in Tp. 77 N., R. XXI W., Sw. ¼ of Nw. ¼ of Sec. 4, is being worked. The company operating it either owns or has options on several hundred acres of coal land at this locality. The mine is worked by means of a shaft forty-five feet deep. The coal averages four feet in thickness and contains little rock. No props are needed in the mine as there is a good sandstone roof. In sinking the shaft sandstone was passed through below the first five feet of soil and drift. The water necessitated considerable pumping. A switch of the Wabash railroad runs to this mine and all the coal is shipped.

DISTRICT BETWEEN DES MOINES RIVER AND ENGLISH CREEK.

Swan.—A large company mine was formerly operated at Swan but on account of the great amount of water it was abandoned in 1898. It was located in Tp. 77 N., R. XXI W., Nw. ¼ of Se. ¼ of Sec. 18. Much coal was removed from this place and yet the supply is far from being exhausted. The seam worked seems to be about thirty-five feet lower than the Morgan Valley coal. It is from three and one-half to five and one-half feet thick. The sandstone met with in the latter place is not present here and the roof is bituminous shale. The coal is considerably harder than that at Morgan Valley.

Coal Creek Mines.—Several small country mines are located in Pleasant Grove township, on Coal Creek, in Secs. 17, 20, and 21, Tp. 76 N., R. XXI W. All of them are shallow and worked either by slopes or short shafts. The seam is seldom more than three feet thick. The following section is taken from this locality, Tp. 76 N., R. XXI W., Nw. ¼ of Ne. ¼ of Sec. 20. The upper part is exposed on the west bank of Coal creek.

		FEET.	INCHES.
9.	Surface wash	5	
8.	Coal		6
7.	Fire clay	2	
6.	Shale, light colored, argillaceous	2	6
5.	Shale, drab, arenaceous	5	6
4.	Sandstone, gray, thinly laminated usually, although in a few places massive	3	
3.	Shale, gray, arenaceous	3	
2.	Shale, black, exposed to water's edge 13 feet, but altogether	30	
1.	Coal	2	6

It is the lowest member which is mined. At some points it is thicker than at this locality.

White Breast Creek Mines.—Along White Breast creek many small mines have been opened, but none have been worked extensively, nor have they shipped any coal. They are most numerous in Secs. 24, 26, and 35 of Tp. 75 N., R. XXI W., and in Secs. 19 and 30 of Tp. 75 N., R. XX W. The following section, seen at the Ritchie mine, Tp. 75 N., R. XXI W., Se. ¼ of Ne. ¼ of Sec. 26, is typical.

		FEET.	INCHES.
10.	Drift and loess	5 to 15	
9.	Sandstone, very hard	4	
8.	Slate, gray	8	
7.	Sandstone, yellow, soft	11	
6.	Coal	2	2
5.	Fire clay	6	
4.	Slate, gray	10	
3.	Coal, just at level of creek	3	9
2.	Fire clay and black slate	60	
1.	Coal	4 to 6	

The second bed of coal is the one usually worked in this region, although some has been taken from the outcrop of the first. The coal varies somewhat in quality in the different mines but in general is quite soft.

Coalport.—Near this town the first mines in the county were opened. When boats passed up the Des Moines river in the early history of the state, Coalport was one of the most important places between Eddyville and Des Moines. At this place they usually took coal which was mined near by. Only a few old buildings now mark the site of this once prosperous village. Its location was Tp. 76 N., R. XIX W., Ne. ¼ of Sw. ¼ of Sec. 14. When navigation on the Des Moines river ceased most of the mines that had formerly been worked with profit were abandoned. The following section is shown at one of the mines, now operated on a small scale, located in Tp. 76 N., R. XIX W., Sw. ¼ of Ne. ¼ of Sec. 23:

		FEET.
6.	Drift	30
5.	Coal	6
4.	Fire clay	10
3.	Shale, light colored	10
2.	Coal	3
1.	Fire clay, to bed of river	5

All of the mines in the vicinity were worked by slopes. The roof is good, so that little timber was needed. The coal is a very soft variety.

Knoxville.—Since the entire region about Knoxville is underlain with coal it might be expected that here numerous mines would be operated. Within a radius of one mile from the courthouse probably a dozen mines have been operated but all are now abandoned. They were all shallow mines and the seam was thin.

Flagler.—At this place the Whitebreast Fuel Company have carried on very extensive mining operations for a number of years. Several shafts have been sunk and about 100 acres have already been worked out. The Hawkeye mine, located west of Flagler in Tp. 75 N., R. XIX W., Se. ¼ of Se. ¼ of Sec. 4, is the largest one now in operation. It is worked by means of a shaft fifty feet in depth. The coal varies in thickness from three to five feet, being quite irregular. There are also a few rolls which almost entirely cut out the coal for short distances. The mine has a good slate roof separated from the coal by two feet of draw slate. About thirty-five men are employed here in summer and seventy-five in winter. A short switch connects the mine with the Burlington railroad, over which the entire output is shipped. The coal in the immediate vicinity of Flagler is similar to that above, except that it averages about five feet in thickness. The drill section of the Flagler artesian well, given on a later page, shows the underlying formations. Although the drilling was distant only a few rods from the mines no coal bed was penetrated.

DISTRICT SOUTHEAST OF ENGLISH CREEK

It seems probable that in a few years Liberty township will be producing more coal than any other in the county. In the vicinity of Bussey, Hamilton, and Marysville are several mines which have been worked for years, while several large ones are now being opened.

O. K. Coal Company's Mines.—This company has operated several mines west of Bussey, two of which are of special importance. It owns considerable land in this locality, and also the coal underlying large tracts owned by individuals. It has mined altogether about seventy acres.

The oldest mine now in operation is situated in Tp. 74 N., R. XVIII W., Nw ¼ of Nw. ¼ of Sec. 23. This is worked by a shaft sixty feet in depth, and the coal runs from four to five feet in thickness. It is overlain by about fifty feet of slate which forms an excellent roof. About seventy feet below this seam is another about three feet in thickness, which is however quite impure. On an average about 125 men are employed in this mine. It is connected with the Burlington road by a switch.

The other mine of the O. K. Coal Company has just recently been opened, and it bids fair to become the largest and most important in the county. The company owns the coal under about 600 acres. The shaft, forty-five feet in depth, is located in Tp. 74 N., R. XVIII W., Nw. ¼ of Ne. ¼ of Sec. 17. In prospecting over this area the maximum thickness of the coal was found to be thirteen feet, the minimum five feet, and the average about eight and one-half feet. There is a good slate roof about eleven feet in thickness. The coal is medium hard and very glossy. There is little water to interfere with the work. From the foot of the shaft the coal rises slightly toward the northwest and dips toward the southeast. A switch will connect this mine with the Burlington railroad.

Hamilton Mines.—Several mines are located in the vicinity of Hamilton, the most important of which is that owned and operated by the York Coal Company, and located along the Wabash railroad, about half a mile north of town, in Tp. 74 N., R. XVIII W., Se. ¼ of Sw. ¼ of Sec. 26. It has only recently been opened. The shaft is 164 feet deep, and the coal is from three to six feet in thickness. The roof is in some places sandstone, in others slate. Near the foot of the shaft are a number of rolls and bowlders which entirely shut off the coal for a considerable distance. In one direction the coal was found after passing throngh a roll for a distance of thirty-three feet, while in another direction a roll was encountered seventy-two feet in length. Drill records indicate that the rolls are less frequent a few hundred feet away from the shaft. If this proves to be true the mine can be worked with profit, but otherwise not.

Marysville Mines.—The Marysville mines are all country mines, located along Cedar creek. There seems to be an abundance of good workable coal in this vicinity, and no doubt in the near future large mines will be opened. The States coal mine, located in Tp. 74 N., R. XVIII W., Sw. ¼ of Sw ¼ of Sec. 30, is perhaps the most important, but it is not being operated at present. It was a slope mine, with the entrance about fifteen feet above the level of the creek. The coal dips slightly toward the west, and the seam ranges in thickness from seven to eight feet, with an average of about seven and one-half feet. The coal is very glossy in appearance and of excellent quality. The roof consists of "soapstone," which is so firm that no propping is needed in any of the entries. This bed of coal does not seem to be merely a local deposit, but apparently extends for several miles.

As already stated, no attempt is made to correlate the various coal seams situated in different parts of the county, as it is impossible to trace any deposit for any considerable distance, yet something may be said in a general way concerning the deposits. It seems certain that the Dunreath coal is older than that now being mined south of the Des Moines river, and that those deposits, or other deposits of the same age, have been carried to considerable depth in the southern part of the county by the dip of the strata in that direction. It is not meant that the coal beds north of the river are continuous, for this is known not to be the case, but merely that there are beds of the same age in the southern part of the county. If this supposition be true, the coal supply of Marion county is vastly greater than is usually supposed, and when the upper beds are exhausted in the southern half of the county there will yet remain a large supply of good coal at a depth probably not exceeding 400 feet. Half a dozen accurate deep well records in this region would be sufficient to prove or disprove this supposition, but unfortunately these are altogether lacking.

Building Stone.

The building stones belong to the Saint Louis and Des Moines formations and consist of sandstones and limestones. At the present time no extensive quarrying is carried on at any place in this district. Little stone is being shipped out of the county and, on the other hand, but little is being shipped in. Few stone buildings have been constructed within the past few years, and thus almost all the material quarried is used for foundation purposes.

Saint Louis Limestone.—As has been said before, the Saint Louis consists principally of limestone and is found outcropping along the streams in the eastern portion of the county. Stone both of the Pella and Verdi beds has been quarried, the former, however, much more extensively. This is due both to its superiority and to its greater extent. At every outcrop of the Pella beds, with few exceptions, stone has been or is at present quarried.

The largest quarry in this rock is located on Cedar creek, southwest of Tracey, in Tp. 75 N., R XVIII W., N. ½ of Se. ¼ of Sec. 35. The section exposed at this point has been given in the discussion of the Saint Louis formation. This quarry is only a short distance from the Burlington railroad, with which it has been connected by a short switch. It extends for about half a mile along the bank of the creek. Although hundreds of carloads of stone have been removed and shipped to all parts of the state, the quarry has been worked only a short distance back into the hill. It has been operated about eighteen years, and at times there have been as many as forty men employed, although at the present time there are, on an average, not more than six. A stone crusher was used here for a short period and in this way the thin bedded and fragmentary rocks, which are usually wasted, were utilized. The principal beds in this quarry are the 16, 17, and 19 inch ledges. From the latter, blocks measuring three feet three inches by five feet can be easily obtained, and occasionally even larger pieces are removed. The bed suitable for flagging stone is better developed in this quarry than in any other in this area and its quarrying would be profitable if there were more of it. It is of uniform thickness and can be removed in large blocks suitable for side walks.

Another quarry, formerly worked quite extensively but now abandoned, is located north of Durham near the Rock

Island railroad, in Tp. 75 N., R. XVIII W., Sw. ¼ of Sec. 4. Considerable stone has been shipped from here. The individual ledges differ very little from those in the above mentioned quarry. It was operated by J. H. Rees of Harvey, who has just recently opened another in the Pella beds in Tp. 75 N., R. XIX W., Sw. ¼ of Sw. ¼ of Sec. 1. The latter is situated between the Rock Island and Burlington railroads, with the former of which it will be connected by a stub switch. The section here is as follows:

	FEET.	INCHES.
Soil and loess	3	
Limestone, thinly bedded	6	
Limestone ledge		8
Limestone ledge		8
Limestone ledge, coarse grained, dark in color, weathering white, principal layer of quarry		20
Limestone, variable thickness		6—20
Limestone ledge		8
Limestone ledge		6
Limestone ledge		6
Arenaceous limestone, soft, of little value		14
Limestone, very hard, breaks irregularly	3	

Although this quarry has just been opened, considerable stone has been shipped from it to Oskaloosa and Washington and has found a ready market. The joints are from two and one-half to ten feet apart, thus making it possible to remove large blocks.

Nearly all the stone used in Pella is obtained from two limestone quarries located about one and one-half miles southwest of the town on the Pella-Knoxville road. The stone differs very little from that given in the above section except that a marl bed, varying in thickness from four to eight feet, overlies the limestone.

Another quarry deserving mention among those of special importance is that belonging to J. R. Morris, located in Tp. 75 N., R. XVIII W., Ne. ¼ of Se. ¼ of Sec. 13. The section here is as follows:

	FEET.	INCHES.
Limestone, thinly bedded, greatly fractured.......	5	
Limestone ledge, of no value on account of its inability to withstand frost........................		6
Limestone ledge, similar to above.................		6
Limestone ledge, fairly good stone.................		10
Limestone ledge, fairly good stone.................		8
Limestone ledge, granular in texture, joints 4 to 10 feet apart, principal stone of quarry....		18—20
Limestone ledge		4
Limestone ledge, very hard, seldom worked.......		10
Shale, black.......................................		1—2
Shale, gray, soft....................		12
Limestone, thinly bedded, crystalline..............		12

The stone from this locality is all consumed by local trade, the annual output being about 100 perch.

The limestone of the Pella beds, as may be seen from the sections just given, varies little in the different quarries, so that it is possible to describe it in a general way. The rock is homogeneous in structure and usually fine grained; cavities are not common, only one layer containing many. In this layer they are merely the openings between the valves of brachiopods, and these are frequently almost entirely filled with calcite crystals.

As is shown from the sections already given, the layers are of convenient thickness for building purposes, and also for flagging. With the exception of the upper beds, the joint planes are not so numerous as to prevent the securing of blocks large enough for all ordinary purposes. The joints run true, so that the stone can be readily removed in blocks of convenient size; it also breaks evenly, so that the waste in dressing is very small. The rock is quarried both by drilling and blasting, no sawing machines being employed. Formerly some of the stone was crushed for street paving and for ballast.

The Saint Louis limestone, while far better than that of the Coal Measures, is not of superior quality. The layers vary greatly in durability, some being little affected by frost, while others disintegrate in a few years when subjected to alternate thawing and freezing. Some foundations built of this stone present a fresh, almost unweathered appearance after fifteen to twenty years exposure to the weather, while in other cases the rock began to crumble in a very short time. In general, it does not resist frost well, due no doubt to the large amount of water which it is able to absorb. The stone is of good color, becoming very white when exposed to the air.

The following tests and analyses were performed upon specimens secured from the large quarry on Cedar creek, near Tracy. The tables are taken from an article by H. F. Bain, in one of the earlier reports of the Survey:*

CRUSHING TEST.

STONE.	HEIGHT—INCHES	CROSS SECTION—SQUARE INCHES.	BREAKING STRESS—POUNDS PER SQUARE INCH.	
			Spalling	Failure.
No. 31, Saint Louis limestone	1.95	4.12	7300	9500
No. 32. Saint Louis limestone	2.00	4.20	5200	9900

ABSORPTION TEST.

STONE.	PER CENT. OF INCREASE.		
	24 Hours	Week	Total.
No. 31, Saint Louis limestone	2 28	99.	3.27

CHEMICAL COMPOSITION.

$CaCo_3$	94.60
MgO	3.17
Al_2O_3	.49
$FeO+Fe_2O_3$	.17
Ins	1.57

Although the Saint Louis limestone in this county is not being quarried as extensively as formerly, there is a good demand for it, and a considerable quantity is being shipped to

*Properties and Tests of Iowa Building Stone, vol. VIII, pp. 402, 410, 412.

adjoining counties. The chief drawback to the extensive quarrying of this stone is the thickness of the overlying drift. The outcrops are confined to the valleys and ravines, and as the beds are followed back into the hills the drift becomes thicker, until the stripping is necessarily so great as to make quarrying impracticable. On this account it will be impossible for such extensive quarries to be worked in this county as in other parts of the state.

Coal Measures.—In the Coal Measures, limestone, conglomerates, and sandstones have all been quarried for building purposes. The first two scarcely deserve mention, as they occur only in limited areas and are inferior in quality. If it were not for the scarcity of good building stone over a large portion of the county, the Coal Measure limestone would perhaps nowhere be quarried. It is heterogeneous in composition, breaks irregularly, produces a rough surface when weathered, and can scarcely be dressed without great waste. It is used for foundation purposes and for walling wells.

The sandstones of the Coal Measures have been very extensively quarried throughout the county, notably at Red Rock. At this place the largest quarry in the county, and one of the largest in the state, is located. At present, however, it is not in operation. At many other places there are small sandstone quarries which supply a limited local trade.

The Red Rock sandstone was formerly shipped to many places in and out of the state, especially to Des Moines and St. Louis. The rock, while comparatively soft, does not crumble and is very resistent to weathering agencies. It was formerly blasted in quarrying, but this shattered it so badly as to render some of the material almost unfit for use and more recently it has been taken out by channeling. No joint planes are present in the rock, and since a vertical face of nearly ninety feet is exposed, it is possible to secure blocks of any size desired. Because of the difference in color of the various parts of the rock it is quite difficult to secure large blocks of a uniform color throughout. Thus to work the quarry with profit it becomes necessary to remove large quantities of material which must be assorted, especially if it be used for the construction of entire buildings. When this is done there must necessarily be considerable waste on account of the coloring matter being distributed in irregular blotches rather than in layers. Mottled stone has been used to some extent but is not always desirable. Notwithstanding these difficulties, by judicious selection rock of uniform color varying from light gray to a deep brick red may be secured, suitable for the construction of the finest buildings. This stone possesses another desirable quality in that it can be readily carved, thus making it suitable for decorative purposes.

The sandstone is very durable; since the cementing material is silicious and ferruginous, it is not easily dissolved and water has little effect upon it. Again, being fine grained and the grains well assorted, it is not effected to any great degree by changes in temperature. Although the concretions and pockets of loose sand, previously mentioned, are obstacles in the successful operation of the quarry, yet it seems that with proper management it might become one of the most extensive and profitable quarries in the state. The amount of necessary stripping is small, the quality of the stone is good, and the supply is practically inexhaustible.

Lithographic Stone.

Several years ago some specimens of stone were obtained from the Coal Measures in the southeastern part of the county, which were pronounced by several lithographers to be true lithographic stone of very good quality. The one making the discovery did not attempt to develop a quarry nor to learn the extent of the deposit. Should the beds prove to be extensive, lithographic stone might become one of the most valuable economic products of the county. Numerous finds of this stone from various parts of this county have been reported from time to time, but at present almost all of this material used in the United States is imported from Germany. Since the locality where these specimens were obtained is kept secret, the writer has been unable to investigate further, and consequently this unsatisfactory reference to the reported find is all that can be given at this time.

Lime and Cement.

At present neither of these products is manufactured within the county, the supply being derived from outside sources. Formerly, however, lime was burned at various places, especially in the eastern part of the county, and in sufficient amounts to supply the local demand. This lime, while it was not of the best quality, proved to be quite durable and was used exclusively for many years. In it, manufacture limestone composed almost entirely of calcium carbonate was used. It was obtained from both the Coal Measures and the Saint Louis formation.

In recent years there is a decided preference for the gray magnesian limes obtained from dolomite, and this has led to the abandonment of the old kilns. The magnesian limes while darker in color, seems to have a decided superiority over the calcareous lime in point of durability, hardness, and adhesiveness. Cheap transportation has also aided the former lime, which is produced in large quantities in other parts of the state, to gradually drive out the poorer material. No cement has yet been produced in this part of the state, but it seems not at all improbable that some of the Saint Louis marls may be found suitable for this purpose.

Clays.

Marion county, in common with most of the adjoining counties, is well supplied with clay. There are many deposits of good clay that have not yet been utilized, but which should in time give rise to important clay industries. The clays, of which there are several different kinds, suitable for various purposes, have thus far been used in the manufacture of brick, tile, and pottery.

Brick.—At the present time there are four brick plants in operation, viz: the Pella Brick and Tile Company, located in the eastern part of Pella; the Wright brickyard, a short distance north of Knoxville, Tp. 76 N., R. XX W., Se ¼ of Sw ¼ of Sec. 25; the King brickyard, southwest of Knoxville, Tp. 75 N., R. XIX W., N. ½ of Nw. ¼ of Sec. 17; and the Wright brick yard, north of Bussey, Tp. 74 N., R. XVIII W., Ne. ¼ of Ne. ¼ of Sec. 14. In early days small quantities of brick were burned in other places in the county, but only for the construction of a few buildings.

The clays are obtained from the loess and the Coal Measure shales, the former being used most extensively. This is owing to the fact that it is found in large quantities; is easily obtained, since it is only necessary to remove the sod and a small quantity of loam; and, in addition, it makes a very good quality of common brick. There are three different kinds of loess clay: the gray surface material, the yellow clay, and the blue clay. These are occasionally used separately, but usually better results are obtained by using a mixture of the different varieties. The chief objection to the loess in the manufacture of brick is that there is frequently considerable loss in the drying process, due to cracking. To prevent this they must be dried slowly. Steam dryers have been found impracticable for this reason.

At the King brickyard some Coal Measure shale is used, sometimes alone, sometimes mixed with loess. There is little waste in this kind of clay in the drying process, since it does not readily crack even when dried rapidly. These brick can also be burned much harder than those made from the loess. Sidewalk brick is produced at this place, but no attempt has been made to produce paving brick. Some brick taken out of the kiln next to the furnace where they had been subjected to greater heat seems to indicate that a very good quality of vitrified brick might be produced.

Tiling.—Considerable drain tile is used within the county, most of it being produced locally. A large quantity is also shipped to neighboring points. The tiling is made in connection with the brick at the various brickyards. Loess is used exclusively for its production and is well suited for the purpose, because of its burning to vitrification at the relatively low temperature of 2100 to 2300 F. It is better adapted to tile than to brick, since it is possible to dry the former without cracking under conditions where it is impossible to make brick. If the clay is thoroughly worked there is very little waste from cracking in the drying process and almost none in the burning. The larger sizes of tiling, such as used for culverts, are not made, but only those smaller ones with an internal diameter of from three to eight inches.

Pottery.—Formerly pottery was made at the King brickyard, at Coalport and at Attica. On account of the great reduction in prices of pottery in recent years, its manufacture has been abandoned at all three places. The potter's clay appears to be of good quality for the production of the common grades of pottery. It is found in the Coal Measures. It occurs in only a few localities, but where found it is frequently ten or twelve feet in thickness. The principal deposits are near Attica, and here a number of small potteries were formerly located. For many years the ware produced here, consisting of jugs, jars, churns, flower pots, etc., supplied the entire demand for a considerable area about Attica, and was shipped to various points in this state and Missouri.

Ochre.

In the vicinity of Hamilton a deposit of yellow ochre occurs, which, from outcrops and well borings seems to be quite extensive. It has been detected in well borings about two miles from where it outcrops, and it is believed to be continuous between these two points. If it should be found suitable as a pigment it would become one of the important resources of the county. Samples of the material were sent to a paint manufacturing company for examination, with the request that they report as to the quality and value of the material. Their report is unfavorable on the whole, and yet the ochre is said to have the necessary constituents for paint, though in small quantity. Though it has a commercial value it is rather a low one. The chief objections to it are the presence of several impurities, principally calcium carbonate and small grains of sand. The samples were all collected near the same point, and it is possible that these impurities may not be present in all parts of the deposit. In one instance at least this ochre has been used with satisfactory results. A number of years ago a house in Hamilton was coated with paint made from this ochre and it has proved to be quite durable. The color, though not a decided yellow, is very good.

Copper.

From time to time there have been rumors of valuable deposits of copper within the county, caused by the discovery of small copper nuggets. These have been found of various sizes, ranging from a few ounces to four pounds in weight. In every case, so far as could be ascertained, the copper was picked up at the surface or was found in the glacial drift. It furnishes, therefore, no indication of deposits of copper within the county. Two possible hypotheses have been suggested to account for the occurrence of these isolated nuggets. One explanation is, that the copper was brought by the Indians, as it is known that they used the metal in the manufacture of their weapons and ornaments; the other is that it was carried from the Lake Superior region by glaciers in the same way that the glacial bowlders have been transported. Probably both these hypotheses are correct and the copper was brought here by the Indians and by the ice sheets.

Lead and Zinc.

In the course of the present survey frequent reports were met with of rich bodies of lead and zinc ore in the county. Whenever the exact location of these supposed deposits could be secured, the strata were carefully examined, but no evidence of the presence of either of these metals was found. With respect to the zinc, it is probable that the iron carbonate, siderite, which is found in the large septarial concretions in the black shale, has been mistaken for zinc blende. It closely resembles it in color, so that it is not surprising that such an error has been made.

Other Minerals.

Among the other mineral products, gypsum is probably the most common. This, however, is found in such small quantities as to be of no economic importance. It occurs in the usual diamond or needle-shaped crystals of small size, in certain black shales of the Coal Measures. Iron pyrites is frequently found in the Coal Measure shales and in the coal, but not in sufficient quantity to be of any value.

Oil and gas have been searched for, but have been found only in very small quantities. At times the water from certain wells has a thin film of oil on the surface, indicating the presence of small amounts of this mineral.

Water Supply.

The water supply of the county is derived from running streams and wells. At present no use is made of the water power, there being no mill or other plant run by water. This is mainly due to the fact that the average slope of the streams is small, especially so in the larger streams, as shown in the table previously given. The city water works of Knoxville obtains its supply from White Breast creek.

The wells are usually shallow, since the water is found in the drift. Owing to the heterogeneous character of this material and its irregular distribution, water is obtained from small sand-filled pockets or from small veins. Two wells, situated only a few rods apart, may obtain water at different depths, drawing their individual supplies from different sources. The Coal Measures also contain water, but this is usually so strongly impregnated with mineral substances as to be unfit for household purposes. The water obtained from the Saint Louis formation, in the eastern part of the county, is of good quality, although in places somewhat hard on account of the large amount of calcareous material held in solution.

On the uplands in the northern part of the county, between the Des Moines and Skunk rivers, and also in the southern part, there are a number of deep wells varying from 100 to 300 feet in depth. The water in these is obtained from the Coal Measures and is usually of poor quality, except when found in sandstone, as is occasionally the case. In recent years the water supply of the shallow drift wells seems to have been decreasing, thus making it necessary for a great many of them to be deepened. While the average rainfall has not materially changed it does not seem to have been as well distributed throughout the year as formerly, and there are more frequent drouths.

Springs occur in a few places, but they never have sufficient flow to be of much importance. Water-bearing strata are seldom exposed, and where they lie near the surface the seepage is concealed by the drift or loess. Boggy places are thus formed rather than springs.

Artesian Wells.—There are several artesian wells in the northern part of the county which range from 200 to 800 feet in depth. Unfortunately no records have been kept, or else the records are so incomplete as to make it almost impossible to determine the age of the horizons from which the water is obtained. The most complete record, and the only one that can be depended upon, is that of the flowing well at Flagler, drilled by the Whitebreast Fuel Company. It is located in

Tp. 75 N., R. XIX W., Nw. ¼ of Sw. ¼ of Sec. 2. The record is as follows:

		FEET.
0-5	Clay	5
5-17	Sand	12
17-45	Limestone	28
45-51	Sandy shale	6
51-123	Sandstone	72
123-130	Limestone	7
130-143	Magnesian limestone	13
143-153	Limestone	10
153-160	Sandy shale	7
160-185	Limestone	25
185-191	Sandy shale	6
191-194	Limestone	3
194-198	Sandy shale	4
198-291	Limestone	93
291-292	Hard white rock	1
292-454	Limestone	162
454-524	Sandy shale	70
524-526	Sandy shale	2
526-590	Limestone	64
590-621½	Sandy shale	31½
621½-687	Limestone	65½
687-752	Lime rock	65

In this well a small flow of water was obtained at 320 feet, and a strong flow at 626 feet. In the latter case the water was probably in Devonian strata. Two flowing wells about 200 feet in depth, located in the Des Moines river bottoms, near Red Rock, seem to obtain their supply from the Coal Measures.

In none of these wells is there strong flow, nor is the force sufficient to throw the water any considerable distance above the surface. The water is highly mineralized, the chief minerals in solution being iron and sulphur. The water from the Flagler well was found to be unfit for boiler purposes on account of its corrosive action. That from the other artesian wells would probably act in a similar manner as the composition seems to be practically the same, if one may judge by the taste and odor. It is claimed that the water from the Flagler well possesses as great curative properties as that of the famous Colfax well of Jasper county.

Soils.

The soils of this county may be classified as loess, drift and alluvial. This classification is based on the different kinds of material composing them, and the source from which they have been derived. The loess soil is by far the most important, since it covers the greater part of the county. Where erosion is not active enough to remove large amounts of the surface material each year, the upper foot or two of the loess becomes mixed with a large amount of vegetable material, thus rendering it much darker in color than the underlying portions. With sufficient rainfall this soil is very productive and is well adapted to the raising of almost all kinds of crops. On account of its porosity, it absorbs and holds a large amount of water instead of allowing it to pass downward freely by percolation. Nearly all of this water is available for the use of plants, since the roots are able to withdraw it from the loess as the plants require it. Moreover, because of the great porosity of the loess, when not covered by a dense mat of vegetation, such as bluegrass, it increases the relative amount of ground water compared with the surface drainage water.

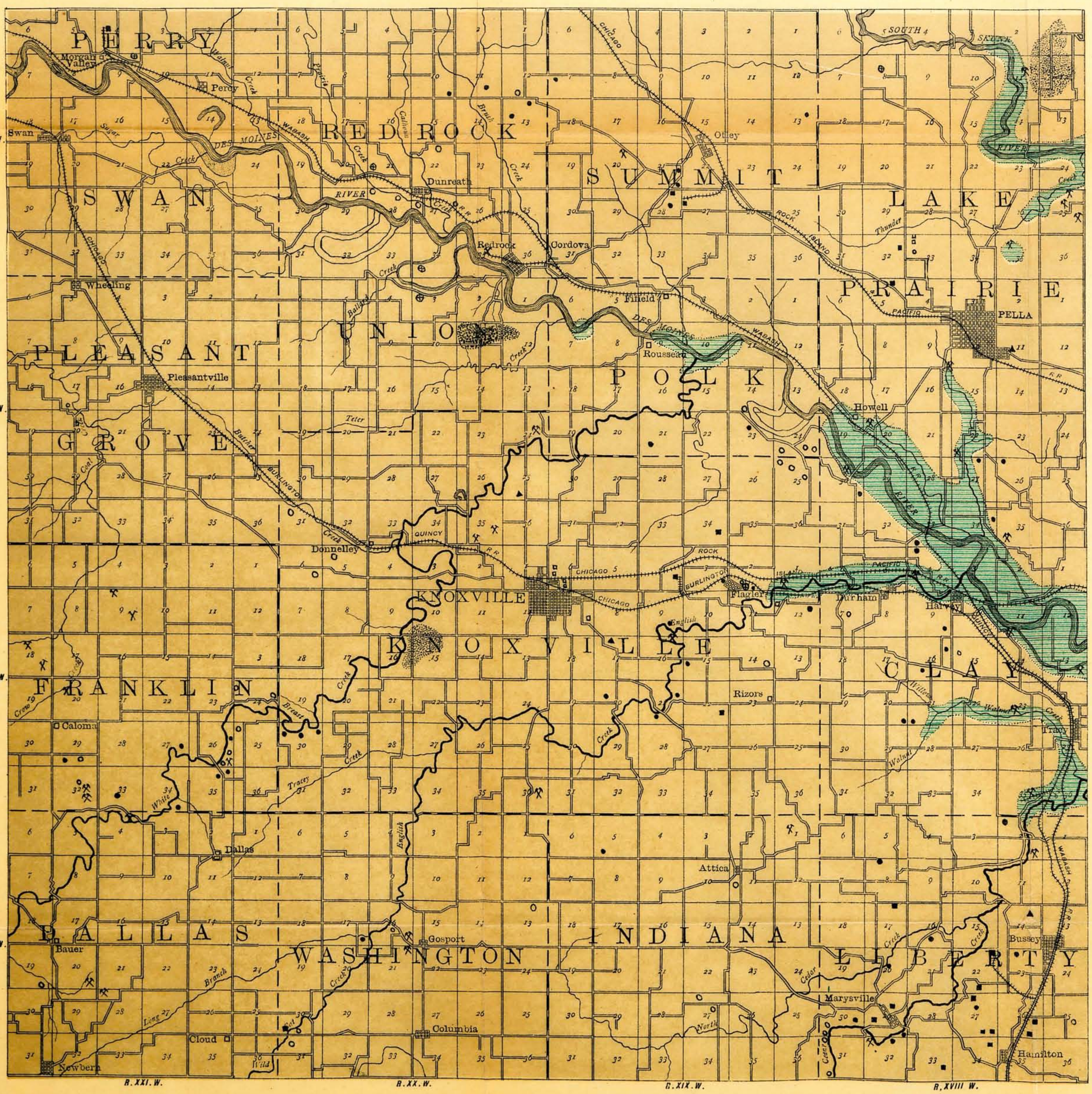
The drift soils are relatively of small extent and are found chiefly on hillsides. They are less fertile than the loess or the alluvium. At times the boundaries between the loess and the drift can be determined by the appearance of the crops as well as by the color of the soil. The drift soils are usually designated as clay. Their unproductiveness is in a measure due to their position, since erosion is apt to be so active on the hillsides as to remove the soil mixed with vegetable material as rapidly as it is accumulated. This soil does not hold water well and frequently bakes on the surface after a heavy rain.

The alluvial soils are composed, as already stated, principally of the vegetable filled loess of the uplands and are the most productive of the county. The only drawback is due to their position. In wet years they are flooded and their cultivation thus prevented.

ACKNOWLEDGEMENTS.

In the preparation of this report the author has been very kindly received by all persons from whom information was sought, and for this reason much valuable material was secured which could not otherwise have been obtained. Everyone seemed to take a personal interest in the matter, and, though they cannot all be mentioned individually in this place, the writer wishes to express to them his indebtedness.

Among those who have contributed their services Mr. H. F. Bain should be mentioned; also Professor Calvin, Mr. F. M. Kinne, and Mr. Herbert Bellamy, of Knoxville, Mr. E. Randall, of Monroe, and Mr. Morgan Faust, of Hamilton. The work was greatly facilitated by the help thus rendered. The Whitebreast Fuel Company, The O. K. Coal Company, and the Red Rock Coal & Mining Company, have also promoted the investigations by putting some of their drill records at the command of the Survey.



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF MARION COUNTY, IOWA.

BY

B. L. MILLER

1901.

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

DES MOINES (Coal Measures)

SAINT LOUIS

INDUSTRIES

QUARRIES

COAL MINES

SHAFT

SLOPE

ABANDONED MINES

CLAY WORKS

ARTESIAN WELLS

DRAWN BY F. C. TATE

IOWA LITHO. CO.

GEOLOGY

OF

POTTAWATTAMIE COUNTY

BY

J. A. UDDEN.

GEOLOGY OF POTTAWATTAMIE COUNTY.

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INTRODUCTION.

LOCATION AND AREA.

Pottawattamie county is next to the largest county in the state. It embraces an area of nearly nine hundred square miles. Its greatest length from west to east is forty-four and a half miles. From north to south it measures twenty-four miles. The north, east, and south boundaries consist of the straight lines of the government surveys, while the west boundary coincides with the boundary of the state and follows the main channel of the Missouri river. As this is subject to changes, the area of the county is slightly variable. Counting from the south, the county is the third in order of those which border on the Missouri river.

PREVIOUS INVESTIGATIONS.

Several writers have heretofore contributed to our knowledge of the geology of this county. While employed as state geologist, Professor C. A. White pubiished some notes on the surface geology of Pottawattamie county in his first annual report in 1868,* and in 1870 he gave a brief description of the outcrops of the older rocks within its area.† In 1887, W J McGee gave an account of the discovery of a fossil Bison in Council Bluffs.‡ In the annual reports of the present Survey Professor W. H. Norton§ has given some data on the artesian wells near the same city, and Professor B. Shimek has given an account of the loess and the loess fossils at Council Bluffs.‖

*First Annual Report; State Geologist, C. A. White, Des Moines, pp. 55-63. 1868.

†Geology of Iowa, C. A. White, Des Moines, pp. 76-81, 1870.

‡Am. Jour. Sci. vol. ,XXXIV pp. 27-220. 1887.

§Iowa Geol. Surv., vol. VI., p 340.

‖Journal of Geology, February-March, pp. 122-140, 1899.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Pottawattamie county is very uniform, consisting in the main of upland slopes and several flood plains, with some strips of upland plains and a few terraces.

Flood Plains. The flood plain of the Missouri river occupies about seven per cent of the area. The width of that part of the valley of the Missouri river which is included between the north and south boundaries of the county, varies from nearly four to six miles from bluff to bluff, and the width of the bottom land on the east side of the river ranges from twenty rods to five and a half miles, with an average of three miles. For the most part this plain has an elevation of less than twenty feet above the average stage of water in the river. The latter has a general slope to the south of about one foot and five inches to the mile. There are frequent evidences of quite recent changes in the course of the main channel on this flood plain. These consist of marshy stretches and lakes, which have the outline of a bow or crescent, such as Honey Creek lake in Secs. 2, 3, 10 and 11 of Crescent township, Big Lake, in Secs. 11, 13, 14 and 23, Tp. 75 N., R. XLIV W., and Boyer lake, west of the village of Crescent, whose bottom is now mostly drained, and Lake Manawa, two miles south of Council Bluffs. The channel has shifted more than a mile from the place it occupied at the time of the making of the first land survey a half century ago. West of Council Bluffs it has receded a fourth of a mile to the west. Near the south line of the county it has shifted nearly a mile to the east, and southwest of Lake Manawa a bend to the northeast has moved westward. North of Council Bluffs a cut-off on an old "ox-bow" has transferred two square miles of land from this state to Nebraska, while in Crescent township this loss has been compensated by two somewhat smaller cut-offs west of Honey Creek lake and the village of Crescent respectively. The general tendency of these changes has been to straighten the channel. It is in part a result of the recent removal of the timber growing on the bottom lands. This was formerly floated out and thus aided in obstructing the water more than it does at present. But it appears that the straightening of the channel is also partly a result of the more prompt run-off from the general drainage of the river, brought on by the cultivation and deforesting of the upland basin. This has resulted in higher floods which have a shorter duration, and make the current more swift while it lasts. A comparison of the radii of curvature of seven of the bends of the old river with seven of the present bends gives an average of one mile for the bends of the old meanderings and two miles for the new. This readjustment in the rhythm of the meanderings has resulted in some sharp bends at the junction of the new curves with some of the old. One of these places is a mile below the present mouth of Pigeon creek; another is in Sec. 3, Tp. 75 N., R. XLIV W., and still another a mile south of Lake Manawa. At each of these places the river now makes almost a right angle, cutting rapidly on one side, while extending the other bank like a sand spit on the line of the new curve.

From the nature of the bluffs which border these bottoms on the Iowa side it is evident that the widening of the river bottoms has been a slow process, lately taken up only at irregular and widely separated intervals and at different points on the bluff line. Where the great stream has sapped the bluffs most recently these are very steep and have been but little furrowed by erosion, presenting a smooth and straight escarpment. Such places are seen between Council Bluffs and Crescent, and north of Crescent opposite Honey creek. The most dissected and ancient aspect of the bluffs is found in their reentrant recesses, as just below the mouths of the valleys of Honey and Pigeon creeks and at several points in the long semicircle of bluffs in Lewis township.

The flood plain of the West Nishnabotna is next in importance. South of the junction of its two branches the width of its valley is one and two-thirds miles, but it is nearly two miles in width from here to Carson, where it suddenly narrows down to less than half a mile. Between Carson and Macedonia it again opens out to about one mile, but just northwest of the latter place its width is scarcely more than one-eighth of a mile, and at the same time it makes a sharp and short turn to the west. This turn, as well as the abrupt narrowing of the valley, is due to the stream encountering the bed rock, which has more effectively withstood the effects of erosion than the loose drift. On the south line of the county the valley is again a mile and a half wide. The average elevation of the Nishnabotna valley in this area is one hundred feet above the Missouri river. From Avoca to the south line of the county this flood plain descends about eighty feet, or nearly three and four-tenths feet to the mile.

The bluffs which bound this valley on either side recede with a gentle slope, frequently one-fourth of a mile in length. No recent cutting has taken place anywhere in these bluffs, which have an average height of one hundred feet. Their greatest height, as well as most abrupt slope, occurs on the west side of the valley from one to three miles south of Avoca. On the south line of section 18, in Knox township, the brink of the bluff rises one hundred and fifty feet above the bottom land. For several miles here the bluff line runs in a series of loops a mile wide and with the concavity facing the river. These are separated by rather narrow spurs of upland which intervene and project nearly half a mile beyond the rest of the bluff. It is quite evident that the recesses are due to undercutting by the river and that the curves correspond to the curves of the meandering current. As these loops have a radius which averages ten times the length of the radius of the meanders of the present stream, it is to be inferred that the cutting which produced them was done at a time when the volume of the water in the river considerably exceeded that of the present stream. This may have been coincident with a glacial advance, occurring after the deposition of the drift in this region.

In the southeastern corner of the county the valley of the East Nishnabotna river occupies an area of about seven square miles. Its flood plain is only some ten or twenty feet above that of the West Nishnabotna. The west bluffs run a course a little west of south from a point on the east line of section 24 in Wright township to near the southwest corner of section 35 in Waveland township. In the south part of the latter township this bluff has a long and low slope, but near the north line where the river is at present cutting under the base it is in places quite abrupt and nearly one hundred and fifty feet high.

Quite large plains, or bottom lands, have also been formed by the smaller streams. For the size of the streams these bottoms appear slightly wider in the western than in the eastern part of the county. East of Council Bluffs there is an abrupt narrowing of the valley of Mosquito creek, due to the presence of bed rock. The width is otherwise quite uniform for each stream, as may be seen from the following measurements:

AVERAGE WIDTHS OF FLOOD PLAINS OF THE CREEKS IN POTTAWATTAMIE COUNTY IN FRACTIONS OF A MILE.

NAME OF CREEK.	TOWNSHIP 77 N.	TOWNSHIP 76 N.	TOWNSHIP 75 N.	TOWNSHIP 74 N.
Walnut creek	....	....	One-fifth	One-fifth.
Graybill creek	....	One-fourth	One-fourth.	One-fourth.
Silver creek	....	One-fourth.	One-fourth.	One-third.
Middle Silver creek	....	....	....	One-third.
Keg creek	One-fifth.	....	One-fourth	One-half.
Mosquito creek	Two-fifths.	5-twelfths.	One-third.	One half.
Pigeon creek	One-third.	3-fourths.	....	....

The uniform width of the bottoms of these creeks is partly a result of the shape of their long and narrow basins, but it must also be regarded as a result of protracted work performed since the time when the cutting of these streams had backed up to their present heads.

The southward pitch of all these flood plains is very nicely adjusted to two factors. It diminishes with increase in the size of the streams, and, in case of the smaller streams, increases with the approach to a direction normal to the valley of the Missouri river.. Three instances may suffice for illustration:

PITCH OF FLOOD PLAINS IN POTTAWATTAMIE COUNTY.

	Pitch per mile.	Approximate length in miles	Trend in degrees from a line parallel with the Missouri.
Missouri river.	1.4	1,000	0°
West Nishnabotna	3.5	60	27°
Mosquito creek	5.4	42	50°

Uplands.—The main topographic feature of the county consists of an old drift plain into which the lowland plains just described have been cut and again partly filled. The surface of this drift plain has a general gentle slope to the southwest, the east end sloping more to the west. The average elevation of the plain above sea level, at each of the four corners of the county, is about 1,230 feet at the northwest, near Loveland, 1,330 feet at the northeast, in the vicinity of Walnut, 1,250 feet at the southeast, in Waveland township, and about 1,200 feet at the southwest, in the west part of Keg Creek township. This makes the general slope to the west along the north boundary of the county a little less than three feet per mile, and that along the south boundary slightly more than half a foot to the mile, while the descent from north to south along the west border is about one foot, and along the east border more than three feet to the mile.

The principal streams which cross the county from north to south divide this plain into a succession of broad, parallel swells, with a central divide and two gentle, lateral slopes, which lead down to the bluffs of the streams on either side. Along the two sides of the West Nishnabotna river this descent of the surface on the two adjacent swells back of the bluffs is from thirty to sixty feet in a mile. It should be understood, however, that this describes the general contours alone.

The surface of each swell is by no means an even arched plane. It consists rather, of a skeleton of ridges and divides which separate a multitude of small branching drainage lines, the deepest part of which lie from 50 to 200 feet below the divides. The greater part of the surface is thus taken up by slopes which run from the bottom of the draws to the top of the ridges. These slopes are therefore the most important of the topographic elements to be considered. With a range of from 50 to 200 feet of total descent, by far the greater number approach quite closely the height of 100 feet. The slopes exceeding this height occur close to the larger streams, in particular the Missouri, and those which come much short of it occur only near the headwaters of the smaller drainage lines. A vertical section of an average upland slope of this kind exhibits a double curve with a concave contour below and a longer convex contour above. An average of fifteen measurements on slopes taken in the region away from the Missouri river shows the pitch of the steepest part of the slopes to be about seven degrees from the horizontal, making a grade of about thirteen feet to the hundred. As the length of the whole slope ranges up to half a mile the average descent is considerably less.

The topographic features so far described may be regarded as being in the main the result of aggradation by the present drainage, which has reached a high degree of maturity. But there are a few features which must be looked upon as the result of other causes. While there is not an entire quarter section of land which is not invaded by some ramification of the drainage, there are a few ragged patches of flat upland. These probably constitute less than one-hundredth part of the total area of the drift plain. The largest tract of the kind is north of the upper forks of Graybill creek, south and northwest of the village of Walnut. Smaller tracts are seen at intervals along a line from one to four miles east of the bluffs of the Missouri river, as in the west tier of sections in Keg Creek township; in Secs. 13, 23 and 24, Tp. 75 N., R. XLIII W.;

in sections 8 and 17 in Boomer township; in the country from one to two miles east of Loveland; and notably in the uplands one or two miles east of Crescent. Still smaller and less perfectly level strips are found on the divides in sections 4, 5 and 18 in Norwalk township; in sections 32 and 33 in Neola township; in the country three miles northwest of Carson, above the headwaters of Mud creek; in sections 7 and 8 in Pleasant township, and between the upper forks of Indian creek in Waveland township. Excepting the flats nearest the Missouri bluffs it will be noticed that these tracts all occupy the divides which are farthest away from the principal streams. These no doubt represent the surface of a glacial drift plain, which elsewhere has been extensively changed by erosion.

The flat areas near the bluffs of the Missouri can probably not be accounted for in this way. At some points on these flats the surface rises in low, round swells, from ten to twenty feet higher than the surrounding flat and covering from twenty to forty acres of ground. These flats and swells are to all appearances an expression of the process of the deposition of the loess, which in this region has a thickness of from sixty to a hundred feet. This bluff border has other features which are peculiar. Approaching the Missouri from the east the upland streams become deeper and narrower in the last two or three miles from the flood plain. The slopes become steeper and may run down at last with an angle of twenty-five degrees, or even more, from the horizontal. Most of the divides contract to narrow ridges, which at last are barely wide enough to permit cattle to proceed in single file along their crests, when using them as the most convenient routes connecting different parts of a hilly pasture. Next the bluffs the land is a bewildering maze of ridges and ravines. The whole height of the ridges consist of loess, and the ravines only now and then cut into the bowlder clay. This topography is plainly a result of erosion, and everywhere are beautiful illustrations of carvings made by the present creeks and gullies. But even here we find some forms that suggest another origin. A few of the ridges rise and widen close to the very brink of the bluffs, and the ravines come out around them to the bottom lands by circuitous routes. In fact, the general descent of the upland to the Missouri river may be said to be interrupted at the outer border by an ill-defined and disjointed elevated edge, where some of the divides rise half a hundred feet above the height of the land to the east. The most pronounced development of this accentuated margin of the upland plain is seen in the bluffs near the southern boundary of the county, near the north city limits of Council Bluffs, in the region south of Crescent, and in the bluffs north and south of Honey Creek station. These border spurs appear particularly conspicuous above the angles between the principal creeks and the bluff line of the river. They are no doubt to be regarded as incidents intimately associated with the deposition of the loess, and their forms suggest a building up by deposition, rather than a carving out by erosion. Possibly they are the result of an accumulation of loess, which has taken place contemporaneously with the erosion.

Table of Elevations.—The following elevations of places in the county are taken from Gannett's Dictionary of Altitudes:

	A.T.
Avoca, C., R. I & P. R. R. track at depot	1,140
Carson, R. R. track at depot	1,066
Chautauqua	1,019
Council Bluffs, O. & St. L. and C., B. & Q. R. R. crossing	982
Council Bluffs, C., R. I. & P. and C, B. & Q. R. R. crossing	982
Council Bluffs, U. P. R. R., bridge abutments	1,033
Council Bluffs, track at U. P. R. R. depot	987
Council Bluffs, U. P. R. R. transfer station	984
Council Bluffs, low water, Missouri river	962
Council Bluffs, high water Missouri river	982
Council Bluffs, bench mark in stone door-sill of C., M. & St. P. R. R. round house, eight feet from south-west corner	982

	A. T.
Council Bluffs, copper bolt in stone, three feet from northwest corner of boat yard storehouse...........	976
Council Bluffs, copper bolt in stone in southeast corner of court house yard....	991
Crescent, C. & N. W. R R..................	990
Hancock, C., R I. & P. R. R.........	1,113
Harlan Junction, C., R. I. & P. R. R..................	1,137
Honey Creek, C. & N W. R. R	1,107
Honey Creek, top of bolt in west end of south bridge seat of plate girder, bridge No. 988, on C., & N. W. R. R.	1,005
Island Park, C, B. & Q R R.........................	975
Island Park, copper bolt in stone forty six feet east of K. C. & St. J., and C, B. & Q R. R. track..........	968
Loveland, C. & N. W. R R	1,004
Loveland, copper bolt in stone abutment on southwest corner of C. & N. W. bridge No. 979................	1,001
Mindon, C., R. I. & P. R. R............................	1,197
Neola, C., R. I. & P. and C., M. & St P. R. R. crossing..	1,101
Neola, C, M. & St. P. R. R............................	1,106
Oakland, C., R. I. & P. R. R	1,105
Underwood, C, M. & St. Paul R. R..................	1,073
Underwood, C, R. I. & P. R. R.......................	1,081
Walnut, C., R. I. & P. R. R...........................	1,284
Weston, C, R I. & P. and C., M. & St. P. R. R	1,045

HISTORY OF THE DRAINAGE.

From the foregoing description of the topography it is evident that its present character is chiefly a result of erosion. The author is inclined to regard it as in part, also, a result of atmospheric and fluviatile sedimentation, perhaps to some extent contemporaneous with the more important factor of stream erosion.

The general slope to the west is probably a feature inherited from preglacial times, the region being part of an ancient plain with gentle slope in that direction. But all of the minor features of this old plain are buried under the drift, and it is doubtful if any of them are reproduced on the surface of the heavy covering of Pleistocene deposits. From such data as have been secured bearing on the elevation of the old surface of the bed rock, it does not appear that the highest elevations of this surface coincide with the highest points of the land of to-day. In the northeast corner of the county bed rock appears at nine hundred and eighty feet above sea level, and in the southeast corner it rises a hundred feet higher. At Macedonia it is higher up than at Avoca. Our knowledge of the details of the topography of the preglacial land justifies no conjectures as to the preglacial valleys under the main drainage lines of the present surface, though such a correspondence has been made out for present drainage lines in some other parts of the state. The drainage of this region seems to have been developed after the deposition of the drift, mainly by deepening of the main channels and tributaries of streams which were established upon the disappearance of the ice from the region. The comparative width of these valleys and the almost universal erosion of the uplands testify to the long duration of this work. This county lies outside of the limits reached by the later drift sheets, the Wisconsin, the Iowan, and probably also the Kansan. While these drift sheets were being laid down farther north and east, this region was subjected to the work mainly of destructive forces. The intensity of their action may at times have varied, or the work may even have been suspended for a period, but during most of the time it appears to have been going on.

There is reason to believe, as already stated, that the course of the principal creeks and also of the greater number of their smaller affluents were determined before the ice had fully disappeared. This region lies toward the southwestern margin of the great central lobe of the glaciated area, and the direction of glacial motion was toward the same quarter, more or less parallel with the main drainage lines. Ice scorings in the valley of the West Nishnabotna run parallel with the general course of this stream. There is a gradual change in the course of the larger streams from only two or three degrees west of south in the east end of the county, to an average of thirty degrees west of south in the west end.

This suggests an approximation to the radii of motion in the ice field, and such an adaptation to this motion is noticeable in the whole southwestern part of the state. The close proximity of some of the creeks which have long and straight parallel courses, indicates that the plain on which these streams were first marked out must have had an unusually regular surface. It is probable that the surface of a great ice field would be more regular and hence more favorable for the inception of drainage systems of such regularity, than the surface of the drift after the ice was all removed. Middle Silver creek and Little Silver creek run side by side almost in a straight line for twelve miles and are less than two miles apart. The main fork of this creek and Middle creek run a parallel course for twice this distance, diverging slightly to the south, and are only from two to four miles apart. Mosquito creek and Keg creek run in long parallel curves for twenty-four miles up into Harrison and Shelby counties, and are only from four to five miles apart. While such an unusual regularity would be most likely to develop on the surface of a great ice field, it would hardly by itself be sufficient to suggest such an origin. But it is accompanied in this case by another persistently recurring feature in the secondary drainage lines of similar import. The greater number of these trend from northwest to southeast on both sides of the primary streams. The angles which the left tributaries make with the main trunk are obtuse, while the angles between the trunk and the affluents on the right side are acute. The tributaries from the southeast actually run on lines which are continuous with those of the tributaries coming from the northwest, though the streams run in opposite directions. The tree-like figure of each little drainage system is regularly unsymmetrical in such a way that the branches of the figure hang down on one side at just about the same angle as they point upward on the opposite side.

The branches of Mosquito and Honey creeks perhaps furnish the best illustrations of this habit, and, disregarding

Walnut creek, such examples are the rule rather than the exception in the tributaries of all the streams in the county. The lines on which the tributaries from the two sides of the streams run are sometimes also continuous, so that the two valleys from opposite sides of the main stream occupy, as it were, a common trough which crosses the valley of the main trunk diagonally, and which is interrupted by the divides between the drainage systems. The Honey creek and the Pigeon creek systems show this arrangement in several places. Again, we sometimes find that the lines of the right tributaries of one system are continuous with the lines of the left tributaries of the next system to the northwest. This relation obtains between some of the tributaries to Mosquito and Keg creeks in Norwalk township, between a few tributaries of Ballard and Graybill creeks in Knox and Layton townships, and between Graybill and Jordan creeks in the north part of Centre township. Indeed, there are instances where the secondary streams form continuous lines which cross no less than three different drainage systems. In the main, the drainage may be said to tend to have a latticed arrangement, where the heavy, continuous lines of the main streams run from north-northeast to south-southwest, and the faint, more interrupted and irregular lines of the tributaries run from northwest to southeast. It is also to be noted that the lines of the secondary streams are separated by intervals of quite uniform length. They are mostly about four-fifths of a mile apart.

Were this a driftless region such a feature of the drainage would best be explained as a result of the structure of the country rock. The drainage lines would be found to bear some constant relation either to the prevailing joint systems or to the strike and dip of the terranes. But in this county we find the bed rock deeply buried under glacial drift and consisting mainly of soft shales that lie in an almost horizontal position. It is improbable that the structure of this rock can in any way have determined the nature of the present drainage. It is well known, however, that glacial streams tend to take a course parallel with the ice movement.* This may account, as already indicated, for the direction of the main streams. For the inception of the secondary streams it would only require that there should be some slight ridging of the original surface in a northwest-southeast direction. Two conditions suggest themselves as competent for the production of such a ridging on the surface of the original drift plain. The retreat of the ice may have resulted in the production of a series of diminutive morainic elevations, or the surface of the ice fields may have been modeled into wavelike swells by the action of the atmosphere, as has been observed in the interior of Greenland. On an even surface, like that of an extensive ice field, it is evident that very small inequalities would suffice for determining the flow of surface water resulting from the melting of a stagnant glacier, and that once started, drainage lines on the ice would be apt to maintain themselves in their first channels until they were securely engraved in the drift below the melted ice.

Should the origin of the secondary streams not date as far back as to the time of the making of the drift plain, it seems that their regular direction and rhythmic repetition would have to be assigned to some cause connected with the deposition of the loess.

At the time the government land surveys were made, a good many bottoms of the larger streams as well as of small upland creeks, were less well drained than they are today and were marked as swampy tracts on the survey charts. Typical examples occur in the bottoms at the head waters of Little Silver creek, in York and Pleasant townships, and along the affluents of Middle Silver creek, in York and Washington townships. These lands have become dry pastures or fields, either by artificial means or by the natural cutting of channels by the streams below the surface of the flat bottoms, induced by the destruction of a rank native vegetation through pastur-

*The Glacial Gravels of Maine and their Associated Deposits. George H. Stone, U.S. Geol Surv., Monograph XXXIV, p. 320.

ing. Many small creeks which now have well established furrows twenty feet deep, requiring good bridges for the wagon roads, could be crossed by teams and heavy vehicles almost anywhere in the early days before the country was settled. In fact it seems that the conditions existing at that time rather favored the building up of the land over these bottom lands than a lowering of their surface by erosion.

"Cat-steps" is a local name given to an irregular, stair-like configuration of the surface sometimes seen on the steeper part of the loess covered slopes. They constitute a minor local topographic feature. Each step is a line of recent faulting or slipping of the loess, which has crept down the slope. The displacement may amount to as much as two or even three feet in the vertical direction. One "step" forms a gentle curve which runs parallel with the sides of the hill. The curve itself is a succession of smaller jagged turns and bends. The steps usually follow one below the other at intervals of from one to five feet. A chance observation in the grading of a wagon road exhibited plainly the fault plane below the surface. There is good reason to believe that this faulting is a result of a gradual recent diminution of the ground water in the loess, causing this to shrink somewhat in bulk. It has made its appearance with the slow drying up of shallow wells and swampy draws. "Cat-steps" are most common in the north west part of the the county. A similar slipping or faulting of the loess is sometimes seen on a larger and more regular scale in the face of the bluffs of the Missouri river.

STRATIGRAPHY.

General Statement.

The oldest rocks which are exposed in the county belong to the Coal Measures. These extend down at least a thousand feet below the surface and are found in most places at a depth of less than three hundred feet. They apparently lie in an almost horizontal position but are probably tilted slightly to the southwest. In the southeastern part of the county, and at a few other points, the Coal Measures are overlain by some remnants of soft sandstone and shale of Cretaceous age, probably ranging from ten to one hundred feet in thickness. These two formations may be regarded as constituting the country rock. On their surface there may rest some buried and insignificant remnants of Tertiary deposits, but they are otherwise covered directly by the drift. The latter averages slightly more than two hundred feet in thickness for the whole county, and consists of about one hundred and forty feet of bowlder clay and sixty feet of loess. In the valleys of the creeks and rivers, which have almost everywhere eroded the drift, we find the still later deposits of alluvium. The succession of these several members is indicated in the following table:

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial.
		Glacial.	Loess. Pre-Kansan.
	Tertiary (?)		Equus Beds (?)
Mesozoic.	Cretaceous.	Dakota.	Nishnabotna.
Paleozoic.	Carboniferous.	Upper Carboniferous.	Missourian.

Deep Explorations.

Five artesian wells which have been sunk in Council Bluffs have supplied some data on the strata below those exposed in natural sections. Two of these wells were drilled by Mr. Conrad Geise at his old brewery on Upper Broadway. Mr. Robert F. Rain, who superintended the work, has furnished the following memory statement as to the nature of the materials which were penetrated:

		FEET.
1.	Surface silt (loess ?)	55
2.	Bowlder clay	5
3.	Limestone, easy to drill	12
4.	Shale, about	250
5.	Limestone, probably largely like shale, with iron pyrites in the lower part, about	330
6.	Dark carbonaceous material giving off gas when retorted, about	8
7.	Shaly material, about	340
8.	Gray sandstone	114
	Total depth	1,114
	Elevation of curb of well	1,030 A .T

At the round house of the Milwaukee railroad another well has been drilled to a depth of 750. Messrs. W. H. Gray & Bros. of Chicago, who drilled this well, state that they went through the following strata:

		FEET.
1.	Drift	70
2.	Lime rock	100
3.	Shale	480
4.	Sand rock	100
	Total depth	750
	Elevation of curb of well	980

At the Iowa School for the Deaf and Dumb two deep wells have been drilled and the present superintendent, Mr. H. W. Rothert, has kindly furnished the following "copy of a memorandum as to the artesian well" (the well last made):

		FEET.
1.	Surface material	90
2.	Shale	300
3.	Sand	80
4.	Lime rock	100
5.	Shale	250
6.	Lime rock	100
7.	Sand rock	40
8.	Lime rock	50

		FEET.
9.	Sand rock	30
10.	Shale	35
11.	Some sandstone	25
	Total depth of well	1,100
	Elevation of curb of well about	1,010 A. T.

In the museum of this institution there is preserved a set of drillings from the same well. These were examined by the writer and found to be mostly shale with some limestone and sandstone, as below.

DESCRIPTIONS OF DRILLINGS FROM AN ARTESIAN WELL AT THE IOWA SCHOOL FOR THE DEAF AND DUMB.

		DEPTH.
1.	Lavender colored shale, not calcareous	290
2.	Calcareous bluish shale, with some small chips of limestone	325
3.	Blue, tough, calcareous shale	355
4.	Calcareous blue shale, with some chips of limestone	400
5.	Blue shale, not calcareous, with a few chips of limestone	470
6.	Red calcareous shale or marl	500
7.	Very faintly calcareous, bluish gray shale	630
8.	Gray quartz mixed with some calcareous grains	745
9.	Greenish shale, with some fragments of limestone	810
10.	Dark limestone mixed with some shale and sand	860
11.	White calcareous fragments and grains of transparent and of milky quartz, ground up	920
12.	Gray shale, slightly calcareous	980

Besides these there were three more samples taken at unknown depths, two consisting of a pure white limestone cut up into thin chips, and the other being a yellow limestone, ground rather fine.

It will be noticed that the records from the different wells differ greatly, almost too much to be correlated as sections of the same series of rocks. The record from the old brewery wells was given from memory and the great thickness of the middle limestone may be in part an exaggeration. The record from the well belonging to the Milwaukee railroad mentions no limestone at the same depth, but a gentleman who watched the work states that there was considerable limestone above the sand in which water was obtained. The record of the well at the School for the Deaf and Dumb is from notes taken at the time the well was made and is verified by a set of samples of drillings. The limestone in numbers 4 and 8 of the descriptive record corresponds to calcareous shales or marly rock in the samples (numbers 6 and 12). Such rocks as have been explored here could hardly fail to be reported differently by different drillers, for they consist, in the main, of shales which graduate on the one hand into limestone, and on the other, into sandstone*.

Making due allowance for all sources of error in the data at hand it is apparant that there is about 1,000 feet of rock belonging to the Upper Carboniferous underlying the lowest exposures in the county. The upper 300 feet consist of shaly beds with some layers of limestone, the next 200 feet is probably also shaly, but with beds of limestone and sandstone; then there is again some two or three hundred feet of shaly beds, which are followed by alternations of sandstone and limestone, with some shale, extending as far down as the explorations go. There can be no doubt that the sandstone which furnishes the water belongs to the Des Moines stage, and the limestones which lie 500 feet below probably represent the Pennsylvanian. From two to three hundred feet of the upper part of the section apparently belong to the Missourian stage.

CARBONIFEROUS.

THE MISSOURIAN.

There are only a few places in the county where strata of the Missourian stage are exposed. These are in the south part of the valley of the West Nishnabotna and in the bluffs of the Missouri south of Crescent. There is also an old quarry in these beds in the lower part of the valley of Mosquito creek.

*Compare record of boring in Omaha, Report on the Paleontology of East Nebraska, etc., F. B. Meek, pp. 87-88.

Beginning farthest south, in the valley of the West Nishnabotna, we find some rock coming out under the foot of the receding point of the bluffs in the Nw. ¼ of the Sw. ¼ of Sec. 27, Macedonia township. This is near the location of the old Carter and Doland mill. The beds seen at this place are as follows:

SECTION NEAR THE OLD MILL SITE, MACEDONIA.

		FEET.
6.	Yellow marly shale with *Ambocœlia umbonata*, and *Chonetes granulifera*	2.6
5.	Blue shale	.9
4.	Bluish, dark compact limestone, apparently structureless, with occasional joints of crinoid stems and *Ambocœlia planoconvexa*, *Athyris subtilita* (large), *Pinna peracuta*, *Productus nebraskensis*, *P. longispinus*, *Rhombopora lepidodendroides*, *Polypora submarginata*, *Fistulipora nodulifera*, *Pinnatopora*	1
3.	Yellow shale	3
2.	Bluish gray limestone	5
1.	Yellow shale	5

At the northeast corner of Sec. 27 and the soutwest corner of Sec. 22, in the same township and range, rock has been quarried at intervals in the foot of the north bluff of the river for a distance of nearly a quarter of a mile. The following section appears:

SECTION IN TOMPKIN'S QUARRY NEAR MACEDONIA.

		FEET.
5.	Dark gray limestone, in thick layers above, where abundant irregular concretions of black chert occur: fossils: *Athyris subtilita*, *Productus costatus*, *P. cora*, *P. nebraskensis*, *P. pertenuis*, *Fusulina*	4
4.	Disintegrated limestone or marly shale with *Chonetes granulifera* and *Fusulina cylindrica*	1.5
3.	Hard, dark and gray limestone	1.5
2.	Gray marly shale with numerous fossils above	5
1.	Yellowish white and soft limestone with *Fusulina* in abundance (not well exposed)	1

The lowest number has been the main quarry rock. The beds above are frequently much weathered so as not always to appear in the section in full thickness. Number 2 is quite marly and contains more fossils above than below. On the old dumps along the quarry there were seen a number of fossils which evidently came from this shale.

Near the northwest corner of Sec. 23, in Macedonia township, there is a quarry belonging to Mr. John Martin, in which the same beds are exposed.

SECTION IN JOHN MARTIN'S QUARRY.

		FEET.
8.	Drift.	
7.	Traces of a weathered shale.	
6.	Hard, compact, structureless, gray limestone with occasional crinoid stems and other fossils. *Lophophyllum profundum*, *Bellerophon carbonaria*, *Seminula argentea*, and *Peripristis semicircularis* were noted. The rock is also characterized by the presence of occasional irregular curving layers of a finely laminated calcareous material which has a texture simulating organic structure	1.3
5.	Grayish, light marly shale with many fossils and containing occasional small irregular crevices filled with white calcareous flour The following fossils were noted: *Ambocœlia planoconvexa*, *Archæocidaris*, *Aviculopecten carboniferus*, *Chonetes granulifera*, *Derbya crassa*, *Erisocrinus typus(?)*, *Fusulina cylindrica*, *Lophophyllum proliferum*, *Productus longispinus*, *Rhombipora lepidodendroides*, *Seminula argentea*	5.
4.	Dark and greenish shale, not calcareous in its lower part and almost without fossils	4.
3.	Marly white limestone with *Fusulina* in abundance	6.
2.	Three ledges of gray, somewhat compact limestone, each about a foot in thickness. These are separated by thin seams of soft marly material. The upper ledge has dark nodules of chert which contain numerous small fragmen's of organic structures	3.
1.	Yellow limestone of soft texture with many fusulinas, exposed	3.

About two feet of the lower ledge in this section is again seen in the bed of a small creek about a quarter of a mile to the northeast of this quarry. It is here a bluish gray limestone and contains a *Pinna*, frequent small specimens of *Fusulina cylindrica*, and some crinoid stems.

In the Sw. ¼ of the Sw. ¼ of Sec. 14, Macedonia township, Mr. Hartson Bryant has for many years quarried rock from some ledges which in part are the same as numbers 1 and 2 in John Martin's quarry, and in part consist of a ledge below this.

SECTION IN HARTSON BRYANT'S QUARRY.

	FEET.
3. Somewhat compact limestone with quite frequent fragments of crinoid stems	1.5
2. Rather soft, yellowish white, limestone with *Fusulina cylindrica* in abundance, also *Pinna peracuta*	3.5
1. White, slightly more indurated limestone, with *Lophophyllum profundum* and *Fistulipora nodulifera*. The latter fossil in irregular masses, as much as two inches in diameter	2.

On the west line of the Ne. ¼ of the Se. ¼ of Sec. 10, in the left bank of the West Nishnabotna, the bed rock is being cut into by the river and is exposed when the water is low. The entire section is less than four feet.

SECTION IN THE RIVER BED SOUTH OF CARSON.

	FEET.
2. Black carbonaceous shale splitting into very thin laminæ. (Among the shingle of this slate there were found several specimens of *Campophyllum torquium*, one *Aulopora*, and some of *Lophophyllum profundum*)	2.
1. Bluish gray, soft limestone in layers from two to four inches thick and broken into rectangular or rhomboidal blocks by numerous joints of two quite uniform directions. This rock contained many fossils, among which were identified *Fusulina cylindrica*, *Chonetes glaber*, *C. granulifer*, *Productus cora*, *P. costatus*, *Seminula argentea*, *Aviculopecten occidentalis*, *Edmondia*, sp. *Schizodus wheeleri*, another small lamellibranch, and *Bellerophon crassus*. Some of the fossils were preserved only as casts. This limestone contained one thin layer which was filled with *Chonetes*	1.5

Only a few rods to the southeast of here on the other side of the railroad and twenty-five feet above the river bed, a shaft was sunk some years ago in search of coal. The materials explored are given in the following section, as reported:

SECTION OF ROCKS EXPLORED SOUTH OF CARSON.

		FEET.
6.	Loess	10.
5.	Pebbly clay	16.
4.	Black "slate"	4.5
3.	Hard shale or limestone (explored mostly by drilling)	80.
2.	Shale	28.
1.	Black slate	1.

It is quite evident that the black shale (4) and the shaly limestone (3) in this shaft are the ledges exposed in the stream close by. On the old dump of the excavation there were seen *Fusulina cylindrica*, *Aulopora*, sp., *Campophyllum torquium*, *Lophophyllum profundum*, *Ambocœlia planoconvexa*, *Chonetes granulifer*, *Derbya crassa*, *Hustedia mormoni*, *Pugnax uta*, *Spirifer cameratus*, and *Spiriferina kentuckiensis*.

Most of these apparently came from the shale (4).

Under the base of the bluff west of the river and north of the mill, in the Se. ¼ of the Se. ¼ of Sec. 3, Carson township, rock has been quarried in several places from some beds of limestone, whose weathered and eroded edges barely come into view. The land where quarrying is carried on at present belongs to Mr. David Snapp.

SECTION SEEN IN DAVID SNAPP'S QUARRY.

		FEET.
6.	Hard, strong gray limestone with many frequent fragments of brachiopods and crinoid stems and containing *Spirifer cameratus*, *Productus nebraskensis*, *Athyris subtilita* (large) and some *Bryozoa*	6.
5.	Indurated gray shale	.7
4.	Dark, soft limestone of rather fine and uniform texture, but varying in color from gray to black, containing *Productus nebraskensis*, *P. costatus*, *Chonetes glabra*, *Ambocœlia planoconvexa*	1.
3.	Shale	.5
2.	Impure, fine grained, soft, and dark limestone	.5
1.	Greenish gray shale, exposed	2.

The same ledges have been quarried half a mile farther north (Schreinert's old quarry), but the bank is now covered with debris and the rock could not be found in place. In some loose fragments of yellow limestone *Chonetes granulifera*, *Aviculopecten carboniferus*, *Productus nebraskensis*, *Ambocœlia planoconvexa*, and spines of an *Archæocidaris* were noted.

In the town of Carson Mr. J. W. Everson was sinking a well on the edge of the bluff north of Broadway street at the time of the author's visit. Bed rock was encountered at a depth of thirty feet. This consisted of limestone and shale as follows:

SECTION IN J. W. EVERSON'S WELL AT CARSON.

		FEET.
5.	Limstone, with some chert	2.
4.	Gray shale	1.
3.	Light colored shale	2.
2.	Blue shale	2.5
1.	Bluish gray limestone, consisting of an indurated compact mass of minute particles of organic structure. Imbedded in this are many larger fragments, such as bits of bryozoan skeletons, shells and crinoid stems. The largest of these are usually surrounded by an incrustation consisting of thin concentric layers of white structureless calcite. Occasionally there are small grains of iron pyrites	2(?)

In the material taken out of this well were seen *Fistulipora nodulifera*, *Ambocœlia planoconvexa*, *Chonetes granulifera*, *Derbya crassa*, *Dielasma bovidens*, *Hustedia mormoni*, *Productus cora*, *P. nebraskensis*, *P. pertenuis*, *Pugnax uta*, and *Seminula argentea*. Most of these fossils. if not all, were from the shale above the lower limestone.

In the north bank of the West Nishnabotna river about twenty rods west of the center of section 22, Macedonia township, there were seen some blocks of limestone and some lumps of black shale which had evidently not been far removed from their ledge. Probably they were almost in situ in the bed of the stream at that place.

The localities enumerated above include all known exposures of the country rock in the valley of the West Nishnabotna in this county. From this river westward the drift is less deeply eroded, and no more rock is seen until we approach the Missouri river. On the left bank of Mosquito creek, near the center of the west line of Sec. 21, Tp. 75 N., R. XLIII W., there are some excavations which were made in quarrying limestone many years ago. The strata are not now well exposed and no quarrying has been done for many years. In White's report* the rock is described as consisting of about seven feet of limestone with marly partings. Some of the upper layers are said to have been flinty. From specimens picked up on the site of the quarry it appears that the limestone at this place is of two kinds. One chip consisted of indurated, calcareous, fragmental rock of fine texture, in which the fragments are largely composed of some organic structure. These are more or less rounded by trituration, and are sometimes surrounded by a thin accretive crust of structureless calcite, and then resemble incipient oolitic grains. These minute fragments are buried in a structurless and opaque cementing matrix of the same composition. A considerable number of the organic particles consist of small, unbroken fusulinas, which seldom have a diameter of more than one-half of a millimeter. The other type of limestone represented in the fragments likewise had a clastic, compact structure, in which larger fragments of shells and joints of crinoid stems are firmly imbedded in a copious matrix composed mostly of very minute calcareous particles. Both of these phases may be said to resemble the fine coral sand of the ocean, excepting that most of the fragments are perhaps not from corals but from other organisms, and that the sand has been thoroughly solidified in a hard matrix, which was laid down with the sand or which may have been introduced later by percolating water. The two phases of

*Geology of Iowa, C. A. White, 1870, vol. 1, p. 379.

the rock described above differ mainly in the perfection of the sorting of the fragments.

In the Se. ¼ of Sec. 27, and in the Ne. ¼ of Sec. 34, Crescent township, beds of limestone and shale are almost continuously seen at the base of the bluffs of the Missouri river for a distance of three-fourths of a mile, rising about twenty feet above the plane of the adjacent bottom land. Some quarrying was done at this place several years ago and the exposures show a succession of beds nearly twenty feet in thickness.

GENERAL SECTION IN SECTIONS 27 AND 34, CRESCENT TOWNSHIP.

		FEET.
5.	Yellowish and gray limestone in ledges from six inches to one foot in thickness, compact near the base, occasionally brecciated, and at times having a finely oolitic texture. A polished specimen of this rock is seen to consist of rounded and incrusted calcareous fragments imbedded in a matrix of almost transparent crystalline calcite. The fragments are of different sizes. Some have a diameter of nearly a millimeter, and these are mingled with others of about one-fifth that diameter. Most appear elliptical in section. Some of the large fragments have a nucleus with a structure like a fragment of *Stictopora*. A few still larger fragments were pieces of small shells. This specimen also exhibits several small, crooked joints or fissure veins filled with pure crystalline calcite. Another specimen appeared to the unaided eye as an ordinary compact gray limestone, but was seen, under a lens, to be fragmental, consisting largely of small fusulinas, some of which were surrounded by a thin calcareous crust. These, together with finer fragmental material, were imbedded in a structureless calcareous matrix. Occasionally the fragments were welded together as if by partial solution and redeposition of this substance. Minute crevices and veins were abundant everywhere, filled with crystalline calcite. There were also frequent plain evidences of small faulting and brecciation by fracture..................................	5
4.	Yellow shale..	2

	FEET
3. Yellowish gray limestone, with occasional fusulinas, compact in texture above but occasionally oolitic below, in some places quite soft. Contained *Allorisma subcuneata*................................	2
2. Blue shale with numerous fossils and occasional crystals of selenite. The fossils observed were: *Fusulina cylindrica* (small size), *Archæocidaris triserrata*, *Eupachycrinus verrucosus*, *Erisocrinus typus*, *Fistulipora nodulifera*, *Rhombopora lopidodendroides*, *Chonetes granulifer*, *Meekella striatocostata*, *Productus cora*, *P. costatus*, *P. nebraskensis*, *Seminula argentea*, *Spirifer cameratus* (large).....	5
1. A simple massive ledge of fine-grained oolitic limestone, seen to contain a species of *Chenomya*, *Bakevellia illinoienses* (?), and having on its upper surface partly imbedded, *Axophyllum rude*, *Lophophyllum proliferum*, *Athyris subtilita*, *Productus cora*, and frequent crinoid stems. In a thin section of the rock in this ledge the oolitic spherules are seen to be imbedded in a transparent matrix of crystalline calcite. They average about one-fourth of a millimeter and barely fall below the limit of ready recognition to the unaided eye. The macroscopic aspect of the rock is that of an ordinary fine granular limestone. The rounded grains are usually elliptical in section and they sometimes have a crystalline, transparent nucleus. In other cases the nucleus is a minute organic fragment, such as a tiny bit of fusulina or of the joint of a crinoid stem. These nuclei are surrounded by an opaque crust of structureless calcite, about one-fortieth of a millimeter in thickness. Exposed....	3

So far as the author is aware the localities above described include all exposures of the Upper Carboniferous rocks in the county. Some of the wells have penetrated these beds below the ledges exposed to a depth of from twenty to nearly 200 feet. The descriptions of the strata explored in these wells is found in the table of wells on a subsequent page, under Nos. 1, 5, 6, 23, 30, 32, 38, 41, and 57. By referring to this table it will be seen that the strata thus explored consist in the main of shale with some ledges of limestone. At Carson and Macedonia a thin seam of coal was found at a depth of some 120 feet below the limestone in the quarries, and some 930 feet above sea level. Near Minden a like seam was encountered at about 990 feet above the sea level. This was overlain by a few feet of hard, fragmental limestone and then sixty feet of shale, after which followed some hard chert-bearing rock. The Avoca wells encountered limestone almost on a level with the quarries farther south, and this was succeeded below by about seventy feet of shale. Combining these records with the known exposures around Macedonia and Carson we can construct a section of about 150 feet of the Missourian in the West Nishnabotna valley, in this county. This general section is as follows:

GENERAL SECTION OF THE MISSOURIAN IN THE VICINITY OF MACEDONIA.

		FEET.
10.	Cherty limestone with many producti	4
9.	Shale	1.5
8.	Blue, hard limestone	1.5
7.	Shale, marly and fossiliferous above	5
6.	Limestone, characterized by abundant fusulinas and a large nodular *Fistulipora nodulifera*	8
5.	Shale (thickness unknown)	5(?)
4.	Black, fissile, carbonaceous shale, with a fauna including several corals	3
3.	Soft limestone, with a fauna characterized by a large proportion of lamellibranchs	2(?)
2.	Shale, with some layers of soft limestone in the upper part and probably some limestone farthest down	120
1.	A thin seam of coal	1

Correlations.—The observations made in this survey verify the conclusions of previous observers in this region to the effect that all of the Coal Measure rocks exposed belong to the Missourian stage (see table of fossils). It may further be stated that the rocks in the general West Nishnabotna section are the equivalents of the beds exposed in Stennett's quarry in Montgomery county. Even the individual beds in the two sections can be correlated with certainty. The Stennett quarries were examined by the author, in company with Dr. Calvin, and the following parallel between the two localities was easily made out.

GENERAL SECTION NEAR MACEDONIA.	SECTION AT STENNETT'S QUARRY.*
No. 10 same as	No 10
" 9 " "	" 9
" 8 " "	" 8
" 7 " "	" 7
" 6 " "	1, 2, 3, 4, 5, 6

The relation between the ledges exposed near the Missouri river and those of the Macedonia section is not quite so clear. White's statement† that the Mosquito creek quarries were in the same ledges as those exposed in the bluff south of Crescent, is corroborated by the observation on the lithological character of the ledges. At both places there is an oolitic limestone of fine texture. But there are no exposures which enable us to connect this Missouri river section with that made out for the country to the east. It cannot be established with certainty whether the limestone at Crescent is an equivalent of that seen in the valley of the West Nishnabotna, or if it is not, whether it underlies or overlies the latter. Still, there is some reason to think that it is higher up in the section than this.

In his "Report on the Palæontology of Eastern Nebraska" Prof. F. B. Meek has given the record of a deep boring at Omaha, extending four hundred feet below the surface.‡ Number 2 in this section is "doubtless the rock quarried below the city." From his description of the rock in this quarry (p. 86) it is quite evident that it is identical with the ledges near Crescent. The record of the Omaha well shows that there is another limestone, with carbonaceous material below, at a depth of about seventy-four feet. This is followed by a hun-

*Lonsdale, Iowa Geol. Surv., vol. IV., p. 392.

†See Geology of Iowa, vol. I, p. 379.

‡Final Report of the U. S. Geological Survey of Nebraska, F. V. Hayden, Washington, 1872, p 87.

dred feet of shale, under which there is another limestone with some shale and a thin seam of coal. This makes a succession of beds quite like that in the general section at Macedonia. Meek's number 22 in the Omaha well seems to correspond to our number 1, his number 13–21 to our number 2 and 3, his number 12 to our number 4, and his number 10 to our number 6. If this correlation be correct the Crescent limestone would lie about fifty feet above the quarry rock at Macedonia and Carson. In sinking the piers of the Union Pacific railroad bridge at Omaha a limestone was found at depths averaging seventy feet below the river. This is no doubt Meek's number 10. It should be the quarry ledges at Macedonia, if our interpretation as given above is correct.

It is to be noted also in this connection that of the twenty fossils observed near Crescent, eight forms are different from those found near Carson and Macedonia.

In Page county Dr. Calvin has found that the horizon of the Nodaway coal is 120 feet below the Stennett quarry beds. The carbonaceous shale and coal at the same depths at Macedonia and Carson probably represent the same horizon in Pottawattamie county.

LIST OF FOSSILS OBSERVED IN THE MISSOURIAN IN POTTAWATTAMIE COUNTY BY J. A. UDDEN.	Macedonia Mill.	Thompkins' Quarry.	Martin's Quarry.	Ravine, Secs. 14 and 23, Macedonia.	Bryant's Quarry.	River bed, Carson	Coal Exploration.	David Snapp's Quarry.	Schreinert's Quarry.	Carson Well.	Crescent Quarries.	Henton, Mills County.
Foraminifers—												
Fusulina cylindrica Fischer		†	†	†	†	†	†				†	
Anthozoans—												
Autopora, sp						†	†					
Axophyllum rude White & St. J											¶	
Campophyllum torquium Owen						†	†					
Lopophyllum profundum E. & H		†	†		†	†	†		†		†	
Echinoderms—												
Archæocidaris		†			†				†			
Archæocidaris edgarensis Worth. & Mill												†
Archæocidaris triserrata Meek											¶	

LIST OF FOSSILS OBSERVED IN THE MISSOURIAN IN POTTAWATTAMIE COUNTY BY J. A. UDDEN.	Macedonia Mill	Thompkins' Quarry.	Martins' Quarry	Ravine, Secs. 14 and 23, Macedonia.	Bryants' Quarry.	River bed, Carson.	Coal Exploration	David Snapp's Quarry.	Schreiner's Quarry.	Carson Well.	Crescent Quarries.	Henton, Mills County.
Echinoderms—Continued—												
Archæocidaris (jaw plate), sp											¶	
Erisocrinus typus Meek & Worth			†								†	†
Eupachycrinus verrucosus White & St. J											¶	†
Hydreiocrinus mucrospinus McChesney		†										
Bryozoans—												
Fenestella shumardi Prout (?)					†							
Fistulipora nodulifera Meek	†	†			†					†	†	†
Pinnatopora, sp	†											
Polypora submarginata Meek	†	†			†							
Rhombopora lepidodendroides Meek	†	†	†								†	†
Brachiopods—												
Ambocoelia planoconvexa Shumard	†	†	†				†	†	†	†		†
Chonetes glaber Geinitz						†		†				
Chonetes granulifer Owen		†	†			†	†		†	†	†	†
Derbya crassa Meek & Heyden		†	†				†			†		†
Dielasma bovidens Morton					†					†		
Hustedia mormoni Marcou		†			†		†			†		
Martinia contracta Meek & Worth		†										
Meekella striato-costata Cox					†						†	
Productus cora D'Orbigny		†				†				†	†	
Produstus costatus Sowerby		†				?		†			†	†
Productus longispinus Sowerby	†	†	†		†							
Productus nebraskensis Owen	†	†						†	†	†	†	
Productus pertenuis Meek		†								†		†
Pugnax uta Marcou		†			†		†			†		
Rhipidomella pecosi Marcou					†							
Seminula argentea Shepard	†	†	†		†	†		†		†	†	†
Spirifer cameratus Morton		†			†		†	†			†	†
Spiriferina kentuckiensis Shumard						†		†				
Lamellibranchs—												
Allorisma subcuneata Meek & Hayden											¶	
Aviculopecten carboniferus Stevens			†						†			
Aviculopecten occidentalis Schumard						†						
Bakevellia illinoiensis Worthen (?)											¶	
Chenomya, sp											¶	
Edmondia, sp						†						
Pinna peracuta Schumard	†			†	†							
Schizodus wheeleri Swallow						†						
Gasteropods—												
Bellerophon carbonaria Cox			†									
Bellerophon crassus Meek & Worthen						†						
Straparollus catilloides Conrad											¶	
Vertebrates—												
Teripristis semicircularis N. & W			†									

¶ Species thus marked were observed in the Crescent quarries only.

Geographical Conditions.—The geographical conditions prevailing here at the time the Missourian deposits were made are indicated by the nature of the beds as well as by the imbedded fossils. The fauna is not littoral, but rather off-shore. Attached forms, such as can be safe only in the quiet depths of the sea, are well represented. The persistence of single ledges of limestone and thin beds of shale over distances of many miles, as shown in the Stennett and Macedonia quarries, requires a uniformity of conditions which could not exist in the sea except at some distance from the shore. Oscillations of the land are indicated by the frequent changes from calcareous to clayey, to sandy, and to carbonaceous deposits. The ocean bottom was probably still sinking when the uppermost beds of our section were made.

Cretaceous.

In time, the bottom of this Missourian sea was again elevated and the land area was extended farther to the southwest. This happened sometime during the Triassic or Jurassic age. The new land was promptly submitted to the action of destructive agencies, and much of it was again carried out into the receding sea, forming, perhaps, part of the Jura-Trias terranes of the southwest. Then this region was again submerged, and the sea advanced beyond it an unknown but considerable distance to the north and east. Thus we find the old eroded land surface of the Missourian overlain by the littoral deposits of this new sea.

The unconformability between the Carboniferous and Cretaceous systems is not seen at any place in this county, but it is well known that there is such an unconformability in other localities. Evidence of its existence is, however, not entirely lacking. In a well (see table of wells, number 57) in the south-eastern part of the county the Carboniferous rises to an elevation of 1,130 feet above sea level, while in another well not far off, the Cretaceous sandstone stands at an elevation of 1,025 feet above sea level. This indicates a buried hill or ridge of the old land, for in this region the Carboniferous strata are, to all appearances, quite undisturbed and lie in an almost horizontal position.

The principal exposures of the Cretaceous are in the west bluffs of the Nishnabotna in the southeastern part of the county. Near the center of the north line of the Ne. ¼ of Sec. 36, Wright township, the north bank of a ravine which

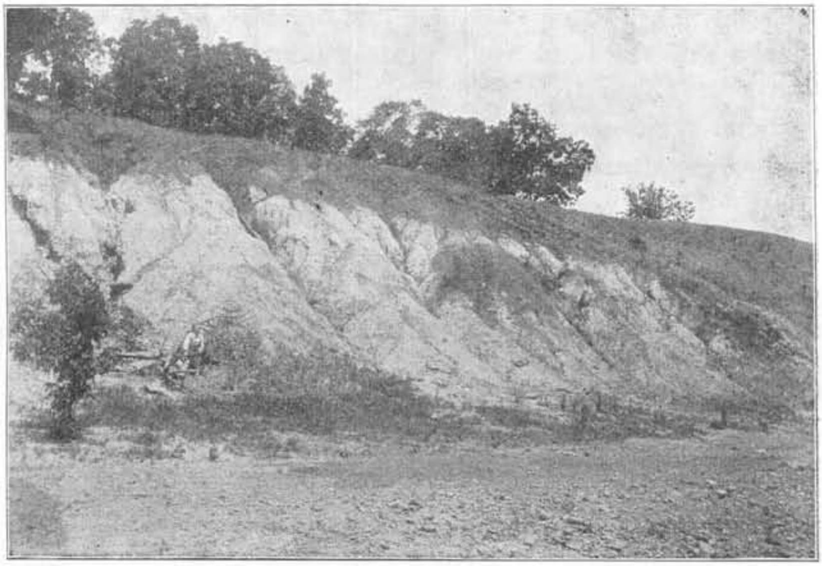


FIG. 13. Exposure of Cretaceous clay with concretions of clay ironstone, north line of the Ne. ¼ of Sec. 36, Wright township. Photo by J. L. Oakleaf.

comes down from the upland consists of a bluish gray clay or shale rising about thirty feet above the bed of the little stream. The top layer has a tinge of purple and red and along some seams of coarser texture it has a yellow color. The bedding is somewhat irregular. Some layers are sandy and these are in places partially indurated. Near the middle of the slope there is a dark carbonaceous streak. In this there were found some imprints of netted-veined leaves, which were coated with a thin film of carbonaceous material. Close by there were also found imbedded small pieces of wood in the state of charcoal. At several points on the bank were a number of large concretions of siderite, varying from four inches to three feet in diameter and flat and irregular in shape. Their surface is red and oxidized to a depth of half an inch, and their interior is frequently cut in different directions by wide shrinkage cracks. The surface of these cracks is covered by a glistening, thin, brown coating of iron oxide. In some

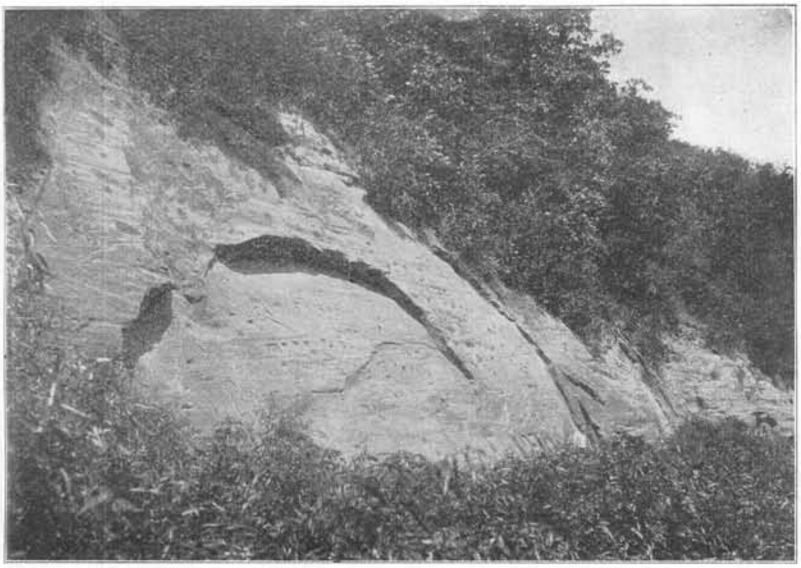


FIG. 14. Nishnabotna sandstone in west bank of the river on the Ne. ¼ of Sec. 36, Wright township. Photo by J. L. Oakleaf.

instances they were found to be filled bv pure white crystalline calcite. Some slight exposures of this same clay occur along the wagon road which leads north from here. It evidently underlies a part of the high bottom which follows the foot of the bluffs in that direction. Some low, mound-like elevations on this terrace appear to be made up of the same material.

Along the west line of the same quarter of the same section (Ne. ¼, Sec. 36, Wright township) there is a long escarpment of sandstone running nearly due north and south for more than a quarter of a mile, facing the river, and forming its west bluff. At its greatest height it rises nearly fifty feet, measured from the lowest ledge seen in a vacated bed of the stream. This sandstone is of very uniform, fine texture, of a gray or pure white color and quite friable, so as to be readily crushed in the hand. At its most northern exposure the

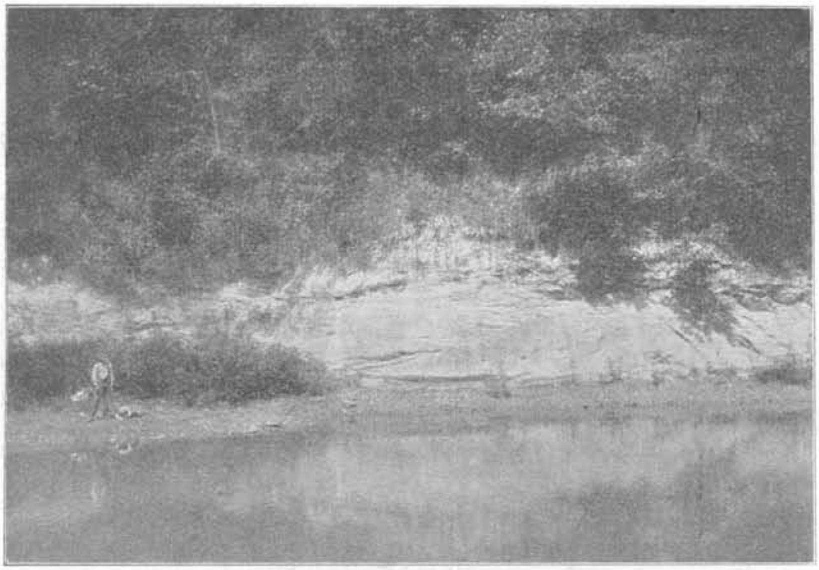


FIG. 15. Change from sand below to clay above, in the Cretaceous deposits in the west bank of the East Nishnabotna river, near the center of the north line of Sec. 1, Waveland township. Photo by J. L. Oakleaf.

whole thickness is almost a single ledge, though a thick stratum near the middle is obliquely bedded.

Following the escarpment southward the sandstone was seen to be overlain by the clay described above. The top of the sandstone descends so as to be only about ten feet above the water in the river and gives place to the argillaceous stratum, which again appears, and is not far from thirty feet in thickness. Still farther south, near the center of the north line in Sec. 1 of Waveland township, the sandstone is once more exposed in the river, rising only five feet above the water. On top of it there rests forty feet of light gray clay or shale, in which there are also some seams of fine sand.

The general section made out from these localities is as follows:

GENERAL SECTION OF THE CRETACEOUS DEPOSITS IN THE WEST BLUFFS OF THE NISHNABOTNA.

		FEET.
3.	Grayish white or dark clay, weathering yellow and red, with occasional streaks of fine sand and of dark carbonaceous seams, and with concretionary lumps of siderite	37
2.	Alternations of clay and fine sand	3
1.	Fine white or gray sandstone, of very uniform texture, and in part oblique bedded	42

The clay has not been observed at any other localities than those mentioned above. But two more outcrops of the sandstone were seen. One is eleven miles away to the southwest, and is in the right bank of a ravine a few rods east of the road bridge near the south corner of Sec. 28 of Grove township. Only a few square yards of the rock are in view, forming a vertical wall, not more than five feet high, which is capped by the drift. It is a somewhat disintegrated, soft, fine yellow sandstone, with well marked oblique bedding.

The other locality is to the north, not far from the southeast corner of Sec. 1 of Wright township. Here a small tributary of Indian creek has cut a deep valley heading westward. In the south bank of this ravine, not far from where it crosses the boundary of the county, there is a yellow sand with occasional indurated layers and blocks of sandstone of a brown color. The exposures are unsatisfactory, but this sand is evidently identical with a sand rock which appears a half mile farther east along the same creek and which consists of a moderately coarse, and, in places, pebbly sandstone of variable hardness and texture. It is a phase of the Nishnabotna sandstone.

Geographical Distribution.—Sandstone and shale of similar character and maintaining the same relations to each other have been found overlying the Carboniferous in several wells in the eastern part of the county. East of Second or Graybill creek in Grove and the south part of Center townships, well drillers report a soft sand rock under the drift almost always present on the uplands. It is reported to vary from white, through yellow, and brown, to bright red in color. It is usually soft, but occasionally there are some hard layers. It is mostly free from pebbles. On the uplands in Waveland and the southern part of Wright townships the same sandstone is also found in deep wells. In some places the clayey shale above the sandstone has been penetrated. (See table of wells, Nos. 55, 56, 58, 59, 60, 61, 62.) The sandstone has also been encountered in at least one well in Valley township (well No. 52, section 12) and it is reported as occurring under the bottom land in the valley of the West Nishnabotna in section 35 in Macedonia township (well No. 33). At other places the deep wells usually go into the shales and limestone of the Carboniferous system directly from the drift clays. On the east side of the West Nishnabotna, from Oakland south, the drift contains a rather large amount of Cretaceous material. Fragments of the clay ironstone concretions from the clayey shale are frequent near this place. They can be distinguished from similar material of the Missourian by their texture and more fresh appearance. Two bowlders of Cretaceous rock were also observed and were identified by their fossils. Near Macedonia Dr. G. L. Stempel several years ago obtained a fragment of an Ammonite which also appears to have come from the drift (well No. 37).

Positive evidence of Cretaceous deposits under the drift is limited to the territory east of the West Nishnabotna. At Walnut and at Avoca it is absent, as also in some wells in Wright township. West of the West Nishnabotna there is evidence from several wells (Nos. 1, 4, 5, 15, 16, 19, 20, 21, 24, 25, 34, 40, 44) that it is absent, and doubtful evidence of its presence in one instance. This is from the records of a well made near the northeast corner of Sec. 22 of Norwalk township. Here the drill is said to have gone through 150 feet of "white shale or chalk" under fifty feet of drift (well No. 48). Below this there was limestone. This white material may have been a part of the Cretaceous formation, though it seems doubtful that such a high outlier of a loose rock should have withstood the action of the ice which deposited the drift. In any case, there seems to be no doubt that Cretaceous beds are absent from the greater part of the area comprising the western two thirds of the county.

Correlations.—Dr. C. A. White, who first described the sandstone in Wright and Waveland townships,* called it the Nishnabotna sandstone and referred it to the Cretaceous age. Later Dr. Calvin showed that the sandstones in western Iowa, which overlie the Paleozoic rocks, are to be correlated more particularly with the Dakota formation of the Cretaceous system.† Sandstones and shales, with similar relations, in Woodbury, Carroll, Plymouth and Guthrie counties have been referred by Bain to the same stage.‡ Prof. F. A. Wilder§ has lately described the Cretaceous in Lyon and Sioux counties and Lonsdale described several out-crops of the same beds in Montgomery county.‖

While there is considerable variety in the lithological character of these beds in different localities, there is no reason to doubt the correctness of the conclusion that all represent the same group, the Dakota. The deposits vary in coarseness from conglomerates to fine clay. In Pottawattamie county the conglomerate may perhaps be present, but it is not exposed. The lowermost sandstone exposed was seen to contain a few small scattered pebbles not exceeding half an inch in diameter. In a lot of twenty such pebbles different materials were represented, as follows:

*Geology of Iowa, White, vol II, p. 11.
†Am. Geologist, vol. II, p. 300.
‡Iowa Geol. Surv., vol. V, p. 267; vol. VII, pp. 1-45; vol. IX, p. 73; vol. VIII, p. 329.
§Iowa Geol. Surv., vol. X, p. 108, 1900.
‖Iowa Geol. Surv., vol. IV, p. 412.

CHARACTER OF PEBBLES IN THE DAKOTA SANDSTONE IN POTTAWATTAMIE COUNTY.

Porous white chert	75 per cent.
Yellow quartz	10 per cent.
Quartzite	10 per cent.
Yellow chert	5 per cent.

The chert pebbles which predominate resemble the weathered chert from the Palæozoic limestone, and these constitute the greater part of the Dakota conglomerates elsewhere in the state. The sandstone itself is rather more uniform in composition than in other localities. The mechanical components of three samples from the principal exposure and representing the lower, the middle, and the upper ledges, are as follows:

DIAMETER IN MILLIMETERS.	SAMPLE FROM NEAR BASE OF SANDSTONE.	SAMPLE FROM MIDDLE PART OF SANDSTONE.	SAMPLE FROM UPPER PART OF SANDSTONE
	PER CENT.	PER CENT.	PER CENT
4—2	tr.	tr	
2—1	.1	tr.	
1—½	10.6	tr.	.3
½-¼	12.7	2.3	25.3
¼-⅛	73.9	95.8	72.1
⅛—1-16	2.6	1.9	2.0
1-16—1-32	.1	.1	.2

In its general facies the sandstone at this place is quite unlike the Dakota, for it is free from the infiltrated oxide of iron which elsewhere cements the deposits into a more solid mass. Here we find it to have a pure white or gray color and very slight coherence. But in its upper part, where it runs into clay, there are hard layers with yellow as well as brown colors, and it contains concretionary, ferruginous nodules, like those which characterize the Dakota sandstone on the plains. Some are spherical, some dumb-bell shaped, and some quite irregular in form. The clay is evidently also to be referred to the Dakota. It is in places arenaceous, it is not calcareous, and it contains imprints of leaves of dicotyledonous plants. Its large siderite concretions are remarkably like the siderite ore in the Potomac shales of the Atlantic slope. In its general appearance, its color, and in containing bits of black charcoal it resembles a shale which the author has seen in Dakota sandstone in Ellsworth county, Kansas.

Conditions of Deposition.—The conditions under which these deposits were made are well known from observations of geologists at other localities.* They are littoral accumulations laid down in an advancing sea. This conclusion finds corroboration in this county also. In the very base of the sandstone, round balls of clay from one to three inches in diameter were observed, evidently rolled by the currents which brought the sand. A clay like that in these balls was resting on the sand. Evidently the sand was being transported by subaqueous currents which eroded and redeposited its own sediments over and over again. This sifting gradually left the sand behind, and made it quite free from finer sediments which were kept in suspension in the more turbulent waters and only settled in quiet land-locked waters or at greater depths farther out in the sea. At one place the upper layers of the sand, which are interbedded with the overlying shale, appeared as if they had been disturbed. They were broken into lumps which had been separated and tilted and

*See previous references.

had the interspaces filled with the clay. There was almost a breccia of soft sandstone and clay. If the deposition was rapid such a breaking up of sandy layers in the clay might have resulted from pressure of the superincumbent material while all of the sediments were quite soft. Littoral deposition is always comparatively rapid.

The Cretaceous sea must have advanced a considerable distance to the east of Pottawattamie county, for there are outlers of its sediments a hundred miles distant in that direction. There is no doubt that they once had a considerable development and covered the underlying Carboniferous rocks everywhere in this region with a depth of at least two or three hundred feet.

Tertiary Erosion.

The bottom of the Cretaceous sea was finally elevated and formed an extensive inland plain, and there is no good evidence that this region has since been submerged. This plain was submitted to long-continued and extensive erosion, by which most of the Cretaceous deposits in this county were removed. These conditions no doubt prevailed during the greater part of the Tertiary age. It gave the land a low relief, which now lies concealed under the drift. For a knowledge of this relief our main reliance is the records of explorations made in deep wells. There have been collected for this survey data from sixty-four wells in the county and these are given in a separate table. In thirty-five instances the country rock was reached. The extreme differences in the elevation of the old land surface as revealed in these records, is less than three hundred feet.

WELL RECORDS IN POTTAWATTAMIE COUNTY*.

Belknap Township.

NO.	LOCATION AND OWNER	SITUATION	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
1	Near the schoolhouse in Oakville.	Lower edge of bluff.	1,140	90	Loess, 10 feet; bowlder clay with gravel, 60 feet; sand and gravel, 5 feet; soft blue clay which caved in, 15 feet.	1,060
2	Isaac Killion, in Sw. cor. Sec. 6.	Upland.	1,300	150	Loess, 60 ft; bowlder clay, 90 ft. No water.	1,150-*
3	J. Q. McPherrin, Ne. ¼ of Sec. 5.	High upland.	1,330	370	Yellow clay, 45 ft; yellow and blue "hard-pan" and clay, 323 ft; sand, 2 ft.	960—
4	J. O. Humbert, Oakland.	Edge of bluff.	1,190	302	Loess and bowlder clay, 121 ft; shaly limestone, 10 ft; hard, flinty rock, 6 ft; soft, white limestone or shale, with some blue limestone, 155 ft.	1,069

Boomer Township.

NO.	LOCATION AND OWNER	SITUATION	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
5	Henry Gittins, near center S. line, Sec. 34.	Upland slope	1,170	188	Yellow loess, 40 ft.; red loess, 80 ft.; yellow sand, 5 ft.; blue clay, 20 ft.; a little sand; "red hardpan" 8 ft.; then white limestone, with shale and coal near bottom, 35 ft.	1,017
6	John Schroeder, center E. line of Sec. 30.	Lowland.	1,065	120	Rock at about 120 ft.	945
7	J. Schroeder, Ne. ¼ Sec. 30.	Upland.	1,140	180	Stopped in rock. Seam of ochre found in the well.	
8	James Driver, Sw. cor. Sec. 21.	Upland.	1,230	Unknown	Loess 70 feet.	

Carson Township.

NO.	LOCATION AND OWNER	SITUATION	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
8½	Carson.	Back of bluff.	1,166	65	Brown or reddish loess 40 ft., "joint clay" 25 ft.	1,100
9	Carson.	Edge of bluff.	1,091	41	Drift 30 ft., decayed limestone 1 ft., blue shale with fossils 8 feet., blue limestone 2 ft.	1,060
10	Exploring shaft near river ½ mile S. of Carson.	Base of bluff.	1,066	146	Loess 10 ft., bowlder clay 16 ft., black shale 4 ft., hard shale or limestone 80 ft., shale 28 ft., black shale 2 ft.	1,046
11	Se. cor. Sec. 2, Tp. 74 N., R. 40 W.	Bluff.	1,166	135	Loes 35 ft., gumbo and bowl 'er clay 100 ft., gravel at bottom.	1,031

*A minus sign after the figures signifies elevation above sea level to which drift was penetrated without encountering bed rock.

Center Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK
12	David Wentz, Sec. 10.	Upland.	1,270	100	All drift.	1,170
13	M. Mullen, Ne. ¼ Sec. 1.	Upland.	1,340	156	Loess, yellow and blue bowlder clay with some sand to within 10 ft. of bottom, then blue silt and quicksand with snail shells, some 9 ft., then gravel 1 ft.	1,184
14	Wm. Whitney, Sw. ¼ of Sw. ¼, Sec. 28.	Upland.	1,270	246	Loess 40 ft., bowlder clay 70 ft., some sandy clay 75 ft., gray, soft, sticky clay 50 ft., some gravel in bottom.	1,024

Garner Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK
15	W. T. Sapp, near center Sec. 6.	Upland.	1,300	280	Loess 275 ft., then sand and blue clay 5 ft.	1,020
16	E. Dillon, center N. line, Ne. ¼ Sec. 9 Tp. 75 N., R. 43 W.	In creek.	1,060		Rock at 30 ft. below surface	1,030
17	J. W. Smith, Sw. ¼, Sec. 1, Tp. 75 N., R. 44 W.	Upland.	1,220	200	All drift.	1,020—

Grove Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK
18	John Harding center of E. line, Sec. 32.		1,150 (?)	98	Drift 68 ft., soft sand rock 30 ft.	1,082

Hazel Dell Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK
19	Se. ¼, Sec. 29.	High upland.	1,300	286	Loess, yellow, 130 ft., red, similar material 50 ft., blue clay without pebbles or gravel, 94 ft., sand 11 ft., hard red clay 1 ft.	1,014
20	General section given by E. A. Archibald, well maker.	Upland.	1,230		Yellow clay from 40 to 80 ft.; red clay from 20 to 100 ft., yellow sand 1 to 10 ft., blue clay from 2 to 130 ft., light colored sand from 1 to 25; then "hard-pan" or shale too hard to bore with auger. Under this there is rock.	
21	J. H. Gregg, Se. ¼ Sec. 33.	Upland.	1,300	300	Yellow clay and darker 200 ft., then alternating blue clay with sand about 100 ft., then red shale and limestone at bottom.	1,000
22	Elija Moss, near center S. line Sec. 11.	Upland.	1,250	220	All drift with gravel and sand at bottom.	1,030—

Keg Creek Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
23	Theo. Stortenbecker, Ne ¼ Sec. 13.	Slope	1,300	150	All drift.	1,130—

Kane Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
24	Hafer's lumber yard, Council Bluffs.	Bottom.	1,010	101	Alluvium 10 ft., blue clay 88 ft., red geest (?) 3 ft. Limestone in bottom.	909
25	C. F. Anderson, on N. line of Sec. 19.	In creek.	1,050		Loess, bowlder clay and gravel. Rock at 50 feet.	1,000

Knox Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
26	Avoca water works, five wells	Low.	1,140	170	Yellow silt 26 ft., sand and gravel 10 ft., blue bowlder clay 54 ft., limestone with blue shale below 80 ft. (Sample of shale blown up by dynamite seen by author.)	1,050

Layton Township

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
27	Walnut town water-works.	Low upland.	1,284	300	Loess and gumbo 100 ft, blue bowlder clay 65 ft., gravel 3 ft., blue bowlder clay 35 ft., red sticky clay with bowlders 90 ft., fine white sand 6 ft., limestone.	984
28	Old town well at Walnut.	Low uplands.	1,280	305	Loess and gumbo 100 ft., blue bowlder clay 180 ft., soft, white clay, 20 ft, limestone at bottom.	975
29	Chris Simonson, center N. line Sec. 15.	Upland.	1,310	424	Loess and gumbo 100 ft., blue bowlder clay 100 ft., some sand, tough blue clay with small pebbles 50 ft., white pebblel ss clay 30 ft., hard, flinty rock 40 ft., softer rock 60 ft., red, very hard fragmental rock, 7 ft., white, water bearing rock, black shale 10 ft.	1,103

Lewis Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
30	Dumphries P. O.		1,180	42	All loess.	

Macedonia Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
31	Town of Macedonia		1,150		Drift 60 ft., limestone and shale 45 ft.	1,090
32	Near center W. line Sec. 35.	Bottom land.	1,054	25	Sandstone at bottom.	1,029

Macedonia Township—Continued.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
33	A. Anderson, Ne. ¼ Sec. 25.	Graybill bottom.	1,080	30	Shale in bottom.	1,050
34	Near center of S. line of Sw. ¼ of Sec. 17, Tp. 40 N., R. 74 W.	In a ravine.	1100?	30	All drift, limestone at bottom.	1,070
35	O. F. Wilson, center Sec. 16.	Low upland.	1,150	118	All drift.	1,032—
36	Near center N. line Sec 23.		1,165	100	Loess, then bowlder clay with many bowlders down to rock at bottom. An ammonite was found, probably in a bowlder in lower part of this well.	1,065
37	Macedonia, center of village.		1,125	95	Drift 60 ft., limestone 10 ft., some seams of shale and hard limestone and then some black shale.	1,065

Minden Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
38	W. White, S. line Sec. 7.	Creek bottom.	1,100	80	Bowlder clay from 35 ft. below surface to 79 ft., then sand	1,020—
39	Town water works.	Terrace.	1,197	75	Loessy alluvium 35 ft., sand and gravel 5 ft, bowlder clay, blue, 38 ft., sand 2 ft.	1,120—
40	Horace Everett, near center N. line Sec. 5.		1,240	400	Drift 300 ft, then limestone and shale. Coal seam near 400 ft. below surface.	940

Neola Township

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
41	H. S. Watkins, Se. ¼ Sec. 17.	Upland slope.	1,250	140	Loess and gumbo 90 ft.; black bowlder clay 25 ft.; red pebbleless clay becoming white and harder below, 25 ft.	1,110—
42	Jno Lane, Sw. ¼, Sec. 22.		1,300	120	Rock or large bowlder at bottom.	1,180 ?
43	Neola, town well	Loess terrace.	1,106	48	Loess about 35 ft., then sand and gravel.	1,058—
44	H. Dowling, near Sw. cor. Sec. 7.	Upland slope.	1,275	198	Loess 20 ft., sand and bowlder clay 130 ft., blue clay 40 ft., white sand 6 ft., red clay or soapstone 2 ft.	1,089
45	J. O'Brien, center S. line Sec. 28.	High upland.	1,300	146	Loess 60 ft., bowlder clay 65 ft., soft, white clay 15 ft. No water.	1,154

Neola Township—Continued.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF RED ROCK.
46	C. Green, center N. line Sec. 10.	Low ground.	1,170	100	Soil and bowlder clay 70 ft., light, sticky clay, without pebbles, 30 ft.	1,070—
47	L. P. Wilkinson, near center E. line Sec. 23.	Upland.	1,230	150	All drift.	1,080—

Norwalk Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF RED ROCK.
48	Horace Everett, Ne. ¼, Sec. 22.	Upland divide.	1,250	210	Loess and bowlder clay 50 ft., clear white "shale or chalk" 150 ft., then limestone.	
49	M. Hannivan, near Sw. cor. Sec. 18.		1,230	250	Sand in bottom of well.	980—

Silver Creek Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF RED ROCK.
50	Jerry Lewis, Se. cor. Sec. 14.	Upland.	1,250	260	Loess 80 ft., pebbly clay 80 ft., blue bowlder clay 100 ft.	990—

Valley Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF RED ROCK.
51	Chas. McKinney, Sw. ¼ Sec. 12.	Upland.	1,300	188	Loess and gumbo 120 ft., soft sand rock 68 ft.	1,120
52	James Watts, near Hancock.	Upland.	1,240	250	Blue shale at 250 ft.	995
53	Ne. cor. Sec. 29.		1,230	131	Loess 40 ft., with snail shells below. Bowlder clay 90 ft. This changes from yellow to blue color several times.	1,099—
54	Wm. Clark, Sw. cor. Sec. 35.	Upland.	1,255	130	All drift.	1,125—

Waveland Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF RED ROCK.
55	Center S. line Sec. 19.	Upland.	1,230	115	Drift 100 ft., red and hard sandstone 15 ft.	1,115
56	L. Boughman, Nw. ¼ Sec. 13.	Lower slope of bluff.	1,170	120	Drift 100 ft., sandstone 20 ft.	1,070
57	Grant Pierson Sec. 2.	Upland	1,240	242	Loess 20 ft., bowlder clay 120 ft., limestone and shale 100.	1,130

Waveland Township—Continued.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
58	J. W. Hempstead, Se. ¼ Sec 20.	Upland slope.	1,270	100	Sandstone in bottom.	1,170
59	C. C. Neely, Ne. ¼ Sec. 20.	Upland.	1,300	120	Loess and bowlder clay. Sandstone below.	1,180

Wright Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
60	Ely Clayton, Nw. ¼ Sec. 2.	High upland.	1,320	100	Loess and bowlder clay 90 ft., white clay 10 ft., then sand.	1,230
61	Se. cor. Sec. 35.	Upland.	1,263	238	Loess 65 ft., bowlder clay 125 ft., then soft sandstone to bottom.	1,073
62	John Black, Ne ¼ Sec. 35.	Upland.	1,270		Loess 70 ft., bowlder clay 130 ft., then some sandstone. Depth not known.	1,070

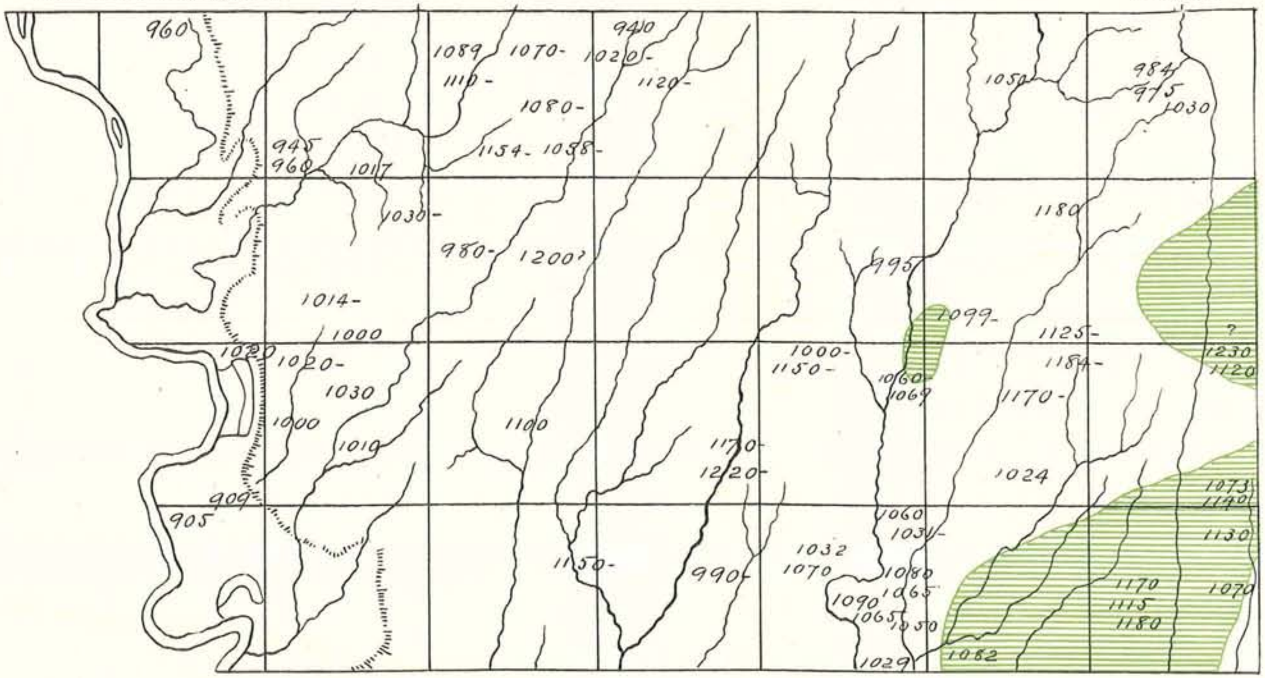
York Township.

NO.	LOCATION AND OWNER	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	TOP OF BED ROCK.
63	J. L. Graham, Sw. cor Sec. 24.	Upland.	1,310	140	Loess 40 ft, "gravel clay" 15 ft., bowlder clay with a middle layer of sand to the bottom.	1,170—
64	Near center W. line Sec. 23.	Upland.	1,320	100	Loess and bowlder clay.	1,220—

The Pleistocene.

There seems to have been an almost level plain with here and there low swells capped by Cretaceous sandstone (see map, plate VI), such as are now seen skirting the edge of the Dakota in Kansas, though probably somewhat more subdued. The present elevation of this buried plain averages one thousand and twenty feet above sea level.

During the Pleistocene age this plain was overrun by an extensive continental ice field from the north, which covered it with debris, mostly bowlder clay, to a depth of from fifty to two hundred feet. Later there was an accumulation of loess on all the uplands. The latest of all deposits are materials composing the alluvial plains of the present drainage.



GEOLOGICAL MAP OF POTTAWATTAMIE COUNTY.

Also shows the elevation of bed rock above sea level. Uncolored area is Missourian. Green areas are Cretaceous. Figures with a minus sign indicate that bed rock does not come up to the level given.

Ante-Glacial Silt and Sand.—Near the center of section 33 of Lewis township, the base of the bluff is seen to consist of a fine gray sand overlain by a blue clay, which is separated from the loess above by a sharply defined line. This section is given below:

		FEET.
1.	Loess	3.
2.	Laminated, very tough, fine blue calcareous clay, with occasional pebbles and cobbles of chert, and with a few calcareous concretions	8.
3.	Fine gray sand, with irregular lentils of a finer white material, and with some flat calcareous concretions	2.

About one-fourth of a mile farther west the same beds appear again in the same situation. But at this place there is some bowlder clay between them and the loess, and the blue clay is again overlain by sand. At the south end of the exposure there is a straight joint which runs obliquely down across the ends of the strata and sharply separates them from the loess, which appears to have slid down along the joint.

		FEET.
4.	Loess (coming down across the ends of the numbers below)	5.
3.	Yellow bowlder clay	1.
2.	Gray sand	2.
1.	Blue, tough, fine, laminated, calcareous clay	5.

Some traces of the same beds appear under the bluffs about two miles to the north, and again at Henton, in Mills county, four miles south. At the latter place a part of the clay is of a chocolate color, and some of it is disturbed, evidently by the action of the ice which deposited the overlying bowlder clay. A clay having the same relation to the drift has been reported by Todd in the Missouri bluffs, near Pacific Junction*.

Tough blue and red clays, with occasional pebbles, have also been noted in several wells in the county (see wells, Nos. 27, 28, 29, 45, 49, 60).

*The Moraines of Southeastern South Dakota and Their Attendant Deposits, Bulletin 158, U. S. Geol Surv. p. 89.

The occurrence of occasional Archean pebbles in these sands and clays, and their calcareous nature, relegate at least part of them to the drift deposits. They apparently bear the same relation to the till in this region as some similar deposits which the author has described in Muscatine county on the Mississippi river*. They are in all probability sands and silts that accumulated in slack water lakes and ponds in front of the advancing ice field which brought the till.

The Bowlder Clay.—The average thickness of the bowlder clay on the uplands is estimated at one hundred and forty feet. Separate estimates based on field notes and well records for the several townships and averages for the ranges running north and south give the following figures:

Average Thickness for Ranges.		*Average Thickness for Townships.*	
Range 38	132 feet.	Township 77	180 feet.
" 39	180 "	" 76	190 "
" 40	127 "	" 75	137 "
" 41	193 "	" 74	101 "
" 42	160 "		
" 43	116 "		
" 44	30 "		

These figures show that the bowlder clay is heaviest along the divides between the principal streams and that there is a rapid thinning as we approach the Missouri river. They also indicate a gradual general thinning from north to south. The thinning along the principal streams is no doubt chiefly due to the erosion which the bowlder clay has suffered, but the difference between the north and south part of the area is more likely due to the difference in the original amount of drift laid down.

The bowlder clay in this county resembles, in all respects, that found in other parts of the north central states. Bowlders, pebbles, gravel and sand are imbedded in a tough, fine, and calcareous groundmass of clay. Good exposures are not frequent. The deepest section is seen opposite Honey Creek

*Iowa Geological Survey, vol. IX, p. 328.

lake, in Sec. 2, Tp. 76 N., R. XLIV W. At this place excavations made in the bluffs for the railroad have laid bare the bowlder clay to a depth of nearly fifty feet. The lower part of the section shows a dark, and in many places almost black till, which is somewhat tough and uniformly fine textured. Bituminous black films were occasionally noticeable on exposed surfaces, and at one point there were small crystals of selenite which evidently had formed in situ. About twenty feet above the level of the road-bed irregular and large pockets of sand were seen. Above these there was twenty feet more of till. This was somewhat harder and had a gray color, which turned into yellow near the surface. From this point all the way to the north boundary of the county bowlder clay is often seen in the base of the bluff, and fresh deep exposures show a dark till like that seen at the base near Honey creek. The same may be said with regard to that part of the Missouri bluffs which extend from the north line of Kane township northward to within two miles of the village of Crescent. In most places all along these bluffs gravel and sand overlie the till and separate it from the superincumbent loess.

Another quite deep exposure of the till was observed near the center of the west line of the Sw. ¼ of Sec. 3 of Grove township. Jordan creek is there cutting into its left bank, which is sixty feet high. This is composed mostly of bowlder clay, which is dark blue below and changes to yellow above. Occasionally, as near a creek west of Minden, and also near Avoca, the dark bowlder clay is seen to be cut by wide leached joints, above which it is partly oxidized and yellow. Very frequently there are calcareous concretions and pockets of white calcareous flour in the upper yellow till. This is particularly frequent along the leached and discolored joints.

Compared with the till alone the Mississippi there has been less leaching of the surface under the loess in this region. The till here is frequently calcareous up to the base of the loess, and at times has a remarkably fresh aspect. While in the vicinity of the Mississippi the Kansan till is thoroughly leached under the loess, so that its limestone and dolomite, and even its diabase pebbles may be wholly removed from the upper four or five feet of the till, it is seldom that some limestone pebbles are not present at the very top of the bowlder clay in this county. The clay itself is usually calcareous to within two or three feet of the surface, and quite often up to the very top. In some places there has even been an accumulation of calcareous material in the upper part of the till in the form of concretions and pockets of flour-like calcite, as already stated.

Whether the till found in this county represents the deposits of one or more ice incursions, is a question which cannot be settled from the evidence at hand. In the exposures which the author has seen there is nothing to indicate that there is more than one drift sheet, unless it be a single obscure instance in a railroad cut in the Se. ¼ of Sec. 13 of Layton township, where a leached drift seems to be overlain by a few feet of yellow calcareous bowlder clay. From some wells the makers report red bowlder clay lying under blue till. This may indicate a weathered surface of an older drift sheet, but it may also be explained as due to changes brought about by percolating ground water, following lines of easy penetration.

Some evidence bearing on the question of the single or multiple origin of the till in this region was sought in a somewhat extended series of examinations of the erratics of the bowlder clay. Thirty-six samples of one hundred pebbles each were obtained from different places in the county and from different levels in the drift. Ten of these samples were from the lower part of the bowlder clay, not far above the underlying bed rock; sixteen samples were taken farther up from the base of the till, but not near its upper surface; and ten were taken from that part of the unleached till which lies next under the loess. These pebbles measured about one-third of an inch in diameter, and were collected in such a way as to make them represent the different kinds of rock in the relative numerical abundance in which they occur in the drift. Averaging the proportions for each kind in the three groups, from the lower, the middle, and the upper part of the drift, it appears that the admixture of the different varieties of rock in the three groups is very much alike.

TABLE SHOWING THE AVERAGE PER CENT OF DIFFERENT KINDS OF ROCKS REPRESENTED AMONG PEBBLES ABOUT ONE-THIRD OF AN INCH IN DIAMETER IN THE BOWLDER CLAY OF POTTAWATTAMIE COUNTY.

KINDS OF ROCKS.	Average of ten samples from the lower part of the till.	Average of sixteen samples from the middle part of the till.	Average of ten samples from the upper part of the till.	Average for the county.
Quartz	4.0	3.6	4.2	3.9
Granite	14.6	13.2	12.7	13.5
Greenstone	2.9	3.9	4.6	3.8
Hornblende rock	1.5	.9	.7	1.0
Schists	1.2	1.0	.8	1.0
Syenite	....	.1	.2	.1
Slate	....	.4	.3	.2
Jaspilite	....	....	.2	.1
Magnetite	....	.1	....	tr.
Diabase	12.8	16.3	19.8	16.3
Keweenawan eruptive	.2	.4	.3	.3
Epidote	....	.1	....	tr.
Porphyritic eruptive	.1	....	....	tr.
Quartzite	2.6	1.5	2.2	2.1
Sioux quartzite	1.5	2.9	2.6	2.3
Dolomite	6.7	2.7	3.1	4.2
Chert	5.7	6.7	6.3	6.2
Limestone	31.6	35.1	35.8	34.2
Shale	2.6	.5	.3	1.1
Pyrites	.8	.2	....	.3
Clay ironstone	.9	2.9	1.1	1.6
Sandstone	.2	.4	.3	.3
Niobrara	5.3	2.3	1.6	3.1
Benton	3.9	4.3	2.4	3.5
Buhrstone (?)	.2	.2	.2	.2
Silicified wood	.1	....	....	tr.

It will be seen from this table of averages that there is no marked difference between the pebbles of the deeper drift and those of the upper drift. There is a slight increase of granite and of hornblende rock, schists, dolomite, and Niobrara shale toward the base of the drift, and a slight decrease in the same direction of greenstone, diabase, limestone, syenite, and slate.

But this difference is altogether too insignificant to be regarded as necessarily indicating a difference in origin of the upper and the lower parts of the till. Negative evidence is, however, of little value on this point, for if there have been separate ice incursions here these may have come so nearly from the same direction each time that the erratics of the resulting deposits would be the same in each case.

The dark blue bowlder clay seen in deep exposures is in all probability identical with the so-called pre-Kansan drift of the south and southeastern part of the state. It resembles the latter in its field appearance, color, toughness, structure, and position, resting as it does on the bed rock. Even the decayed vegetation, which is so characteristic of the pre-Kansan elsewhere, is not lacking here, though it is less abundant. The ice sheet which deposited the Kansan drift, possibly never extended as far west as this region. If the yellow till which is seen in the more superficial exposures is not merely a modified form of the lower and darker till, it may prove to belong to the Iowan age.*

Valley Drift Gravel.—In the bluffs bordering the larger stream valleys the till is often capped by more or less gravel and sand. Nearly all of the sand and gravel pits which have been worked in the county belong to this class. These deposits are evidently of glacial origin, for in some places they are seen to be interbedded with lentils and layers of bowlder clay, or overlain by the same. The greatest development of glacial gravel and sand is under the loess along the bluffs of the Missouri river, especially north of Kane township. They frequently reach a thickness of twenty to thirty feet, and have in many places been cemented into a solid mortar rock by percolating calcareous water which drains through this open stratum from the uplands back of the river. Along the West Nishnabotna these gravels have a much smaller development, but present the same characters. Some

*See the Moraines of Southeastern South Dakota and their attendant deposits, J. E. Todd, Bull. 158, U. S. G. S.

are seen about fifty or sixty feet above the flood plain in the west bluff three miles south of Avoca.

Without wishing to express it as a mature conclusion, the author is inclined to the view that these deposits represent the work of the present streams at a time when their course was first marked out on the stagnant ice field which brought the underlying bowlder clay. These streams may then have followed open valleys or extensive tunnels in the ice. In either case there would be opportunity for the ice to float out and deposit some till with the stream gravel. Another feature of these deposits, not mentioned above, is the presence, in some places, of sharply and clearly cut joints and faults that follow numerous straight and intersecting plains in the gravel and sand. Such faulting could hardly have taken place in this unconsolidated and heterogeneous material unless it was frozen at the time. A conspicuous instance of complex faulting of this kind was observed in a gravel pit just south of Loveland station.

The Gumbo or Red Clay. Many well diggers report what they call a "red clay" as resting on the till of the uplands. It is said to be as much as forty feet in thickness, but may be much less than this, or it may be entirely absent. They usually describe it as being without pebbles. In the north part of the county there is often a brownish-colored, tough, silt-like deposit associated with the upper surface of the till and lying under the loess. It is more sticky and clayey in its physical aspects than the latter and resembles the gumbo described by Leverett in the Mississippi region. Sometimes it is gray in color and quite like the loess, but it is always more impervious to water than that formation. More often it resembles what is usually called a joint clay, breaking up when dying into a number of small angular fragments. In some places it changes downward into bowlder clay and at other places it seems to be continuous upward with the loess. In the former case it frequently contains drift pebbles. Even when resembling the loess, it is seen to contain an occasional small pebble. Everywhere it is thoroughly leached and free from calcareous material, giving no response to acid. In one instance it was seen to contain small globular concretions of impure manganese oxide, like those found in the gumbo and the white clay in Illinois. In its mechanical composition it usually resembles the loess quite closely, so that more than ninety-five per cent may be said to consist of loess. This will be clear from the following table of analyses:

TABLE SHOWING PERCENTAGES OF MATERIALS OF DIFFERENT GRADES OF COARSENESS IN SAMPLES OF LOESS AND OF GUMBO.

DIAMETER OF FRAGMENTS. (IN MILLIMETERS.)	GUMBO.									LOESS.											AVERAGES.	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
	Nw. cor. Sec. 22, Minden Tp.	Three miles west of Avoca, 5 ft. above bowlder clay.	2½ miles E. of Walnut.	R. R. cut, Sec. 13, Layton Tp.	R. R. cut, Sec. 13, Layton Tp.	R. R. cut, Sec. 13, Layton Tp.	R. R. cut, Sec. 14, Layton Tp.	From a well 5 miles N. of Walnut.	Braddyville, Iowa.	Light yellow loess, Sec. 33, Boomer Tp.	Council Bluffs, base of bluffs.	Council Bluffs, 20 ft. above base.	Council Bluffs, 40 ft. above base.	Council Bluffs, 60 ft. above base.	Council Bluffs, 20 ft. from top of bluff.	Council Bluffs, 15 ft. from top.	Council Bluffs, 8 ft. from top.	Council Bluffs, 2 ft. from top.	Council Bluffs, 10 inches from top.	Council Bluffs, top soil.	Average composition of gumbo.	Average composition of loess.
8—4	.5	......	......	......	......	......	......	......	......	......		......	....	......	......	......	......	......	......	......	tr.	......
4—2	.9	.1	......	......	......	......	......	......	......	......	......	......	....	......	......	......	......	......	......	......	.1	......
2—1	.9	.1	tr.	......	......	......	......	......	......	......	......	......	....	......	......	......	......	......	......	......	.1	......
$1-\frac{1}{2}$	3.3	.4	tr.	tr.	......	tr.	......	tr.	.1		......	......	....	......	......	......	......	......	......	......	.4	......
$\frac{1}{2}-\frac{1}{4}$	2.7	.9	.4	.5	tr.	tr.	tr.	tr	.2		tr	......	....	......	......	tr.	tr.	......	......	tr.	.5	......
$\frac{1}{4}-\frac{1}{8}$	8.3	3.2	1.0	3.5	.2	tr.	.1	.2	3.3	tr.	1.0	1.9	.7	.3	.1	.2	.1	tr.	tr.	.1	2.2	.4
$\frac{1}{8}-\frac{1}{16}$	6.5	8.3	7.5	5.0	2.5	20.6	4.0	5.6	14.9	2 3	12 8	8.9	18.0	2.8	.8	5.2	6.5	6.0	1.1	5.3	8.3	6.2
$\frac{1}{16}-\frac{1}{32}$	52.9	53.3	56.7	45.4	59.0	47.3	62.5	52.5	54.2	69.2	66 0	62.4	65.1	65.0	56.2	66 9	64.0	66 0	61.8	66.0	54.9	64.4
$\frac{1}{32}-\frac{1}{64}$	15.1	22.1	20.8	31.9	25.1	19.3	22.5	30.6	17.4	19.9	17 9	19.6	13.0	26.0	34.2	20.9	19.4	22.1	29.6	21.3	22.5	22 2
$\frac{1}{64}-\frac{1}{128}$	5.0	9.9	9.0	8.9	8.8	9 1	8.0	6.4	6.5	7.5	1.8	5.7	2.5	5.0	7.0	5.7	7.9	4.9	5.9	5.9	8.9	5.4
$\frac{1}{128}-\frac{1}{256}$	1.4	1.3	1.8	2.5	2.5	1.5	1.1	2 0	1.5	1.0	.4	1.1	.3	.6	.5	1.0	1.3	.8	.7	1.4	1.8	.8
$\frac{1}{256}-\frac{1}{512}$	.9	.5	1.4	.7	.6	.5	.3	.8	.4	.1	.1	.2	.1	.2	tr.	.3	.3	.3	.2	.2	.7	.2
$\frac{1}{512}-\frac{1}{1024}$	1.0	.4	.4	1.2	1.2	1.3	.9	.8	.8		......	tr.	tr.	tr.	tr.	.1	.2	.1	......	tr.	.9	tr.
$\frac{1}{1024}-\frac{1}{2048}$	tr.	tr.	......	tr.	tr.	tr.	......	tr.	......		......	......	....	......	......	......	......	......	......	......	tr.	......

Excepting the samples which evidently consist of leached bowlder clay (Nos. 1, 2, and 3), the main difference between the loess and the gumbo is the presence, in the latter, of small pebbles and sand, and of about one or two per cent of exceedingly fine particles measuring less than one two-hundred-and fifty-sixths of a millimeter in diameter. The latter consists largely of oxide of iron, and it is evidently this ingredient which renders the deposit comparatively sticky and impervious to water. A dry lump when moistened absorbs the liquid and swells up visibly.

Natural exposures of the gumbo occur mostly in the creek valleys, and it is not always possible to distinguish it from the loess, into which it apparently frequently graduates. When it is laid bare and exposed to the action of erosive agencies, the fine sand which it contains is apt to be left behind on the surface in white streaks along the rills, and this sometimes gives it a characteristic appearance. At other times its presence is indicated by the growth of some small Scirpus or other plants requiring moist ground.

It would be premature at the present time to express any opinion as to the origin of this deposit. Probably it is mostly an old loess, which has been clogged up by interstitial deposition of fine ferrugiuous material through the agency of the ground water. Perhaps it is in part a fluviatile deposit, made at a time of semi-stagnant drainage, or possibly it is of varied origin, being in some places a surface wash, or a disintegration product derived from the underlying bowlder clay, and at other places a modified upland loess, or a river silt. On some low uplands, which border the West Nishnabotna valley northwest of Macedonia, the loess quite closely resembles the gumbo. Much more extensive observations will be needed to make out the full history of the gumbo. So far as the author knows it contains no fossils in this county.

The Loess.—The loess is the latest and uppermost deposit on the uplands. It consists of dust, or silt, of very uniform texture, sixty per cent of its bulk being made up of particles which have a diameter ranging from one-sixteenth to one-thirty-second of a millimeter, and less than two per cent of its bulk consisting of fragments having a diameter exceeding one-eighth, or coming short of one one-hundred-and-twenty-eighth of a millimeter (see table page 257). It is therefore open and porous to percolating water. It usually breaks along vertical fractures, and it seldom, if ever, shows any traces of bedding planes. It is usually grayish yellow in color. In this county there is an imperceptably gradual general change in color from slightly more yellow in the east to more gray towards the Missouri river. Local exceptions to this general rule are found, however. Parallel with this change there is also a slight change in texture, the yellow loess being a trifle finer and less open than the gray loess in the Missouri river bluffs. Calcareous material is usually, but not always, absent from the upper part of the deposit. In this area the base of the loess is sometimes calcareous on the hillsides, as if the lime were left by water escaping by evaporation along the moist band on top of the bowlder clay, or the gumbo. It may either be disseminated throughout the mass of the loess, or collected into nodules or concretions, or it may impregnate a layer or zone so as to render it slightly harder than the loess above and below. This harder layer is occasionally seen in the base of the formation, along the Missouri river. The carbonate of lime is here present in small acicular crystals, barely visible when magnified two hundred diameters. The concretions or "clay dogs" vary very much in size, from that of a small grain to masses three feet in diameter. Some of the latter are seen two miles north of Council Bluffs. When the calcareous material is evenly disseminated throughout the mass, it probably never was disturbed by the ground water and consists of the original calcareous grains laid down with the siliceous bulk of the deposit.

The loess covers the uplands everywhere. On the steepest slopes it runs out and the bowlder clay or the gumbo comes into view below it, but slopes of less than four or five degrees from the horizontal hardly ever show the till. Its thickness varies in the same general way as its color and texture, being greatest in the west and least to the east, and changing rapidly within short distances. As a rule it is heavier along the upland divides than along the smaller streams. The average greatest thickness in the east half of the county is probably fifty feet, but it is frequently less than forty feet. In the Missouri river bluffs it is seldom less than seventy or eighty feet, and it is occasionally as much as 150 or 200 feet in thickness, according to the reports of the well makers.

Just north of the village of Loveland, Boyer river has lately sapped the bluffs and there is a bare escarpment showing about ninety feet of loess resting on bowlder clay. The lower half of this loess is pebbly, and appears a little more yellow than the upper part, in which no pebbles could be found. The two are separated by a dark band in which some bits of charcoal were noticed. All of this loess is calcareous, and contains frequent fossil snail shells. It is possible that the lower, darker division corresponds to the gumbo in other localities, but it differs from that formation in having the open texture of the loess and many calcareous concretions of large size.

The fossil remains which have been found in the loess in this county are, as elsewhere, those of land animals and land vegetation. Peat and wood have been found in the base of the loess in some wells near Carson. Peaty material was observed by the author in the same situation in the railroad excavation near the west line of Sec. 13, Layton township. Fragments of wood were also observed in the clay pit of the brickyard at Avoca, and in the loess at Weston. The bones of an elephant are reported to have been found on Sec. 34, in Washington township, apparently in the loess. The horn cores of a *Bison latifrons** bave been dug out of a well in the loess, at a depth of fourteen feet, not far from the quarter post of the

*Seen and identified by the writer.

east line of Sec. 28, James township.* At Council Bluffs an *Ovibos cavifrons* was found twelve feet below the surface in the loess at a point 130 feet above the river.† In tunnelling the cellars into the loess hills back of Conrad Geisse's old brewery, on Upper Broadway in the same city, it is claimed that a grooved stone ax was taken out from under thirty feet of loess and forty feet from the entrance of the cellar excavation. The ax has an adhering incrustation of calcareous material on one side, evidently deposited by ground water. The loess at this place has possibly been disturbed by creeping or by rain wash, but its appearance suggests nothing of the kind. It is quite typical loess for this region. The ax was discovered by the workmen engaged in excavating the cellar and immediately shown to Engineer Robert F. Rain, who superintended the work, and who still has possession of it.

The invertebrate fossils of the loess consist of some small terrestrial mollusks, with a few aquatic forms. It is significant that the latter species occur farthest away from the larger streams, on the divides least affected by erosion, in situations which at an earlier date must have had poor drainage and which have probably been the sites of small ponds. Thirteen small collections of these fossils were made at as many different points in the county. These were submitted to Professor B. Shimek, of Iowa City, who has kindly identified the species represented. His report, with interpretations of the features of the fauna observed, is here given in full, and will prove interesting on account of its bearing on the origin of this formation:

REPORT BY PROFESSOR B. SHIMEK ON THE LOESS MOLLUSKS.

1. Center of S. line of Se. ¼, Sec. 18, Knox township.
   Helicina occulta, Say. 1

*Measurements of these horn cores were taken by Mr. J. LeRoy Oakleaf as follows:

	RIGHT CORE.	LEFT CORE.
Largest circumference	28.5 centimeters.	28.5 centimeters.
Length measured along inner curve	30 "	29 "
Length measured along outer curve	37 "	36 "
Depth of inner curvature	5.9 "	5.2 "

†Am. Jour. Sci. (3) XXXIV, pp. 217-220.

Succinea avara, Say. 1.*
Succinea, 7†
Pyramidula striatella (Anth.), Pils. 2.
Zonitoides shimekii (Pils.), 1.

2. New cut along Illinois Central railroad, just north of Council Bluffs.
Helicina occulta, Say. 1.
Succinea, 12.
Pyramidula striatella (Anth.), Pils. 1.
Pyramidula alternata (Say.), Pils. 5.
Vitraea indentata (Say.), P.? Imperfect 1.
Polygyra leai (Ward.), Pils. 2.
Polygyra multilineata (Say.), Pils. 1.

3. Railroad cut one-half mile east of Walnut, Iowa.
Succinea avara, Say. 2.
Succinea, 5.
Pyramidula striatella (Anth.), Pils. 5.
Zonitoides shimekii (Pils.), 1.
Zonitoides arboreus (Say.), St. 5.
Conulus fulvus (Drap.), Müll. 1.
Vertigo bollesiana, Morse (?) 1.
Polygyra multilineata (Say.), Pils. 1.
Vallonia gracilicosta, Reinh. 1.

4. Bluff near Weston, Iowa.
Helicina occulta, Say. 1.
Succinea avara, Say. 3.
Succinea, 4.
Pyramidula striatella (Anth.), Pils. 5.
Zonitoides shimekii (Pils.), 1.
Bifidaria pentodon (Say.), St. 4.
Vallonia gracilicosta, Reinh 5.

5. Clay pit in brick yard at Avoca, Iowa.
Helicina occulta, Say. 5.
Succinea avara, Say. 1.
Succinea, 5.
Pyramidula striatella (Anth.), Pils. 1.
Zonitoides shimekii (Pils.), 2.
Bifidaria pentodon (Say.), St. 1.
Polygyra multilineata (Say.), Pils. 1.
Vallonia gracilicosta, Reinh 2.

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*These numbers indicate number of specimens collected of each species, and are hence an index of the relative frequency of each species.

†In all these lists *Succinea* includes S. *obliqua* Say. and S. *grosvenorii* Lea. At least no distinction is made between them here, because of the difficulty of separating the younger specimens. Both species, however, are quite common in the series.

6. Neola, Iowa.
   Succinea avara, Say. 12.
   Succinea, 1.
   Pyramidula striatella (Anth.), Pils. 3.
   Zonitoides shimekii (Pils), 3.
   Zonitoides arborens (Say.), St. 1.
   Bifidaria pentodon (Say.), St. 4.
7. Southeast corner of Sec. 14. Keg Creek township.
   Succinea avara, Say. 2.
   Succinea, 4.
   Pyramidula striatella (Anth.), Pils. 2.
   Zonitoides arboreus (Say.), St. 1.
   Polygyra multilineata (Say), Pils. 1.
   Vallonia gracilicosta Reinh. 1.
   A small fragment of charred wood.
8. Upper slope of low bluff in Carson, Iowa.
   Helicina occulta, Say. 5.
   Succinea avara, Say. 4.
   Succinea, 11.
   Pyramidula striatella (Anth.), Pils. 6.
   Zonitoides shimekii (Pils.) 2.
   Bifidaria pentondon (Say.), St. 1.
   Polygyra multilineata (Say.), Pils. 1, (and fragments).
   Vallonia gracilicosta, Reinh. 1.
   Sphyradium edentulum alticola (Inger), Pils. 1.
9. Light upper loess, railroad cut, one mile east of Walnut, Iowa.
   Succinea avara, Say. 7.
   Pyramidula striatella (Anth.), Pils. 4.
   Conulus fulvus (Drap.) Müll. 1.
   Bifidaria pentodon (Say.), St. 3.
   Pupa muscorum, L. 2.
   Sphyradium edentula alticola (Inger.) Pils 4.
10. Lower part of loess in the high bluff just north of Loveland, Iowa.
   Succinea, 3, imperfect.
   Helicodiscus liveatus (Say.), Morse. 1.
   Pyramidula alternata (Say.), Pils. 1, fragment.
   Zonitoides arboreus (Say.), St. 1.
   Bifidaria armifera (Say.), St. 4.
   Pupa muscorum, L. 1.
11. Railroad cut in the divide three miles northwest of Avoca, Iowa.
   Succinea avara, Say. 9.
   Succinea, 3.
   Pyramidula striatella (Anth.), St 7.

Conulus fulvus (Drap.), Müll. 2.
Polygyra leai (Ward), Pils. 2.
Polygyra multilineata (Say.), Pils. 3 fragments.
Vallonia gracilicosta, Reinh. 3.
Bifidaria pentodon (Say.), St. 3.
Pupa muscorum L. (?) 1 broken.
Limnaea humilis, Say. 2.

12. Deep railroad cut in the divide west of Minden, Iowa.
Helicina occulta, Say. 1.
Succinea avara, Say. 2.
Succinea, 2.
Pyramidula striatella (Anth.), Pils. 4.
Polygyra leai (Ward) Pils. 1.
Limnaea humilis, Say. 1.

13. Railroad cut in the divide two and one-half miles northeast of Minden, Iowa.
Helicina occulta, Say. 18.
Succinea avara, Say. 10.
Succinea, 15.
Pyramidula striatella (Anth), Pils. 17.
Zonitoides shimekii (Pils.), 1.
Polygyra multilineata (Say), Pils. 10 (mostly broken).
Vallonia gracilicosta, Reinh. 3.
Limnaea caperata, Say. 6.

"In the proceedings of the Iowa Academy of Sciences for 1898 I discusssed in detail the loess fossils of Council Bluffs. The foregoing sets of fossils from other localities in Pottawattamie county emphasize the peculiarities of distribution discussed in that paper. Of the thirty species therein discussed nineteen are included in the collections now submitted and but four species are with certainty added, none of them new to the loess of the west. The fossils from exposures 1 to 9 inclusive are strictly terrestrial, and include two species not heretofore reported from the county, namely: *Pupa muscorum* L and *Sphyradium edentulum alticola* (Inger) Pils. The former is now extinct in Iowa and the latter is very rare."

"The collections from exposures 11, 12 and 13 differ from the preceding only in containing specimens of two species of fresh water pulmonates. *Limnaea humilis* Say., and L. *caperata* Say. Neither of these species has heretofore been reported from the county but both have been found in the loess of Iowa and Nebraska. Both species are now found commonly in Iowa, in shallow pools and ponds, the former often on mud-flats, and their bearing on the question of the conditions under which loess was deposited has already been sufficiently discussed."*

"The collection as a whole adds emphatic evidence of the fact, no longer to be doubted, that the loess was not of subaqueous origin. B. SHIMEK."

Terrace and Alluvium.--Opposite Oakland there is a terrace on the west side of the West Nishnabotna river, and some second bottom lands are also seen south of Avoca on the east side. These are remnants of an old flood plain which must have been some thirty feet higher than the present bottoms. They are covered with at least twenty feet of loess-like silt. A similar, but higher terrace, is seen occasionally along Mosquito creek, as below Neola. At the latter place loess, which forms the upper twenty feet of the material of the terrace, rests on stream sand and gravel, into which some wells have been sunk. Traces of a terrace are also seen on the East Nishnabotna, on Keg and Silver creeks, in the bluffs of the Missouri river, and along the lower courses of some of its small affluents. The most conspicuous instance is in the south half of section 6, Kane township, south of Council Bluffs. At this place the upland north of Mosquito creek is prolonged southward into a terrace flat, which is about seventy feet higher than the bottom land. From a remnant of an old terrace north of Loveland, at the base of the Missouri river bluffs, just south of the north boundary of the county, the following fossils were taken and have been identified by Prof. Shimek:

Helicina occulta, Say. 2.
Succinea grosvenorii, Lea, 10.
Helicodiscus lineatus (Say.), Morse. 2.
Pyramidula alternata (Say.), Pils 1.

*Shimek, Proc., Iowa, Acad. Sci. vol. V. pp. 34, 35.

Bifidaria holzingeri (Sterhi.), 1.
Leucoochella fallax (Say.) Try. 2.
Polygyra leai (Ward) Pils. (?) a fragment.
Unio, fragment of a heavy shelled species.
Fragment of a bone.

It is covered by a heavy deposit of loess. Evidence is wanting as to whether the making of these old flood plains was caused mainly by the former existence of a lower gradient, or merely by the over-loaded condition of the streams at an earlier period. Whichever is the case, most of the old filling of these valleys has been cut down by the present streams from thirty to seventy feet.

The valley of the Missouri river has a filling about seventy feet deep under the present flood plain, and there is a similar filling in the upper part of the West Nishnabotna valley. The lower part of this filling usually consists of gravel and sand, and the upper part is mostly stream sand and silt. This is well shown in some records made by the chief engineer, George S. Morrison, of the new Omaha bridge of the Union Pacific railroad at Council Bluffs, built in 1888. The five piers of the main bridge are two hundred and fifty feet apart, and beginning on the Council Bluffs side, the notes on the materials excavated for each one are as follows:

		TOTAL DEPTH.
Pier A.	Silt and sand, 51 feet; mud, 2 feet; sand and mud, 17 feet	70
Pier B.	Silt 30 feet; fine sand, 2 feet; fine sand with some brush and logs, 5 feet; fine sand, 37 feet	76
Pier C.	Fine sand, 45 feet; gravel and sand, 7 feet; coarse gravel and sand, 8 feet; gravel, sand, and mud, 15 feet	75
Pier D.	Fine river sand, 53 feet; gravel, sand, and some clay, 12 feet	65
Pier E.	Fine river sand, 40 feet; coarse sand, very coarse gravel and occasional bowlders of limestone, 18 feet	58

Some wells in the valleys of the smaller streams show that there is sand and gravel under the finer alluvium of these also (Nos. 27, 40, 44). The alluvium now forming during floods and overflows, is in almost every case a fine silt, very much like the loess from which it is evidently derived. But it is frequently mingled with a large percentage of vegetable matter and humus, giving it a peaty consistency. In the smaller ramifications of the ravines it lies as a filling of considerable depth, and is evidently a wash from the surrounding slopes, which has settled among the rank vegetation in the bottom of the draws. Before the land was tilled and drained many of these small bottoms were marshy. Since then, the streams have cut small channels through the marshes and drain the ground more promptly.

Deformations.

The few exposures of the bed rock which are found in this county show but slight indications of tilting or folding. At Macedonia the ledges in the quarries north of town are about thirty feet higher than they are along the river southwest of the village. This appears to be a minor local tilting. The difference of elevation of the main ledges at Carson and at Macedonia, a distance of about two miles, is less than this. There is, at any rate, a small dip to the south. If the correlations between the rocks at Macedonia and those at Henton are correct, there is also a dip to the west, amounting to about 120 feet in twenty miles, or about six feet to the mile. The general tilting is thus to the southwest, but whether it is more to the south or more to the west, cannot be determined with certainty.

Joints.

That the Paleozoic rocks have a slight dip to the southwest is indicated also by the main trend of the joints in the bed rock. The opportunities for observations on these are scarce, but the direction of thirty-two joints were taken, mainly at three different localities. It is quite evident that these form two main sets, in one of which the joints have a general direction of about N. 20° W., and the other of about N. 70° E. This also indicates that the direction of the dip is not due southwest but must rather be a little more either to the south or to the west. The data secured on the direction of the joints are as follows:

Table Showing Directions of Joints in the Country Rock in Pottawattamie County.

IN THE VICINITY OF MACEDONIA.

N. 74° E. N. 83° E. N. 31° E. N. 63° E.	N. 52° W. N. 86° E. N. 65° E. N. 42° E.	N. 65° E. N. 13° E. N. 30° E. N. 80° E.

IN THE VICINITY OF CARSON.

N. 48° E. N. 1° E. N. 69° E. N. 69° E.	N. 53° E. N. 15° W. N. 74° E. N. 14° W.	N. 43° E. N. 3° W. N. 15° W.

ONE MILE SOUTHWEST OF CRESCENT.

N. 35° W. N. 17° W. N. 32° W. N. 33° W.	N. 70° E. N. 55° E. N. 30° W. N. 56° E.	N. 25° W. N. 60° E. N. 80° E.

Ice Scorings.

At Hartson Bryan's old quarry in the Sw. ¼ of Sec. 14, Tp. 74 N., R. XL W., the uppermost ledge is planed and scored on its upper surface. The planed surface is flat and the striae are very perfectly preserved except in a few places, where they have been etched away by surface water. Much of the scored rock has been removed by quarrying, but a great deal more of it is apparently left intact under the overlying bowlder clay. The direction of these striae is very nearly north and south, with minor variations, and correspond therefore with the direction of the river valley. Three measurements gave S. 2° W., S. 2° W., S. 10° E. This locality is on the edge of the valley of the West Nishnabotna river, which here runs nearly south. There may have been a local deflection due to this valley, while the general direction of glacial motion more probably had a greater divergence to the southwest, as already set forth.

ECONOMIC PRODUCTS.

Building Stone.

Building stone is scarce in this county. Mr. David Snapp has a small quarry in the base of the bluff north of the mill on the west side of the river, opposite Carson. About 300 perch is taken out in a season. There is very heavy stripping and only some four or five feet of rock. This is a limestone, which has been considerably disintegrated in some places, while at others it is perfectly sound. There are two abandoned quarries half a mile north of this one. Mr. John Martin owns a quarry located in the Nw. ¼ of the Nw. ¼ of Sec. 23, Macedonia township, and about half a mile north of the village of the same name. Though the rock at this place is of good quality, the stripping is quite heavy and no rock has been taken out for some time. Hartson Bryan owns another quarry a short distance to the north, in the same ledges, but very little rock has been removed lately. Another old quarry is located along the north bank of the river, near the northwest corner of Sec. 27, in the same township. At this place considerable rock has been obtained but there is no work going on at the present time. The stripping is heavy. In the west end of the county there is some available rock under the bluffs of the Missouri river, a mile southwest of Crescent. It is a strong limestone, which will furnish good dimension stone, in blocks nearly two feet thick from one of the ledges. But the stripping rises to a hundred feet and most of the available rock has been used. Lime was for a long time burned at this place, but a few years ago this ceased to be profitable. Another old quarry, abandoned long ago, was in the north bank of Mosquito creek near the west quarter post of Sec. 21, Tp. 75 N., R. XLIII W. From the foregoing statement it will be seen that nearly all of the building stone used in this county is imported.

Clay Industries.

Since stone is so scarce, it is quite natural that there should be a good demand for brick. There are no less than eleven firms engaged in the manufacture of brick. Six of these are in the city of Council Bluffs. Macedonia, Avoca, Carson and Oakland each have one, and one yard has just been opened near the east line of the county, opposite Griswold. The clay which is used is mostly loess. The manufacturers frequently have the practice of mixing some of the soil with the loess, in order to make the clay stronger. At Carson the same material has been used until recently, when alluvium, from the West Nishnabotna valley, mixed with sand, has been substituted. At Macedonia, at Oakland, and near Griswold, the clay now used is a disturbed and perhaps partly washed loess, which rests on alluvial deposits just below the upland bluffs. It merges downward into alluvial sand. At all three places this clay seems to be quite strong, owing, perhaps, to a slight admixture of some fine silty material.

The brick makers in Council Bluffs have succeeded in making good paving brick from the loess clay. This is done by burning the product hard, until it is almost vitrified. It makes a very hard and quite strong brick of dark color outside, with usually a lighter core. It is found to be impracticable to burn the whole kiln as hard as this, and the paving brick is culled from the rest. Some of the brick is burned to a medium hardness, and this is occasionally selected and used for the construction of sidewalks. Some common soft red brick always remains, and this is sold for foundations and buildings. During the last ten years a large amount of street paving has been done in this city and four-fifths of the brick used, if not more, have been made at home. As the farm land in this region is well drained there is no great market for tile, and the only place where these are made at present is in the brickyard at Macedonia.

SUMMARY OF STATISTICS ON BRICK AND TILE IN POTTAWATTAMIE COUNTY.

NAME OF OWNER AND LOCATION.	Clay used.	How dried.	Open kilns.	Down draft kilns.	QUANTITY OF PRODUCT. Common brick.	Pavers.	Tile.	Number of men employed.	KIND OF MACHINE	Value of product (Estimated.)	REMARKS.
Wickham Brothers, North Eighth St., Council Bluffs	Loess	Shed	6	....	1,750,000	1,750,000	....	32	Monarch	$ 27,000	Brick used in filling paving contracts.
John P. Weaver, Avenue L, North Eighth St., Council Bluffs	Loess	Shed	3	2	2,500,000	1,000,000	....	30	Brewer and Quaker	26,500	Exported to Omaha, etc.
Martin Hughes, Avenue L, North Eighth St., Council Bluffs	Loess	Shed	1	4	2,000,000	1,000,000	....	30	Seward	20,000	Market: Council Bluffs and Omaha.
L. C. Besley, Upper Broadway, Council Bluffs	Loess	Shed	1	2	1,000,000	500,000	....	18	Machine made	13,750	Market: Council Bluffs.
Henry Brugen Hemke, Nw. ¼, Sw ¼, Sec. 6, Tp. 74 N., R. 43 W	Loess	Open	2	....	1,100,000	100,000	....	9	(?)	8,500	Market: Council Bluffs.
Dye Brothers, Macedonia	Terrace loess	Shed	2	....	900,000	....	500,000	10	Machine made	11,300	Country and village market.
Seifert Brothers, Avoca	Loess	Sun dried	..	Patent	600,000	.....	....	10	New Quaker	4,200	Principally home market.
Saul Redfern, Carson	Alluvium and sand	Sun dried	1	....	500,000	....	....	4	....	3,500	Town and country market.
D. V. Kinzie, Oakland	Terrace	Shed	1	....	400,000	....	....	5	....	2,700	Town and country market.
S. B. Norcutt, West of Griswold	Terrace	Sun dried	1	....	300,000	....	....	4	....	2,100	Town and country market.
Carl F. Anderson, Council Bluffs	Loess	Sun and shed	1	.....	400,000	....	....	5	....	2,400	Town and country market.
Total	....	......	19	9	11,450,000	4,350,000	500,000	157	....	$ 121,950	....

Water Supply.

Until recent years farmers on the uplands have quite generally depended on surface wells from twenty to fifty feet in depth. The water in such wells comes from the base of the loess, on top of the bowlder clay or of the gumbo. On the river bottoms, driven wells are in general use, and the water is drawn from the stream sand or gravel. Such wells hardly ever fail, if deep enough. But on the upland most farmers now draw water from the bowlder clay or from under this. The wells which derive their water from the till rely on such little seepage as there is in this formation. They are, therefore, usually made at least a foot in diameter and set with large tile. A good supply of water is all important as a fire protection in the small towns, and we find in most of them steam pumps with high tanks. The State School for the Deaf and Dumb is supplied from two artesian wells about 1,000 feet in depth. The water comes from the Des Moines sandstone, and at first had a head of sixty feet. An analysis of the water is as follows, according to Floyd Davis, chemist to the State Board of Health:

	PARTS PER 100,000.	GRAINS PER GALLON.
Silica and insoluble residue....	.931	.543
Alumina and oxide of iron.....	.211	.123
Bicarbonate of lime..........	16.524	9.636
Phosphate of magnesium......	trace	trace
Bicarbonate of magnesium ...	5.610	3.272
Chloride of sodium............	12.865	7.503
Sulphate of sodium*....... ...	95.551	55.723
Bicarbonate of sodium.........	20.842	12.155
Sulphate of potassium.........	.820	.478
Total....................	153.354	89.433

At the shops of the Milwaukee railroad there is another artesian well of about the same depth. The old Geisse brewery also has an artesian well sunk to the same formation. Its flow is at present quite small, owing to the condition of the

*Estimated as anhydrous sulphate of sodium.

casing, which is old and no doubt corroded. The water supply of the city of Council Bluffs comes from the Missouri river. As this water contains a great deal of silt it is pumped into a system of settling basins and retained while the sediment sinks. When ready to go into the mains the water is clear and pure. The following table contains the statistics of the public water works in Pottawattamie county.

STATISTICS OF PUBLIC WATER WORKS IN POTTAWATTAMIE COUNTY

LOCATION.	SOURCE OF WATER.	Year built.	Depth of wells.	Number of wells.	POWER USED.	Head of pressure.	Pumping capacity, gallons per day.	Length of water mains.	Number of hydrants.	Number of taps.	Cost of plant.
Walnut	Loess seepage	(?)	50	1	Windmill system	140	....	2.5 miles	27	......	$13,500
Avoca	Stream sand	1891	120	3	Steam, Duplex pump.	140	750,000	....	.....	......	10,000
Oakland	Stream sand	1895	22	15 points	Steam pump	162	81,000	....	13	......	6,000
Minden	Drift sand	......	40	1	Gas engine	128	....	1 mile	21	......	....
Neola	Stream sand	1887	40	16 points	Steam pump	140	80,000	2 miles	25	150	7,000
Deaf and Dumb Asylum	Des Moines sandstone	......	1,100	2	Steam pump	......	36,000	....			....
Council Bluffs Water Works	Missouri river	1883		....	Four steam pumps	237	8,000,000	40 miles	282	2,532	....

Coal.

Several explorations have been made to discover coal in this district. In the early days the county board even voted a bounty of $2,000 to any one who should deliver the first coal from a mine in the county. So far coal has not been found in economic quantity, though some thin seams were encountered in borings at Carson, at Macedonia, and in some of the artesian wells. From what is known of the area, it may safely be inferred that coal will not be found in sufficient quantity for mining. Evidence from other points in this part of the state corroborate this inference, and it is quite safe to predict that the bounty offered will never be claimed. Attempts in this direction will prove disappointing.

Road Ballast.

The black and almost peaty soil found on some of the lowest stretches on the flood plains has lately been used for making ballast for railroad beds. For this purpose the black muck, usually called gumbo, is taken up with steam power and mixed with coal, which is ignited. The whole mass is kept burning for weeks, and slowly changes to red cinders or clinkers. This is then hauled away and used on the roadbed. Two suitable locations have been found and used for this purpose; one in Secs. 29 and 32 in Tp. 74 N., R. XLIV W., along the track of the C., B. & Q. railroad, and one in Sec. 18, Tp. 76 N., R. XXXIX W., along the Carson branch of the C., R. I. & P. railroad.

Soils.

The soil of Pottawattamie county does not differ essentially from that of the surrounding region. The upland soil is loess, mixed with more or less humus and decayed vegetation. The principal crop is corn, but wheat, oats and other small grain are also planted. Near the Missouri river some lands are too hilly for tilling, but make excellent pastures. The flood plain of the Missouri is everywhere very fertile, but some parts are low and marshy and subject to inundations. Some have been drained and protected by levees. The valley of the West Nishnabotna is also good farming land. The wealth of the county is in its uniformly rich soil.

Acknowledgments.

For aid in the field work in this county the author is under great obligations to Dr. S. Calvin, the Director of the Survey; also to Mr. J. LeRoi Oakleaf, whose pleasant company and aid he enjoyed during part of the time spent in the field, and to Mr. F. G. Weeks of Carson. Professor B. Shimek has kindly examined the loess mollusks found, and Dr. G. L. Stempel, an accomplished entomologist and extensive collector, residing at Macedonia, furnished some fossils from his vicinity.

IOWA GEOLOGICAL SURVEY

MAP OF THE SURFACE DEPOSITS OF POTTAWATTAMIE COUNTY, IOWA.

BY J. A. UDDEN

1901

LEGEND

ALLUVIUM

LOESS OVERLYING TILL

INDUSTRIES

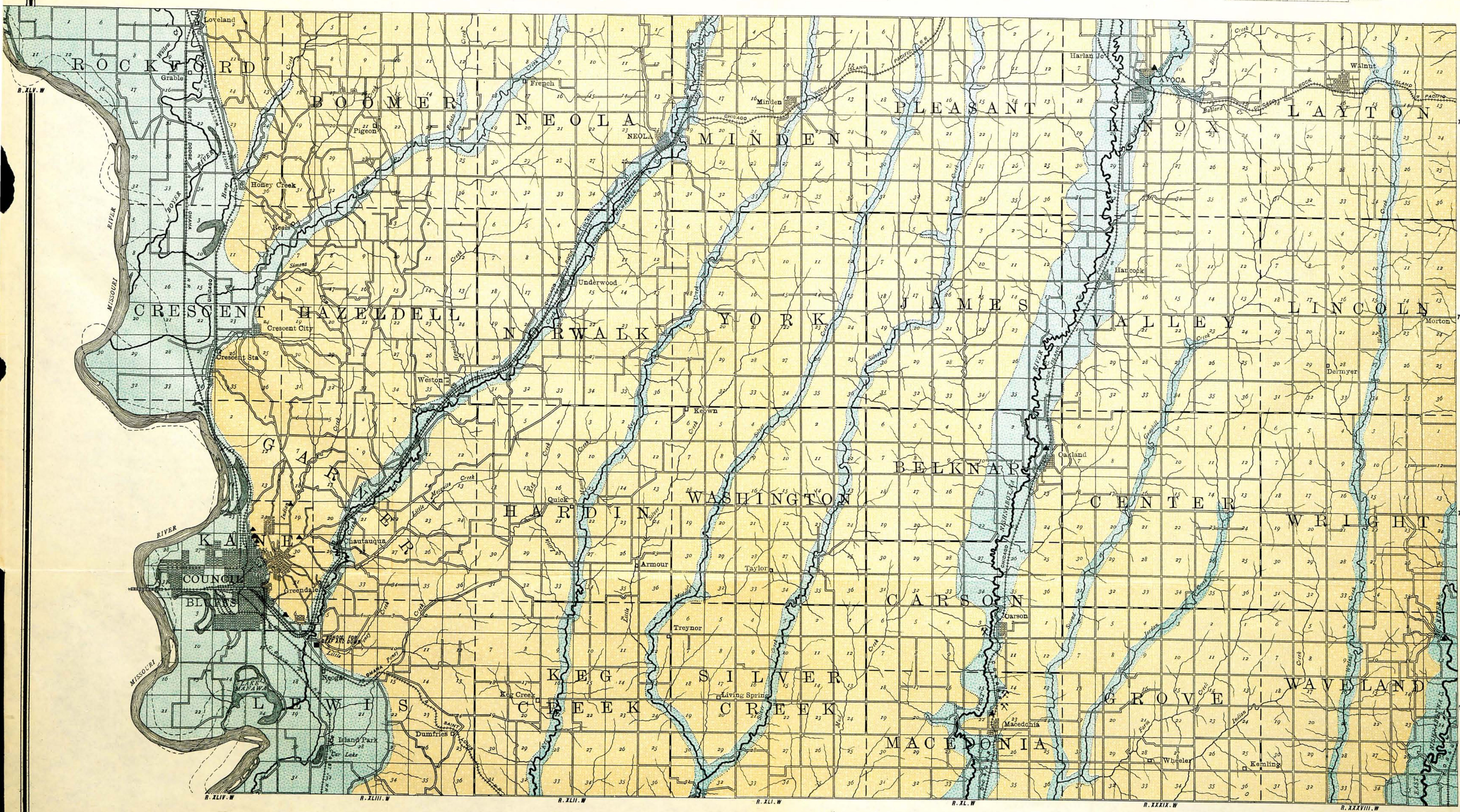
BRICK YARDS ▲

STONE QUARRIES ⚒

Scale $\frac{1}{125000}$

5 Miles.

5 Kilometers.



IOWA LITHO. CO.

DRAWN BY F. C. TATE

GEOLOGY OF CEDAR COUNTY.

BY

WILLIAM HARMON NORTON.

GEOLOGY OF CEDAR COUNTY.

WILLIAM HARMON NORTON.

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INTRODUCTION.

SITUATION AND AREA.

The district mapped and described in the following report comprises an area twenty four miles square, situated nearly midway the state from north to south, and in the second tier of counties west of the Mississippi river. It is bounded on the north by Jones county, on the east by Clinton and Scott, on the south by Muscatine, and on the west by Johnson and Linn. It lies mainly in the doab between the Wapsipinicon and Cedar rivers. The former transects the northeast corner of the area. The latter, from which the county takes its name, crosses it from northwest to southeast, leaving five townships in part or whole on its right bank.

PREVIOUS GEOLOGICAL WORK.

Beyond the immediate valleys of the trunk streams mentioned, outcrops of the indurated rocks are infrequent. The topography of the county, with its drift plains and rolling prairies, presented no salient features to attract the notice of the early students of physiographic geology. There is therefore no long list of scientific papers relating to this area. The earliest geological survey within the limits of the county, that of David Dale Owen* in 1848 and 1849, the final report being published in 1852, records the presence of Silurian, Devonian, or Carboniferous strata at some nine different places in the county. In the survey of Hall and Whitney† less than ten lines are allotted to the county, and these are references of a general nature to forest, prairie and soils.

In the reports of Dr. C. A. White‡ no mention is made of Cedar county, except in certain analyses of peat, the whole attention of this survey being devoted to other regions of the state.

Cedar county is included in the large area whose glacial geology is described by W J McGee in the Pleistocene History of Northeastern Iowa§. References to localities within the county will be found on pages 202, 218, 223, 341, 357, 404, 407, 463.

The present Survey has already recorded a number of features in the geology of the county. Houser‖ has written on the economic conditions of the lime and building stone industries, and Norton¶ has noted the presence of Devonian and Carboniferous outliers and has described the geological section of the Tipton deep well.

Thus the geological work already done in the county is limited in amount and easily summarized. The indebtedness of the present investigation to it is comparatively slight. But it is impossible to place here on record the amount to which we are indebted to the geological work of the present Survey done elsewhere in the state. The mapping of strata,

*Rept. Geol. Sur. Wisc., Iowa, and Minn., D. D. Owen, Philadelphia, 1852.
†Rept. Geol. Sur. State of Iowa, Hall and Whitney, Des Moines, 1858.
‡Rept. Geol. Sur. State of Iowa, C. A. White, Des Moines, 1870.
§U. S. Geol. Sur. 11th Ann. Rept., Washington, 1890.
‖Iowa Geol. Sur. vol. I. pp. 199-207.
¶*Ibid*, vol. III, p. 121.
¶*Ibid*, vol. III, pp. 197-200 and vol. VI, pp. 261-262

the description of deposits, and the elucidation of difficult problems in other counties afford a body of knowledge, experience, criteria and methods of attack of which we have availed ourselves to the utmost. The diagnostics, for example, of the distinct ice invasion called the Iowan, which have been so fully worked out by Calvin in Johnson, Delaware, and other counties, have been carried over into Cedar and applied to similar phenomena here; and, to mention a much less important instance, it would have been far more difficult to interpret the Devonian section in Cedar were it not for the more extensive outcrops already studied in Linn.

PHYSIOGRAPHY.

RELIEF.

A measure of only about 325 feet separates the highest from the lowest elevations in the county. The maximum height is attained in the northwestern part at something over 960 feet, the minimum in the valley of the Cedar on the Muscatine county line at 635 A. T. Omitting from consideration the trenches of the streams, this area of twenty-four miles square forms a fairly even surface which gradually rises towards the northwestern corner from an elevation of 740 feet A. T., at the southwest, 760 at the southeast, and 860 feet at the northeastern corner.

Slight as is this relief when compared with the mountains of Colorado, or the canyons of Arizona, it nevertheless comprises the various records of different geological agènts acting through times almost inconceivable in their length. It possesses, therefore, an historic interest which may equal that of the most stupendous scenery. The historic interest of an ancient document does not depend on the size of its letters, nor are the geological values of the landscapes in Cedar county lessened by the faintness of the characters in which their story is engraved.

On the north lies a narrow plain which we shall know as the Clinton lobe of the Iowan drift plain. This slopes eastward from a height of 900 feet A. T. near Lisbon, to 820 A. T. near Massillon. On the left bank of the Cedar a similar plain, which may be termed the Tipton lobe of the Iowan plain, stretches from the Linn county line to within a fraction of a mile of Tipton, with a maximum elevation of about 800 feet A. T. With the exception of these lobes and an anomalous area at Rochester where constructional contours prevail, the remainder of the county may be described as an upland, everywhere overlooking the Iowan plains, retaining in places, as near Sunbury, much of its initial level surface, but elsewhere worn by long rain wash and stream erosion to a gently undulating prairie, as about Red Oak, or deeply carved into a maze of steep hills, as near Cedar Valley. This is termed the Kansan upland, and it will be more fully described under the head of the Kansan drift. It stands at 960 A. T., south of Mechanicsville, at 900 south of Stanwood, at 860 south of Clarence, and at 840 A. T. near Lowden. In Gower township its altitude is from 800 to 820, and it descends to 760 and 740 in Springdale township, a descent of over 200 feet from the marginal hills overlooking the Clinton lobe of the Iowan drift plain. In Sugar creek township the crests of the Kansan upland are about 800 feet above sea, declining to 760 in Farmington.

The following table gives the elevation above tide of the towns of the county, Gannett's Dictionary of Altitudes in the United States being authority:

	FEET
Bennett	742
Buchanan	750
Centerdale	725
Clarence	829
Downey	683
Durant	720
Lowden	721
Massillon	733
Mechanicsville	899

	FEET
Plato	703
Stanwood	851
Tipton	805

DRAINAGE.

The Wapsipinicon River.—The two master streams of the county are the Wapsipinicon and the Cedar rivers. The former transects the extreme northeastern corner, leaving hardly more than two square miles of the county on the left bank. While its drainage area comprises about one hundred and fifty square miles, its course within the county is only some four miles in length. But even within this short distance it presents both the types of river valleys common in eastern Iowa and in glaciated regions. Where the Wapsipinicon crosses the Jones' county line, it winds over a sandy alluvial plain more than a mile in width. At Massillon it enters a narrow rock-bound valley, in which ledges of Niagara limestone stand thirty feet above the water, the hills on the right bank rising to twice that height above the same datum. At the Clinton county line it escapes from this constricted valley and flows out on a wide flood plain, silt filled to unknown depth. These sharp contrasts are clearly due to glacial interference. A stream flowing over rocks of uniform resistance will excavate a valley homogeneous throughout in width, in depth, and in contours. In such rocks, differences in valley width express corresponding differences in age. Since every stream cut valley must needs be narrow before it is wide, and shallow before it is deep, the gorge at Massillon must be far younger than is the wide silt filled valley above the town; and we must conceive that the stream has been diverted here from its ancient path to the gorge which it has excavated in comparatively recent times.

The method by which a river widens its channel in massive rocks is well illustrated at Massillon. The Gower limestone of the ledges is obdurate in the extreme. It does not break into chipstone under frost, and its laminæ, though etched by the weather on the surface of the cliffs, remain coherent, and the ledges remain horizontal indefinitely. But these limestones, like all indurated rocks, are affected with joints, or natural fissure planes, which here are vertical and distant, cleaving the ledge from top to bottom. They form channels for percolating water, which gradually widens the joint seam by dissolving the limestone along its sides. It is in this way that the "wells" are formed which are found on the top of the ledges, and are as much as five feet in diameter. Thus by

Fig. 16. Ledge of Gower Limestone on Wapsipinicon river, Massillon.

the percolation of water down the joints great blocks are detached from the rock-mass. They are gradually undercut by the river flowing at the base of the ledge, and when undermined, slip, as is shown in figure 16, fall and at last are carried away piecemeal by the stream.

Tributaries of the Wapsipinicon.—The eastern and the northern tier of townships pay tribute, for the most part, to the Wapsipinicon. Its affluents gather the storm water over the larger portion of the Clinton lobe and the northeastern part of the Kansan upland. Pioneer creek flows southeast from the southern margin of the Iowan plain northwest of Mechanicsville, where in wet weather water stands in shallow pools. It receives the drainage of the Kansan island in Secs. 1, 2, and 3, Pioneer township. A branch called Picayune creek, rises at the edge of the Kansan southeast of Mechanicsville, and breaking through the paha ridges south of the village, joins Pioneer creek near the Jones county line. Here the creeks traverse a marshy flood plain a mile wide lying forty feet below the Iowan plain adjacent. A small stream known as Sybil creek drains the Iowan plain north of Stanwood. Mill creek gathers its head waters west of Clarence and maintains a southeast course across the Iowan plain and through a narrow upland of Kansan south of Oxford Mills.

The eastern part of the Iowan plain is drained by two creeks whose course is east and southeast. The northern one drains the country north of the great Lowden paha, and discharges in Clinton county below Massillon. The other, Yankee run, occupies an ancient valley whose floor of rock is buried an unknown distance below the surface. West of Lowden the valley plain is over a mile wide and falls with distinct slope to the southeast. A south branch of Yankee run is of wholly different type. Rising southwest of Lowden and flowing nearly east, it drains an intricately dissected Kansan upland, in which it has cut a comparatively narrow channel. The same upland is penetrated by the headwaters of Rock creek, and south of Bennett, where it shows scarcely a trace of stream cutting, it pays tribute to Walnut and Mud creeks. The longer courses of these three creeks lie in Scott county, and their physiognomy has been described in that report.

The Cedar River.—In its diagonal course across the county the Cedar exhibits the same alternation of wide and ancient, with narrow and recent valleys shown by the Wapsipinicon. Where it crosses the Linn county line it winds down a flood plain two miles wide in meanders, the radius of whose inner curve is three or four times the width of the stream. Above the flood plain rise the steep forest-crowned hills of the Kansan upland on the right bank, while on the left there is a gradual ascent from sandy terraces to the rolling prairie of the Tipton lobe of the Iowan drift plain. At Cedar Bluff the river swings to the left, and sweeping against the hills, which here rise eighty feet to the Iowan prairie, washes their bases of Gower limestone. At the village it breaks directly through a rocky spur projecting from the left bank, thus forming an isolated hill some fifty feet high and about 1,000 feet in length, which rises abruptly from the river on the one side and on the other from the wide flood plain. The present channel of the Cedar where it transects the spur is 600 feet wide, rock-floored and completely filled by the stream. So recently has the river been diverted from the flood plain to the right of the island, that practically no stream-cutting has taken place below the level of the plain, and the farm lands upon it are protected by a levee from high water. The walls of the gorge cut in the soft and laminated Anamosa limestone are still vertical.

The extraordinary behavior of the stream in thus leaving the wide and easy way to the west and climbing, as it were, over the hills on the east, has aroused the attention of the intelligent people of the vicinity, and so striking is the example of a phenomenon not common, that it may be well to consider the ways in which such isolated hills on flood plains are made. Projecting spurs may be formed and afterwards transected in the normal development of meanders. As the stream cuts its curves more and more deeply convex, as it alters its open curves to horseshoe bends and constantly narrows their necks, it, at last, may cut completely through the neck of the inclosed spur, leaving its former crescentic channel slowly to fill with alluvial deposits, and ultimately to be aggraded to the level of the flood plain. If we attempt to apply this theory to the case in hand, and imagine the Cedar as once swinging to the left of the knob in a great horseshoe curve, and cutting the present path of the stream from both above the "island" and below, we shall see at once that the latter does not exhibit the requisite form. Its longer axis is not aligned at right angles to the course of the stream, as it should be if formed in this way, but lies parallel with it.

Such isolated hills on broad flood plains are found also where a narrow tongue of land, intervening between a river and the lower course of a tributary, is cut through by lateral sapping, the master stream thus becoming diverted to the channel of the affluent. If this hypothesis is applicable here we must suppose that the small creek mouthing one and three quarter miles above Cedar Bluff once fell into the trunk stream below the village, and that the ridge once intervening has been wholly consumed with the exception of the rocky "island" under discussion. If this is the case, the valley of the creek, the left bank of the Cedar from the creek to the island, and the channel at the island onght all to present the same topographic forms since they are all of the same age. But the contours of these courses are markedly different. The channel at the island presents every evidence of extreme topographic youth in its floor of rock and its narrow and vertical walls. The others are evidently older, being bounded by hills of moderate slope in which rock but rarely appears. A cogent fact which contradicts both of the theories is this: the valley of the Cedar has not developed in a regular and uninterrupted cycle. The depth of the ancient fluvial floors of rock beneath its wide flood plains forbids us to connect with the cycle to which they belong such a channel as this at Cedar Bluff.

Other solutions of the problem being closed there remains the agency of the great ice invasions of Pleistocene times. When the broad valley of the Cedar was still filled with glacial ice, a superglacial stream finding its way as best it might would here and there discover its ancient channel, while here and there it would be let down upon some rocky spur across which it would cut a narrow gorge such as this at Cedar Bluffs.

It would be expected, also, that for long stretches the ancient strath so filled with glacial ice would be so blocked with ice and land waste that the river would be diverted to a new track. Such is the path of the Cedar from below Cedar Bluff nearly to Rochester, a rectilinear course in a narrow valley cut to a depth of 140 feet in the Kansan upland, bordered with steep bluffs covered with forests and disclosing here and there vertical palisades of Gower limestone.

From Rochester to the south line of the county the valley of the Cedar is of the type described above Cedar Bluff. The river swings from side to side of a flood plain a mile in width. On the right bank the Kansan upland lies about 100 feet above the river. On the left bank the Kansan lies lower, being from sixty to eighty feet above the same datum on the prairies east of Lime City.

The breadth and sloping sides of the wide reaches of the Cedar are evidences of great age, but in themselves alone these characteristics do not imply a preglacial or pre-Kansan origin. Valleys as broad in southwestern Iowa have been found to be post-Kansan by the geologists who have studied that field. But, while the latter are cut in drift, the former are cut in solid rock in large measure. Taking into consideration both the quantity and the hardness of the material excavated, and, in especial, the fact that the drift lies unconformable on the slopes of rock which form the sides of the valley, the conclusion is inevitable that the wide valleys of the Cedar are at least pre-Kansan in age, and may, perhaps, be even pre-glacial.

Terraces of the Cedar.—These remnants of ancient flood plains are well marked on the broader reaches of the Cedar. They testify to the great volume of water, derived from the melting of the ice sheets of Pleistocene time, which once poured through this channel. Connecting with the terraces described in the report on Linn county,* these benches continue without interruption to Cedar Bluff, being more sharply defined on the left bank of the stream. A narrow upper terrace, standing about twenty feet above the lower bottoms and thirty-five feet above the river is marked by a clean scarp and

*Iowa Geol. Surv., vol. IV, pp. 176, 177.

level floor, and its surface is composed of either a yellow, loess-like loam, a rather stiff, yellow joint clay, or of sand.

A typical section is afforded in Cedar township, Sec. 17:

		FEET
8.	Clay, yellow, slightly arenaceous	2
7.	Clay, reddish, sandy, more or less indurated, graduating into No. 6	1
6.	Sand, stratified, yellow and white, from fine to coarse, with some gravel	4
5.	Clay, white	2
4.	Ochreous accumulation, indurated	$\frac{1}{6}$
3.	Sand, light yellow and gray, interstratified with laminæ an inch or less in thickness of white clay	3
2.	Gravel, stratified, with yellow sand	6
1.	Concealed to floodplain	3

The lower bottom land which for the most part stands well above the present floods of the river, is about a mile in width and varies in its superficial deposits from sandy stretches to fine silt and black humus.

In the narrows from Cedar Bluff to Rochester terraces are either inconspicuous or wholly absent, but from the latter station to the Muscatine county line the remnants of these ancient fluvial floors form a most striking topographic feature, everywhere bounding the wide alluvial bottom lands with their sinuous and sharp escarpments. Rochester stands upon a bench of stratified sand and gravel about twenty-five feet above the river, which sweeps southwestward, forming a selvage about the hills as far as the mouth of Crooked creek. About the town benches occur to a height of twenty feet and more above this terrace. These are composed of sand and are rendered indistinct by dunes which surmount them and by their blending with the northwest-southeast ridges of the district. South of Rochester the main terrace on the right bank stands at about twenty-five or thirty feet above the present flood plain of the river. With a width in places of over one-fourth of a mile, it extends nearly to the Muscatine county line where the river swings across the flood plain and impinges on the base of the bluffs of the western bank.

The structure of this bench is shown in many gullies. Below about six inches of humus lies a rather stiff, reddish jointed clay, four feet thick, resembling weathered loess, which passes by interbedding into stratified yellow sand affected with the common brownish bands denoting an admixture in these layers of some clay.

In color, depending on age and degree of ferrugination, and in composition and structure, these terrace deposits agree with those of the age of the Iowan drift, and are taken to have been laid down at the time of the melting of the Iowan ice sheet.

TRIBUTARIES OF THE CEDAR.

Clear Creek.—This large creek drains the Kansan upland in the northwestern part of the county. Two branches draw their head waters, northeast of Lisbon, from the Iowan plain, over which they flow in shallow trenches. Entering the hills of the Kansan they soon descend to a depth of 100 feet beneath these loess-capped summits. The east fork of Clear creek rises south of Mechanicsville on a divide where storm water gathers in temporary ponds, and flowing west and joining the west forks, takes a southwest course through the Kansan upland in a tortuous valley bordered here and there by ledges of Gower limestone which reach a height of about fifty feet. The excellent mill sites thus afforded were early utilized by the erection of three of the largest mills in the county. Within about one-half mile of the Linn county line Clear creek leaves the Kansan and flows out upon the comparatively low area of the Tipton lobe of Iowan drift, and upon this it continues with high terraces until it falls into the Cedar at a normal angle.

Between Clear creek and Cedar Bluff two unimportant streams flow southwest into the Cedar over the Iowan plain. The western of these is diverted in its lower course along the flood plain of the river by its natural levees. The ravines of the head-waters of the eastern of these streams trench through Kansan till and uncover the Gower limestone at about 800 feet A. T., and in section 14, Linn township, the creek has cut some 40 feet in the same beds, the slopes of the rock being covered with Kansan till and loess.

Below Cedar Valley there debouch into the Cedar on the left bank three relatively important streams,—Rocky run, Rock creek and Sugar creek. These all rise on or near the frontier of the Clinton lobe of the Iowan, and pursue southeasterly and southerly courses, changing to southwesterly when within about two miles of their trunk stream. In the plain of Iowan drift west of Tipton, the tracks of Rocky run and Rock creek are deflected, corresponding to the southeastward movement of the Iowan ice.

Rocky Run.—This stream rises south of Mechanicsville, on the Kansan plain, here undissected. Flowing south through Red Oak township, it occupies a channel about five feet deep in a valley lying about thirty-five feet below the summits of the adjacent hills. Across the Iowan plain its strath is in places bowlder strewn. Entering the Kansan upland in Center township, it holds a very narrow, winding valley, which reaches the depth of 140 feet below the level of the upland. The Gower limestone is disclosed at many points, and on the slopes cut by the stream in the rock the loess and the Kansan till descend well down to the present level of the water.

Rock Creek.—The Iowan area directly north of Stanwood and the rolling Kansan area about Red Oak discharge their storm water into the valley of Rock creek. Near Tipton the creek bends to the west about a heavy ridge of Kansan drift, and again to the southeast along the margin of the Tipton lobe of the Iowan. Entering the Kansan again southwest of Tipton, its valley is wholly similar to that of Rocky run in the same area. Near Rochester it leaves the upland and turning abruptly west along its margin falls into the Cedar.

Crooked Creek.—This name is applied to a stream which rises on the flat divide north of Tipton and flows southward through a wide valley cut only in the drift. East of Rochester it crosses a region where the country rock rises nearer to the surface, and here the valley narrows. As the Devonian limestones here traversed are comparatively weak, the narrows are less constricted and less steep of side than the gorges of the streams which cross the resistant limestones of the Niagara.

Sugar Creek.—This is the largest creek of the county. Its course extends from the margin of the Clinton lobe of the Iowan drift south of Clarence, southward to Muscatine county, a straight line distance of eighteen miles. Until it reaches Sugar Creek township, the valley of this creek is cut wholly in the loess and the drift, and over the lower portion of this track is a much wider valley than that of the Cedar from Cedar Bluff to Rochester. From the summits of the Kansan upland one looks across a sunny valley from a mile to a mile and a half wide and eighty feet deep. All the enormous amount of material, a bulk sufficient to refill the valley, has been washed away by the creek and delivered to the river for transport to the sea, and all by the slow processes of erosion now in progress. But the age of the valley cannot antedate the deposition of the drift sheets in which it is excavated. How long is it, then, since these were laid down by the Pleistocene glaciers? Long enough for Sugar creek to have washed out and away each clay-flake, sand-grain and pebble of the bulk which once filled this wide valley.

At the north line of Sugar Creek township the stream passes into a region of much shallower drift, and encountering the resistant rocks of the Gower, has accomplished a much smaller measure of erosion. The strath at once constricts, and from here to Lime City is similar to the valleys of the other creeks of the county cut in the same limestone. A mile south of Lime City the stream emerges upon the drift and flows over wide flood-plains bordered by gently sloping hills southward across the Muscatine county line and enters the old channel perhaps once occupied by the waters of the

Mississippi, designated in the report on Scott county as Durant channel. This broad and ancient waterway transects the southeastern corner of Cedar county. The course of the channel and its relation to the Illinoisan ice have been set forth in previous reports* In Cedar county the channel is now occupied by Big Elkhorn creek, and is about one mile in width and flat bottomed.

Farmington township is drained in part by two creeks which flow south over the southward sloping Kansan plain and empty into Durant channel. Both occupy wide, flat, silt-filled valleys in their lower reaches and shallow swales toward their head-waters, and both lie wholly in drift.

The tributaries which fall directly into the Cedar on the right bank are comparatively short. The most northern of them is Nicholson creek, which presents all the usual characteristics of the smaller streams in Kansan drift. It has cut through into the Gower limestone in its lower course and falls into the river above Cedar Valley.

The southwestern townships of the county are drained by the three forks of Wapsinonoc creek. They occupy wide drift cut valleys with well graded flood plains and well marked dendritic system of subordinate drainage channels. Flowing south across the Muscatine county line the creek traverses the wide alluvial plain of Lake Calvin and empties into the Cedar south of Nichols.

Sinks.—All the drainage of the county is subaerial, except a short underground course of a storm water stream in the southeastern corner of Iowa township. This phenomena is so rare in this region that it may be described in some detail. To one approaching from the south, the sink appears as a normal, narrow, steep-sided little valley, directing its way toward the Cedar. In a distance of eighty rods the ravine descends some sixty-five feet below the upland. Here the water course, strewn with fragments of Devonian rocks, ends

*Udden, Iowa Geol. Sur., vol. IX, p. 344.
Norton, Ibid, pp. 410, 420, 421.

abruptly against a low wall of heavily bedded limestone, and turning to the left plunges through a rock portal about four feet wide into the tunnel through which it finds the remainder of its way to the Cedar. The entrance is now choked with debris, but it is said that the cave, a mere cleft for the most part, but in one place widening to a passage five feet wide and seven feet high, has been followed a distance of 150 feet. From the south, east and west shorter ravines descend to pit-like sinks at about the level of that described, nine of these being counted in a radius of twenty rods. The longer ravine is at right angles to the river, from which it is separated only by a steep and narrow ridge of the same height as the land on either side. The outlet of the sink was not seen.

It is characteristic of some of the streams whose courses lie north-south that the west bank is both higher and steeper than the east. On Sugar creek north of Tipton the hills of the west bank rise rather steeply to a height of seventy to ninety feet above the stream, an elevation reached on the opposite side only at a distance of from two to four miles from the creek. Less markedly the same difference obtains on the branch which empties into Sugar creek near Wilton, on Crooked creek and on the course of Rock creek above Tipton. In so far as the difference may be due to unequal initial depth of loess, another problem is added to those still unsolved as to the origin and distribution of that formation.

The Preglacial Drainage.—Before the advent of the Great Ice the drainage channels of this region were by no means as they are today. Midway the present valleys of the Wapsipinicon and Cedar lay a preglacial channel broader and deeper than are the post-glacial valleys of these rivers. Toward this central trough, here called Stanwood river, the rock surface sloped from either side so that in the immediate valleys of the present rivers it stands 200 feet above the rock cut path of the ancient stream. Another deep preglacial channel lay near the Johnson county line, west of Downey, probably connecting with the depressions found by Calvin* in Johnson county, in Cedar and Scott townships.

Nothing in the present topography gives the slightest hint of the existence of these buried river beds. Their discovery is due to the well drillers of the county, who, in these belts, find that their drills pass through scores of feet of river sand before they grind on the rock 300 feet below the surface of the ground.

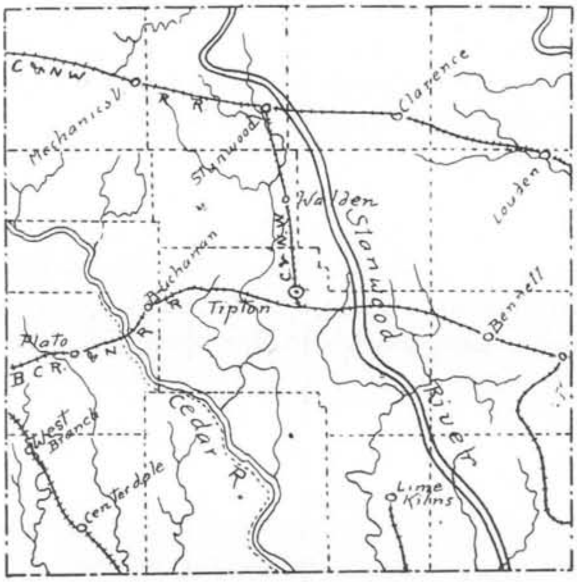


Fig 17. Course in Cedar County of Stanwood River.

Stanwood river enters the county in Fremont township, and, curving strongly to the west, passes southeast to Stanwood. Trending southward east of Tipton, it follows down the east side of Sugar creek nearly to where that stream enters the rocky gorge two and one-half miles north of Lime City. Here it bends to the southeast, and while its course in Farmington township is not well made out with the data at hand, it

*Iowa Geol. Surv., vol. VII, p. 91.

is well nigh certain that it joins near Durant the ancient buried river which passes south through western Scott county, described in the report on that county under the name of Cleona channel.

At Stanwood the rock floor of Stanwood river is 544 A. T. Five miles southeast, at Geo. Kinney's (Sec. 17, Fairfield Tp.), it has declined to 500 A. T., the rock here being struck 320 feet below the surface. Fourteen miles southeast of Stanwood, at John Helmer's (Sec. 23, Center Tp.), it has fallen to 440 A.T., a gradient of seven feet to the mile, as steep as that of the swift Colorado. Cleona river, into which Stanwood river empties, has a fluvial floor in southern Scott county of not higher than 400 A. T. This channel continues, as has been shown by Leverett, to the southeast county of Iowa. To Mount Clara, eighty miles south of Durant, the fall of the floor of this buried waterway is but twenty-six feet. From Durant north, by Cleona channel and the Maquoketa and Mississippi, to the rock floor of the Mississippi at Sabula, is a rise of but nineteen feet in sixty miles. Stanwood river was clearly a tributary of this axial stream, a preglacial Mississippi as it may have been. Data are not at hand to show clearly the character of the preglacial valley further than the general slope toward the trough. Measured from crest to crest, its width is at least seven miles at Tipton, with a sharper descent to a thalweg perhaps two miles wide. Three miles north of Tipton the inner trough, a mile wide, lies 120 feet below a wider one, at least two and one-half miles wide, and rising more than 100 feet higher. If precipitous walls exist, such as those of the bluffs of the Mississippi, in northeastern Iowa, there is no evidence of the fact in the records of the wells. So far as appears, the character of the transverse profiles points to a river at least well on toward maturity. This is in such strong contrast with the steep gradient that the question at once suggests itself how far the gradient may be due to differential uplift. If this is the case, it has not affected to any marked degree the preglacial channel of the Mississippi. The question is a much larger one than Cedar county, and we need do no more than place the local facts on record to be taken into account with those from other districts in reaching general conclusions for the entire region.

The channel of Stanwood river is aggraded with river sand. At Stanwood it is thus filled to a height of 116 feet above its rock floor. Three miles southeast, at Henry Britcher's, drillers report 144 feet of sand overlying the rock, and one report names a figure considerably higher. In a few wells in the channel these deep sands were replaced by glacial tills, as in this section of a well in Fairfield Tp., Sec. 22:

	THICKNESS.	DEPTH.
Yellow clay	30	30
Blue clay, tough	126	156
Sand	10	166
Blue clay	66	232
Sand, to rock	1	233

Such heavy sands are found in wells at some distance from the central line of the trough. For example, at the well of Adam Birk, to the northeast of Tipton, probably two miles from the median line of the valley, and more than 100 feet higher than it, sand 100 feet deep was penetrated below seventy-five feet of yellow clay, the former resting directly upon the rock.

In these channels sands are usually fine of grain. They could have been laid down by streams discharging the waters of the advancing glacier, and overloaded with its silt, or, far more probably, a subsidence in early Pleistocene times diminished the gradient and thus lessened the capacity of the stream to carry its load.

STRATIGRAPHY.

The indurated rocks of the county were deposited during three long, successive cycles of geologic time known as the Silurian, the Devonian, and the Carboniferous. Shales reported in a single deep well sunk in the preglacial channel of Stanwood river, if authentic, belong without much question to a still earlier cycle, the Ordovician, and this age may therefore be placed in the list.

During the long eras after the emergence of the region from the sea, an event wholly accomplished at the end of Paleozoic time, the rocks of the county weathered to residual clays, known as geest. Remnants of this mantle which remain can thus be assigned to no particular age. The incoherent superficial deposits belong to a time notable for the exceptional development of glacial ice in the northern hemisphere and known as the Pleistocene.

The areas of outcrop of each of these formations may be seen by consulting the maps which accompany this report. It will be noted that the larger part of the county is underlain by the Silurian. A much smaller area, lying chiefly in the southwestern townships, is assigned to the Devonian, and here the rocks are for the most part deeply buried beneath the drift. The Devonian limestones are weaker than the Silurian and with preglacial weathering may well have sunk to a somewhat lower relief, allowing upon them a deeper accumulation of glacial drift than would lodge on the harder and higher rocks of the Silurian area.

The succession of the groups and systems of the rocks of the county with their subdivisions is set forth in the following table:

SYNOPTIC TABLE OF FORMATIONS IN CEDAR COUNTY.

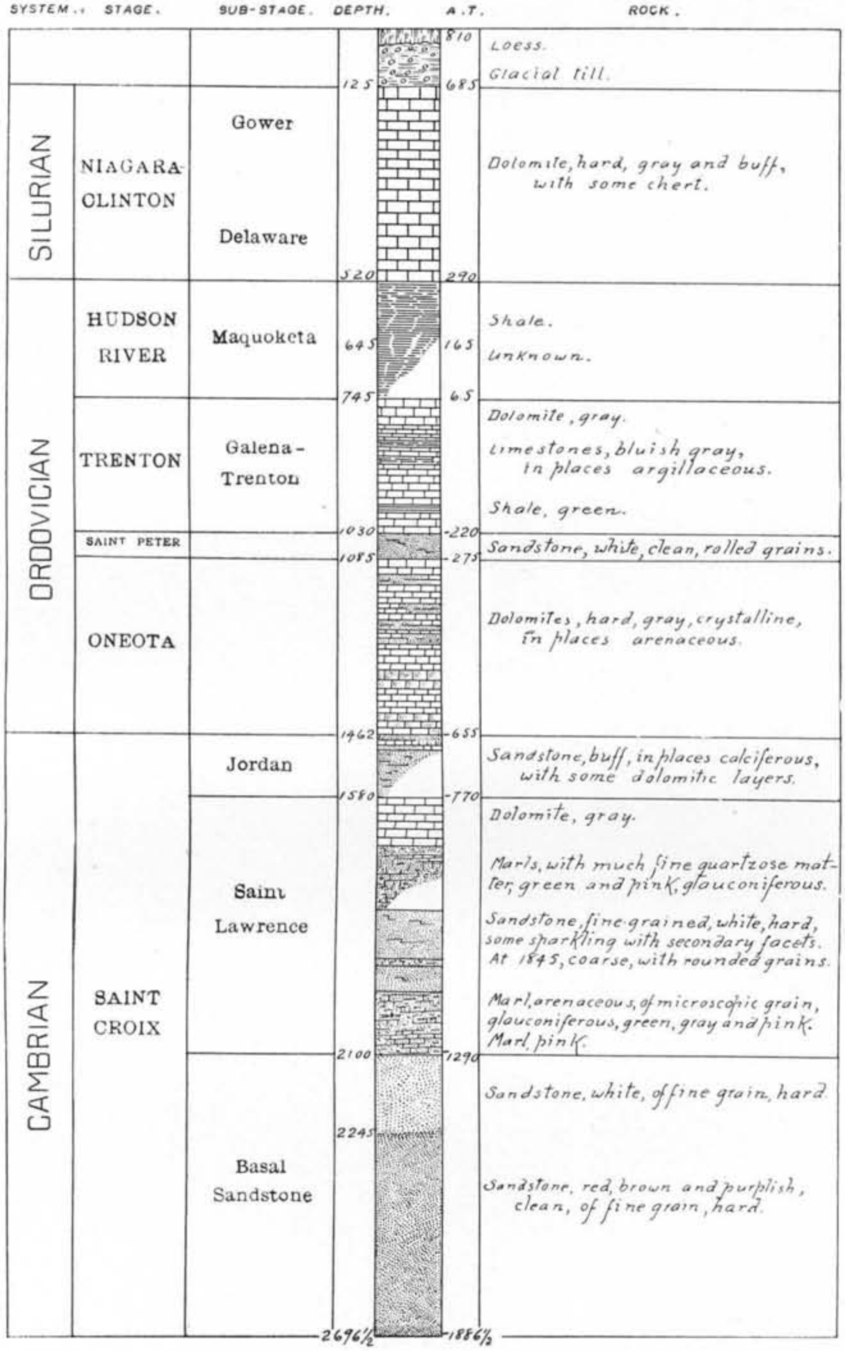
GROUP.	SYSTEM.	SERIES.	STAGE.	SUBSTAGE.
		Recent.	Alluvial.	
Cenozoic.	Pleistocene.	Glacial.	Iowan. Yarmouth. Kansan. Aftonian. Pre-Kansan.	

SYNOPTIC TABLE OF FORMATIONS IN CEDAR COUNTY—CONTINUED.

Residual Clays, or Geest.				
Paleozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.	
	Devonian.	Middle Devonian.	Cedar Valley.	
			Wapsipinicon.	UpperDavenport
				LowerDavenport
				Independence.
				Otis.
				Coggan.
	Silurian.	Niagara.	Gower.	
	Ordovician.	Trenton.	Maquoketa.	

THE DEEPER STRATA.

The outcropping rocks within the limit of the county can hardly represent a vertical measure of more than 250 feet, an amount inconsiderable in comparison with the thousands of feet of stratified rock upon which they rest. Of the nature of these deeper strata much is known, both from their outcrop in areas to the northeast and from deep borings. One of the most interesting of these is the Tipton artesian, one of the deep wells of the United States. The samples of drillings, carefully saved by different citizens of Tipton when the work was in progress, tell in a satisfactory manner the nature and



Geological section of the Tipton artesian well.

thickness of the underlying formations. A report of these has already been published by the Survey.*

During the present investigation a set of samples was obtained much fuller than the incomplete ones used in previous studies. Of the sixty additional samples thus secured, the larger number were of use only in corroboration of the record and section already made out. Several, however, bridged serious gaps, and made it possible to correct the previously published reports. The succession of formations, their thickness, and the character in brief of the rock is exhibited in plate VII.

Ordovician.

According to the log of the well at the tile factory at Stanwood, as reported by Mr. G. W. Sisler, of that village, there was found at the depth of 296 feet, and immediately beneath Pleistocene deposits, 44 feet of black, hard, tough clay, which dried like shale. Any deposit which would answer to this description at this place and depth would in all likelihood be the shale of the Maquoketa. The conclusion is fairly probable that Stanwood river here cut through the Silurian limestones into the shales of the Ordovician. At the town well of Mount Vernon, fourteen miles west of Stanwood, where the Niagara would presumably be at its thickest, beds of shale intercalated with limestone were penetrated from 300 to 325 feet from the surface, the main body of shale not being reached. At Anamosa, where the Gower is well developed, the Maquoketa was found 360 feet from the surface. At H. Britcher's, two and one-half miles south and two miles east of Stanwood, the drill was still working in limestone at 363 feet from the surface at the completion of the well. The question must be left in some doubt, with the probability in favor of the presence of a shale at Stanwood and its reference to the Ordovician.

*Iowa Geol. Surv., vol. III., pp. 197-200.
Ibid, vol. VI., pp. 261-262.

Silurian.

NIAGARA.

The lower beds of the Niagara, the Delaware stage of Calvin, have not been found in the county. Some of the exposures in the northeastern part of the county, where the Delaware stage might be expected to occur, if at all, carry so few fossils that their assignment to any stage is somewhat uncertain. But in the absence of the coralline and pentamerous beds characteristic of the Delaware, they are placed with the higher stage of the Niagara, the Gower, with which their lithological characteristics very well agree.

GOWER LIMESTONE.

The Gower limestone receives its name from Gower township, Cedar county, where its various lithological phases are

Fig. 18 Gower Limestone, Anamosa Type, Cedar Bluff.

well developed, and where it is more extensively quarried in the Bealer quarries, at Cedar Valley, than at any other point in the State. It includes the beds which have been designated as the Anamosa in the earlier reports of the Survey, together with those long known as the LeClaire. The former phase consists of soft, laminated, light buff, granular limestones with gentle quaquaversal dips, and often approximately horizontal. The texture is porous or vesicular, and the lustre dull, relieved by occasional shining facets of minute crystals. Bedding planes are even and parallel, and commonly the rock quarries to dimension stone a foot or less in thickness. Joints are distant and vertical. Fossils are exceedingly rare. Fucoid markings are sometimes seen, and surfaces are not infrequently covered with small, rod-like, flexuous bodies, whose nature is a matter of conjecture.

Found in immediate connection with the Anamosa are beds so different that they were long supposed to belong to a distinct and earlier stage, named the LeClaire. Hall, indeed, who assigned it its name, placed these two phases in different geological series, referring the LeClaire to the Niagara and the Anamosa to the Onondaga Salt Group.

The LeClaire facies is a hard, brittle, gray or bluish gray limestone, sometimes oxidized to buff. It is subcrystalline, and in places of trachytic harshness on account of vesicularity due to the removal of minute fossils. Moulds and casts of fossils abound. These are often gregarious, and while no complete list of species has been made out, the fauna is known to represent that of the Gault of Canada.

The LeClaire occurs in places in mounds fifty feet high and over, in which little semblance of stratification is to be seen. Here the rock is brecciated or conglomeratic. The matrix may be so nearly of the same color and texture as the fragments, that it is with difficulty that the real nature of the massif is made out, or it may consist of a buff, friable, granular limestone sand, distinctly impairing the value of the outcrop, both for lime kiln and for crusher. On the sides and upper surface of these mounds stratification planes are usually seen dipping outward in either direction at high angles. At first obscure, inconstant, and blending with the lumpy rock of the mounds, these bedding planes become comparatively well defined as they pass outward. This is illustrated in plate VIII., taken from the lime quarry at Cedar Valley, and is typical of many exposures in several counties.

A second aspect of the LeClaire is thus presented, in which it is distinctly stratified. Retaining its crystalline texture and hardness, it may even rival the Anamosa in closeness of lamination and evenness of bedding, as at Lime City, where this facies is quarried for building stone. In this phase the layers may lie as in the Anamosa, nearly horizontal, but commonly they are inclined or tilted, and sometimes at angles surprisingly high. As a rule these stratified layers hold their highest dips in juxtaposition to the mounds, gradually decreasing to horizontal with increasing distance therefrom. Where any considerable horizontal section is afforded, they are seen to form synclines between the massifs.

The forces and conditions under which these phenomena of the LeClaire were formed is confessedly one of the difficult problems of Iowa geology. Any theory deserving acceptance must explain the following salient facts.

The dip is seldom constant over any considerable distance. Within a fraction of a mile, or even a few rods, it lessens or increases its angle, and changes or reverses its direction. Some outcrops lead us to believe that the normal dip is radial rather than anticlinal, *i. e.* the layered limestone lies in basins rather than in troughs. Where no great vertical thickness is exposed the slant may appear fairly uniform from top to bottom, but in deep exposures the dip is seen to diminish downward, forming synclinal curves. An inclined layer remains, as a rule, of uniform thickness. This is specially noteworthy in highly inclined and finely laminated layers.

From many observations in Cedar and adjacent counties to the east, north and west, the composite impression remains that the higher angles of dip usually lie between 10° and 30°. But much higher angles have been measured, in Cedar county

Agglomerate mound of Gower limestone with bedding plains on flank.

as high as 70° and in Linn for short distances 90° in the case of small folds (plate IX).

Layers finely laminated are locally flexed and, in rare cases, display abrupt folds with fracture (Fig. 19).

Inclined strata may alternate horizontally within a few feet with brecciated beds, the dip of the separated layers remaining about the same. The fragmental beds are sometimes made of unrolled, angular fragments of massive limestone; while the tilted beds adjacent are finely laminated. Brecciated beds usually form the centers of anticlines of stratified limestone.

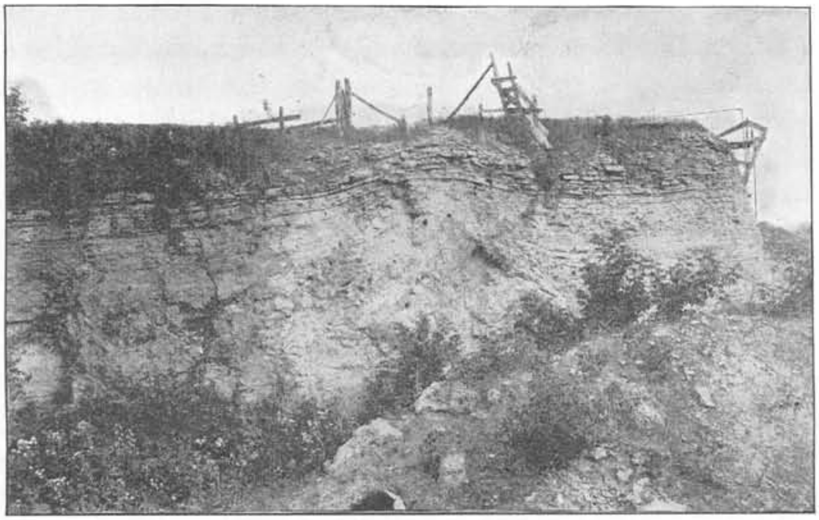


Fig. 19. Massif of Gower Limestone at Lohmann's Quarry, near Lowden.

Planes of cleavage are in all cases coincident with fossil zones, when such occur. In no case has cleavage been seen to pass transversely through a zone of fossils. Even on the most steeply inclined bedding planes, fossils lie as if they had there lived and died, no evidence being seen of their having been swept thither by currents. Thus layers of rhynchonellas, crinoid stems, pentameri, spire-bearing brachiopods, and of rod-like bodies unclassified are affected with the same abnormal dip as are unfossiliferous limestones.

While the law of parsimony requires that all these phenomena be expained by as few causes as possible, it is difficult to relate them all to any one causal process. The theory that these inclined planes are of the nature of slaty cleavage is disproved by the fact that they correspond with the natural bedding planes as shown by the lie of fossils.

The theory which at once suggests itself of folding under lateral pressure, accounts for the position of the massifs in the centre of anticlines, for the brecciation there found, for the flexed and broken strata, and for the variant angles of dip. Radial dips and the thickness of the strata are difficulties on this hypothesis.

The third theory is one suggested in part by Hall, and worked out with painstaking fidelity in the Wisconsin field by Chamberlin. It has been used as a working hypothesis by the Iowa Survey in the reports on Linn, Jones and Scott counties. It is here assumed that at the close of the Niagara huge mounds and ridges were built on the bottom of the shallow Silurian sea, in part by the accumulation in situ of corals, crinoids and molluscous shells, and in part by the drift of calcareous sediments under strong currents. That these reefs were near the surface during their building is attested by their conglomeratic character, due to the same wave action as coral breccia to-day. The fact that massifs are commonly highly fossiliferous is thus explained, as is the steepness of their slopes, and the intercalation on the sides with bedded deposits. That the shore was distant is shown by the purity of the limestones, their freedom from admixture with clays and sands derived from the wash of the land. That the sea was shallow is further implied in ripple marks, mud wash and mud cracks, with which the laminated limestones are sometimes affected.

While these mounds were in building, calcareous mud settled upon their steep sides, forming layers of limestone

Tilted Gower limestone at bridge crossing Rock creek.
Township 80 N., Range 3 W., Section 23, Se. ¼ of Sw. ¼.

dipping outward at various angles and directions, corresponding to the slopes of the mounds. With increasing distance from the mounds, the slant of the strata would decrease until horizontality was reached. Where mounds were in close proximity, steep synclines would result from the gradual filling of the trough, in the manner of cross-bedded deposits laid on initial slopes. Where they were more distant, stretches of obliquely-bedded limestones might be built out from them in the path of a current; and where their influence diminished to zero with increasing distance, beds would be laid down with practical horizontality. Such calcareous sediments would be in places coarse enough to constitute a sand-rock, made of cemented grains of limestone sand. Elsewhere the material might be so fine that it would accrete to a dense and ringing limestone.

All types of the Gower are thus accounted for, and the rapid alternation at the same levels of the LeClaire and Anamosa.

The hypothesis fails to account for the higher inclinations that have been measured. Under the theory of oblique lamination no angle of dip could exceed the angle of repose of calcareous silts under water. While this is no doubt a high angle on account of the property of rapid cementation they possess, it falls far short of the 70° seen at the crossing of Rock creek, on the Tipton-Rochester road, to say nothing of still higher angles.

Even in more gentle dips it seems that there should be at least some slight thickening of the laminæ downward, if deposited as sediments at the present angle of slope. This does not occur; even with laminæ of a fraction of an inch they maintain a constant thickness throughout.

Nor does it account for sharp flexures, folds with vertical limbs, and folds broken at sharpest change of direction. These phenomena, observed at the new quarries in these beds at the Upper Palisades, near Mount Vernon, are, it is true, somewhat exceptional, and they are confined to small areas of a few feet in length. Nevertheless they demand explanation.

So far as the steep angle of slope is concerned, it is possible that on the theory of oblique lamination, these may be explained if we conceive that the steep mounds of the massifs were sometimes undercut by currents. That subaqueous erosion actually occurred in Gower times there can be no doubt. The record is left in channel cuttings such as that noted at LeClaire by Calvin. Thus extensive slides may have taken place, by which large blocks of strata were left at higher angles than those of their original deposition. When these masses show a curvature, there is implied also a flexibility in the fallen blocks.

Thickness of the Gower.—As the base of the Gower is nowhere seen in the county, its full thickness cannot be measured. Cliffs of the LeClaire, a few miles east of the Linn county line, on the Cedar river, measure ninety feet. The Gower is quarried at Cedar Valley to a depth of 116 feet, the maximum thickness observed in Iowa.

Weathering.—The Anamosa stone weathers to thin, detached laminæ, or spalls, but so slow is the process that it need not be taken into account in weighing the value of the Anamosa as a building stone. Wherever the zone of weathering reaches any considerable depth, such as eight to twelve feet, evidence is at hand that the decay is preglacial, and involves immense lengths of time.

The LeClaire stone, when heavily bedded, weathers to deeply-pitted, cavernous surfaces. So uniform is the composition of the limestone, that this exceedingly irregular decay cannot be due to local differences in material, such as the presence of argillaceous matter. Nor is it proven that the pitting is due to local differences in the proportion of calcium and magnesium carbonate, any spot being especially vulnerable where the former was in undue excess. On a rock so uniform in texture and composition, and one which does not break down into chipstone under the action of frost, such cavities may well be formed by the localization of agents of decomposition. Where a lichen takes root, where a mould of a fossil allows water to penetrate, wherever any agency of disintegration or chemical decay is localized, there such pits will result on a stone whose face is consumed only by the detachment of grain after grain. On a differently constituted limestone the face would be broken down before these depressions would have time to form.

It is seldom that a finer illustration of honeycombed limestone is found than that of the rock represented in figure 20, on the road from Tipton to Mount Vernon, on the crossing of Baldwin creek.

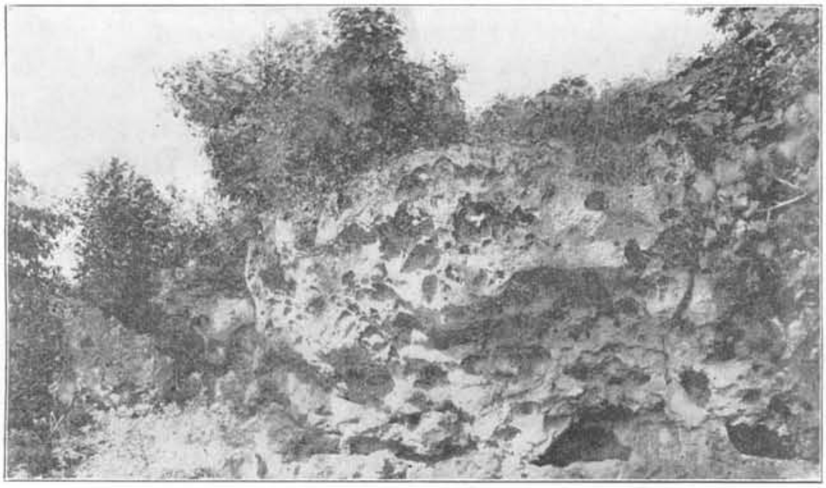


FIG. 20. Weathering of Gower Limestone, Baldwin Creek.

Chemical Composition.—The following analyses, made at the chemical laboratory of Cornell College, under the supervision of Dr. Nicholas Knight, show the exceptional purity of the Gower limestone, and its near approach to a typical dolomite.

BUILDING STONE QUARRY, LIME CITY

	PER CENT.
Calcium carbonate, $CaCO_3$	55.3
Magnesium carbonate, $MgCO_3$	43.0
Ferric and aluminum oxides, Fe_2O_3 and Al_2O_3	1.4
Silica, SiO_2	0.6
	100.3

BUILDING STONE, BEALER'S QUARRY, CEDAR VALLEY.

	PER CENT.
Calcium carbonate, $CaCO_3$	56.4
Magnesium carbonate, $MgCO_3$	42.6
Ferric and aluminum oxides, Fe_2O_3 and Al_2O_3	0.7
Silica, SiO_2	0.4
	100.1

LIME QUARRIES, CEDAR VALLEY.

	PER CENT.
Calcium carbonate, $CaCO_3$	51.27
Magnesium carbonate, $Mg\,CO_3$	48.09
Ferric oxide, Fe_2O_3	0.35
Silica, SiO_2	0.225
	99.935

This analysis shows a remarkably high per cent of magnesium carbonate, about 2½ per cent more than a normal dolomite.

Sections of the Gower.

1. BEALER'S QUARRY, CEDAR VALLEY.

		FEET.
9.	Limestone, buff, magnesian, very soft, Coggan stage.	14
8.	Limestone, weathering into chipstone, in layers up to six inches	1½
7.	Limestone, light gray, rough, massive, very vesicular.	3
6.	Limestone, fragmental, argillaceous	1
5.	Seam of blue argillaceous material extending for 180 feet along quarry face	0.2
4.	Limestone in thin spalls, hard, dense, "flinty"	5½
3.	Limestone, hard, rough, buff, crystalline, highly vesicular, with moulds of spire bearing brachiopods, the spires often remaining in casts	5
2.	Limestone in layers from two to eight inches, laminated	4
1.	Limestone, light buff, granular; lustre dull, homogeneous in grain, slightly vesicular, destitute of silica in any form, fracture even, soft when first quarried, rapidly hardening on drying, bedding planes horizontal, even and comparatively distant, laminated, joints distant, master joints running south-southeast. All quarried for building stone, together with Nos. 2–8, Gower stage	94

A further description of this section will be found on a subsequent page. The quarry whose section has been given above lies just south of the bridge on the right bank of the river. Going up stream, we have an interesting series of exposures which exhibit the rapid change in lithologic types, structure, and attitude so characteristic of the Gower. Ten rods north of the bridge occurs limerock of the LeClaire phase at the same levels, highly tilted to the southwest at angles of from 30° to 45°. Fifteen feet up the side of the cliff lies a layer of spire bearing shells similar to those mentioned in No. 3 of the preceding section. Eight rods to the north the dip has declined to 11° W SW. in a heavily bedded, but finely and for the most part coherently laminated limestone, the softer laminæ being etched out by weathering but not detached. Thirty feet further the rock dips sharply to the northwest at an angle of 12°. Eight rods up stream the rock has assumed the texture of the Anamosa and has been quarried for building stone. Vermicular rod-like bodies occur on the even, smooth faces of the stone. The dip is here 10° W SW. at the southeast end of the quarry. For twelve rods the rock is now concealed. It reappears with a dip of 12° S SE., declining to nearly horizontal within a rod. Thirty rods up stream, at the entrance of the lime quarries, finely laminated crystalline limestone is tilted to 41° S SE., resting apparently on the steep side of a massif of unstratified crystalline limerock a rod away. Twenty rods further on occurs a strongly conglomeratic outcrop which passes on the further side into layered limerock dipping N NW. At the quarry fifty feet of typical limerock is exposed, a hard, brittle, light bluish gray, crystalline limestone with a tendency to break along vertical planes to long, splintery or rectangular fragments. In the center of the quarry the rock is a massif, but from this mound there pass outward and downward bedding planes dipping at high angles. The passage from the layered limestone is shown in plate VIII. The dip varies, the layers gradually lessening their inclination from 40° to nearly horizontal. At the north end of the quarry the following northeast dips were measured near the summit, 36°, 38°, 47°, 49°. Here the crystalline rock again becomes laminated to two and four inches. It is stated by the foreman of the quarry that as these layers continue outward and downward, where now concealed, they pass into granular rock useless for lime.

Near the base of the section a sharp contrast was seen where, in a vertical distance of five feet, were found, between typical limerock above and below, layers of soft granular limestone underlain by four inches of "flinty" laminæ. The fossils observed, *Amplexus* and Favositid corals, *Rhynchonella* and one or more crinoids, were of the LeClaire.

North of the quarry, across a small ravine, cliffs face the river composed of semicrystalline, finely laminated limestone, nearly horizontal, or dipping at low angles to the northwest.

2. EXPOSURES OF THE GOWER ON SUGAR CREEK.

Where Sugar creek leaves the deep, preglacial channel, here known as Stanwood river, and enters the region of the indurated rocks, in Tp. 80 N., R. II. W., Sec. 34, Se. ¼, its channel at once contracts, and from this point to Lime City exposures are frequent along its banks. Immediately at the crossing of the creek between Sec. 34 and the section to the south, Sec. 3, Sugar Creek township, nothing is exposed below the Coggan, which here lies eight feet above the water, or about 700 A. T., according to the United States topographical survey. One mile below, eight feet of gray mottled magnesium limestone, in part fragmental, and difficult to assign to any definite horizon, appear on the left bank, at the bridge. On the right bank (Sec. 10, Sugar Creek township, E. ½), the limerock of the Gower fronts the creek in ledges twenty-five feet high, in which tilted layers are seen to merge into structureless massifs. Further down the stream the finely laminated phase comes into view in the Sw. ¼ of the same section, dipping from 15° to 23° SE., and intermediate in texture between the granular and the crystalline phases. These rocks are in some layers quite fossiliferous, but with a restricted number of species. Eight rods further down stream a quarry has been opened. The dip has here decreased to 7°, and the stone has assumed for the most part the granular Anamosa facies. Twenty feet is exposed of these evenly-bedded layers, which weather to detached laminæ for a zone of twelve to fifteen feet from the surface. Short, flexuous, rod-like fossils cover the faces of some of the laminæ, and about five feet from the base is a zone in which casts of an ostracod crustacean are abundant. One-half mile south a building stone quarry has been opened on the farm of E. Hinkhouse, and at the same distance west, rock at about the same level has been quarried for lime. The next exposures are those a quarter mile south, at Lime City.

3. LIME CITY.

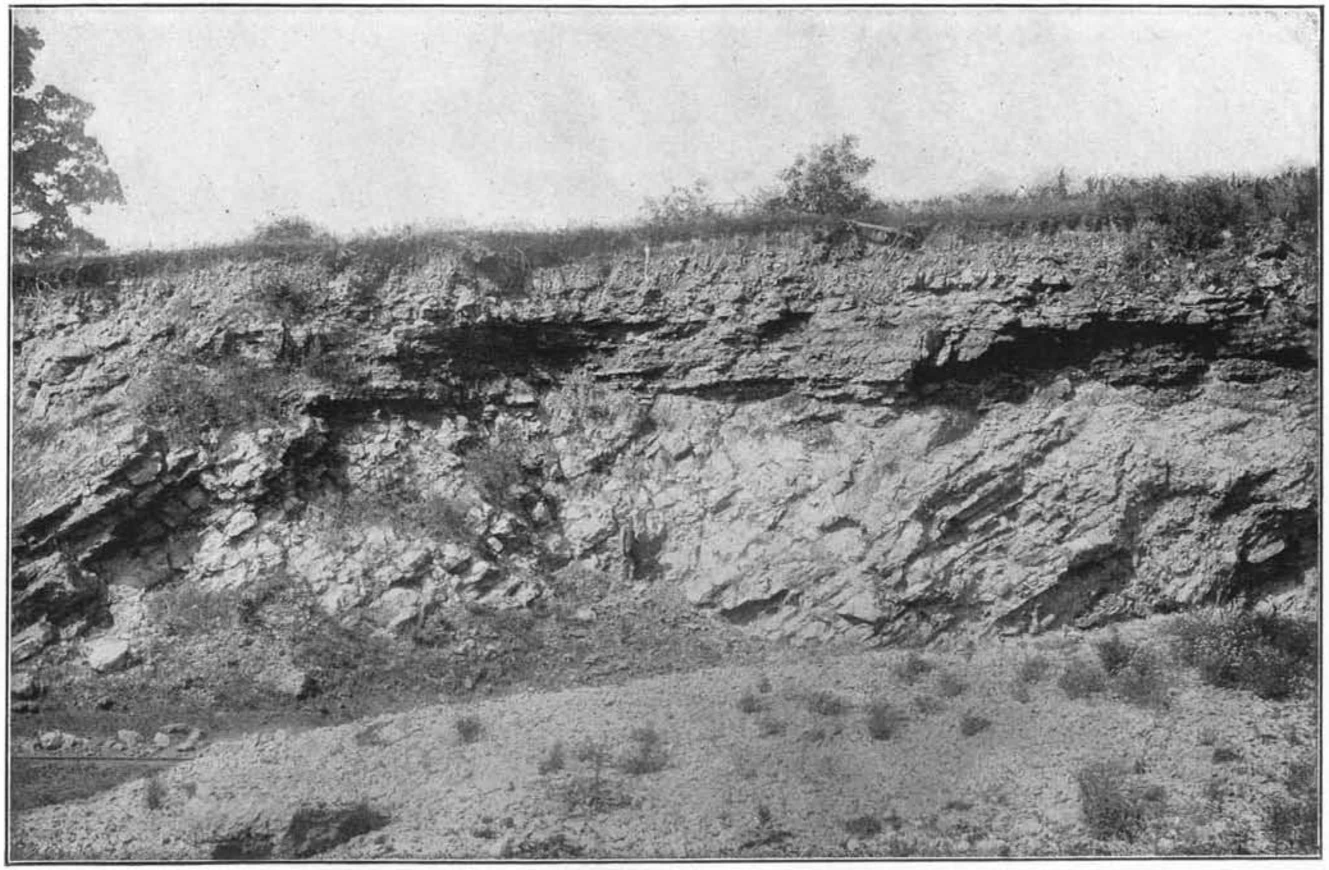
Here extensive quarries have been opened on the right bank of Sugar creek, along a circuit of about one-half mile. The usual rapid horizontal transitions in the limestone encourage lime and building-stone quarries in adjacent outcrops, and a still larger portion is quarried and crushed for railway ballast. To the north the stone is limerock, lying for the most part in confused or structureless mounds. South of these it dips heavily outward and downward from them. Twenty-five feet of Gower is here exposed, a hard, gray, subcrystalline limestone in layers, destitute of lamination, varying in thickness from one-half to two feet. The rock is fossiliferous in places, with moulds and casts of Gower fossils, the planes of highly fossiliferous layers coinciding, as is customary, with the dip of the strata.

Across the small ravine, in which the kilns are situated, the dip has decreased to 28° E SE., the stone continuing of the same type described. On the further side of a little gully the limestone dips 13° SE., and while still hard and crystalline, is now finely laminated. Four rods east a large quarry is opened for building stone. At the west end the dip is 10° SE., and in twenty paces this has become horizontal. The rock does not assume the granular Anamosa facies, although it is as finely laminated and as evenly bedded. The uppermost layers are of the Coggan and transition layers to the higher Devonian terranes. The section is as follows:

		Feet.
3.	Coggan and Otis limestones	20
2.	Limestone, hard, bluish gray, tough, ringing under the hammer, crystalline, finely and coherently laminated, in courses up to three and one-third feet, but readily splitting to layers of six, eight and twelve inches	14
1.	Limestone, gray, vesicular, in heavy courses, rough surfaced	8

From this trough of the syncline the strata rise gradually to the east, dipping 7° SW. a few rods further on. At a distance of 500 feet east of this the dip has increased to 21° SW. At this point, the last quarry to the east, the rock lies in parallel, fairly even courses, varying in thickness from one foot or less, the common dimension, to two and three feet. It is here also finely laminated and crystalline. The hardness of the stone makes it admirably suited to the use of railway ballast, to which it is put.

At several points along the line of the quarries the heavy layers were seen to be marked on their upper surfaces and vertical joint faces with ramifying, or inosculating, shallow channels from 1 millimeter to 2 centimeters in width. The origin of these was not discovered. The upper surface of the Gower at these quarries along a circuit of one-half mile on Sugar creek is even and regular. The structureless mounds, the layers dipping at high degrees and various directions, and the horizontal strata, rise alike to the same plane at which they are bevelled by the horizontal layers of the Goggan (plate X).



Horizontal Coggan beds overlying the oblique-bedded, LeClair phase of the Gower limestone at Lime City.
—*From a photograph by Houser.*

4. CROSSING OF ROCK CREEK, TP. 80 N., R. III W., SEC. 23, SE. ¼ OF SW. ¼.

This section is of special interest in that it presents the Gower more highly tilted than has been seen elsewhere, with such dips, in fact, that it is impossible to account for them by any theory of cross bedding. At the same time it exhibits the usual rapid change in dip both in direction and amount and a radial dip which may be typical, though not so well seen in any other recorded outcrop. The course of the creek

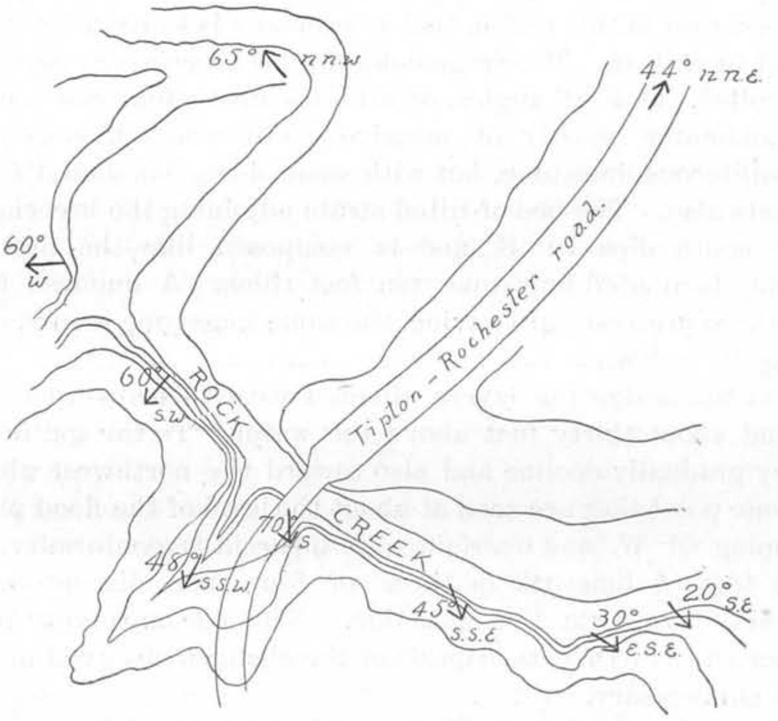


FIG. 21. Sketch map showing variant and radial dips of Gower Limestone. Rock Creek, Tp. 80 N., R. III W., Sec. 23, Se. ¼ of Sw. ¼. Contour interval, 10 feet. One-half inch=10 rods.

along the crest of the anticline is also worthy of note. This and the various dip are shown in the accompanying sketch-map. Rock creek has here cut to a depth of thirty feet in a dome or anticline of the Gower. This is overlain with twenty feet or more of limestones of the Wapsipinicon stage of the Devonian.

At the bridge the roadway scarps the side of the hill and exposes two or more beds of hard, gray, crystalline limerock, laminated to a fraction of an inch. The bed nearest the bridge is fifteen feet thick and tilted at an angle of 58° S. From the second it is separated by a bed of breccia, or scree, eighteen feet wide in which the matrix is soft, granular limestone sand. Considerable argillaceous material also occurs, and in one place a stiff, unctuous, greenish or yellowish clay so much resembling the pockets of Carboniferous clay not uncommon in this region that it probably is to be assigned to that formation. The fragments of this breccia are angular, unrolled, set at all angles, of all sizes up to fourteen inches in diameter, mostly of massive non-laminated, vesicular, fossiliferous limestone, but with some finely laminated fragments also. The bed of tilted strata adjoining the breccia on the south dips 70° S. and is composed like the first of thinly laminated limestone, ten feet thick. A hundred feet to the southwest, up a ravine, the same limestone recurs, dipping 48° S SW.

At the bridge the layers affected with this abnormal dip stand about thirty feet above the water. To the southeast they gradually decline and also toward the northwest where at one point they are seen at about the level of the flood plain dipping 60° W. and overlain with apparent unconformity, by ten feet of limerock in three or four rude discontinuous layers, forming a low anticline. The accompanying map makes any further description of the changes observed in the dip unnecessary.

5. LOHMANN'S QUARRY, TP. 81 N., R. 1 W., SEC. 4, NW. ¼.

Two miles west of Lowden, on a branch of Yankee run, an important quarry has been opened for a number of years, and is now owned by Mr. Lombard Lohmann. Limestone of the Anamosa type has been quarried to a depth of forty-five feet. Joints are distant, the master joints running N. 20 E. The strata are disposed in a distinct anticline. At the south end of the quarry they dip 3° N NW.; at the north, 14° E NE. The following is the succession of layers:

		FEET.
6.	Spalls, weathered into thin plates	8
5.	Flagging, about four inches thick	8
4.	Limestone, rough, massive, once used for lime	3
3.	Building stone, in layers up to one foot	15
2.	Flagging	2½
1.	Building stone, in layers from 5 to 14 inches	6

No. 4 thickens and thins in a most interesting manner, rising as a lens shaped mound twenty-five feet in diameter, at about the center of the quarry, retaining elsewhere the thickness as stated (See plate IX). This mound is obscurely fragmental and the fragments are themselves in places arranged in obscure layers dipping outward as high as 45°. The upper layers of fine grained rock in part pass into and merge with the unstratified mass, and, in part, rise on its flanks. The mound of rough rock is clearly contemporaneous with the even bedded granular building stone on which it rests and by which it is surrounded. The phenomenon of distinctly different lithologic types of limestone formed under slightly different conditions in the same area, at the same time, is here exhibited as in a hand specimen, and it may well be taken to illustrate the relation between the LeClaire and the Anamosa phases of the Gower.

On the creek, a few rods distant to the north, the same layers are seen to dip west and south, forming the northern limb of a syncline.

The Devonian.

The Devonian series in Cedar county comprises several terranes which are grouped under two stages—the Wapsipinicon and the Cedar Valley. The former, named from the excellent section along the Wapsipinicon river, in Linn county, embraces the lower beds of the Iowa Devonian and has been subdivided into several sub-stages—the Upper Davenport, the Lower Davenport, the Independence and the Otis. To these is now added an inferior member, the Coggan, which in earlier reports was classified as Silurian.

THE COGGAN.

The lithological affinities of this limestone are wholly with the Silurian. It is a soft, granular, magnesian limestone, vesicular, often of earthy lustre, differing in appearance from the Anamosa limestone principally in its heavy bedding and absence of lamination. Under the hammer it frequently emits a distinct bituminous odor. Nodules of dark flint may occur in it and these occasionally unite to form a thin continuous layer. At some exposures it takes on a harder and more crystalline aspect.

The composition of the normal type in Bealer's quarry is as follows, according to an analysis made in the chemical laboratory of Cornell college, under the direction of Dr. Nicholas Knight.

$Ca\,CO_3$	58.2
$Mg\,CO_3$	39.5
Fe_2O_3 and Al_2O_3	0.9
$Si\,O_2$	1 2
	99.8

In this dolomite the proportion of calcium carbonate is but two per cent higher than in the Gower dolomite of the Silurian used for building stone and taken from the same quarry.

In the Coggan is found gregarious a small spire-bearing shell, which, in the report on Linn county,* is stated to resemble *Spirifer subumbonus*, Hall. Occuring in the Coggan only in moulds and rare casts, and belonging to a type of wide range, and one difficult to identify in imperfect specimens, it did not seem safe, at the time, to refer it without qualification to this species. Since the publication of the report just cited more perfect specimens, collected over a larger area, have sufficed to convince all who have examined them of their identity with the species named, a well known Devonian type,

*Geology of Linn County, Iowa Geol. Surv., vol. 4, p. 140.

and one found in Iowa only, so far as now known, in the Devonian beds, the Otis, immediately above.

Along with *Spirifer subumbonus* have been found in the Coggan several pygidia of a trilobite. These, together with the brachiopod mentioned, were referred to Dr. John M. Clarke, State Paleontologist of New York, who considers it "a species not far removed from the *Dalmanites erina*, which occurs sparsely in the Onondaga limestone of both New York and Ohio. So far as the specimens indicate, the species has little affinity to typical Silurian forms and its relation to the species cited indicates the Devonic." A small cheek of a *Proetus*, an unidentified *Conocardium*, and a little spiral gastropod complete the fauna of the Coggan beds so far as now known.

It thus becomes necessary to shift the Coggan across the Siluro-Devonian frontier, and to enroll it as the basal member of the Wapsipinicon stage. This position is in accord with the strong apparent unconformity at Lime City and Cedar Valley, where its horizontal beds rest on the highly tilted layers of the Silurian. The magnesic character of the terrane is entitled to no consideration except as corroborating other evidence. The Devonian even of the Cedar Valley stage is dolomitic in the northern counties of the state. Along the forty-second parallel in Iowa the stratigraphic division between the Silurian and the Devonian would seem to be drawn where calcareous sediments change to argillaceous, as at the summit of the Otis, or where dolomites change to non-magnesian limestones, as at its base. Drawing the line as we have done at the base of the Coggan makes against each of these classifications by lithological affinity, but is in accord with the far weightier evidence of fossils.

THE OTIS.

This terrane was first discriminated in Linn county, where it is well marked in the valleys of the Cedar and Wapsipinicon rivers by its position between the argillaceous Independence above and the dolomitic Coggan beneath, by its lithological facies, and by its fossils. It has also been found in Scott county in a narrow strip at the eastern edge of the Devonian area, adjoining outcrops of the Niagara, and immediately underlying the Independence. In Cedar it is less well developed than in Linn, but its outcrops are more numerous than in Scott. It is seldom that it here clearly indicates its place in the Devonian succession, and in only one locality could it be identified by its fossils. The Otis exhibits considerable variety in its lithology. Typically it is a limestone carrying so slight a per cent of magnesia that it effervesces readily and actively at a touch of cold dilute HCl. But its passage beds downwards into the dolomitic Coggan indicate a larger and larger per cent of magnesium carbonate in their composition. It is also a fairly pure limestone, and shows no outward trace of argillaceous admixture. But in several localities it is difficult to draw the line of demarkation between it and the Independence shale.

The most common lithologic type of the Otis is a drab limestone weathering to lighter tints, hard, brittle, ringing, with conchoidal, irregular or splintery fracture, and of fine grain. It is frequently crackled and fragmental, the fragments being small and in apposition, and of the same color and texture as the matrix when this can be distinguished. In this aspect it is heavily bedded, reaching sometimes a thickness of layer of five feet, and is unevenly laid and roughly surfaced. Frequently it is laid in thinly laminated layers. In either case it may be fossiliferous. These types were the only ones discovered in Scott county, but both in Linn and in Cedar considerable lithologic diversity prevails, introducing crystalline, saccharoidal limestones, compact or friable, of various colors, highly crystalline brown or drab layers which break with calcite cleavages, layers mottled with greenish argillaceous material, and others containing fragments or nodules of dark flint or of crystalline silica. In Linn this diversity was diagnostic of the formation as the boundaries of it were there drawn, and the same variant types recur in Cedar at the same horizon.

The thin-shelled, smooth-surfaced little brachiopod, *Spirifer subumbonus* Hall, which, with an obscure coral found by Prof. J. A. Udden, forms the entire known fauna of these beds, is gregarious in the fine-grained phase and occurs also in the granular. It is found from central Linn to the Mississippi. Since the little spirifer of the Coggan beds is identified with the same species, it is probable that further evidence may warrant uniting these two sub-stages. Meanwhile their lithologic facies are so different that, as a matter of convenience for field work, they are still ranked as distinct terranes.

The following analysis, made under the supervision of Dr. N. Knight, is of a pink, saccharoidal, crystalline limestone, a type occurring at a number of localities in the county. The extremely small amount of magnesium carbonate will be noted, showing strong contrast with the Gower dolomites of the Silurian.

	PER CENT.
Silica, SiO_2	0.24
Ferric oxide, Fe_2O_3	0.34
Calcium carbonate, $CaCO_3$	96.73
Magnesium carbonate $MgCO_3$	2.94
	100.25

Another analysis of Otis limestone, from the Sw. ¼ of Sec. 25, Tp. 80 N., R. III. W., was as follows:

	PER CENT.
SiO_2	1.52
Fe_2O_3	0.58
$CaCO_3$	93.61
$MgCO_3$	4.20
	99.91

THE INDEPENDENCE.

No exposures were seen in Cedar county of the fine, fissile, fossiliferous shale found in a shaft at Independence, and given the name of that town by Calvin. At the same horizon in Linn county occur buff, argillaceous limestones, and it is in this form that the Independence is seen in Cedar. These are often marked by irregularities of deposition, channel cutting, lenses of calcareous material, and rapid lateral change in form and constituents of the rock. Occasionally the dark buff, dingy, impure limestone contains angular, small, sparse fragments, either of the same nature as the body of the rock, or of the aspect of the fine-grained, drab limestone of the Otis or Lower Davenport. The latter seem to have been more soluble, and when dissolved away have left angular cavities. Angular fragments of silica are seen frequently, and weathered surfaces may be rough, with a flinty, angular sand left in relief. Siliceous nodules are usually found on all outcrops of these beds, and so peculiar are these that they are diagnostic of the Wapsipinicon stage of the Devonian. The lenticular masses may reach a foot in diameter, and a microsection shows that they are not composed of flint, but of crystalline silica intercrystallized with calcite. The surfaces, therefore, where the calcite has dissolved, have a characteristic rough and carious aspect, and masses may have a harsh vesicularity resembling pumice. The silica resembles gangue quartz in the great number of micro-cavities it contains. The Independence was thus recognized at one point, Sec. 4, Sugar Creek township, in the log of a well driller, who reported a number of "balls of flint, from the size of a hickory nut up to a base ball." At Independence, and at Lafayette, in Linn county, thin seams of coal and coaly shale were found in this formation. Coal reported near Rochester, in a well on the farm of J. D. Ridenours, Tp. 79 N., R. XI. W., Sec. 5, Sw. ¼ of Sw. ¼, may belong to the Independence rather than to any outlier of the Carboniferous. It is said that three and a half feet of coal was struck at a depth of 120 feet and beneath sixty feet of rock. The thickness of the vein is altogether exceptional, unless it includes black shale. The well curb is something more than 100 feet above the outcrop of the Otis on Crooked creek southeast, and of the Independence on Rock creek northwest.

The ordinary appearance of the Independence in Cedar is a rather soft, buff, speckled, magnesian limestone of earthy lustre where weathered, and often so argillaceous that it breaks down into a clay. As one of the weaker Devonian terranes it is a slope maker, and its exposures are rare. Its presence may often be inferred from slopes below ledges of the Lower Davenport or above those of the Otis.

The following analysis of a more siliceous layer of the Independence, exposed on Sugar creek, Sec. 3, Sugar Creek township, was made under the direction of Dr. Nicholas Knight. Macroscopically the limestone was buff, earthy and friable from weathering. The siliceous residue under the microscope displays a field of minute, angular, quartzose matter, with a few larger grains polarizing in high colors :

Silica, SiO_2	18.66
Ferric oxide, Fe_2O_3	2.00
Calcium carbonate $CaCO_3$	58.21
Magnesium carbonate, $MgCO_3$	21.00
	99.87

THE LOWER DAVENPORT.

The lithological characteristics of this unfossiliferous limestone are identical with those described in the reports on Linn and Scott counties. So similar is the limestone in all its outcrops that hand specimens from the Volga, the Wapsipinicon, the Cedar, and the Mississippi could not be told one from another were the labels removed. It is a hard, compact, fine-grained limestone, non-crystalline, breaking with irregular, conchoidal, or splintery fracture. Massive in places, it is also found in places weathering to thin plates. In Linn county it is completely brecciated. In Scott it is but little disturbed. In Cedar its condition is intermediate. Retaining here and there its initial attitude, as at Rochester, it is in places partially or wholly broken into breccia.

When brecciated it presents the appearances noted in previous reports. Specimens are seen where the laminæ retain much of their parallelism although slightly separated. Fine and close lines of lamination are sinuous and flexed sometimes in a hand specimen, and compound brecciation is not infrequent. The common appearance of the breccia of the Lower Davenport is that of a mass of small fragments set close at all angles, the edges remaining sharp and even splintery, the matrix scanty and of much the same material as the fragments, but more granular and slightly lighter colored. Silicious nodules occur similar to those of the Independence, but smaller and in much fewer numbers. Large blocks of laminated limestone are occasionally seen set at all angles, and where the bracciation has commingled higher beds, fossiliferous lighter colored fragments of the Upper Davenport may be in juxtaposition. When massive there is apt to be exhibited on weathered surfaces a crackled or fragmental structure.

Lithologically these beds are very like the drab limestone of the Otis; and except where the intervening argillaceous Independence is present it is hard to tell them apart. Were it not for the clearer sections in adjoining counties, the outcrops in Cedar would hardly suffice to demonstrate the separation of the Lower Davenport from the Otis and its relation to the other terranes of the Wapsipinicon stage. Still, on the right bank of the Cedar at Rochester and south to the county line it directly underlies the Upper Davenport, and in one or more outcrops is superimposed on argillaceous limestones of the Independence. The Otis, on the other hand, directly succeeds the magnesian Coggan, and is overlain by the argillaceous Independence. But no single exposure exhibits both beds of drab, non-magnesian limestone, the Otis and the Lower Davenport, separated by the buff, shaley Independence.

The following analysis made by Dr. Nicholas Knight is in all probability a representative one. The sample was taken from the ledge of the Lower Davenport outcropping above

Rochester on the right bank of the Cedar. The extremely small per cent of magnesia and the comparative freedom from insoluble impurities are strongly marked features of the limestone well exhibited in the analysis:

Silica SiO_2	0.86
Ferric oxide Fe_2O_3	0.30
Calcium carbonate $CaCO_3$	96.91
Magnesium carbonate $MgCO_3$	1.93
	99.70

THE UPPER DAVENPORT.

Where these beds were first recognized under this name, in Linn county, they form a distinct terrane of a tough, semicrystalline, heavily bedded limestone, whose characteristic fossils are *Pentamerus comis* and *Orthis macfarlanei.* This is the horizon of the Gyroceras beds of Calvin, a life zone recognized earlier in Buchanan county as the lowest of the fossiliferous Devonian in Iowa above the Independence. The same beds recur in Cedar at the same horizon, immediately overlying the Lower Davenport. The lithological characters are persistent, and the same species are found in the same relative abundance. The exposures of the Upper Davenport are seen on the divide between Crooked creek and Rock creek in rare outcrops, and on the right bank of the Cedar from the Muscatine county line northward to within three miles of Rochester.

The beds of this terrane in Linn county were seen to be the equivalent of the beds at Davenport, called the Corniferous by the paleontologists of the Davenport Academy of Science; and under the impression that there was here a marked change in fossils, the summit of these beds was made the line of contact between the Wapsipinicon and the Cedar Valley stages. In the survey of Scott county a closer study of the Upper Davenport showed that along with the characteristic species of the beds in Linn county were others, which in Johnson and Buchanan counties occupy a higher place.

Thus in the Scott county report the life zones of *Phillipsastrea billingsi*, and species of Acervularia are included in the Upper Davenport. At Davenport there overlies this terrane a shaly limestone in which *Spirifer pennatus* is common, and this horizon was made the lowest in the Cedar Valley stage. In Muscatine county Udden found it difficult to differentiate the Phillipsastrea beds from those of *Spirifer pennatus* and the Gyroceras, terming all the Phillipsastrea beds. In the two or three fossiliferous exposures in Cedar county in which anything higher than the horizon of *Pentamerus comis* appears, the line of separation between the latter and the higher zones was not clear in the unworked quarries and with the brief time given to the collection of fossils. The *S. pennatus* beds, if distinct, are but little higher than the Phillipsastrea beds, since both fossils occur in the chipstone of tne small quarries near Atalissa. There is no doubt that *Orthis macfarlanei* and *Pentamerus comis* are here basal in the fossiliferous series, but it is not clear that *S. pennatus* and Phillipsastrea did not appear at the same time toward the south of the Iowa Devonian era, while in the central portions their life zones are distinctly separate. It is thus difficult to draw the upper limit of the Upper Davenport and the line of demarkation between the Wapsipinicon and the Cedar Valley. If, with Calvin, this line is placed at the top of the *S. pennatus* beds, all the fossiliferous outcrops in Cedar county may be regarded as Wapsipinicon. If the original line is retained, the horizon of abundant *Spirifer pennatus* will go to the Cedar Valley. On the whole, it seems best to leave the definition of the Upper Davenport to await a final decision after the sequence in the northern counties, such as Fayette and Howard, is ascertained. Either the life zones observed in some counties fail of demarkation in others or their stratigraphical equivalents are elsewhere barren. The latter seems inadmissible, since the horizon of *Pentamerus comis* and *Orthis macfarlanei* is constant, and immediately succeeds the Lower Davenport, a terrane well marked through the entire Devonian area in Iowa, so far as studied, both in its lithological characters, in the stresses to which it has been subject, producing brecciation, and in its superimposition on the Independence.

Devonian Sections.

COGGAN SUBSTAGE.

1. CEDAR VALLEY, BEALER'S QUARRY.

	FEET.
5. Limestone, hard, dense, yellowish gray, breaking into large, rhombic chipstone by diagonal cracks about 6 inches apart	1 to 4
4. Limestone, laminated, of similar texture to No. 5, spalls 1 to 4 inches thick	1
3. Limestone, soft, granular, laminated, with minute moulds of brachiopods	1
2. Limestone, soft, light buff, with occasional lenses of dark flint, fossiliferous with minute moulds, in layers up to 1 foot	2½
1. Limestone, in massive layers about 3 feet thick, soft, earthy, buff, with some flint nodules, and with many characteristic Coggan fossils, *Spirifer subumbonus* Hall, and trilobite pygidia	7

No. 1 rests conformably on horizontally-bedded limestones of the Gower stage.

2. CEDAR VALLEY, LIME QUARRIES.

	FEET.
2. Limestone in horizontal layers, not breaking into thin spalls, but breaking down into clay, with boulderets of disintegration of irregular form, soft, earthy, light gray, speckled (Coggan)	3
1. Gower limestone, of LeClaire phase, either in calcareous massifs or in highly tilted layers	50

3. TP. 80 N., R. III. W., SEC. 4. NE. ¼, ON ROCK CREEK.

The thickness of the following members is estimated from several outcropping ledges.

	FEET.
5. Limestone, hard, flinty, close-grained, in part laminated, non-fossiliferous, in spalls	10
4. Limestone, soft, granular, buff, in layers 9 inches and over	2

		FEET
3.	Limestone, massive, granular, grayish buff, highly vesicular, with numerous casts and moulds of *Spirifer subumbonus* (?) of larger than ordinary dimensions (with layers above referred to Coggan)	12
2.	Gower limestone, LeClaire phase, exposed	1
1.	Concealed to creek..............................	8

4. LIME CITY, BUILDING STONE QUARRY.

		FEET.
7.	Limestone, saccharoidal, slightly pinkish, laminæ up to 4 inches in thickness.....................	1
6.	Limestone, white, saccharoidal, with close coherent laminæ...............	2
5.	Limestone yellowish gray, soft, earthy luster, weathering to layers 2-4 inches thick...........	2½
4.	Limestone, saccharoidal, pink and yellowish gray, decaying into crystalline limestone sand. This changes laterally into a brittle gray rock, in layers 1-4 inches thick, breaking into rhombic chipstone of dull, earthy luster. In places also the same transition occurs in one foot vertical, the "sandy" crystalline rock above graduating into brittle dense "flinty" rock beneath............	6
3.	Limestone, light buff, saccharoidal, in heavy laminated courses weathering to fine crystalline sand..	5
2.	Limestone, massive, highly vesicular, with moulds of Coggan fossils. All the above layers are practically horizontal, magnesian, useless for building stone and are well named "sand rock" by the workmen..............................	3¾
1.	Limestone, Gower hard, crystalline.	22

5. LIME CITY, BETWEEN BUILDING STONE QUARRY AND LIME KILNS

		FEET.
5.	Limestone, magnesian, more or less fragmental, fragments small, mottled, dull, earthy buff and light brownish, weathering to irregular surface caused by relief of harder fragments	2
4.	Limestone, magnesian, light pinkish buff, saccharoidal, laminated............	3
3.	Limestone, magnesian, crystalline, saccharoidal, white or light gray, in heavy layers	5⅝
2.	Limestone, earthy, buff vesicular, Coggan lithologic type, in layers of 26, 18, and 26 inches...	5¾
1	Gower limestone, to railroad tracks.............	12

6 LIME CITY, LIME QUARRIES.

At these quarries, but a few rods distant from the exposures just described, the same beds recur which we refer to the Coggan. They are, as usual, horizontal and are thus in strong contrast with the Gower limestone on which they rest, which is highly inclined, or in unstratified massifs. Unconformity could not be more strongly simulated or exemplified. The Coggan beds are here of light buff color, non-laminated, soft and earthy, useless for any economic purpose except riprap, with strong petroliferous odor when struck with the hammer, and contain an occasional minute mould referred to the characteristic fossil brachiopod of the Coggan. Layers are commonly from six to twelve inches in thickness. The upper rock surface is but little decayed, but for a depth of three feet the upper layers are broken to chipstone by weathering, and are covered with two to three feet of red geest in which glacial pebbles are commingled. In these beds occur flint nodules up to one foot in diameter. The total thickness of these layers referred to the Coggan is here eighteen feet.

7 OUTCROPS ON ROCK CREEK.

The relation of the Coggan to the underlying Gower is seen at several stations on Rock creek. One mile northeast of Rochester (Tp. 80 N., R. III.W., Sec. 36, Sw. ¼ of Se. ¼) typical Coggan beds, massive, soft, granular, and with characteristic moulds of fossils, are exposed with a thickness of some seven feet, the layers being horizontal, and ranging from one to three feet in thickness. They directly overlie highly tilted beds of the LeClaire lithological facies, dipping 44° east in heavy, non-laminated layers, which extend to the water in creek, a thickness of five feet. One-half mile east of this station, and about twenty-five feet higher, higher beds of the Devonian are disclosed on a small branch of the creek.

One and one-half miles north several outcrops on the same creek (Tp. 80 N., R. III. W., Sec. 25,) exhibit the relations of the Coggan with the Silurian beneath, and with higher beds of the Devonian above. Here there is seen toward the head of the ravines, at a height of about fifty feet above the bed of the creek, a dark brown, non-magnesian limestone, identical in appearance with outcrops of the Otis at Cedar Rapids and elsewhere. In the road, about ten feet higher, occurs heavily-bedded granular limestone, weathering white, non-fossiliferous, and whose facies is not characteristic of any particular horizon. Further down the draw north of the road the following section appears:

	FEET.
3. Limestone, soft, buff, vesicular, in layers about 18 inches thick, of Coggan facies. Exposed at two horizons within a space of	8
2. Limestone, buff, horizontally bedded, fine granular. The horizontal face exposed in the bed of the ravine shows interlacing weather seams and imbedded angular bowlders of the LeClaire beneath, up to two feet in diameter, with small imbedded fragments of the same	2
1. Limestone, hard, gray, crystalline, of typical LeClaire facies, in heavy beds, dipping as high as 30°, in recurring ledges to water in creek	20

8. SUGAR CREEK TOWNSHIP, SECTION 3.

On Sugar creek the succession of the Lower Devonian strata is more clearly seen. At the bridge between Sec. 34, Tp. 80, and Sec. 3, Tp. 79, R. II. W., about at the level of the bridge floor, eight feet above the water, rock occurs apparently in place, of typical Coggan appearance, and with characteristic moulds of Coggan fossils, and about one and a half feet thick. For three feet above this no exposure is seen, when there appears a thin layer of Otis limestone, carrying, as so frequently in other counties, *Spirifer subumbonus*, Hall.

THE OTIS LIMESTONE. INDEPENDENCE SHALE. LOWER DAVENPORT LIMESTONE.

No exposures were found in Cedar county exhibiting the Otis beds in any force. This was the more unexpected, inasmuch as this formation is well developed in the counties both to the east and the west.*

9.—The only locality where the Otis has been found in Cedar in its typical fossiliferous beds is on Sugar creek, at the bridge between Sec. 3, Tp. 79, and Sec. 34, Tp. 80. While the section displayed here in the wagon road to the west of the bridge is not well shown on account of the weathering of the rock and the lack of any distinct ledges, it is yet possible to make out fairly well the succession. Nos. 8 and 9 are probably a Coal Measure outlier inset in an ancient channel, and with this exception the beds above No. 6 conform in facies to that of the Independence beds in Linn county in their usual less argillaceous aspect.

		FEET.
12.	Limstone, buff, argillaceous, weathering to calcareous clay, with some harder layers of buff, dense, dark speckled limestone, some finely laminated, all briskly effervescent in cold dilute HCl., with lenticular nodules of silica having carious surfaces from dissolution of intercrystallized calcite.......	18
11.	Limestone, buff, earthy, breaking into rhombic chipstone; at base a layer of green clay one half inch thick..	2½
10.	Limestone, buff, soft, more or less crackled.........	2
9.	Shale, black, argillaceous...........................	⅙
8.	Sandstone, brown..................................	½
7.	Limestone, buff, earthy, crossed with parallel cracks about three inches apart, dipping about 10° N. Briskly effervescent, but apparently magnesian..	5
6.	Limestone, soft, buff, dark speckled, earthy, dipping as above..	1
5.	Limestone, brown, crystalline, non-magnesian, in thin calcareous plates, with *Spirifer subumbonus.* Hall. Otis beds..................................	¾
4.	Limestone, gray, earthy, dipping 10° N., perhaps over a lens, Otis..................................	½
3.	Concealed..	4
2.	Limestone, Coggan	1½
1.	Concealed to water in creek.........................	8

*Norton, Report on Geology of Linn Co., Iowa Geol. Surv., vol. IV.
Norton, Report on Geology of Scott Co., Iowa Geol. Surv., vol. IX.

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10. At the crossing of Crooked creek (Tp. 79 N., R. II W., Sec. 8, Se. ¼), there are exposed in the road about eight feet of rock of Devonian facies. At the summit lies a white saccharoidal limestone, and at the base one of brownish buff color and earthy luster. For the most part the rock of the exposure is thinly bedded. It is slightly flexed, forming low arches. There is considerable difference in the appearance of the layers, but all contain so little magnesia that they readily effervesce in cold dilute HCl. Among the forms noticed are a light gray earthy limestone, one dark drab and crypto-crystalline, and a saccharoidal white limestone, mottled with irregular greenish yellow argillaceous laminæ, the white portions containing considerable clear quartz in minute detached perfect crystals. Carious silicious nodules also occur. The horizon is that of the Otis in the layers which form the transition to the Independence.

11. Ten feet above the summit of the last section as measured by the barometer there is well displayed in the road on a hill a few rods west, a section twenty-five feet thick of typical Lower Davenport limestone, non-magnesian, of finest grain, conchoidal fracture, and for the most part closely laminated. At the base lies a foot or so of light colored saccharoidal limestone. Stresses of various strength producing more or less perfect brecciation are in evidence. Some layers, especially toward the base, are massive and finely fragmental or crackled, the fragments remaining in juxtaposition, and disclosed only on weathered surfaces. There is also considerable breccia of ordinary Lower Davenport type, the "second phase" recognised in the report on Linn county*, where numerous small fragments are set in a scanty and lighter colored matrix. In certain layers the close coherent laminæ are sharply flexed within the limits of a hand specimen. Here and there are large fragments of laminated limestone set at all angles. Another type is seen where the laminæ are detached and separated, but retain

*Iowa Geol. Surv. vol. 4, pp. 158, seq.

within the matrix considerable of their original parallelism. Lenticles of silica occur.

12. A mile north of Rochester on the right bank of the Cedar a little above the mouth of Rock Creek (Tp. 79 N., R. III W., Sec. 3, Se. ¼ of Nw. ¼) a striking ledge of the Lower Davenport overlooks the river:

		FEET.
3.	Limestone. non magnesian, drab, weathering to lighter tints, hard, of lithographic fineness of grain, breaking with conchoidal fracture; in places crackled and fragmental in massive layers two feet thick and more, here and there graduates laterally from such layers into thin calcareous plates a fraction of an inch in thickness	10
2.	Limestone, non-magnesian, gray, semicrystalline, soft, retreating under No. 3 by weathering	2
1.	Unexposed to flood plain of river	25

13. Directly across the river from Rochester the same ledge appears at nearly the same height. A miner's shaft was sunk here some years since which apparently began in this stratum and shows to a certain extent the nature of the strata beneath, concealed in the preceding section by talus. In position and in composition the following numbers readily fall into the Independence, except perhaps the basal layer, which probably is Otis:

		FEET.
8.	Upper portion of shaft, not observed	7
7	Limestone. rough, brown. crystalline	2
6	Limestone, brown, soft, earthy luster, ferruginous and argillaceous, briskly effervescing in cold dilute HCl.	6
5.	Limestone, buff, earthy, speckled with darker spots, thin layered	1
4.	Limestone, bluish, non-magnesian, in part crystalline, in part earthy	4
3.	Limestone, pale buff, argillaceous, weathering to chipstone	3
2.	Limestone, buff, dull earthy luster, laminated, in even layers 2 to 6 inches in thickness	1
1.	Limestone, white, saccharoidal	½

A similar succession is seen imperfectly on the hillside where, from the base up, outcrop in different places a white, soft, crystalline, granular limestone, a brown, crystalline, granular limestone, limestone weathering to thin, drab, calcareous plates, and the heavy ledge stone of the last section.

From the base of the shaft is said to have been taken a massive bluish drab limestone, subcrystalline, with cavities lined with drusy spar. A special interest attaches to this layer, since it is currently believed to contain large percentages of silver. By those interested in Rochester, names are given of chemists in Chicago and in Iowa who, twenty years ago and more made analyses of the rock showing as high as $247 of the white metal to the ton. The analyses themselves are not extant. On this basis there has been considerable labor expended and some money in the exploitation of this "vein." Besides the sinking of the shaft described, a driller was kept at work for some weeks, and several openings have been made in the hillsides adjacent. Neither the rock itself nor its relations and surroundings give the faintest suggestion of any metallic content except pyrite. The following analysis, made at the chemical laboratory of Cornell college under the direction of Dr. Nicholas Knight, is less valuable therefore in disproving the local theories of the rock than in showing the relative amount it contains of lime and magnesia carbonates:

	PER CENT.
Calcium carbonate, $CaCO_3$	78.75
Magnesium carbonate, $MgCO_3$	20.16
Ferric and aluminum oxides, Fe_2O_3 and Al_2O_3	0.10
Silica, SiO_2	0.40
Manganese oxide, MnO_2	0.20
	99.61

14. TP. 79 N., R. II W., SEC. 6, NW. ¼.

North of Rochester a section of special interest is shown in the bed and sides of a little branch of Rock creek. Only about twelve feet is exposed, but three different lithological types occur and in a relation not easy to decipher.

The base of the section at the road bridge and the larger portion of the outcrop consists of a soft, dark buff, or brown, speckled, argillaceous limestone, of earthy lustre, often in laminæ an inch or less in thickness. These are in places flexed, and brecciation is not infrequent, small fragments of dull, speckled, brown limestone being set in a matrix of similar material. In places fragments are of hard, light drab, fine-grained, laminated limestone. These fragments are usually small, and none of the type were seen near the base of the section.

A few rods up stream from the bridge the floor of the shallow trench discloses extremely irregular layers of hard, dense, ringing, drab limestone, often thinly laminated, occurring in lenses and masses up to eight to ten feet in length. The lower layer exposed is about three feet thick, and is fissured and crackled, the fractures being filled with calcite. No brecciation was seen. Above this, masses of the same lithologic facies display considerable brecciation, and the matrix commonly consists of dingy brown, earthy limestone, similar to that outcropping beneath. The upper surface of the drab limestone shows a bluish clay, a geest, three to six inches thick. Overwrapping this limestone of the Otis type, recurs the earthy limestone already described.

The summit of the section is formed of a peculiar pinkish limestone, cemented of small calcite crystalline grains, rather loosely coherent, which produce a somewhat oolitic appearance on weathered surface. This forms a lenticular mass about twelve feet long and five feet thick, from which a surface layer of the same material extends up stream for half a rod. This pink, crystalline limestone is separated from the brown limestone beneath by a thin selvage of plastic, bluish clay.

The general horizon of the outcrop is unmistakably near the base of the Wapsipinicon stage of the Devonian. The brown, earthy limestone is clearly Independence, of the facies of the calcareous beds at Kenwood, Linn county. The brecciation it displays has been described under the so-called first or lowest phase of the Fayette breccia in Linn county. The section at Kenwood, above Cedar Rapids on Indian creek, shows on a large scale similar channel cutting and contemporaneous erosion and similar irregularities of deposition. The lens-like structures of the lighter limestone are altogether similar to those of the Otis limestone as seen in Linn county, and its facies and composition is of that substage.

15. TP. 80 N., R. III W., SEC. 4, NE. ¼.

The most northern outcrop of the pink crystalline limestone just described was found at the locality named above in a road section, at about the hight of the summit of section No. 3, described on a previous page.

	FEET.
2. Quartz, highly vesicular, resembling nodules in Independence.	½
1. Limestone, massive, crystalline, pink, gray and drab, in places forming a fine grained saccharoidal "sand rock," in places a mass of interlocking crystals about one-eigth inch in diameter. In the midst of this ledge are many masses and fragments of black flint. Fragments are also seen of buff and drab close textured laminated limestone. These are most numerous immediately below the upper silicious layer, No. 2, but occur even to the base of the section. Some of these limestone fragments are clearly imbedded fragments. In places on the hill other masses seem to be disintegrated portions of a layer or lenticle	15

16. TP. 80 N., R III W., SEC. 23, SE. ¼ OF SW. ¼.

The variant and abnormal dips of the Gower limestone of this interesting section at the crossing of Rock creek on the Tipton-Rochester road have been already noted. In almost immediate contact with these highly tilted strata of the Silurian lie nearly horizontal beds, which on lithological grounds we have referred to the Devonian. On the right bank of the creek and above the bridge the following sequence is seen:

		FEET.
3.	Limestone, massive, macrocrystalline, rough surfaced on weathering, buff, rapidly effervescent in cold dilute acid, dipping from 5° to 10° SE.	3
2.	Not exposed	4
1.	Dolomite (Gower), laminated, crystalline, lying at angles exceeding 45° to creek, estimated	30

Below the bridge on the same side of the creek the Gower gradually descends and the overlying strata correspondingly thicken. No beds of Coggan type were noted. Opposite an old mill a few rods below the bridge the ledge is more accessible, and presents the following section:

		FEET.
4.	Limestone, briskly effervescent, irregularly bedded, in part massive in bed five feet thick, without trace of stratification and with imbedded fragments of fine grained, yellow magnesian limestone. Abutting on this in places, limestone, drab and dense, weathers to layers about one inch thick. Elsewhere it appears in heavy courses two feet thick, on fresh surfaces showing lines of lamination picked out in different tints, highly crystalline, pink and yellowish green in color. Upper layers are brownish, macrocrystalline, as if compacted of crystalline grains	11
3.	Limestone, reddish, crystalline, saccharoidal, approximately horizontal, briskly effervescent, in two layers	2
2.	Contact of Nos. 3 and 1 not observed.	
1.	Limestone, Gower, dipping 30° S SE.; by barometer.	20

The facies of this pink crystalline limestone is very similar to some found in the Otis at Cedar Rapids, below well marked outcrops of the Independence, and it is to the Otis, therefore, that it is referred, together with the various limestones associated with it.

SECTIONS OF THE UPPER DAVENPORT.

Higher beds of the Devonian than those already described outcrop along the right bank of the Cedar below Rochester.

At this village the highest ledges seen in the bluffs belong to the Lower Davenport. Three miles due south these beds have sunk to the level of the upper terraces of the river. The following section is seen in an abandoned road in Tp. 79 N., R. III W., Sec. 23, Sw. ¼ of Se. ¼:

SECTION 17.

	FEET.
3. Limestone, hard, tough, gray, a coquina of minute fragments of shells, valves of *Gypidula comis*, Owen, very abundant, ten individuals being counted on a surface 6 inches square. Upper Davenport.........	½
2. Breccia, fragments large, non-fossiliferous, up to one foot in diameter, and near surface one noticed 2¾ feet long and 1 foot thick. In several places the matrix is abundant and contains sparce, small fragments. Lower Davenport..................................	6
1. Breccia, fragments dark drab and mostly small, those with diameter of four inches being exceptional. Matrix abundant, coarser grained than fragments, and of a light yellowish color. Lower Davenport ..	2½

18 TP. 79 N., R. III W., SEC. 26, SW. ¼ of SE. ¼.

A mile south of the exposure last described, the Lower Davenport appears at the level of the present flood plain, at the base of a hill fronting the river. Three feet are here seen of finely laminated limestone, brownish drab, with conchoidal fracture, the laminæ often curved. On the hillside to the northwest an old quarry shows ten feet of tough, hard limestone, drab and gray in color, irregularly bedded, in part a coquina, and fossiliferous. The following brachiopods were collected:

Gypidula comis, Owen.
Stropheodonta demissa, var, *plicata*, Hall.
Atrypa reticularis, Linn, winged.
Atrypa aspera, var, *occidentalis*, Hall.
Rhynchonella intermedia, Barris, (?) immature.
Spirifer pennatus Owen

19. IOWA TOWNSHIP, SEC. 35, N. ½.

Here is exposed in the roadway a highly fossiliferous stratum, although the number of species represented is not large. A somewhat higher horizon is indicated than that of the quarry just described. *Spirifer pennatus*, Owen, in large specimens, *Orthis iowensis*, Hall in its ordinary form not approaching *O. macfarlanei*, Meek, *Stropheodonta demissa* of the large normal type, *Atrypa reticularis* and *A. aspera* were the only species collected.

20. QUARRIES NORTH OF ATALISSA.

The highest Devonian exposures in the county are found a few rods north of the Muscatine county line on the right bank of the Cedar one mile and a quarter southeast of the outcrop just described. In the channel of a small creek near water level in the river the Lower Davenport appears in typical hard, dense, brown, non-magnesian limestone, in laminæ from a fraction of an inch to two or three inches in thickness. Only one foot is here exposed, but a little distance up stream and about ten feet higher there outcrops one and three-fourths feet of the same lithologic type, but here brecciated. The matrix is scanty but distinct, and the fragments are many of them parallel and in places still in juxtaposition. Across the creek and about twenty-five feet higher, two small quarries have been opened in the overlying fossiliferous beds. In the western of these, eight feet of fossiliferous, light gray limestone are exposed in layers from one to two feet thick, more or less irregular in bedding and lenticular, intercalated with highly fossiliferous shaly limestone layers six inches thick. In abundance of the species represented *Orthis iowensis* ranks first, *Atrypa reticularis*, second and *Spirifer pennatus* third with about one-third as many specimens as the species first named. Besides these occur *Atrypa aspera occidentalis*, *Stropheodonta demissa* in normal form and in the smaller quadrate and strongly plicated variety, *Crania crenistriata*, Hall and *Phillipsastrea billingsi*, Calvin.

The floor of the quarry adjacent to the east lies eight feet lower than that of the one last described.

		FEET.
4.	Limestone, hard, compact, gray and buff, mottled, in layers from 2 to 4 inches thick, overlain with red geest	$1\frac{1}{2}$
3.	Limestone, shaly, yellow	$\frac{1}{8}$
2.	Limestone, yellowish drab, splitting into irregular layers from 2 to 6 inches thick	3
1.	Limestone, tough, hard, gray, evenly bedded, resistant to weathering in two or three layers	$3\frac{1}{2}$

All these layers are fossiliferous, but owing to the hardness of the stone specimens are difficult to disengage. *Orthis macfarlanei*, was observed in No. 1 and *Spirifer pennatus* in No. 4. Chipstone of the quarry supplied specimens of *Gypidula comis*, *Stropheodonta demissa*, var. *plicata*, an Acervularia and *Phillipsastrea billingsi*, Calvin, *Ptyctodus calceolus* and *Cyrtoceras*.

About thirty-five feet above the base of the hill layers of a comparatively barren limestone have been opened up. In the five feet here exposed no fragments large enough to identify were found. The stone is yellow, breaking up into chipstone.

The Carboniferous.

Sandstones which probably belong to the Coal Measures, to the Des Moines stage of the Upper Carboniferous, are found at a number of localities over the county, but each in a very limited area. Those on Clear creek were described by the writer in volume III of the reports of the present Survey, p. 121. In all these outliers the sandstone is of moderately fine grain, and of various tints of buff and reddish brown, rather friable, but with indurated surfaces, either by secondary deposit of silica, or by deposit of the ferric oxides. Ledges very seldom appear, scattered bowlders of disintegration along hillside or in some draw being alone in evidence. Commonly these are found well down in present valleys, and in one instance on the level of the flood plain of the creek.

The location of several of these is sufficiently well shown on the accompanying map, and doubtless there are many which are not thus recorded. One outlier deserves perhaps more definite mention, that on Rock creek, Tp. 79 N., R. III W., Sec. 1, W. ½. Here on the outer edge of the flood plain a branch has cut through some two or three feet of a laminated, gray and reddish, friable sandstone, indurated on exposed surfaces with purplish brown crusts of ferric oxide, and containing in places finely comminuted fragments of brachiopod shells, too small for identification. In the midst of the laminated sandstone occurs a layer four inches thick, which contains numerous pebbles of clear quartz up to six inches in diameter, and of irregular form and smooth surface. Below there is exposed a few inches of fine, bluish, non-calcareous, plastic clay, destitute of fossils.

The story which is read in these outliers is of special interest. After the deposit of the rocks of the Devonian, this area was slowly lifted from the sea and during the Mississippian suffered long erosion. With the incoming of the Des Moines stage. a subsidence brought the waters of the Carboniferous ocean either far outspread over the area, or, at least, passing far up the river valleys of the time. In either case, siliceous sands were laid down in these valleys, unconformable with the country rock, and it is these sands which are here and there brought to light by the present streams.

The Pleistocene.

PRE-KANSAN AND AFTONIAN.

The ground moraine of the earliest of the great ice sheets which invaded Iowa in Pleistocene times is, in Cedar county, buried out of sight beneath later glacial deposits. In other counties, where it is exposed by erosion and its physical characteristics have been noted, this stony clay is a dense till, nearly black in color when moist. In well drillings and well records it can hardly be discriminated from the deep, unweathered Kansan till, which normally succeeds it, unless they are separated by the silts, the soils, or the vegetal deposits of the intervening interglacial epoch, the Aftonian. According to some of the well-drillers of the county, such old soils and peat beds, recognizable by their dark color, their texture and odor, are sometimes met with, especially in the "deep country," as the well-men term it,—the deep, preglacial, buried channel of an ancient stream, known in this report as Stanwood river. It is said that these vegetal accumulations are found in the the midst of the blue till, dividing it into two members, of which the lower, the pre-Kansan, is the thicker.

In the record of the well at the tile factory at Stanwood, two blue tills are parted by sands, which may correspond to the Aftonian gravels:

NO.		THICK-NESS.	DEPTH.
9.	Yellow clay, Loess	20	20
8.	Blue muck, Ashen loess	7	27
7.	Green, bright, hard clay	1	28
6.	Yellow clay, Kansan?	7	35
5.	Blue clay, pebbly, Kansan	65	100
4.	Sand with fragments of wood, first five feet very fine, coarser below, Aftonian	15	115
3.	Blue clay, hard, pebbly, Pre-Kansan	65	180
2.	Sand	116	296
1.	Clay, black, hard, tough, dries like shale, (Maquoketa shale)	44	340

THE KANSAN DRIFT SHEET.

The Kansan drift extends over the entire county. In the Kansan areas it is reached by every gully which descends below the loess. It underlies the Iowan drift plain and forms the nucleus of the paha hills which rise upon it. Indeed, few exposures of till are found in the county which upon grounds of physical characteristics can be referred to any other formation.

In its normal aspect the Kansan till is a dense clayey till, jointed, and bluish drab in color. Pebbles a fraction of an inch in diameter are plentiful; cobbles and bowlders are rare, except where, as in the immediate vicinity of streams, the till has been washed. It effervesces freely in acid from the considerable amount of limestone flour and meal it contains, derived from the grinding of calcareous rocks in the glacial mill. But so deeply is the Kansan decayed since the remote age of its deposition that few exposures are found in the county where it presents its normal unweathered facies. Two such sections are here given:

SECTION ON CREEK, TP. 82 N., R. IV W., SEC. 30, NE. ¼ OF NE. ¼.

		FEET.
6.	Alluvium, on flood plain, sandy	2
5	Sand, with some clay and an occasional pebble	¾
4.	Clay, loess-like, gray, non-calcareous, with ferruginous concretions	2½
3.	Sand and gravel	¼
2.	Till, brown, jointed, in rhombic blocks, leached of lime for ten inches from the surface, graduating into No. 1	2½
1.	Till, blue, calcareous pebbles small, those of chert and limestone numerous, some of coal; cobbles few, one of pink granite undecayed; cobbles in creek washed from this till, chiefly greenstones, a number faceted.	5

SECTION ON CREEK NORTH OF BENNETT, TP. 81 N., R. I W., SEC. 33, SE. ¼ OF NE. ¼.

		FEET.
4.	Humus, on side of low hill	¼
3.	Till, brownish yellow, calcareous to within one to two feet of the ground surface, in places carrying a moderate number of large pebbles; a few discontinuous thin veins of sand near base	3
2.	Till, brownish drab, calcareous, crumbling readily in hand when moist, not jointed, of the same constituents as No. 1, and graduating upward into No. 3	2½
1.	Till, typical unweathered Kansan, dark drab, traversed by joint cracks at distances of a few inches, hard, dense, predominately clayey, containing many small pebbles, rarely so much as an inch in diameter, a few fragments of coal observed, graduating into No. 2; to water in creek	6

A few feet above this section gray loess appears on the hillside, overlain with loess of the ordinary buff type.

With such rare exceptions as these just described, the exposures of the Kansan till in Cedar county are deeply and thoroughly weathered. By percolating waters, its constituent lime and magnesia carbonates have been taken into solution and carried downward to form calcareous nodules at depths rarely exposed to observation. By the roots of trees and grasses and growing crops, they have been carried upward and built into vegetal tissue. The texture of the till has been altered by frost and by decay so that it crumbles readily into small particles. Still more conspicuous are the superficial changes due to the alteration and the accumulation of the iron compounds of the till. To a depth of from six inches to two or three feet, the Kansan on certain areas has been so heavily rusted that it has turned to a deep terra cotta red, and to this zone of marked ferrugination Bain has applied the felicitous term, *the ferretto.*

Below the ferretto lies a zone in which the till has weathered to reddish yellow, to a yellow distinctly brighter than that of the loess, and to brownish drabs which pass by insensible gradations downward into the bluish drab of the unaltered till. These changes due chiefly to oxidation are most pronounced where the access is most ready to waters charged with atmospheric gases. They are least where the till is densest and most impermeable. Thus even where the mass of the till is unaltered and of normal color, a film is embrowned along the faces of each joint crack, and seams of sand are reddened by rusting.

The ferretto. The significance of the ferretto of the Kansan drift was not fully weighed until the recent work of Calvin and Bain on the glacial deposits of Iowa. It has long been known that the deep red soils of the United States south of the glacial border, the *terra rossa* of southern Europe, and the laterite of the Dekkan, were formed by the decay and oxidation, through vast periods of time, of rocks and clays containing iron in some of its compounds as a constituent. But the salient fact had not been seen that, were the loess removed from the upper Mississippi valley, there would be brought to the light over much of the Kansan area a soil as vividly colored as the red soils of Tennessee and Georgia.

Taking it for granted, then, that the ferretto is a true *terra rossa*, a red *geest* formed on the Kansan Drift, by secular decay, the thickness of the ferretto becomes a measure of the length of time during which the Kansan was exposed to the weather between the time of its deposition and that of its covering with the mantle of the Iowan loess. That this time is exceedingly long and can be measured only in tens of thousands of years is seen in the fact that the Iowan and Wisconsin drift sheets, whose origins are so remote that they must be reckoned in milleniums are still comparatively unleached and unrusted.

Emphasis should be placed, however, not so much on the comparatively narrow zone of greatest ferruginous accumulation, where the clays are dyed the deepest of terra cotta reds, as upon the wider zone in which the primitive color of the till is more or less altered by oxidation. The former depends upon other factors besides the lapse of time, and is not wholly a measure of the length of subaerial decay. It is produced also by the accumulation of ferric oxides in certain strata to which they have been brought by the movement of ground water. Thus from the porous loess there must be a continuous carriage of these oxides downward to the less permeable clays of the Kansan beneath. Even the basal layers of the loess are in places similarly affected, and thus in the midst of the silt an ancient weathered surface may be simulated. The deceptive appearance of a buried soil is added sometimes by the accumulation in the same way of the black oxide of manganese. In the alluvial clays of the creeks of the county a bright red ferretto not infrequently is seen to develop upon an impermeable clay lying beneath heavy humus.

The geographic distribution of the ferretto — using the word in its narrower sense — depends upon much besides age. The relief of the region is an important factor. In Cedar county it is not found on the Kansan drift except on hillsides where the local relief is considerable. On level tracts, and over gently undulating country, the Kansan till is yellow or reddish yellow in color, but the deep red ferretto is absent. On the other hand, it is seldom wanting wherever the Kansan is deeply dissected, as west of Clear creek, north of Bennett, and in the rugged country about Plato and Cedar Valley. This marked difference seen on surfaces of a single drift sheet cannot be due to local difference in age caused by difference in rate of erosion in the two topographic districts. It might be conceived that where the relief is greatest and the present drift surfaces are the youngest, the red ferretto would have been removed as fast as formed, since erosion has been there most rapid, and that it would lie the deepest and reach its darkest shades of color on the level tracts where the processes of removal are most slow. But on the contrary it is where erosion is least that the red ferretto is absent, and where its agents are most active that it is thickest and reaches its deepest dyes.

A control which suggests itself for this distribution of the deep red ferretto is that of the movement of ground water. It is on level or gently rolling tracts that ground water will remain comparatively stagnant and its level comparatively high. It is here that the oxidation of ferruginous constituents will be longest delayed and therefore the ferretto slowest in forming. On the other hand, on the steep hillsides of well dissected districts the movement of ground water is rapid. With every alternation of wet and dry weather alternate couches of water and air descend through porous soils, and the processes of oxidation are accelerated. Not only will the oxidation of the till be carried to its highest degree, but there will be effected a relatively large transference to it of the iron of the loess above.

As a subordinate factor the relative thickness of the loess is worthy of investigation. It may not be found to obtain elsewhere, but in Cedar county there is some connection, which may in part be a casual one, between the red ferretto districts and the exceptionally heavy loess which covers them. To what extent the iron of the ferretto is derived from the superjacent loess is undetermined.

Applying the term ferretto to the wider zone in which oxidation of the till has been effected to any appreciable degree, the factors of relief, movement of ground water, and superior terrane, become wholly secondary, and its cause can only be a subaerial secular decay. The ferretto thus becomes a demonstration of the long interval between the Kansan ice invasion and the later ones known as the Iowan and the Wisconsin, and therefore of the diversity of the Glacial epoch.

The Kansan has been superficially affected by the action of water in two ways, complementary each of the other. By the removal of the finer ingredients of the till there is left a thin zone, oftenest seen on the slopes leading down to streams, in which pebbles are more numerous than in the till beneath. And by a deposit of the finer ingredients washed from the till there results a reddish clay containing more or less sand and gravel, usually not over a foot thick, graduating into the overlying loess, with whose formation it probably was contemporaneous.

A special facies of the Kansan may be mentioned, one developed near the surface, a gray, stony, non-calcareous clay, often with a slight greenish tint.

A typical section is that of Tp. 80 N., R. IV W., Sec. 15, Sw $\frac{1}{4}$:

	FEET.
2. Loess, vertical thickness to summit of hill	10
1. Till, whitish, flaky, pebbles rare, a stiff clay containing considerable sand. Contains so little iron that it changes color but slightly before the blowpipe. Upper surface reddened to a depth of one to three inches, and in places forming an ocherous crust by infiltration from above. Transition to loess abrupt. Exposed in road a vertical distance of..................	5

TP. 80 N., R. I W., SEC. 4, NW. ¼.

	FEET.
4. Loess, exposed at cut about twenty feet below top of hill	3

		FEET.
3.	Red ferretto of Kansan till	2
2.	Till, gray, in places slightly greenish, mottled buff where more sandy, a stiff, flaky clay, reddening but slightly on heating	2
1.	Till, yellow to base of exposure	4

Nos. 1, 2 and 3 are wholly alike in absence of lime, and in kind and size of included pebbles. These are for the most part small, those over three inches being rare. Limestones and cherts not abundant. Small greenstones common and often faceted and scored.

The following exposure is exceptional, in that it shows a calcareous till overlying the gray clay described :

TP. 81 N., R. II W., SEC. 16, NE. ¼, ON LOW HILL OVERLOOKING BRANCH OF SUGAR CREEK.

		FEET
4.	Loess, buff, graduating into No. 3	6
3.	Loess, ashen gray, with red ferruginous stains, bulls' eyes, and minute calcareous tubules. Toward base a ferretto of undulating ferruginous layers 2 to 3 inches wide	3
2.	Till, calcareous, yellow, clayey, pebbles small, rather numerous, limestone and flints rare, no distinct reddening of upper surface	4
1.	Till, gray, non-calcareous, otherwise similar to No. 2.	4
	To flood plain of creek, concealed	5

A few feet further down the hill the loess thins to two feet and the underlying till is non-calcareous. Here the ferretto is clearly derived by leaching from above, instead of by weathering, and the calcareous admixture in No. 2 may have the same origin.

TP. 81 N., R. I W., ON ROAD BETWEEN S. ½ SECS. 11 AND 12.

An interesting section showing zones of ferruginous and manganesic accumulation forming a ferretto.

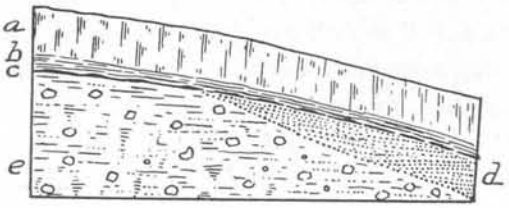


FIG. 22. Section Showing Zones of Ferruginous and Manganesic Accumulation at Base of Loess.

a. Loess, yellow.
b. Loess, ashen, laminated, graduating into c.
c. Ferretto, a reddish stain on upper surface of till, or a few inches below upper surface, width, one inch. This passes out upon "c" as a reddish yellow, ocherous layer three inches thick, overlying and mingling with a thinner black manganesic zone.
d. Stratified sand and sandy clay. Immediately below ferretto is so sandy as not to be plastic.
e. Till, brown, jointed, clayey, Kansan facies.

TP. 81 N., R. I W., SEC. 9, NORTH ROAD.

A section exhibiting an uncommon aspect of the Kansan where lime is carried downward to form calcareous concretions.

		FEET.
4.	Humus	½
3.	Loess	2½
2.	Clay, transition from loess to till, intermediate in color and texture of clay	1
1.	Till, reddish brown, jointed, a stiff clay with no cobbles; its included pebbles rarely one inch in diameter, non-calcareous to depth of six feet where there is a zone of hollow, round, calcareous nodules	6½

Further down this hill ashen loess lies above No. 2, and through it runs a ferretto three inches wide of limonite crusts.

Topography of the Kansan.—The origin of the present topographic forms of the Kansan drift sheet will be most easily understood if the entire area of the formation is conceived in its initial aspect of a fairly even and undissected drift plain. The inequalities which need be postulated are few. While the initial surface probably had the slight depressions, the low swells, which are found on drift plains of later age, no trace has been discovered of the more salient features of glacialogic relief, such as the great morainic hills of the later drift. Distinct drumlinoid ridges, however, fluted it in places and here and there a continuous sag indicated the line of a preglacial river in whose valley the drift had settled by compression and condensation. Conceiving that the Kansan area was originally, then, a plain of very slightly diversified relief, it follows that the present topographic contours are those developed by erosion. At the greatest distance from the streams where the work of running water is still slight, the initial plain remains apparently little changed. For two miles north of Tipton, for example, the divide between Sugar creek and Rock creek is a tabular narrow area so level, so unscored by drainage channels, that in a wet season, as that of 1899, storm water lingers in small pools within hailing distance of the ravines leading steeply down to the creek to the east. Within the city limits and for a half mile south this level upland, only nibbled on the edges by the streamlets, is a model at hand in the teaching of physiography in the high school at Tipton. Examples of the initial upland plain on a much larger scale occur on the Cedar-Wapsipinicon divide from Sunbury north, nearly to Clarence. This area is an extension of the New Liberty plain described in the report on the geology of Scott county*. This gradually passes into the gently undulating country of Farmington and Fairfield, and with a deepening of every streamway with increasing distance from the divide, passes by insensible gradations into the rugged region south of Lowden.

It is in the same upland whose remnant levels have been mentioned, that the deep and intricate dendritic systems of ravines have been carved which characterize tracts of considerable size in different parts of the county. These maturely dissected regions occur wherever the upland stands

*Norton Iowa Geol. Surv., vol. IX, p. 410

high above near base levels, where the streams have been able therefore to cut it well to pieces. A single description will suffice for all these tracts,—for Center township southwest of Tipton, for Gower township about Plato, for Springfield township south of Lowden, for Pioneer township southwest of Mechanicsville, and for a little island of Kansan drift a mile north of the last named village. In each the residue of the original levels of the upland mav be seen in the even sky-line of the crests, and the initial surface may be restored in imagination by refilling the valleys with the material which has been washed out and away to the river and the sea. In each the long crests of the ridges rounded to the weather curve are so narrow that they sometimes afford scant space for roadway. Rarely have they been broken up into detached hills by the meeting of the heads of the gullies which trench their flanks. Along these even winding crests are laid out excellent roads, smooth, well drained, and underlain by the loess, in dry weather an admirable elastic pavement. Sooner or later one must descend to the level of creek or river, and here the road follows out on the spurs which buttress and rebuttress the stem lines of the divides, like the pinnules of a compound pinnatifid leaf. At the head of the ravines the descent is quite too steep for a road.

No dubitation is permitted the raindrop which anywhere falls in these regions. Its easy path has long since been fixed for it. It courses down the steep hillside, taking with it a modicum of the soil; it runs down the gully into the ravine and out along the way of a wet weather stream to creek and thus swiftly on to the river. Thus these areas are incised with a system of drainage channels which join one another as twig joins stem, and branch the tree trunk. This arborescent system is so complete that it would be difficult to find room where another ravine could be inserted, a fact painfully in evidence on roads laid out with that undeviating rectitude so pleasing in conduct, but so uneconomic in roads.

In considering the contours of these dissected uplands it must be remembered that the Kansan drift is here covered with a mantle of loess, and that it is in this soft yellow silt that the ultimate branches of the erosion system are developed. The loess was laid down, however, after a large portion of the dissection of the upland had been accomplished. It follows down the till slopes of hillsides, and the undisturbed lamination of it within a few feet of the present flood plains proves that its presence there is not due to creep.

FIG. 23. Loess-Kansan landscape south of Lowden.

Indeed, some considerable part of the excavation of these valleys is pre-Kansan, if not preglacial. For where they are cut in rock, till rests on the long decayed rock with its mantle of geest descending to the water way with a slope and surface apparently unaltered by ice invasions.

A characteristic loess-Kansan landscape with spatulate ravines is presented in figure 23, but as with much of the work of the camera, the impression is lost of depth of valley which is received in the presence of the object.

The larger portion of the Kansan is much less deeply and intimately dissected than the areas we have described. Here the drainage system is indeed complete, the whole area is reduced to slope, but these slopes are gentle. The rounded crests of the undulations too low to be called hills, reach the initial level of the upland in which they have been carved, and thus afford an even sky-line. Everywhere the loess forms the subsoil, but the drift will be found at no great distance from the surface, except near the margin of the Iowan.

Thus one initial plain of Kansan till but recently mantled with loess, gives rise according to the degree of its dissection by runing water to the level tracts above Sunbury, to the gentle rolling prairie of Fairfield township, and to the maize of steep hills south of Buchanan.

Advance and Retreat of the Kansan.—With variations of climate the front of a glacier may retreat and again advance. During its retreat glacier water will throw down silts and sand upon the ground moraine laid bare by the removal of the ice. Upon the readvance of the ice these water laid deposits may be covered by another ground moraine, and the stratum of stratified silt interbedded between the glacial tills, forms a lasting record of the backward and forward movements of the ice front. The only instance which so far has come to the notice of the Survey in the case of the Kansan, was found at Carey's quarry south of Tipton (Tp. 80 N., R. III W., Sec. 13, Sw. ¼ of Nw. ¼). Where the like has been seen elsewhere in Iowa, the upper and lower tills are so markedly dissimilar that they are referred to distinct ice invasions and the intercalated deposits to an interglacial epoch. But in this case both tills are Kansan in facies, as is shown in the appended section. The inference seems safe of a local readvance of the Kansan, although it is possible that the lower till may be an altered pre-Kansan, and the interstratified deposits Aftonian.

	FEET.
8. Brown, stiff, sandy clay	3
7. Clay, less sandy, resembling loess	2
6. Clay, reddish brown, jointed	1
5. Kansan ferretto, reddish brown, highly oxidized	½ to 1

	FEET
4. Kansan till, stiff, non-calcareous, jointed; pebbles small, few reaching 1 inch in diameter; till reddish yellow mottled with gray, sandy and highly oxidized at base....................................	8
3. Clay, light buff, sandy, with an occasional pebble, loamy, non-calcareous, merging into a gray and light buff pulverulent loess-like silt, in places stained orange and red, stratified, flexed and crumpled.....	3
2. Sand and gravel, heavily ferruginated, indurated but not cemented, dark reddish brown, with pebbles up to 5 inches in diameter of which the granites are rotten	2
1. Till, non-calcareous, completely oxidized, like No. 4, but carries larger pebbles and cobbles, small fragments of coal and limonite nodules, resting on limestone..	3

THE PAHA.

The drumlinoid hills of eastern Iowa, loess-capped, with an inflexible trend from west-northwest to east-southeast, were named paha by McGee.

While the work of the survey in Cedar county has certainly not solved the riddle of the paha, it has added some salient facts, which must be met by any theory of their origin.

In distribution we may discriminate three areas on which paha are found: an area peripheric to the Iowan frontier, in part within the Iowan drift, and in part situated on the Kansan overlooking the Iowan plains below, and an area upon the Kansan too remote from the Iowan border to have been under the control of the glacier ice of that invasion.

An example of the latter is found in Iowa township. The interstream area between the Cedar and Wapsinonoc creek includes flat, tabular tracts, and these may occur within half a mile of the river. As the upland descends below 750 A. T., it is traversed by long, distant, parallel swells of pahoid orientation. From twenty to forty feet high, they are comparatively broad, and their sky-line is often fairly even, although the eye may catch here and there the curve of the convex lens. These extend into Muscatine county, where their origin is attributed by Udden to glacio-fluvial action accompanying the Illinoian invasion. Similar low pahoid swells are seen on the Kansan upland in Fairfield township, on the divide between Sugar creek and the affluents of the Wapsipinicon, at right angles to the ridges which would normally be produced by the erosion of a dendritic system of drainage. In Red Oak township indistinct pahoids flute the Kansan upland between Rock creek and Rocky run. Southwest of Mechanicsville the Kansan undulates in similar swells, numerous and well defined.

Whether these flutings represent drumlins of Kansan drift, covered with an even veneer of loess, or are silt bars of loess laid in some ancient body of water, or wind rows of this light loam, or whether they are hills of erosion, the modeling or sculpture of their forms can hardly be referred to the present order of erosion, but must belong to the same order of events which produced the paha of the Iowan border, which they so closely resemble. The pahoids just described have attracted little attention even from students of land forms. On the other hand the paha, which are peripheric to the Iowan, are among the most striking reliefs in eastern Iowa, and may well give name to their region, the Land of the Paha, as McGee has termed it. It is because they are so closely associated with the Iowan that they have heretofore been treated as a phenomenon of that drift. Where they override the Kansan upland, they have been classed in the category of the heavy loess, which fringes the Iowan as with a moraine. Where they rise isolated from the Iowan drift, they have been treated as genetically related to that ice invasion, but the paha are so closely associated with the Kansan on this border that they may be treated as detached portions of it, even when entirely surrounded by the younger drift. Within the Iowan area paha are limited to the margin. So far as the topographic sheets of the United States Geological Survey indicate, the instances are rare indeed where paha are found at any considerable distance from the loess covered Kansan. In Cedar county the interior of each lobe of the Iowan stands clear of paha, while they cluster in the lee of the Kansan upland and fringe its sides. In Bremer county unpublished notes of these northern paha show that they preserve there their trend, and affect in all instances the immediate vicinity of the Kansan. In Linn a low, isolated paha stands on the wide drift plain north of Marion, an exception without a parallel in the observation of the writer.

The concord in height between the Kansas upland and the paha which fring it may not be without significance, nor the fact that both alike are covered with loess. Considering the difficulty in distinguishing tills, it is probably of less consequence that so far as seen in the few sections afforded of the nuclear till of paha, this has been of Kansan facies.

From the west county line pahoid hills surmount the edge of the Kansan from Lisbon to Mechanicsville. In the writer's report of Linn county, this belt of hills was termed the Lisbon paha ridge, a designation that the progress of the survey has not shown to be of any particular utility. No topographic contrast could well be stronger than that here brought to view in a walk of a few rods across the frontier which separate the areas of the younger and older drift, when one leaves the low and level plain with an occasional bowlder, its roads black with deep humus, its fields covered with grains and grasses, and climbs the boat shaped hills to the south, crowned with the primeval forest of white oak and maple, the road yellow with the loess, and looks down on the two contrasting topographies, the labyrinth of steep hills to the south, whose larger streams lie in broad deep valleys, and the levels to the north where the same streams head in sloughs and take their courses in channels indenting the level of the prairie by perhaps less than twenty feet. Paha also skirt the Kansan for some three miles west of Mechanicsville, lying north of the tracks of the Chicago & Northwestern railroad. From

Mechanicsville east, a low, narrow, and fairly even topped ridge separates the two areas. East of Clarence the paha become more conspicuous, their crests standing eighty and 100 feet above the Iowan, here descending the valley of Yankee run. South of Lowden paha occur abutting on the Kansan, but not rising to its summit level. The line of these remarkable hills continues east to the Wapsipinicon river, and with some interruptions to the Mississippi. The physiognomy and structure of the belt in Scott county is described in the report of that area in volume IX of the present Survey.

On the north the Clinton lobe is bordered by a line of lenticular hills which enter from Linn county and extend to north of Mechanicsville. They stand about forty feet above the plain and the county road which runs along their bases gives their orientation. This ridge skirts a beautiful little island of Kansan lying north of Mechanicsville, and in its lee to the southeast cluster a bevy of these drumlinoid hills, as characteristic perhaps as any in Iowa. Most striking of them all is the one to the northeast, named Stanwood paha by McGee. The length of this ridge is two and one-half miles, and this may be increased by one mile if we may add another ridge to the northwest in direct alignment and separated by a gap of only twenty rods, the channel of Picayune creek. The width is not more than a quarter mile, and its height some ninety feet. The crest is slightly undulating, and the lateral slopes, which descend at an angle of 7°, are smooth and but slightly eroded. Of the terminal slopes, that to the southeast is the more gentle, the ridge tailing out in this direction upon the marshy drift plain. The higher crests of the hill are made of typical pulverulent loess. As it declines to the southeast the loess contains disseminated grains of sand, and one or two knobs are said to be sandy. Where Picayune creek divides it, stratified sand of the usual type underlies the loess, and at the extreme northwest there is exposed in the road, about twenty feet above the base, ten feet of till, yellowish brown, rather sandy, non-calcareous, with small pebbles. By analogy with other paha we may infer that till rises much higher than this, and may constitute much of the bulk of the ridge. There is no trace of rock nucleus. In a boring near the base, at the house of Mr. O. S. Burleigh (Sec. 9, S. ½ Fremont Tp.), the drill passed through 146 feet of glacial deposits, mostly blue till, without encountering rock. As the well curb is about 830 A. T., the rock surface cannot here rise above 684.

Stanwood paha is but one of a series of parallel hills of similar form which extend south to the Kansan line at

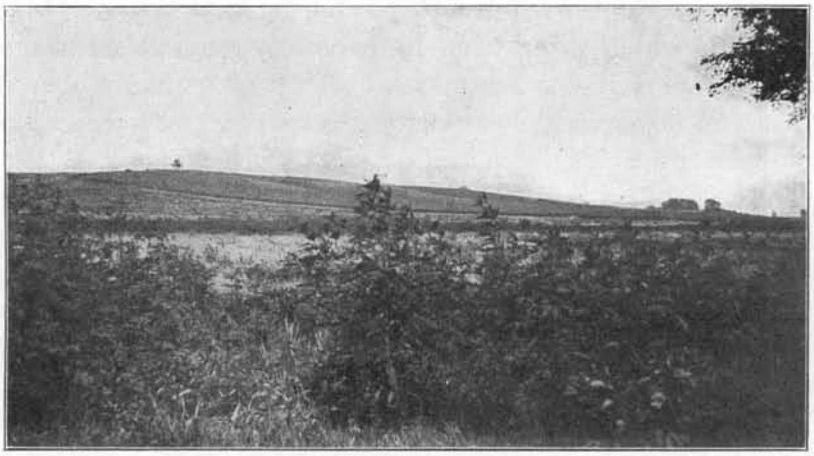


FIG 24. Stanwood Paha, southeast end looking east.

Mechanicsville. On some of these the loess mantle is thin reddish till of Kansan aspect appearing well up toward the summits. On others the loess is wanting, the whole hill, so far as appears, being composed of Kansan drift. Around these hills wraps the Iowan area, often marshy to their bases. North of the Stanwood paha two or three short paha rise about twenty feet above the wide marshy flood plain of Pioneer creek. To the northwest across the creek lies an upland as high as the summits of the paha. This upland, which seems to have been the main path of the Clinton ice lobe whose vestiges remain in many large bowlders and a sandy till, descends to the creek in lobes of pahoid orientation composed of reddish Kansan till with perhaps a thin veneer of Iowan in places.

Northeast of the Stanwood paha the north margin of the Clinton lobe lies in Jones county. A detached paha near the north line of the county overlooks Mill creek from a height of over 120 feet. The south slopes of this bold ridge are lobate, and at the northwest, about forty feet below the crest, a till of Kansan aspect is found in excavations for cellars, the loess being here absent.

In the northeast part of the county an island of Kansan topography, loess covered and intimately dissected, extends from Massilon on the right bank of the Wapsipinicon nearly to Oxford Mills. The margin of this upland breaks into narrow pahoid crests and a series of paha flank it to the south and southwest. Some of these, sixty feet high, are wholly destitute of loess and are composed of a brownish, non-calcareous till either accreted around a rock nucleus or at least resting on a rock foundation. In the Kansan upland the drill reaches the Niagara limestone at from 750 to 760 A. T. On the sides of the detached pahoids, rock outcrops at from 750 to 780 A. T. A number of hills of this group show sand and loess on their summits.

South of this cluster of paha the Iowan plain passes into Clinton county through three gateways, each from a mile to a mile and a half wide, separated by two massive ridges with the orientation of paha. The northern of these is much the larger, and it forms one of the most interesting topographic forms of the state. In bulk it is king of paha, if it may be classed among them. In length it is over six miles, and in width ranges from a third of a mile to a mile and a half. On the south side it is well dissected or lobate and its contours here are similar to those of the Kansan areas well matured. Ramifying lobate spurs strike southwest from the central ridge. The crest is complex, with inosculating loess boat-shaped hills, which rise 160 feet above the plain at the south.

On the northeast the slopes are more simple. The sky-line is shown in figure 25, a view taken from the Iowan plain to the north. The bowlder in the foreground, one of the largest seen in the county, measures 7 by 4 feet and is of pink granite.

Sections on both sides of the ridge prove a till nucleus which rises within at least forty or fifty feet of the summit. On the southern spur, in sections 26 and 27, Massilon township, this till exhibits the normal Kansan characters, being

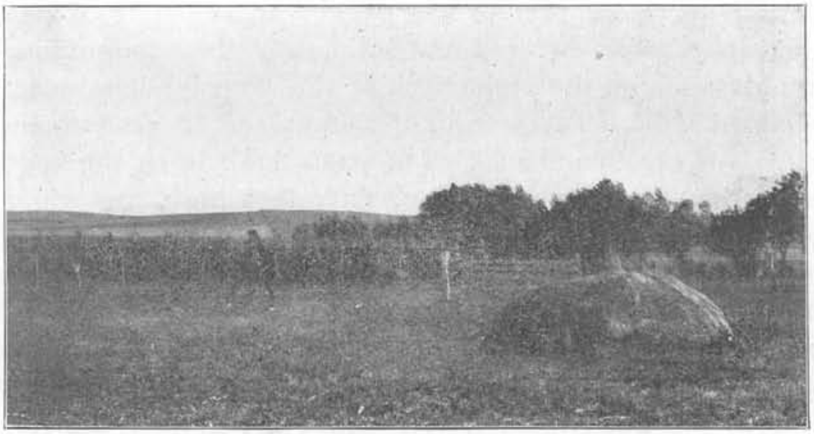


FIG. 25. Sky-line of pahoid ridge north of Lowden from Iowan plain to north.

a very stiff clayey till, reddish yellow in color, with but few cobbles, and leached of lime to a depth of seven feet from the surface. On the north side the roadway section shows the common relation of loess and till seen on deeply dissected Kansan regions. Typical yellow pulverulent loess, weathered brown superficially, is the only deposit seen for about thirty-five feet from the top of the hill. At this point the basal layer of the loess is transected—a pinkish loam, more or less distinctly laminated, with ferruginous concretions and tubules, reaching a vertical thickness of a foot or more. Overlying this basal loess is an irregular black layer of manganesic accumulation from one to three inches thick.

About fifty feet from the top of the hill a shoulder of till is crossed by the road exposing ten feet in vertical measure. The upper one foot on which the pink loess rests is a clayey reddish till with sparce pebbles, passing downward into reddish non-calcareous till in which small pebbles are plentiful, but predominantly clayey.

Little information as to the structure of the ridge was obtained from well records.

The following wells are along the crests:

John Weibe, Sec. 21, Se. ¼, depth 144 feet; to rock, 85 feet "all in solid yellow pebbly clay." (This record does not distinguish the loess from pebbly tills.) No sand or gravel, rock at 755 A. T.

Ernest Schleuter, Sec. 27, Nw. ¼ of Nw. ¼. Yellow clay (loess and yellow till) 40 feet, blue hard pan 132 feet, total depth 172 feet, a little sand and water at 110 feet. Rock surface not over 688 A. T.

Luis Heuser, depth 222 feet; elevation of curb 810 A. T. Sec. 26, Se. ¼.

Chas. Kramer, Sec. 28, depth 183 feet; to water 180 feet.

Parallel with ridge just described lies a much shorter paha, which also extends from the drift plain near Clarence, and terminates two miles west of Lowden. Its crests are distinctly convex and reach about the hight of the Kansan upland to the south.

The paha of the Tipton lobe are less numerous and striking than those of the area we have described. They are inconspicuous or absent on the Kansan margin on the right bank of the Cedar, but at Buchanan several short elliptical paha form with their flowing contours an impressive and beautiful feature of the landscape. They are scarcely one half mile in length and rise 100 feet above the creek at their base. They are heavily mantled with loess, and no drift appears upon their sides. Three miles west of Tipton the plain marked on the map as Iowan forms a lobelet extending south between Rock creek and Rocky run. This is skirted by paha and along it run narrow sands ridges, some of them less than ten feet high, aligned with the paha of the region.

In the immediate vicinity of Tipton there occur well within the Kansan, both west and south of the town, fine ridges of this class, but with rather flat tops. So far as the structure of these is shown they consist of loess underlain by stratified sand. In one distinct ridge of northwest-southeast trend south of Tipton, lines of lamination dip conspicuously outward as seen in fig. 26.

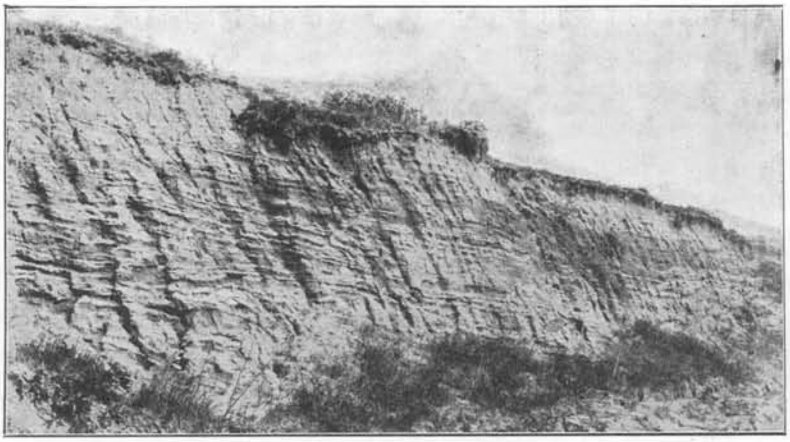


FIG. 26. Stratified sand and loessid silt in pahoid ridge, south of Tipton.

No very distinct paha mark the north border of the Tipton lobe. In Cedar township, in especial, occur sandy ridges with hummocky summits and with the pahoid trend near the margin, and about 150 feet above the Cedar river.

A tract at Rochester extending east to Crooked creek presents some difficulties in classification. Constructional profiles so prevail that it was a question whether it should not be included in the Iowan. It stands well below the Kansan upland to the northwest, and the parallelism of its reliefs is in contrast with the dendritic drainage of that area. The higher paha have as usual a nucleus of Kansan till and are mantled with loess. The low parallel ridges are mantled with sand and a brownish sandy clay, or consists of the same, recalling the aspect of the Iowan near Cedar Bluff. Though no bowlder dotted drift of Iowan facies was found on this tract, it would probably have been mapped as Iowan, had it been possible for that ice sheet to have had access to it. It is surrounded by typical Kansan areas, and it does not appear that the long, narrow gorge of the Cedar below Cedar Bluff would have made a practicable path for glacier ice.

Origin of Paha.—With our present limitation and uncertainty of knowledge any extended discussion of the origin of these unique and enigmatic reliefs would be useless. The parallelism of their axes at once suggests a genetic kinship with drumlins. Their form points in the same direction, but such rounded contours would obtain by weathering on any hill capped with so soft a silt as the loess. Assuming that they are loess-mantled drumlins of Kansan drift, raises the difficult question why they should congregate around the borders of a far later ice sheet. Where the margin of Iowan and of Kansan coincide, as about the driftless area, this may be expected, but surely not where the margins are separated by the width of the state, as in Cedar county and west. On the other hand, the assumption that the cores of the paha are drumlins of the Iowan drift is confronted with as serious objections,—the involved assumption of a virtual Iowan peripheral moraine composed of drumlins, the presence of the Kansan drift in the paha, and the pahoid ridges on Kansan areas. The second of these could be met by the admission of the essential similarity of the tills of both drift sheets, and the impracticability of discriminating one from the other in most cases. The third would be avoided were the Iowan border extended for about fifteen miles to the south, under the assumption that the normal topographic features of that drift sheet were here masked by the loess, or by the hypothesis that the direction of both flows was the same.

The hypothesis is attractive that paha are eskers of loess, or that they are silt bars laid down wherever caught by snag of rock, or hill of drift. The absence of loess on certain pahoid hills closely associated with paha seems to prove that the direction of their major axes was given by the constant and rectilinear movement of ice, rather than by currents of water and of wind. The presence of loess on their summits may be attributed to whatever causes are responsible for its presence on the Kansan upland. The absence of loess on the Iowan plain is explained by the protection afforded by the mantle of Iowan ice at the time when the loess was laid down. The cores of the paha may at this time either have been islands in the *mer de glace*, or, being overridden by the ice, they may have caused long crevasses in which, or because of which, loess was deposited on the summits below.

THE BUCHANAN GRAVELS.

It has been discovered by Calvin in his work in Buchanan and Delaware counties that the retreat of the Kewatin glacier in northern Iowa was attended by the deposition, on uplands and in valleys, of heavy gravel trains which in the long lapse of time that has since elapsed have become reddened by rust, decayed, and leached of their lime. These water laid deposits contemporaneous with the Kansan are termed the Buchanan gravels. One exposure was found in the county which possesses the characteristics of this formation.

Tp. 81 N., R. IV W., SEC. 15, Ne. ¼ of Se. ¼

		FEET
3	Clay, pale buff, with disseminated sand merging into No. 2	$1\frac{1}{2}$
2	Sand, yellow, with disseminated rare pebbles	1
1	Sand, dark red, with disseminated pebbles. Upper surface with more abundant gravel, slightly undulating and conforming to slope of hill. Junction with No. 2 sharply distinct, stratified, pebble lines and lines of coarser sand irregular, discontinuous and apparently often backset at angle of 6° to 8° toward hill. Pebbles mostly below 1 inch, but some cobbles, these angular, often rotten, sometimes striated and faceted, limestones and cherts comparatively few. In places so indurated as to be cut with trowel with difficulty, but in general friable	5

Toward the base of the hill the red sand and gravel thins with a corresponding increase in thickness of the yellow sand above. Eight feet above the creek No. 1 is overlain by an ashen loess-like silt 20 inches thick which passes upward into the a yellow loessial loam two feet thick. This grades into the yellow sand of No. 2 by interstratification. This sand at the edge of hill is 15 feet thick.

In the above section we may consider No. 2 as the loessial sands so often found associated with the Iowan border. No. 1 which has every mark of greater age will then fall into the Buchanan gravels.

It is a noteworthy fact that such exposures are exceedingly rare. Sand is not common even in the immediate vicinity of streams, and a fine clay usually overlies the Kansan on the uplands. There is thus marked a considerably less slope to the Kansan surface at the retreat of its parent glacier in Cedar county and therefore a slacker drainage than that which obtained in the counties to the north, where the Buchanan was first studied.

THE IOWAN DRIFT.

Just west of the Linn county line the Iowan drift sheet divides, one lobe—that designated in this report as the Tipton lobe—passing south along the left bank of the Cedar and the other and larger—the Clinton lobe—extending across the northern townships of the county. In the latter the Iowan drift reaches its greatest extension to the southeast.

The topography of this drift sheet in each of its lobes in Cedar county corresponds with that of other areas described by Calvin in the reports of the present Survey and in his monograph upon the subject in the Bulletins of the Geological Society of America.

On a well nigh featureless plain of glacial till, which slopes gently to its borders, or at least to its border on the south, the streams have cut shallow troughs. Interstream areas are so largely undrained that some ponds still survive the gradual decrease of ground water during recent decades. At the time of the settlement of the country sloughs were common, and large tracts were so marshy that the occupation of this portion of the county was considerably delayed. These initial depressions have nearly all yielded to ditch and tile, but a few shallow ponds still linger in wet weather, one at the edge of Mechanicsville, and others on the plain west of that village.

Bowlders.—The bowlders of the Iowan area in Cedar are neither so large nor so numerous as those left in Delaware, Buchanan and Bremer counties by the Iowan ice field, but in these repects they resemble those of the Marion till plain in Linn, with which the lobes in Cedar are continuous. The distribution is far from uniform on either lobe. They are rarely seen on the Clinton lobe, from the Linn county line, as far east as Clarence. Thence to Clinton county they are more plentiful, and they are specially numerous in the lobelet southeast of the village, where they may be counted by the dozens, many more than three feet in diameter.

On the Tipton lobe they are, on the whole, more common than on the northern area, as perhaps would naturally follow from its lower altitude and connection with the great drainage channel of Cedar river. They are specially numerous north and west of Cedar Bluff. In the interior of the lobe, from Cedar Bluff to Tipton, they do not impress one as being more numerous than the Kansan would probably show, were the loess removed.

The natural habitat of the bowlder is the low ground of swale or meadow. Rarely are they seen on hilltop or high on hillside. From their natural "station" they have been largely removed to the roadside, a place most convenient for the farmer and for the passing geologist. Many also have been buried to make way for the mower, and many have been built into abutments for bridges and foundations for barns and houses. In a few decades these important witnesses to the Iowan ice invasion will be beyond reach of ready summons.

Lithologically they are for the most part of a pinkish or flesh colored granite or gneiss. Traps are not uncommon, and the reddish crust which forms upon some of them by the rusting of their ferro-magnesian constituents sometimes takes the tinge of the pink granites when seen at a distance.

The bowlders are usually more or less rounded, at least on exposed faces. In other words their form is that of bowlders of disintegration. This process is uninterrupted. Crystals of feldspar, flesh red and flat faced, are ever being detached and scattered at the base. But so exceeding slow is the process that it is reasonable to suppose that these rounded forms were assumed by long weathering on their parent granite ledges in Minnesota and Wisconsin, whence they were brought by the ice, the earliest emigrants into the state.

Where large Iowan bowlders have been broken up, it is often found, according to Calvin, that they rest comparatively near the surface of the ground on surfaces planed by the abrasion of the rocks over which they have been dragged by the ice. Smaller stones so planed and scored are sometimes so set that the surfaces affected are exposed to view. Such bowlders cannot belong to a superglacial drift, unless they were thus beveled on their parent ledges before their journey to Iowa was begun.

Little is seen on either of the lobate areas of the Iowan of typical pale yellow, clayey, calcareous till, described by those who have studied the Iowan in the counties to the north of Cedar. The following is the only instance within the areas of a till which when tested reacted for lime within the depth of the exposure, and this was found below a layer of loess:

CUT ON B., C R & N. RY., TP. 81 N., R. III W., SEC. 34 Sw ¼.

		FEET.
5.	Humus, and humus colored sandy clay	4
4.	Sand, pale yellow, moderately fine	1
3.	Clayey sand, reddish brown	½
2.	Loess, buff	2
1.	Till, sandy above, clayey below, calcareous, destitute of bowlders and cobbles, rather loamy and loose of texture and resembling loess in color	3

But over large tracts there lies a deposit which seems eminently characteristic of the Iowan, though not yet recognized as such so far as is known to the writer. This is a sandy till with many pebbles and cobbles, and an occasional bowlder. It is traced in sandy humus and is corelated with the sands which near the Iowan frontier underlie the loess.

It is in the prevailingly arenaceous nature of its deposits that the Iowan stands in conspicuous contrast with the Kansan. Sand is rarely seen on Kansan areas, except near the frontier of the younger drift. Even along water ways the loess usually graduates downward into a reddish clay which rests upon the ferretto of the till. But near the border of the Iowan the loess passes downward by interbedding into heavy, yellow, stratified sands. This peripheric sub-loessial sand is one of the most valuable means of tracing the border of the Iowan ice from which the streams bearing these sands were discharged.

With the exception of this superficial arenaceous layer the till exposed on Iowan areas has not been discriminated from the Kansan by the writer. It is not to be expected that tills of different ice invasions will be so markedly unlike that their age can be told by their structure and composition. And it may be assumed that an overlying drift sheet will contain much material reworked from the older one subjacent. It is not proven therefore that the clayey till resembling Kansan on those areas referred to the Iowan does not belong to the Iowan stage. A few typical sections of the drift of these areas are now given.

FREMONT TOWNSHIP, SEC. 4, Se. ¼ OF Ne. ¼. EXCAVATION FOR CELLAR.

		FEET.
4.	Humus	1
3.	Humus colored sandy clay	¾
2.	Clay, sandy, stiff, hard	1¼
1.	Till, non-calcareous, reddish yellow, predominantly clayey, pebbles small	2

At a well a few feet distant, blue, hard, stony clay was struck at a depth of twenty-four feet, sand fourteen feet thick at eighty-eight, and rock at 120, overlain with blue clay.

LINN TOWNSHIP, SEC. 15, Nw. ¼. AT BRIDGE OVER WET WEATHER STREAM.

		FEET.
2.	Humus and humus colored sand	$2\frac{1}{2}$
1.	Till, yellow, predominantly clayey, non-calcareous, pebbles small and comparatively few, forming a vertical wall of stiff clay	2

In the bed of the gully lay four bowlders, three of them granite, from one to two feet in diameter. As bowlders lie on the surface in an adjacent field, it may be taken that these belong on top of No. 1.

DAYTON TOWNSHIP, SEC. 14, Ne. ¼ OF Ne. ¼.

At the quarry at this locality on Mill creek a pit five feet in diameter contains tills of distinctly different appearance, as shown in figure 27.

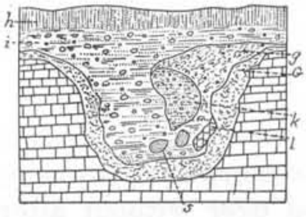


FIG. 27. Cavity formed by weathering and filled with drift.

G Lining the cavity formed by weathering is an unctuous clay of finest grain, formed by decomposition of the adjoining rock and is preglacial.

g Less dark in color, and containing rare pebbles of the drift, is also a residual clay, somewhat kneaded by glacial action.

i A yellowish brown, sandy till, and from its composition and place in the pit may be regarded as Iowan.

k A rounded mass of till, reddish brown, clayey, containing rotten pebbles, evidently a bowlder of Kansan till thrust by the Iowan glacier into the pit.

s Rounded masses, ten inches in diameter, of yellow-brown sand handled when in a frozen condition by the Iowan glacier.

l Fragment of adjoining limestone.

h Humus.

The Tipton Lobe.—The rock surface beneath this area is much more uniform than that beneath the Clinton lobe, and is everywhere found at no great depth. All the shallow creeks which cross the plain have chiseled their channels in the rock, and wells reach it from ten to fifty feet from the surface.

On the Tipton lobe the evidence of the action of glacier water is specially conspicuous, and here the influence may be traced of the nearness of the great drainage channel of the Cedar. Sand is a common constituent of the soil. It is found in hummocky ridges and low swells, often of pahoid trend, and occasionally occurs, as north of Cedar Bluff, in small tracts of little dunes.

This lobe presents an exception to the usual undissected character of the Iowan surface, where northwest of Cedar Bluff two creeks and their branches which head in the Kansan, cross it on their way to the Cedar. In this limited area the aspect of the topography is abnormal in the depth of the rock-cut valleys, the width of flood plains, and the amount of dissection. The bowlders scattered over the surface and the fact that it lies in the direct and only path to the typical Iowan area west of Tipton, are, perhaps, sufficient reasons for mapping this region of western Linn township as Iowan, although the ice here passed over without altering to any marked degree the lie of the land. Here no clear marginal ridge marks the separation from the Kansan to the north and it is hard to draw the line of demarkation except by the border line of the loess and the height of adjoining Iowan areas.

East of Cedar Bluff the Tipton lobe conforms with sufficient closeness to the normal Iowan drift plain. To the north the line of juncture with the loess-covered Kansan is so marked that it has been followed by a diagonal road in Red Oak township, the main thoroughfare from Tipton to Mechanicsville. The Kansan border here rises from twenty to forty feet above the Iowan, perhaps a little more than the thickness of the loess, although this is here comparatively thin. To the south the sinuous line of forest covered Kansan hills forms an impressive frame to the broad Iowan prairie. This appearance is in part due to the fact that near the margin the Iowan slopes somewhat rapidly southward to the valleys of Rock creek and Rocky run. For in its central portions the prairie is as high as the hilltops of the Kansas upland which lies to the south and east. If the heavy loess were removed from the latter, it would stand at a lower level than the Iowan to a degree probably corresponding to the general southward and eastward descent of the surface in the county. Thus here at least it is unnecessary to suppose that the Iowan ice sought out areas of lower ground in the preexisting land surface, or that it excavated that surface to any extent by its advance. The difference in height between Kansan upland and Iowan plain is due to the presence of loess upon the former.

The Clinton Lobe—to now take up some of its characteristic features in detail—stretches across the northern portion of the county, the line of the Chicago & Northwestern railroad marking approximately its southern limit. From the Linn county line to Stanwood the railway runs close under the front of the Kansan upland. From Stanwood to Lowden the lobate outline of the Iowan carries at one place nearly two miles south of the line of the railway. Geologic and glaciologic control is seldom more strikingly illustrated than here where the front of an ancient glacier determines the line of a transcontinental highway of commerce. Along the Iowan plain the line is run in tangents at the minimum of expense for cuts and fills. A mile or so to the south, across the comparatively hilly country of the Kansan, the expense of construction and of operation would have been much greater.

Several possible causes suggest themselves of the origin of this plain as a topographic feature. The initial preglacial rock surface may have been left so slightly eroded that it has controlled the later deposit of drift upon it. Or, although deeply chiseled by erosion, it may have been leveled by the earlier drift by filling its depressions. And the Kansan drift plain formed in either way, by the smooth veneering of a preglacial rock surface, or by plastering full its depressions, may either have remained unscored by erosion until overrun by the Iowan, or it may have been closely gashed by long erosion, as is seen today in the deep valleyed Kansan about Plato, and then have been leveled by the invasion of the Iowan ice, its valleys filled with Iowan drift, and its hills perhaps cut down.

Of these different possible explanations, the one which seems to meet the case is that which places the present plain under the control of a previous drift plain of the Kansan. That it is not under the control of the rock surface is clear, since this varies widely in its relief. From Mechanicsville west, the Niagara lies everywhere near the surface at an elevation of about 890 A. T., and is disclosed by all the shallow creeks which cross the plain. From Clarence east rock is reached at a depth of a few feet. But this subsurface of rock is crossed in Fremont township by a deep preglacial valley whose rock floor lies nearly 300 feet below the surface of the Iowan plain.

Nor can we attribute the plane surface of the Iowan to any considerable extent to either erosion or aggradation by the Iowan ice. The Iowan drift is typically scanty and thin. No proof is found that the ice planed away preexisting hills of the Kansan. If such planation is assumed it cannot be granted that it passed below the weathered superficial surface, for many facts go to prove that the present weathered zone of the Kansan is pre-Iowan, and the Kansan drift or drift indistinguishable from it, is often found deeply weathered on Iowan areas. Nor is any proof at hand that the Iowan filled preexisting depressions to any considerable extent in the county. In the few cases in the county where excavations have been seen in present depressions, the aspect of the drift has been Kansan with the possible exception of a thin veneer of Iowan.

We are then left to the assumption that the region was originally a Kansan drift plain, left little scored by erosion on account of distance from local base levels of erosion, a drift plain diversified perhaps by drumlins, but otherwise resembling the level Kansan tracts about Bennett and Sunbury.

The question remains as to the relative elevation of the Iowan and Kansan. To the traveler on the great railway which passes along the southern margin of the plain, the line of hills with their pahoid summits which marks the Kansan frontier at once give the impression that the Iowan occupies a region of lower altitude. But if the loess were removed the difference in height of the two drift sheets would be inconsiderable. At Lisbon where the Iowan is highest the crests of the hills to the southeast overlook the plain from a height of only 40 feet. At Mechanicsville the difference is 60 feet. From Stanwood to Clarence, where the altitude of the Kansan decreases, the difference is from 20 to 40 feet. About Lowden, where the Iowan follows down the broad descent to the Wapsipinicon now occupied by Yankee run, the hills of the Kansan rise over 100 feet above the plain. Therefore with the exception of the eastern end of the plain in Cedar county, it stands little, if any, lower than the Kansan drift would appear if the loess, whose thickness here may be taken to be about 40 feet, were removed.

The Loess. The distribution of this yellow siliceous silt is presented in the map of Pleistocene deposits. Its greatest thickness is adjacent to the Iowan margin, where it is at least 40 feet deep. In the interior of the Kansan area drift appearing on the hillsides often shows that it cannot exceed a thickness of ten or fifteen feet.

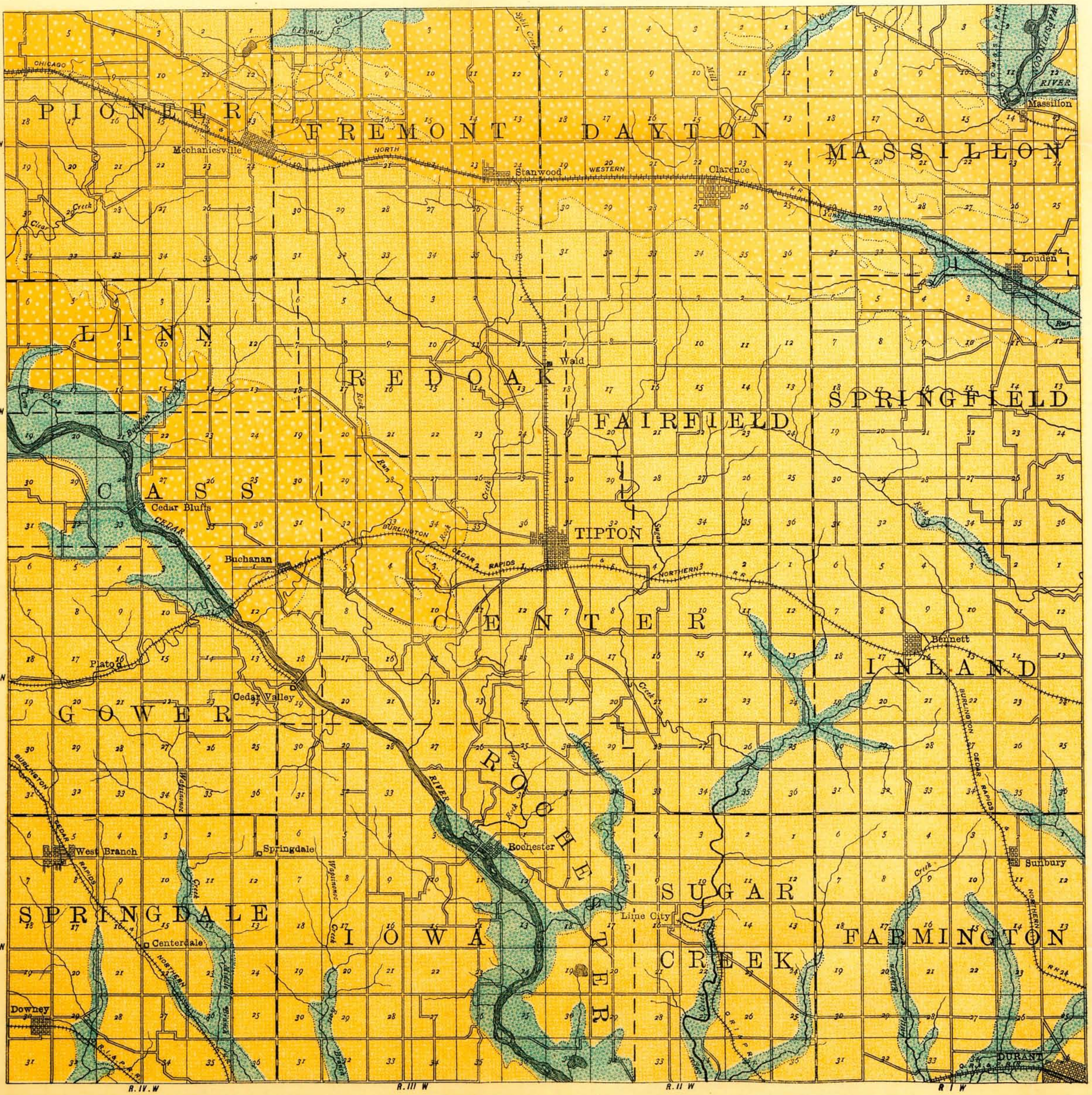
The different aspects of the loess, its graduation beneath into a bluish gray, more pervious, calcareous and fossiliferous silt, often laminated, and its weathering superficially into a finer and darker clay, have been fully described in the reports of the Survey, and no detailed account is thought necessary.

As in Scott county it graduates near the Iowan margin downward, and sometimes laterally, into stratified sand, and on the Kansan passes often into a basal layer more clayey and redder owing to wash from the till beneath. A few sections are appended.

BEALER'S QUARRY.

		FEET.
6	Weathered loess, brown, fine of grain and in part finely jointed, traversed with narrow parallel sinuous bands which when wet show darker than the remainder, conforming in general direction with slope of hill.......	5
5	Loess, typical light buff, pulverulent, breaking down in great blocks along vertical cleavages; towards base interstratified with thin, tortuous, discontinuous veins of fine white, orange and red sand, dipping with the hill	14
4	Loess, fine, pulverulent, with brownish spots and lines..	4
3	Loess, finely laminated, laminæ of thickness of fine cardboard, slightly undulating, picked out by weathering and readily detaching in hand specimen, darker in color and more clayey than the loess above into which it graduates by imperceptible gradations............	7
2	Red geest, and red till, either composed in part of geest, or weathered to same color, with pebbles of northern rocks	1½
1	Rock, rotten.	

In other parts of the quarry the rock is overlain by eight feet of till, the upper five feet of which is highly oxidized, the surfaces of joint blocks an inch and less thick being deeply stained red, the lower three feet being yellow and yellowish gray. Although but few cobbles and bowlders appear in situ, a number are left on the rock surface after hydraulic stripping, the largest observed being two feet in diameter. The till is here leached to within one foot of the underlying rock. Upon the till rests a distinct pebble layer one half to one foot thick, the maximum diameter being five inches; and upon this a zone of reddish clay stiffer than loess and sandy beneath, on which true loess rests, with distinct change of color at line of parting.



IOWA GEOLOGICAL SURVEY

MAP OF THE SUPERFICIAL DEPOSITS OF CEDAR COUNTY, IOWA.

BY

WILLIAM HARMON NORTON

1900.

Scale $\frac{1}{125000}$

Miles: 1 ½ 0 1 2 3 4 5

Kilometers: 1 ½ 0 1 2 3 4 5

LEGEND

GEOLOGICAL FORMATIONS

ALLUVIUM

IOWAN DRIFT

KANSAN DRIFT
OVERLAIN BY IOWAN LOESS

DRAWN BY F.C. TATE

IOWA LITHO. CO.

Remains of the Mammoth. Several finely preserved teeth of *Elephas primigenius*, the Mammoth, were found on the farm of A. T. Whitnell, Sec. 6, Springfield Tp. Se. ¼ of Se. ¼. These were found in a "washout" in a small creek. Above the washout a bed of white alluvial clay is overlain by gravels. In which of these the teeth occurred is impossible to say. Two of them were kindly donated to the museum of Cornell college.

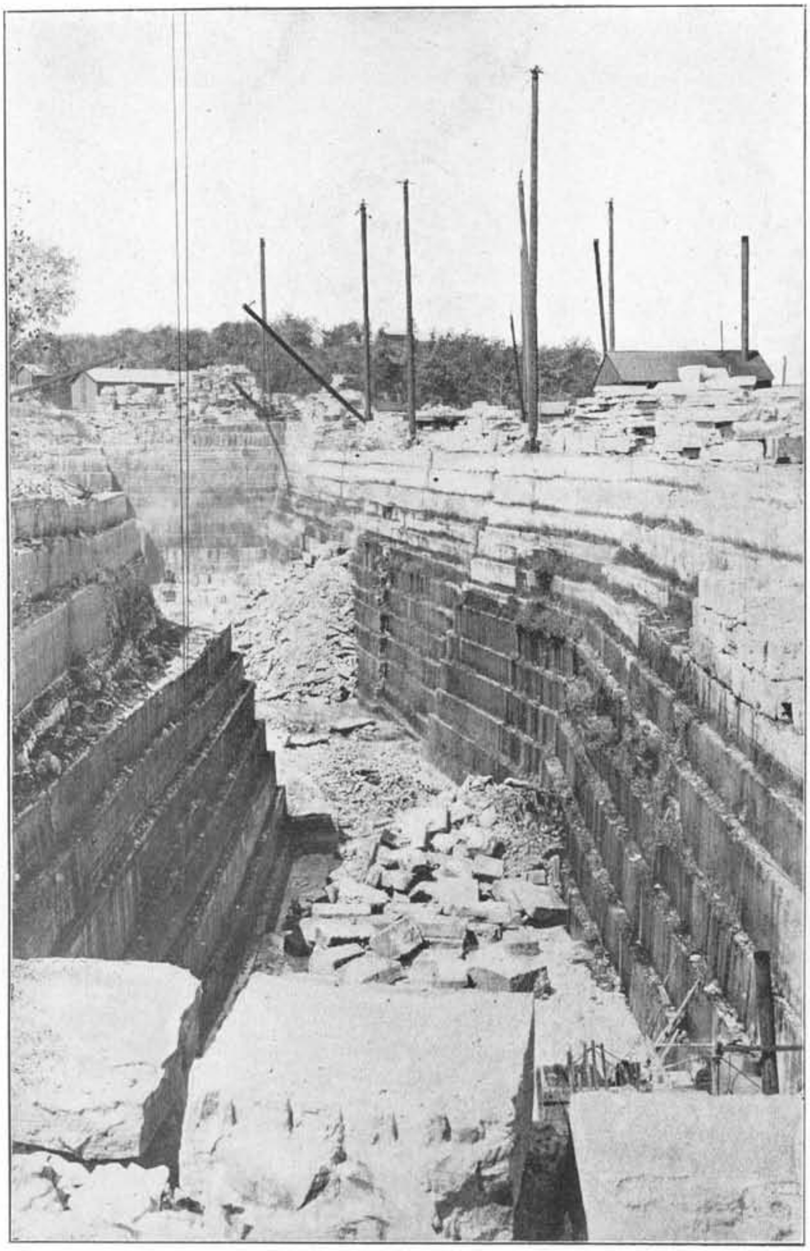
ECONOMIC GEOLOGY.

Building Stone.

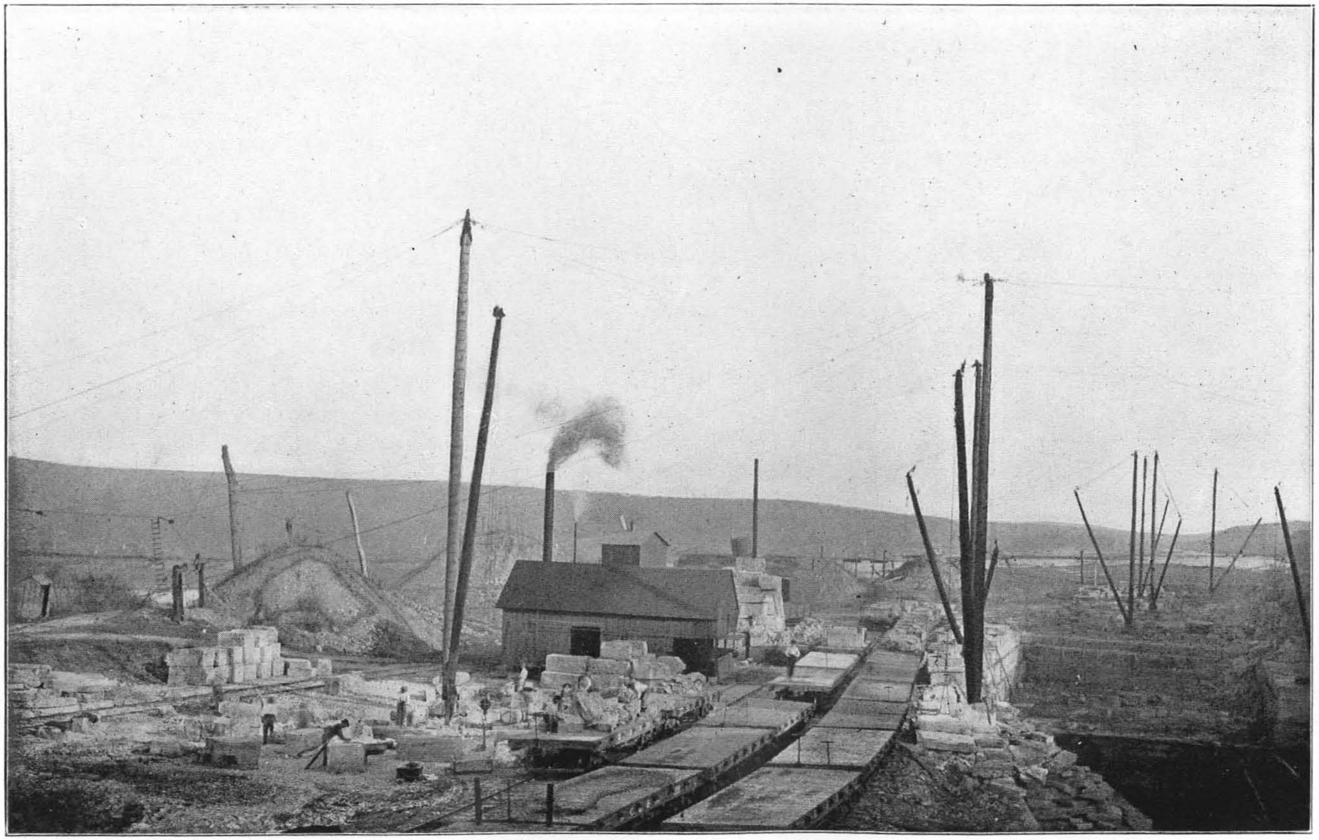
Cedar ranks easily first among the counties of the state in the value of the yearly output of building stone, a preeminence due chiefly to the quarries at Cedar Valley and Lime City. Building stone of excellent quality is found widely distributed over the county and while the small quarries which have been opened in almost every township do not greatly add to the large amounts contributed by the two quarries mentioned, yet their value and convenience to the rural districts and neighboring towns is greater than mere statistics could show. There is hardly a section in the county where a farmer or townsman can not get a load of cheap good stone within easy hauling distance. Thus in Pioneer township there are quarries at Peet's Mill and elsewhere on Clear creek; in Cedar township at Cedar Bluff and two and one-half miles north of that village; in Gower township at Cedar valley and Plato; in Center at several quarries south of Tipton; in Rochester along Rock creek; in Iowa near Atalissa; in Sugar creek at Lime City and a number of quarries north of that village; in Springfield southwest of Lowden; in Massilon along the Wapsipinicon, and in Dayton township near Clarence. Nearly all of the building stone quarried in the county is furnished by the Gower stage of the Silurian, the only exception being that of the Devonian quarries in Iowa township near the Muscatine county line. The good qualities of the Anamosa phase of the Gower limestone have long been recognized and have frequently been set forth in the countv reports on the counties of eastern Iowa. Its even and smooth bedding, its uniform grain, its comparative softness in working with saw and chisel when fresh from the quarry, and its hardness when recementation has taken place on drying, its obduracy to all chemical agencies of rock decay, and its resistance to frost, its pleasing color and the absence of any injurious minerals which might weaken, strain or impair its ease of working, all these characteristics contribute to make the Anamosa one of the best building stones of the West.

Bealer Quarries.—In value of output, and perfection and cost of machinery, these quarries are the most noteworthy in Iowa and are among the largest of the Mississippi valley. They are located some six miles southwest of Tipton on the right bank of the Cedar. The village which has sprung up about them is called Cedar Valley, and a spur connects with the Cedar Rapids-Clinton line of the Burlington, Cedar Rapids & Northern Railroad near Plato, about two miles northwest.

The quarries were opened seventeen years since by Mr. E. J. C. Bealer, who, as a practical bridge architect, saw the great value of the stone at this point for bridge piers and all heavy masonry. The chief quarry now in operation was opened in November, 1894, and no expense has been spared to equip it with modern and effective machinery. A levee costing $20,000 has been built along the river front for protection against floods. Railway tracks in the quarries are so built that the force of gravitation is utilized to the utmost and no locomotive engines are required to make up the train of loaded cars which in busy seasons is sent out daily. The stripping of the quarry, consisting of twenty-five feet of soft silt known as loess, and less than ten feet of pebbly glacial clay, is cheaply and expeditiously handled hydraulically by means of a high duty steam pump, capacity three quarter million gallons per day, and suitable pipes and hose. In quarrying the stone there are employed one single and three double steam channellers and four steam drills. One of the



Bealer's Quarry, Cedar Valley. Main pit.



Bealer's Quarries, Cedar Valley. General view.

channellers used in the quarry holds, it is claimed, the championship record in its line of work. "It has been made to cut 400 feet in five hours, and for ten hours its record is 750 feet." The plant includes also four eighty horse-power engines, two forty horse-power, and five engines of fifteen horse-power, one steam pump, low duty, capacity three quarter million gallons daily, and three pumps each of one quarter million gallons capacity, one pumping to reservoir and the others for general purposes. There are fourteen derricks in operation, ten of which are supplied with steam hoists lifting from four to twenty tons each. A large machine shop is well equipped for repairing and rebuilding the tools and machinery of the plant.

The usual force at work aggregates 100 men, constituting with their families an industrial colony of more than usual prosperity, if one may judge by appearances. They occupy neat cottages of good size and kept in repair, situated on both sides of the river and commonly with a small allotment of land. Most of these properties belong to the owner of the quarries, and a just pride is evidently taken in the sociologic as well as the economic success of the enterprise.

With the present force and equipment forty-five cars per day can be loaded and shipped without difficulty and the full capacity of the plant is often taxed to the utmost.

The output consists chiefly of bridge stone of three grades. The proprietor contracts for completed bridge piers and has a large force employed in their construction. Dressed dimension stone are cut in the yards and crush stone, rip-rap, rubble and curb stone are included in the products of the quarry.

The quarries were opened in natural ledges fronting the river in the face of bluffs rising about 120 feet above the stream. These ledges have been quarried away over an area of several acres, and on the platform thus formed a pit 300 by 125 feet has been sunk to a depth of sixty feet below the level of water in the river, and another of like dimensions has recently been opened. The lower ninety-four feet is used for bridge and dimension stone, the stone becoming of finer grain and better quality, it is said, with increasing depth to the present quarry floor. Above this lies a ledge twenty-two feet thick used only for rip-rap, rubble, railway ballast, and macadam, for which it is admirably adapted. It includes hard, fine grained spalls, a four foot layer of hard, highly vesicular, crystalline limestone, and four feet of laminated limestone in layers from two to eight inches thick. On this ledge rests a bed of about twelve feet of soft earthy limestone, called the Coggan, wholly worthless for any industrial purpose, and constituting a part of the stripping.

The quarry stone belongs to the Silurian system, Niagara series, and to a stage which the writer has called the Gower, from the township in which Bealer's quarries are situated. Other things being equal, a geological formation is best named from the locality where its industrial uses are most fully developed, and the coincidence of scientific with commercial names is desirable whenever it can be obtained. Unfortunately in the present case the stage could not be termed the Cedar Valley after the village, since that name has already been applied to a stage of the Devonian. No locality in Iowa, whose name is at all available, so fully represents the different phases of this important formation as does Gower township in Cedar county.

Of the Gower limestone there are several phases, representing different modes and circumstances of deposition. Most important of these is the phase quarried at Bealer's, a laminated, light buff, granular, even bedded building stone. Nowhere in the state is it found of greater thickness or better suited to the purpcses to which it is put. As a dolomite, it withstands chemical decay indefinitely, while its texture makes it resistant to frost to a high degree. So few are open bedding planes that in the deep pit mentioned there were found but two or three pervious to water. When this excavation was made, it was put down in two pits separated by a wall of stone left for the time unquarried. One of these pits being left for a while unpumped, water stood in it twenty-five feet above the floor of the adjoining pit, and even under this head there was no seepage.

In the distance between the bedding planes this stone differs from many outcrops of the same formation. The rock, however, is laminated throughout and may be split along these planes to layers one foot in thickness without difficulty, and in places to eight and nine inches. On natural outcrops adjacent long weathered outcrops often show close lines of lamination, but these are strongly coherent, beyond the usual in this formation, and permit the quarrying of permanently solid blocks of as great thickness as called for. The common size of the blocks raised from the lower part of the quarry is six and one half feet long and three and one quarter feet wide and thick, weighing each something more than four tons.

In some of the outcrops of the Anamosa phase of the Gower stage there are found, especially toward the summit, thin layers or laminæ of a compact, drab, fine grained limestone, called by workmen "flint" on account of its hardness, brittleness, and fracture. Such seams are a direct injury; under the weather they break into small rhombic chip stone. Since their coefficient of expansion is different from that of the adjoining layers, they tend to form in time a horizontal cleavage of the block of which they form a part. At Bealer's quarry these seems are practically absent, and the stone free from this element of weakness as well as of all deleterious accessories, can be strongly recommended as of the highest durability.

Cedar Bluff.—Immediately above the bridge at this village, a ledge of Anamosa stone has been quarried to some extent for local supply. The face of the ledge is here some thirty-five feet. The upper seven or eight feet are weathered to thin spalls. In the middle lies a stratum of seven feet of fine grained, light yellow limestone of pure Anamosa type. Below this the stone shows an alternation of harder and softer laminæ, the harder being of finer grain and more brittle. The best building stones are said to be taken from the bed of the river at the base of the ledge.

Below the village the same formation outcrops on both sides of the river in ledges up to fifty feet in height, showing the same granular laminated limestone, horizontally bedded in even courses, weathering in places to thin calcareous plates, but for the most part standing in undivided layers up to two feet in thickness.

McLeod's Quarry, Tp. 82 N., R. I W., Sec. 12, Sw. ¼.—On the left bank of the Wapsipinicon, less than one half mile below Massilon, this quarry shows a face of twenty-five feet of vesicular, semicrystalline limestone, the upper fifteen feet massive or obscurely bedded, the lower ten feet in rough layers from eighteen to thirty inches thick, all buff in color and sparingly fossiliferous. Just below the village on the right bank of the stream, the same layers form a picturesque ledge about thirty feet high.

Frink's Quarry, Tp. 82 N., R. II W., Sec. 14, Nw. ¼ of Se. ¼. The following section is here shown

		FEET.
4.	Limestone, rough, in layers from one half to one foot thick, weathered	4
3.	Limestone, in eight inch layers	2
2.	Limestone, exceedingly rough, crystalline, deeply pitted with rounded cavities up to five inches in diameter	2
1.	To creek level, not exposed	13

The layers here form a gentle syncline dipping 2° north at south end and 6° south at the north end.

Burrough's Quarry, Tp. 80 N., R. III W., Sec. 22, Sw. ¼.—The Gower is here quarried on a small scale on the left bank of Rocky run. For 8 feet above the creek, a very fair granular building stone lies in layers from 7 to 18 inches thick, weathering superficially to spalls 2 to 4 inches thick. The dip to the southeast is perceptible. An adjacent ledge reaching a height of 20 feet above water level is composed of laminated limestone, hard, gray and crystalline. A few rods away an old pot kiln attests the possibilities of the stone as a lime maker. Here a layer identical with No. 4 of Whann's quarry is found above the limerock. Across the creek and down the stream on the same farm, about 50 feet of this hard, crystalline, laminated limestone is displayed in overhanging ledges and hillside outcrops. Toward the base the rock weathers to thin spalls, but above the laminæ are coherent, and the cliff breaks down in immense blocks. About 15 feet above the limestone a few fragments of yellow sandstone were seen in a shallow ravine, but no distinct outcrop was found. All the limestone in this section resembles the Anamosa stone in its lamination and in its horizontal or nearly horizontal bedding. Nowhere is it disturbed, tilted, or conglomeratic, as is so commonly the case with the LeClaire. And yet in their hardness, color, and crystalline texture, these beds on Rocky run are distinctly of the LeClaire type.

Wallick's Quarry, Tp. 81 N., R. IV W., Sec. 16, Ne. ¼ and Se. ¼.—Two and one half miles north of Cedar Bluff the Anamosa phase is here quarried for local uses. The rock rises to the surface in the low hills, so that no stripping, except of weathered spalls, is necessary. The rock is of the ordinary phase of the finely laminated, fine grained, light buff building stone of the Gower. It is in thin layers, dipping 11° SE., and shows a face of twenty feet.

Hecht's Quarry, Tp. 82 N., R. II W., Sec. 14, Ne. ¼ of Ne. ¼.—The following section is seen at Hecht's quarry:

	FEET.
3. Limestone, spalls, irregularly shaped chipstone, buff, resembling conglomerate of harder centres with matrix of limestone meal	4
2. Limestone, rough, semicrystalline, cores gray, weathering to buff	1
1. Limestone, for the most part evenly bedded, buff or gray, thickness of layers from above downward in inches: 8, 18, 10, 15, 19, 24, 12, 18, 18. At west end a dip of 3° W., in centre slightly S.; at east end a perceptible dip SW	$11\frac{5}{6}$

Cary's Quarry, Tp. 80 N., R. III W., Sec. 13, Sw. ¼.—About two and three-fourths miles southwest of Tipton two quarries have been opened on Rock creek. Mr. M. C. Cary here quarries a face of 15 feet in layers mostly of the thickness of flagging, but some reaching 9 inches. At the west end of the quarry the stone is hard and crystalline, of the LeClaire phase, in layers 6 inch thick and upward and dipping 12° S SE. Two rods east this has passed into the Anamosa phase, but slightly harder and more crystalline than typical, dipping 3° E., the juncture being now concealed.

Twenty-five rods southwest of this section a small quarry has been opened showing a mound of hard limerock at the north end, and, the juncture again being obscured, at the south Anamosa stone, some layers being soft and granular, and others harder and more compact. The layers here run from 1 and 2 inches to 9 and 12, and dip from 30° W NW. to 38° N NW.

Whann's Quarry, Tp. 80 N., R. III W., Sec. 14, NE. ¼ of NW. ¼.

		FEET.
5.	Limestone, light buff, hard, fine grained, luster earthy, resembles Bertram beds of Linn county	2
4.	Limestone, buff, softer, with numerous branching vertical tubes one to two mm. in diameter	1
3.	Limestone, hard, gray, crystalline	1½
2.	Limestone, buff, more or less vesicular, in layers from 8 to 30 inches thick, with bands of harder crystalline gray rock	5
1.	Limestone in layers as above, buff, granular, laminated	6½

The dip here is a gentle one to the southwest. A few rods up stream the ledge is seen to form a low syncline.

Lime.

Rock of the highest excellence for the manufacture of lime is as broadly distributed over the county as is good building stone. This is due to the many areas where the Gower limestone is exposed by erosion, and to its rapid alternation at the same horizon between its two lithological phases. At no great distance from the quarries of the granular, evenly bedded Anamosa stone, there will be found outcrops of the crystalline, massive or obliquely bedded dolomite, which takes its name from LeClaire, the town in Scott county where its typical features were seen and described by Hall nearly fifty years ago. Thus, at Lime City and at Cedar Valley, lime and building stone quarries are in close proximity. It is to these two places that the manufacture of lime is at present restricted. This is not due to any special advantage in the quality of their limerock over that of other localities in the county too numerous for mention, but to the facilities with which the rock can be handled and the product placed on the market. In almost all portions of the county the explorer of outcrops of the country rock finds the white heaps of half burned lime and the ruined walls left to show the place of pot kilns. During recent years of business depression all of these have been abandoned. With the increasing prosperity of the building interests we may expect that the pot kiln will again become a local rival of the large plants equipped with patent draw kilns, as has already taken place in adjoining counties.

The upper beds of the Silurian furnish a limerock of the highest degree of excellence. It is from them that some of the largest kilns in Ohio, Wisconsin, and Illinois, as well as Iowa, draw their supply. The lime burned in Cedar county is identical with that of the well know kilns at Racine and Port Byron. Its preeminence depends upon its chemical and physical qualities. It is notably free from silica in all its forms, and from argillaceous or ferruginous impurities. The large per cent of carbonate of magnesia present makes it a cool lime, slow to set, slow to slack, and it is to such limes that architects, masons, and plasterers now invariably give preference over the so-called hot limes burned from non-magnesian limestone. The hardness and durability of mortars made from this lime approaches that of cement. Buildings are seen in which it was employed, where, after thirty-five years of weathering, the joints seem as fresh as when struck. Wholly minor advantages are the brittleness of the rock, which aids in its breaking to suitable dimensions for the kiln, and its vesicularity, which gives more ready access to heat in burning and to water in slacking.

The purity of the Gower dolomite is demonstrated in the following analysis made in the chemical laboratory of Cornell college under the supervision of Dr. Nicholas Knight:

LEDGE ON ROCK CREEK, TP. 80 N., R. 3 W., SEC. 23, SE. ¼ OF SW. ¼.

Calcium carbonate, $Ca\,Co_3$	55.76
Magnesium carbonate, $Mg\,CO_3$	43.85
Ferric oxide and aluminum oxide, $Fe_2\,O_3$ and $Al_2\,O_3$	0.26
Silica, $Si\,O_2$	0.12
	99.99

The total impurities of this specimen of the dolomite used in lime making throughout the county are but little more than one-third of one per cent.

Lime City.—The quarries of this plant are situated on the right bank of Sugar creek, five miles northwest of Wilton, a spur of the Chicago, Rock Island & Pacific connecting them with the main line at that junction. The rock is of the usual LeClaire facies. Dynamite is used in blasting, and the stone is sent to the kilns by a tram running on a trestle. Four patent draw kilns are in operation, and the lime can be loaded from the sheds directly on the cars. Some years since petroleum was used as fuel in one of the kilns, but only wood is now employed for calcination. The region about Sugar creek is forested, and wood is obtained at moderate expense. The output finds ready market along the lines of the Chicago, Rock Island & Pacific railway in Iowa and the states west. The amount of stripping is very slight. The beds of the Coggan, which overlie the limerock, are shipped for riprap and ballast, being wholly unavailable for lime or building stone.

Cedar Valley.—The lime plant at Cedar Valley consists of three patent draw-kilns, each with a capacity of 120 barrels, and the usual storage and cooper sheds. Of the quarry face of sixty feet scarcely any is unavailable for lime, and the expense of stripping is inconsiderable. The rock is economically handled, and the lime is loaded on the cars of the Burlington, Cedar Rapids & Northern railway. It has found a wide market over Iowa and the states adjacent to the west. Wood is employed as fuel, and is brought in from the heavily wooded hills of the Kansan upland on both sides of the river.

Clay.

Brick and Tile.—No shale of economic importance is found in Cedar county. The only clay utilized in manufacture is the loess, and this extends so widely over the county that material for brick and tile exists in close proximity to every town. It is utilized at present only at the county seat, whose central position gives it an advantage as a distributing point. The brick and tile factory at Stanwoad was burned recently and has not yet been rebuilt.

Brick and Tile Factory, G. H. Kettell, Tipton.—This plant is situated in the south portion of the town, and comprises three kilns, two of them down draft, with a capacity of 95,000 brick; two Bennett clay machines, with a capacity of 14,000 brick and 10,000 three-inch tile per day, operated by a twenty horse-power engine, and drying sheds holding 125,000 brick.

The brick turned out are the common machine pressed brick, and are of excellent quality, of even texture, dense and ringing, and of good color. The tile are made of the same material and are equally good.

The clay pit shows from six to twelve feet of stiff, yellow loess loam, not readily friable when dry, and destitute of clay dogs and fossils. Where thinnest it is underlain by non-calcareous, yellow till, and where deepest by sandy layers and the bluish loess silt. Besides supplying the local demands of the largest town in the county, the factory ships over the Burlington, Cedar Rapids & Northern and the Chicago & Northwestern railways. The station of the latter is only a few blocks distant, and a switch of this railway enters the yards.

Road Materials.

The clays of the county offer an inexhaustible supply for burning for ballast. It hardly seems probable, however, that their use for this purpose will ever be necessary, considering the fact that the county abounds in a stone unexcelled among limestone in hardness and durability as road metal. Crushed stone of the Gower limestone is used in large quantities as ballast on the lines of the B., C. R. & N., and the C., R. I. & P. railways, the former taking it from the Bealer quarries at Cedar Valley, and the latter from the quarries at Lime City. It can be obtained at reasonable expense from either of these places for county roads and town streets, and in the majority of the towns of the county a crusher could be set at work on rocks of the same formation and of equal value exposed in the vicinity.

The movement for good roads in the county has hardly more than begun. Scarcely a city or village street has been redeemed from the primitive dirt road of the early settlers. But the near future will no doubt witness rapid progress in municipal paving and road making in the area, and the facility with which good road metal can be obtained will greatly hasten this movement. It is of prime importance to remember that no stone, however valuable, will make a good road unless some intelligence is used in its construction. The traditional method of dumping rock of any and all sizes on an ungraded and undrained roadway, has long been proven the shortest way to its permanent ruin. From the beginning such a dump makes an execrable road, rough with loose stones, and it fast goes from bad to worse. In towns it is often impracticable to use it as foundation for any superstructure and its removal is too expensive to be considered. It thus postpones indefinitely the laying of a good street, either of brick paving, asphalt, or macadam.

Sand.

This valuable material for building is obtained along the rivers of the county at little if any more than the cost of hauling. A somewhat inferior grade is found in the sands beneath the loess near the Iowan margin. Occasionally sand is taken from dunes and pahoid ridges on the Iowan area.

Water Power.

The larger creeks of the county are perennial streams affording considerable water power, which has in the past aided largely in the development of the region. Commonly they traverse rock-cut reaches giving excellent sites for dams. Of these there were utilized early in the history of the county three on Rock creek, one on Pioneer, one on Sugar, and three on Clear creek. Several of these mills were large structures and well fitted for the part that they had to play, using power equivalent in some instances to twenty horse-power. With the rapidly changing conditions of the milling industry, and the shrinking and less constant volume of water at disposal, these water powers which so long and faithfully served the needs of the pioneers fell into disuse. The last dam was washed out in 1899 and the last mill using water power abandoned. It is quite impossible to say how distant is the day when in an age of electricity these creeks will again be harnessed to serve the needs of the people.

No dams have ever been built across the Cedar or Wapsipinicon within the county limits. On the former power could be obtained economically and in large quantity in the narrow reaches from Cedar Bluff to Rochester, but the distance to any town of size makes its utilization indefinitely remote.

Soils.

The fertility of the soils in Cedar county is well known far beyond its limits. In the average assessed valuation per acre of its farm lands it is surpassed in Iowa only by Scott and Polk counties, in each of which these values are enhanced by large urban populations. This high value is due in part to a number of causes other than geologic, such as the length of time that has elapsed since the settlement of the county and the character and skill of its citizens. But a leading factor in the agricultural prosperity of the area is the abounding fertility of its soils.

None of the soils in the county is the result, at least directly, of that commonest of soil making processes, the secular decay of underlying rocks. Here and there, however, may be seen remnants of the ancient soil which covered the county before the episode of the great Ice Invasion, a soil formed by the decay in place of the limestones of the region. This is a stiff, unctuous, reddish clay, often seen directly overlying the rock. Compared with the glacial tills which now cover it, this residual clay, or geest, must be considered a very poor soil or subsoil indeed, and a large measure of the prosperity and wealth of the region must be referred to the successive invasions of vast sheets of ice in the yesterday of geologic history, which buried the geest beneath richer deposits or removed it entirely. In pre-Pleistocene times the agricultural advantages of the region were distinctly inferior to those of the present, and it is perhaps fortunate that the agriculturist had not then made his appearance upon the scene. It was the slow but resistless movement of immense bodies of glacial ice which ground to powder the rocks in their path from the region of the far north, and commingled the component minerals of limestones, shales, sandstones, granites and other igneous rocks into one heterogeneous ground moraine, which embraces every valuable constituent which rocks can supply to soils and growing crops. And because this drift is for the most part finely comminuted—a commixture of rock flour and rock meal, with sand, gravel, and an occasional bowlder—it breaks down rapidly into a most fertile soil. Water penetrates it, oxygen, carbon dioxide and the humic acids permeate it, the roots of trees and plants push their way down through it, earthworms and other animals burrow in it. So soon as it was laid down Nature with her multifarious agencies began to develop upon the bare, gray surface of the ground moraine the deep rich soils which to-day are the delight of the farmer.

Furthermore, by wash of water and perhaps also aided in part by the wind, particles intermediate in size were selected from the drift and laid down in a silt too fine to be called sand and too coarse for clay—the loess. This yellow loam spread widely over the area contains all the mineralogic richness of the glacial tills, and is, moreover, far more porous and accessible to soil making agencies. Brief, then, as has been the time since these deposits of till and loess were laid, it has sufficed for the production upon them of soils of a depth and richness unsurpassed in all the Mississippi valley.

Ever since glacial times there has also been in progress a redistribution of soils. The season of 1899 supplied a striking illustration of the movement of soils ever to lower levels, and at last by way of the creek and the river to the sea. The heavy rains of the spring of this year washed the plowed land on the hillsides to an extent seldom seen. At the lower end of each little gully was outspread thin alluvial fans of the blackest and richest soils, in places covering several acres. All the creek bottoms received an accretion of soil mingled in places with corn stalks and various debris washed by the floods from higher up the stream.

Thus the soils developed on glacial till and loess have been washed down to lower levels for thousands of years to form the deep alluvial soils of the creek and river flood plains, but never, at least before the settlement of the country, at a rate sufficient to remove the soils of the uplands faster than they were formed.

Thus the soils of the county may be divided into two classes, those of primary derivation developed directly by the decay of subsoils and subjacent rock, and those of secondary derivation, produced from the primary soils by wash of water.

Primary soils may be further classified according to the geological nature of the underlying formation from which they have been developed. Thus we have in Cedar county the soils of the Iowan areas developed on the Iowan drift and its washed and blown sands, the soils developed on the Kansan till, and the soils produced on the loess loam.

Judging by the value at which farm lands are held in different parts of the county, the most desirable of these soils are those of the loess where it is comparatively thin and where it is but slightly dissected. A thickness of from ten to twenty-five or thirty feet of the loess secures an adequate underdrainage and at the same time allows water in dry weather to rise easily to the surface by capillary attraction from the couche lying upon the impermeable till beneath.

The fertility of a soil depends largely upon its nitrogenous constituents and these are derived from the decay of organic matter. It is the organic matter, or humus, which, mingled with the finely comminuted earthy material derived from the decay of rocks, gives its black or dark color to the superficial layer commonly known as the soil. The amount of humus present depends on the ratio between the rate of its accumulation and the rate of its removal by rain wash and other agencies. Where the latter is practically zero it accumulates indefinitely in peat bog and marsh. Where the latter comes to be in excess of the former, as on steep deforested hillsides, the humus is soon entirely washed away. The availability of any soil for agriculture depends also on its drainage. On level or undrained tracts soils are exceedingly rich in humus, but they are too wet for profitable farming. Steep slopes are well drained, but the humus, because so rapidly washed away, is scanty and the soil is infertile. The golden mean is found where erosion has been sufficient to reduce the region to slope, but where the slopes are as yet very gentle. It is here that, in the accurate language of the farmer, "the land lies just right."

It is well drained, and at the same time is covered with deep, black humus soil, rich in all the ingredients which go to the feeding of crops.

The golden mean just described is reached over extensive tracts in Cedar county, especially over the loess covered Kansan. In Fairfield township, where land is said to be held at the highest price per acre, in Farmington, Iowa, Springdale, Inland, Red Oak, and in parts, in fact, of every township included in the Kansan area, the wealth of the soil and the ease with which it is cultivated, is reflected in the large and well kept farms, commonly of 160 acres and more, supplied with every convenience of farm machinery. Commodious houses, well painted, and comparing not unfavorably with the average houses in the towns of the county, have replaced the humble homes of the pioneers, these relics of a bygone stage in social evolution being set to one side to serve as granaries or tool sheds. Rows and clusters of shade trees, belts of wind-breaks of soft maple, or more rarely of conifers, well grassed and well fenced door yards bright with flowers, orchards of apple, cherry and plum, with an occasional experimental peach tree or apricot, large, well built barns and sheds for the stock, for which the county is famous, deep, unfailing wells, equipped with wind engines, and sometimes affording a house supply under hydrostatic pressure,—all these are evidences of the fertility of the soil, which must not escape the attention of the geologist. Not infrequently an abandoned farm, abandoned to a tenant by its owner who has moved to town, where the rental yields an adequate support without labor, is a further proof of a long continued prosperity, dependent at last analysis upon geologic and climatic conditions.

In unpleasing contrast are the deeply dissected regions of loess-Kansan topography which have been frequently mentioned in this report. Here land values are comparatively low, being sometimes not more than half that of farms where the same geologic formations have suffered less erosion.

Under the plow the soil fast washes down the steep hillsides. Gullies start with heavy rains, and, rapidly deepening, soon escape the control of the careless farmer. In a few years it is imperative to refurnish the soil with nitrogen by seeding to clover, or to turn it to pasture. At the worst this is a region of from two to ten acre allotments, of the log cabin and the two or three room shack of the clearing. At the best it is farmed in prosperous sheep and cattle ranches of hundreds of acres. On these the roughest land is retained in its native timber. In such large tracts some excellent plow land is always found, and the remainder is used for pasture.

These two types of farming lands, so markedly different and producing such divergent sociologic conditions, have after all precisely the same subsoils. The loess underlies each, and the difference between the two types is at bottom merely a difference in angle of slope, dependent upon distance from local base levels of erosion and on preglacial conditions.

In each certain advantages accrue from the absence of native stone or glacial bowlder in the way of plow or mower, and still more in the looseness of the texture of the loess which permits roots to go deep to draw moisture and food. Acting as a sponge, the loess rapidly absorbs moisture in wet weather and when not too deep gives it back in dry by capillary attraction to surface layers. It has long been recognized that it is unsurpassed as a subsoil for vineyard, orchard, and all vegetation whose roots strike deep.

Iowan Soils.—The typical Iowan till and its high value as a subsoil has been fully described by Calvin in his reports on the counties where it is extensive. Rich in the salts demanded by the grains it is better adapted to the culture of wheat and oats than is the loess.

The sandy till which represents the Iowan in Cedar county forms a deep, warm, mellow soil suitable to all crops. The Iowan area forms some of the best farming land in the county, and the description of the farms on the best of the loess-Kansan will apply also to the best of the Iowan. Upon the whole, however, the Iowan farms are not valued so highly as are those on the gentle rolling Kansan. On account of the immaturity of the Iowan plain the natural drainage is imperfect. This is now remedied for the most part by ditches and tiling, but the evident disadvantages of the undrained tracts delayed the settlement of considerable of the area. The land has not yet had time to produce the improvements seen in districts longer farmed, and its market price is therefore still somewhat less.

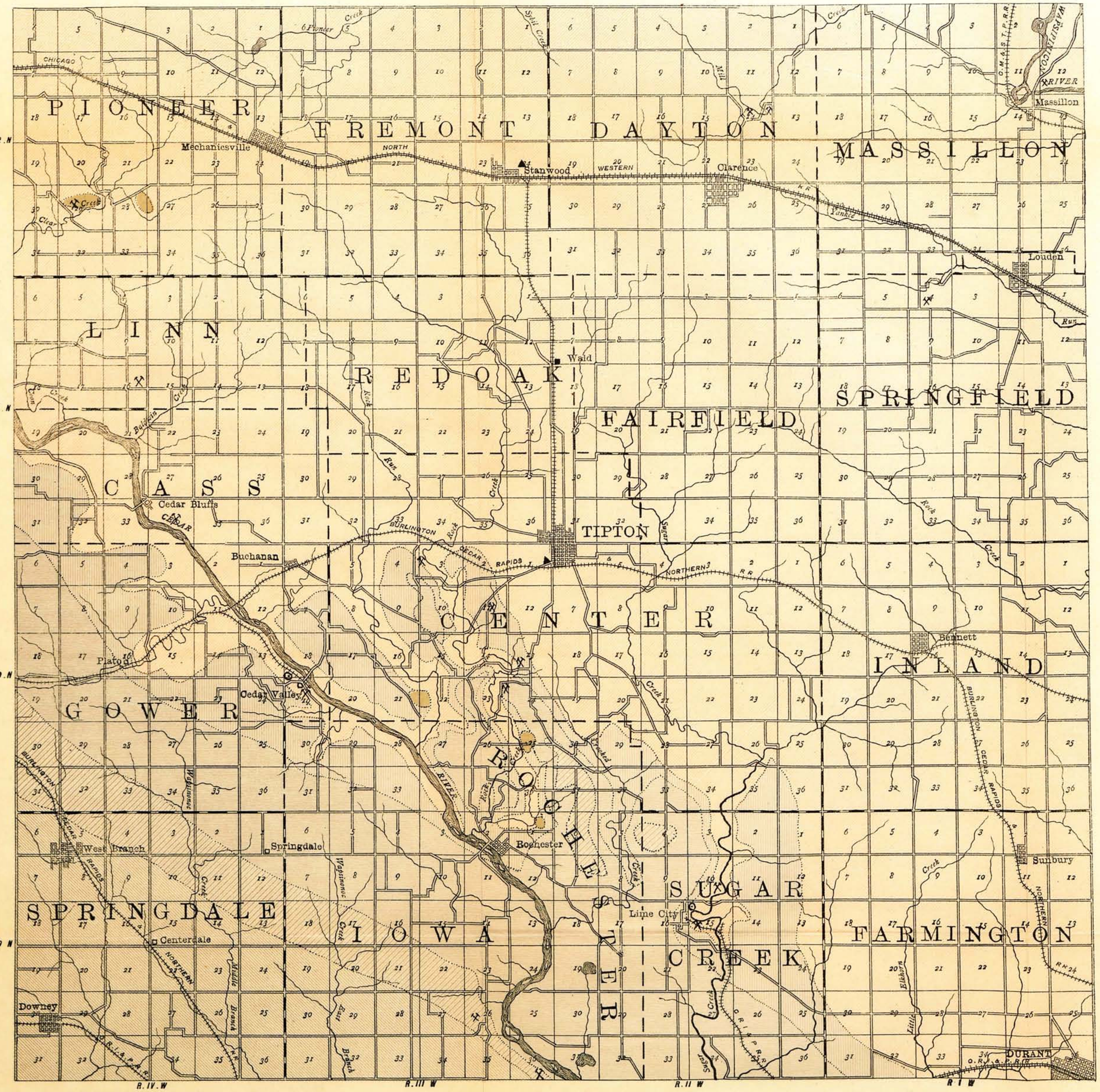
The bowlders of the Iowan are not plentiful enough to form any special embarrassment to farming operations. A very small per cent of the labor required in New England for this purpose would here suffice to remove them all. And in no case is the plow compelled to work in a heavily stony till. It is rarely that the plow discovers the till beneath the deep soils which overlie it. The nearness, however, of the till brings the level of ground water high on all tracts where its movement is not accelerated by slope, and on such levels the land is cold and wet until tiled, when it becomes of the best. On the Tipton lobe especially, and near the terraces of the Cedar river, sandy soils occur which have all the advantages and defects of such soils everywhere. In the season of 1899 the large rainfall in spring and early summer gave these soils a distinct advantage over the clayey soils of the loess, and when the field work of the survey was finished in July there was nowhere in the county a better stand of corn than on the sandy soils of the Iowan plains. In dry seasons the relative advantages of the two soils is reversed. In a drought crops may suffer severely on the sandy knolls and ridges, while they are uninjured on lower ground where the humus is deep, and on large areas where a sandy clay, probably of the same age as the loess, overlies the till.

A class of soils geologically distinct from those described are the alluvial soils of the flood plains of the streams. The ancient flood plains of the rivers which now stand as terraces twenty feet and more above the water are underdrained by basal beds of sand, and therefore, like all such old fluvial floors, are apt to suffer in times of protracted drought. Where a few feet of reddish, sandy clay underlies the humus, as is frequently the case, drought is less severely felt than where the humus is spread on strata of sand.

The lower bottoms and the flood plains as a whole embrace along with these sandy tracts many square miles of excellent farm land. So deep is the rich, black alluvium that it is often two feet and more in depth before a change in color can be be detected. The map of the county exhibits the distribution and the great width of these alluvial tracts along reaches of the Cedar and Wapsipinicon rivers and the larger creeks.

In the valleys of the smaller creeks the change in regimen due to cultivation can sometimes be seen. The peaty humus of the swale is overlain with a few inches of lighter colored soil washed from the adjacent hill sides since the country was settled.

On the whole corn is the staple crop of all the areas of the county, Kansan and Iowan as well, but the latter is more largely given over to pasture meadow and the smaller grains than is the former.



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF CEDAR COUNTY, IOWA.

BY

WILLIAM HARMON NORTON

1901.

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

DES MOINES	CARBONIFEROUS
CEDAR VALLEY	DEVONIAN
UPPER DAVENPORT	DEVONIAN
OTIS, INDEPENDENCE AND LOWER DAVENPORT	DEVONIAN
COGGAN	DEVONIAN
NIAGARA	SILURIAN

INDUSTRIES

- CLAY WORKS ▲
- QUARRIES ⚒
- LIME KILNS ⊙

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IOWA LITHO. CO.

GEOLOGY OF PAGE COUNTY.

BY

SAMUEL CALVIN.

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INTRODUCTION.

SITUATION AND AREA.

Page county is situated well toward the southwest corner of Iowa. The state of Missouri forms its southern boundary, and the single county of Fremont on the west separates it from the Missouri river. It is bounded on the north by Montgomery and on the east by Taylor. It embraces part of the territory which was for some time in dispute between Missouri and Iowa. Its location is such as to make it one of the most important agricultural counties in the great state to which it belongs. All the pasture and meadow grasses usually cultivated in this latitude flourish; small grains yield generously; bountiful crops of corn mature year by year without a single recorded failure; apples and the other fruits of the mid-temperate zone produce abundantly. In matters of soil and climate, in the fortunate location between the extremes of both north and south, Page county is exceptionally favored.

In area the county under consideration embraces somewhat less than sixteen congressional townships. The falling short is due to the fact that the Iowa-Missouri boundary does not follow the lines of the congressional surveys, but cuts through sections 31 to 36 of the southern tier of townships—the tier numbered 67 North—so as to leave not more than one-fourth of these sections on the Iowa side of the line. On the other hand the county loses in area by reason of the fact that the north line of the second row of townships north of the Missouri boundary is a correction line, and sections 1 to 6 in each of these townships is fractional. In place therefore of having an area of 576 square miles—the theoretical number in sixteen congressional townships—the number of square miles in Page county is approximately 530.

PREVIOUS GEOLOGICAL WORK.

Dr. C. A. White was the first geologist to give more than passing attention to the area which constitutes the subject of the present discussion. He visited Page county in 1866, and, in his report to the governor, at the beginning of 1867,* there is an interesting description of the region, in which the soils, forest lands, coal beds and limestone ledges receive especial notice. In White's final report of the Geological Survey of Iowa† the geological structure of the county is more fully described. In the volume referred to the limestones of the county—those along the east branch of the Tarkio being particularly mentioned—are assumed to be the equivalent of beds at Winterset,

*First and Second Ann. Rept. of Progress of the State Geologist, Etc., Des Moines, 1868.

†Report on the Geol. Surv. of the State of Iowa, by Charles A. White, M. D., Des Moines, 1870 vol. I, pp. 348-353.

near the base of the Upper Coal Measures. While recognizing the fact that the Upper Coal Measures (the Missourian stage of more recent writers on the geology of Iowa) attain a thickness of about 180 feet near Winterset, within ten miles of the attenuated eastern edge of the formation, Dr. White entertained the belief that beyond the margin of Madison county the strata of this stage have practically no dip to the west—at least the dip is not greater than the slope of the surface toward the Missouri river—and that there is little, if any, increment in the thickness of the beds in this direction. Two hundred feet is the maximum thickness assigned to this formation, a thickness but little in excess of that of the Winterset section. It was believed, therefore, that the members of the Winterset section recur at all the outcrops throughout the several counties of southwestern Iowa, and efforts were made to correlate the different exposures with recognized divisions of the assumed standard section in Madison county.

In volume II of the current series of reports on the Iowa Geological Survey, Keyes‡ gives a brief account of the coal deposits of Page county as they were known in 1894. On page 159 of the work cited the author reviews the different estimates which have been made by various observers respecting the thickness of the Upper Coal Measures—estimates ranging from 200 feet by White to more than 1,400 feet by Winslow. The latter estimate was made for the Upper Coal Measures of Missouri, but Keyes concludes that the actual figures, probably for Missouri as well as Iowa, lie between the two extremes. He assigns to the whole Coal Measure series in southwestern Iowa a thickness of about 800 feet.

In his work on "The Artesian Wells of Iowa," Norton has occasion to refer only briefly and incidentally to Page county. In a sentence or two he describes* a prospect hole bored near Clarinda in search for coal. While, however, no facts are given relating very directly to the details of geological struc-

‡Iowa Geol. Surv., vol. II. Coal Deposits of Iowa, by Charles Rollin Keyes, Des Moines, 1894.
*Iowa Geol. Surv., vol. VI, p. 339; Des Moines, 1897.

ture in the county under discussion, in connection with the records of borings in other counties he presents data which throw much light on the actual thickness of the Upper Coal Measures in this part of the state, and aid very materially in settling questions concerning the probability that the limestones of Page county are the equivalent of beds near the base of the Winterset section. The record of the Glenwood well† is particularly instructive in the fact that it shows clearly the division between the Upper and Lower Coal Measures, indicating for the former a thickness 670 of feet. The beds exposed in Page county are well up in the series and must be far above the top of the section described by White, in Madison county. The significance of the data collected since White's visit to this locality will be discussed on subsequent pages of this report.

Among the later attempts to fix the stratigraphic relations of the puzzling succession of limestones and shales to be found in the Missourian series is that of Keyes.* In his paper, in volume VII, of the Proceedings of the Iowa Academy of Sciences, Keyes reviews exhaustively the literature relating to the geology of southwestern Iowa and contiguous areas, and makes an effort to correlate the various typical exposures which geologists have described. While his work is the best that has yet been attempted in this line, it will doubtless require considerable revision before all the problems involved are satisfactorily settled. The difficulty experienced by geologists in correlating widely separated outcrops of beds belonging to the Missourian series arises from a number of facts. Shales are more common and are developed to a far greater thickness than was realized by the first observers. The shales alternate with comparatively thin beds of limestone. The fauna seems to have been very persistent, and the same species of fossils recur in successive beds of shales and limestones throughout practically the whole thickness of the

†Op. cit., pp. 343-347.

*Formational Synonymy of the Coal Measures of the Western Interior Basin, by Charles R. Keyes; Proceedings of the Iowa Acad. of Sc. for 1899; vol. VII, p. 82 et seq., Des Moines, 1900.

formation, for which reasons the paleontological method is not available in tracing beds from one locality to another. In preglacial time, as a result of erosion during the long period between the retreat of the sea and the advent of glacial conditions, the limestones formed escarpments and the thicker shales developed long, undulating slopes between the projecting limestone ridges. During the glacial epoch the region was covered with a thick mantle of drift, which effectually concealed all stratigraphic details. Subsequent erosion has cut through the drift in a comparatively few and completely detached localities, the greater portion of the rock surface being still hidden from view. The projecting limestone escarpments were the first to be uncovered,—they were practically the only portions of the formation that the first geologists saw—and since they contained essentially the same fossils, the conclusion was a natural one that the various outcrops were simply repetitions of the same beds. Later geologists, with a larger number of outcrops and the records of many borings available for study, are yet handicapped in the portions of the area covered with deep drift, by the inability to trace formations continuously over any great extent of country, and by the lithological and faunal resemblances of beds occupying different positions in the geological column. The problems of correlation are still farther complicated by strong dips and relatively sharp folds, which cause the same beds to appear at different levels within comparatively short distances. Near Henshaw, in Taylor county, there is a difference of thirty-five feet in the altitude of the Nodaway coal-seam in less than one-fourth of a mile, and the same coal dips sixty-five feet between the old Shambaugh mill, in Sec. 7, Tp. 68 N., R. XXXVI W., and the Ingraham coal mine, in Sec. 2, Tp. 68 N., R. XXXVII W., a distance less than two miles. Where so large a proportion of the area is effectually concealed by deep drift, it is impossible to reckon with the folds and erratic dips of the strata. And since in most cases no aid can be derived from paleontologic evidence, the relations of the limestones outcropping in one stream valley to those in another can not be determined by ordinary surface observations. Furthermore, in the drift-covered regions there is nothing in the way of natural surface exposures to give any clue to the thickness of the shale beds between the different horizons of limestone. The records of some well borings, to be noted later, now put us in possession of facts which help to solve the problem of the relation and thickness of strata belonging to the Missourian series, a problem that otherwise could not well have been solved in a region as deeplv covered with drift as southwestern Iowa.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface of Page county is a completely dissected and deeply eroded drift plain. The present topography is not modified or determined to any very large extent by erosion in the indurated rocks. The stream cutting which has brought about the present surface configuration of the region is limited almost entirely to the thick mantle of drift which overspreads this part of Iowa. The principal topographic features of the county are the deep, nearly parallel stream valleys which traverse the area with a direction a little west of south and alternate with a corresponding number of intricately carved ridges. The two most important valleys are those of the Nodaway and Nishnabotna.* The Nodaway river enters the county less than four miles from the northeast corner and following a direction in general almost due south, it crosses the state line less than six miles from the southeast corner. Throughout its whole length the valley is broad and deep. (Fig. 28.) Its walls rise on either side to heights

*Nishnabotany, Nishnabotny, Nishnabotony, Nishnabotane and Nishnabotena are some of various spellings for the name of this river which may be found on maps of Iowa, and in literature relating to Iowa when the river is mentioned. On January 9, 1901, the United States Board on Geographic Names decided that the correct spelling is Nishnabotna, and the decision is published in *The National Geographic Magazine* for Febuary, 1901, page 87.

ranging from 160 to nearly 200 feet. The bottom of the valley varies from two to three miles in width, and upon this broad plain the stream meanders freely, but within limits much narrower as a rule than the space between the bluffs. On the whole the stream flows nearer the eastern than the western side, and the slopes of the bluffs on the east are in general steeper than those on the west. The valley bears every indication of maturity, in some places approximating

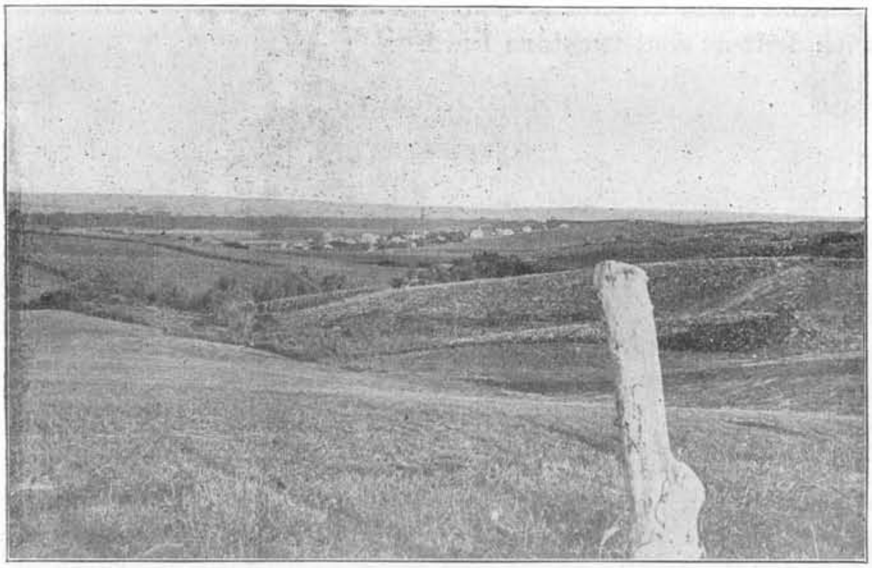


FIG. 28. View across the valley of the Nodaway from the highland northwest of Hepburn. The extent to which the side of the valley has been carved by erosion is shown in the foreground.

old age. It is well opened up. Not only have the walls receded so as to present the width of bottom land mentioned above; but the slopes, especially on the west side, are, in the main, long and gentle, mounting to the highland only at the greatly narrowed summit of the divides three or four or five miles back from the margin of the valley plain. At many points between Hepburn and Clarinda, for example, the long, gradual slopes of the bluffs blend almost imperceptibly into the gentle eastward slope of the bottom of the valley.

Just at Hepburn there is an unusual bit of topography which, seen from the bottom of the valley, presents the form of bluffs high and steep, in which short, rapidly-ascending gullies have been carved by lateral drainage. The lateral ravines are steep-sided and narrow. Within a small area in this vicinity the topographic forms are surprisingly young (Fig. 29), and in marked contrast with those which characterize nearly all the rest of the county. The river in this

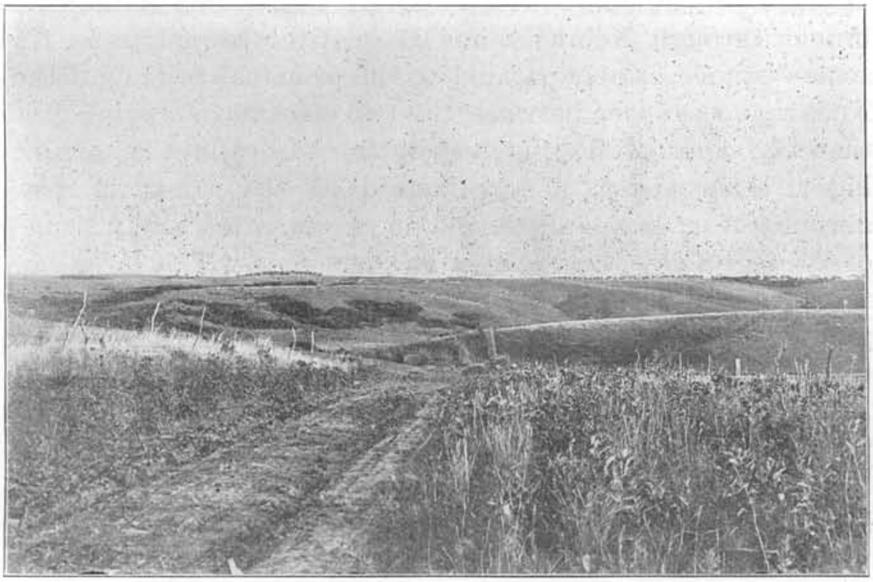


FIG. 29. The steep slopes and narrow ravines indicative of youthful topography, west of Hepburn.

locality is now three-fourths of a mile or more east of Hepburn, but the topography referred to clearly indicates beyond very much question that in times comparatively recent the stream washed the foot of these western bluffs, undercutting what had been a salient, eastward projecting ridge and causing the recession in the lower part of the bluff to keep pace with that at the summit. Since then the stream has swung back toward the east, and the bluffs at this point are now suffering modification only by the wash and wear of the ordinary storm waters. Between Hepburn and Clarinda, as already noted, the sides of the valley fade away into gentle slopes, but farther south, at a number of points along the east side of Harlan and Amity townships, the bluffs on the west side of the stream, incised more or less by lateral erosion, become comparatively steep.

The east branch of the Nodaway enters Page from Taylor county, in section 1 of Nebraska township. It, too, flows in an old valley—a valley wide, deep and flat-bottomed like that of the main stream described above. The course of the east branch through Nebraska and East River townships is, for some distance, nearly parallel to the principal branch of the Nodaway, the space between the two streams averaging less than two miles. The ridge separating the valleys is narrow, high, rather sharp, deeply incised on the sides; it rises abruptly from both valleys and, in places, attains an altitude of 200 feet above the water in the channels. This is one of the most prominent ridges, one of the most conspicuous topographic features in the county. Its base is narrower than either of the adjacent valleys.

The valley of the Nishnabotna is of the same character as the valleys already described. Its great width—greater even than that of the Nodaway, or any of its branches—and the long, gentle slopes of the sides, are all indicative of a long period of erosion. Near Essex the west side of the valley is the steeper, but this feature of steeper bluffs shifts from side to side, appearing west of the stream in one place and east of it in another. The valleys occupied by the branches of the Tarkio are, in the main, repetitions of those of the Nodaway and the Nishnabotna. The streams have cut deep trenches, and the valleys have been widened by the recession of their walls under the influence of weathering and storm-water erosion. Even the smaller, more or less intermittent streams have valleys disproportionately wide and deep.

A topographic feature, rather common throughout the county, is well illustrated in the southwest corner of section

15, Colfax township. It is evident that for a time deposition took place in the branches of some of the smaller valleys, which partly filled them with a heavy body of black loam eight or ten feet or more in depth. Lately, erosion has begun anew, and has cut fresh, deep, narrow, ragged-sided trenches in the loam (Fig. 30). Some readjustment of relations, some disturbance of the previous balance of forces acting on the surface, has started a new erosion cycle in a great number of

FIG. 30. Deep, narrow trench cut by recent erosion in the bottom of one of the broad depressions in the surface. The deep, black loam in which the trench is cut indicates aggradation of the small valley for a long period before the recent trench cutting began.

individually limited areas. Disturbances quite sufficient to result in the erosion of these new, deep, V-shaped, annoying trenches, now so commonly found along the principal lines of surface drainage in every part of the county, are not infrequently produced by the artificial cutting of drainage ditches along roadsides or for the passage of water under road culverts. Indeed, any interference with the natural surface of the ground in the lower part of the small valleys is almost certain to start the process, and, once started, the trench backs up into the adjacent fields and meadows with surprising rapidity. The trench does not fade out, but terminates abruptly with practically its full depth, at the upper end; and so miniaturé waterfalls are formed where the storm waters pass from the uneroded portion of the field to the new made channel. The upper end, however, does not remain stationary for any considerable length of time. It rapidly advances up the sloping area which it drains, its rate of progress depending on the frequency of storms and the volume of water which discharges into it. The trenches in question, ruinous sometimes to the fields, annoying always to the farmer, afford illustrations of what is known as "headward erosion," a geological phenomenon which follows a law as unfailing and inexorable as the law of gravitation, an effect which owners of land should be able to foresee and against which they should take every reasonable precaution to guard.

All that part of southwestern Iowa which is drained by affluents of the Missouri river exhibits an older and maturer type of topography than regions in the same latitude east of the great water-shed. The main topographic features in both areas are due to water sculpture in the superficial sheet of drift; but west of the water-shed the surface is much more deeply trenched by erosion, the stream valleys are wider, with more gradually sloping sides, the whole area is dissected back to the divides between the major valleys, there being no uninvaded flat spaces or plateaus such as are commonly found in the regions occupied by Kansan drift farther to the northeast. At a distance from the stream valleys profiles of the surface in any direction would show a series of convex curves sweeping through arcs of such extent as to indicate a very considerable relief. (Fig. 31.) In passing from the western to the eastern side of the water-shed, between Osceola and Chariton for example, the change in topographic type is very striking. On the one side is the deeply trenched and thoroughly carved surface with the elevations between the drainage courses exhibiting full rounded maturity; on the other, an area trenched to a much less extent, the details of sculpturing less numerous and complete, and the convex profile curves in many cases flattened at the top. The observer gets the impression of having passed suddenly into an area of younger and flatter topographic detail. The region east of the water-shed is covered with what has become established by usage in the literature of geology as the Kansan drift.

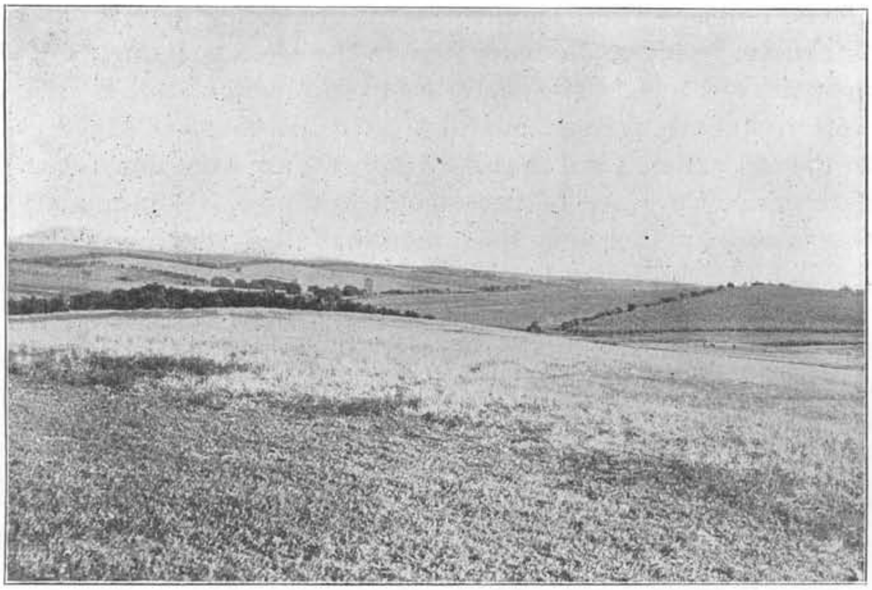


FIG 31. The sweeping, convex curves characteristic of mature, erosional topography on the highlands between the stream valleys. View taken four miles west of Clarinda.

Can it be that the older topography west of the divide is developed on the pre-Kansan drift? The answer must await more extended investigations in the field. It is certainly a fact, however, that the topography of Page county belongs to a fully mature erosional type, a type in which sculpturing of the original drift plain has been carried much farther than in average areas of the recognized Kansan drift in southeastern Iowa.

Over a large portion of Iowa the present topography is controlled to a greater or less extent by the configuration of the preglacial surface. The old rock cut valleys and intervening hills were only partly disguised by the sheets of drift which were subsequently spread over the area. In many cases the present drainage follows preglacial valleys, a result which would necessarily follow from the fact that, even if the entire surface had been levelled by the ground moraine of the latest ice sheet that overflowed any given area, the glacial detritus where it filled the valleys, owing to its greater thickness, would settle more than in the areas of thinner drift over the hill tops. Thus sags in the surface of the drift plain were frequently formed, conforming in direction and windings to the old valleys; and these, wherever they were developed, determined the lines of subsequent drainage. Page county was covered with a very thick mantle of drift which probably levelled the surface and obliterated for a time even the larger details of the preglacial topography. But in the settling of the drift and readjustment of the drainage after the retreat of the ice the new streams were directed by depressions in the drift plain along the courses of the old valleys. The work of the streams since the disappearance of the ice has been only partly successful in re-excavating these valleys. At Clarinda the Nodaway river has not yet reached the original rock surface, for wells at the level of the city water works go down from forty-five to fifty feet in the superficial detritus. That the old valley was wider than the present one is indicated by the record of the well at the Clarinda hospital where, starting part way up the side of the valley, the drill penetrated to a depth of seventy-two feet without reaching the bottom of the loose materials with which the ancient water course was filled. The depth of the glacial detritus in the valley of the Nishnabotna at Shenandoah was not ascertained; but the wells at the water works, on the low bottom-land toward the river, end in a bed of blue clay, probably glacial till, at a depth of forty-five feet from the surface.

The best evidence of a modern stream following an ancient, filled, and only partly re-excavated water course is found at Blanchard in the valley of the Tarkio. Here a well, partly bored, partly dug, was made to supply the railway tank with water, and it is said that rock was reached at a depth of 178 feet. The rock mentioned seems to have been limestone, and it is possible that some shale was penetrated without being differentiated from the superficial materials. But, according to the testimony of persons on the ground when the well was made, pieces of bark and wood were brought up from a depth of ninety or ninety-five feet, large bones which, judging from the descriptions given, must have belonged to the mammoth or the Mastodon, were found fifty-four feet beneath the surface; and beds of sand and gravel were reported to occur at various depths. There is clear evidence that the bottom of the preglacial valley which the Tarkio has partly reopened, was many feet lower than the level of the present stream.

DRAINAGE.

The drainage of Page county is fully mature. Practically every part of the surface is thoroughly drained. With the exception of a few small and unimportant areas in the flood plains of the streams where shifting of the meanders has left temporary wet places, there are no marsh lands in the county. There is one rather striking characteristic which the drainage of our area shares in common with all southwestern Iowa: the drainage basins of all the streams are remarkably long and narrow, the valleys are parallel or practically so for long distances, and the intervening spaces are disproportionately long in comparison with their width. The eastern third of the county is drained by the Nodaway and its branches; the various forks and branches of the Tarkio drain all the central and southwestern part; a relatively small area in the northwestern part of the county is drained by the Nishnabotna; and Walnut creek, whose drainage basin lies almost entirely west of the county, receives the drainage of a square mile or two in the extreme northwest corner.

Elevations.—In Gannett's Dictionary of Altitudes the elevation of Villisca, a short distance north of the Page county line, is placed at 1050 feet above tide, Clarinda 1009 feet, Essex 992 feet, and Shenandoah 975 feet. These figures refer in each case to the surface of the road bed at the railway station. Hawleyville has an elevation about the same as Clarinda. The high points of the divide between the two branches of the Nodaway reach a height of about 1200 feet, and this may be taken as an approximate average for the higher eminences in the eastern and northern parts of the county. The figures given indicate a general slope of the whole county towards the west and south.

STRATIGRAPHY.

The geological formations of Page county are not very numerous. They belong at most to three different series, the series being separated from each other by long periods of time. The oldest of the formations in the county, occurring at the surface, belongs to the later part of the Carboniferous system; the next in order of age is a member of the Upper Cretaceous series; and lastly there are Pleistocene beds consisting of the loose deposits of drift, loess and alluvium which cover by far the greater part of the surface. The Carboniferous and Cretaceous are marine deposits; the Pleistocene beds owe their origin to the action, first, of glacial ice, and, second, of winds and surface drainage waters. The two marine deposits are separated by an interval equal to the Permian, Triassic, Jurassic and Lower Cretaceous combined; the Upper Cretaceous is separated from the Pleistocene by the whole length of the Tertiary. The taxonomic relations of the strata are shown in the following:

SYNOPTICAL TABLE OF THE GEOLOGICAL FORMATIONS OF PAGE COUNTY.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial Deposits.
		Glacial	Kansan Drift?
Mesozoic.	Cretaceous.	Upper Cretaceous.	Dakota Sandstone.
Paleozoic	Carboniferous.	Upper Carboniferous or Pennsylvanian.	Missourian Limestones and Shales.

The Carboniferous System.

MISSOURIAN STAGE.

General Discussion on Relations of the Strata.—The deposits of the Missourian stage are made up of alternating beds of shales and limestones, the shales predominating so that much the greater part of the entire formation is composed of argillaceous strata. To appreciate the conditions under which these deposits are exposed in Page county, and generally in southwestern Iowa, it is necessary to have in mind some facts relating to the geological history of the region as well as to the characteristics of the indurated rocks. This region, with its relatively thin beds of limestone alternating with much thicker beds of shale, was subject to erosion for long periods before the beginning of the glacial epoch. Valleys were cut, and on their sides, as noted on a preceding page, the shale beds formed long gentle slopes, while the limestones gave rise to more or less prominent offsets or escarpments. During the glacial epoch this surface was deeply covered with drift, the depth of the till sheet averaging probably not less than 200 feet. All the indurated rocks were thus effectually concealed; and were it not for subsequent erosion, our knowledge of the preglacial geology of this portion of the state would now be very imperfect, since any knowledge of the subject could have been gained only at the expense of deep borings. Since the glacial epoch the streams, in the main following the old water courses, have cut in places down to the level of the walls of the ancient valleys. Where limestones occurred the beds now project more or less, owing to their greater power of resisting the processes of weathering. On the other hand any shales which may have been exposed by late erosion, have broken down as rapidly as the streams cut into them and so have been reduced to gentle slopes which were at once concealed by their own waste or the wash from higher levels. Such surfaces are now, in general, sodded over and blend indistinguishably into the slopes produced by erosion of the drift. It thus comes about that while the shale beds are much thicker than the limestones in the Missourian stage, the limestones are much the more conspicuous. By far the greater part of Page county, however, is yet covered with its mantle of drift; it is only in a few places that the limestone strata with some associated shaly layers are available for study; and an examination of these natural exposures tends to create the erroneous impression, so generally entertained by the earlier observers who visited the region, that the formation is made up largely of limestones.

There seem to be two distinct limestone horizons in Page county, the first being exposed at intervals along the two branches of the Nodaway, while the second is typically developed in the valley of the east Tarkio. The limestones on the Tarkio were correlated by White with certain members of the Winterset section, but he is less explicit in correlating the calcareous beds exposed at Braddyville, Hawleyville and other localities in the eastern part of the county.* It now seems certain, however, that the Page county limestones lie some hundreds of feet above the top of the Winterset section.

*In the report of the Geological Survey of the State of Iowa, by Dr. Charles A. White, published in 1870, in discussing the Geology of Page county, on page 349, the general statement is made that "The strata thus far discovered [in the county] are all referred to the horizon of the lower half of the series of limestones and shales of the Winterset section." In speaking of the limestones on the Tarkio, page 352, certain layers are definitely and explicitly regarded as "equivalent with No. 2 and No. 3 of the Winterset section, in Madison county."

Near Clarinda, in the Sw. ¼ of Section 36, Tp. 69 N., R. XXXVII W., a prospect hole was bored for coal. The drilling was carried to a depth of 1002 feet, and the part of the record which seems to relate to shales and limestones of the Missourian stage, is as follows:

		THICKNESS.	DEPTH.
9.	Clay and gravel (Pleistocene)	50	50
8.	Shale, partly marly, varying in color	100	150
7.	Limestone	5	155
6.	Light shale	20	175
5.	Very hard limestone	20	195
4.	Shale	105	300
3.	Limestone	20	320
2.	Shale, partly marly, black, blue and red	180	500
1.	Limestone	20	520

Only thin beds of limestone, and these separated by thick shales, are reported from a depth greater than 520 feet. No. 1 in the preceding table seems therefore to be the base of the Missourian, and to correspond to the Winterset limestones described by White and Bain in Madison and Decatur counties. No. 8 evidently lies below the level of the Braddyville and Hawleyville limestones, and the limestones of the East Tarkio are yet 125 feet higher than those exposed on the Nodaways. The total thickness of the Missourian in Page county is at least 625 feet. This agrees well, so far as thickness is concerned, with determinations made by Professor Norton, in his study of drillings from the deep well at Glenwood, a locality about forty-five miles in a straight line northwest of Clarinda. According to his interpretation the equivalents of the Winterset section are found in alternating beds of shale and limestone from 740 to 815 feet below the surface; and, subtracting the 175 feet of loose surface materials, the base of the Winterset section is 640 feet below the stratum which, at Glenwood, constitutes the top of the Missourian. The rocks immediately beneath the drift at Glenwood are limestones which, as will at once be noted, occupy essentially the position in the series that would be assigned to the limestone ledges outcropping in the valley of the East Tarkio. Beyond the mere matter of thickness, however, the parallelism between the Glenwood and Page county sections of the Missourian does not seem to extend; for the reported beds of limestone in the Clarinda boring are thin, few in number, and far apart as compared with the limestone layers penetrated at Glenwood. For example, in that portion of the Glenwood section which should correspond to the part of the section at Clarinda referred to the Missourian, there are sixteen limestone layers recorded in place of four; and their aggregate thickness is 240 feet, against the sixty-five feet at Clarinda. It must be said, however, that samples of drillings from the test hole at Clarinda were not examined by anyone connected with the Survey. The person who kindly furnished a copy of the record, as it was preserved, reports that "a man took the layers passed through, but it is not very perfect." The object of the boring was to find coal, the depth of the hole at different stages was determined with reliable accuracy, but it is possible that the limestones were not always carefully discriminated from the shales, and that a part of the discrepancy between the two records referred to may be thus accounted for.

In the Iowa Academy paper of Keyes, already cited, the Missourian formation is divided as in the following table. The thickness assigned by Keyes to the several beds, from a study of the whole field, is given in the first column of figures; while in the second column is given the thickness of what seem to be the corresponding members as they appear in the drill hole at Clarinda. The difference between the minimum and maximum thickness of the several portions of the Missourian, while seemingly large, is probably not greater than occurs in other sedimentary deposits which extend over large geographical areas:

Missourian Formations.

DIVISIONS OF THE MISSOURIAN, KEYES.	THICKNESS.	
	General Section.	At Clarinda.
11 Cottonwood limestone	10	
10 Atchison shales	500	
9 Forbes limestone	30	
8 Platte shales	150	100
7 Plattsmouth limestones	30	5
6 Lawrence shales	300	20
5 Stanton limestones	35	20
4 Parkville shales	100	105
3 Iola limestone	50	20
2 Thayer shales	75	180
1 Bethany limestones	100	20

Correlations.—The Bethany limestones of the general section of Keyes are practically identical with the alternating beds of shale and limestone in White's Winterset section. In the record of the Clarinda well it is probable that the upper portion of the Bethany or Winterset division was counted as shales and appears in the greatly increased thickness of No. 2. Nos. 1 to 5, inclusive, have about the same aggregate thickness in both columns and it would require very little adjustment to bring about practical agreement; but the great discrepancy in No. 6 can only be harmonized on the hypothesis of local differences in the rate of sedimentation. Whatever may be said, however, about the accuracy of the assumed correlations between the members of the general section and the section penetrated by the drill at Clarinda, there is no question that the limestones on the Nodaways, at Hawleyville and Braddyville, are the exact equivalent of what has been called by Keyes the Forbes limestone. This limestone is overlain by shales—the Atchison shales of Keyes, the Wabaunsee of Prosser—which attain a great thickness in Nodaway and Atchison counties, Missouri. A section of these shales 125 feet in thickness is exposed near Burlington Junction, in Missouri, and at the base of the section occurs the Nodaway coal seam which is recognized as marking a definite horizon near the junction of the Forbes and Atchison divisions of the Missourian formation. It is the basal portion of the Atchison or Wabaunsee shales that is penetrated by the shafts of the coal mines in the neighborhood of Clarinda and Shambaugh. At the Ingraham coal mine, in the northeast quarter of section 11, Tp. 68 N., R. XXXVII W., there is a thickness of seventy-five feet of this shale between the limestone cap rock and the base of the drift, and near Shambaugh the cap rock is overlain by sixty or seventy feet of the same formation. Between six and seven miles southwest of Shambaugh, in the northwest quarter of section 29, Amity township, Mr. G. H. Lowrey passed through more than 100 feet of shale without reaching the cap-rock overlying the Nodaway coal. On the farm of Mr. H. Larrabee, in the southwest quarter of section 22, Tarkio township, an 18 inch seam of coal was found in boring a well, at a depth of 180 feet from the surface. There can be little doubt that this is the Nodaway coal; and yet if the dip between the old Shambaugh mill, in section 7 of East River township, and the Ingraham coal mine two miles to the west, were constant, the coal seam in the Larrabee well should be more than 300 feet from the surface. Sixty feet below the mouth of the Larrabee well, and about sixty feet above the level of the water in the east Tarkio, there are numerous outcrops of the limestones for which the Tarkio valley has long been noted. These limestones lie about 125 feet above the Nodaway coal seam and constitute the second and last assemblage of limestones in Page county. Furthermore these limestones are evidently the southward extension of the beds which are quarried on a comparatively large scale near Stennett in Montgomery county; and these, on the other hand, are the equivalent of the limestones near Macedonia in Pottawattamie. At Stennett some of the beds are unusually rich in the small grain-like fossil called Fusulina, and Fusulina is the most common and characteristic form in certain beds along the Tarkio and near Macedonia. While it is not possible to attach much importance to the presence of Fusulina, since it occurs in all the Missourian limestones from the Bethany upwards, the species—*Fusulina cylindrica*—attains an unusual development at this horizon. Now the Cottonwood limestone of Kansas and Nebraska is rich in Fusulina, so much so that it has been referred to in the literature of geology as the "Fusulina limestone." The Cottonwood beds have been traced from Kansas into Nebraska, up opposite Iowa, along the high land forming the rim of the Missouri river valley; and it need occasion no surprise if they should be found at essentially the same level on the east side of the river. The occurrence of this uppermost limestone of the Missourian stage in Page, Montgomery and Pottawattamie counties in Iowa would be all the more probable if, as seems to be the case, the body of shales which attains such great thickness in Atchison county, Missouri, and the adjacent parts of Kansas and Nebraska, thins rapidly towards the northeast.

It must be said, however, that the discussion of this problem, in the present state of knowledge, is not likely to lead to definite conclusions. For example, it is difficult to reconcile the great amount of limestone reported from the Glenwood well* with the results of observations in other localities. The great number and thickness of the calcareous layers so reported may mean that the development of limestones is different in different parts of the Missourian area; that beds occur in one place, which, by thinning out in certain directions, are not found in other places; and that it is not possible to correlate all the limestones known in Page, Pottawattamie and neighboring counties with the members of the general section studied by Broadhead, Prosser. Haworth, and Keyes, in regions farther south and west, However the facts may be interpreted or explained, it is certain that the great body of shale which overlies the Nodaway coal in Page county and which is exposed in natural section near Burlington Junction, Missouri, appears not to be

*Iowa Geol. Surv., vol VI, pp. 343-345.

represented in the Glenwood well. The coal shafts of Page county go through a thickness of 100 feet of these shales in which there is not a trace of limestone; and in the Burlington Junction section of fully 125 feet, there are only occasional impure calcareous bands which at most attain a thickness of a few inches, but there is nothing that would be regarded as limestone. On the other hand, in the Glenwood record, the thickest of the non-calcareous beds which could correspond to the Atchison shales of Keyes, does not exceed

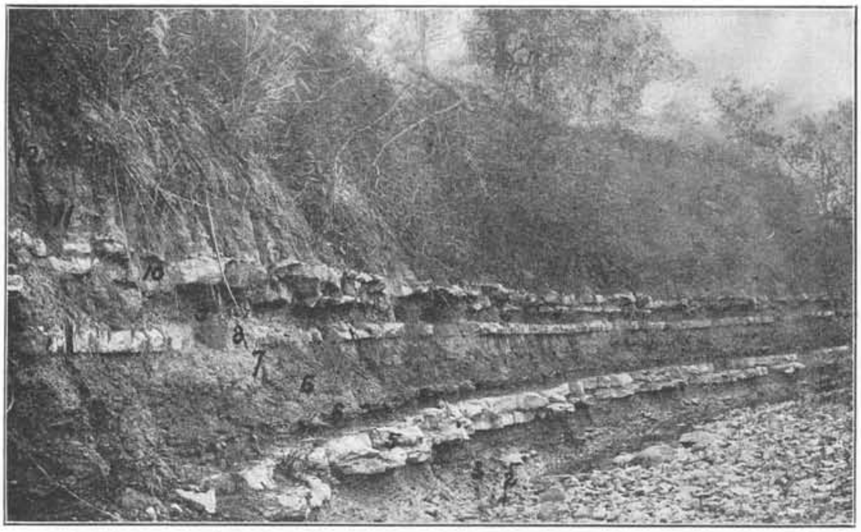


FIG. 32. Exposure of the Forbes limestone near Hawleyville.

twenty feet. Whether, therefore, the limestones on the Tarkio are to be correlated with the Cottonwood limestone of Kansas and Nebraska, or whether they are beds that feather out before reaching the states mentioned, is a problem which must be left to future investigation.

Typical Sections of the Missourian in Page County.—The limestones exposed along the Nodaways constitute the lowest member of the Missourian seen in Page county. As already noted, they may be correlated with the Forbes limestone of Keyes; and according to this author they are the fifth of the series of calcareous beds occurring in the Missourian stage. One of the best exposures of the beds in question is seen near Hawleyville, in the southeast quarter of the southeast quarter of section 12, Nebraska township. The land is owned by Mr. J. M. Molnux, and it is traversed by a small ravine which enters Page from Taylor county. The small valley is occupied by an intermittent stream which carries the surplus storm waters from a rather limited area to the East Nodaway. At the point where the ravine crosses the county line, and for a few rods down the valley towards the west, layers of limestone alternating with shale occur in the steep bank on the south side of the valley (Fig. 32). The following detailed section may be noted:

		FEET.	INCHES.
14.	An aqueous loess-like silt with occasional pebbles and small pockets of red sand near the base	10–15	
13.	Gravel composed of crystalline pebbles	0	3–10
12.	Drift with pebbles and small cobblestones	1	
11.	Yellow marly fossiliferous shale	1	8
10.	Limestone somewhat decayed and broken into irregularly shaped fragments; nodular in places, sometimes apparently made up of a single layer, in some places double	0	6–11
9.	Dark, carbonaceous, fossiliferous shale containing such forms as *Rhombopora lepidodendroides*, *Chonetes granulifera*, *Chonetes verneuiliana* *Derbya crassa*, *Ambocœlia planoconvexa*, *Athyris subtilita*, *Bellerophon carbonarius*, and the small S.raparollus described by Hall in his report on the Geology of Iowa as *Euomphalus rugosus*,—the *Straparollus catilloides* (Conrad) of Keyes	0	6
8.	Dark colored, earthy or clayey limestone with many of the species of fossils found in No. 9.	0	6
7.	Shale gray in color, but otherwise similar to No. 9 and containing the same fossils	0	8
6.	Dark, carbonaceous, slaty or fissile shale.	2	
5.	Limestone separated into two layers by a thin band which is very rich in a species of Derbya differing slightly from the normal average form of *Derbya crassa*. The same form		

		FEET.	INCHES.
	of Derbya occurs in the overlying portion of the limestone......	1	
4.	Gray, lean shale........................	1	
3.	Limestone in the form of nodules a few inches in thickness, nodules disconnected, not forming a continuous layer......................	0	6
2.	Light colored shale...........................	0	8
1.	Limestone in the bottom of the creek, thickness not measured.		

One-fourth of a mile farther up the small valley, in Taylor county, there are a number of exposures which show that the yellow shale, No. 11 of the section described, has a thickness of four feet, and that the upper part of this layer contains disconnected slabs of an impure but very fossiliferous limestone. *Chonetes granulifera* is the most abundant species, but *Productus cora*, *Myalina subquadrata* and a species of Pinna also occur. A number of small slabs containing *Fusulina cylindrica* were found on the weathered slopes, but the bed from which they came was not seen in place.

In the west bank of the river, south of the mill at Braddyville, a very interesting section was formerly exposed; but the surface has more recently been covered with riprap to protect the bed of the railway which is here located near the edge of the slope. It is still possible to make out the succession of beds described in the following section:

		FEET.	INCHES.
10.	Thin band of impure limestone...............	0	6
9.	Yellowish, fossiliferous shale.................	1	3
8.	Black, slaty, carbonaceous shale splitting up into thin, brittle laminæ....................	2	
7.	Impure limestone with many shells of Derbya embedded in the lower part of the layer; in the upper part the fossils are comminuted and indistinguishable.......................	0	8
6.	Thin band of shale crowded with the same form of Derbya occurring in No. 5 of the Hawleyville section. This form is intermediate between *Derbya crassa* and *Derbya robusta*.................................	0	2

	FEET.	INCHES.
5. Thin bed of limestone like No. 7 containing shells of Derbya and Myalina...............	0	2
4. Dark shale varying somewhat in thickness, about	1	
3. Hard, impure, nodular limestone, breaking into fragments on exposure to the weather......	0	8
2. Light drab shale, imperfectly laminated and containing concretionary nodules	2	
1. Limestone beneath the level of the water in the river.		

This section is essentially the same as the preceding one. The equivalent of No. 5 of the Hawleyville exposure is divided into its three constituent parts in the notes of the Braddyville section and numbered 5, 6 and 7. Numbers 8 and 10 above represent 6 and 8 respectively at Hawleyville; the two foot band of black, brittle shale and the six inch layer of limestone being identical in the two localities. Above number 10 the section at Braddyville is so much altered by weathering and creep that the succession of beds is rather obscure. Some of the shale beds, especially numbers 2 and 9, are at Braddyville much thicker than their equivalents farther to the northeast.

Before the advent of the railway and the application of riprap to the bank, the beds at this point were much better exposed; and certain layers above the level of those now accessible to observation furnished a large number of species of fossils unusually well preserved. The region was visited by the writer in 1875, and the following partial list of species is based on collections made at that time:

Fusulina cylindrica Fischer,
Derbya robusta Hall,
Chonetes verneuiliana Norwood&Pratten,
Productus semireticulatus Martin,
Productus cora D'Orbigny,
Orthis pecosi Marcou,
Spirifer cameratus Morton,
Athyris (Seminula) subtilita Hall,
Fistulipora nodulifera Meek,
Chonetes granulifera Owen,
Productus costatus Sowerby,
Productus longispinus Sowerby,
Productus symmetricus McChesney,
Dielasma bovidens Morton,
Spiriferina kentuckiensis Shumard,
Hustedia mormoni Marcou.

At the site of the old Shambaugh mill (Fig. 33), in the Sw. ¼ of the Nw. ¼ of section 7, East River township, there is an exposure which shows:

	FEET.	INCHES.
9. Yellow, weathered shale	4	
8. Black shale	1	
7. Yellow shale	1	3
6. Yellowish, impure limestone which at the north end of the exposure is in two layers—the upper 14, and the lower 18 inches in thickness. The lower bed thins and runs out in a few yards toward the south. Average thickness	2	

FIG. 33. The site of the old Shambaugh mill near Clarinda.

5. Yellowish shale, present in some parts of the exposure and not in others	0	6
4. Black slaty shale	0	6
3. Grayish, fossiliferous, non-laminated shale which disappears and re-appears in distances of a few yards. Among the fossil species noted are: *Lophophyllum proliferum*, plates and spines of Zeacrinus, *Rhombopora lepidodendroides*, *Chonetes granulifera*,		

	FEET.	INCHES.
Productus longispinus, *Productus pertenuis*, *Derbya crassa* represented by numerous small, fragile individuals, *Spiriferina kentuckiensis*, *Ambocœlia planoconvexa*, represented chiefly by detached valves, but very abundant, *Athyris subtilita*, *Straparollus catilloides*, *Bellorophon percarinatus*, *Bellerophon carbonarius*, and a small Pleurotomaria.	2	
2. Coal..	1	6
1. Drab shale down to river....	8	

The members of this section above No. 2 are all very variable in thickness. At the north end of the exposure the fossiliferous bed, No. 3, thins out, and bed No. 4 rests directly on the coal. The fossiliferous bed, however, is quite generally present at this horizon. The dull gray, non-fissile clay of which it is composed, crowded with its characteristic and characteristically preserved fossils, is readily recognized in the waste dumps from the coal mines of the region. Its presence is thus detected at all the old coal mines on the east side of the river south of the exposure described. It is recognized in the Howard mine and other mines near the village of Shambaugh, and it appears with all its characteristic features in the mines at Henshaw in Taylor county. The coal, No. 2, is the Nodaway coal, which is the basis of all the coal mining in the neighborhood of Clarinda and Shambaugh.

The foregoing section lies above the beds exposed at Hawleyville and Braddyville. The exposure at Braddyville seems to be the summit of a small anticlinal fold as suggested by White, for the coal is about at the level of the river at Shambaugh, and at Burlington Junction it has descended until it lies thirty feet below the water level. Eight or nine miles north of Villisca, on the east branch of the Nodaway in Montgomery county, there is a small mine in which the coal is found about thirty feet above the water in the stream. It appears, therefore, that the average dip of the strata is a little greater than the descent of the valley. The top of the limestone, No. 6, which forms the cap-rock of the coal throughout all this region may be regarded as forming the division between the Forbes limestone and the Atchison shales. It is part of the system of limestone beds alternating with shales, seen at Hawleyville and Braddyville, and no other limestone layer of any consequence occurs above it for a distance of more than 100 feet.

The lower part of the heavy body of shale which lies above the cap-rock limestone is penetrated by the shafts of the Howard and Fulk mines in the Nw. ¼ of section 36, Harlan township, by the shaft of the Ingraham mine near Clarinda, and by all the other coal shafts in the eastern part of the county. But these shafts are now timbered so as to hide the section, the only facts now obtainable being that they passed through beds of variously colored shale. A good natural section of these shales is exposed near Burlington Junction, Missouri, and a brief description of it will help to illustrate the character of the beds overlying the Nodaway coal and the cap-rock limestone. The colors of the exposed beds, it will be remembered, have been modified by weathering, and are not those which would be found in sinking a shaft through fresh strata.

		FEET.	INCHES.
20.	Blue shale	10	
19.	Yellowish green, calcareous shale	0	3
18.	Concretionary marly shale	2	
17.	Bluish green shale, not calcareous	3	
16.	Yellowish, calcareous concretionary shale	1	6
15.	Greenish blue shale	1	
14.	Calcareous, ferruginous sandstone	0	6
13.	Sandy shale with concretionary nodules in the upper part; the nodules showing the structure of septaria	10	
12.	Band of impure limestone with obscure impressions of fossils		2
11.	Sandy shale	2	
10.	Thin bands of fossiliferous limestone, with *Productus cora* and other species, alternating with sandy shale which carries septarian nodules near the bottom	5	

		FEET.	INCHES.
9.	Gray shale	3	
8.	Thin layer showing cone-in-cone at top and bottom, structureless in the middle	0	7
7.	Gray shale with occasional large septarian nodules	25	
6.	Calcareous band with plates of Zeacrinus, Fustulipora and Rhombopora, *Productus longispinus*, *P. nebrascensis*, *P. semireticulatus*, *Spiriferina kentuckiensis*, *Ambocœlia planoconvexa* and *Straparollus catilloides*	0	4
5.	Dark shale, with some calcareous bands, fossiliferous near top, down to level of water in the river	25	
4.	Shale in shaft of coal mine a short distance from where the section was taken, below level of river	30	
3.	Cap-rock	2	
2.	Shale above coal	4	
1.	Coal	1	6

The Burlington Junction section shows the beds immediately above the coal, but it evidently includes only a part of the whole thickness of the Atchison shales. To these shales, as already noted, Keyes assigns a thickness in northwestern Missouri of 500 feet. At all events, at the Burlington Junction exposures there are no indications of the next limestone—the Cottonwood limestone—which should follow the shales in ascending order.

It must be said, however, that the Atchison shales either thin out rapidly toward the northeast, or they are divided by a limestone which does not extend into Missouri, Nebraska and Kansas, where the Missourian formations have been most carefully studied; for in the valley of the Tarkio in Page county there is a very conspicuous limestone which seems to hold a position only about 125 feet above the sections exposed on the Nodaways. Beginning at Coin and extending up the valley, especially along the east branch of the Tarkio, heavy limestone ledges are quarried, the quarries occurring at intervals up to the north line of the county.

Near Coin there is a quarry of this limestone on the land of Mr. J. H. Palmer, on the Sw. ¼ of the Se. ¼ of section 29, Lincoln township. Owing to weathering and decay the ledges are here somewhat displaced, and the detached blocks occur in clayey, residual materials. The true relations of the beds cannot be made out; but weathered bowlders of the limestone indicate that the upper layer is rich in Fusulina; while beds that seem to have been displaced but little, and show only slight effects of weathering, furnish very excellent building stone in the form of a blue, fine-grained layer, sixteen inches thick, which breaks readily at right angles to the bedding planes into blocks suitable for use in all kinds of substantial masonry. A few rods southwest of the point where the building stone is taken out, and at a lower level, there is an exposure, in place, of another bed of limestone, which, however, is soft and easily decomposed. This limestone crops out for some distance in the hillside, between the Palmer homestead and the river.

More satisfactory sections of the Tarkio limestone are found farther up the valley. In sections 22 and 27 of Tarkio township there are a number of quarries and natural exposures from which it is possible to make out the following succession of the beds belonging to this horizon:

		FEET.	INCHES.
8.	Fusulina limestone	1	
7.	Shale	3 to 5	
6.	Limestone, rather soft	0	8
5.	Blue, fine-grained, hard limestone, breaking at right angles to the bedding planes into excellent blocks for building purposes. The most important quarry stone of the county	1	4
4.	Shale	12	
3.	Limestone rather softer than No. 5, but of fair quality	1	6
2.	Shale	3	6
1.	Limestone	2	

The quarry ledge has been worked quite extensively on the land of Mr. Geers, on the Nw. ¼ of section 27. The work has been carried on lengthwise along the slope of the west side of the valley, so that operations have not been carried very far into the hill. Near the surface the shale No. 7 has suffered by decay and weathering, and allowed the Fusulina bed, No. 8, to come down upon No. 6; but where a fresher part of the section is exposed the shale attains the thickness reported above. On the farm of Mr. Wolf Miller, in the Se. ¼ of the same section, a large quantity of stone has been taken out; but since the one ledge, No. 5, is all that is sought for, there has been no effort made to maintain a quarry face which would show a section of the beds. At a few points the Fusulina layer is seen resting on No. 6, the intervening shale having been wasted and removed by weathering.

The beds below No. 5 are shown in a well on the Geers place. No. 3 is seen naturally exposed near the barn of Mr. Harlan in the Sw. ¼ of the Se. ¼ of section 22; while the blue ledge, No. 5, is quarried a little farther up on the hillside. There are several small quarries on the land of Mr. Barrabee, in the Sw. ¼ of section 22. In the Ne. ¼ of section 15, Mr. O. Erickson has a a quarry which uses the ledges numbered 1 and 3. These beds, each separable into two or three distinct layers, are thicker and firmer here than they are farther south, and the intervening shale is much reduced. A good quality of stone is taken out, and it is obtained with greater ease than the products of some of the other quarries noted. *Myalina subquadrata* is a common fossil in the Erickson quarry. On the north side of the road from Erickson's, in the Se. ¼ of section 10, stone has been taken from the same beds worked in the Erickson quarry and also from the characteristic "blue ledge" of this region, No. 5. There are many other openings furnishing stone along this branch of the Tarkio. Mr. C. Apple has a quarry in section 14, of Tarkio township; and farther north, in Fremont township, there are quarries in sections 24, 25, 35, and 36. There are also some openings on the smaller branches of the stream in Douglas township.

Some of the best natural exposures of the limestone of the Tarkio are seen in the bed of a small stream near the southwest corner of section 18, and the adjoining part of 19, in Douglas township. On the south side of the road running between these sections there is an exposure due to undercutting of the stream, which shows:

	FEET.	INCHES.
5. The limestone cap above the quarry ledge......	0	8
4. The "blue ledge" of the quarries farther south.	1	2
3. Calcareous shale containing numerous fossils, such as *Fusulina cylindrica*, *Rhombopora lepidodendroides*, *Derbya crassa*, *Meekella striatocostata*, *Enteletes hemiplicata*, *Chonetes granulifera*, *Productus nebrascensis*, *P. semireticulatus*, *P. cora*, *Pugnax uta*, *Spirifer cameratus*, *Ambocœlia planoconvexa*, *Athyris subtilita*, together with numerous stem segments of Zeacrinus..................	7	
2. Calcareous, yellow, marly clay	0	4
1. Limestone with fossil fragments, generally barren, soft and yellow when weathered, but harder and bluer when fresh................	1	2

No. 1 comes down to the level of the bottom of the creek and is the equivalent of No. 3 of the preceding section. No. 2 of this section was not recognized farther south. The other members will be easily correlated. No. 3 is somewhat variable in its characteristics. The fossils are not distributed uniformly in any of the layers, but seem to have formed local colonies. East of the point where the section was made, ledges 4 and 5 are exposed continuously for some distance along the sides of the small valley. On the north side of the road there is a bed of limestone in the bed of the creek, which lies below No. 1. At all of the quarries visited, with the exception of those mentioned at Erickson's, the "blue ledge" is the only bed that is regarded with favor. In Fremont township the eight inch layer, No. 6, affords servicable quarry stone for some purposes.

The limestones exposed in the Tarkio valley have an inclination southward a little greater than the grade of the stream. In sections 22 and 27, Tarkio township, they have an elevation about fifty feet above the water in the channel, while at Coin they are less than twenty-five feet above the water level. As a whole the calcareous beds, particularly 1, 3 and 6, increase in thickness and firmness toward the north, while the alternating shale beds become correspondingly thinner. Near Stennett, in Montgomery county, what are evidently the equivalents of the limestones under considera-

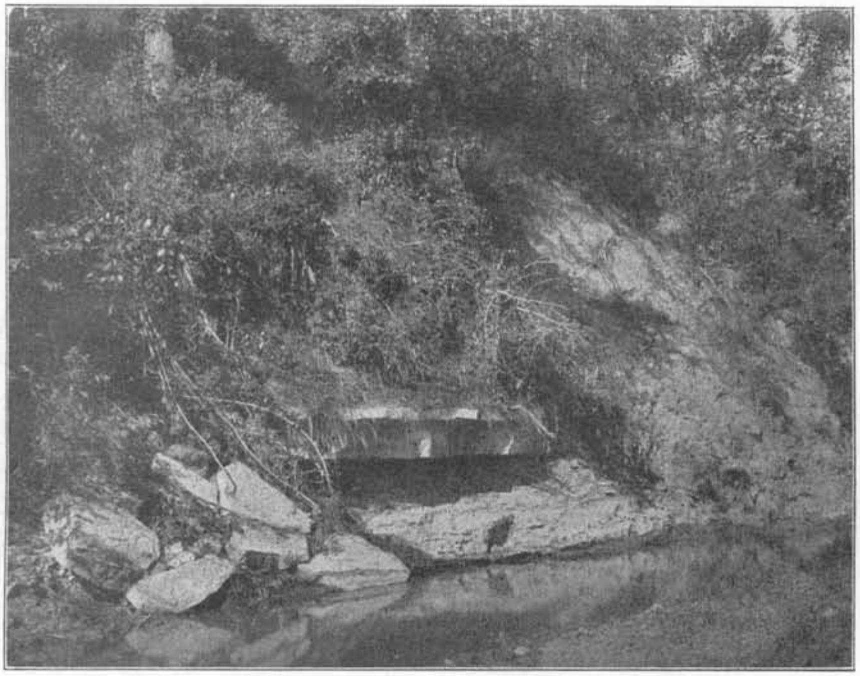


FIG. 34. Exposure of the "blue ledge" and associated strata southeast of Essex.

tion have become much thicker at the expense of the intervening shales, and a greater number of the layers are crowded with the small grain-like shells of Fusulina.

One of the few exposures of the indurated rocks occurring in the western part of the county is seen in the valley of a small creek in section 31 Fremont township, and section 36 of Pierce, a mile and a half or two miles southeast of Essex.

The beds are the equivalent of those seen on the Tarkio. The eight-inch cap and the sixteen-inch blue ledge, underlain by shale, are shown in figure 34. The blue ledge is the same fine-grained, compact stone that it is farther east, and it breaks into blocks at right angles to the bedding planes the same as elsewhere. The eight-inch layer is here separated from the blue ledge by a thin bed of shale. The Fusulina limestone, No. 8 of the Tarkio section, is not quite so rich in the small shells which give character to this bed farther east, and which are so exceedingly common at Stennett. While certain parts of the bed are crowded with the small fossils in question, other parts are quite barren. This bed carries other species of fossils to a somewhat greater extent than elsewhere. *Enteletes hemiplicata*, *Productus semireticulatus*, *P. longispinus* and *Ambocœlia planoconvexa* are among the forms noted. At this point many Fusulina occur in the blue ledge. This exposure near Essex illustrates the fact that, except in a general way and in the case of a very few persistent layers, the strata of the Missourian stage are exceedingly inconstant in thickness and lithological characters. There is here a strong dip to the west, but the grade of the stream channel is greater in this direction than the dip. On this account lower and lower beds appear successively when the exposure, which continues some two or three hundred yards west of the township line, is followed down the valley. The most variable beds are those which lie below the level of the blue ledge. A certain layer, for example, when first seen in the bed of the stream, is calcareous, hard, firm, and breaks off at right angles to form a miniature fall. Traced farther down as it appears in the bank, it grades into a soft shale. Other layers show the same transition from a limestone in one place to shale in another. The limestone does not feather out, but it grades out, the layer persisting, but becoming more and more argillaceous until it grades into a true shale. Even the blue ledge, the most persistent of all, varies in thickness and in fossil contents, certain parts being rich in Fusulina, while others show none.

The relations of the Tarkio limestones to the Nodaway limestones have not been very satisfactorily determined. The Nodaway beds dip to the west quite rapidly as shown by the difference in altitude between the coal seam at the site of the old Shambaugh mill near Clarinda, and at the Ingraham mine a mile or two to the west. The dip, if constant, would carry the coal about 300 feet below the level of the limestone in the Tarkio valley. The dips, however, are not constant. The strata are folded more or less; and the deep mantle of drift precludes the possibility of following the beds from one locality to another. A well bored on the farm of Mr. H. Larrabee, in the Sw. ¼ of section 22, Tarkio township, was carried down to a depth of 300 feet; and an eighteen inch bed of coal is reported at a depth of 180 feet from the surface. This is beyond much question the Nodaway coal, lying much nearer the surface than would be expected if the strata had a uniform dip. From the position of the well mouth the depth of the coal below the Tarkio limestone is found to be about 125 feet.

On land belonging to C. A. Linquist in the Nw. ¼ of section 24, Fremont township, a thin bed of coal lying above the limestones of the Tarkio valley has been worked on a small scale. The shaft is located on the hill top overlooking the deep valley of the east branch of the stream. The section as reported by persons who had opened and worked the mine, is:

	FEET.	INCHES.
6. Black soil	1	
5. Red soil, with pebbles (drift)	40	
4. Bluish clay (may be shale, possibly drift)	10	
3. Limestone, roof over coal	3	
2. Coal		6 to 14
1. Fire clay		

One of the earlier attempts to work the mine was by means of a drift on the east side of the hill, starting in at the level of the coal. The beds here, as usual, dip slightly to the west so that the drainage was toward the breast of coal instead of toward the pit mouth. Another effort was made to open the mine on the west side of the hill so as to take advantage of the slope in keeping the mine dry; but the roof limestone proved to be shattered and broken, and gave so much trouble that the shaft was finally located on the summit of the ridge. The level of the coal on the east slope of the ridge is thirty-five feet above the blue ledge of limestone, which has been somewhat extensively quarried for half a mile or more along the hillside. With the horizon of the Linquist coal may be correlated the coal seam found on the land of Mr. O. H. Brewer, in the Nw. ¼ of section 20, Tarkio township. The information is furnished by Dr. George L. Smith that at a depth of fifty feet, commencing about fifteen feet above the bottom of West Tarkio creek, Mr. Brewer found a layer of limestone one foot in thickness, beneath which occurred four feet of shale and one foot of coal.

Dr. George L. Smith, to whose extensive and accurate knowledge of the geology of the county, the Survey is indebted for much of the information relative to the region about Shenandoah, writes that he has found a natural exposure of the indurated rocks on the West Tarkio, and the only one in Grant township. It occurs in the Se. ¼ of the Se. ¼ of section 25. On the east side of the creek, in a gully, there is an exposure of "blue slate" two and one-half feet in thickness. It lies about ten feet above the level of the water in the creek, and in the opinion of Dr. Smith it lies above the horizon of the Linquist coal. Dr. Smith's views relative to the stratigraphic position of the exposure seem to be well founded, and the "blue slate" of this locality may be looked upon as the highest of the Missourian strata observed in Page county. The entire section of this formation, so far as developed in the county, may be generalized as follows:

	FEET.
6. The "blue slate" in section 25, Grant township, thickness unknown..................................	

		FEET.
5.	Linquist coal with overlying beds................ ..	14
4.	Shale between Linquist coal and the limestones of the Tarkio valley......................	35
3.	Limestones of the Tarkio valley and associated shales	27
2.	Shales between Tarkio valley limestones and the Nodaway coal...	125
1.	Nodaway coal with the limestones and shales at Hawleyville and Braddyville	20

Deep Drill Holes.—There are very few deep drill holes in the county which throw any light on the Missourian section. The most important boring was put down near Clarinda, and to this reference has already been made. The location was chosen in the Nodaway valley, and the first rock encountered lies below the level of the Hawleyville and Braddyville sections. The deep well on the Larrabee farm is important as showing the relations of the limestones of the Tarkio valley to the Nodaway coal. Some years ago a hole was bored to a depth of 700 feet, near the southwest corner of the Nw. ¼ of section 21, Grant township; but the only record obtainable was the statement that the drill passed through two coal beds, each from one foot to eighteen inches in thickness. The depth to the coal, or the distance of the seams apart, could not be obtained. It is possible, however, that the boring passed through both the Linquist and the Nodaway seams. Even allowing for more than the normal dip toward the south and west, the depth of the well was sufficient to pass beyond the lowest of the two coal horizons.

Another deep drill hole in Grant township is located in the Nw. ¼ of section 14. The record as reported shows that the drift here is 180 feet in depth ; that underneath the drift is a body of sandstone sixteen feet in thickness ; that at a depth of 310 feet a fourteen-inch seam of coal was encountered ; and that the drill continued down through shales and limestones to a depth of 400 feet. All other details are lacking. The sandstone beneath the drift is probably of Cretaceous age and belongs with the formation to be noted under a subsequent heading. The fourteen-inch coal is very probably the Nodaway seam, as the depth is approximately that at which this vein should be found, if present at all. The upper, thinner coal of the Linquist horizon may be locally absent, or it might easily be overlooked. On land belonging to Mr. Falk, a few rods southeast of the opening in the side of the valley to the Linquist coal mine, a test hole was made in search for coal. The boring began below the level of the limestones. No samples were kept, but the record as preserved in manuscript by Mr. Falk is as follows:

		FEET.
16.	Clay	15
15.	Limestone	1½
14.	Blue shale	3
13.	Brown soapstone	6
12.	Blue soapstone	13
11.	Soft slate	16
10.	Two ledges of "stone"	3
9.	Light clay	8
8.	Soft slate	25
7.	"Stone"	1
6.	Dark slate	2
5.	"Stone"	3
4.	Fire clay	2
3.	Dark slate	1
2.	Fire clay	1
1.	Limestone	16

This gives a depth of 116 feet, almost enough, according to the record of the Larrabee well, to reach the Nodaway coal. If the shale beds, as seems in some instances to be the case, thin toward the north, it may be possible that the coal horizon is represented in the dark slate, No. 3, and that the limestone, No. 1, is equivalent to the beds beneath the coal, exposed at Hawleyville and Braddyville. The log of the boring, as it stands, is believed to be worthy of permanent record; but carefully preserved samples from other borings should be submitted to careful study and examination before final interpretations or correlations respecting this part of the Missourian section are made.

The Cretaceous System.

DAKOTA STAGE.

Sandstones of the Cretaceous system are indicated at a few localities in Page county. They are usually found in wells and borings which have penetrated the drift. As a rule they are completely concealed by the heavy mantle of Pleistocene deposits which everywhere overspread the surface. Neither the extent nor the outlines of the areas in which these sandstones occur can at present be known; and for this reason the areas on the accompanying map, which are colored to indicate the presence of the Cretaceous, must be regarded as only a provisional attempt to map this formation. Along Buchanan creek, on the land of Mr. J. D. Maxwell, in the Sw. ¼ of section 15, Buchanan township, there are some very unsatisfactory outcrops of a micaceous sandstone which is probably Cretaceous. This sandstone has been penetrated at a few points where small pits have been dug in search for coal. It overlies shales and shaly limestones of the Carboniferous. It is not very thick, and the area it covers is probably quite limited. Well diggers report a sandstone, twenty feet below the surface, in the northern part of the town of College Springs. From the best information obtainable, the sandstone dips toward the north, and disappears abruptly south of the college. No samples were seen. Nothing is known as to the character or thickness of the sandstone at this locality. The facts reported by persons familiar with the locality are placed on record in the hope that the attention of those who have opportunities to collect data may be stimulated and more precise information obtained for use in completing the final geological map of the state.

The most satisfactory evidence of the presence of Cretaceous sandstones in Page county is found in the vicinity of Shenandoah. The bed of sandstone already noted beneath 180 feet of drift, in section 14 of Grant township, may be referred to the Cretaceous without much question. A similar sandstone is found in wells, beneath the drift, at a number of points in sections 15, 16, and 17; and the same sandstone is known to occur as far south as the Se. ¼ of section 16 in Morton township. At the point last named the drift is seventy-six feet in thickness. In sections 15, 16, and 17, of Grant township, the sandstone lies under from twenty to forty-five feet of drift. The upper surface of the sandstone is very irregular, as if it had suffered a great deal of erosion before being covered with the superficial till. So far as learned the sandstone was passed through at one point only—the wells in other cases getting water before reaching the bottom of the formation—and the thickness reported is fifteen feet. The difference in level between the upper surface at the point where the stone was penetrated and the upper surface at some lower points in the neighborhood, is more than fifteen feet—a fact which would indicate an unconformity between the sandstone and the underlying shale. The deposit in question varies greatly in hardness, some beds being almost quartzitic while others are loose and practically unconsolidated.

The Pleistocene System.

KANSAN DRIFT.

The surface of Page county is very generally covered to a great depth with glacial deposits. The drift is unusually heavy, attaining a thickness in places of 200 feet. The topography of the county, as previously noted, is due almost wholly to erosion of the superficial materials. The amount of rock cutting is comparatively small. Valleys walled with drift have a depth of 200 feet, and wells on the divides not infrequently reach depths below the level of the water in the streams before encountering the indurated rocks. The drift of Page county in this report is referred provisionally to the Kansan, though it possesses many characteristics which suggest the age of the older pre-Kansan till.

The materials forming the drift are here very variable. They lack the constancy exhibited by the blue Kansan clay of south-central and southeastern Iowa. The best artificial section of the glacial deposits in the county is found in the great railway cut in the south half of section 33, Tp. 69 N., R. XXXVI W. (Fig. 35.) The fresh unaltered clay first breaks down, on exposure to the weather, into a crumbling, powdery product altogether unlike the tough, persistent blocks which weather off the fresh blue Kansan when it is exposed in the eastern

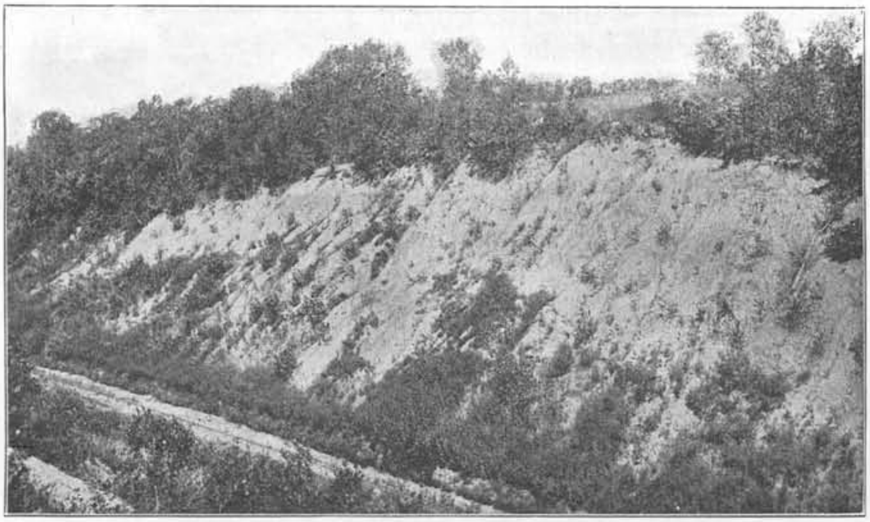


FIG. 35. The deep railway cut near Clarinda.

part of Iowa. Leaching and oxidation have descended to a depth of twelve or fifteen feet from the surface. In the fresh till in the lower part of the cut, limestone pebbles are numerous, but in the weathered zone the calcareous fragments have been completely dissolved out; the granites are wholly decayed, and nothing but hard, fine-grained greenstones remain. The limestone pebbles below the zone of weathering are very frequently enlarged by deposition of the calcareous matter held in solution by descending ground waters; and calcareous concretions representing the dissolved pebbles and limestone flour carried down from the leached zone, are sprinkled over the surface of the slope in the lower part of the cut. Greenstoen cobbles and pebbles are common throughout the whole thickness of the exposure, and a very large proportion of these are planed and scored on one or more sides.

The indications of age in the drift of Page county are found in a number of its characteristics. In the first place the extent to which the surface is eroded bears evidence of a long lapse of time. The stream valleys are all deep and wide; the great width, rather than the depth, affording some measure of the length of time the work of valley making has been in progress. The whole surface of the country over the divides, from one stream valley to another, has been carved into a system of completely rounded ridges, separated by wide and deep-cut ravines, as shown in Figures 28, 29, 30, and 31. In the second place the processes of weathering and oxidation have affected the surface so as completely to change the character of the original materials, to a depth, in places, of at least fifteen feet. The iron constituent of the till is completely oxidized. The calcareous material is all leached out and carried away, part of it being removed from the region and carried by drainage waters to the sea, part having been carried downward by descending ground waters, to be redeposited in the form of concretions. Not only have all the limestone fragments of all sizes up to ten or twelve inches in diameter, been dissolved, but most of the granites are completely disintegrated into non-coherent granules, now scarcely distinguishable from the original fine constituents of the till. In the third place, there is in Page county one evidence of age which is not presented by the Kansan drift in the eastern part of the state. Thoughout a large portion of the county the loess overlying the drift is thin, and the gulches carved by erosion along the roadsides cut down through it and expose the pebbly till. Between the loess and the till there is a sheet of gravel (Fig. 36) conforming to the contact between the two deposits. The loess is young as compared with the drift.

Before it was laid down the surface had been eroded to practically the same extent as now; all the present topographic features had been developed; the surface in all its contours and inequalities was covered with the sheet of gravel referred to; and it was on this surface that the loess was deposited. The gravel is made up of pebbles, which were at first distributed through that part of the drift which has been removed by erosion. The finer portion of the till was easily trans-

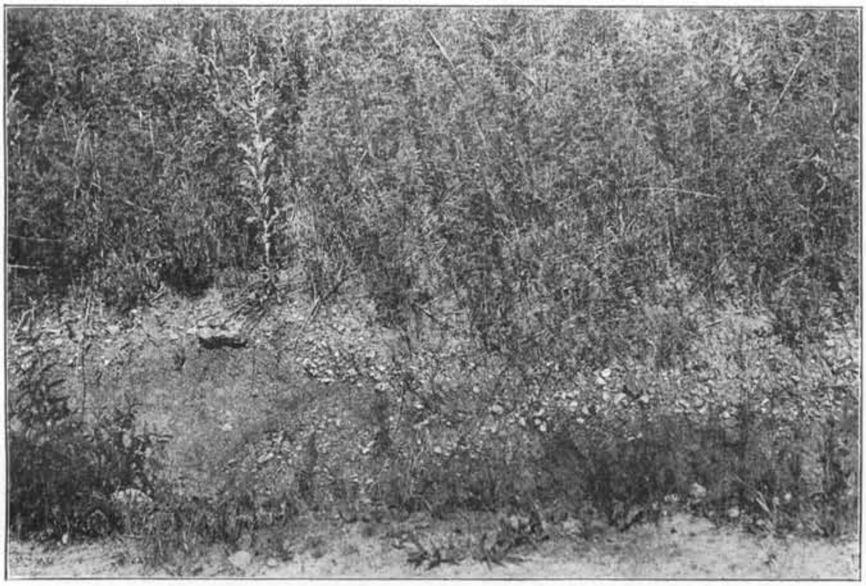


FIG. 36. Thin sheet of residual gravel between loess and Kansan till, north of the center of section 17, Lincoln township.

ported by the sheet-water which drained the general surface, while the pebbles from quite a thickness of the drift—too heavy to be carried along—were concentrated by the transportation of the fine clay in which they were embedded, and left as a sheet of residual material, from which finer constituents had been sorted and removed. The residual gravel indicates two things: First, the erosion of a considerable thickness of drift from the surface, and, second, the consummation of the process by currents of sheet-water too weak, even on slopes quite steep, to transport rounded pebbles an inch or more in diameter. The process, so carried on, was one requiring time. It is worthy of note that, although the till was originally rich in limestone pebbles, no pebbles of this composition are found in the residual gravels, nor are there pebbles of any kind except those of the hardest and most resistent of the crystalline rocks. Quartzites are very common.

The Loess.—The surface of the county is very generally covered with loess. As a rule this material is not very thick, yet there are places where it reaches a depth of twenty feet or more. The average thickness does not exceed two or three feet. The loess is much younger than the till upon which it lies. All the changes in the character of the drift surface, which have been referred to as indicating a long period of erosion and weathering, had taken place before the loess was deposited. Along the north line of the Se. ¼ of section 33, east of the river, in Nodaway township, a road cut through the summit of the ridge shows the loess at that point to be about twenty feet thick, and yet underneath this thick mantle the weathering of the surface of the drift is as complete as in places where the loess is thinner. It is conceivable that where the loess is thin the weather may continue to affect the underlying till, but the thicker deposits of loess would protect the surface beneath it from any change. The changes now apparent were accomplished before the deposition of the loess. In the deep railway cut in this same section, the thickness of the loess above the weathered, ferretto zone, is thirteen feet, and this weathered zone is at least twelve feet in thickness. In some instances there are indications of two distinct beds of loess. For example, on the top of the hill east of the Crabill brickyard, the freshly cut surface showed:

	FEET.	INCHES.
4. Light colored loess, not very ferruginous.......	6	
3. Yellowish sand, the upper 10 inches clay colored, the lower part showing cross bedding. The laminæ in the cross bedded portion are		

		FEET.	INCHES.
	inclined toward the east, away from the river valley....................................	2	6
2.	Dark colored, ferruginous, weather stained loess, quite different in appearance from No. 4....	5	
1.	Very much weathered drift, ferruginous, leached, the còbbles and pebbles much decayed, the whole stained with organic matter; exposed.	7	

A part of the foregoing section is illustrated in figure 37. The two beds of loess are very distinct in color, No. 2 show-

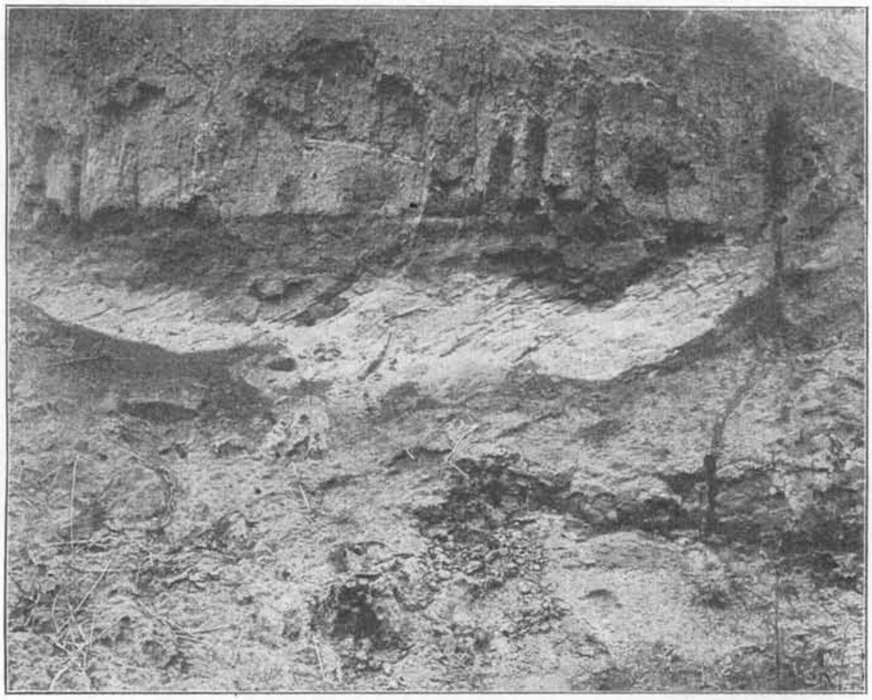


FIG. 37. View showing sand, partly cross-bedded, separating an old, weather-stained loess from an overlying, fresher body of the same material. View taken on hill east of Clarinda.

ing signs of much greater age than No. 4. The obliquely bedded sand, No. 3, may probably be of eolian origin. The altitude is 160 feet above the present flood plain of the river, and it is scarcely conceivable that this material could have been deposited by currents of water flowing toward the east.

The prevailing dry winds, however, are from west to east, and the cross bedded sand may represent readjustments which took place during a period when winds blew with more than usual force.

Flooded Valley Deposits.—In nearly all the valleys of Page county there is a formation which in some of its phases resembles loess; but in other of its aspects it is clearly an aqueous deposit. It has evidently been laid down since the valleys reached approximately their present depth. North branch near Clarinda has its channel cut in this material. It is yellowish in color, tough, jointed and obscurely stratified. Unlike loess it contains occasional pebbles and pockets of sand. A small greenstone, two inches long and showing glacial planing on two sides, was taken from this silt in the bank of North branch. No. 14 of the Hawleyville section illustrates the character of the deposit. Above the section described at Braddyville, west of the railway track, there is a body of this clay, twenty feet thick and forming a distinct terrace fifty yards or more in width at the top. The hard, enamelled scales of the gar pike, Lepidosteus, were found in this bed at Braddyville, the scales retaining their proper relations to each other as if the fish had been buried at the time the silt was forming. Between the point where the scales were found and the railway station, some recent cutting shows beds of stratified sand below the level of the clay. The same yellow silt is found beneath sandy alluvium in the valley of Buchanan creek, east of Braddyville. It is well shown in the bank of the Nishnabotna river west of Essex, where it is overlain by six feet of a fine, loess-like silt and two or three feet of black loam. At the Rankin Brothers' brickyard at Shenandoah, the section of the clay pit shows:

		FEET
3.	Loess-like clay	8
2.	Bluish stratified clay, clearly an aqueous deposit, but flexed more or less as if laid down on an uneven surface	1
1.	Porous, dark, granular clay	7

Numbers 1 and 2 are separated by a ferruginous band which looks as if it had been weathered and oxidized by long exposure to the air. The porosity of No. 1 is due in part to flexuous tubes, one-eighth of an inch in diameter, which pass vertically through it. The tubes are evidently places from which slender plant roots have decayed, for in the upper member, No. 3, there are similar tubes with the rootlets still in place. Some of the tubes in No. 1 are blackened with carbonaceous material due to the decay of the root tissues. No rootlets pass through No. 2. The tubes in the lower member of the section were made by plants which grew upon its surface before the overlying members were laid down. Nos. 1 and 3 resemble loess, but No. 2 records a distinct episode between the more recent and a more ancient period of loess formation during which the valley was temporarily flooded.

The distribution of this deposit is practically universal in all the valleys below a certain level. There has been some valley cutting since it was laid down, but little as compared with what took place beforehand. In the discussion of the topography of Page county there is a somewhat guarded suggestion that the drift upon which the topographic forms are developed by erosion, may be what geologists have been calling the pre-Kansan. Should later study prove this suggestion to be true, the flooded valley deposits would find easy explanation in the hypothesis that the water-shed, as really seems to be the case, coincides with the margin of what has been called Kansan drift. The great thickening of the drift along the water-shed and the marked difference in the character of the till and the maturity of the topography on opposite sides of the divide, certainly favor the probability of such an hypothesis being true. The principal streams of southwestern Iowa have their sources in the water-shed. The melting Kansan ice, under the conditions assumed, would furnish great volumes of turbid water which could find outlet only along the courses of these streams; and large quantities of silt would be distributed along the valleys. Granting this to be the explanation of the flood-water deposits so conspicuous in this territory, the principal part of valley making, on this assumption, would be referred to the Aftonian interglacial interval. An alternative suggestion may be made to the effect that the flood deposits belong to the age of the Iowan drift. The phenomena around the Iowan margin indicate that during the melting of the ice sheet belonging to this age the land was low, and the waters flowing away from the margin were too sluggish to transport objects larger than grains of rather fine sand. It is possible that the depression of the surface proceeded so far that slack water was backed up into the valleys of Southwestern Iowa, and that the formation discussed was thus deposited. The land was high during the melting of the Kansan ice as indicated by the overwash sheets and valley trains called Buchanan Gravels throughout northeastern Iowa. These point to energetic torrents flowing on relatively steep slopes and capable of carrying very coarse material. The deposits in question, however, are fine silt indicative of slack-water conditions. While the Iowan ice sheet did not come within many miles of Page county, it may have invaded the upper part of the Missouri valley and so have contributed volumes of water loaded with a large amount of fine yellow mud, which, following the Missouri and backing into the tributary valleys, produced the effects observed. On this supposition there would be ample time for the cutting of the valleys to their present depth between the retreat of the ice which distributed the Page county drift and the culmination of the Iowan invasion. Whatever may be the explanation, these valleys have been cut in the drift of the county, and they have been occupied by floods of turbid water since the major part of the valley making was accomplished.

Alluvium.—The broad bottoms of the stream valleys are everywhere covered with a rich alluvial deposit, which has accumulated slowly, partly by wash from the long slopes on either side, and partly by deposition from the very muddy streams when they overflow their flood plains. The streams of this region during all the medium and high stages of water carry an unusual amount of fine silt in suspension. Some of the alluvium, at least, is younger than the flood deposits described in the preceding section.

Deformations and Unconformities.

The rocks of Page county show a number of small folds and eccentricities of dip, but none are of very great amplitude. The most important is the Braddyville anticline. The rocks exposed in the sections of Braddyville and Hawleyville seem to constitute the crest of a fold, the axis of which trends north-northeast and south-southwest. The axis passes east of the old Shambaugh mill and all the coal mines in that vicinity, and in its northward extension it passes east of Henshaw in Taylor county. West of the axis the coal dips strongly toward the west. Between the Shambaugh mill and the Ingraham coal mine there is a dip of sixty-five feet in about two miles, while at Henshaw there is a dip of thirty-five feet in a quarter of a mile. East of the Burnside shaft at Henshaw the Braddyville limestones rise to the surface in the wash of a small creek, and at a level not very much below the mouth of the pit. The strong inclination noted in the localities mentioned is not continued as far west as the limestone quarries on the Tarkio, for there the beds assume a more nearly level position. The limestone exposed in section 36 of Pierce township, near Essex, dips rapidly westward, and indicates another fold which is probably parallel to the Braddyville anticline.

The principal unconformities to be noted are, *first*, that between the Carboniferous and the Cretaceous strata, and, *second*, the unconformity between the Pleistocene deposits and the underlying indurated rocks.

Soils.

There is little to be said concerning the soils of Page county. There is practically but one class, and that is the best. The surface is almost everywhere covered with loess.

The depth of the loess is not great, except in a few localities, but whether deep or not it is loose, easily cultivated, and so porous as to give the freest access to air and moisture. Even the underlying till, which was at first tough and intractable, has been thoroughly subdued and pulverized at the surface by long exposure to weather and the modifying effects of organic agencies. The annual growth and decay of the rank prairie vegetation for many centuries, the burrowing of animals that live beneath the surface, the influence of frost and rains, together with the chemically active constituents of the atmosphere, have all contributed to the making of a mellow soil, rich in all plant foods, and thoroughly permeable to great depths, to gases and moisture. The soils are not only deep and mellow and exceptionally fertile, but they are free, as a rule, from the bowlders which, in many parts of the United States, encumber the surface of the drift. There are here ideal conditions for succesful, scientific agriculture. Black, sandy alluvial loams have been developed in the broad valleys and other lowlands, and cover a large proportionate area of the surface. In the high quality and uniform excellence of her soils, Page county is not excelled by any similar area in Iowa, and Iowa furnishes a standard which is surpassed in very few instances the world over. Immense crops, especially of corn, annually bear testimony to the wealth-producing power of the soils; and this wealth expresses itself again everywhere in homes of comfort, culture and intelligence; in active, busy, growing towns, and in all the other external signs of thrift and prosperity.

ECONOMIC PRODUCTS.

Coal.

Next to the soils, which enormously outrank all the other geological formations of the county in economic value, may be reckoned the coal. The most important seam is that known as the Nodaway coal. It is this that is mined at Henshaw and New Market in Taylor county. The seam underlies Page county to an extent not fully determined. It crops out in the river bank at the old Shambaugh mill, and it is worked by shafts at the Ingraham and other mines near Clarinda, and at all the mines in the neighborhood of Shambaugh. At a distance greater than three or four miles west of the Nodaway river, it in general lies too deep to be worked with profit. The vein is very persistent. It is known in Adams, Montgomery, Taylor and Page counties in Iowa, and it is quite extensively worked at a great many points down the Nodaway valley in Missouri. The thickness of the vein is unusually constant, the range being from fourteen to eighteen inches; and the quality varies but little over large areas. The coal is usually worked by the "long-wall method." The Ingraham mine in the Ne. ¼ of section 11, Tp. 68 N., R. XXXVII W., is one of the new mines of the county, and one of the most important. The coal is found at a depth of about 100 feet from the surface. The shaft passed through the following succession of strata:

		FEET.
7.	Soil and drift; drift very much weathered near the top, and along joints to a greater depth	22
6.	Yellow shale	20
5.	Blue laminated shale	50
4.	Non-laminated shale	3
3.	Cap-rock	1½
2.	Shale	2
1.	Coal	1½

Quite a number of mines have been opened and worked at various times near Shambaugh. Lately most of the mining in this region has been done by J. W. Turner, Henry Fulk and G. W. Howard. Somewhat recently a shaft, more than 100 feet in depth, was made on the Maley farm, and good coal was found; but at the time the mine was visited very little had been taken out.

That the Nodaway coal was laid down on an extensive area of sea bottom is shown by the large territory over which it is distributed, the practically unvarying thickness and other characteristics of the seam, and the manner in which the coal is interstratified with marine sediments. There is no soil bed below the coal, and it is overlain, without transitional deposits, by shales rich in marine fossils. It bears a constant relation to a bed of limestone of nearly uniform thickness, the cap-rock, which likewise carries a number of typical marine species. That the coal was made of terrestrial plants is also clear; for an examination of the coal itself shows recognizable impressions of fern fronds, together with the stems of other pteridophytes. The microscopic structure is in accord with the evidence derived from more casual examination; the characteristic vascular tissues of ferns and their Carboniferous allies are readily detected.

Not much is known of the Linquist coal. It has not been prospected except at the one locality where an attempt was made to mine it with rather unsatisfactory results. The Linquist mine, as already noted, is located in the Nw. ¼ of section 24, Fremont township. Only a few thousand bushels altogether have as yet been taken out. The relations of this coal to the other members of the general Missourian section have already been discussed. The coal is doubtless present under quite a large area in the county. Since it lies near the surface it can be mined inexpensively; and when found under better roof, it will prove an important addition to the geological resources of the region.

The amount of coal mined in Page county varies from year to year. The output for any given year will not be recorded here; the reader being referred to the annual report of the Survey on Mineral Statistics. The limited thickness of the Nodaway coal precludes the possibility of working it on an extensive shipping or commercial scale. It, however, satisfactorily supplies local needs, and is an important factor in the development of the country. Its persistence or continuity over a large area makes prospecting a simple and easy matter, and wherever it occurs within 150 feet of the surface there is no doubt of the possibility of working it at a profit. It should be found within working distance of the surface on the East Tarkio, and it will yet be worked in many neighborhoods where it is not yet prospected.

Building Stone.

The stone quarries of Page county are of local importance. Some building stone is taken from the limestones of the Hawleyville and Braddyville horizon, but the greater part of the quarrying is done in the valley of the Tarkio. Local quarries are here quite numerous, and the more important of these have been already noted. The "blue ledge" of the Tarkio limestone is the most serviceable and the one most generally sought for. The stone has excellent lasting qualities, and is suitable for quite a variety of purposes. In meeting local needs this stone has a value difficult to estimate.

Brick and Tile.

The clay industries of the county are capable of much greater development than they have yet attained. The Carboniferous shales afford raw material for the manufacture of a large variety of clay products, from pottery to sewer tile and paving brick, but so far, in this county, no attempt has been made to utilize this inexhaustible source of supply. Just north of the county line, at Villisca, the McNaughton brickyard, well equipped and operated on a large scale, makes use of Carboniferous shales; but even here only a few of the possibilities of the material are realized. In Page county there are a number of brickyards, but all use Pleistocene clay.

One of the largest brick making plants in this county is operated by Mr. J. M. Crabill, on the east side of the river at Clarinda. River silt, or alluvium, is used. The plant is equipped with steam power, a Monarch machine made at Burlington, Ohio, large drying sheds, and all other necessary tools and machinery. The capacity of the machine is about 40,000 brick daily. The brick are dried on pallets, and are burned in large clamp kilns. There are three kilns, each with a capacity of 500,000. The annual output ranges from 2,000,-000 to 2,500,000. The local market is supplied and shipments are made abroad within a radius of 100 miles.

There are brickyards at Essex and Coin, which also use alluvial clays. At both places the brick are moulded by hand, dried on the yard, and burned in small clamp kilns. The yard near Essex is located west of the Nishnabotna river, in a locality where the yellow, flood-water deposits described in a foregoing section of this report, occur in great abundance. These deposits might be used in tile making, and there are other purposes to which they are adapted.

The Rankin Brothers operate a large brick and tile plant at Shenandoah. The clay used is a loess-like silt divided by a band of blue clay of undoubted aqueous origion. Steam power is used. There is a stiff-mud, auger, end-cut machine of the latest pattern; and there are well constructed drying sheds and all the other equipments for the manufacture of brick and tile. Six clamp kilns are used. The output of brick will average about 2,000,000 annually.

South of the state line at Blanchard there is a brick yard using a heavy bed of clay which is well stratified throughout a thickness of fifteen to eighteen feet, and capped by three or four feet of loess. The main body of this clay belongs to the age of flooded river valleys.

Water Supplies.

The streams of the county afford a large proportion of the people permanent supplies of water suitable for certain purposes. Wells, however, in some form or other, are the principal source from which water for domestic uses is obtained; and wells, after all, constitute the main reliance for all purposes for which water is needed, throughout the greater part of the county. Water is found in sand and gravel beds at various depths in the drift. Owing to the great depth of the Pleistocene deposits, it is seldom necessary to bore into the indurated rocks, water in abundance usually appearing before they are reached. In the neighborhood of Shenandoah, in sections 16 and 17 of Grant township, the drift is thinner than usual, ranging from fifty or sixty down to twenty feet, and a few wells are known to have entered the Cretaceous sandstone. Water seems to be abundant in this formation. In only one case was the entire thickness penetrated. Dr. Smith reports a case which illustrates in a typical way the water-bearing quality of the Cretaceous formation. Mr. A. Culp, who owns the Se. ¼ of section 16, Morton township, had a well dug on his place. At seventy-six feet he found sandstone and went into it five feet when water forced him to cease.

A well is reported to have reached "slate" at a depth of twenty-eight feet, in section 25, Nodaway township; another in section 24 of same township reached the shale at a depth of 108 feet; and in section 28 of Harlan township wells, it is said, reach rock at seventy-five or 100 feet. Along the ridges on both sides of the East Tarkio valley the limestone is encountered at depths ranging up to sixty or seventy-five feet. In general, however, water is obtained in beds of sand or gravel in the drift, before the underlying rocks are reached, and some of these drift-wells are fully 200 feet in depth. Beginning on the highlands of the divides, they descend below the level of the water in the adjacent streams.

Clarinda is supplied from a number of drive wells located in the lower part of the city, in the Nodaway valley. The wells end in gravel or coarse sand, at depths ranging from forty-five to fifty-nine feet. The supply is not all that those most interested desire. The amount pumped reaches about 70,000 gallons a day. At the hospital, near Clarinda, one five-inch and two six-inch Cook wells were used in 1899. The depth is seventy-one feet, and water is found in a bed of coarse gravel, eight feet in thickness, overlying blue shale. The amount pumped reaches about 110,000 gallons daily. The beds down to the shale beneath the water-bearing gravel are river deposits, which record a certain amount of aggradation or filling of the valley since erosion reached its maximum depth.

The town of Shenandoah draws its water supply from a number of drive wells supplied with Cook points, located in the river valley northwest of the main part of the city. The conditions here are quite similar to those at Clarinda. The wells stop in sand and gravel, at a depth of about forty-five feet from the surface. The volume pumped exceeds 80,000 gallons a day. The Nishnabotna valley has been aggraded in the same manner as that of the Nodaway.

A number of small springs are found along the small creek west and southwest of the town of College Springs. On land belonging to Mr. J. Dunbar, in the Nw. ¼ of the Nw. ¼, of section 5, Amity township, there is a mineral spring which has attained some reputation for its medicinal properties. Formerly patients resorted to this spring in considerable numbers to drink the water, and use it in the form of baths. The results were usually highly beneficial. More recently, for lack of time and capital to provide and maintain the requisite accommodations, no effort has been made to attract patients. The water, according to the report of Mr. Juan H. Wright, Analytical Chemist, Saint Louis, Missouri, contains per gallon:

Carbonate lime	8.415 grains
Carbonate magnesia	3.813 grains
Carbonate iron	3.566 grains
Sulphate iron	1.141 grains
Sulphate magnesia	3.761 grains
Chloride sodium	2.840 grains
Silica	.576 grains
Organic matter	1.265 grains
Carbonic acid	42.300 cu. in.
Bromide magnesium	trace
Phosphoric acid	trace

Water Power.—Owing to the fact that the streams of Page county have been working at their valleys long enough to cut their channels to grade, there are no water falls to furnish natural water power. Power has been obtained artificially at a few points on the Nodaway and East Nodaway, by putting in dams. There is a well equipped mill using 80 horse power, at Braddyville; a new mill has recently been erected at Shambaugh; and there is a mill with nine foot head of water, doing an excellent business at Hawleyville. Formerly there was a good water power at the site of the old Shambaugh mill near Clarinda; but the mill burned and the property has been allowed to fall into decay. There is also a small mill on the Tarkio river near Coin.

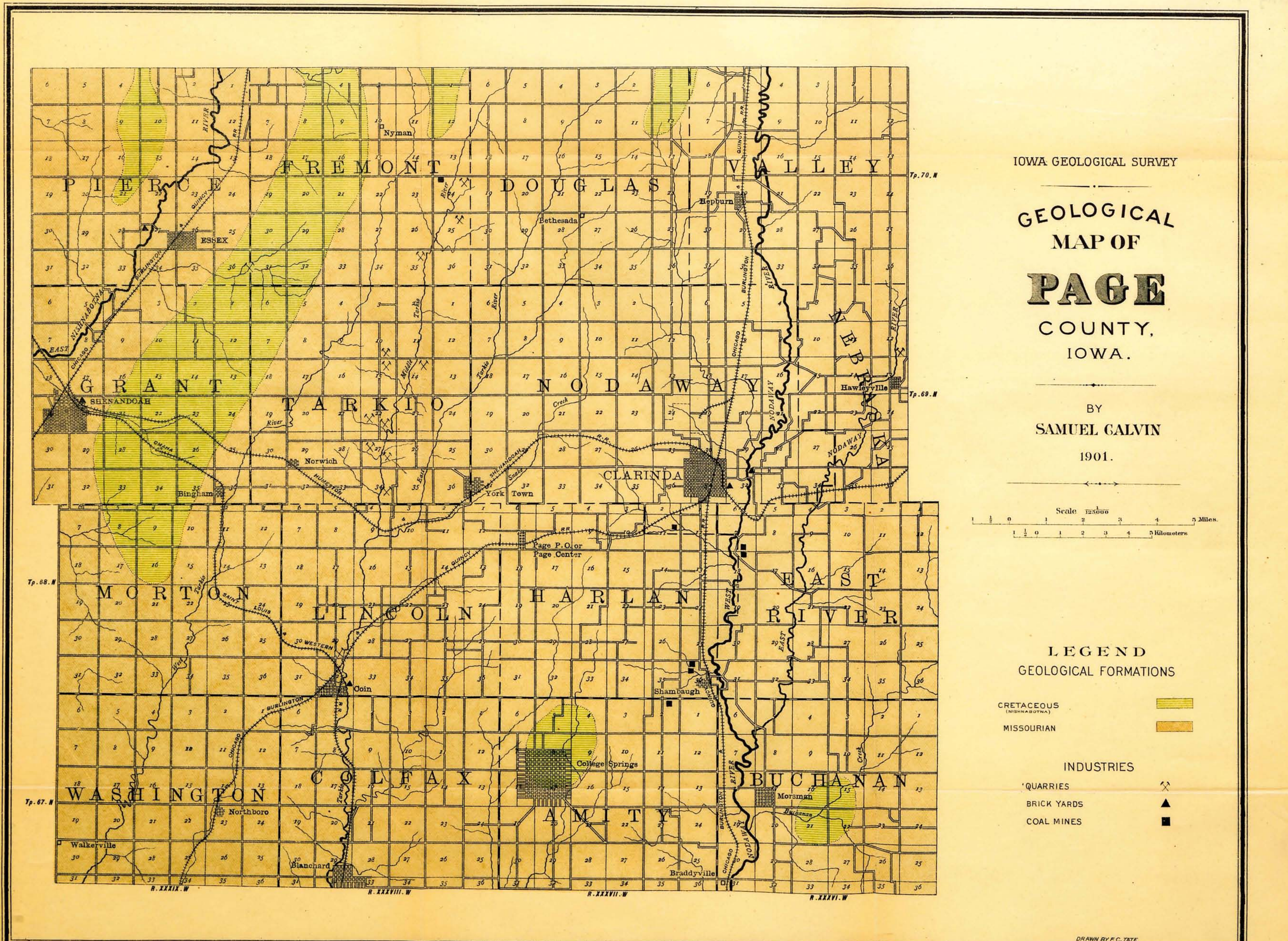
Summary.

Page is preeminently an agricultural county, and the cultivation of her splendid soils must always remain the principal industry of her people. The topography is of the mature erosional type. The surface is rolling, presenting on all the high lands a succession of swells and sweeping convex curves, with surfaces insuring perfect drainage, but not so steep as to cause serious wash or waste of the soil, or to interfere with easy cultivation. The stream valleys are old, wide, and deep. Practically all the topographic features have been devėloped in the deep mantle of drift which overspreads the surface. This dift is very old as compared with the glacial deposits covering northeastern and north-central Iowa.

With the exception of a few small and undefined patches of Cretaceous sandstone, the rocks beneath the drift belong to the Carboniferous system and to the Upper Coal Measures, or Missourian stage. These strata consist of limestones and shales, the shales predominating as to thickness, but the limestones appearing in the greater number of natural exposures owing to their greater powers of resistance. The shales and limestones found in Page county occupy a position from 500 to 600 feet above the Bethany or Winterset limestones that lie at the base of the Upper Coal Measures. There are two limestone horizons in the county, one represented by the exposures at Hawleyville and Braddyville, and the other by the ledges outcropping in the valley of the East Tarkio. These limestones are separated by more than 100 feet of shale. Near the top of the lower limestone there is an important coal seam, the Nodaway coal, which has been mined quite extensively along the valley of the Nodaway and its branches in Iowa and Missouri. The coal is from fourteen to eighteen inches in thickness, and has the great advantage of maintaining uniform characteristics as to thickness and quality over large areas; and over a large portion of the region in which it is known, it lies near enough the surface to make mining comparatively inexpensive. The persistence of this seam insures an aggregate volume of coal within a given territory quite equal to that occurring in other localities where coal mining is carried on on a more extensive scale. The Nodaway coal in Page county is capable of much greater development than it has yet attained. Some of the new mines, the Ingraham mine near Clarinda for example, show some of the possibilities in this direction. The Linquist coal, which lies near the top of the Missourian section in this county, has not yet been prospected enough to enable any to forecast its possibilities.

The building stone industry is not likely to attain much greater prominence than it has already. The ledges quarried in the Geers and Erickson quarries will always be of great local importance. The quality of the stone as material for bridge peers and heavy foundations, especially in the case of the "blue ledge," is all that could be desired. The fact, however, that in general there is but a single ledge available will prevent the installation at any point of labor-saving appliances, and hence the work of quarrying will remain comparatively expensive.

The clays of Page county are inexhaustible as to quantity and excellent as to quality. Shales similar to those above the Nodaway coal are manufactured on a large scale into



IOWA LITHO. CO.

paving and structural brick, at Nebraska City, and they are used extensively in brick making at Villisca. At present only Pleistocene clays are worked at the various brick and tile plants in this county. The Pleistocene deposits include (1) glacial clays or drift, (2) yellow, silt-like clays, which were laid down in flooded valleys. (3) loess, which seems to present an older and a later phase separated one from the other by aqueous or eolian deposits of a different type, and (4) alluvial sands and silts of recent origin, found in the valleys, especially upon the flood plains of streams, overlying all deposits which are referable to the coming and going of the great ice sheets of the glacial period.

The question of rock oil and natural gas is one of universal and ever present interest. The strata underlying Page county are probably as rich as the average rocks anywhere in bituminous material from which oil or gas might be derived by natural distillation. There are some anticlinal folds, as the Braddyville anticline, which might afford conditions for the accumulation of these products; and if boring is to be successful, it must be done along or near the crests of these folds. The prospect hole near Clarinda, to which reference was made in the early part of this report, could scarcely have been more favorably located, and yet this boring was carried down 1002 feet without finding either gas or oil. No assurance can be given that these products occur in commercial quantities beneath the surface of this region, but if either is found, it will be at a depth greater than 1000 feet. It must be remembered however, that the folds here are small, and small folds could not affect the strata to any considerable distance from the surface. The test hole referred to has explored the rocks away beyond the depth at which the small superficial folds could possibly produce any effect.

Apart from the natural resources, which a study of the Geology of Page county reveals, the phenomena of the region are of the highest scientific interest. In these counties of southwestern Iowa there is material which, when properly collated and interpreted, will aid in the solution of some of the intricate problems of geological history, and many of these problems will have very direct economic bearings.

NOTE ON THE CORRELATION OF THE CLARINDA WELL SECTION WITH THE SCHEMATIC SECTION OF THE CARBONIFEROUS.

BY CHARLES R. KEYES.

The Clarinda well section, as given by Professor Calvin on page 419 is of special interest at this time for the reason that it furnishes very important exact data regarding the formations represented in the southwestern part of Iowa. These formations are nowhere very well exposed at the surface, partly on account of the peculiarities of the surface relief, and partly because the stratified rocks are covered by unusual thicknesses of glacial deposits. The general section of the Coal Measures has been accurately determined farther to the south, and along the Missouri river and many of its tributaries in Missouri and Kansas, because of the many fine outcroppings. In the tracing of the boundaries of the several terranes from Missouri into Iowa certain unlooked features in the stratigraphy and the geological structure are met with that are not forced upon the attention of the observer when approach is made wholly from the Iowa side.

In consequence, several modifications of interpretation are suggested in the consideration of the general correlation of the beds passed through in sinking the Clarinda well. The changes in themselves are of small import and do not materially affect the conclusions reached by Professor Calvin. However, as tending towards accurate results which must be obtained with reference to the region still farther north, the proposed modifications in the correlation of the beds of the Clarinda well are thought to be worthy of note.

The parallelism of the formations and beds of the two sections are best shown in tabular form:

TERRANES OF THE MISSOURIAN SERIES.	Thickness in Feet.	
	General Section.	Clarinda Well.
11. Cottonwood limestone	10	
10. Atchison shales	500	
9. Forbes limestones	30	
8. Platte shales	150	{ 100 5 20
7. Platsmouth limestones	30	20
6. Lawrence shales	300	105
5. Stanton limestones	35	20
4. Parkville shales	100	}
3. Iola limestones	50	} 180
2. Thayer shales	75	}
1. Bethany limestones	100	20

The most noteworthy feature brought out is the fact of the absence of the Iola limestones. This terrane thins out and disappears before reaching the southern limits of Iowa. The Thayer and Parkville shales are thus brought together in Iowa, giving to the shale formation immediately overlying the Bethany terrane, an unusual thickness.

In the Platte shales is a limestone five feet in thickness. Thin bands of limestone occur in all the shale formations and the presence of one of them in the Platte is not anomalous. Instead of being regarded as representing one of the great limestones it is best considered as an unimportant layer that is liable to be found at almost any horizon in the shales. By ignoring the presence of this thin limestone in the upper part of the Clarinda well, the more normal thickness of the Platte shales is displayed.

This readjustment gives for the thickness of all the beds passed through in the well the values that should be expected from a consideration of the work done in Missouri.

The Clarinda well was manifestly begun at a horizon a few feet beneath the top of the Platte shales. The Forbes formation, which is represented in the region by the limestones exposed at Hawleyville and Braddyville, were of course not encountered. The Nodaway coal, which is an easily recognizable horizon throughout a large area in southwestern Iowa, should be expected to be found about 100 feet above the top of the well section.

GEOLOGY OF CLAY AND O'BRIEN COUNTIES.

BY

THOMAS H. MACBRIDE.

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THOMAS H. MACBRIDE.

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INTRODUCTION.

LOCATION.

The two counties which form the theme of our present discussion lie in the extreme northwest portion of Iowa. They are a part of the great northwest prairie, a region only recently come to the state of complete settlement and cultivation. Osceola and Dickinson bound these counties on the north, and so separate them from the Minnesota line; on the west Sioux county divides them from the western boundary of the state; on the south are Buena Vista and Cherokee counties; on the east lies Palo Alto.

For purposes of study and detailed description, all these counties must be viewed together. No partial treatment such as here attempted can give any very satisfactory idea of the situation, from the standpoint of physical geography, or even topography. The local student must in justice alike to himself and his theme, consult reports of all the counties named, and indeed of the whole state. The natural history of this region, past and present, though seemingly simple, monotonous, and so uniform that the story of a single township might be taken as the type of any or of all, nevertheless in a thousand minor ways shows peculiar differences of an interesting and instructive kind. The student of topography finds his problem ever changing, often within limits singularly narrow, within a mile or two, and the forces which have affected the condition he would describe have acted nowhere in precisely the same way; rather have they inter-acted in such a manner as to produce results the most varied and surprising. Even in these prairie regions, no traveler, however expert, can predict what is to be found in the next township, much less the next county. We have, generally speaking, in these two counties all the diversity of which a prairie is capable, especially in a region destitute of indurated formations, where the only plastic material is the bondless, unstable drift. We have hill-bordered lakes, rush-grown marshes and fens, slow-creeping, tortuous creeks; we have miles of upland perfectly level, at length cut by erosion channels so deep and with walls so precipitous as fitly to receive the name of canons; from the sides of these canons issue springs giving rise to clear perennial streams; we have hill-country, high, irregular, tossed about with no reference at all to present drainage; we have fine rolling prairie where the drainage is perfect, the slopes long and gentle and every thing contributes to fortunate husbandry.

The native flora likewise is interesting, both in character and distribution, and its study will be of economic importance in our effort to solve the problems of the treeless prairie, the problems of forestation and ornamental planting for the homes of a cultured people.

PREVIOUS STUDY OF THESE COUNTIES.

Some members of the celebrated Lewis and Clark expedition may have reached this part of Iowa, in 1803-6. We have seen that certain of the party had personal knowledge of the Okoboji and Spirit Lake country.* Nicollet reports that he saw both the origin and the debouchment of the Little Sioux river, but he was unable to follow its windings, and his map of its course is hypothetical, chiefly. Owen maps the region† and appears to have visited it. At any rate, his map shows a remarkably accurate knowledge of the course of the river just named, especially in that part of its windings which fall under consideration in this present report. Hall, of course, did not reach our present problem, as his investigations were confined largely to a study of the rock exposures of the eastern portion of the state. Dr. White‡ devotes a page or two to our counties, but, of course, gave less attention to what was then an unoccupied and unsettled prairie.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of these counties is, of course, in some ways very similar to that of the adjoining districts already described in these reports. We are still on the western

*See vol. X of the present series, pp. 190-1.
†Geol. Surv. of Wisconsin, Iowa and Minnesota, map.
‡Report on the Geol. Surv. of Iowa, vol. I, pp. 204-5.

margin of the Wisconsin drift, and the same agencies were efficient here that brought about further north the more remarkable topographic features around Okoboji and Spirit Lake. In one sense our present history is but a continuation of the former. We ought to find the same knobby drift here claiming its share of the terrane, the same gravel trains following the course of the streams, the same pebbly drift spread out in level plains, or marked anon by the sculpture of erosion; and, as we may presently discover, we do find all these general features; and yet the whole scene is different and the landscape may fairly and with reason claim a new description.

The morainic hills which in Dickinson county are a feature so conspicuous, cease there rather abruptly just north of the southern boundary of the county. They are succeeded by a high but marshy plain which continues south into Clay county for several miles, drained with increasing efficiency, especially to the westward by Meadow Brook. To the east, however, the marshes presently deepen into lakes, the characteristic morainic topography gradually reappears, so that nearly the whole eastern side of Clay county is given up to typical knobby drift, generally in less pronounced form, but sometimes showing disconnected hills and ridges 150 to 200 feet above the stream valleys. The best display of this topography is seen in Freeman and Logan townships, passing thence east in full strength into Palo Alto county. Some of the more characteristic and notable of these hills may be seen from the railway train as the traveler passes the town of Ruthven. The hills lie to the south, and more than one of them enjoys a local reputation of being "certainly the highest point in the state." If brought to the actual test, however, they would surely one and all disappoint all local ambitions in this respect by perhaps two or three hundred feet.

As we pass south through the eastern townships of Clay county the hills grow lower, gradually fading from the landscape to the south and east, though the general level is still high and continues so far around towards the west and into Buena Vista county. At Gilletts Grove the hills meet the Little Sioux river and deflect it almost directly westward, sending it ploughing through great beds of typical Wisconsin drift, as we shall see, until the stream passes beyond our present limits.

There are traces of this same form of morainic material in Waterford township of Clay county, but aside from this all the remaining territory now under consideration may be described as a level plain, not that it is absolutely level; it is a watershed of the prairie type, sending its waters east and west, all indeed into the Missouri river at the last, but strangely and paradoxically enough, starting the great majority of its streams toward the east and south.

Constructional Valleys. In the whole region now under consideration, nearly every important valley is at first wholly constructional. Some of these valleys are mere depressions in the general surface; some are the beds of lakes; some have been lakes and are now largely filled up or have found a more recent outlet and are more or less perfectly drained; others accommodate the waters of some slender, tortuous, but perennial stream, by courtesy called a river. Of course, where streams now occupy these valleys erosion must be taken into account, but in these cases even the amount of erosional excavation is generally insignificant by comparison. In order rightly to understand what lies before us in our discussion, we must keep ever in mind the difference between a valley of erosion and a valley of construction; the former is a ditch, a drainage channel shaped by the descending waters; the latter, the constructional valley, may have almost any form or contour. In the more strictly morainic part of our present territory the valleys of construction are basin-like and form the beds of marshes or lakes; westward they are generally long, more trough-like, arcurate, parallel to each other and to the local margin of the drift. Of the first type we have illustrations through all the eastern part of Clay county, Swan lake, Trumbull lake, Lost Island lake, Elk lake, Mud lake, not to speak of dozens of unnamed swamps and marshes occupying basins which have no reference to drainage either past or present, and owe to present erosion only diminished depth, income and not out-go. Some of these lakes are of sufficient size and permanence to merit special description. Mud lake, in Garfield township, is rather shallow, a marsh in very dry seasons, but described as showing ordinarily a handsome expanse of water, covering nearly an entire section. Elk lake, in Logan township, is a thing of beauty, a little gem, begirt with native trees and surrounded by precipitous hills; said to be fifteen or twenty feet deep, not at all marshy, overflowing to the east where it joins certain wide marshy fens of Palo Alto county; certainly worthy of preservation if for no other reason than for its attractiveness. Elk lake is a typical morainic pool and owes its existence to precisely the same conditions which gave us Spirit Lake and Okoboji.

Much larger than Elk lake are Trumbull and Swan in Lake township. Taken together they are four or five miles long, of varying width, never exceeding a mile, and cover in all probably three square miles. These are permanent bodies of water, though with marshy borders and consequent variable expanse. Trumbull lake seems to overflow in two directions. The ordinary outlet is westward to join a great slough that stretches through the northwestern part of Lake township, but on occasion also, at least until very recently, the waters of Trumbull lake have had escape to the east, through a marsh here known as Mud lake again, to join at length Lost Island lake and so find exit through the outlet of the latter body.

Lost Island lake is a real lake, worthy to be ranked with those of Dickinson county to the north. The greater part of its expanse is in Palo Alto county, but its outlet is in Clay county, it forms part of the Trumbull series and therefore may properly be here considered. It covers altogether some four square miles. Its extreme length is perhaps six miles; its greatest breadth, two miles; and it is reported twenty or thirty feet in greatest depth. It is furthermore said to be fed by perennial springs that boil up from the sandy bottom. Its shores are beautifully indented, winding, often forming sandy beaches; to the north and east are low gravelly hills that serve to break the horizon; to the south and southeast, lie wide undrained flats and marshes, extending half way across Freeman township. Where marsh and lake are at their narrowest, the public highway crosses by a long wood-bridge, supported on piles driven into the muddy bottom. From this bridge the view northward and eastward across the lake is one of the finest. Several handsome farmhouses stand along the shores and provision is here made to entertain the summer tourist. From spring till late in fall these lakes less disturbed by boatmen, seem to be the abode of innumerable wild fowl. Ducks sail in flocks above the surface or plash all day long in the sunlight; killdeer, snipe, and tilting sand-pipers run along the muddy flats and sandy beaches; amid the dark bulrushes the startled bittern croaks and rises; in the more sombre autumn days the sedgy swamps rustle and sway with the gathering clans of strident blackbirds, when yellowheads, redwings, cowbirds, actually becloud the bul-rush-darkened landscape.

All these lakes lie in valleys of constructional type. They differ from similarly formed depressions to the west of them in that they are shorter; they form lakes and not river channels. They go with the moraine and are not found outside of it. However, in Clay county are to be seen some remarkable intermediate types. For instance, in Meadow township, extending through sections 9, 17, and 19, in Lake, and sections 25 and 36, in Meadow, is a long, narrow marsh. It is really a valley with tolerably steep banks in many places, formed by low, approaching hills. In wet seasons a lake, at other times nearly dry, its outlet stretches off toward the east and unites with that of Trumbull, and so establishes relationship with the general series.

But a more remarkable valley of the constructional type may be seen in Logan township. As one drives south from Elk lake, he suddenly comes in view of an immense valley, sweeping in a broad curve from east to west entirely across the township. The depression lies from 100 to 120 feet below the general level, and is broad enough in its greatest expanse to receive the waters of the Mississippi. But in some places we look in vain even for a stream. We find but a marsh with no discoverable current. In other places a small rivulet may be discovered winding back and forth across the level bottom land. The rivulet receives small affluents from the north, some from the south, but, strangely enough, the valley narrows as we approach the mouth, until near where it debouches into the valley of the Little Sioux, it becomes simply an erosion channel, hemmed in on both sides by precipitous hills. This valley with the little stream that wanders through it is called Elk creek; its general course is westward, it receives the overflow of Elk lake, not directly as it appears, but by the way of the chain of fens and marshes mentioned above, lying in Palo Alto county, away to the east of the point of origin. West of section 15 the banks of the valley are very precipitous, remarkably so when we consider that their material is nothing more resistant than the common pebbly Wisconsin clay. The sides of the valley, the banks, for such they really are, are broken everywhere by short, little, narrow gutters and secondary ravines seaming the grassy sides, affording the general impression of very recent erosion. In fact, everything indicates that rapid erosion is going on now. The land is shaping itself almost before our eyes. Give us a little time and these beetling banks will loose their minatory character; long, gentle slopes will take the place of bluffs, now so steep and so forbidding; even the table-land will vanish and long, low valleys will lead its waters down to the then persistent channel of Elk creek.

Such constructional valleys occur all over the area we here describe. Some of these will be further discussed under the general topic drainage. It remains only to repeat that they are especially characteristic of a morainic region. As has been said, kames and lakes, ridges and trough-like valleys make up especially the eastern and northern parts of Clay county. These features diminish somewhat southward; the southeastern part of Garfield township is a high but marshy table-land; but in the northwestern part of the township the kames and ridges are high enough and strong enough to change the course of the river, as already noted, soon to be particularly described. In Buena Vista county to the south they will doubtless reappear to furnish forth for Storm lake a setting at once adequate and appropriate.

These hills are not anywhere continuous but occur in groups, marking, as it appears, local halts and recessions of the disappearing ice. However, these hills, the high plains between the streams and the level plains which lie in some places by the streams themselves, form three distinct types of topography discoverable within the limits of our present discussion. These are all associated under the general topic, "drainage," and may be conveniently discussed under such heading.

DRAINAGE.

The streams of the region before us flow generally south, southeast or southwest at length, but the country as a whole has a southeastward slope. Thus, a profile of the recently constructed line of the Chicago, Rock Island & Pacific railway shows a rather uniform declivity from section 32, Tp. 98 N., R. XL W. to section 33, Tp. 94 N., R. XXXV W. Nevertheless, points on the open prairie, north and south in Clay county, show the same elevation. The country throughout is rather better drained than are some of the adjoining counties. This is owing in large part to the fact that the constructional valleys referred to inaugurated a system of watercourses to which subsequent erosion on all sides has more or less extensively contributed. However, the streams of Clay county especially, those tributary to the Little Sioux in particular, are creeping, sluggish currents, winding about, as Meadow Brook, from slough to slough. Even the larger streams, the so-called rivers, are exceedingly dilatory currents having the slightest fall, even long after their union with each other. The Little Sioux passes entirely across Clay county from north to south and forms its only drainage channel; in O'Brien, a branch of the Little Floyd, Mill creek and Waterman creek are similarly beneficent and efficient. Each of these streams is here worthy of special study and description.

The Little Sioux river enters Clay county near the northwest corner of Summit township and follows a broad constructional valley to the southeastern corner of the same township. By this time the valley has widened southward into a broad, sandy plain, the common basin here of the Sioux and the Ocheyedan. Meeting the Ocheyedan the united waters of the two streams flow sluggishly athwart the same sandy plain eastward until they encounter the westward slopes of the morainic hills already described as occupying the entire eastern side of the county. By these slopes turned southward the stream passes out of Sioux township into an erosion valley continually narrowing, the course nearly south but very tortuous, between high banks of Wisconsin drift, to Gilletts Grove; here the gravel mounds of the moraine approach again from the south and send the river westward and southwestward five or six miles until, reinforced by the waters of Willow creek, it starts south again and goes winding through great beds of drift as before, now south, then east, north, south, then west, then south again beyond the limits of the county, only to emerge again at a point about four miles further west to cut for less than half a mile the south line of Douglass township, then out again and on westward some five miles further when it reappears in Peterson township, traverses most of its southern sections and finally cuts the O'Brien county line at an angle of forty-five degrees, flowing straight to the northwest. In O'Brien county the course, though tortuous, is westward but for a short distance, a mile or two, when the stream suddenly bends southward and so passes beyond our limits for good.

That a prairie stream, draining a country destitute of rocky ledges or denser strata, should pick out a course so crooked

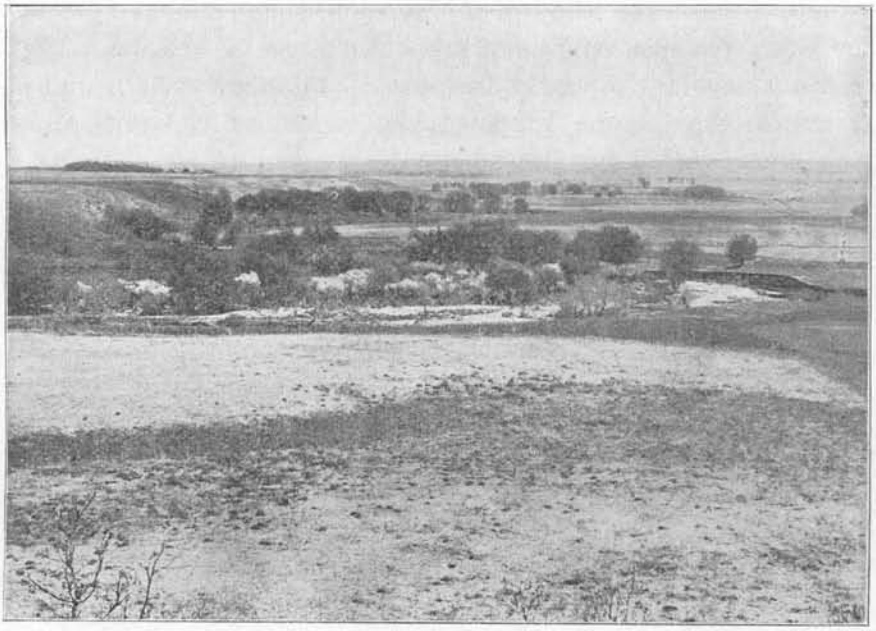


FIG. 38. Where Willow creek debouches into the valley of the Little Sioux.

is certainly a matter of curious interest. The contrasts shown when one compares different parts of the river valley are also very strange. The upper part of the valley from Summit township to Spencer and beyond, is wide and shallow, flanked generally on both sides by beds of gravel. At Spencer the valley has widened to a broad sandy plain, some two miles wide and seven or eight miles long. Here the river even after it has received the additional waters of several tributaries still occupies but a narrow channel, shall we say ditch, in the midst of the plain, its banks are of black alluvial soil, and its flood plain is perfectly evident, nowhere wide, but about ten feet lower than the gravel and marked generally, as in the neighborhood of Spencer, by a distinct terrace. As we proceed southward all this changes. The gravel follows us of course, and is to be seen at intervals for the entire course of the stream, but the valley itself suddenly becomes narrower and deeper, the stream winds between high banks that are steep, precipitous, though of clay, cut on each side and gashed by sharp ravines, canons of present or recent erosion. This feature becomes so marked that in Herdland township and in Lee township (Buena Vista county) immediately south of it, the river valley has long been designated as the "straits," often no more than half a mile wide and at the railway bridge above Sioux Rapids even much less. The exact distance here as quoted by the railway engineers is nineteen hundred and ninety feet. The same thing is seen at Peterson, ten or twelve miles by rail farther down the stream, and indeed throughout the whole course of the river from Gilletts Grove south and west. The bluffs of clay are in some places two hundred feet high, and the effect is picturesque in the extreme. The railways have laid their tracks across the valley by bridges, eighty feet above the water, and the trains go swinging and creaking and winding about the sharp turns of the precipitous face of the clay bluffs and through channel-like cuts as if we were indeed in a land of mountains and rocks.

Between Sioux Rapids and Peterson the valley widens out, especially in the vicinity of Linn Grove and west, where a tributary comes in from the south. Here the course of the stream was doubtless determined in large part by some constructional depression which possibly remained for some time a lake or marsh before the stream affected the present deep channel from Peterson northwest. The yet remaining marshy plain west of Linn Grove and the accumulated sands about the town of Peterson, which overlie the Wisconsin drift, may be explained by some such supposition.

Waterman creek, which drains the eastern tier of townships in O'Brien county, shows an exact parallel, only on a much smaller scale. Its valley also is notable for inequalities of width; the average of the flood plain is perhaps half a mile. The stream rises northwest of Hartley and for eight or ten miles is simply a prairie creek wending along through an almost level country, with slow current, as if from slough to slough. Just before it reaches Grant township it receives an important tributary, Little Waterman, from the west, and forthwith begins to cut into the body of the Wisconsin clays, and so breaks down to the level of the Little Sioux through a series of chasm-like valleys, the walls almost perpendicular banks of clay, sometimes one hundred and fifty feet high. Barry creek, which comes in from the west, and Henry creek, which runs parallel to Waterman on the east, and is tributary to the Little Sioux, offer on smaller scale exactly the same topography. Indeed, the freaks of erosion as displayed by these streams in the southwest corner of O'Brien county are unmatched so far in a prairie country. No photography can do justice to the subject. One is reminded of the Bad Lands and the Mesas of the distant west. The proverbial section-line road which elsewhere follows like a path of destiny the laws of the surveyor, here, for once, falls baffled, toils painfully up the channel of some lateral stream or ceases altogether, leaving the traveler by wide detours to find, if he may, some easier thoroughfare, some gentler gradient.

The comparative newness of the landscape is shown by the peculiar instability of the banks where erosion and change is still, with rapidity, going on. Little narrow gutters run down the face of the bluff sometimes at intervals to be measured in rods. These in winter are choked by snow; in summer they form conductors for rain water of higher grounds and deepen rapidly where not protected as they sometimes are by a curious growth of little burr oak trees. The face of the bluff is every where so steep that landslides are a common feature. Every spring patches of grass-covered slope slip down, sometimes acres of it in a place. This was especially noticed in the valley of Waterman. The marvel of it all is that no sooner one ascends the bluffs than he finds himself upon a plain often almost perfectly level. Section 31, in Peterson township, for instance, is only partially drained, shows lakes and kettle-holes, though only a mile from the river and one hundred and sixty-five feet above it. Driving along the plain from the west, for example, the explorer approaches without the slightest fore-warning these wonderful ravines. Beautiful farms are thrust out like promontories into the valley of the river commanding, as the channel bends and winds, prospects romantic in the extreme, shining meadows, glittering waters, wooded slopes, sunny fields, and shadowed chasms.

Such is the topography of the Little Sioux valley as it skirts our southern limits, a distance of twenty or thirty miles as the river flows. It is simply a successful effort on the part of the Little Sioux river to cut through the broad morainic ridge of Wisconsin drift which, through all the upper course of the stream, as far south as Spencer, has been able to restrain its waters, sending them to the south and east, parallel to the course of the Des Moines. This ridge occupies all the central portion of Osceola county, the northern half, roughly speaking, of O'Brien county, and continues in a southeastern course diagonally across Clay. It represents, so far as reported, the farthest great out-push of Wisconsin clay in this direction; the outer southwestern boundary of the formation is not yet clearly delimited. The belt of morainic hills already referred to as occupying so large a part of Dickinson county, and all eastern Clay, is recessional, marks the margin of the retreating glacier, the point at which it ceased to be aggressive, halted and laid its far transported, mingled burdens down. When the final retreat began the ice over the ridge in question appears to have been comparatively thin. At first all drainage went over the western slope, spreading a burden of sand and gravel over all the country to the west and south, filling all low places, as at Sibley and Sheldon, flooding the water courses which we name the Rock and Floyd, with their minor tributary streams. Mill creek also received its share and Waterman was likewise a channel for a lessening drainage from the margins of the melting ice. As thawing went on and the retreat proceeded toward the north and east, the margin of the ice rested at length in the constructional valley that now accommodates the Ocheyedan river. Waterman and Mill creeks were now shut off. The course of the principal drainage went south and east, possibly by way of the Coon river and the Des Moines. At any rate the drainage from the melting ice found a wide lake bed where to-day stands the town of Spencer, and proceeded to fill it up with sand. Here, it would appear, was in those days a lake far wider than any now existent in northern Iowa. We may read its limits by traversing a plain of sand; we may follow its low shores north of Spencer, and especially on the east and south, with ease. Lake Spencer, if so we may call this prehistoric water, included perhaps all of Lost Island lake and the whole system round about it. To the east its waters may have filled in part the Logan township slough. However we may attempt to explain it, the fact is evident that for some time Spencer lake received all the drainage from melting ice in this part of Iowa, and its whole area, as well as the broad areas now occupied by the Ocheyedan and the upper Little Sioux, was in this way filled with sand and gravel. Lost Island lake was out of the course of drainage and remained deep. The case is parallel to that of Spirit Lake and that of Okoboji in Dickinson county.* The deposition seems to have gone on steadily until the gravel had filled up not only Spencer lake from east of Dickens almost to Everly, but had choked up all the affluent streams as well, at least as far back as Milford. All this time erosion had been working northward from a pre-Wisconsin channel

*See vol. X of this series, pp. 210-11.

south of Cherokee and eastward by what, as we have seen, was a constructional valley entering from the southeast the valley of Waterman creek, working back in fact along the present valley of the Little Sioux until it cut through at Peterson, forming the rapids there (a mill-seat, by the way, so narrow is the valley), and drained first the constructional marsh or lake that lay in the vicinity of what is now Linn Grove. This out of the way, erosion began at what we now call Sioux Rapids, cut through the divide of Wisconsin clay that limited our Spencer lake waters to the south, possibly near Gilletts Grove, the "straits" were excavated, and Lake Spencer drained. The erosion of subsequent time has sufficed only to cut down the narrow channel which in the gravel plain or old lake bottom the rivers with their flood plains occupy today. The bridge at Spencer crosses this channel entire, flood plain and all. This also accounts for the gravel banks which form a topographic feature so conspicuous in many places, as in Sec. 20, Tp. 97 N., R. XXXVII W. The newness of the whole situation as it now presents itself becomes more evident the more we study it. The narrowness of the river channel from Gilletts Grove to Sioux Rapids, the very fact of the rapids, used by the pioneer for milling purposes, the peculiar erosion features at the mouths of all tributary streams, of Willow creek and Waterman, the erosion now in progress, every bank gashed with narrow gullies, steep and trough-like, as the valleys of a roof, eroded with every summer shower—all these things seem easily explainable only on the theory that the Little Sioux river has only recently, as things geologic go, made its way across the divide and found an outlet by way of Waterman valley down the Missouri drainage slope. The Little Sioux would thus seem to be a tributary to Waterman creek rather than the reverse. The possibility of this appears when we reflect that the body of drift with which we are concerned is known to cover an earlier land surface already long the subject of erosion and amply supplied with drainage channels. South of the known limits of this later drift these channels are still in service, the creek and river valleys of the country; the ultimate drainage system of today is just the same as before the later drift came on. The Wisconsin simply obliterated all the sources of the streams and we have but to consult a map and in imagination carry back the older channels as they now appear, to form at least an approximate conception of their former direction and position. The northwest corner of Iowa has always been a highland and the drainage has for ages been toward the south. During the reign of the glacier the pre-Wisconsin channels beyond the ice margin were constantly in use as their far-spread gravel trains now abundantly approve. As the ice retreated the waters would no doubt tend to cut back into their earlier channels, and this certainly sometimes happened; but in many places constructional depressions on the surface of the newly uncovered drift seem to have started streams in new channels, only here and there or at the last to become coincident with those preglacial. Thus Waterman creek, probably Mill creek too, represents an older valley; possibly the original course of the Little Sioux. Compare, for instance, the present course of that stream south of Cherokee, the course of Waterman creek and the upper course of the Ocheyedan. The vast pile of drift extending diagonally across Osceola county, as already described, acted as a dam when once the ice retreated, while a great constructional valley carried the waters far to the east, again to be sent westward by the morainic hills about Sioux Rapids and northward, hills perhaps still encased in ice. The course of the Coon river suggests still another pre-Wisconsin drainage channel which might once have carried the waters of the Little Sioux. This channel would have extended from a point in the present valley of the Little Sioux, west of Linn Grove, south through a range of now existing swamps to Storm lake. This is but a suggestion, and may not be further discussed until the topography of Buena Vista county is better known.

However this may all be, the deep, narrow channel of the Little Sioux results from a comparatively late draining of what we have been calling Spencer lake, for the most part a wide marsh, when the ultimate drainage came on. Once the Little Sioux had cut its deep channel, the Waterman, too, found opportunity to cut back and down to the level of the larger stream and has since then effected, in larger part, what we see in Grant and Waterman townships, cutting what was once almost a level plateau into the holes and chasms we have already described. The same thing occurred at the mouth of Willow creek, in Clay county. Willow creek comes out into the channel of the Little Sioux, in Herdland township, nearly a hundred feet deep; empties into the "straits" in fact.

The whole eastern part of Gillett's Grove township is remarkable as typical Wisconsin prairie on the upland, and yet characterized by drainage which narrows the channel at its debouchment. South of Spencer is a wide plain, thousands of acres as level as a floor; a Wisconsin plain with no evident kettle-holes, and no perceptible or evident drainage, save here and there a few shallow, far-reaching creek bottoms; no sculpture, except in the immediate neighborhood of the river. Here, however, the carving is always notable, emphatic, in deep relief, the sides of the channels steep, precipitous, the valleys narrow as in a land where limestone and not simple drift had formed the subject matter on which the sculptor had plied his art.

In all these cases it is to be noted that, as a rule, the east and northeast sides of the streams slope down more gently; the steeper banks are on the west and southwest. Erosion is manifestly greater on slopes warmed by the western sun. There are, of course, many exceptions, due to various local causes. In the vicinity of Sioux Rapids, and all along the narrow course of the river here, the north banks, also, are generally precipitous. The north bank of the river near Sioux Rapids, seamed with line-like erosion channels, is shown in figure 39.

The Ocheyedan river scarcely merits further attention here. Entering Clay county at the extreme northwest corner, it lies in a valley of construction all the way until its union with the Little Sioux. On the west it is controlled by a high plateau of Wisconsin drift, but on the east, especially between Ocheyedan and Stony creek, there are not infrequent traces of morainic deposits of kame and sand hill type, although, for the most part, low and inconspicuous, most notable in the southwest part of Waterford township.

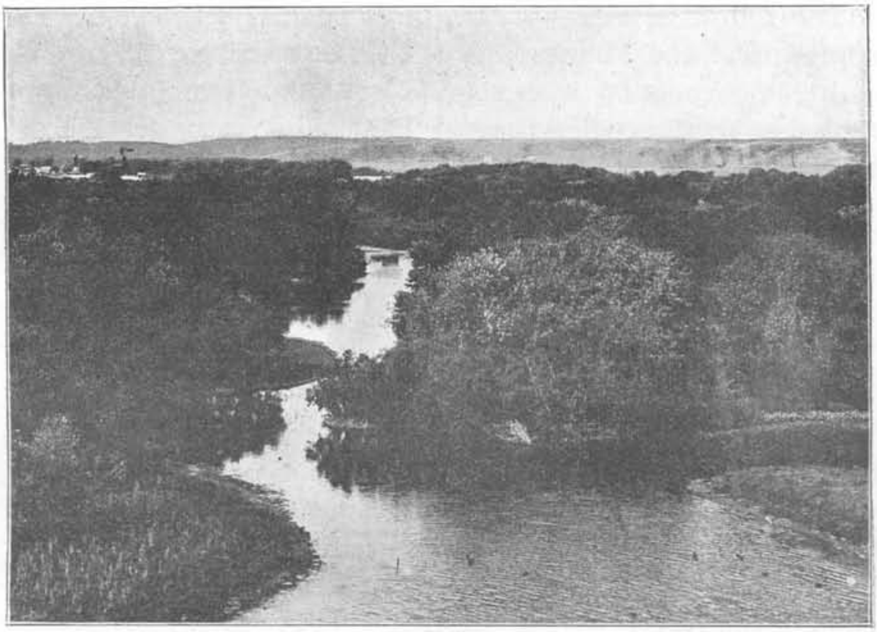


FIG. 39 View of the north bank of the Little Sioux river north of Sioux Rapids.

Concerning the drainage of O'Brien county there is little further to be said. Waterman creek has already received sufficient attention. Mill creek and Little Floyd are interesting because, as seems from present knowledge, their topography is much older. No one can visit these valleys and not notice the contrast, between the Foyd, for instance, and the Waterman. In the Floyd valley there is an easy gradient, a rather wide flood plain with immense deposits of gravel. Mill creek shows the same features; in the neighborhood of Primghar and Paulina the secondary streams are even well developed and the drainage is perfected. One might be disposed at first sight to call the landscape Kansan, but all southwestern O'Brien county is certainly a Wisconsin plain. Mill and Little Floyd probably occupy pre-Wisconsin channels or have been longer subject to erosion. This whole problem must remain indetermined until the southwest margin of the Wisconsin drift is at last definitely known and traced.

The following table of elevations kindly furnished by the engineers of the Minneapolis & St. Louis railway are interesting in connection with the subject of topography, as presented on the preceding pages. The points named are almost in a north and south line across Clay county.

	FEET ABOVE TIDE.
Langdon	1066.
Spencer	1010.
Greenville	1091.
Bed of Willow creek	966.
Cornell	1089.
Sioux Rapids	1005.

Langdon is in the "knobby drift" region; Spencer, as we have seen, in the plain of an ancient lake or marsh; Greenville, on a perfectly level prairie, has the same altitude as Cornell, on the other (south) side of Willow creek; Sioux Rapids (station) is about fifty or sixty feet above the flood plain of the river.

STRATIGRAPHY.

The number of geological formations to be described in these two counties is small indeed. The whole surface deposit from side to side is referable to the glacial series and to the Wisconsin stage. We are not without traces and intimations of older deposits, but these are rare and casual. The fine prairies, the broad marshes, the steep bluffs, the alluvial plains, are all assignable to the familiar Wisconsin drift. The following synoptical table may be tentatively constructed:

SYNOPTICAL TABLE.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene or Quaternary.	Recent.	Alluvium. Wisconsin loess.
		Glacial.	Wisconsin gravel. Wisconsin clay. Pre-Wisconsin sands; alluvial. Kansan. Pre-Kansan sands and gravels.
Mesozoic?	Cretaceous?	Upper Cretaceous?	Dakota sandstone?

The first *alluvium* in the above table is made up of recent deposit near all the principal streams. It is a fine silt, comparatively free from gravel or sand, black with organic matter. It is well exposed in many places along the Little Sioux, forms the existing river banks, as at Spencer, and in the neighborhood of Peterson. A similar deposit at Sioux Rapids and at Linn Grove forms the material used in the manufacture of tile and a fair quality of brick. The storm-waters have sifted out the pebbles characteristic of the ordinary drift and have deposited along the stream beds the finer material of typical Wisconsin clay, mixed with abundant organic matter.

The Wisconsin Loess.—The second member of the present series is so named here to provide for a curious loess-like deposit found capping the typical Wisconsin gravel, as at Sheldon, and in several places in the northwestern part of O'Brien county. Similar loess-like deposits in the southwestern townships of Osceola county, taken with the peculiar topography of that region, led the present author to map southwestern Osceola as possibly pre-Wisconsin.* The topography is probably referable to pre-Wisconsin erosion, but the loess deposits

*See vol. X of this series, pp. 219, 240, and map.

are no doubt more recent than the Wisconsin gravels, that is, than the Wisconsin ice. This Wisconsin loess is very uneven in deposition, sometimes only a few inches, sometimes several feet in thickness, not especially pure, and may possibly, in some places, after all, be an aqueous deposit of the same age as the underlying gravel. The material, however, shows often the peculiar angular fracture of true loess. In such localities loess-kindchen are not infrequent. Professor B. Shimek of the State University of Iowa, a well known student of the loess and its fossils, has visited some of the localities of best exposure and regards the deposit as consisting of true loess, whatever may be its source or origin. Similar deposits have been commonly observed only a little farther west,* and are discoverable north as far as Ashton, and east as far as Hartley.

The Wisconsin Gravels constitute the third member of our series. These are widely distributed. They are in the main of two distinct sorts, occupying two distinct sorts of location. The first are morainic, or, at least, are deposited in localities not in the pathway of recent drainage; the second occupy the existing drainage channels and are the so-called gravel-trains. Of the first type the gravel pit at Sheldon may be cited as an illustration. Here, high above the valley of the nearest stream, is a vast pile of clean gravel, containing bowlders not a few, some of them rotten and course, others hard and all unchanged, the whole pile more or less evidently stratified and water laid from top to bottom. The mass is, however, pure, almost free from any trace of organic matter. It seems to have contained at one time lime in considerable amounts. This, with other soluble mineral matter, has been very largely leached out by water, doubtless from the surface, and has effected to cement in layers several inches thick all the lowest strata. The pit has been long worked by the railway engineers and these indurated masses when broken up, make, it is said, excellent ballast. Large masses were observed so well cemented as to be with difficulty broken by

*See vol. X of this series, pp. 118-9, and pp. 147-9.

use of the sledge hammer. Under these indurated layers occurs the usual Wisconsin clay, if the reports of the workmen are to be taken in evidence; the clay is not ordinarily exposed. A similar gravel pit is worked to similar purpose just north of Cornell, in Clay county. This pit is already exhausted. Its floor is blue clay, but there is not lacking true Wisconsin drift here and there above the Kansan. A small but interesting bed of similar make-up is to be seen in the railway cut immediately north of Sioux Rapids; others are on the morainic knobs south of Ruthven, and others in various places in the northern part of Clay county, often worked by the farmers for the excellent road material. The isolated knobs of the Ruthven moraine seem to be in many cases entirely made up of gravel. A beautiful mound of this character, bowlder-strewn, lies just south of Elk lake.

Gravel deposits of the second type are found in nearly all the stream valleys. Those along the Ocheyedan, the Little Sioux, Mill and Floyd creeks, are particularly noteworthy. From Willow creek and Waterman these deposits are conspicuously lacking. This accords with what has been already surmised as to the probable history of these streams. Their principal erosion has occurred since the ice finally retreated. But the amount of gravel laid down in the valleys of the other streams named is something surprising. From the time the Little Sioux enters Clay county until it reaches the "straits" its banks are bordered on this side, now on that, anon on both, by vast beds of gravel. From Everly east to Dickens there is practically nothing but gravel. Its thickness as a deposit is reported at from twenty-five to thirty feet, resting on blue clay, full of water. Drive-wells are in common use over the whole plain. In fact the deposit is continuous, or practically so, from Milford south. Those interested may compare the west bank of the Little Sioux in Sec. 20, Tp. 97 N., R. XXXVII W., with the terraces in Milford township in Dickinson county. At Spencer the city well is nothing else than a great pit some thirty feet in depth and of nearly as great diameter sunk in the Wisconsin gravels. Similar deposits mark the course of Mill creek, especially south of Paulina; along the margins of the Little Floyd are found the same conditions. All this represents the movement of large quantities of water in a general southward direction, but in a measure independent of the present drainage system of the country and apparently prior to its establishment.

The Wisconsin Clays.—These, commonly called "pebble dirt," constitute nearly everywhere the ordinary subsoil of the country. All the rich upland prairies have for their basis the pale, buff-colored, pebbly drift. It is exposed on every highway where the least cutting has been judged needful to improve the road; it shows at every well mouth, whitens the top of every storm cave and slips and slides in masses great or small down the faces of the bluffs of Waterman and the Little Sioux. Its thickness appears to be variable in the extreme, but cannot be very accurately stated from the data at present available. The reports of well diggers are our best sources of information for the country at large. Occasionally an erosion cut or a railway excavation goes through and reveals the underlying formations. Thus, in the neighborhood of Sioux Rapids, on the west side of the "straits," the railway cutting reaches blue clay at a depth of some forty-five or fifty feet. This does not, however, reveal the total thickness of the Wisconsin at this point, as the cutting is on the face of the bluff considerably below the level of the prairie of the immediate neighborhood. Along the southern margin of the territory here described the Wisconsin clays are, at a maximum, perhaps 150 feet in thickness. The deposit thins out to the west and northwest. West of Hartley and Sutherland the deposit, if well records may be believed, is very thin indeed, nowhere more than twenty-five feet, generally not more than five or six, sometimes no more than two or three; sometimes none; "only black dirt and then blue clay." Thus the well at the county farm east of Primghar is said to be 700 feet deep, "with a foot or two of yellow clay." The deposit seems to be thinner in the vicinity of Mill creek, thicker again in Caledonia township, where well records indicate a depth of at least fifty feet. West of Hartley and north of Primghar, the highland of O'Brien county, 150 feet above the streets of Hartley, the thickness is "only five or six feet, then blue clay."

Pre-Wisconsin Sands.—Well diggers report that just beneath the "pebble dirt," as the Wisconsin is commonly called, a layer of sand and gravel not infrequently occurs. Just how general this may be is a question. At the south end of the highway bridge in section 28, Waterman township, there is a curious exposure of pre-Wisconsin sands. The usual Wisconsin clay, here rather abundantly surcharged with bowlders, makes up the upper part of the exposure, plainly capping a deposit of fifteen or twenty feet of stratified, water laid sand. The Little Sioux river has cut into the base of the deposit and so brought about the exposure. The arrangement of the sand in layers lends color, so far as may be, to the idea expressed above that Waterman creek possibly lies in the line of a pre-Wisconsin stream. It is further to be noted here that there are springs along the Waterman at various points in Waterman township. Some of these springs issue from sand. They doubtless owe their emergence to a somewhat extended sand-couche resting upon a layer of impervious clay.

Kansan Drift.—Under the ordinary surface deposits, whatever their character, everywhere over the whole region we here discuss, the notorious "blue clay" is a matter of unanimous report. It is exposed, as already stated, in the railway cutting near Sioux Rapids, in the gravel pit south of Greenville; it is reached by well diggers in every part of the country, sometimes even in cellars. This clay is regarded as forming part of the widespread Kansan drift, representing an old ice-invasion long preceding that which deposited the Wisconsin clays. It is, where freshly exposed, generally dark blue or gray in color, sometimes fine and pure, sometimes sandy or mixed with gravel; everywhere charged with bowlders, "nigger-heads," usually exceedingly hard, not very large, varying in abundance in various localities.

The thickness of the blue clay varies in a striking way within limits comparatively narrow; thus in Clay county it is reported at from thirty to sixty feet. In O'Brien county wells 200 and 300 feet "through the blue clay," are not uncommon. The well at the county farm, east of Primghar, is reported 700 feet, nearly all blue clay; on the Boyd farm in Caledonia township is a well said to be 1,000 feet deep, through the blue clay "nearly" all the way! In every case it is essential to go through the blue clay to make sure of a constant and abundant water supply; hence if we had an exact record of the wells of this prairie region we should be in position presently to understand this most important deposit very much better than now. Well diggers have here an opportunity to serve in a peculiarly effective way at once the cause of science and the interests of the community in which they may be employed. It is not very difficult to keep a log of the various wells sunk, and every such record, aside from its scientific interest, would be at once somewhat of a guide as to the probabilities in attempting other wells in the same neighborhood. The cases cited in this report are all from the memoranda of well diggers. If these had been made for our purpose they had been of the highest advantage. As it is they are only suggestive because only approximately accurate. They instruct us in a general way. For instance, beneath the blue clay in our locality occurs either sand or sand rock or both. It is impossible from the reports we have to say what it is in any particular case. It is probably in some cases pre-Kansan sand and gravel; in others, the top of the Cretaceous series as here laid down. There seems to be everywhere a uniformly aquiferous layer just below the blue clay.

It is instructive to reflect that of all the deep wells bored within our present territory, and they are many, not one reveals any evidence of coal. Of course not one was bored in premeditated search for coal or mineral wealth, but the evidence is certainly just as decisive for all that. There is no coal in the drift at any rate, and the drift in these counties is often of great depth. The well at Peterson, for example, is reported as follows:

	FEET.
Sand and gravel	20
Blue clay	80
Sand	20

In the lower sand is found abundance of fine water. This well is not far from the river and is probably a hundred feet or more below the general level of the surrounding country, that is, of the drift, so that the drift in the neighborhood of Peterson is not less than 200 feet deep, and is probably much deeper.

Pre-Kansan Sands.—Everywhere in both counties a successful well is described as going through the blue clay and striking sand. In this sand, as just remarked, there is always abundant water. This experience is so uniform over a wide portion of the state that even without other evidence we should be warranted in naming as a distinct member of our Iowa drift series the pre-Kansan sands. But there is other evidence, not to be cited here, which leads us everywhere to expect just what the well diggers report. The depth of the formation is not known; it is somewhat variable, certainly nowhere very thick. If reports are to be credited, the formation is sometimes lacking and the blue clay rests directly upon sandstone. This is by no means improbable.

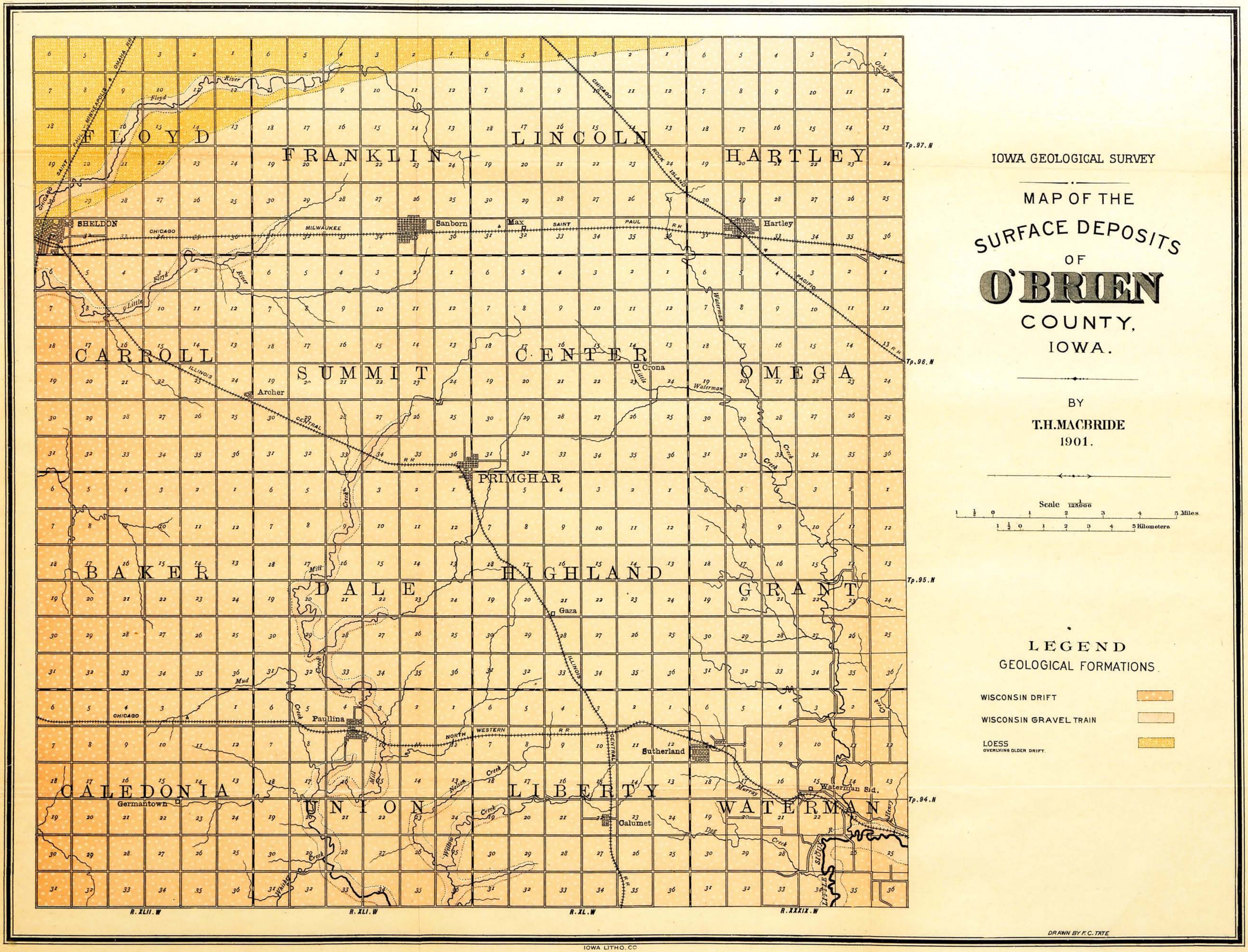
Cretaceous Sandstone.—This is listed here simply to provide for the deposit referred to in the preceding sentence. Sandstone is not infrequently reported, sometimes below the clay, sometimes below clay and a bed of sand. This is not inconsistent with the evidence given by the record of the deep wells on either side of our region, as at Emmetsburg and Sanborn.

ECONOMIC PRODUCTS.

The economic products of this part of Iowa are neither numerous nor varied. This region is not a land of mountains and valleys, of crystalline rocks freighted with gold and silver or other metallic ores; neither is it a region of sandstones or limestones and shales, exposed by long erosion on the banks of every stream; we have rather to do with a simple prairie, where vegetation has for some thousands of years been contributing a wealth of organic matter to the surface soils now of a fertility unmatched, resting upon subsoils of unusual depth, and of a constitution for the support of all our agricultural plants simply unrivalled.

Soils.

The soils of the two counties in question are almost uniformly of one description. We find almost over the whole area the same deep, rick, black, fertile loam, well adapted, as abundant experience has proved, to meet all the requirements of successful agriculture. Configuration of the surface makes tillage a matter of the greatest ease; there are no hills, save the few bluffs along the streams as heretofore described, and these are not given at all to tillage; on the other hand, aside from these few steep slopes, it would seem that every acre might be subjected to the plow. The whole country is one vast, beautiful field, adorned with groves, and mapped in summer with the colors of a varied harvest. In some places, as about Spencer, the soil is warmer, more sandy, but is none the less productive. The subsoil is nearly everywhere calcareous, continually yielding up the very materials needed for the most successful raising of wheat. Even the marshes and swamps that have been thought for so long a detriment to this portion of Iowa, are vanishing, and well directed drainage will soon have left no trace of them in the continuously cultivated field.



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Sands and Gravels.

The few exposures of sand and especially of gravel in these counties have been of the highest value in many ways. Wherever accessible they have been entensively worked by the railway companies for ballast. The gravel pit at Sibley has already been referred to, as also that near Cornell. Such deposits are quite as valuable for road making as for ballast, and the principal towns have fine streets made of this simple material. The time is doubtless near when the rural highways will receive as much attention as those of the city have received, and these gravel beds of the northern drift will then be estimated at their true value.

Brick Clay.

Good deposits of brick clay are yet a desideratum in both counties. The common drift contains too much lime. The blue clay seems to contain too much gravel and sand. That, however, exposed in the bottom of the Cornell gravel pit seemed to promise better results in this regard. At Sheldon Mr. A. S. Hurley manufactured last year 700,000 brick. Mr. Hurley uses the loess-like deposit above the gravel in that neighborhood, mixed with a certain proportion of soil taken from near the surface. The brick shown by Mr. Hurley are a fair quality of rather soft brick. Some of his kilns are first rate, but the quality, he reports, is uneven.

At Sioux Rapids, just south of the Clay county line, Mr. J. F. Cooley is making good soft brick at the rate of 500,000 per year, and tile at the rate of 700,000 per year. Mr. Cooley uses an alluvial Wisconsin clay. At Spencer, Mr. Ira Hilliard has for a long time been manufacturing a fair quality of soft brick. He, too, uses a form of alluvial clay mixed with soil taken from near the surface.

Fuel.

The fuel supply of these counties is thus far wood. As will appear in the list of forest trees to be given further on, the early pioneers found native timber in this part of Iowa in considerable variety and in amount sufficient for their immediate uses. Some of the primeval trees are still standing, showing that the supply was not exhausted when the railways began to bring coal within convenient reach. At present almost every farmer has in his grove a supply of fuel, if not wholly adequate, at least so far productive as to make him, for the greater part of the year, independent of importations.

It is the belief of many that coal may be found in northwestern Iowa, once we put ourselves to the trouble to make the necessary investigation. Coal in Iowa and elsewhere has usually been revealed by erosion. The rivers and streams have cut down through the overlying rocks and uncovered the coal which is supposed to lie spread out everywhere beneath the surface. In northwestern Iowa the streams have nowhere reached the indurated formations at all and it is accordingly thought necessary to make exploration by boring, and it is thought that if the boring be only continued far enough and deep enough coal is sure to be encountered in Clay county, for instance, as surely as in Polk or Mahaska. The first part of this assumption is well founded. The streams have certainly reached no coal, nor anything suggesting it, and if coal exists beneath the surface at all its presence must be revealed by artificial means.

Fortunately or unfortunately, as the case may be, we have at hand a very considerable number of borings, more or less deep, bearing directly upon our problem. These are the deep wells which all over this section of Iowa the industrious farmers have been sinking, are sinking every day, for the purpose, not of finding coal it is true, but of securing a permanent supply of pure water. However, these all answer our purpose just as well. Every one according to its depth answers the question whether there is coal or not in the particular locality where the well goes down. Nearly all the wells in this part of the country, and there are hundreds of them, go through the blue clay. Very rarely are these wells less than one hundred feet deep; they are generally from 250 to 500 feet deep, and sometimes very much deeper. It will be conceded, then, that if there be coal here beneath the surface it is pretty deep down and lies all below the blue clay. This practically puts any coal there may be out of our reach. We should have not only the great depth to contend with, but, what is worse, the strata below the clay seem saturated with water, water under considerable pressure, that would render difficult, if not wholly impracticable, the operation of a mine at that horizon.

But it is by no means certain that we can find coal even in the strata reached after we pass the blue clay. Indeed the evidence we have is discouraging. Many wells in these two counties have been sunk considerable distances beyond the blue clay without encountering the faintest suggestion of anything like the coveted mineral. A deep well at Emmetsburg goes down more than 600 feet beyond the blue clay without a trace of coal. Directly west, in one of the counties now considered, at Sanborn, is another well whose fountains are more than a thousand feet below the blue clay and no trace of coal yet. The probabilies of finding coal along the line of Chicago, Milwaukee & St. Paul railway in this section are evidently not very great. Nor is this all. If reports are true there is a well in the southwestern corner of O'Brien county 1,000 feet deep with no report of coal; Sioux City a little further southwest, continuing a line from Sanborn in the same direction, has a well more than 2,000 feet deep and no coal. At Holstein, directly south of Sanborn we have another very deep boring with the same report. The chances then of finding coal, not to say of working it, in the counties thus reviewed are evidently not the best, at least until we descend more than a thousand feet below the surface. Now this is all apart from anything a geologist might say about the subject, forming his opinion on what he knows of Iowa and the extent and arrangement of its various rock strata. All the statements made above record facts, reported not by geologists, but by men who dig wells; men who seek not to establish a theory, but to find water. Their testimony, at least, ought to be convincing.

At Peterson many years ago a well was sunk with the avowed purpose of finding coal. By the report of the man who made the boring coal was found. By the courtesy of Mr. J. A. Kirchner of Peterson the writer was permitted to read the "log" or record of the enterprising, if less scientific, contractor who made the boring. We present the record, not for its accuracy at all, but as a curious illustration of human ingenuity where knowledge fails or is in any way defective. The table is here reproduced from and extra edition of the Peterson Pilot and bears date, August, 1883.

	FEET.
"Sand and boulders	10
Blue clay	47
Sand rock	15
Reddish brown and pink feruiginous sand, containing large amount of pofery* and carbonaceous matter	13
Steatite serpentine	10
Arenaceous shales, very hard iron bands;	10
Magnetic oxide iron in alternate layers pofery	5
Sand pocket black sand	1
Feruiginous steatite and oxide of magnesia	4
Bituminous shales and slate	4
Coal	3½
Good pure fire clay	3½
Coal	3⅓
Fire clay and shale	3⅔
Good coal	3
Limestone "	..

Enticed by such remarkable prospects we are not surprised that the little community enthusiastically supported a movement to proceed at once to develop the natural resources thus revealed and only 120 feet below the surface. A company was formed, a carefully constructed shaft was carried down at cost of many thousand dollars. A log of the shaft seems not to have been preserved, but from the memory of one who watched the excavation it was something like this:

*Original orthography preserved.

	FEET.
Sand and gravel	20
Blue clay	85
Quick sand	?
Sand and gravel or sandstone	30

At this juncture for reasons unexplained the work was abandoned. The water gave a great deal of trouble and perhaps afforded the principal excuse for suspending operations.

The discrepancy between this log and the former is sufficiently marked. Indeed, the latter record more nearly coincides with that of the town well some rods further to the west. Supposing the shaft to have been begun twenty feet higher up the slope than the point at which the boring began we still have over 100 feet in which the two records may be compared foot for foot. The contrast is all the more surprising when we further reflect that the distance from the mouth of the boring to that of the shaft does not exceed thirty rods, perhaps does not equal twenty. Who may resist the conclusion that the first log is made up of misstatements intended to mislead?

As these lines are written the newspapers of the country are bringing tidings of the discovery of petroleum in the center of Clay county. Judging by what we know of the structure of this part of the country, judging from data gathered as above, the chances for finding coal-oil in Clay county are about equal to those of finding coal. The question of the presence or absence of petroleum will of course be answered in this case also by the sinking of a prospect hole. For the sake of the enterprising people who make the investigation let us hope that the prognosis of science may here fail of justification, and that if oil should refuse to flow, a well of purest water may at least reward their toil.

Water Supply.

From what has been said in the last few pages there can be in the mind of the reader no doubt as to the abundance of the water supply in this part of the state. An unfailing supply of the best water may be obtained, it would appear, almost anywhere by piercing the blue clay, and this, while thick, is nowhere so thick as to make drilling impracticable. The deep well at Sanborn, however, is a disappointment; it pierces the strata far below the blue clay and derives water from the lowest source only. The earlier water veins reached were shut off, as encountered, by the casing. In a great many places the deep well is not yet a necessity. In some places it probably never will be. In all localities marked by the presence of gravel shallow wells are all-sufficient. Drive wells have been mentioned in connection with the Spencer plain. The public well at Sheldon is not deep, is simply excavated in the gravel described elsewhere in this report.

The streams coursing the counties before us are of the highest importance from the present standpoint. The Little Sioux, the Ocheyedan, the Little Floyd, Waterman, Mill creek and Willow creek are all perennial streams of greatest service to those contiguous to their channels. The mill at Peterson possesses the only water power now in use in either county. The amount of fall at this point is such as to warrant the expectation that the power may still find profitable employment, even if the manufacture of flour should no longer prove desirable.

Acknowledgments.

In the prosecution of the work of which the present pages furnish some account, the writer would tender his best thanks and acknowledgments to the many citizens of the two counties who were ever willing to assist in every possible way where the author sought to gather the necessary data. Special thanks are due Mr. J. A. Kirchner, of Peterson, as also Mr. C. W. Fillmore of the same village. Mr. W. H. Bloom aided us in the neighborhood of Sutherland and Mr. C. E. Jacoby in the region about Sioux Rapids.

The writer would also tender grateful acknowledgments to Mr. Marvin Dey, of the Chicago, Rock Island and Pacific railway, for the profile of the two counties studied, and to Mr. H. G. Kelly, of the Minneapolis & St. Louis railway, for similar favors. Throughout the author has also enjoyed the advice and assistance of the director of the Survey, Professor Samuel Calvin, and of the assistant geologist, Mr. A. G. Leonard.

FIG. 40. Primeval oaks by the Little Sioux, near Peterson.

IOWA GEOLOGICAL SURVEY

MAP OF THE SUPERFICIAL DEPOSITS OF CLAY COUNTY, IOWA.

BY

T. H. MACBRIDE

1901.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

WISCONSIN DRIFT PLAIN

KNOBBY DRIFT

WISCONSIN PARTIALLY STRATIFIED
OUTWASH GRAVEL AND ALLUVIUM

DRAWN BY F. C. TATE

IOWA LITHO. CO.

FORESTRY NOTES FOR O'BRIEN AND CLAY COUNTIES.

The traveler through the northwestern counties of Iowa is treated to continual surprise in the number and variety of arboreal species certainly native to these prairie regions. Every river valley, every sequestered or protected nook has its trees. True, these are at present mostly rather small, probably in many cases not more than fifteen or twenty feet in height, probably in most cases not more than fifteen or twenty years of age, but they are vigorous and abundant and show a disposition to form a forest, often exhibit genuine forest conditions, all in such a way as to make certainly successful any well advised attempt to raise forest products on the prairies. In some places the primeval trees still stand. (Fig. 40). All the better specimens of course have long since been cut away to build and warm the homes of the pioneers, but enough remain, in regions less conveniently accessible, to show at least what these ancient trees were like, how they braved, in many an individual case, the perils of their own frontier position and have even lived to see in happier days a generous progeny. (Fig. 41). This figure is especially interesting. The thinly clad branches of an ancient elm may be seen in the illustration, rising above a dense mass of umbrageous trees. This is the "lone tree" of Lone Tree township, Clay county, dying now, chiefly because of recent ill usage, but at one time, as the story goes, the only tree on all the wide prairie west of Spencer. No one now passing and seeing the abundant young forest, not of elms only, but of varied species, extending around the old elm and up and down the Ocheyedan here, would ever think that these trees are all indigenous, and that twenty-five years ago there was not another tree in the township. Another view here offered shows a bur oak and its descendants. (Fig. 42). Such trees are not infrequent in out of the way places, on the crown of some steep bluff or on an exposed hilltop, as in the neighborhood of Peterson, along the highway leading west. It would seem thoughtless indeed if the owners of such trees should fail to appreciate their significance. The hardiness they

FIG. 41. Lone Tree, surrounded by the new forest.

exhibit, which centuries of fire and storm have not sufficed to overcome, appealed to the sympathetic pioneer and speaks eloquently for the possibilities of future years, when the efforts of nature shall be less disturbed by such unfriendly conditions. The young forests along the Little Sioux are as beautiful in effect as any, and if not destroyed prematurely by their impatient owners, will yet prove a source of abundant profit.

The success of tree planting has been everywhere marked. A farm without a grove is anomalous. If along the highway one such does appear, we may be sure the land is rented; the

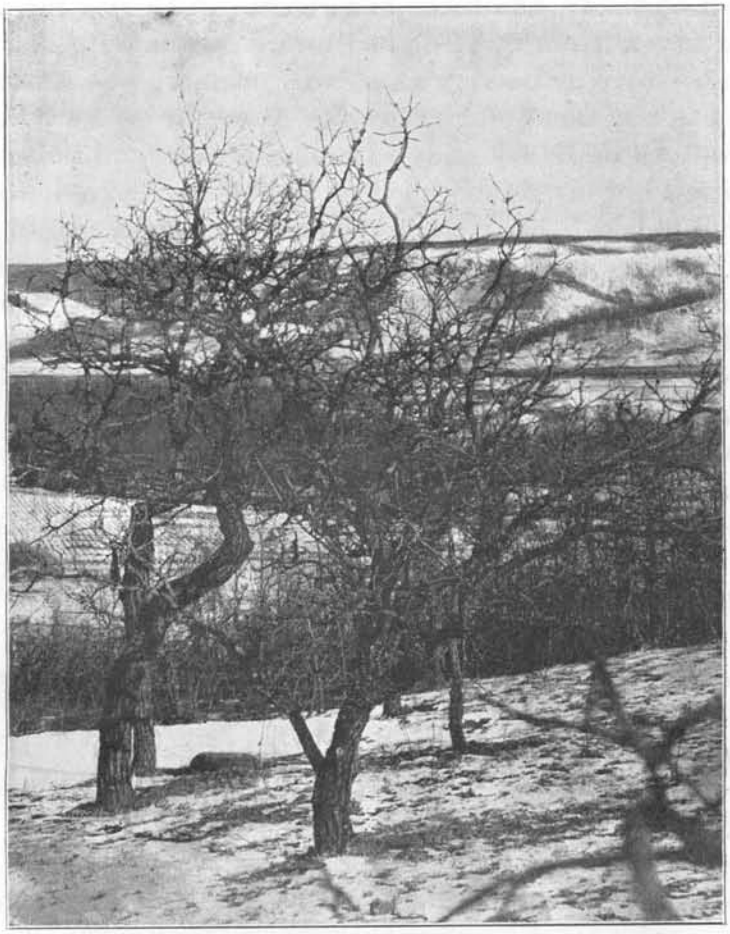

FIG. 42. An aged burr oak and its progeny.

owner has not sufficient interest in his land to make it beautiful, nor sympathy with his tenant to seek to make him comfortable. The persistence of native species and the abundant success of the planted varieties leaves no doubt that in these two counties also timber supplies of all sorts adequate for home consumption may easily be produced.

The trees native to O'Brien and Clay counties were all at first confined to narrow areas around the more prominent bodies of water, the lakes and rivers. All along the Little Sioux river, from Spencer southward, trees were not rare. Gilletts Grove by its very name will preserve the history of vegetation in that neighborhood. Trees were not wanting to the valleys of Henry and Waterman creeks, and there were not a few in the neighborhood of Lost Island lake and some about Elk lake. Nearly thirty species of woody plants have been reported from this "treeless" region, and the personal observations of the present writer confirms the report in nearly every case. The woody plants of the region are as follows; native unless otherwise stated.

Tilia americana Linn. Basswood, Linden.

Common in Gilletts Grove, about Peterson and in the valley of Waterman creek. This is a most valuable and hardy tree. It grows rapidly, is a fine shade-tree, its flowers afford the bees material for the finest honey, and its trunk at last makes a valuable kind of soft lumber. The tree does best in rich soils, but is also to be found climbing the clay bluffs of the Wisconsin drift; so that in northwest Iowa it will probably grow wherever planted.

Xanthoxylon americanum Mill. Prickly Ash.

A vigorous shrub, of spicy twigs and foliage, small flowers followed in August by bright red, berry-like fruit which presently breaks open revealing a pair of shiny black seeds. Not rare in the valley of the Little Sioux from Gilletts Grove south. Useful only as an ornamental shrub. The flowers are of two sorts on different bushes and to secure the fruit the two must be found and planted near each other.

Acer saccharinum Linn. *Acer dasycarpum* of Ehreart and of the books. Common Maple, Soft Maple, White Maple.

This is the maple everywhere commonly planted as shade tree and wind-break. Reported indigenous about Peterson.

One of our most valuable prairie trees, very hardy and ready to grow on all sorts of soil, rapidly attaining usefulness as bringing shade in summer, protection in winter. The most valuable friend of the farmer-pioneer. The wood though soft makes excellent fuel and a grade of lumber not to be despised. Unfortunately the barbarous lopping to which, under pretense of pruning, the trees are everywhere subjected, opens the heart of the tree to the weather and to speedy decay and so good logs from cultivated trees are seldom seen.

Acer negundo Linn. Box Elder.

Native to the stream valleys; exceedingly common in the valley of the Little Sioux near Peterson. Doubtless spreading since the fires have been checked. Everywhere a favorite for wind-breaks and commonly planted. This is also a useful tree as a temporary protection or nurse for trees of better quality.

Rhus glabra Linn. Smooth Sumac.

This is the common sumac of all the northern woods east of the Rocky Mountains. In the counties here studied it is small, dwarfed and not common. Well worthy of preservation and cultivation as an ornamental shrub. Nothing lends quite the same rich brilliancy of color to the autumn landscape, nothing to equal the glowing foliage of the sumac. Contrary to popular impression, the shrub is not poisonous. The poison sumac, poison ivy, three-leaved ivy, *Rhus vernix* Linn., was not observed nor is it reported in either county, although it may certainly be expected wherever woody species flourish at all. It may be known by its three-foliolate, three-parted, leaves and loose clusters of whitish, berry-like fruit, hanging on the leafless stems in fall and winter. The plant is of very variable habit, sometimes a vine climbing by rootlets attached to the bark of trees, sometimes a low shrub, one to four feet high, common about fence posts where seeds are dropped by perching birds. Formerly reported from the eastern part of the state only, it is now doubtless distributed over the whole area and will be found probably, in every county. The fruit is poisonous, and for some people the plant is poisonous, even to the touch, especially when the leaves are vigorous, or when the plant is in flower; in this latter case, however, most people appear to be immune. Thousands of people unconsciously walk over poison ivy, pass by it, even handle it, every year, and yet suffer no ill consequences.

Prunus americana Willd. Wild Plum.

A common tree forming thickets here and there by the roadside, especially on the shores of Lost Island lake, along the Little Sioux, and in similar situations everywhere. A beautiful ornamental tree, nothing finer when in bloom; valuable as a hardy fruit stock and as constituting an element of a northern grove; inured to severest climatic conditions of every sort. This and the Wild Crab are largely held in check by rabbits, which, in winter, girdle the stems of young shoots; otherwise the species would be of almost universal distribution.

Prunus virginiana Linn. Choke Cherry.

Found only in the valley of the Little Sioux. A rather handsome little tree, tending to form thickets, covered in spring by showy clusters of white flowers; later laden with shining black fruit, the delight of the wild birds.

Pyrus iowensis. Crab Apple.

Common in thickets about Lost Island lake and along the Little Sioux. A fine ornamental tree; the bloom beautiful and sweet, the fruit not without value, and the tree, itself, admirable to the formation of a thicket, as a wind-break, or protection against snow drifts and storms.

Cratægus coccinea Linn. Hawthorn. Red Haw.

This species occurs occasionally with the preceding along the river and is commendable in much the same way.

Symphoricarpus occidentalis Link. Wolf Berry.

This is a handsome little shrub characteristic of the borders of the northern woods. Growing in clumps, the stems two or three feet high, with handsome axillary flowers in July and August, succeeded by beautiful white berries in fall. Deserves a place at the border of every northern lawn.

Sambucus canadensis Linn. Elderberry.

Not common; probably escaped from cultivation here and there. Planted sometimes in gardens by those who esteem the fruit, and like to share it with the birds.

Viburnum lentago Linn. Black Haw.

Mr. Kirchner reports this from near Peterson. It is a small tree popularly known and appreciated for its fruit. Useful chiefly as an ornamental shrub, or as an index of the possibilities of the region where it occurs by nature. The tree loves rich soil and bespeaks forest conditions.

Fraxinus americanus Linn. White Ash.

Native to both counties and everywhere commonly planted. One of the most valuable, if not the most valuable tree in northwestern Iowa. Native to the whole region, along streams and by the lakes; by the farmers everywhere wisely planted in groves and wind-breaks, clean and healthy, this tree makes splendid wood, good timber for all farm purposes, is long-lived, tough and strong. It should now supplant in large measure the less desirable cottonwood and box elder.

Ulmus americana Linn. Common Elm. White Elm.

This is another hardy and common species. The only tree for street planting. Some rather fine specimens are still standing on the county line of Clay county, immediately north of Sioux Rapids.

Ulmus fulva Michx. Slippery Elm.

Mr. Kirchner reports this species as native to the valley of the Little Sioux. Less valuable than the preceding and not common. *Ulmus racemosa* Thomas, should be found in these counties as it occurs about Spirit Lake, but was not observed, nor is it on the list of trees reported.

Juglans nigra Linn. Black Walnut.

This most valuable species is also reported from the groves about Peterson, by Mr. Kirchner. Specimens were also observed in the southeastern part of Clay county. These trees are easily raised from the seed and they grow at first rapidly on the prairie soils, but the walnut is essentially a forest tree and can flourish under forest conditions only. Growing walnuts must be protected by the presence of other trees. They flourish best in sandy, but not impoverished soil, and in low but well drained grounds. In ash and black walnut the farmers of northern Iowa have at hand two timber trees of highest value. They should be introduced in groves of box elder and soft maple and allowed to slowly, in part at least, supplant these less desirable forms.

Carya amara Nutt. Bitter-nut. Pig-nut.

Not common. Yet to be seen here and there in the valley of the Little Sioux. A tree of comparatively small value. It grows slowly and has few qualities to recommend it in the present case except as the wood may be used for fuel.

Corylus americana Walt. Hazel. Hazelnut.

Common wherever there is native woodland, it is in a measure a nurse for other species. It may often be seen in patches out at some distance from the established forest and by holding leaves and especially snow, has served to check in spring the ravages of fire, which is of old the destructive foe of seedling trees.

Ostrya virginica Willd. Ironwood.

A rather common tree along the Little Sioux and by the banks of Waterman creek, of slow growth it forms wood of remarkable density and is serviceable in making tool handles, in the repair of farm machinery, etc.

Populus deltoidea Marsh. Cottonwood.

Common everywhere and everywhere planted. Mr. Griffin has beautiful rows of this tree near Greenville, in Clay county, and groves of the species are to be seen on every horizon. Fig. 43. Valuable chiefly in single rows or as isolated or scattered trees, border to a grove of some other species; less successful when used to form a plantation. The trees in the middle of a grove of cottonwood are stunted, even die out entirely, and are in every way a disappointment. When planted along the highway these trees, as in the case cited, make a handsome avenue, but their shade, refreshing to the traveler, is at the same time deleterious to growing crops in the field. For

FIG. 43. A row of noble cottonwoods shades the highway

this reason the farmer is apt to esteem such decoration of his holding too expensive. Planted on north and south lines they are less objectionable, and on the south side of an east and west highway they are almost without injurious effect.

Juniperus virginiana Linn. Juniper. Red Cedar.

This seems to be the only evergreen native to the region. It is reported to have been at one time common along the steep bluffs of the Waterman. Specimens brought from these localites are now to be seen in many dooryards, but none were observed in their native habitat. A remarkably hardy tree is this, well adapted to the region, enduring shade, making fine borders, hedges, etc. The tree suffers much from snows, where fully exposed, and often becomes crooked and straggling with age.

These are the principal woody plants of the counties we have been studying. The list is not very long but surprisingly long for a treeless region. At any rate, we have here a variety sufficient to guide us in our planting in this part of Iowa, and to make possible very handsome grounds and homesteads, as the experience of the farmer in many places already begins to show. The more common fruit trees are to be seen everywhere planted, and of conifers many introduced species were observed, such as the larch, the Norway spruce, the white pine, and especially the Scotch and the Austrian pine. The last named seems to be by far the better of the imported species.

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