GEOLOGY

OF

POTTAWATTAMIE COUNTY

BY

J. A. UDDEN.

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CONTENTS.

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 published 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 southwest 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 illinoiensis* (?), 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.	Morton's Quarry.	Ravine, Secs. 14 and 23, Macedonia.	Bryant's Quarry.	River bed, Carson	Coal Exploration.	David Snapp's Quarry.	Sorensen's Quarry.	Carson Well.	Crescent Quarries.	Henton, Mills County.
Foraminifers—												
Fusulina cylindrica Fischer	..	†	†	†	†	†	†	..	..	..	†	..
Anthozoans—												
Autopora, sp	..	..	..	....	..	†	†	..	..	..	¶	..
Axophyllum rude White & St. J	..	..	..	....	..	..	..	..	..	..	¶	..
Campophyllum torquium Owen	..	..	..	....	..	†	†	..	..	..	..	..
Loppophyllum 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.	Bryans' Quarry.	River bed, Carson.	Coal Exploration	David Shapp'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 offshore. 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

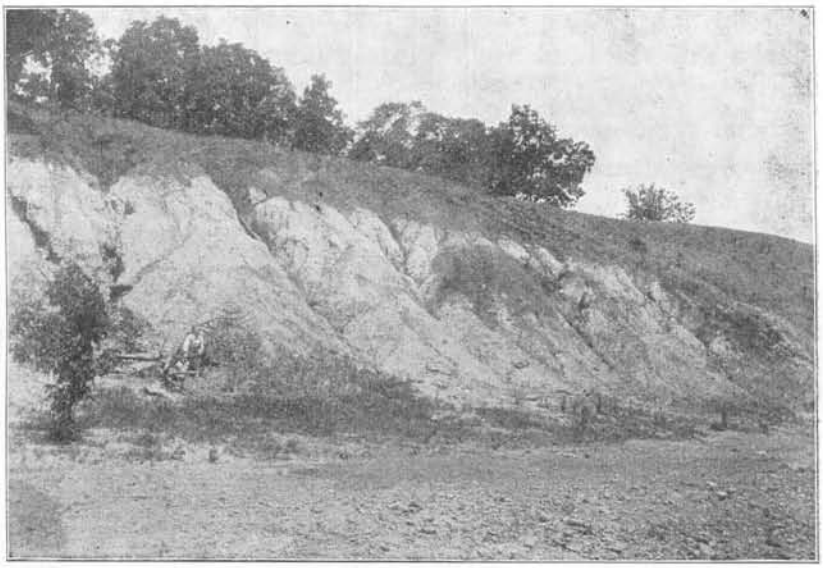


FIG. 13. Exposure of Cretaceous clay with concretions of clay ironstone, north line of the Ne. ¼ of Sec. 36, Wright township. Photo by J. L. Oakleaf.

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

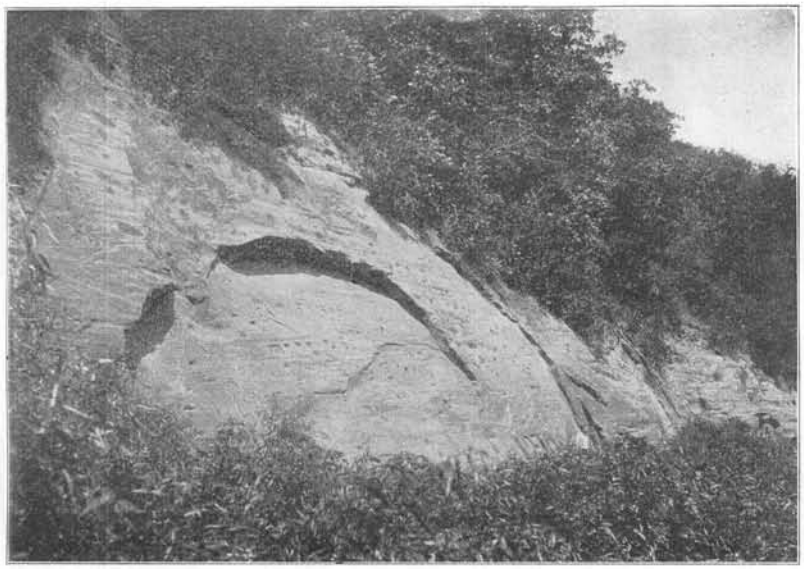


FIG. 14. Nishnabotna sandstone in west bank of the river on the Ne. ¼ of Sec. 36, Wright township. Photo by J. L. Oakleaf.

instances they were found to be filled by 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

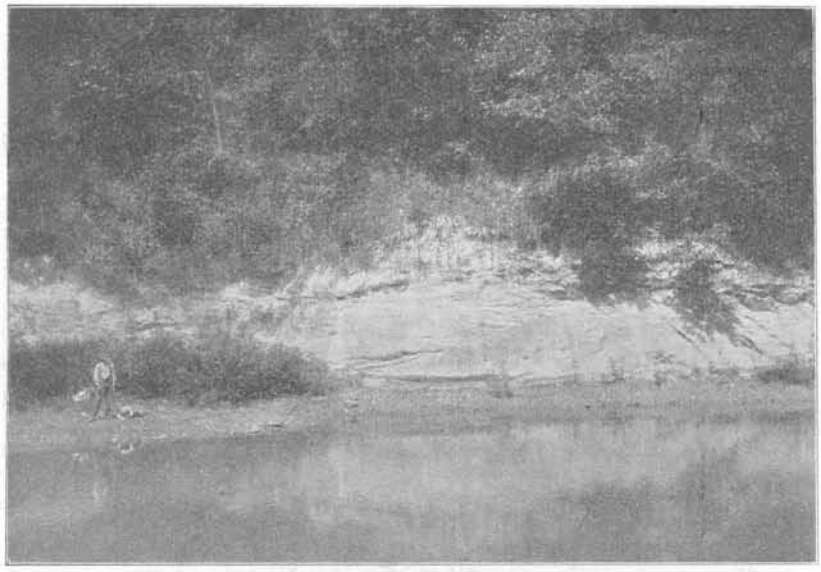


FIG. 15. Change from sand below to clay above, in the Cretaceous deposits in the west bank of the East Nishnabotna river, near the center of the north line of Sec. 1, Waveland township. Photo by J. L. Oakleaf.

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 "hardpan" 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.

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.

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.

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.

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.

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.

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.

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

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.

30	Dumphries P. O.		1,180	42	All loess.	

Macedonia Township.

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 RED 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.

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

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 BED 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.

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.

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.

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.

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.

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

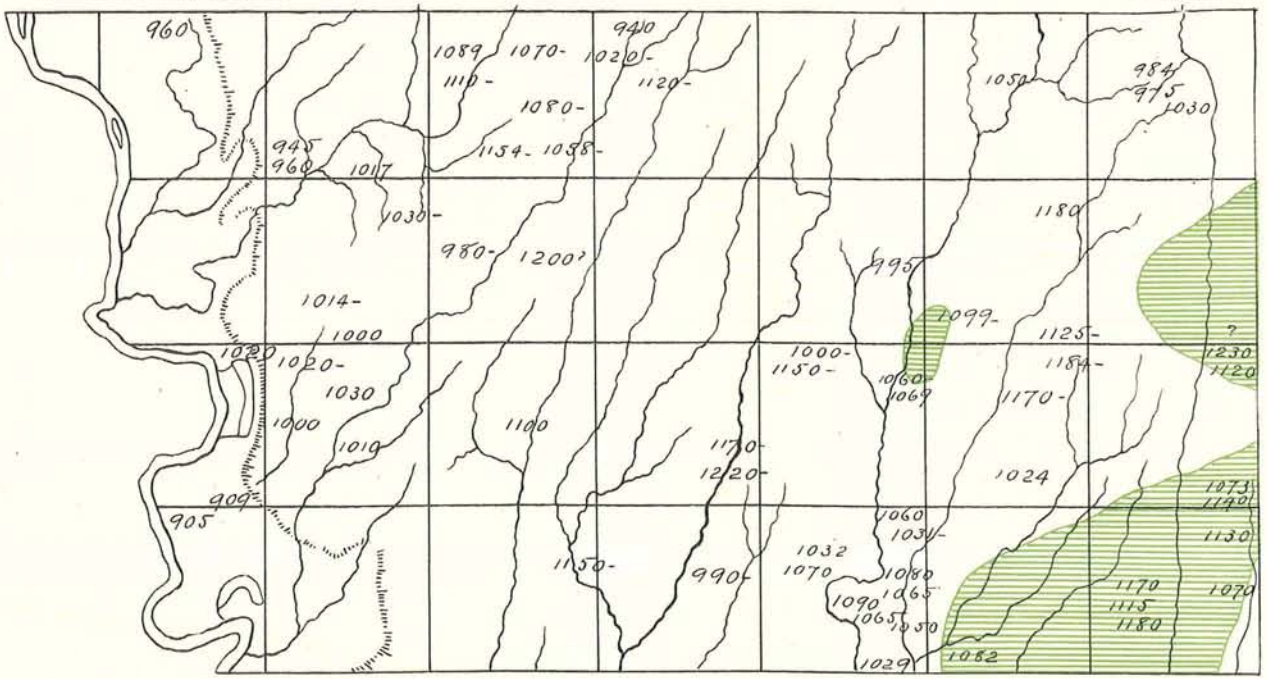
York Township.

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—½	3.3	.4	tr.	tr.	.....	tr.	.....	tr.	.1		.....	.....	....	.....	.....	.....	.....	.....	.....	.....	.4	.....
½—¼	2.7	.9	.4	.5	tr.	tr.	tr.	tr	.2		tr	.....	....	.....	.....	tr.	tr.	.....	.....	tr.	.5	.....
¼—⅛	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
⅛—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
1/16—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
1/32—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
1/64—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
1/128—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
1/256—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
1/512—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.
1/1024—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.

* 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 re-

ported 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.			Number of men employed.	KIND OF MACHINE	Value of product (Estimated.)	REMARKS.
					Common brick.	Pavers.	Tile.				
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 road-bed. 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 1/125000

5 Miles.

5 Kilometers

ROCKFORD · BOOMER · NEOLA · MINDEN · PLEASANT · KNOX · LAYTON

CRESCENT · HAZELDELL · NORWALK · YORK · JAMES · VALLEY · LINCOLN

GARFIELDER · HARDIN · WASHINGTON · BELKNAP · CENTER · WRIGHT

KANE · COUNCIL BLUFFS · LEWIS · KEG CREEK · SILVER CREEK · CARSON · GROVE · WAVELAND

MACEDONIA

Loveland · Grable · French · Pigeon · Minden · Neola · Honey Creek · Beals · Underwood · Harlan Jc · Avoca · Walnut · Hancock · Morton · Crescent City · Crescent Sta · Weston · Keown · Oakland · Dermyer · Quick · Chautauqua · Armour · Taylor · Greendale · Treynor · Carson · Keg Creek · Living Spring · Macedonia · Island Park · Dumfries · Wheeler · Kemling

Tp. 77. N · Tp. 76. N · Tp. 75. N · Tp. 74. N

R. XLIV. W · R. XLIII. W · R. XLII. W · R. XLI. W · R. XL. W · R. XXXIX. W · R. XXXVIII. W

DRAWN BY F.C. TATE

IOWA LITHO. CO.