GEOLOGY OF MUSCATINE COUNTY.

BY

J. A. UDDEN.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

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

EARLIER INVESTIGATIONS.

The first geologist who published observations on the territory within the limits of this county was Dr. D. D. Owen. With a corps of observers which he organized in 1839 he

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

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

Dr. C. A. White, who was state geologist from 1866 to 1870, in his Report on the Geological Survey of the State of Iowa, refers to the occurrence of a peat bed near the mouth of Wap-

sinonoc creek, and on page 281, in the second volume, gives a figure showing the relations of this peat to the local drainage conditions. The first volume of the same report contains, on pages 139–164, a report, by Prof. Theodore S. Parvin, on meteorological observations, made at Muscatine during the years 1839–1847.

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

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

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

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

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

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

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

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

PHYSIOGRAPHY.

TOPOGRAPHY.

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

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

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

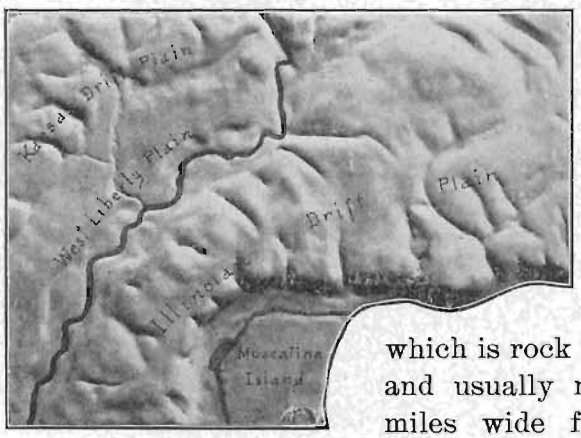


FIG. 30. Photograph of a clay model representing the main topographic features of Muscatine county.

The Mississippi Bottoms. — For a distance of about eighteen miles above the city of Muscatine, the Mississippi river occupies a rather narrow valley, which is rock bound on both sides and usually not more than two miles wide from bluff to bluff. Along that part of this valley which follows the southeast bound-

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

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

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

The surface of this plain is not entirely without relief. There is a slight general slope to the south of about three feet to the mile. The elevation of its north end is about 663 feet above tide, and of the south end, at the county line, about 615 feet. On its northeast corner there is an island-like highland, covering about two square miles, and occupying parts of sections 7, 8, 17 and 18 in Moscow township. This

rises seventy-five feet above the surface of the plain, and has a well-marked bluff line to the north and east, while on the southwest it merges more gradually into the plain around it.

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

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

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

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

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

The northwest slope of the plain is quite different in aspect from that just described. The streams here have seldom cut their valleys more than sixty or seventy feet deep. In Wilton and Stockton townships this cutting mostly falls short of fifty feet. The streams occupy wide, shallow depressions in the upland, and these are separated from each other by low and flat, swells of land. Nearest the divide of the upland these depressions are not so well marked, nor are they conspicuous nearer the margin in the west part of Wilton township, or north of Musketo creek, in Moscow township. But south of this creek they make the dominant feature of the landscape, especially along the bluffs of the Cedar and for one or two miles inside of it. They are most pronounced nearest the Cedar bluffs, where they usually connect with a knolly marginal ridge which follows the bluffs and rises in places as high as twenty or thirty feet above the upland inside. In general their course is from west-northwest to

east-southeast. In the north half of section 13, in Cedar township, a narrow ridge of this kind forms the north slope of a creek for some distance, and separates from it a chain of small, undrained ponds. In Secs. 12, 21, 28, 32 and 33, Tp. 77 N., R. III W., the ridges run into dune-like hills, some of which are seen to be now drifting before the wind. Similar conditions exist in Secs. 6, 7 and 12, Tp. 77 N., R. II W., where several small ponds are hemmed in among dune hills. In Moscow and Bloomington townships the area of the ridges encroaches farther on the upland than at any other place, reaching beyond its divide as far as within two miles of Muscatine, following the shallow sag which unites the basin of Mad creek with that of Musketo creek. Some isolated ridges are seen just above the bluffs around Muscatine Island, about four or five miles west from Muscatine.

The Kansan Drift Plain.—Kansan drift, covered by a sheet of sand and loess, forms an upland to the northwest of Muscatine county and extends into it, occupying the two north tiers of sections in Goshen township, the greater part of Wapsinonoc township, and a tract of six or seven square miles in the northwest corner of Pike township; in all about forty-four square miles. The Wapsinonoc creek, coming in from the northwest, divides the plain in the county into an east part, sloping to the south, and a west part which slopes to the southeast. The average elevation of both of these tracts is about 700 feet above the sea level. The bluff line terminating this highland in Wapsinonoc and Pike townships is rather straight, abrupt, and of a uniform height. In Goshen township the terminating bluff is more sinuous, for the most part less abrupt, and more variable in height. Apparently there has been less cutting in this direction by the waters which have filled the lowland than toward either the east or the west. Features are seen here and there which suggest a submerged slope. Some small hills lie out in the plain, that have been detached from the main upland by an erosion which must have long preceded the making of the low-

land plain to the south. One instance of this kind is in the southwest quarter of section 1, in Goshen township. Other instances of similar import are the isolated elevations, already noted, south of Atalissa and southwest of Moscow. With the exception of a limited area in the west part of Wapsinonoc township, all of the Kansan drift plain in the county is dissected by streams with wide and open valleys. Along the Big Slough in Wapsinonoc, and also in the vicinity of West Liberty, there are some indications of terraces at elevations varying from thirty to sixty feet above the lowland plain.

Table of Elevations.

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

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

DRAINAGE.

The Kansan drift plain is, as just stated, everywhere well drained by streams which come down from the north and from the west through wide valleys out on the West Liberty plain. Big Slough, which runs east through the central part

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

That marginal part of the Illinoian drift plain which is covered by scattered dunes and paha-like swells has a drainage quite different from that of any other land in the county. Nearly all of it belongs to the basin of the Cedar. As previously stated, the Cedar bluffs on this side of the river, south of Musketo creek, have a crest, through the gaps in which the streams from the upland must pass before emerging on the bottoms. Just inside the crest there are frequently small, undrained ponds, or there is a drainage away from the crest into some lateral tributary of the creeks. Farther away from the river, from points half a mile or less from the bluffs to the head of the streams, the drainage in each little basin is

quite efficient, owing to the general slope westward. The land nearest each stream is mostly comparatively low and flat, rising farther away into wide swells, which separate the basins of the different streams. In the north part of Fulton township, some creeks occupy deeper and narrower flat bottoms, which, previous to the tilling of the land, were marshy and which are now meadows. The central sections in Fulton and Wilton townships are more flat than any other part of the drift plains in the county. This land is on the divide between the Mississippi and the Cedar river basins. The ravines are shallow and far between. The early settlers found these lands too wet for tillage. There are a few very low swells, and occasional very shallow, small, undrained basins, otherwise the surface is an even plain. Similar conditions are observed in the adjoining tracts in Moscow, Bloomington and Sweetland townships. Undrained ponds are, perhaps, somewhat more frequent, and part of the surface slightly more uneven. To the south the flat top of the divide is not quite as wide, but it is marked by an interrupted line of very shallow depressions of the surface all the way to the Louisa county line. The drainage of the slope to the Mississippi is almost perfect, the gradient of all the streams being steeper and the modifications of the preglacial valleys by the drift being less. The only exceptions consist of a few very small depressions almost on the brink of the bluffs immediately east, west and southwest of the city of Muscatine. How the bottoms of the Mississippi are drained, has already been made sufficiently evident in the discussion of their topography.

STRATIGRAPHY.

General Relations of Strata.

The rocks which are naturally exposed in Muscatine county belong to the Paleozoic and Cenozoic groups. A conglomerate of unknown age may prove to be Mesozoic. The Paleozoic is represented principally by Devonian limestones and shales, which appear along the Mississippi river and some of

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

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

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

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

UNDERLYING FORMATIONS.

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

ROCKS PENETRATED IN THE WILTON WELL.

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

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

From the records of wells in the adjacent counties it is clear that number 1, in the above table, is the Saint Peter sandstone, number 2 is the Galena-Trenton limestone, number 3

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

Succession of Rocks Below the Devonian.

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

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

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

SILURIAN.

NIAGARA LIMESTONE.

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

DEVONIAN.

MIDDLE DEVONIAN.

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

ing the two will be treated together, but the dividing line will be indicated, whenever practicable. The Upper Devonian, which consists of the Sweetland creek beds, will be discussed separately.

THE FAYETTE BRECCIA AND THE CEDAR VALLEY LIMESTONE.

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

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

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

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

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

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

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

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

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

FEET.

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

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

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

FEET.

6. (*10–11*) Weathered ledges of limestone, with scattered casts of cyathophylloid corals..... 2–4
5. (*9*) Traces of a carbonaceous black seam of limestone with Stromatopara..... ½
4. (*9*) Thick-bedded, bluish, dolomitic limestone, with casts of *Spirifer parryanus*..... 9
3. (*8*) Soft, shaly material, with large specimens of *Atrypa reticularis* and other brachiopods..... 1

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

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

FEET.

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

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

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

FEET.

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

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

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

Close up to the contact with the coal measures some siliceous nodules were seen in the most thoroughly altered ledges, measuring from half an inch to four inches in diameter. This rock is very hard and tough. The ledges of number 5 have been quarried most extensively. They exhibit a uniform grain and break rather easily with a conchoidal, even fracture, with almost equal readiness in all directions. The lowermost ledge is two feet in thickness. The bedding planes are even and well marked; but the ledges frequently exhibit an oblique fracture running in long curves at angles from 10° to 45° from the horizontal, so as to simulate bedding planes for distances of two or three feet. Farthest down the creek, where this number first comes into view, and close by the abandoned tile works, the ledges are seen to have weathered along the joints

and bedding planes into a loose, clayey material, so that only the centers in the blocks are sound. It is possible that the green clay, number 4, may be the result of disintegration of the base of the number above. It does not always appear in the same position in other places. *Atrypa reticularis*, which it contains, is like the specimens found above in being of large size, but unlike them in having the calcareous matter of the valves preserved, the fossils above being casts. Number 3, also, exhibits changes due to weathering. Farthest down in the creek, close to the wagon bridge, it lies in thin, straight, floor-like layers, but farther up, under the old storehouse of the tile factory, an excavation shows a hard and tough rock, with only faint and more distant traces of bedding joints. At this junction of numbers 2 and 3 there is a peculiar, crack-like structure, described farther on. The clay containing *Athyris vittata*, below number 2, is not now well exposed. It may possibly, also, be a product of disintegration from the overlying ledges.

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

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

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

ROBINSON CREEK SECTION.

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

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

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

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

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

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

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

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

A quarter of a mile farther up the creek a limestone corresponding to number 3, in Wresley's quarries southwest of Moscow, is exposed in the bed and left bank of the creek. It contains *Acervularia davidsoni*, *Spirifer parryanus* and *Athyris vittata*, the latter being abundant. Resting on this there is a gray rock of very uniform grain in regular ledges, with a smooth conchoidal fracture. This is an altered phase of number 1 in the foregoing section. It contains a few specimens of the same Cystodictya seen in the latter, and is overlain by number 2 in the same section. The ledges appear to have undergone some peculiar change which gives them an unusual appearance. This change may have consisted of the infiltration of siliceous matter, of which they contain about 6 per cent. Whatever is the nature of the change it has so thoroughly

affected the rock that at the line where it ceases, near the south end of the exposure, it suggests an unconformity between the two numbers. At three different places farther up the creek the same phase appears again. The rock is evidently less affected by weathering than other limestone in the region. With its more uniform texture it ought to make a good building stone.

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

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

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

		FEET.
5.	(7, 8) Thin and shelly limestone, full of brachiopods and also containing *Gomphoceras ajax?*	4
4.	(7) Disintegrated, fine grained, dolomitic limestone (not well exposed)	6½
3.	(6) Soft, very much weathered and crumbling, yellow rock, with *Athyris vittata* in profusion on the slope.	5
2.	(6) Somewhat brecciated, hard, gray, coral-bearing limestone, containing *Alveolites goldfussi*, Strombodes *Acervularia davidsoni*, *Athyris vittata*, *Atrypa reticularis*, *Stropheodonta demissa* ("Small, but identical with one found at Alpena, Mich." Calvin). From the base of the number, scattered, small, vertical plates, ¼ inch thick, extend into the fine grained ledge below	5
1.	(5) Compact, fine grained, light-colored limestone, not very rich in fossils, with *Monticulipora monticula*, *Orthis iowensis*, *Spirifer parryanus* (small size, six inches below the top of the number) and *Spirifer pennatus* (farther down)	3

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

of the southeast quarter of section 4 in Montpelier township, there is an old quarry in the south bank of this tributary which shows the following succession:

CARPENTER'S QUARRY SECTION.

		FEET.
7.	(9, 8) Shaly, yellow material, or clay, apparently residue from decayed limestone. On the slope of this shale were observed *Atrypa reticularis*, *Orthis iowensis* (one thin variety, also the usual form), *Strophedonta demissa* (of variable size), Platystoma, *Spirifer subcaricosus* (small, short-hinged), *Cyrtina carvilineata*	7
6.	(8) Hard, solid ledges, a foot in thickness, in places almost filled with shells, mostly *Atrypa reticularis*. A large form of *Athyris vittata*, with sinus and fold more marked than usual, was also seen	3
5.	(7) A layer of fine grained limestone, cut by a network of vertical plates (Fig. 2) made up of material like that in the ledge above	¾
4.	(7) Shaly, dirty, calcareous material, same as number 3 in the Robinson creek section	⅙
3.	(7) Fine grained, gray limestone, thin-bedded above, more thick-bedded and dolomitic below. Gomphoceras and a reniform Stromatopora in the upper part, Cystodictya below	2
2.	Concealed	5?
1.	(5, 6) Gray limestone, in somewhat irregular ledges, containing many fossils, such as Monticulipora, Ptychophyllum, stem joints of crinoids, Fistulipora, *Acervularia davidsoni*, *Atrypa reticularis*, *Athyris vittata*, *Cyrtina umbonata* exposed in the bed of the creek	3

Number 5 in the above section follows the creek for some distance up, but at last it disappears under the coal measures. In the opposite direction, along the middle branch of Pine creek, this ledge is quite conspicuous for a considerable distance, and it has been quarried in several places in sections 6 and 7, Tp. 77 N., R. 1 E. In the west half of section 8, the underlying bluish, dolomitic ledges are weathered along the joints, exhibiting blocks with a solid interior surrounded by a two-inch crust of altered rock. The peculiar networks of plates (Fig. 31) is seen on some ledges in a gully southeast

FIG. 31 Network of vertical plates extending into the top of the Cystodictya ledges. Seen from above. Reduced about ¼. Specimen in Carpenter's quarry, on Pine creek. Photograph by W. H. Norton.

from the center of the west line of section 8. Along the west branch of Pine creek, the same ledges (numbers 3–6 in last section) form the south bank of the creek for half a mile in sections 17 and 18, where they have also been quarried. Near the line of the Fifth Principal Meridian, the stream runs over coal measure shale, but the Cedar Valley comes up again in section 12 in Sweetland township. From this section northward, only drift is seen until we come to the old Hanson quarry in section 35, Tp. 78 N., R. 1 W., now occasionally worked north of the road by Mr. R. J. Vance. The main rock taken out here, on both sides of the stream, is number 3 in Wresley's quarries southwest of Moscow, and lies about ten feet lower down in the section than number 6 in the section at Carpenter's quarry, which is the main quarry limestone along the lower course of this branch. The section at this place is as follows:

FEET.

4. (6) Yellow, marly clay, a residue from disintegrated limestone, with numerous specimens of *Athyris vittata*, *Atrypa reticularis* and *Stropheodonta demissa* (all sizes)..... 1
3. (6) Weathered, hard limestone, full of fossils, in beds about eight or ten inches in thickness, stylolitic surfaces frequent near the junction with the number below, and containing Stromatopora, *Favosites alpenensis*, *Cystiphyllum americanum*, *Acervularia davidsoni* (frequent), Strombodes, *Atrypa reticularis* (abundant), *Spirifer parryanus* (frequent), *Spirifer asper*..... 8
2. (5) Yellow limestone in thin, hard layers, somewhat weathered, with frequent joints of crinoid stems and *Striatopora rugosa* (near base), *Spirifer parryanus*, *Spirifer subvaricosus*, *Spirifer asper*, Aulacophyllum, *Chonetes scitulus* (near base), rather continuous with the number below..... 3
1. (4) Partial exposures of impure, weathered, slightly argillaceous limestone, containing *Monticulipora monticula*, *Stropheodonta demissa*, *Spirifer pennatus*, *Cyrtina hamiltonensis* 6

Some of the fossils listed in number 1 run up into number 2, and *Spirifer asper* in the latter occurs in number 1. At the dividing line, *Megistocrinus latus* is known to occur in other localities, and from there upward joints of crinoid stems are profuse at this place. The thickness of these crinoid-bearing layers is less than it is known to be farther east. One-fourth of a mile farther up the creek the south bank exposes a ledge which belongs a little lower down in the general section. This ledge is almost a shell breccia of *Atrypa aspera*, and is to be correlated with the upper part of number 1 in the Wresley quarries. *Favosites emmonsi*, *Acervularia davidsoni* and *Tentaculites hoyti* were found in the same ledges in a place close by. Occasional outcrops of the ledges of the old Hanson quarry occur in the south bank of the creek above this place, as far up as to the center of section 25, Tp. 78 N., R. I W.

On the Mississippi River, West of Pine Creek.—Returning to the Mississippi river we find small exposures of the Cedar Valley limestone in a few places close to the bank, between

the mouth of Pine creek and the town of Fairport. Near the center of Sec. 30, Tp. 77 N., R. I E., the basal part of number 3 in Lowry's run section appears near the mouth of Schmidt's run. At Fairport some ledges which are not well seen in any of the previously described sections come out in the river bank and form the base of a shelf of land on which the town is built. The section is best made out near the west end, close to the kilns of the pottery works.

SECTION AT FAIRPORT.

		FEET.
8.	(*11*) Dolomitic limestone in ledges from 8 to 10 inches, rather hard, with casts of *Stropheodonta demissa* (very high and somewhat wider than the ordinary form), and of the calyx of a Zaphrentis.....	3
7.	(*10*) Thin layers of a hard, fine grained limestone, emitting a bituminous odor when struck with the hammer, containing, near the base, *Cranæna roemingeri*, *Orthothetes chemungensis*, *Stropheodonta demissa* (coarse costae), *Grammysia* (?), *Straparollus cyclostomus*, *Straparollus decewi*, Platystoma, *Pleurotomaria arata*, Gomphoceras, *Nautilus buccinum* (?), *Dipterus calvini*. A seam with frequent stylolitic surfaces separates this number from that below.....	2¼
6	(*10*) Compact limestone charged with ramifying growths of a Peronella (Idiostroma).....	1½
5.	(*10*) A thin seam of carbonaceous material.....	1/12
4.	(*10*) Limestone, frequently containing some large, laminated Stromatopora with small, dome-like elevations, or with a mammillated surface, also Amplexus (frequently semi-compound), and *Cladopora dichotoma* (?)	1
3.	(*9*) Dark and hard dolomitic limestone, with a Cyathophyllum and occasional Stromatopora.....	1½
2.	(*9*) A dark or black carbonaceous layer filled with a Stromatopora, with concentric wave-like rings.....	⅜
1.	Soft, bluish, dolomitic limestone, in somewhat heavier ledges than the numbers above, containing casts of *Orthis iowensis* (large forms), *Spirifer parryanus*, *Atrypa reticularis*, and *Stropheodonta demissa*.....	2

Number 1 in this section extends down below low water in the river. It is number 5 in the Montpelier creek section. Numbers 3–8 are apparently represented by the uppermost

Stromatopora-bearing beds occurring in several places east of Pine creek.

West from Fairport to west of Wyoming Hill the Cedar valley is mostly hidden by the later rocks which run out almost to the bank of the river. Under Wyoming hill, at its west end, extending up a few feet above low water, is a limestone of a brown or yellow color, with casts of a few Cedar valley fossils. In Sweetland creek, near the center of section 27, eight feet or more of a hard, dolomitic, yellow limestone is seen in the left bank of the creek, under the Sweetland Creek shale. This consists of ledges from six inches to a foot in thickness. Close by it contains large, broken fragments of Stromatopora, and at various points *Spirifer parryanus*, *Stropheodonta perplana*, Zaphrentis (casts of calyx), and *Straparollus cyclostomus*. In the next creek two feet of the same ledges appear in the bank. In Campbel's run, which comes down from the bluffs near the west line of Sec. 21, Tp. 77 N., R. I W., there is a section equivalent in part to the one at Fairport. It is as follows:

		FEET.
6.	(*11*) Dolomitic, rather hard limestone, in regular ledges above, with occasional fragments of Stromatopora, especially frequent below	7
5.	(*10*) Bituminous, black, somewhat calcareous material, containing a large per cent of gas, oil and carbon (in all amounting to 60 per cent of one sample), and with occasional specimens of Stropheodonta with very coarse costæ	½
4.	(*10*) Compact, brittle limestone of a gray or dark gray color, emitting a bituminous odor when struck with the hammer, in ledges from six to ten inches, containing an Amplexus, the upper six inches being highly fossiliferous, and containing among other forms a Monticulipora (with unusually fine tubes), *Dielasma calvini*, *Cranæna romingeri*, *Conocardium altum*, *Athyris vittata* (with sinus and fold well marked), *Leptodesma rodgersi ?*	2
3.	(*10*) Limestone, like the above, containing Amplexus in greater frequency, and also *Straparollus cyclostomus*	1
2.	(*9*) Dark, carbonaceous layers, with imprints of a large Stromatopora	½
1.	(*9*) Blue, somewhat porous dolomitic limestone	1½

Not quite a mile west from here, in Geneva creek, there is a similar succession of ledges, which appears to extend a little higher up in the stratigraphic column. This runs as below:

		FEET.
10.	(*11*) Disintegrated or weathered limestone, with large, white fragments of Stromatopora and *Atrypa reticularis* (large)	3
9.	(*11*) Band of dark, bituminous, calcareous material	½
8.	(*11*) Blue, dolomitic limestone, somewhat porous	3
7.	(*11*) Dark limestone, with occasional lumps of Stromatopora	3
6.	(*10*) Gray limestone, emitting a bituminous odor when struck with the hammer, containing *Cranæna iowensis*, *Athyris vittata* (a flat form) and other fossils	½
5.	(*10*) Seam of black, bituminous material, containing a Stropheodonta with very coarse costæ	1½
4.	(*10*) Dark, hard, somewhat dolomitic limestone, with occasional moulds of *Amplexus*, highly fossiliferous at top, with *Conocardium altum* and other lamellibranchia	1
3.	Not seen	2½
2.	(*9*) Black, carbonaceous layer, with Stromatopora of wavy, concentric structure	½
1.	(*9*) Blue, soft, dolomitic, slightly porous limestone, with tubular impregnations of a deeper blue color, in ledges from six to eight inches in thickness, containing casts of *Spirifer parryanus*, *Atrypa reticularis* (a large form), *Orthis iowensis*, Bellerophon and Pleurotomaria	3

On Mad Creek.—The remaining localities where the Cedar Valley may be seen in the county are confined to Mad creek. Near the center of the west line of section 25, in Park Place Addition in north Muscatine, a few feet of an apparently brecciated limestone forms the bed of the creek. It contains occasional specimens of *Straparollus cyclostomus*, Stromatopora and Amplexus, and has in places a bituminous odor, noticeable when the rock is crushed. There are also seams of carbonaceous, dark limestone in some of the ledges. A mile farther north, and northwest of the center of section 24, there is in the bed of the creek a finely granular, dolomitic

limestone, dipping at a low angle to the southwest. It consists of ledges some six inches in thickness, with faint traces of darker, cylindrical, fucoid markings, small nodules of pyrites and moulds of the valves of some brachiopods. Ten or fifteen rods farther up, the stream runs over some broken ledges like the highest number in the Geneva creek section.

The General Section.—To correlate the different numbers in the described sections is usually not difficult. Owing to differences in weathering there may be considerable variation in the appearance of the same ledges at different places; but the fossils present in each, the general lithological character of the several ledges, and the presence of peculiar structural features at some horizons enable us readily to recognize the larger divisions. Sometimes we may even recognize each separate ledge or layer at the different exposures, and know its position in the general succession, often to within the limits of a foot, or even an inch. For convenient reference a general section has been prepared, distinguishing eleven divisions into which the series may naturally be grouped, and indicating the horizons of the different fossils. In the local sections above figures are inserted referring each number to its place in this general section. (Plate VI.)

Some peculiar structures have been referred to and mentioned in the descriptions, consisting of vertical plates extending from the bases of some ledges into the rock below. These occur at three different horizons in the section, near or at the base of the Phillipsastrea (*2*) ledges, at the base of the Strombodes (*6*) ledges, and at the base of the Gomphoceras (*8*) ledges. These plates are usually about half an inch in thickness, coming to a blunt, somewhat thinned edge below. At the lowest horizon they are straight and do not extend very deep down the margin, making a gentle curve in the way of a segment of a circle, the vertical width decreasing, first slowly and then more rapidly, toward the two ends. Their length varies from two inches to a foot or more, and they intersect haphazard, no definite pattern being discernible in their

arrangement. In the second horizon, at the base of the Strombodes-Athyris ledges, the vertical depth of the plates is often as much as four inches, exceptionally more, and they occur in intersecting radiating clusters, each plate usually terminating endwise in a vertical margin which may extend laterally farther out below than above. In some cases the edges of these plates exhibit small longitudinal flutings that suggest organic markings. At the highest horizon, under the base of the Gomphoceras ledges, there is a continuous network of plates, appearing less straight above and extending down six inches or more (Fig. 31). On some weathered slabs of these ledges the whole structure, superficially, has a slight resemblance to mud cracks. The plates at all three horizons consist of the same material as the rock in the ledges immediately above, from which they extend. In each case this is a limestone, full of fossils, almost a shell and coral breccia, and fragments of these fossils, exceptionally entire valves of brachiopods, make up a part of the substance of the plates. The rock into which the structures extend is at the two upper horizons of a compact limestone with few fossils, or none, in places having a texture reminding one of lithographic stone, and becoming somewhat dolomitic farther down. They seem thus to mark horizons of a twice or thrice repeated sequence of events in a period of Devonian history. In each case they mark a sudden change from conditions of deposition of fine calcareous sediments, in which we find sometimes a few brachiopods, to conditions of accumulation of great numbers of fossils in a sparse, calcareous matrix. Then followed in each case a slow and more gradual return to the previous conditions, which apparently also favored the process of submarine dolomitization, since the fine-grained sediments are found to be more or less dolomitic, especially above. A fourth repetition of the same sedimentary cycle is indicated in the two upper members of the section, and doubtful indications of the plate structure have been noticed near the base of the Stromatopora breccia. But at this level there occurs another

change, which consists in the introduction of several lamellibranchia for a short space, indicating a more shallow sea, and this is accompanied by the accumulation of some bituminous material, the presence of which has a similar import. This may be looked upon as an event in a greater cycle, and would naturally modify or obscure the incidents of the smaller one.

Distribution.—The Fayette breccia, consisting of the four lower members of the general section, forms a crescentic belt of unknown width (south of the Otis and Independence, if these occur in the county), entering the county somewhere to the northwest, in Wapsinonoc or in Goshen townships, and extending east under parts of Moscow, Wilton, Fulton, and probably also under some of the northern sections in Pike, Lake, Bloomington and Sweetland townships, where preglacial erosion is deep. The drift over this region is thick, and the only exposures known are in Secs. 3, 5, 6 and 8, in Tp. 78 N., R. II W., in Secs. 23, 27 and 34, Tp. 78 N., R. I W. Bowlders of it occur as the main ingredient in a drift gravel west of Stockton, indicating its presence close by that place.

The Cedar Valley limestone forms a broad belt to the south of this. It most likely underlies the greater part of Wapsinonoc, Pike, Lake and Fruitland townships, and may possibly extend into Orono, Cedar and Seventy-Six. When not overlain by later formations it constitutes the bed rock in Bloomington, Muscatine, Sweetland and Montpelier townships, and the south part of Fulton. In the six first named townships not a single outcrop is known, owing to the deep drift there, and in the five last named townships it is for the most part covered by the Des Moines, coming into view only along the river and farther north in the valleys of Pine creek, Mud creek and Sulphur branch. A narrow strip of it most likely follows the north margin of the area covered by the Des Moines in these townships.

SWEETLAND CREEK BEDS.

In Muscatine, Bloomington, Sweetland and Montpelier townships some argillaceous beds are frequently found overlying the Cedar Valley limestone. These contain a fauna quite different from that of the latter, and are unconformable with this as well as with the coal measures above. For reasons which will presently appear it is proposed to call them the Sweetland Creek beds.

Typical Exposures.—Following the north bluff of the Mississippi westward, the first occurrence of these beds is to be seen in the bank of a creek which comes down from the north, east of the town of Montpelier. About twenty rods north of the bluffs the basal sandstone of the coal measures rests on some olive-gray shale, with green bands, rising about three feet from the bed of the stream in the right bank. This shale is altogether unlike the dark shale of the coal measures in appearance. The layers are more even and uniform. An unconformity between the two is also evident, and the lower formation soon disappears. In the river bluff the same creek is undermining a cliff of coal measure rock, which rests on the Cedar Valley limestone for the greater part of its length, but at the south end the base of the coal measures rises somewhat abruptly, first on an eroded slope of the limestone, and then over some decayed yellow clayey beds which intervene and run up ten or twelve feet above the limestone. The present condition of the bank does not afford an opportunity to study closely the nature of the clay beds, but in all probability they belong to the same strata as the shale above.

To the west of the town, a short distance up Robinson creek, and northwest of Mr. G. W. Robinson's residence, some green clay is seen in the south bank of the creek, apparently resting on the eroded surface of the Cedar Valley limestone. At the base of this clay there is a thin layer of more stony material, and this contains specimens of *Ptyctodus calceolus* and small teeth of other fishes. This is the basal layer of the

Sweetland Creek beds. About one-half mile further up the same creek, near the north line of section 23, Montpelier township, below a small fall in the creek, the following section is seen:

		FEET.
13.	Coal measures.	
12.	Dark bituminous shale with two or three bands of green shale; the dark next the green exhibiting a complex network of thread-like green extensions from $\frac{1}{2}$ to 2mm. in thickness, lying approximately parallel with the bedding. Occasional lingulas found	1
11.	Dark bituminous shale with small spheroidal crystalline nodules of pyrites, occasional lingulas and *Spathiocaris emersoni*	2
10.	Concealed (next number a few rods farther down)	2 ?
9.	Light greenish shale	1
8.	Dark olive-gray shale	$\frac{3}{8}$
7.	Green shale	$\frac{3}{8}$
6.	Greenish calcareous shale, almost stony, containing cylindrical or flattened fucoid markings slightly more greenish than the matrix	$\frac{5}{6}$
5.	Dark gray shale	1
4.	Grayish-green pyritiferous rock with minute fragments of unrecognizable fossils	$\frac{1}{4}$
3.	Dark gray shale	$\frac{1}{4}$
2.	Greenish-gray, somewhat stony shale, exhibiting concretionary conchoidal fractures when weathered	$\frac{1}{4}$
1.	Greenish-gray argillaceous and pyritiferous fine-grained dolomitic rock in layers a few inches in thickness, with fucoid impregnations or markings like those in number 6, $\frac{1}{4}$ inch in diameter	$1\frac{3}{4}$

At the south end of this outcrop there is a small displacement in the ledges, which, dipping at a considerable angle south of it, soon disappear under the coal measures. The displacement is no doubt local and probably due to the falling in of some cavern in the underlying limestone.

Westward for the next three miles these beds do not appear, although the contact between the coal measures and the Cedar Valley limestone frequently comes into view. In the Pine creek basin they must have been removed by erosion previous to the deposition of the coal measures. Their next

appearance is in Schmidt's run, about a mile east from the railroad station at Fairport. North of the wagon road, under the bluffs, they may be seen in the left bank of the run. There are several outcrops farther up, and the following section was made out, unconformably overlain by the coal measures:

		FEET.
4.	Dark, almost black shale, with green seams from 1 to 4 inches thick, near which the darker shale exhibits a network of filamentous extensions of green clay...	7
3.	Greenish, light-colored shale.....	3½
2.	Greenish, stony and hard shale.....	½
1.	Greenish, gray, soft shale.....	1½

Just west of the railroad station at Fairport, where a wagon road follows a ravine up the bluff, this ravine exposes the following section:

		FEET.
7.	Coal measures, resting unconformably on the numbers below.	
6.	Weathered shale, of alternate light and dark layers....	5
5.	Dark gray shale.....	5
4.	Grayish-green shale, with two bands of darker shale in part perforated by coarse, curving filaments or cylinders of green shale.....	3
3.	Concealed	2?
2.	Dark gray shale, with curving, cord-like cylinders of green shale, about $\frac{1}{8}$ inch in diameter.....	3
1.	Greenish, argillaceous dolomite, in layers about 6 inches in thickness.....	1

In a small ravine which comes down from the west side of Wyoming hill there is seen, under and north of the wagon bridge, about eight feet of gray and green shale, with some stony layers. The Cedar Valley limestone comes out in the river bank just below and the coal measures overlie the exposure, rising about 100 feet above it.

Along Sweetland creek the relation of these beds to the formations above and below them is better exhibited than at any other place in the county. About one-third of a mile north from the river bank they come out into view on both sides of the creek, and they are also seen in a small tributary

which runs into the creek from the east. Combining all the exposures at this point the following succession of separate layers is evident:

		FEET.
11.	Dark gray bituminous shale, with one or two thin, green bands about 4 feet below the highest exposure. Occasionally small, flat concretions of pyrites are seen. Next the green layer the shale is dark, filled with a maze of fine green filamentous lines. Drift overlies	8
10.	Dark shale, containing lingulas, *Spathiocaris emersoni*, Rhynchodus, and a fossil resembling *Solenocaris strigata*. This number is continuous with No. 11	1½
9.	Greenish clay, with flat concretions of iron pyrites, frequently having white, stony lamellar extensions from the margin	3
8.	Dark shale	½
7.	Greenish, stony shale, with a conchoidal concretionary fracture	½
6.	Hard, light grayish-green shale, with white, flattened, cylindrical fucoid concretions of a concentric structure in horizontal positions	¼–½
5.	Greenish, argillaceous or arenaceous, fine grained dolomite, in ledges from 4 to 10 inches in thickness, with occasional lingulas and a fragment of a cast of a gasteropod near the base, frequently exhibiting small, cylindrical, concretionary impregnations of a deeper green, and occasionally impressions of plant-like fibrous structure covered with a thin layer of bituminous material	3
4.	Greenish shale	1½
3.	A stony seam filled with finely granular pyrites, and occasionally showing larger lumps of the same mineral, in one instance associated with plant like fibrous impressions, frequently containing rounded, worn fragments of fish teeth	1½–¼
2.	Green, hard shale	½
1.	Greenish stony layer, with frequent, mostly rounded fragments of teeth of *Ptyctodus calceolus*	½

Under the lowermost layer containing fish teeth, the uneven surface of the upper ledges of the Cedar Valley limestone is seen, and at least eight feet of this rock is exposed. In some of the shallow depressions in its upper surface a

seam of black bituminous material is found. At one point this forms a layer two inches in thickness. Near the south end of the exposure farthest down the creek, the upper beds come down over the uppermost ledge of the limestone, which runs out as if worn away. The surface of the limestone has been partly uncovered. It is brown in color, uneven from erosion and frequently studded with nodules of iron pyrites or covered by a continuous incrustation of the same mineral. In the west bank of the creek the basal sandstone of the coal measures overlies the eroded edges of numbers 6, 7 and 8 in the above section, which rise under it in a hillock (Fig. 1, plate V). In the gully to the east the section is continued higher up and the coal measures do not appear. Some distance farther up Sweetland creek they are again seen unconformably overlying the dark gray shale in the east bank, with erosion contours extending down three feet into the lower formation. At this place the basal conglomerate contains rounded lumps of the dark shale, three or four inches in diameter. Still farther up the creek the darker shale, corresponding to number 11 in the above section, appears at several places in the bed of the stream, rising in one instance about five feet in the bank. The last seen is about 100 paces south from the wagon bridge near the north line of section 27. In each of these places the characteristic green layers with their accompanying network of green threads in the confining dark shale may be seen.

About three-fourths of a mile west of Sweetland creek, near the east line of section 28, in Sweetland township, a smaller stream exposes the following section:

		FEET.
5.	Coal measures.	
4.	Alternate layers of dark and greenish shale.....	4
3.	Fine grained, light yellowish-gray, impure dolomite in thin ledges.....	2½
2.	Greenish shaly rock with a thin, harder layer below..	2½
1.	Upper ledges of the Cedar Valley limestone, ferruginous and worn superficially.....	1-2

In Campbel run, which comes down to the river through the northwest corner of section 21, in the same township, a simi-

lar succession of layers is seen at the point where the stream passes the line of the river bluffs (Fig. 2, plate V). The following section appears very clearly:

		FEET.
11.	Base of the coal measures.	
10.	Dark gray shale with lingulas near the base	3
9.	Greenish shale	3½
8.	A layer of harder, almost stony, shale	½
7.	Greenish-gray shale weathering with a conchoidal fracture into small spheroidal nodules and chips	1±
6.	Grayish, fine grained, impure dolomite	1½
5.	Greenish shale	1±
4.	A thin and stony, in places highly pyritiferous, seam associated with small selenite crystals when decayed, in places almost filled with rounded fragments of the tritors of *Ptyctodus calceolus*	$\frac{1}{10}$–$\frac{1}{5}$
3.	Greenish shale	½–1
2.	Greenish fine grained rock with fish teeth	$\frac{1}{6}$–¼
1.	Upper ledges of the Cedar Valley limestone with a slightly eroded surface, frequently covered with pyrites.	

Number 10 in the above is seen in two or three places farther up in the creek, but it soon disappears under the base of the coal measures.

Along Geneva creek, in the northwest quarter of section 29, in the same township, the basal layers of the preceding sections are seen in the bed of the stream opposite the Geneva schoolhouse, and below the wagon bridge. The main stony ledge forms the bed of the creek for a distance of ten or twenty rods a quarter of a mile farther up. About half a mile north of the schoolhouse the shale above this ledge rises some six feet in the west bank, and is overlain by the basal conglomerate of the coal measures, from which a small spring issues. Combining these exposures the succession of the layers may be given as in the following section:

		FEET.
13.	Basal conglomerate and sandstone of the coal measures.	
12.	Dark gray and ferruginous, evidently somewhat disintegrated dark shale	⅘
11.	Light greenish-gray shale	⅘

		FEET.
10.	Dark lavender colored shale	1⅙
9.	Green shaly rock	½
8.	Concealed	?
7.	Green rock in even thin layers with regular vertical rather equidistant joints	1½
6.	Concealed	?
5.	Greenish shale (opposite the schoolhouse)	1
4.	Pyritiferous green stony layer with cylindrical straightish fucoid impregnations	⅔
3.	Green shale	1
2.	A conglomerate of fish teeth, containing *Ptyctodus calceolus* and Synthetodus frequently in a worn condition and imbedded in a greenish argillaceous fine grained dolomite	¼
1.	Beds of the Cedar Valley limestone containing large fragments of Stromatopora, with the upper surface unevenly eroded.	

From this point westward no more is seen of the beds under consideration until we come to East Hill, in Muscatine. Under the south bluff of this hill the railroad bed has been excavated in the upper dark shale seen in the foregoing sections. These shales rise here about thirty feet above the bed of the road, and they have been so disposed to slip, that piles and a stone wall have for many years been needed to keep the embankment from coming down on the track. These were removed late last fall and the face of the embankment was cut away several feet. This work left the shale well exposed. The section above and below the railroad bed is as follows:

		FEET.
2.	Dark or gray bituminous shale, with three parallel bands of green shale a few inches in thickness and about three or four feet apart, weathering into fine chips of a yellowish light-gray color, containing small flat concretions of pyrites, joints in some of the freshly exposed shale filled with numerous small crystals of selenite disposed in branching patterns, the basal part containing a lingula and exhibiting the peculiar network of green thread-like extensions observed in previous sections near the transitions to green shale	36
1.	Green shale	2

The top of number 2 is unconformably overlain by the coal measures, and has evidently been weathered previous to their deposition. Below number 1 the section is concealed in the river bank. The base of this layer is about ten feet above low water. There is little doubt that it is the equivalent of number 9 in the Sweetland creek section, and the lower layers of these beds may possibly all have been exposed above water at this point before the railroad embankment was made. As these lower layers aggregate about seven feet in thickness at other places, it will be noticed that the extreme thickness of the whole formation at this place is about forty-five feet. This is the greatest thickness that has been seen anywhere in the county.

Just above the wagon bridge which crosses Mad creek near the center of the northwest quarter of section 24 in Bloomington township, some ledges equivalent to numbers 6, 7, 8 and 9, in the Sweetland creek section, appear in the bank of a tributary from the east. Again in the creek running east through the north half of the northwest quarter of section 26 in the same township some thin ledges of rock and some green shale corresponding to numbers 3, 4 and 5 in Sweetland creek come into view from under some coal measure beds.

Geographical Distribution.—So far as known, the above places include all the exposures of the Sweetland creek beds in the county. There is good reason to assume that they underlie the coal measures in most of Muscatine, Bloomington and Sweetland townships, and that scattered outliers occupy the same position in the east half of Montpelier township. In all probability their outcrop in the river bluff is continuous from Wyoming Hill to Muscatine, though mostly concealed by the talus under the bluffs.

General Section.—The separate layers and ledges of the formation have a remarkably uniform development, varying but slightly in different places. The basal layer, though only about three inches in thickness, can always be recognized in its place, and invariably contains the characteristic fish teeth.

FIG. 32. Thread-like extentions of green shale, in the dark layers of number 4, in the general section of the Sweetland Creek Beds.

From six inches to a foot above this layer there is a pyritiferous stony seam from one-half to two inches in thickness, and this is readily identified in all the creeks in Sweetland township, where the lower part of the section appears. The peculiar maze of green threads which extend into the dark shale, where this comes into contact with green layers, have been observed in almost every case where they are due in the section, all the way from Muscatine to Montpelier. It is, therefore, no very difficult task to combine the local outcrops into a general section.

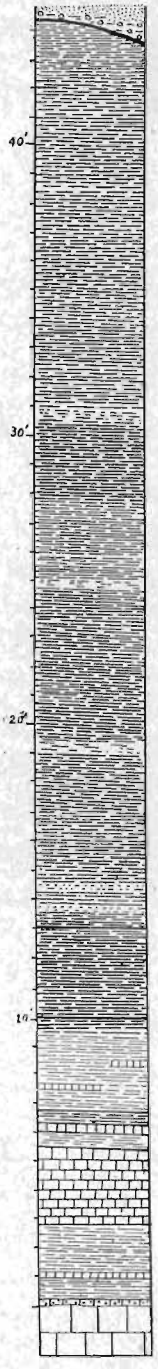


FIG. 33. General section of the Sweetland Creek Beds.

GENERAL SECTION OF THE SWEETLAND CREEK BEDS.

		FEET.
7.	Dark bituminous shale, occasionally containing small flat concretions of iron pyrites, with three thin bands of greenish shales respectively about 5, 9 and 12 feet from the base	33
6.	Dark shale, with thin seams of blue shale, the dark containing two species of lingula. *Spathiocaris emersoni*, Rhynchodus, and a fossil resembling *Solenocaris strigata*	3
5.	Greenish shale, with occasional stony layers, containing flat concretions of pyrites frequently bordered by lamellar marginal extensions of a white dolomitic material	3½
4.	Alternating layers of greenish stone and dark shale, the latter in part containing a network of thread-like extensions (Fig. 32), of the former. The green shale has elongated flattened concretions resembling fucoidgrowths and lying parallel with the bedding. The stony layers are frequently charged with small grains of pyrites and contain minute fragments of fossils	2
3.	Greenish fine grained argillaceous magnesian lime stone impregnated with iron pyrites and calcium phosphate, in ledges from 4 to 10 inches in thickness, with cylindrical fucoid impregnations slightly more greenish than the matrix and from 3 to 6 millimeters in diameter, containing two species of lingula, a fragmentary cast of a helicoid gasteropod, and imprints of some fibrous structure like that of some plant stem	3½
2.	Hard greenish-gray shale, with a stony pyritiferous layer that contains fish teeth and impressions of vegetable tissue about 10 inches from base	3
1.	Argillaceous dolomitic stony layer containing *Ptyctodus calceolus* and other forms resembling Syntheto-dus	¼

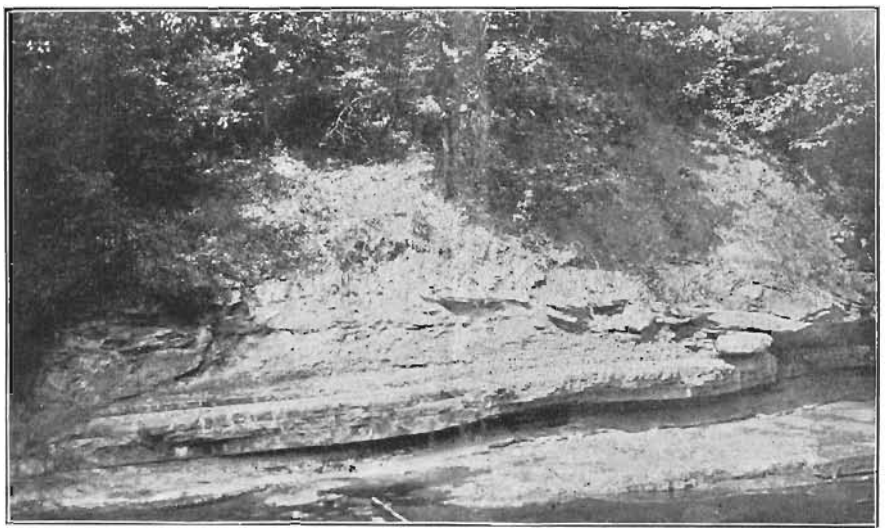


FIG. 1. Sweetland creek beds with coal measure sandstone uncomformably above, and Cedar valley limestone below. *5*, coal measure sandstone; *4*, variable beds of the Sweetland creek shale, No. 4 of the general section; *3*, stony ledge, No. 3 of general section; *2*, greenish-gray shale, No. 2 of general section; *2'*, pyriteferous seam in No. 2; *1*, basal layer, No. 1 of general section, containing fish teeth, and resting on oxidized surface of Cedar valley limestone. Exposure on Sweetland creek, center Sec. 27, Twp. 77 N., R. 1, W.

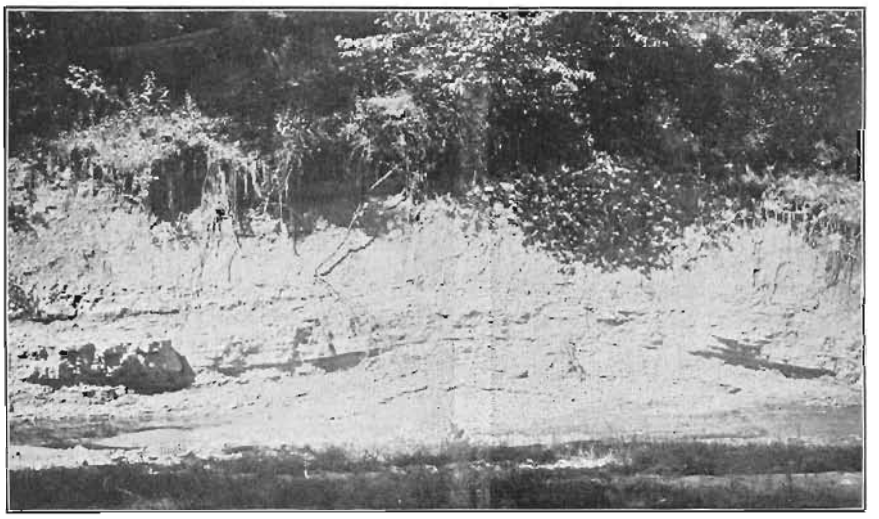


FIG. 2. Sweetland creek beds, unconformable on Cedar valley limestone, Campbell's run, SW. Sec. 21, Twp. 77 N., R. 1., W. *5*, variable beds of the Sweetland creek shale, No. 4 of the general section; *4*, stony ledge in Sweetland creek beds; *3*, greenish-gray shale, No. 2 of general section; *3'*, pyriteferous seam; *2*, basal layer with fish teeth; *1*, eroded surface of Cedar valley limestone.

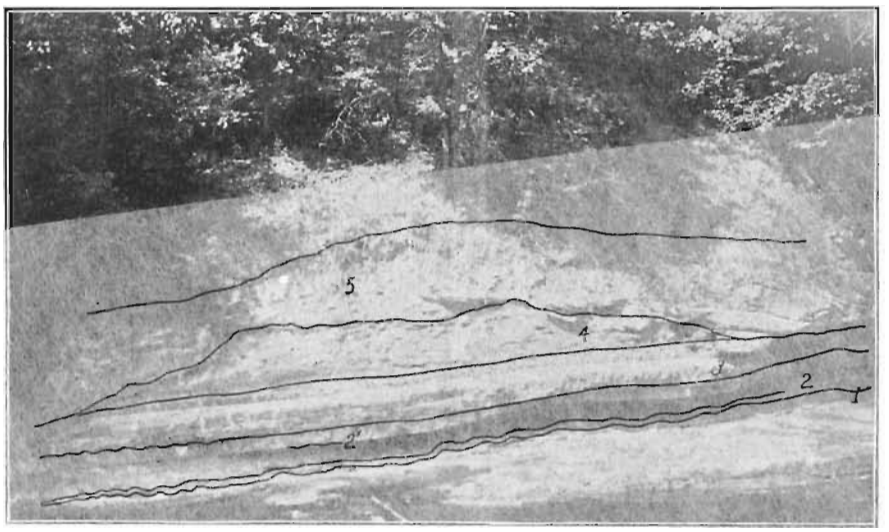


FIG. 1. Sweetland creek beds with coal measure sandstone uncomformably above, and Cedar valley limestone below. *5*, coal measure sandstone; *4*, variable beds of the Sweetland creek shale, No. 4 of the general section; *3*, stony ledge, No. 3 of general section; *2*, greenish-gray shale, No. 2 of general section; *2'*, pyriteferous seam in No. 2; *1*, basal layer, No. 1 of general section, containing fish teeth, and resting on oxidized surface of Cedar valley limestone. Exposure on Sweetland creek, center Sec. 27, Twp. 77 N., R, 1, W.

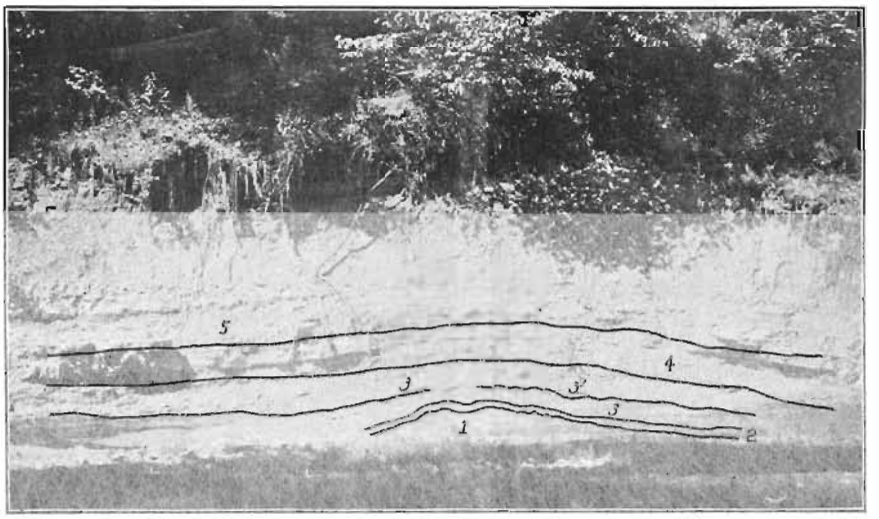


FIG. 2. Sweetland creek beds, unconformable on Cedar valley limestone, Campbell's run, SW. Sec. 21, Twp. 77 N., R. 1., W. *5*, variable beds of the Sweetland creek shale, No. 4 of the general section; *4*, stony ledge in Sweetland creek beds; *3*, greenish-gray shale, No. 2 of general section; *3'*, pyriteferous seam; *2*, basal layer with fish teeth; *1*, eroded surface of Cedar valley limestone.

Lithological Peculiarities.--The greenish ledges turn grayish-yellow on weathering. The main stony ledge, number 3, often protrudes as a shelf over the clay below it, which is more easily removed by erosion. In two instances an efflorescence of epsomite was noticed forming on the face of the clay thus protected from rain by the overhanging rock. The material found in the shells of the lingulas of this ledge was unaltered, but in one instance slightly dissolved away. The tubular impregnations in the stony layers of the formation appear to be marked off from the mass of the rock so as to sometimes weather out like casts of fucoid stems. In other instances they appear like slightly more colored parts of the rock. The thread-like extensions of green clay, which form a network in the dark shale at some horizons where it comes in contact with the lighter shale, vary in coarseness at different places. There is nothing to indicate a structural boundary between the green in the threads and their dark matrix, and there is hardly anything to suggest that they have an organic origin. It seems more likely that they have resulted from some progressive change in the mineral nature of the shale. Excepting the lingulas the fossils which occur in the layer numbered 6 in the general section are all of a black and bituminous substance, which is apt to break and fall out in drying, leaving only a mold. The dark shale in numbers 6 and 7 is fine and very uniform in character. Occasionally it is difficult to distinguish from the coal measure shale, but the latter usually contains small mica scales, which are absent from the former. Where not weathered these beds contain a considerable amount of bituminous material, which on distillation yields inflammable gas and oil. The several layers of the formation have been examined for phosphate by Dr. J. B. Weems, who finds 2.01 per cent of calcium phoshhate in number 7, 1.94 per cent in number 6, 2.09 and 2.18 per cent respectively in two analyses of material from number 5, 3.18 per cent in number 4, 6.82 and 5.29 per cent respectively in two

analyses of material from number 3, 5.43 per cent in number 2, and 4.86 per cent in number 1.

Structural Relations.—As already shown, a pronounced unconformity separates this formation from the overlying coal measures. The erosion interval preceding the deposition of the latter has left its marks, not only in the reliefs which extend from the top of these beds to a considerable distance below their base into the underlying limestone, but also in the weathering of the Sweetland Creek beds, especially where these rise high. In such places the lamination appears indistinct, and the shales are oxidized and leached. After the deposition of the Sweetland creek beds they were raised and subjected to erosion and sculpturing, which no doubt removed the greater part of them. Only remnants are left. Then, again, the land was submerged, and the topography just sculptured was covered over by the variable shore deposits of the coal measures.

It has also been shown that there is an unconformity with the underlying Cedar Valley limestone. But this unconformity indicates altogether different conditions. The upper formation is, in this case, not a shore deposit. The basal member of the Sweetland Creek beds is a thin layer of argillaceous dolomite, containing no littoral detritus, and it is unusually uniformly developed, though only two or three inches thick. It is a sediment made in the sea at such a slow rate that the teeth of dying fishes accumulated rapidly enough to make at one place as much as one-fourth of its bulk. This layer follows the small inequalities in the surface of the lower rock like a mantle. None of these are very high or deep. On a distance of a few rods none appear to exceed two feet in vertical extent. Near the Geneva school the basal tooth-bearing layer appears to occupy a place eight feet lower than the highest ledge in an abandoned quarry close by. The surface of the limestone is, however, plainly eroded, and apparently to some extent oxidized. In the east bank of Sweetland creek the highest ledges of the limestone run out to the

south, and the overlying formation comes down over their beveled edges. An unconformity of this kind is most likely caused by subaqueous erosion, due to marine currents, followed by renewed sedimentation in the same sea. Such events may have been accompanied by an approach of the shore line. This is, perhaps, indicated by the presence of faint traces of vegetation in the later member in this case. But at the very beginning of the second accumulation the shore was not near enough to leave a trace of anything coarser than clay. Even this was scarce at first, when calcareous sediments predominated. The persistence of each thin layer over distances of several miles goes to show that the conditions under which they were laid down were uniform over wide areas, and such conditions are not to be found in the proximity of the shore line. Everything considered, this unconformity was most likely caused by changed conditions in the sea and its currents, in all probability consequent upon some orogenic movements affecting the ocean basin.

Fossils.—The fossils so far found in this formation are few, but they are many enough to indicate that it must be referred to the Upper Devonian or the Chemung. The fibrous plant-like impression from number 3 was found extending over a slab a foot long and about three inches wide. In the pyritous layer in number 2 there was a similar, much smaller, impression. The mold in both instances was covered by a bituminous crust an eighth of an inch in thickness. In this no organic structure could be detected. The lingulas which occur in numbers 3 and 6 have been submitted to Dr. Charles Schuchert, who says that one species is apparently identical with an undescribed species from nodules in the "Black Shale," or the Genesee; one is related to *L. melie* Hall, from the Cuyahoga shale, and another to *L. nuda* Hall, from the Hamilton. The author has also observed one lingula in number 6, which resembled *L. subspatulata* M. and W. Some small bilobate fossils from the same number in the general section have been examined by Dr. J. M. Clarke, who has

reported that they are identical with *Spathiocaris emersoni* Clarke. This fossil occurs in the Portage group, in New York, and has not previously been reported from the west. In the same layer the author found one fossil which resembled *Solenocaris strigata* Meek. This form is known to occur in the "Black Shale" of the Ohio valley. The cast of a gasteropod found in the stony ledge, number 3, was too fragmentary for more exact determination. Dr. C. R. Eastman has examined all the fish remains found, and states that the greater number of the teeth from numbers 1 and 2 are *Ptyctodus calceolus* M. and W. He finds them on the average smaller than usual, but in other respects perfectly like the type. He also reports that there are several other forms of flat, crushing teeth, which are allied to Synthetodus from the State Quarry fish bed in Johnson county. From the bituminous, dark shale, number 6, he identifies a Rhynchodus, related to *R. excavatus* Newb., from the Hamilton in Wisconsin.

LIST OF FOSSILS IN THE SWEETLAND CREEK BEDS.

Lingula, *sp.* undet...Identical with one from the Black Shale
L. cf. melie Hall.....Cuyahoga Shale
Lingula, *cf. nuda* Hall.....Hamilton
Lingula subspatulata M. and W. (?).....Black Shale
Spathiocaris emersoni Clarke.....Portage Shale
Solenocaris strigata Meek (?).....Black Shale
Ptyctodus calceolus N. and W..Hamilton and State Quarry Beds
Rhynchodus, *cf. excavatus* Newb.....Hamilton

IMPRESSION OF PLANTS.

Synthetodus.....State Quarry Beds
Gasteropod.

Additions will no doubt be made to this list. As it is, it indicates a correlation with the Upper Devonian of New York, and more particularly with the Devonian Black Shale of the interior, which also is regarded as a part of the Upper Devonian. To this shale it shows another resemblance in having the basal layers stony and containing a comparatively high per cent of calcium phosphate, while the upper part is a black shale. It will be remembered that in Perry and Hickman

A GENERAL SECTION
OF THE
CEDAR VALLEY AND THE WAPSIPINICON STAGES IN MUSCATINE COUNTY, IOWA,
WITH A
TABLE OF FOSSILS, REFERRED TO HORIZONS WHERE THEY HAVE BEEN OBSERVED.

11 *Stromatopora breccia.* Hard, gray limestone, in part blue and dolomitic, with occasional hollow molds of corals and sometimes large fragments of stromatoporas, ledges from 6 inches to 1 foot in thickness, 8 feet.

10 *Straparollus ledges* Fine-grained limestone, in part dolomitic, ledges from 3 inches to 1 foot, carbonaceous or bituminous black seams above and below, where it is rich in fossils, occasional stromatoporas, 5 feet.

Main Dolomite. Blue dolomite, weathering yellow, of an even texture and with a conchoidal easy fracture frequent molds of fossils, lower ledges over 2 feet thick, 9 or 10 feet.

9

8 *Gomphoceras ledges.* Tough calcareous gray limestone in heavy ledges which split on weathering, full of fossils, with a network of vertical plates extending into the rock below, 5 feet.

7 *Cystodictya ledges.* Somewhat dolomitic (at least below), blue or light gray limestone of a uniform texture becoming calcareous and fine grained above, fossils usually not removed by solution, occasional joints of crinoid stems above, 6 feet.

6 *Stromlades ledges.* Hard calcareous rock full of corals and brachiopods, sometimes weathering into a marl in irregular ledges which split on weathering, occasionally brecciated and mingled with the beds below, branching vertical plates of the material in the lower ledge extending down into the next member, 8 feet

5 *Megistocrinus bed.* Calcareous, somewhat shelly or brittle rock, without definite ledges, containing numerous joints, of crinoid stems, 5 feet.

Spirophyton—Scitulus beds. Somewhat brittle and slightly argillaceous blue limestone with oblique joints, occasionally slightly brecciated, usually with many brachiopods in a fine-grained matrix, weathering rather rapidly, 17 feet.*

4

3 *Vanuxemii beds.* Alternate ledges of limestone and marly or clayey ledges, with more corals than the beds above, 5 feet.

Phillipsastra beds. Tough, gray limestone in heavy ledges, full of corals and brachiopods, vertical lamellar extensions from the lower surface of some ledges at or near the base, 7 feet. It is at the base of this bed that Calvin draws the line between the Wapsipinicon and Cedar Valley stages.†

2

Basal breccia. Fine-grained, compact, very pure limestone, frequently brecciated, destitute of fossils, emitting a faint bituminous smell when struck with the hammer, exposed in the county 25 feet.

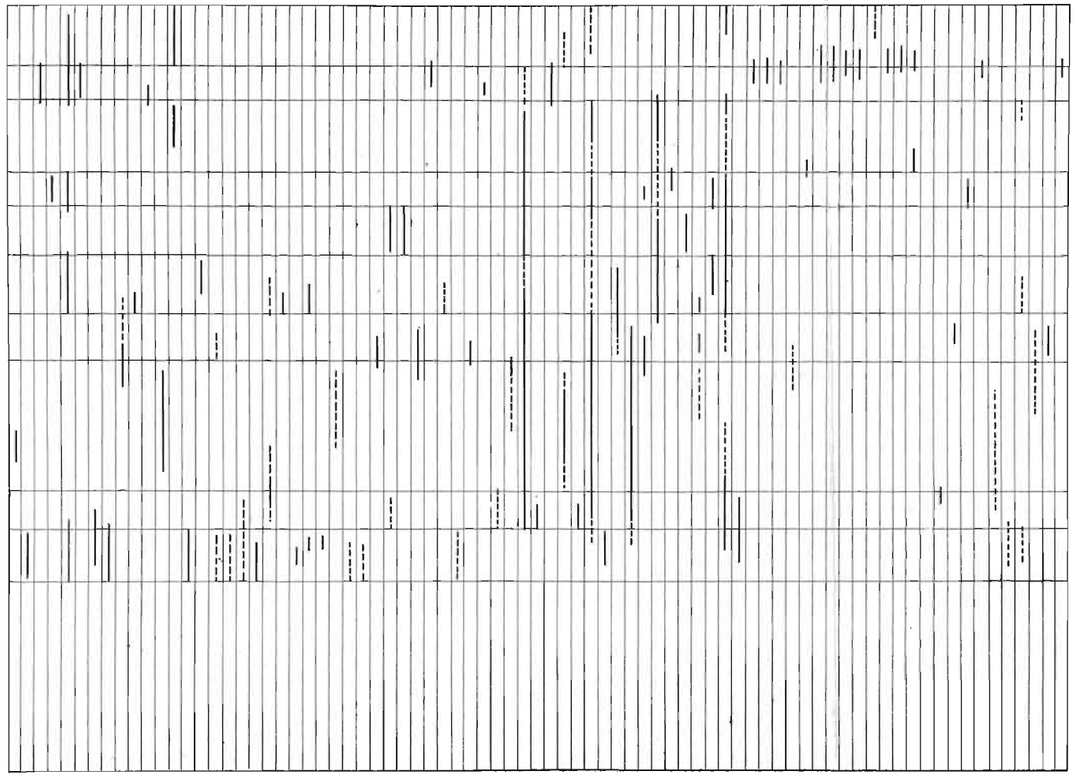
1

* Nos. 3 and 4 are the *megistocrinus farnsworthi* beds of Johnson county. The *spirifer pennatus* beds of Calvin, Geology of Buchanan county, are stratigraphically equivalent to No. 1 of this section S. C.

† The beds immediately below the *Phillipsastrea* horizon are very rich in fossils in Buchanan county, and constitute the *spirifer pennatus* beds of Calvin See report on Buchanan county, Iowa Geol. Survey. Vol. VIII. S. C.

Spirophyton structures.
Astrotsongya hamiltonensis W. and W.
Stromatopora (concentrica goldf.?)
Stromatopora (reniform).
Stromatopora (all kinds).
Idiostroma (Peronella).
Favosites alpenensis Winch.
Favosites placenta Rom.
Favosites emmonsi Rom ?
Alveolites goldfussi Billings.
Amplexus
[Streptelasma rectum Hall.]*
Zaphrentis (casts of calyx).
[Oboophyllum magnificum Billings.]
Psychophyllum.
Aulacophyllum.
Calophyllum.
[Diphyphyllum hallı E. and H.
[Diphyphyllum archiaci Bill.]
Acervularia davidsoni E and H.
Strombodes.
Phillipsastrea billingsi Calvin.
Cystiphyllum americanum E. and H.
[Cystiphyllum sulcatum Billings.]
[Elaeacrinus elegans Conrad.]
[Stereocrinus triangulatus Barris.]
[Dolatocrinus.]
[Megistocrinus latus Hall.]
Spirorbis.
Cystodictya (near hamiltonensis Uhlr.).
Monticulipora monticula White.
Monticulipora (very fine cells).
Fistuliporella.
Cladopora lowensis.
Cladopora dichotoma Hall.
[Orbiculodea.]
Chonetes scitulus Hall.
Orbis lowensis Hall.
[Orbis vanuxemi Hall.]
Orthothetes chemungensis.
Strophodonta demissa Conrad.
[Pholidostrophia iowaea Hall.]
Strophedonta demissa Conrad.
Spirifer subundiferus M. and W.
Spirifer asper Hall
Spirifer pennatus Owen.
Spirifer subvaricosus Hall and W.
Spirifer parryanus Hall.
Cyrtina curvilineata White.
Cyrtina hamiltonensis var. recta Hall.
Cyrtina umbonata Hall.
Athyris vittata Hall.
Atrypa reticularis L.
Atrypa aspera Schlotheim.
Crania romingeri Hall.
Dielasma calvini Hall?
Crania iowensis Calvin.
[Avicula.]
Carneocylus lyrata Conrad.
Conocardium alum Keys.
Grammysia.
Leptodesma rodgersi Hall.
Pleurotomaria arata Hall.
Bellerophon.
Straparollus cyclostomus Hall.
Platystoma.
Platyceras rectum,
[Lenticulites hoyti White.]
[Gomphoceras abruptum Hall?]
Gomphoceras ajax Hall?
Nautlus buccinum Hall?
[Goniatites.]
[Phacops bufo Green.]
Ptyctodus calceolus M. and W.
[Heteracanthus uddeni Lindahl]
[Dinichthys pustulosus Eastman.]
Dipterus calvini Eastman.

* Species in brackets have not been observed in Muscatine county, but are known to occur at the indicated horizons not far beyond its limits.



counties, in Tennessee, the Black Shale changes downward into the phosphate rock.*

This comparison may be better shown in tabular form.

RELATION OF DARK SHALE TO PHOSPHATE-BEARING ROCK IN IOWA AND IN TENNESSEE.

IOWA.		TENNESSEE.
Bed No. 7 contains 2.01% of phosphate	Dark Shale.	Black Shale, containing little or no phosphate.
" " 6 " 1.94% " "		
" " 5 " 2 13% " "		
" " 4 " 3.18% " "	Variable Beds.	
" " 3 " 6.05% " "	Greenish-gray pyritiferous rock and shale.	Light gray to bluish-black phosphate rock, with disseminated pyrites.
" " 2 " 5 43% " "		
" " 1 " 4.86% " "		

The indicated correlation appears all the more probable, as there exists under the phosphate-bearing rock in Tennessee an unconformity, which is believed to be due "not to the existence of a land area and subaerial erosion, but rather to non-deposition, by reason of strong marine currents."† The renewal of the conditions of sedimentation in the Paleozoic sea in the late Devonian age may not have been quite simultaneous in the two localities, though nothing is known to indicate the contrary, but there seems to have been at any rate a parallel in the sequence of events.

CARBONIFEROUS.

During the time of the deposition of the rocks of the Lower Carboniferous series farther south, Muscatine county was above water, at least for a time which was long enough wholly to remove any materials that might have been laid down in the first stages of the period. The earliest rocks which appear after the Upper Devonian are those of the Des Moines stage of the Upper Carboniferous.

DES MOINES.

In the south half of the east end of the county there is a part of an outlier of the Upper Carboniferous, which is cut

*See the Tennessee Phosphates, by C. W. Hayes. Seventeenth Ann. Rep. U. S. Geol. Surv., Part II.

†Loc. cit., p. 534.

off from the north margin of the Illinois coal field by the valley of the Mississippi river, and extends into Scott county on the east. The materials of which it is composed are very variable, consisting of conglomerate, sandstone, shale, fire clay, coal, and limestone. These change in short distances, and local sections present great differences.

The point farthest west where these rocks have been observed is in Lowe's run, in the Ne. qr. of Sec. 32, Tp. 77 N., R. II W. Beginning farthest up in the west branch of this stream the section exposed is as follows:

		FEET.
4.	Light colored shale, disturbed by glacial action and worked into the till	4+
3.	White or ferruginous and yellow or brown sandstone, in beds of varying thickness, sometimes with oblique bedding	10
2.	Laminated, black, carbonaceous, very soft sandstone, with frequent impressions of plants	4
1.	Sandstone, mostly dusky yellow or brown, following the bed of the creek some distance down	(?)

Number 3 has been quite extensively quarried, and is used mostly for foundations and retaining walls. Under the bluff two miles west of Muscatine there is an abandoned quarry in a sandstone which rises about fifteen feet in the bluff. This is possibly a continuation of number 1, in the Lowe's run section. Along the branches of Pappoose creek, in the city of Muscatine, sandstone, shale or coal is always seen, wherever the creek has cut down below the drift. In the northwest part of the city, near the adjoining corners of sections 26, 27, 34 and 35, a sandstone fifteen feet thick lies at an elevation of at least 125 feet above the river. In places it is directly overlain by loess, no bowlder clay being present. Under this sandstone there is a small seam of coal, which appears in a creek southeast of the crossing of Logan and Cedar streets. In going up the main branch of Pappoose creek the coal measures make their first appearance a short distance above the junction of Star and Cedar streets. Com-

bining the rock exposures seen in the south bank of the stream at this place with some exposures in a gully from the same side, where some rock has been quarried, the following section is apparent:

		FEET.
5.	Shelly, yellow or gray sandstone	9
4.	Somewhat ferruginous sandstone, in ledges about a foot in thickness, with occasional impressions of Lepidodendrons	8
3.	Irregularly-bedded, fragile, ferruginous sandstone, with frequent concretions of iron pyrites and impressions of Lepidodendrons	6
2.	A seam of impure coal	1
1.	Fire clay (in the bed and in the bank of the creek)	4

This same vein of coal is found at a higher level to the north on the other side of the creek, where it has lately been worked on a small scale. A little farther up in the creek all the visible rock is like the upper member in the above section. There is a ravine in which fifty feet of it is seen, rising to within thirty feet of the general upland level.

The escarpment in West Hill, fronting the river, has been examined by several geologists, and we may quote here the account given by Hall more than thirty-nine years ago, which is as follows:

		FEET.
8.	Thin-bedded sandstone, with shaly layers	19
7.	Massive sandstone, with large concretions	10
6.	Seam of coal or shaly coal, with under clay	4
5.	Shaly sandstone, with shaly partings, more shaly in the lower part	8½
4.	Thin-bedded sandstone, with shaly partings	5
3.	Heavily-bedded sandstone	6
2.	Green shale	3
1.	Distance to level of river (covered)	20

The coal seam (number 6) of the section is, as originally described by Whitney, not very regular, but is divided into several smaller and somewhat irregular areas toward the river. To the west a short distance it becomes more regular, and attains a thickness of two and one-half to three feet. A

little farther westward it appears to thin out entirely, allowing the sandstones above and beneath to come together. There are, perhaps, several coal seams in this outlier. The thickness of the one worked varies from an inch to more than three feet.* It may be added that of the large spherical concretions mentioned in Hall's section, and figured in the earlier reports, none are now in sight. A large specimen, which is seen as a beautiful ornament in front of a residence in the central part of the city, has been brought from across the river in Illinois. Working of the coal vein in this section long ago ceased. Some of the entries on the old Smally property extended back from the bluff more than 1,000 feet.

In that branch of Mad creek which runs through the northern part of sections 26 and 27, in Bloomington township, shale and sandstone come into view in several places. Such is also the case in the branch opposite to this, from the east. A small quarry has furnished some sandstone in the east bank of Mad creek, near the center of the east line of the northeast quarter of section 13. But at no place in the basin of this creek does the Des Moines formation have any considerable thickness, owing, as it appears, to preglacial erosion along the course of the stream.

In East Hill, fronting the river, some coal has been mined high up in the slope. Under this coal there is about four feet of fire clay and then a basal sandstone of variable thickness, from four to six feet. This rests on the uneven surface of the upper bituminous shale of the Sweetland Creek beds. From this point to the east line of the county the coal measures are always present in the bluffs of the Mississippi, or at a short distance back, occupying a position under the drift and above the Devonian rocks. In section 30 in Sweetland township most of the exposures consist of shale. In the east half of this section is the old Hoor coal bank, no longer operated. Doctor Keyes has reported that the floor in this mine was a soft, gray fire clay, and the roof was a sandstone,

*Keyes. Iowa Geol. Surv., vol. II, p. 477. Des Moines, 1894.

quite firm and rather compact, and he gives the general section as follows:

		FEET.
5.	Shale, bluish, argillaceous	10
4.	Sandstone	2
3.	Coal	3
2.	Fire clay	4
1.	Hidden to river level	30

East of Geneva creek in section 29, Sweetland township, there is more sandstone. This has a thickness of twenty-five feet in the quarries on Mr. Stark's farm. At this place it is seen to have a joint or fissure which is filled with plates of fibrous or columnar white calcite from half an inch to two inches in thickness. From here to Pine creek the prevailing rock of the formation is sandstone, which reaches its greatest development in the county between Wyoming Hill and the west arm of Pine creek. Over this tract preglacial erosion has been less effective than over any other part of the county. The character of the Carboniferous in this region can be best shown by giving some local sections.

In the east bluff of Sweetland creek, east from Mr. Nettlebush's coal mine, in section 27, Sweetland township, the succession is as follows:

		FEET.
4.	Rather hard and strong sandstone in ledges frequently several feet in thickness	30
3.	Seam of coal and black shale	3
2.	Soft, arenaceous shale, with a coaly seam near middle	70
1.	Sandstone, conglomeratic at base, extending below the bed of the creek	10

The coal mines referred to are on the northeast quarter of section 27. The coal there is the equivalent of number 3 in the above section.

The different beds which are to be seen at Wyoming Hill, in the face of the bluff are somewhat like those given above, but there is less shale and more sandy material.

WYOMING HILL SECTION.

		FEET.
9.	Drift and loess, mainly loess	30
8.	Sandstone of uniform texture in beds several feet thick, soft and disintegrated above	30
7.	A seam of coal and fire clay	3 (?)
6.	Dark shale with frequent small ferruginous concretions	12
5.	Sandstone, partly thin-bedded and partly in beds two feet in thickness	17
4.	Seam of coal	½
3.	Shaly sandstone in irregular slanting layers interbedded with dark seams of sandy shale. Very variable	45
2.	Sweetland creek beds	8
1.	Cedar Valley limestone to low water	5

In a gully which comes down at the west side of the hill, the base of number 3 is seen to be a conglomerate about a foot in thickness. Farther up the same gully what appears to be an equivalent of number 6, is seen to contain impressions of fern leaves in profusion. The numbers 3 and 5 have yielded impressions of Lepidodendron and Calamites, sometimes of large size.

A somewhat generalized section of the Des Moines constructed from observations around Fairport and in the run next east of this village is as follows:

		FEET.
4.	Disintegrated fine sandstone with oblique lamination, in places shaly	40
3.	Shale, in part light, in part dark	10
2.	Finely laminated, hard or fragile sandstone, with fine, long slanting lamination	20
1.	Dark shale and sandstone, variable and usually with a thin conglomerate at base	10

Back of the bluffs, in a ravine not quite two miles east of Fairport, a sandstone occurs at an elevation of about fifty feet above the river. This stone is literally filled with black and carbonaceous impressions of plants. Much of it is ripple-bedded and under it there is a seam of coal resting on fire clay.

South of the center of section 20 on the last high spur of the bluffs west of Pine creek there is an old abandoned coal mine at an elevation of about 110 feet above the river. It has furnished considerable quantities of coal in former years. The seam is overlain by a black limestone, in part concretionary and in part bedded. The latter contains quite a number of fossils, among which Dr. Calvin has recognized the following species:

Chonetes mesoloba N. & P.
Chonetes parvus Shum.
Spirifer cameratus Morton.
Derbya crassa M. & H.
Productus muricatus N. & P. (?)
Aviculopecten occidentalis Shum. (?)

This limestone is interesting as being the only member in the coal measures known in the county containing marine fossils. It is easily recognized both lithologically and by its fossils as being the equivalent of the limestone overlying Dr. Worthen's coal number 1 in Rock Island county, in Illinois.

East of Pine creek the coal measures are more shaly, and cliffs of sandstones are seldom seen along the streams. These have wide valleys with comparatively long slopes, on which evidences of small landslides now and then appear. Seams of impure coal are included in the shales and sometimes crop out in the bed of the streams. Near the east line of the county at Montpelier and in the creek next east of this, a sandstone rises in vertical walls about thirty feet high. It is white and thin-bedded, and of more variable composition at the base. In the bed of Montpelier creek the thin-bedded stone is seen to have beautiful ripple marks. In the other creek the base is coaly and shaly, an interrupted vein following the contact of the coal measures and the Cedar Valley limestone for about a mile up the stream. More or less pronounced indications of a carbonaceous or coaly deposit at this

horizon are found in Montpelier creek, Robinson creek, Lowry's run, and in the east and middle branches of Pine creek in sections 4, 7 and 8, of Montpelier township.

The west bluff of Pine creek, all the way from Pine Creek Mills to near the junction of its two main branches near the center of section 17 in Montpelier township, consists of a high and frequently vertical escarpment of solid sandstone, from fifty to a hundred feet high. This sandstone rests on softer shaly beds, into which the creek has cut its valley. The sandstone has been partly undermined by the stream; furthermore it is cut by vertical joints; and for these causes blocks of the rock break off and fall down, forming a talus below. Near the north end of the escarpment some large blocks of

FIG. 34. Devil's Lane, from the south; Wild Cat Den. Photo by Calvin.

the whole formation of the sandstone have begun to creep out and down on the underlying shale and have left a deep fissure ten feet wide between the detached blocks and face of the main ledge. This fissure is known as Devil's Lane (Fig. 34). A remnant of another block lies still farther out, having advanced farther down toward the creek. This must have been detached first from the parent ledge. A third block

is just in the process of being detached and is ready to join the procession in the rear, (Fig. 35). On the surface of the ground above, there are three sunken pits in a row over the forming crevice. This is open below, at the south end, and is known as the Niche. North of the Lane there is a recess in the wall which has been called the Bake Oven. Some distance to the north of this, close up to the brink of the wall, another small recess in the sandstone has been formed. This received the name of Wild Cat Den from the Nimrods among the early settlers in the region. The beautiful scenery along this mural escarpment, is enhanced by some native pines that rise in sombre grandeur from the brink of the wall. During the warm season it attracts from the cities and from the surrounding country, many visitors, who find comfort in the cool shade of the bluff and enjoy refreshing drinks from the chalybeate springs that issue from under the base of the sandstone. Some years ago a cast of the curving, tapering, radical end of a calamites tree was found in one of the blocks of the talus below this cliff.

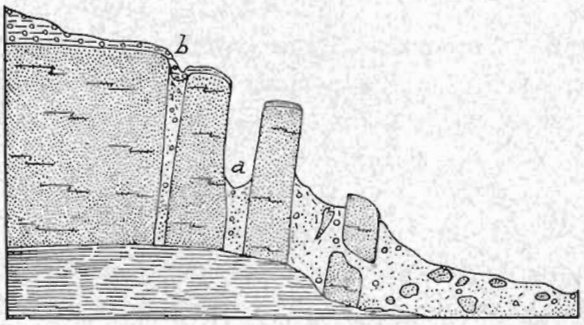


FIG. 35. Detached blocks of coal measure sandstone creeping on a foundation of shale, near Wild Cat Den. *a*, Devil's Lane. *b*, Settling of the ground above a widening joint.

Northward from the river the Des Moines rapidly thins out. Near the east line of the county it is last seen in the south half of section 1, in Montpelier township. Along the east branch of Pine creek it disappears in the northern portions of sections 3 and 4. Near the center of the south line of the latter section there is about thirty feet of sandstone, mostly disintegrated to an incoherent sand, with here and there some hard, thin, ferruginous layers. At Atteneder's old quarry,

near the north line of Sec. 18, Tp. 77 N., R. I E., the sandstone is sixty feet high in the quarry wall. A small amount of shale separates it from the Cedar Valley limestone below. But in two miles farther up the creek the whole formation gives out. In Sweetland creek it is last seen near the south line of Sec. 10, Tp. 77 N., R. I W. Away from the creeks, and under the upland drift, it no doubt reaches somewhat farther north. A well at Pleasant Prairie has penetrated thirty-two feet of dark shale and sandy material, which must belong to the coal measures. Beds of this kind are also reported from a deep well near Summit.

In the west bluff of Cedar river, northwest of Moscow, small blocks of Des Moines sandstone were observed. These were of such a character as to lead to a suspicion that there was an outlier of this rock under the drift close by. This supposition was verified in examining some drillings from a well on the farm of Mr. Frank Barnes. These contained Carboniferous shale with pyrites that had come from below the drift. The same shale has been reported by drillers from some wells just east of Atalissa. Very small pockets of coal measure shale lie on the limestone at one place in Gatton's quarries, south of the Chicago, Rock Island & Pacific railroad, in the northwest quarter of section 8 in the same township.

General Section.—If a general succession in the Des Moines beds were to be indicated the following appears to the writer as representing the nearest approximation at present possible:

		FEET.
6.	Black limestone, arenaceous, and with marine fossils	2– 4
5.	Coal and fire clay.	
4.	Sandstone, sometimes replacing the number below	30–100
3.	Coal or carbonaceous shale	0– 50
2.	Argillaceous and arenaceous, very variable beds, with frequent impressions of plants and occasional seams of coal near base	10– 40
1.	Basal conglomerate, very variable, in places replaced by sandstone, black shale or coal	0– 10

Unconformity with the Devonian.—Some time before the Des Moines was deposited in this region the Devonian sea had retreated, and the land thus uncovered had been subjected to extensive denudation. One result of this denudation was the development of a peneplain, which cut the Devonian rocks some fifty feet deeper down near the north end of the county than along the Mississippi farther to the south. Hence the uplift was most likely accompanied by a slight tilting of the land toward the south. In the area under consideration the greatest inequalities in the ancient Carboniferous land surface which are evident do not exceed forty or fifty feet, but they are frequently abrupt and well marked. (Fig. 36.)

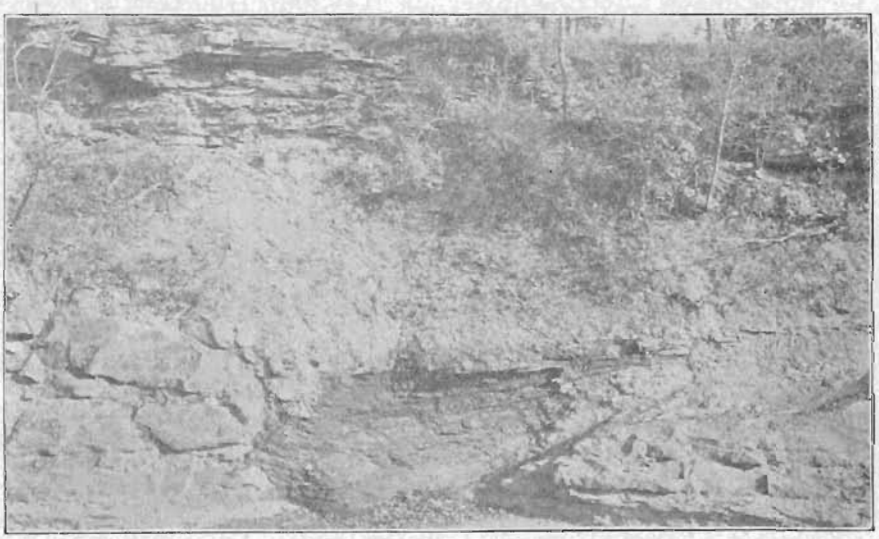


FIG. 36. Unconformity between the Des Moines and the Cedar Valley limestone in the east bank of Sulphur branch, in Montpelier township. Photo by Calvin.

Wide crevices filled with coal measure clay sometimes follow the joints down from the old surface in the limestone. These filled caverns are occasionally such as to suggest that the ancient land had at some time an underground cavernous drainage. Farther east stalactitic matter and travertine may still be found on the bottom of some caverns which are otherwise filled by coal measure shale.

The character and distribution of the basal conglomerate sheds some light on the nature of the old land. The conglomerate is usually best developed in the low depressions in the older rocks, as if made along the courses of the land streams. Sometimes the large fragments are quite angular. These seldom make up the greater part of the rock, but lie imbedded in a sandy matrix. In the east bank of Lowry's run, in section 22 of Montpelier township, a conglomerate of this kind is seen. At the south end it is cut by an unconformity at an angle of about thirty-five degrees from the horizontal, and is directly overlain by a coal seam dipping north with this angle. This marks a local incident in the advance of the Carboniferous sea. It indicates that the conglomerate is rather to be regarded as a product of the work of land streams on a sinking coast than as a residue from beach erosion. The materials which are represented in the larger fragments of the conglomerate show that it was brought mainly from the north and northeast. The average size of these fragments is from one to two inches in diameter. A list of the more commonly represented rocks in the conglomerate is here appended.

MATERIALS IN THE BASAL CONGLOMERATE.

1. *Niagara chert.*
2. *Niagara dolomite.*

These two contain recognizable Niagara fossils, such as joints of crinoids, brachiopods and favosites. The Niagara dolomite is frequently silicified.

3. *Fayette breccia* (silicified blocks, seen in Montpelier creek at the contact of the coal measures with the Sweetland creek shales, occurring singly in four or five places, a foot in diameter, one having a small pocket filled with zinc blende unchanged, having the superficial appearance of blocks subjected to the solvent action of water).

4. *Quartz nodule from the Fayette breccia* (known from its texture and peculiar pitting of the surface).

5. *Sweetland Creek shale* (near local outliers of the same formation).

6. *Red chert* (source not known).

The Carboniferous Record.—The general succession in the Des Moines of this county shows that the coast of the advancing sea was low, allowing only a small quantity of coarse materials to be brought down by the land streams. (Fig. 37.) As the sea advanced there was at first shallow

FIG. 37. Basal conglomerate of the Des Moines, in the left bank of Montpelier creek near the bluff of the Mississippi. Photo by Calvin.

water, where the surface waves produced ripples in the heaping sand. Then beaches and sandpits were formed, hemming in coastal marshes, where mud accumulated and vegetation flourished and became imbedded. The sandstone in Sweetland township is frequently bedded in a way suggesting that the beach sand at this stage was blown about by the wind, which may have aided in the making of isolated marshy places. After some time the sea had so far gained the ascendancy that calcareous deposits were laid down in waters with a brachiopod fauna. The advance was in all probability continued with interruptions for some time, but at this point our

record ceases, having been obliterated by erosion during later eras.

CRETACEOUS ? ?

THE PINE CREEK CONGLOMERATE.

On the right bank of the west side of Pine creek, a short distance north from where it leaves section 34, Tp. 77 N., R. 1 W., there is a pebbly sandstone, unlike the coal measure conglomerate in the surrounding country. This sandstone is mostly brown in color, changing to yellow. It has a rather coarse texture, compared with the coal measure rocks, and is somewhat more variable in this respect. The best exposure appears in a small gully, which comes down the hill from the west, some twenty rods north of the south line of the section. In all a thickness of about sixteen feet is seen. Springs issue from the base of this rock, along the slope to the creek, indicating finer impervious underlying beds. The lower part of the section has one ledge which is two feet in thickness. But the bedding is irregular and the layers vary much in thickness in short distances. Some of the ledges are strong enough to be used for building stone, while one or two are loose sand. Even the hardest layers break easily under the hammer. In these the sand and gravel is cemented by a black matrix of peroxide of iron. The uppermost ledges are somewhat finer than the lower. Two sets of quite regular joints here cut the rock. One set bears west of north and the other north of east. Along these joints the ferruginous material is most profusely deposited. Some of the ledges are cut up into rhomboidal blocks about a foot in length and from eight to ten inches in width. These have a shining black hard crust, half an inch or more in thickness, which on some of the blocks has separated from the lighter and softer rock within, forming thin, straight and smooth plates. Above this brown sandstone there is a yellow loose sand containing small bowlders of greenstone and granite. On top of this sand there is bowlder clay and loess. Small exposures of the conglomerate occur for a distance of

a quarter of a mile along the west side of the creek to the south of this place.

The degree of induration, in the pronounced jointing, and the general ancient aspect of this conglomerate render it reasonably certain that it is not a part of the drift which overlies it. But it has pebbles of Archæan rock, and one of these is nearly six inches in diameter. None of them were observed to be scored, though quite a number were examined. The average size of the pebbles is from one-fourth to two inches in diameter. On the other hand, it is not believed that it can belong to the coal measures. Some of the pebbles appear to be pieces of coal measure concretions and lumps of coal measure clay, and the aggregation of rocks represented in the pebbles is unlike anything observed in the coal measure conglomerate. For comparison, a collection of fifty pebbles was made, representing the average sizes. The proportion of specimens of different rocks in this lot was as follows:

	PER CENT.
Yellow chert	32
Greenstone	26
Granite (mostly red)	10
White quartz (some of a faint, pink color)	8
Fragments of coal measure rock	4
Light red orthoclase	2
Black felsite	2
Porous Niagara chert	2
Chalcedony	2
Orthoclase-biotite rock	2

The only conclusion which can at present be drawn as to the age of this conglomerate, is that it is post-Carboniferous and preglacial. Dr. Calvin, who has seen it recently, pronounces it identical in nature with the Rockville conglomerate described by McGee. It also somewhat resembles the Cretaceous conglomerate found in Guthrie county by Mr. Bain. Possibly it may be an outlier of the Lafayette formation, observed farther south by McGee and by Salisbury.

In the south bluff of West Hill in Muscatine, just east of Broadway street, there lies on top of the coal measures and

under the drift a small remnant of a conglomerate somewhat resembling that above described. It is seen for a distance of only three or four rods and its greatest thickness is three feet. It is plainly uncomformable with the beds below. The base is a very pebbly sand, held in a dark ferruginous matrix, which, in some places, does not wholly fill the interstices between the pebbles. The upper surface is a brown ferruginous, moderately fine sandstone of about the same hardness and aspect as the middle ledges in the Pine creek conglomerate. It is seen to contain three rounded bowlders from eight inches to one foot in diameter. One of these consists of gneiss, one of mica schist and one of quartzite. In a collection of 100 pebbles from this ledge, different rocks were represented by the number of pebbles indicated in the following list:

	PER CENT.
Greenstone	26
White quartz	26
Yellow chert	18
Granite (mostly red)	7
Light red orthoclase	5
Coal measure rock	4
Black felsite	3
Quartz-biotite schist	3
Faintly pinkish white quartz	2
Quartz speckled with jasper	2
Red quartzite	1
Hornblende rock	1
Milky quartz	1
Gneiss	1

The author is inclined to the opinion that this conglomerate in Muscatine and that exposed on Pine creek are both outliers of the same formation.

As to the age of this conglomerate the author has no opinion to offer except as indicated above. The complexity and uncertainty of the problem is fully stated in a letter recently received from McGee, in which he says: "The greater part of the brown sandstones in that region are of course

Carboniferous, and outliers of that age occur at intervals northward through Scott and Clinton counties, and I believe also in Jackson and Linn, within suggestively few miles of the Rockville conglomerate. Several of these outliers have come to light since I left the state; and, as you will remember, it was chiefly the evidence of the Cretaceous outliers northward and of the Cretaceous fossils in the drift that led me to correlate the Rockville deposit with the Mesozoic. Subsequently I have worked on the Lafayette formation, and found it to form the record of a wonderfully extensive continental subsidence, followed by an impressive continental uplift. I have traced the Lafayette deposits well up into southern Illinois, while Salisbury and others have found outliers of what appears to be the same formation still farther northward; and I am convinced that remnants of this formation ought to exist in the Mississippi valley, at least as far northward as Keokuk, and probably as far as Davenport or even Clinton. Finally, I long ago observed in Dubuque and Delaware counties peculiar sub-drift or basal-drift deposits unconformably underlying what we now call the Kansan drift-sheet; they are made up of ferruginated liviviated loam (probably what Bain would call ferretto) containing quartz pebbles and, as I remember, a few granitoid pebbles. On first examining this deposit, I was disposed to consider it glacial in origin, though much older than the lower till, the Kansan of to-day, and I described it, with these ideas in mind, in a paper published in the Geological Magazine of London about 1879 or 1880. Subsequently, being unable to trace the deposit over any considerable area, I rather neglected it, and, in the preparation of a report on northeastern Iowa, I assumed it to be a subaerial accumulation containing some detritus from the Rockville conglomerate, and perhaps other formations intervening between the Paleozoic and the Pleistocene—the assumption being, I believe, implicit, since I do not recall referring to the matter specifically. Accordingly there appear to be four distinct series of deposits to which local

accumulations of brown sandstone might be assigned, the criteria for comparison and correlation being sadly vague."

PREGLACIAL EROSION.

Nature of the Data.—The number of deep wells, which the farmers have found it necessary to make on the uplands, give us some information concerning the nature of the old land surface that is buried under the drift in the west end of the county. In the course of the survey records of a number of such wells have been obtained, mostly from well makers. A table is given below, in which these wells are enumerated by sections and townships. The second column in the table gives the location of each well, and the name of the owner when known. The third column describes the situation with regard to topographic features. The fourth gives the elevation of the top of the well, with regard to sea level. This has been obtained from railroad levels, and from the topographic sheets of the United States Geological Survey in the north tier of townships. For the other part of the county the elevations given are mostly either aneroid measurements or estimates. The fifth column gives the depth of the well from the surface. The sixth column describes the materials which have been penetrated. The information obtained on this subject is the least satisfactory, except as to the elevation of the bed rock. Well makers generally fail to distinguish between the pebbleless yellow loess and pebbly, yellow bowlder clay. Both are usually reported as "yellow clay." In the same way a blue silt or soil-bed is not always reported separately from blue bowlder clay. But the records are given for what they are worth, in the hope that in the light of future explorations some of them may prove useful. The depths to the bed rock are given with greater confidence, as depth is of the greatest practical importance to the well makers, who have more than one way of knowing when rock is encountered. The last column gives the elevation of the top of the bed rock in feet above sea level, in which case the

figures are in *italics*, or it gives the level at which the well stopped in drift, in which case the figures are in ordinary type. It will be noticed that the wells are quite uniformly distributed over the uplands, while the lowlands are represented by only a few borings. The data on the bed rock levels seem quite sufficient for the construction of fifty-foot contours over all except the south tier of townships. A map giving the contours is presented in plate vii. It is believed fairly to represent present explorations, and may be used with some confidence in making estimates on the construction of new wells.

WELL RECORDS IN MUSCATINE COUNTY.

BLOOMINGTON TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
1	G. Parks..... Sec. 5, Tp. 77 N., R. 11 W.	Upland.....	720+	115	Loess and blue clay, 10 ft of sand at bottom.....	605
2	J. Greiner..... Sec. 3, Tp. 77 N., R. 11 W.	Upland.....	740+	200	No rock.....	540
3	County farm..... Sec. 33, Tp. 77 N., R. 11 W.	Upland.....	720+	208	Clay 100 ft, sand 20 ft, clay 60 ft, limestone 28 ft.....	540

CEDAR TOWNSHIP.

4	William Verink..... Sec. 14, Tp. 76 N., R. IV W.	Low upland..	690	85	Loess 15 ft, yellow sand 40 ft, blue clay without pebbles 10 ft, white sand with gas 15 ft.....	605
5	C. Carpenter..... Sec. 33, Tp. 76 N., R. IV W.	Upland.....	730+	125	Loess and yellow sand, blue clay, sand below.....	605
6	Louis Eliason..... Sec. 36, Tp. 76 N., R. IV W.	Upland.....	720+	154+	Mainly till, gravel at bottom.....	566
7	A. Cone..... Sec. 24, Tp. 76 N., R. IV W.	Low upland.	660+	200+	Soft till 130 ft, hard blue till 60 ft..	460
8	C. Hadley..... Sec. 36, Tp. 76 N., R. IV W.	Low upland..	680	158+	Gas at 126 ft.....	522
9	J. Fanning..... Sec. 15, Tp. 76 N., R. IV W.	Low upland..	670	130+	No rock.....	540
10	S. Littrell..... Sec. 35, Tp. 76 N., R. IV W.	Low upland..	680	205+	Loess and yellow sand 20 ft, blue clay, sand and gravel.....	475
11	T. M. Brown..... Sec. 34, Tp. 76 N., R. IV W.	Low upland..	680	150	Loess 15 ft, yellow sand 8 ft, blue clay 100 ft, muck at 130 ft, gravel at bottom.....	530

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

FRUITLAND TOWNSHIP.

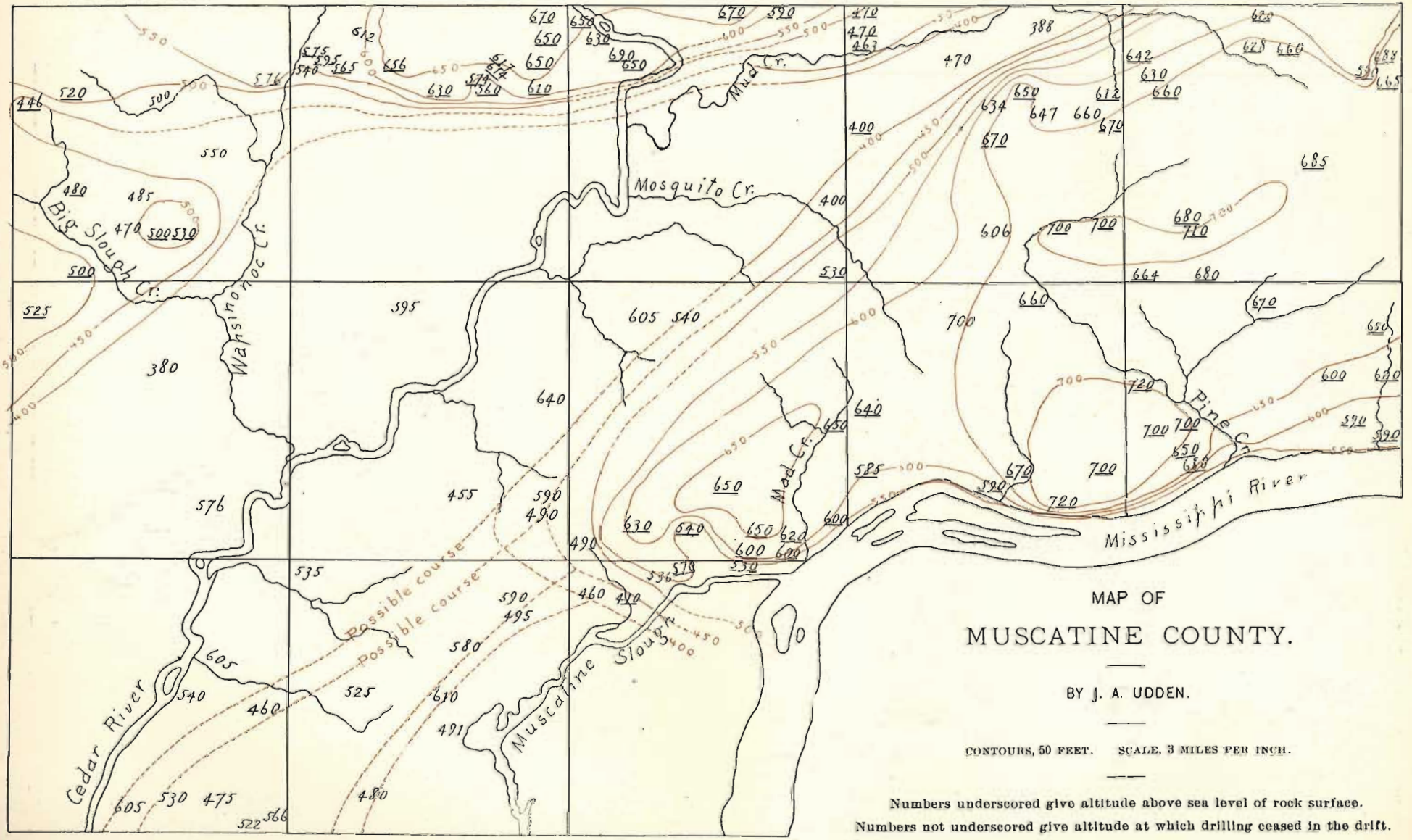
Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
12	Charles S. Miller	Below bluff	570+	110	No rock	460
13	Hershey Creamery, Sec. 4, Tp. 76 N., R. II W.	Base of bluff	580	44	No rock	536
14	G. W. Kincaid, Sec. 5, Tp. 76 N., R. II W.	Below bluff	570	160	Three wells entered rock at this depth	410

FULTON TOWNSHIP.

15	Sedo Hayden, Sec. 7, Tp. 78 N., R. I E.	High upland	780+	120	Gas from near the bottom of drift.	660
16	Sec. 23, Tp. 78 N., R. I E.	Upland	760+	75	Rock at bottom	685
17	Town of Stockton	Upland	720+	110	Drift 100 ft deep	620
18	B. Otto, Sec. 7, Tp. 78 N., R. I E.	Upland	750+	105	Rock at 98 ft.	642
19	George Deming, Sec. 7, Tp. 78 N., R. I E.	Upland	760+	130	Yellow and blue clay 60 ft, brown sticky clay 12 ft, blue clay 58 ft.	630
20	J. Reimers, Pleasant Prairie.	Upland	740+	92	Drift 60 ft, black shale 32 ft.	680
21	C. Wolfe, Sec. 33, Tp 78 N., R. I E.	Upland	738+	144	Yellow clay 30 ft, blue clay 40 ft, quicksand 7 ft, blue dirt (probably in part shale) 38 ft, rock to 144 feet	600
22	J. H. Broders, Sec. 3, Tp. 78 N., R. I E.	Upland	740+	106	Yellow and blue clay, 70 ft, sand 8 ft, limestone 28 ft.	660
23	Sec. 31, Tp. 78 N., R. I E.	Upland	780+	121	Drift 116 ft, rock 5 ft.	664
24	Sec. 12, Tp. 78 N., R. I E.	Upland	748+	158+	Yellow clay and sand 20 ft, blue clay 120 ft, rock at 158 ft, timber at 140 ft.	590
52	Hans Brookman, Sec. 12, Tp. 78 N., R. I E.	Upland	720+	32	Drift with gravel and bowlders at base; solid rock at bottom	688
26	H. Stoltenburg, Sec. 12, Tp. 78 N., R. I E.	Upland	730	105	Drift to near 70 ft, then soft white limestone	665
27	Ernest Muller Stockton	Upland	715	150	Drift to 47 ft, soft limestone to bottom	668
28	Pleasant Prairie		750+	90	Drift 40 ft, shale and sandstone	710

GOSHEN TOWNSHIP.

29	West Liberty Plain, southwest of Atalissa	Lowland	650	?	Loess 6 to 10 ft, fine sand a few ft, coarse sand, below 25 ft; depth unknown	?
30	Cyrus Overman, Sec. 10, Tp. 78 N., R. III W.	Near bluffs	670+	40	Disintegrated rock in bottom	630
31	In the bluff in the east part of Atalissa	In slope of bluff	684	90	Drift 80 ft, coal measure shale 10 ft	604



MAP OF MUSCATINE COUNTY.

BY J. A. UDDEN.

CONTOURS, 50 FEET. SCALE, 3 MILES PER INCH.

Numbers underscored give altitude above sea level of rock surface.
Numbers not underscored give altitude at which drilling ceased in the drift.

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

GOSHEN TOWNSHIP—CONTINUED.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Red rock above sea level.
32	W. Lundy... Atalissa (north part).	On the bluff.	690+	43	Drift 43 ft, then rock.....	647
33	Frank Barnes..... Sec. 1, Tp. 78 N., R. III W.	Upland.....	700+	156	Drift 50 ft, coal measures 100 ft, limestone 6 ft.....	650
34	Atalissa.....	Bottom land at base of bluff.....	664+	.....	Loess 10 ft, sand +, blue clay to 35 ft, sand +.....	....
35	W. A Howell..... Sec. 5, Tp. 78 N., R. III W.	Upland.....	670+	.....	Yellow clay 15 ft, blue clay 35 ft, sand 8 ft.....	612
36	Isaac Dickinson..... Sec. 9, Tp. 78 N., R. III W.	Upland.....	720+	78	Yellow clay 15 ft, blue clay 25 ft, dark sand 4 ft, hardpan 20 ft, soft yellow sandstone (came up in small lumps) 14 ft.....	656
37	Atalissa (Markham).....	Base of bluff	670+	110	Yellow clay and sand 38 ft, blue clay 71 ft, sand and limestone....	560
38	Atallssa (Overman).....	Base of bluff	670+	136	Yellow clay and sand 42 ft, blue clay 44 ft, blue limestone 44 ft, porous brown limestone 6 ft, wood 40 ft from top.....	574

LAKE TOWNSHIP.

39	Southeast sections in Lake township, general section.....	Upland.....	740	250	No rock in several wells ranging in depth from 150 ft to 250 ft. A general section of the drift is as follows: Loess and sand 20 ft, blue clay 100 ft, water sand 10 ft, blue clay.....	490
40	F. D. Wood..... Sec. 27, Tp. 77 N., R. III W.	Upland..	720	265	No rock.....	455
41	C. Humphries..... Sec. 13, Tp. 77 N., R. III W.	Upland	740+	100	Bottom in sand.....	640
42	Isaac Sager ..... Sec. 25 Tp. 77 N., R. III W.	Upland.....	740+	150	No rock.....	590

MONTPELIER TOWNSHIP.

43	C. Howard..... Sec. 19, Tp. 77 N., R. I E.	Upland.....	730+	100	Drift 20 ft, sandrock 80 ft. limestone under this.....	710
44	Daniel Grimm, Jr ..... Sec. 6, Tp. 77 N., R. I E.	Upland.....	730+	20	Loess a few feet, an old soil, with dark, winding, vertical cylinders resembling filled gopher holes, extending down into the underlying pebbly clay, some 5 ft thick. Below this a sticky silt and then a reddish clay.....	....

MOSCOW TOWNSHIP.

45	Near north line Sec. 2, Tp. 78 N., R. II W	Slope.....	680	.....	Rock at a depth of about 90 ft.....	590
46	Summit Sec. 26, Tp. 78 N., R. II W	Upland.....	730	200	Rock in bottom.....	530

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

MUSCATINE TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
47	Cemetery, west of city.....	On bluff... ..	720+	424	Yellow clay 40 ft, blue clay 100 ft, dark sand 40 ft, blue clay 10 ft, limestone, varying in hardness, 234 ft.....	530
48	Gunserhauser's well.....	On terrace...	695	75	Drift 60 ft, then coal measures.....	620

SEVENTY-SIX TOWNSHIP.

51	J. Venatta..... Sec. 2, Tp. 76 N., R. III W.	Upland.	740+	150	No rock.....	590
52	Patrick O'Brian..... Sec. 17, Tp. 76 N., R III W.	Upland.....	700	175	No rock.....	525
53	Daniel McCabe ..... Sec. 11, Tp. 76 N , R. III W.	Base of Mississippi bl'ff	575	80	Sand, blue clay, and gravel.....	490
54	H. J. Jeffries.. ..... Sec. 22, Tp. 76 N., R. III W.	Base of bluff	585+	94	Yellow clay above, red sand 60 ft, white sand and gravel.....	491
55	I. Reed..... Sec. 15, Tp. 76 N., R. III W.	Upland.....	730+	100	No rock, gas at bottom.....	610
57	Bluff of the Mississippi river Sec. 10, Tp. 76 N., R. III W.	In bluff	715+	115	Loess 12 ft, black gumbo or soil 2 to 3 ft, mainly blue till 100 ft.....	600
58	A. Migim..... Sec. 10, Tp. 76 N., R. III W.	On a drift ridge.....	750+	170	Loess 12 ft, yellow till 38 ft, gravelly sand 25 ft, blue till, 25 ft, yellow cemented gravel 10 ft, blue till, very hard and stony, 60 ft....	580
59	Isaac Eperly..... Sec. 32, Tp 76 N., R. III W.	Upland.....	720+	240+	Loess 10 ft, yellow sand 10 ft, blue clay down.....	480

SWEETLAND TOWNSHIP.

60	Frank Nettlebush. .... Sec. 27, Tp. 77 N., R. I W.	Upland.....	730+	340	Loess 20 ft, clay, sand, and gravel 40 ft, soft sand rock 40 ft, "soapstone," coal measures 57 ft, limestone 185 ft.....	670
61	John Monsen..... Sec. 20, Tp. 77 N., R. I E.	Upland.....	740+	304	Drift 90 ft, coal measures 120 ft, limestone 94 ft.....	650
62	Muscatine Terra Cotta Lumber Co..... Sec. 30, Tp. 77 N., R. I W.	Under bluff..	585+	205	Shale 18 ft, loose rock 2 ft; solid rock 1·5 ft, slight escape of gas was noticed	585
63	Daniel Roberts..... Sec. 18, Tp. 77 N., R. I W.	Upland.....	720+	80	Yellow clay 3 ft, sand and clay 77 ft.	640
64	J. Newman..... Sec. 4, Tp. 77 N., R. I W.	Upland.....	760+	60	Soil and yellow clay 5 ft, blue pebbly clay 25 ft, forest bed 10 ft, ash, clay changing to sand 20 ft..	700
65	S. Wintermirte ..... Sec. 36, Tp. 78 N., R. I W.	Upland.....	780+	65	Yellow clay 8 ft, stony clay 40 ft, creek gravel 4 ft (with snails and bivalves), yellow clay and blue, with pebbles, 10 ft, ash clay 5 ft, sand.....	715
66	P. Brossart..... Sec. 26, Tp. 77 N., R. I W.	Upland.....	765+	200	Drift 130 ft, sandstone and shale 65 ft, then limestone 5 ft.....	635

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

PIKE TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
49	G. N. Aylesworth..... Sec. 26, Tp. 77 N., R. IV W.	West Liberty plain.....	635	59	Sand 30 ft, clay 10 ft, gravel 19 ft...	576
50	Nichols.....	West Liberty plain.....	638	250	No rock, all clay, sand and gravel. The well was tubed over 250 ft...	388

WAPSINONOC TOWNSHIP.

67	Christian Wolfe..... Sec. 28, Tp. 78 N., R. IV W.	Upland.....	725+	240	Unknown 40 ft, blue clay 60 ft, sand 6 ft, yellow clay 25 ft, blue clay with muck, wood and sand 107 ft, sand 8 ft.....	485
68	West Liberty artesian well.	Upland slope	696	1768	Depth of drift 120 ft; this consists of yellow clay 25 ft, quicksand 2 ft, blue clay 38 ft, sand and gravel 55 ft; bed rock 1,648 ft...	576
69	Brooks' farm..... Sec. 7, Tp. 78 N., R. III W.	Upland slope	640+	100+	Drift 100 ft, hard rock 40 ft, softer rock with water	540
70	John Venatta..... Sec. 8, Tp. 78 N., R. III W.	Upland slope	665+	245	Drift 100 ft, limestone 145 ft	565
71	Frank Hunter..... Sec. 23, Tp. 78 N., R. IV W.	Upland slope	670+	120	Bottom of well in sand.....	550
72	Louis Watson..... ..... Sec. 7, Tp. 78 N., R. III W.	Upland slope	690+	138	Loess 15 ft, blue clay 50 ft, rusty yellow clay with many boulders 30 ft, soft brown limestone 43 ft..	595
73	George Venatta..... Sec. 9, Tp. 78 N., R. III W.	Upland slope	670+	220	Yellow clay with some boulders 20 ft, blue clay 60 ft, brown clay with many boulders 15 ft, blue limestone 80 ft, soft brown material 8 ft, hard limestone 29 ft, soft limestone 8 ft.....	575
74	Adolf Vogle..... Sec. 27, Tp. 78 N., R. IV W.	Upland.....	730+	200+	Rock in bottom...	530
75	T. W Stoops..... Sec 8, Tp. 78 N., R. IV W.	Upland.....	740+	220	Loess 6 ft, yellow clay 20 ft, sand 2 ft, blue clay 160 ft, sand 28 ft, rock at 220 ft, of cream color.....	520
76	Pliny Nicholls..... Sec 20, Tp. 78 N., R. IV W.	Upland.....	700+	367	White limestone from 220 ft to 350 ft, below this a porous brownish rock.....	480
77	John Gibson ..... Sec. 18, Tp. 78 N., R. IV W.	Upland.....	730+	284	Loess, yellow clay, blue clay with a layer of sand. 12 ft of "river sand" with shells and a tooth of "an animal," drill stopped on rock.....	446
78	Robert Wagner..... ..... Sec. 15, Tp. 78 N., R. IV W	Upland.....	675+	175	Mostly drift.....	500
79	Fred Kirchner..... ..... Sec. 32, Tp. 78 N., R. IV W.	Upland.....	700+	398	About 200 ft to rock which was white and hard above, reddish and porous below.....	500

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

WILTON TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
80	William Boot..... Sec. 9, Tp 78 N., R. I W.	Plain	710+	240	Sand 90 ft, blue clay 100 ft, sand and gravel 10 ft.....	470
81	Three miles south of Wilton	Plain.....	700+	300	Drillers report going down 300 ft and finding no rock (Teeple).....	400
82	Wilton (north part of town)	Upland.....	700+	230	General section, sand and clay 100 ft, sand fine above, coarse below, 130 ft, then there is rock; drift-wood occurs at a depth of 100 ft..	470
83	Charles Norton..... Sec 13, Tp. 78 N., R. I W.	Upland	725+	113	Soil and yellow clay 14 ft, blue clay with pebbles 24 ft, sand 2 ft, lime-stone 23 ft.....	612
84	W. Felthorn..... Sec. 13, Tp. 78 N., R. I W.	Upland.....	760+	100	Yellow and blue dirt 14 ft, brown sand 7 ft, blue clay 68 ft, sand 10 ft	
85	C. W. Colliers..... Sec. 14, Tp. 78 N., R. I W.	Upland.....	760+	113	Yellow clay 8 ft, blue clay 32 ft, black hard pan 68 ft, gravel 5 ft..	647
86	Hans Kai..... Sec. 10, Tp. 78 N., R. I W.	Upland.....	740+	101	11 ft rock in bottom	650
87	Fred Nolte..... Sec. 15, Tp. 78 N., R. I W.	Upland.....	730+	96	No rock.....	634
88	Smith..... Sec. 15, Tp. 78 N , R. I. W.	Upland.....	770+	134	Brown sand 10 ft, blue clay 20 ft, sand 30 ft, blue clay 40 ft, rock 35 ft	670
89	M. A. Roy..... Sec. 27, Tp. 78 N., R. I W.	Upland.	741+	135	Yellow clay and sand 20 ft, blue clay 108 feet, sand 6 ft, then rock.	606
90	E Reimers..... Sec. 2, Tp. 78 N., R. I W.	Upland.....	700+	312	Yellow clay, sand, and gravel 60 ft, blue dirt 80 ft, quicksand 60 ft, blue clay 90 feet, coarse river sand 22 feet, no rock.....	388
91	Wilton artesian well.....	Low upland.	690	1480	Drift 220 ft, limestone 280 ft, shale 180 feet, limestone 300 ft, sand-stone 120 ft.....	470
92	George Wildasin..... Sec. 12, Tp 78 N., R II W.	Low upland.	710+	.....	Yellow clay 6 ft, sand 4 ft, "swamp clay" with vegetation 4 ft, gray stony clay 5 ft, ashy clay and sand.....	....

Preglacial Topography.—(Plate viii.) A comparison of the contours of the preglacial land with the present topography shows a partial correspondence between the two. The low-lands of the West Liberty plain occupy a low tract on the preglacial land surface. Wapsinonoc creek, Mud creek, Mad creek, and Pine creek lie in preglacial valleys. But that part of the course of the Cedar which runs from northwest to southeast, in the north part of the county, comes down from an old upland, and that part of the Mississippi which is above

Muscatine crosses the north end of an old divide. These positions of the two great rivers are evidently due to changes in drainage brought about by the deposition of the drift. An old upland crest extends north and a little east from Wyoming Hill. It is continued to the south and east in Illinois. The bed of the river is rock-bound for more than forty miles above Muscatine, and the valley is comparatively narrow and practically without bottom lands. This part of the valley is of much more recent making than the buried low lands under the West Liberty plain. The deep northeast extension of this lowland under Mud creek may have been occupied by some great stream in preglacial times, but our present knowledge neither warrants nor disproves the supposition that it marks an earlier course of the Mississippi. But it is quite evident that no such great stream flowed in the present channel of the Mississippi previous to the deposition of the drift. The drainage from either side of the valley at this place is not yet fully adjusted to the present conditions, as is evident from the fact that much of the land nearest the river drains into the great stream by circuitous routes through smaller valleys of evident preglacial existence. The main cause of the change is probably to be sought in some obstruction outside the limits of the county, but the selection of the particular course here is most likely due to overflow following the line of an earlier, smaller and local stream. The minor preglacial contours in the region have a decided east and west trend.

It is evident that on the whole the glacial work in the region has resulted in the reduction of reliefs by partial filling of the low tracts. These were the result of long continued and effective erosion, compared with which the destructive work performed after the making of the first drift is insignificant.

THE PLEISTOCENE.

The era of extensive erosion during which the ancient reliefs just described were carved out came to an end at the advent of the glacial period, during which the country was overrun by extensive ice fields at, it seems, three different times. The eroded terranes appear to have suffered but slightly from the ice incursions in this region. The old topography has not been much changed. There was hardly any planing of the surface. No scorings have as yet been observed on the bed rock in Muscatine county. On the contrary there is evidence that even the less coherent surface accumulations in the region were not always disturbed, being rather simply buried under the glacial detritus accumulated.

ANTE-GLACIAL SILT.

Occurrence.—On top of the bed rock, and under the lowermost member of the drift, a silt sometimes appears, associated with scant soil beds and loess-like deposits. The best instances are seen along that branch of Mud creek which is followed by the Muscatine division of the Burlington, Cedar Rapids & Northern railroad, in the north part of Muscatine township. The outcrops occur in the bank of the stream not far from the north line of the Nw. qr. Nw. ¼ Sec. 26, and also in the Ne. qr. Ne ¼ Sec. 27, Tp. 77 N., R. II W. At the former place it is blue, rather coarse laminated calcareous silt, with lentils of finer silt and pockets of rusty sand imbedded, weathering to yellow or rusty-gray. It appears to be slightly disturbed and is overlain by cross-bedded sand and gravel, over which there is dark blue till. At the latter place the following section was seen in the low north bank of the creek.

		FEET.
4.	Blue silt with ferruginous blotches and oxidized spots and streaks, slightly calcareous below	1½
3.	Dark, loess-like, non-calcareous silt containing flattened roots or branches of woody plants, and *Succinea lineata* and *Pyramidula striosa iowensis*	½
2.	Very fine, blue, calcareous laminated silt	½
1.	Coarser, calcareous, laminated, blue silt, like that seen farther up the creek	1

The wood in number 3 is gymnospermous. The coal measures appear in the bed of the creek immediately below this place. Near the junction of this branch with Mad creek some silt, similar to number 1 in the above section is, together with some peat, worked into the base of a dark blue till, and some distance farther up the stream this dark till gradually changes downward into a similar blue silt. In Mud creek the same silt is occasionally seen in the same situations under a dark bowlder clay in the bed of the creek. The first instance noticed is under a high bank on the east side of the creek, near the west end of Polk street, in Park Place addition. Here it is much contorted, evidently from being overridden by the ice which deposited the drift. A few rods farther up it appears again in the opposite bank and is partly worked into the till and partly graduates into it. Similar exposures of it appear in the left bank of the creek near the north line of section 24, in Bloomington township, and in the tributary coming from the west in the northwest quarter of the same section. At the latter place it has plainly been tilted and worked by the ice. In that branch of Pappoose creek which is crossed by the old Butlerville road, now Russell avenue, just east of the center of the east line of section 34, in the west part of Muscatine, a thickness of eight feet of the same silt appears in the bank of the ravine below the street bridge. The surface of the material is of a rusty, gray color, which changes to dark blue farther in where the weathering has not reached. The coal measures come out close by, south of the creek, at a higher level, being there overlain by bowlder clay. This indicates that the silt is confined to the lower part of the gully.

In the valley of Sweetland creek this silt is found at a place about 100 paces north from the center of the south line of section 15, in Sweetland township. In the west bank of the stream at this point the following section was exposed.

		FEET.
4.	Ferruginous, stratified, yellow, pebbly clay resembling a terrace deposit	3
3.	Yellow calcareous till (running into No. 2)	5
2.	Very calcareous bluish till with fragments of wood in the lower part, kneaded into No. 1 below	2
1.	Finely laminated, calcareous blue silt	4

Close by, to the north from this place, the silt rises twelve feet in the bank above the creek. A few feet below its upper surface it gradually becomes coarser and at the same time blotched, as if weathered, and farthest down, more like a till or reddish clay, and containing some pebbles. The bed rock rises above the level of the uppermost part of the section close to the north.

A similar deposit is seen under the wagon road bridge, and north of it near the mouth of the small creek which comes down to the river on the east of Wyoming hill, a mile and a half west of Fairport. At this place some of the layers are almost black, and it is cut by conspicuous straight joints.

In the northeast corner of section 34, in Sweetland township, below the old Hanson quarry, in the west bank of the creek, there is a section of blue silt and loess-like material so like the one seen in the lower west branch of Mad creek that there can be no doubt that the two represent identical conditions. It is as follows:

		FEET.
6.	Bowlder clay, pebbly and somewhat stratified	2
5.	Stratified sand	1½
4.	Fine, unctuous silt	1½
3.	Blue, loess-like material with vertical, cylindrical, ferruginous impregnations, three inches in diameter and less, resembling the "pipes" common in some phases of loess	3
2.	Dark, mucky, slightly effervescing silt, with imbedded, flattened roots and twigs of gymnospermous woody plants and with thin and very fragile shells of pulmonates resembling those seen in No. 3 in the section north of Muscatine	½
1.	Blue, mottled, laminated silt like that seen on Sweetland creek, extending below the bed of the creek	2(?)

Still another instance of this silt occurs in Sulphur branch, just above the last outcrops of coal measure shale north of the south line of section 1 in Montpelier township. It is dark blue, with a few scattered sand grains, and contains vertical, cylindric impregnations of iron oxide. Over it there is a dark, mucky layer with fragments of wood, and this is overlain by bowlder clay. In one place it was seen to be cut by a nearly vertical vein, four inches wide, of a sandy till connected with the till above.

Probable origin.—It will be noticed that in each one of the above described localities the bed rock appears close by, usually not more than two or three rods away. In all but two places the formation lies in preglacial valleys now partially filled with drift. In four cases it is seen to be overlain by the lowermost drift known in the region presently to be described. For the most part it is calcareous and frequently it is plainly water bedded. Sometimes it graduates into drift. At other times it is disturbed by glacial action and partly worked into the bowlder-bearing drift. In four places it contains a layer that resembles a marshy soil, with plants, snail shells and some peaty material. Of the snails, which have been examined and identified by Professor Shimek, *Pyramidula strigosa iowensis* Pilsbry is regarded as a form now extinct and *Succinea lineata* W. G. B. is noted as "very common in dry regions to-day from Upper Missouri to the highlands below Natchez, in Mississippi." Both are well known species from the loess. The imbedded plants are flattened roots or branches, a half inch and less in diameter. All that have been examined show the pitted tracheid tissue of gymnosperms. North of Muscatine, and in the west branch of Pine creek, the shell and the plant remains lie imbedded in a thin layer resting on laminated silt and succeeded above by loess-like material. On Pine creek this is again capped by water-bedded silt.

It seems most likely that this silt and loess accumulated in front of the margin of the first ice field. The prevailing calcareous nature of the thin-bedded silts indicates such a source. The plainly marked lamination of these shows that their deposition was comparatively rapid. In a region of deep reliefs, such as this was at the advent of the first ice, the drainage must have been frequently ponded up against the ice in many of the preglacial valleys. The drainage from the margins of the ice must have brought large quantities of calcareous silt into these ponds, and this would be confined to the valleys alone. Mud flats might form in this way, on which plants and snails may have found a temporary *habitat*. Occasionally loess-like wind drift might also accumulate in such situations. The advancing ice may later have overrun and disturbed such deposits, plowing them up and mixing them with drift in some places, and at other places leaving them undisturbed in the positions in which they are now found. The presence of gymnospermous vegetation indicates at any rate that boreal climatic conditions were not far off when these deposits were formed. Possibly a part of them may be preglacial loess.

GLACIAL DEPOSITS.

General observations.—The main deposit of the drift is the glacial bowlder clay. In Muscatine county this occurs in three different phases which are known as pre-Kansan, Kansan and Illinoian, the two former being separated by the Aftonian gravel (forest and soil beds?), and the two latter by the Buchanan gravel and the Yarmouth soil and leached horizon. The field relations of these members of the drift can be best set forth in describing some typical sections from the border of the region of the deep drift.

In the bluff in the west part of the city of Muscatine, at the crossing of Main and Third streets, some excavations have lately been made that expose a nearly vertical wall of drift, not far from seventy feet high. The section is about as follows:

		FEET.
6.	Loess (in the slope above)	2-10
5.	Yellow till with white powdery, disintegrated, calcareous concretions in the upper part (Illinoian).	15
4.	Yellow sand with some gravel (Buchanan?)	
3.	Blue till, apparently somewhat disturbed, with a network of wide, oxidized joints, and with some pockets of sand extending down from above (Kansan)	10
2.	Sand and gravel, mostly rusty red, occasionally with layers standing at angles considerably exceeding 40° from the horizontal, contorted and faulted (Aftonian)	14
1.	A dark blue till with bits of gymnospermous wood, changing downward into a dark silt and associated with peaty material (pre-Kansan)	3-20

Number 5, in the above, appears again on the grounds opposite the Catholic church farther up in the bluff, where its calcareous concretions occasionally contain gravel and sand, appearing like mortar rock. At the present stage in the excavation below it is seen to run out as a lens in the west end of the hill. Number 3 is the most conspicuous part of the wall in the excavation. Number 1 is not well exposed at present and can only be seen when the rubbish below is cleared away. A well just below this place is reported to have penetrated twenty feet of "dark clay and muck." The top of this well is on a level with the floor of the excavation.

At the place where Lowe's run leaves the uplands in the Ne. qr. Sec. 8, Tp. 77 N., R. II W., Fruitland township, this stream is at present cutting under a bluff in the right bank and has laid bare the following section:

		FEET.
6.	Yellow and blue till cut by vertical oxidized joints, with a ferretto zone and decayed granite bowlders above and with a horizontal sharply defined base (Kansan)	30
5.	Fine ferruginous sand (Aftonian?)	½
4.	Alternating bands of yellow and white cross-bedded sand (Aftonian?)	8

		FEET.
3.	Pebbly, light gray or yellow, cross-bedded sand and gravel (Aftonian?)	3½
2.	Fine ferruginous silt (Aftonian?)	½
1.	Dark, almost black, homogeneous bowlder clay, with bits of gymnospermous wood, limestone and greenstone pebbles and occasional pockets of yellow sand (pre-Kansan)	7

The top of number 1 in this section is a horizontal plane, except at certain places where numbers 2 and 3 make some abrupt and pocket-like detours down into it. Its lower part is almost a pebbleless silt at one point. Numbers 2, 3, 4 and 5, though some of them are very thin, remain, nevertheless, persistent for the whole exposure. Number 6 is in one place almost as dark as the lowermost member and quite like it in texture. In the slope above the top of number 5 there is some more till rather more sandy. This may possibly represent the Illinoian. The same drifts are seen at the bluff in the left bank of Kincaid's run, two-thirds of a mile farther west.

SECTION IN KINCAID'S RUN.

		FEET.
5.	Yellow, sandy till (Illinoian?)	12
4.	Stratified ferruginous gravel and till (Buchanan or Yarmouth?)	3
3.	Yellow and light blue bowlder clay with white chert, leached for two feet at top (Kansan)	18
2.	Ferruginous sand and silty material	3 (?)
1.	Dark, almost black till, weathering rapidly to brown, silt-like at one point, with straight joints and some pockets of sand and gravel extending down from the number above, otherwise having a straight plane for its upper surface (pre-Kansan)	2

Farther up in this creek there is an excavation in the right bluff where a bowlder clay, which is equivalent to number 3 in the above section, terminates above in a leached gray zone two feet high, on which there rests a calcareous and more sandy till twelve feet thick. Just above this place a gravel, which appears to be equivalent to number 2 above, is more

than twelve feet thick and is changed into a mortar rock by the infiltration of a calcareous matrix. The section last given is almost exactly duplicated in the south bank of the stream, something more than a mile above this place, near the cross-roads in the Se. qr. of Sec. 36 Tp. 77 N., R. III W.

In the margin of the deep drift, where it runs up on the higher bed rock, there thus appear, nearly complete at four places, the same successive phases of drift, viz.:

6. Loess.
5. Yellow till, somewhat sandy.....Illinoian.
4. Sand, stratified till, or a leached horizon.....
.....Buchanan and Yarmouth.
3. Yellow and blue till, the main bowlder clay.....Kansan.
2. Sand and gravel, sometimes cemented.....Aftonian.
1. Dark till.....pre-Kansan.

The exposure on Main street in Muscatine has been examined by Calvin, Leverett and Bain, who have identified the several drifts as indicated. In the study of the drifts in the ravines farther west the author has had the advice of Dr. Calvin, with whom he had the privilege of examining these places a second time. It seems that the nature of these sections, as well as the general features of the drift throughout the county, are in full accord with the theory of a multiple drift, even if this region cannot be regarded as furnishing any important part of the general evidence on which the divisions of the drift have been established, and these divisions are here adopted as furnishing the most satisfactory point of view in a description of the drift in the county.

Drift pebbles.—It will be perceived that the locality offers good opportunities for comparative observations on the character of the three bowlder clays. In course of the work a study of the pebbles in each has been made, which may be worth recording. One hundred pebbles, ranging in size from one-fourth to one-half an inch in diameter, were collected at two points from each drift, care being taken that no selection of any kind should be made except as to size. Notes were

taken as to the nature of the rock from which the pebbles were derived, and as to the extent to which they were rounded, scored and polished. These observations were tabulated and the results expressed in percentages for each of the drifts as below:

Percentages of Different Rocks among the Pebbles in the Three Bowlder Clays o Muscatine County.

KINDS OF ROCKS.	PRE-KANSAN.		KANSAN.		ILLINOIAN.	
	From Lowe's run.	From Kincaid's run.	From Main street, Muscatine.	From half mile east of Lowe's run.	From East hill, Muscatine.	From Main street, Muscatine.
Limestone (not dolomitic)	38	39	28	29	3	7
Chert	11	17	12	5	9	8
Limestone (red, decayed)	.....	.....	1	.....	1	4
Chert (Oolitic)	.....	1	.....	.....	.....	.....
Dolomite (Niagara)	3	7	3	16	60	56
Sandstone (coal measures)	.....	1	3	1	.....	1
Clay-ironstone (coal measures)	.....	.....	2	.....	1	2
Sand (in paste of limonite, Pine creek conglomerate?)	.....	.....	.....	.....	1	3
Pyrites (coal measures)	1	1	.....	.....	.....	.....
Coal	.....	.....	1	.....	.....	.....
Quartz (white)	8	8	12	8	6	5
Greenstone	15	10	10	8	4	5
Quartzite	4	4	6	13	1	4
Granite (red)	.....	2	3	5	2	1
Granite (white)	4	3	4	2	3	2
Diabase	1	3	1	12	4	2
Felsite (black)	5	.....	5	1	.....	.....
Schist (micaceous)	4	2	4	1	.....	1
Chalcedony	2	1	2	.....	.....	.....
Hornblende rock	3	.....	.....	.....	.....	.....
Slate (black)	1	.....	1	.....	.....	.....
Jasper	.....	.....	.....	.....	1	.....

Mechanical Character of Pebbles from the Three Bowlder Clays in Muscatine County.

	Pre-Kansan till.	Kansan till.	Illinoian till.
Per cent of rounded pebbles	38	42	29
Per cent of scored pebbles	17	11	8
Per cent of polished pebbles	13	10	2

It will be noticed that as to kinds of rocks represented the Illlinoian drift differs most markedly from the other two, which are in this regard quite alike. Dolomitic limestone is much more frequent in the uppermost drift than in the other two. This dolomite is mostly Niagara limestone. In the two lower bowlder clays the limestone pebbles are nearly all non-magnesian, of a dull white appearance. The rock does not resemble the Cedar Valley limestone. Chert and greenstone are more frequent in the two lower drifts. As to mechanical characters it will be observed that scored, well-rounded and polished pebbles are least common in the upper drift. Rounded pebbles are most frequent in the middle drift, and the scored and polished ones in the lower. The great number of dolomitic white pebbles in the Illinoian is apt to give the impression that scored pebbles are particularly frequent in this drift, but this does not appear to be corroborated by a crucial examination of fragments of the size used in this case. For evident reasons different kinds of rock have not been affected to the same extent by these mechanical processes. This is well illustrated in the table below, and from the same observations as the previous one. It seems that the difference as to scoring may be partly accounted for by the variations of the proportions of the frequency of different rocks:

Mechanical Character of Drift Pebbles of Different Kinds of Rocks.

PER CENT OF WELL-ROUNDED PEBBLES OF—		PER CENT OF SCORED PEBBLES OF—		PER CENT OF POLISHED PEBBLES OF—	
*Black felsite	71	Greenstone	25	*Black felsite	55
Greenstone	49	Limestone	18	White quartz	22
White quartz	48	Dolomitic limestone	6	Limestone	18
Limestone	44	Diabase	5	Chert	15
Quartzite	28	Quartz (all kinds)	2	Greenstone	4
Dolomitic limestone	27	Granite	1		
Chert	20				

*The persistent rounding and polishing of the black felsite pebbles, as well as the absence of scorings on them, suggests that these are derived from some water-laid gravel or conglomerate.

The pre-Kansan Till.—This is the designation given by Bain to a bowlder clay which lies under the Kansan near Afton, in Union county. It is separated from the latter by the Aftonian

gravel. There can hardly be any doubt that this drift in Union county and the lowermost dark drift in this county are identical. Their general appearance and their relation to the overlying beds are alike and the same. In this county the pre-Kansan drift is compact and rather tough when not weathered, not particularly hard, but rather floury when dry, almost black, but somewhat rapidly changing color on exposure to the air, usually without conspicuous joints, and containing frequent fragments of gymnospermous wood. In Union county, as well as here, it is associated with silt and loess-like deposits, and there are indications of peaty deposits above it. Besides occurring west of Muscatine, it has been noticed in some places along Mad creek, and perhaps in one place on Sweetland, and at one point on Sulphur branch. If it represents the product of a separate ice period it is quite natural that it should be found sparingly in low places in a region where the abrasive work of the Kansan ice was slight. Such seems to be its situation in this county. It is represented by number 1, in each of the preceding typical sections.

Aftonian Gravel.—This formation was first described by Professor Chamberlin. In the sections given above it is represented by number 2 on Main street, in Muscatine, by numbers 2, 3, 4 and 5 in Lowe's run, and by number 2 in Kincaid's run. It is believed to be the main water sand in the wells in Lake township, lying most commonly about a hundred feet below the surface, and frequently coming out in the base of the bluff west of Muscatine for a distance of four or five miles, where it gives rise to numerous and copious springs. In the east half of section 6, in Fruitland township, it is at one place about twelve feet deep and consists of sand, gravel and some bowlders. In Kincaid's run it is at one place cemented by a strong calcareous matrix. At the center of the west line of section 34, in Sweetland township (Tp. 77 N., R. 1 W.), and close by a small bridge, there is a fine sand or loose sandstone of a peculiar twisted structure. This Calvin is inclined to regard as Aftonian. It lies under Kansan drift,

being exposed for only about a rod square. Part of it is fine and part of it coarse and gravelly. Mica scales are common in the finer layers. It is cut by rather conspicuous straight joints. In three lots of pebbles from these Aftonian gravels, yellow chert, greenstone, white quartz and red granite were the prevailing rocks. These sands and gravels may represent an interglacial interval. They are quite well worn and sorted.

Kansan Till.—This drift sometimes changes downward by gradual transition into the pre-Kansan, but more often it is separated from the latter by the Aftonian. Most commonly it rests on bed rock, ranging in the east part of the county from nothing to 100 feet in thickness and changing from a blue color below to yellow above, where it is frequently leached to a depth of six feet and has a ferretto zone or soil layer. Usually it is cut by irregular joints, which are made more conspicuous by weathering. When dry it is usually very hard where unweathered. Frequent greenstone bowlders are regarded as one of its characteristic features, as also a species of decayed granite bowlders in weathered exposures. In such places fragments of yellow chert are usually conspicuous. This till is represented by number 3 in the Muscatine section on Main street, by number 6 in Lowe's run, and by number 3 in Kincaid's run. In the Muscatine bluff, west of these places, it is believed to rise from fifty to 100 feet above the Aftonian gravel, frequently underlying the loess. It is the main till, nearly everywhere the principal, exceptions being found in southern Cedar township and at East hill in Muscatine. West and north of the West Liberty plain it underlies the loess everywhere, but east of the Cedar it is frequently separated from the loess by the much thinner till of the Illinoian stage. This drift has so frequently been described that a further account of it in this place seems unnecessary.

Buchanan gravel and Yarmouth soil.—Calvin has described some gravels in Buchanan county which were formed in con-

nection with the disappearance of the Kansan ice, and Leverett has discovered a leached horizon with an ancient soil underlying the Illinoian in Des Moines county. Both formations may be said to belong to the interval between these two drifts. The Buchanan represents the gravel-forming period marking the close of the Kansan, and is accordingly but a phase of the latter. The Yarmouth represents the interval between the close of the Kansan and the oncoming of the Illinoian. The gravels seen to be rare in this county. Number 4, in the Main street section, is one of the few instances of its presence. Some gravel underlying a calcareous till in a railroad cut near the county line, about three miles west of Stockton, may belong here. A leached horizon, the Yarmouth, at the top of the Kansan is more frequently in evidence, as will be remembered from the drift sections given. In the road which runs up on the bluff near the center of section 6, in Fruitland township, a similar dividing zone is found in connection with some sand and gravel as indicated below:

SUCCESSION OF DRIFT DEPOSITS NEAR CENTER OF SECTION 6, IN FRUITLAND TOWNSHIP.

		FEET.
7.	Loess, somewhat calcareous, rising with the slope above	10
6.	Yellow, very calcareous till with mostly dolomitic pebbles (Illinoian)	4
5.	Leached, dark sandy clay (Yarmouth?)	2
4.	Gray leached sand (Buchanan?)	3
3.	Yellow ferruginous sand (Buchanan?)	5
2.	Blue and yellow till with well marked ferruginous joints, chert fragments and greenstone pebbles (Kansan)	95
1.	Concealed (springs from Aftonian gravel not far off)	

Illinoian Till.—After the interval which is recorded in the deposition of the Buchanan gravel and in the formation of the Yarmouth soil and leached surface there was an ice incursion from the east, depositing drift material in Scott, Muscatine, Louisa, Des Moines and Lee counties in this state, and over the greater part of the state of Illinois. It was first recog-

nized as a distinct drift by Leverett, who has called it the Illinoian, and who has traced its boundary through Illinois, Iowa and Missouri. It differs from the Kansan in being somewhat less leached, and in having a topography not quite as old, in presenting a fresher appearance, in containing a larger proportion of bowlders of Keweenawan rock and in having (in this county) many dolomitic limestone pebbles. It is believed to have occasional erratics of a conglomerate known to occur on the east shore of Lake Huron, and copper nuggets are also supposed to be more frequent in this drift than in the Kansan.

In Muscatine county the Illinoian drift has not reached any great development. It seems to occur only in separate areas on the Illinoian drift plain, where undoubted exposures of Kansan till underlying the loess are very common. The terminal moraine which should cross the county from northeast to southwest is nowhere well marked, unless it be in the south part of Cedar township. From indications of the topography the principal marginal accumulations of this ice field have been made out to follow in the main the divide between the Cedar river drainage and the drainage of the Mississippi, excepting in Cedar township, where it comes out to the southwest approaching the Cedar river. Along the course of the divide there are occasionally low and wide swells of land rising slightly above the general level, and also some small, undrained ponds, usually covering a fraction of an acre of ground. Such ponds are seen in sections 33, 34 and 35 in Cedar township, 2, 3, 15 and 22 in Seventy-Six township, in 29 and 32 in East Lake township, in 10, 11, 13, 15 and 16 in Bloomington township, and in section 4 in Sweetland. The topography indicates, however, that the Illinoian drift does not terminate with this limit, but that there are small extramarginal accumulations as far out as to the bluffs of the Cedar river and to the Mud creek valley. The presence of loess and sand renders a definite determination of the locus

of the Illinoian border very unsatisfactory, if not quite impossible.

Some occurrences of this till have already been described in the typical sections west of Muscatine, and these may be passed by here. It is well exposed in East Hill, where several streets are graded down into it. The greatest thickness is seen in the clay pits of the brickyards on either side of Second street. Farther down in the face of these excavations there is a calcareous blue silt with alternating layers of fine sand. This silt is taken out for the manufacture of brick, and a thickness of ten feet is often exposed in the bank. It is calcareous and for the most part finely laminated. Some of the coarser layers are ripple-bedded. In one place its upper surface appeared as if worked into the till above. This till varies from eight to fifteen feet in thickness and is all Illinoian. It is grayish-blue in color below and yellow above, and contains numerous pebbles of dolomitic limestone and bowlders of Keweenawan eruptives. The upper unleached surface of this till is covered by a sand of apparently the same age, for it contains occasional striated pebbles and bowlders of the same rocks and of the same general appearance as those in the bowlder clay. In two feet this sand changes upward into coarse and stratified loess which, in its turn, is succeeded by typical yellow floury loess of a finer grain. The author believes that the lower calcareous silt at this place is a deposit formed in some marginal glacial water, subsequently overrun by the ice containing the bowlder clay which now lies above it, and that the bowlder bearing sand which rests on this till was a contemporaneous deposit, either on the till or on the ice itself, at some stage of its disappearance from this region.

Some twenty rods east of the center of section 24 in Bloomington township, in the south bank of the railroad cut, a fresh looking till appears, which is calcareous to within two feet of its upper surface, where there is a slight ferretto zone under the base of the loess. To the south of the creek,

which is here followed by the railroad, the land rises in a low and broad loess-covered ridge running parallel with the creek and suggesting an underlying deposit of the same till. The Illinoian already noticed in the bluff near the center of section 6, in Fruitland township, is connected with a similar topographic feature, for close by to the west there is a ridge running a little west of south. Superficially this ridge consists of loess, below which there is sand with some pebbles and bowlders. This ridge is certainly built by some constructive agency and not a result of erosion.

In the southwest quarter of section 32, in Cedar township, the river cuts into the east bluff, which is here made up of the swell supposed to represent the terminal moraine of the Illinoian ice lobe. The till is dark and blue below, cut by somewhat weathered joints of a peculiar clustered arrangement and appearing quite unlike the weathered joints in the Kansan. The entire bluff, a hundred feet in height, consists of this till, capped by loess. The bowlders which it contains are frequently planed and more fresh in appearance than those of the Kansan till. Chert is somewhat scarce and there is a greater proportion of Keweenawan material, such as agate nodules, diabase, red slaty sandstone and gabbro. Bowlders and pebbles of limestone are common. On approaching the county line this till somewhat suddenly becomes sandy, which fact perhaps may be looked upon as corroborating the topographic evidence of the existence of a drainage course on the Illinoian ice from the east, following a depression across the upland from the Mississippi to the Cedar, just south of the county line.

A yellow till, leached for about three feet down from its upper surface, is seen under the loess in a road grading near the center of the south line of the southeast quarter of section 28, in Bloomington township. Judging by its appearance and its pebbles it is probably to be referred to the Illinoian.

The places enumerated here are not supposed to be all the localities of exposures of this till, but they appear to be the

most important ones. In the region of Pine creek this till seems to be absent, as also in Sweetland creek valley, leaving the Kansan topography unmodified.

The small development of the Illinoian till and the absence of a well defined terminal moraine in this county seems to be due to two causes. Coming from the southeast, as the ice must have done if its motion was normal to a perpendicular to its margin, there was a tract of high land present to obstruct its progress in the west end of Rock Island county, in Illinois, and in the southeast part of Sweetland township on this side of the river. In the basin of Pine creek there is, as just stated, a total absence of Illinoian drift. The high land to the south may have retarded the flow in this direction and prevented it from bringing in much of its drift. Another circumstance which may have contributed in reducing the quantity of the drift from this ice is to be inferred from the conditions indicated for an efficient marginal drainage and ready ablation of this segment of the ice lobe. Mr. Leverett has shown that at the time of the maximum development of the Illinoian ice the waters of the Mississippi most probably followed the Mud creek swale from the Wapsipinicon south of Dixon, past Durant and Wilton, to Moscow, at which place it emerged on the low lands of West Liberty plain. The great river thus followed closely the margin of the ice, rendering the removal of drift uncovered by ablation of the marginal ice easy and prompt. Part of what might, under different circumstances, have formed a marked terminal moraine may therefore be deposited under the West Liberty plain.

Evidence of such ablation is not wanting. In an excavation made by the Chicago, Rock Island & Pacific railroad, near the west line of section 5, in Fulton township, the loess rests on sand and gravel, associated with what appears to be some Illinoian till. This gravel consists of more than 80 per cent of Devonian limestone, the lower fossil-bearing beds being represented as well as the unfossiliferous brecciated beds. It is a

crush gravel, formed most likely in the ice or under it. Some pebbles were left in situ in the process of breaking, other stronger fragments being forced into them. This gravel cannot have been transported any great distance. In such case it would be found mixed with a greater quantity of other drift material from other localities. The only place from which it seems likely that Devonian rock of this kind can have come is to the southeast (see chart on preglacial topography), where ledges of the kind represented come up to an unusual height. In all probability transportation by the ice was to the northwest. The presence of the gravel indicates a removal of finer material of the drift, and this would naturally be taken in the same direction. A mile and a half east of Stockton, on the same road, another excavation, newly made at the time of observation, exhibited highly tilted beds of silt and sand and gravel ten feet high under loess. These materials constitute apparently the central body of a long, low and flat ridge running northwest-southeast, indicating a drainage line on the ice having the same direction as in the previous instance.

Near the center of Sec. 8, Tp. 77 N., R. II W., where a branch of Chicken creek crosses the road running east and west, there is seen under the loess on the east side of the bridge, a deposit of coarse, stratified ferruginous sand several feet deep. This may possibly belong here, for it appears to be replaced on the west side of the ravine by a sandy till somewhat stratified, and not unlike the Illinoian.

A yellow sand is very generally present under the loess over the outer slope of the Illinoian drift plain. It varies in thickness from a mere streak to ten feet and more. In the southern part of Moscow township, south of Little Musketo creek, in the northwest part of Bloomington township, in Lake township, in the northwest part of Seventy-Six township, and in Cedar township a similar sand frequently forms a large part of low, flat, loess-covered ridges which extend out radially to the margin of the drift plain as previously described. Superficially some resemble the paha described by McGee,

but the genesis and structure are wholly different. A few of these ridges have been lately modified by wind action. It is believed that some, if not most of them, may have been produced by drainage lines on the Illinoian ice, which very likely at some time extended out of the bordering low lands. Such an explanation of them is suggested not only by the topography, but also by the fact that the sand occasionally contains pebbles and small bowlders, as has been observed on section 1, in Seventy-Six, and on section 12, in Lake township. Occasionally they consist of clay and sand, so placed that an open well may have one wall in the coarse and the other in the fine material. In fact they appear to have a structure akin to that seen in the ridge east of Stockton. The high slope of the silt beds in that ridge plainly indicates tilting after deposition. To account for such tilting we may regard the ridges as accumulations along drainage lines on the surface of the ice. They may have been augmented by wind action at the time of making or afterward. As the ice melted away the beds settled down to their present altitude, forming disconnected low ridges trending in the direction of the drainage lines. One of these ridges follows, like a typical osar, the present course of a stream. It is the one already referred to in the description of the topography as having been observed near the north line of section 14, in Cedar township, following a creek on its north side. It is about twenty feet high and ten rods wide, with a chain of small undrained ponds on the north side, and consists of sand, occasionally mixed with clay. Between these ridges or wide swells there are flat and low stretches of land from one-fourth to one-half a mile wide. In the absence of exposures it cannot be made out whether all these swells consist of Illinoian drift or whether some represent old Kansan divides, and the intervening flat lands are in old valleys between, which have been filled with overwash from the Illinoian ice. In either case the topography here at times indicates the presence of some drift which is later than the Kansan, and most likely pro-

duced by drainage from the outer margin of the Illinoian ice. Attention has already been called to the fact that this drift was not sufficient in quantity to fill the inequalities of the topography of the Kansan and impress the land with a topography of its own. At the vanishing of the ice itself the old valleys naturally determined the new drainage. Along the course of the Pine creek, Sweetland creek and Mad creek, which had deeper valleys than the other streams, there seems to have taken place at this time a deposition of various materials such as gravel, stratified, sandy bowlder clay, sand and fine laminated silt that deserve special notice. It may be that part of them were formed earlier and really represent the Illinoian drift, and it is possible that some have a later date than this and should not be referred to this stage at all.

An instance of this kind is the stratified bowlder clay mentioned in describing the ante-glacial silt as occurring near the south line of section 19, in Sweetland township. It forms an ill-defined terrace on the west side of the creek. In Sec. 26, Tp. 78 N., R. 1 W., there is a well-defined terrace from fifteen to twenty feet higher than the bottom land of the creek. It follows the west branch of Pine creek for nearly a mile, varying in width up to at least twenty rods. In some places the material of this terrace is yellow stratified sand, and in other places it consists of fresh looking calcareous till, faintly stratified. This till, as well as the yellow sand, runs upward into loess which forms a capping from three to five feet thick over most of the whole terrace. Similar imperfectly defined terraces appear in section 2, in Sweetland township, along the same creek. In the lower valley of Pine creek there are several remnants of a terrace rising generally twenty-five or thirty feet above the bed of the creek. Near Pine Creek mills, on the east side of the stream, the upper part of this terrace consists of fine laminated, purplish-brown silt, which contains calcareous nodules. It is overlain by loess and the separation between the two is trenchantly marked. Farther down the whole terrace is well exposed in

the right banks of the creek. In the bed of the stream at this point the coal measures appear, rising some twelve feet from the creek bed. On top of this there is five feet of clayey gravel, then a foot of yellow silt, and above this about seven feet of alternating layers of yellow and red silt. Part of the latter is exceedingly fine and unctuous. Some rods to the west this fine silt is overlain by porous loess. The same silt occurs in the same relation to the loess half a mile to the south. At each point these materials contain pebbles of the Niagara dolomite, in that respect resembling the Illinoian drift, which otherwise is conspicuously absent. It is also highly calcareous.

Along Mad creek, in Muscatine, there is a terrace of similar structure. A spur of it is cut across by the Burlington, Cedar Rapids & Northern railroad, close by Eighth street, at which place its upper part consists of a finely laminated, highly calcareous, red or blue silt, with numerous calcareous nodules. Eight feet from its upper surface there are some coarse seams which contain pebbles of Niagara limestone. In the east bluff of the creek, on Ninth street, a thin sheet of loess rests on a laminated sand twelve feet deep. In the upper part of this sand there are several pebbly seams containing material mostly from the Niagara limestone. This sand apparently replaces the Illinoian drift, which is seen associated with a little of the fine silt on the opposite side of the creek. In Park Place addition the same fine dark silt of the terrace occurs on both sides of the creek. Where not covered by loess it forms a tough, impervious soil. It has recently been exposed by grading just east of the Muscatine Pickle works. Another most interesting occurrence of it is in a small ravine opposite Fourth street in East Hill. At this place it changes downward into Illinoian till, which is slightly stratified, and it is abruptly succeeded on the brow of the hill by typical porous loess. On the opposite side of the ravine there is more till and less silt, but otherwise the succession is the same.

The gravel which has been worked on Mr. Samuel Sinnett's farm, near the southeast corner of section 23, in Bloomington township, probably also belongs to the stage of ablation of the Illinoian ice. It overlies a till which resembles that of other exposures referred to this stage, and the two are in fact interbedded. It contains much Archæan material, but there is also a considerable amount of Niagara dolomite.

The Sangamon Soil and Leached Horizon.—After the disappearance of the Illinoian ice no more bowlder clay was deposited in this county. The water of the Mississippi found a lower overflow along its present channel, and ceased to come down by way of Mud creek channel. Some patches of loess and sand appear to have covered the Illinoian deposits from the first, but for the most part the surface of the land at this time consisted of Kansan and Illinoian till. This surface was for a long time being leached and oxidized by atmospheric agencies, and a soil was formed in the same way as soils are formed to-day. On low grounds sand and peaty accumulations were laid down. Deposits of atmospheric dust were, perhaps, also made in favorable situations. This stage has been called the Sangamon soil and leached horizon by Leverett, who finds it particularly common in the valley of the Sangamon river, in Illinois. It is frequently seen in Muscatine county. Near the southwest corner of section 14, in Bloomington township, a ravine has cut under the loess and some yellow sand. Beneath this there is a dark, peaty, muck, with imbedded wood. In the country to the northeast from here, in Wilton, and especially in Sweetland township, a mucky soil with wood is reported by well makers as very frequent at this level. West of the center of section 6, in Montpelier township, on Mr. Daniel Grimm's farm, Mr. Charles Alteneder found under the loess a buried soil on a bowlder clay which was perforated by what appeared to be filled gopher holes.* In a ravine on the east part of section 1, in Montpelier township, the ash-colored base of the loess over-

*Professor Witter reports having seen wood from this muck, at another place, on which there were marks of a beaver's teeth.

lies a thin seam of black muck filled with decayed vegetation, and this in turn rests on a sticky, blue, leached soil, which forms the upper surface of the underlying bowlder clay. A deep peat which, probably, also is to be referred to this formation, occurs in a ravine at the northwest corner of the southwest quarter of section 34, in Sweetland, at a point where this leaves the loess and begins to cut down in the bowlder clay below. Near the center of the southwest quarter of section 12 there is a peat which contains large pieces of gymnospermous wood, and from which were taken some elephant bones, now in Mr. Charles Weir's museum in Muscatine. Traces of peaty material are seen in the base of the loess in the old clay pit near the corner of Eighth and Chestnut streets in Muscatine. One-eighth of a mile southwest of the center of section 19, in Pike township, there is a spring in the bluff of the Kansan drift plain. Right above this spring there is ten feet of loess, which rests on a black soil of bowlder clay. Near the center of the southwest quarter of the same section the same soil is seen higher up under six feet of loess. In this township the old soil rests on Kansan till. On the highest uplands the surface of the till under the loess, as a rule, presents a leached and oxidized zone in all parts of the county.

Lake Calvin.—During the time these soils and leached horizons were forming on the higher ground the lowlands along the Cedar were covered by a lake-like expanse of the Cedar river, and were being filled with gravel and sand. An important instance of evidence to this effect was found near the north line of the northwest quarter of section 23, in Cedar township, on the land belonging to Mr. W. B. Verink. At this place a stream runs down from the upland to the Cedar bottoms. In the cut of the road on the west section line the following drift section was noted:

		FEET.
3.	Loess, slightly sandy in places and running into laminated silt below, which appears slightly disturbed	10
2.	Peat, in irregular pockets and lumps	2
1.	Grayish-white, leached sand, with a weak incipient calcareous matrix	6

On the north side of the creek the same succession appears, but here the peat and sand have been cut away toward the creek, and the loess comes down over their eroded edges. Not far from the center of the north line of the same section the creek has exposed the peaty material again. The section here is as follows:

		FEET.
6.	Sandy loess, in places irregularly stratified	7
5.	Sand	1
4.	Stratified, yellow sand, with some fine, bluish silt	5
3.	Peaty layer, with black fragments of plants, partly disturbed	1
2.	Pinkish or yellow diatomaceous mud	½
1.	White, stratified sand to below the bed of the stream	12

The bed of this creek is about on a level with the West Liberty plain. Samples of the diatomaceous mud which lies under the peat have been examined by Mr. P. C. Myers, of the University of Iowa, and he has identified fourteen different forms of diatoms, a list of which he has published in the Proceedings of Iowa Academy of Sciences, vol. vi, pp. 52–3, giving the habitat of each species.

LIST OF DIATOMS FROM THE DRIFT IN CEDAR TOWNSHIP.

SPECIES AND HABITAT.

1. *Navicula abaujensis* Pant. Fossil in fresh-water deposits, Hungary.
2. *Navicula borealis* (Ehr.) Kuetz. Fresh water, cataracts, rivers and wet moss, all over Europe and America.
3. *Navicula gibba* (Ehr.) Kuetz. Found everywhere in fresh water.
4. *Navicula major* Kuetz. A cosmopolitan species in fresh water.
5. *Navicula nobilis* (Ehr.) Kuetz. Var *dactylus* (Ehr.) V. H. In bogs; also found fossil.
6. *Navicula rupestris* (Prinn.) Hantz. On wet rocks.
7. *Navicula placentula* (Ehr.) Kuetz. In rivers in Europe and America, also marine, sometimes fossil.

8. *Eunotia diodon* (Ehr.) In rivers, on wet rocks, sometimes fossil; found also in springs and rapids.

9. *Eunotia gracilis* (Ehr) Rabenh. In boggy, swampy places.

10. *Eunotia major* (Wm. Sm.) Rabenh. In fresh water everywhere.

11. *Stauroneis phœnicenteron* (Nitz.) Ehr. Cosmopolitan.

12. *Cystopleura gibba* (Ehr.) Kunze. Common in fresh water, also fossil and marine.

13. *Cymbella cymbiformis* (Kuetz.) Breb. Var. *parva* (Wm. Sm) V. H. Common everywhere in fresh water.

14. *Hantzschia amphioxys* (Ehr.) Grun. Common everywhere in fresh water.

From this list and from the comparative number of individuals of each species Mr. Myers infers that the conditions attending the deposition of this mud were probably such as are found in shallow bogs subject to gentle overflows from some creek or river. This view is in accord with the evidence from the containing beds. These consist of sand and silt and occupy a level at which such materials could not have been laid down in any quantity except in slack water. The sand under the peat is very pure and much more like a littoral lacustrine sand than sand deposited by a creek. In all probability the sand was a deposit in the lake near its margin. As the filling proceeded marshy conditions were produced and at this stage the diatomaceous mud and peat were made. Later on these were covered by a few feet of variable layers of silt and sand, such as are now forming over bottom lands.

Sandy water-bedded deposits of a similar nature occur under the loess on Mud creek, near Wilton, and have yielded the remains of a mastodon or elephant. Dr. Calvin investigated this locality for the University of Iowa, at the time of the discovery of the bones in 1874, and gave an account of the fossils and the containing beds to President Thatcher. The main facts presented in this report are summarized below:

The bones were found in the south bank of the creek about half a mile south of Wilton, at a point where the stream coming from the north bends abruptly to the west. Measured from the water, the bank at the time rose nearly thirty feet high. The several bones lay at about the same level in the bank. The skeleton had evidently arrived entire at the place but it was dismembered and scattered before it became finally imbedded. The deposits containing the skeleton were modified drift, consisting of alternating strata of very fine sand and clay. The

fineness of this material, the regular stratification and absence of organic matter, indicated that at the time of the imbedding of the skeleton, the locality was covered with comparatively deep, clear and still water, "having nothing of the character of a marsh but rather resembling the bottom of some wide lake or some large, slowly moving river." The topography of the surrounding country and the nature of the drift itself, favored the idea that a lake at one time covered the territory of the West Liberty plain and reached up to Wilton, and that sediments from some in-flowing river had aided in filling this lake. "*Occasionally larger bodies carried by some more powerful agency, found their way out to the deeper parts and became covered up by the accumulating sediment.*" The evidence was conclusive that the sediments containing the bones were laid down after the ice had disappeared from the region. In the excavated skeleton the cranium and the cervical vertebra were missing, but of the vertebræ there were exhumed nine of the dorsal, two sacral, and one caudal; besides thirteen ribs, one segment of the sternum, parts of both of the innominate bones, one femur, the right tibia, a number of the tarsal, metatarsal and phalangeal bones, one patella, the right scapula, the lower end of the humerus and some carpal and metacarpal bones. The right scapula was in a particularly perfect condition. Measurements were taken as follows:

	INCHES.
Scapula—	
Length, from margin of glenoid cavity to superior angle	39
Width from posterior angle to opposite border	28
Glenoid cavity, diameters	9½, 5½
Circumference of head	32½
Weight, 51½ pounds.	
Longest rib, on outer curve	52
Widest rib, across	4
Vertebra (first dorsal)—	
Width and depth of centrum	5½
Across lateral process	11½
Length of dorsal process	10
Height of neural arch	2⅛
Width of neural arch	2½
Right tibia—	
Length	35
Circumference at top	22½
Circumference at middle	10¾
Humerus, circumference at lower end	37

The water in the lake in which these deposits were laid down appears to have stood highest at the time of the disappearance of the Illinoian ice. Over the north and west slope of the Illinoian drift plain the loess is often underlain by a yellow sand. In one or two places this sand has been observed to be water-bedded.

It will be remembered that the Illinoian drift on East Hill in Muscatine appears to be continuous with sand that changes upward into loess. Less than half a mile from this place to the northeast several Archæan bowlders come up above the surface of the loess, eight having been counted on an area of a few acres. The largest one is at least four feet in diameter and the smallest one a little less than one foot. One is seen in the cut of the road going down the bluff along the south line of section 25. The loess at this place is only about five feet deep and the bowlder comes up to within six inches of its surface. In section 23, in Bloomington township, bowlders are sometimes seen on top of a sand under the loess and extending up into the latter, which in such places, usually, is thin. In section 35, in Moscow township, wells are reported to enter a sand which is twenty feet deep, under four or five feet of surface loess. Some bowlders have also been found on the surface of low lands in this section. Along Musketo creek in section 23, sand and loess frequently interchange and replace each other. One bowlder was seen resting on loess near the south line of section 8, in Wilton township, one in the southwest quarter of section 11, and one near the center of the west line of section 2, in Moscow.

At none of these localities where bowlders have been found is the loess more than a few feet deep, nor does it have the appearance of the typical upland loess. It is at the same time more clayey and more sandy, resembling certain phases of alluvial deposits. The bowlders lie on comparatively low upland, not exceeding 700 feet above the sea level. The two first mentioned localities are in a wide, shallow depression of the Illinoian drift plain, which extends from the valley of Mad creek northwestward. The bowlders were, in all probability, transported by floating ice on the surface of the lake at an early stage, when its waters stood high, and were probably stranded on the shore. Before the disappearance of all the inert remnants of the ice farther to the south, where the flow had been stronger than here, there may have been a

temporary drainage across the land from below Moscow to the Mississippi near Muscatine. The high stage of the lake must, however, have been of short duration, for the bowlders are few and not associated with any indications of a shoreline. It may indeed have been of the nature of a periodic or an accidental overflow. For most of the time of its subsequent existence it must have been a wide expansion of the Cedar river, somewhat like Lake Pepin in the Mississippi of to-day, with its water level but slightly higher than the present surface of the West Liberty plain. At this level there has been some cutting, and it seems to have been maintained until the basin was filled. This probably occurred near the advent of the Iowan ice to the north. The sand ridge which frequently crests the bluffs on the east border of the plain is most likely a wind drift formed on the lee side of the lake a this stage.

With regard to the nature of the filling, not very much is known. Over the whole lake plain, excepting the Cedar bottoms and a strip of varying width following these on the west, there is usually a superficial deposit very much like a loess, ranging from five to fifteen feet in depth. This must have been deposited latest and probably after the river began to meander on the old lake bottom. Downward it changes gradually in a few feet to a yellow sand, and this in turn rests on gravel and sand. At Nichols the filling has been explored to a depth of 250 feet (some reports make it 300 feet). Near Atalissa it is known to reach down 100 feet. At the old ford in section 36, in Goshen township, riffles of bowlders appear in the bed of the river and the greater number consist of greenstone, yellow chert, granite and white quartzite. The fragments are noticeably angular and are probably derived from the Kansan drift. On section 32, in Orono township, the river cuts into the gravel of the plain bed. Some of the bowlders are from two to four feet in diameter, and some were seen to have plain glacial scorings. The most frequent rocks among the bowlders are diabase, granite, greenstone

Trenton limestone, Niagara limestone, and Sub-Carboniferous limestone resembling the Burlington. The latter must have been brought from the south or west. To sum up, part of the filling in the preglacial basin was most likely furnished by the Kansan drift. In the deposition of the uppermost gravel floating ice seems to have aided in bringing some of the bowlders.

The topographic features of the lake plain have already been described in a previous chapter. The full history of the lake can not be made out, since none of its shore lines appear above the level to which it has been filled. The occurrence of diatoms and mastodon remains in some of its sediments is in itself significant of the age of some of the upper part of its filling, for diatoms and mastodon remains have both been taken from the Sangamon soil resting on Illinoian till in the west part of Davenport, in Scott county.* The correlation

*The diatom-bearing mud in this place has been examined by Dr. Astrid Cleve, of Upsala, Sweden. She reports the following forms:

Cymbella gastroides Kuetz. Rare.
Eunotia monodon Ehr. Common.
Eunotia prærupta Ehr. Common.
Eunotia prærupta var. *bidens* Grun. Common.
Hantzschia amphioxys (Ehr.) Grun.
Navicula amphibola Cl. Common.
Navicula semen Ehr. Common.
Pinnularia commutata Grun.
Pinnularia streptoraphe var. *minor* Cl.
Pinnularia streptoraphe var. *styliformis* Grun.
Stauroneis phœnicenteron var. *amphilepta* Ehr. Rare.
Stauroneis javanica Grun. Very rare.

From other samples taken later Mr. P. C. Myers has added the following to the list of identified diatoms from the same place.

Eunotia gracilis (Ehr.) Rabenh. (Not common.) Bogs and stagnant ponds.
Eunotia diodon Ehr. (Common.) Springs, rivers, cataracts.
Encyonema cæspitosum Kuetz. (Very rare.) Stagnant water, lakes, rivers.
Gomphonema subtile Ehr. (Very rare.) Quiet water, fossil in Europe.
Gomphonema dichotomum Kuetz. (Very rare.) On algae in quiet, fresh water in Europe and America. Fossil in Silesia.
Meridion constrictum Ralfs. (Very rare.) Living and fossil all over Europe and America.
Navicula borealis (Ehr.) Kuetz. (Not rare.) In rivers, cataracts, wet moss; Europe and America. Also alpine.
Navicula elliptica Kuetz. (Not rare.) Fresh water, brackish water, in lakes, and fossil.
Navicula dicephala Ehr. (Common.) Everywhere in fresh water.
Navicula placentula (Ehr.) Kuetz. (Common.) Rare in fresh water, common in brackish, also common as fossil.
Navicula mutica Kuetz. (Not rare.) Common in brackish water, rare in fresh water ponds and lakes. Fossil in Prussia.
Navicula hilseana Janish. (Common.) Fresh water lakes.

☞ Continuation of notes on following page.

with the Sangamon rests, however, on better evidence, which must be sufficiently clear from the account given.

In conformity with precedents this fossil lake should properly be known by the name of its discoverer, whose distinguished service to science since the time of his observations in this region, twenty-five years ago, has so greatly advanced our knowledge of American geology.

The Loess.—Excepting the bottom lands and some sandy tracts on West Liberty plain, and on the west slope of the Illinoian drift plain, loess invariably covers the drift throughout the county. It is best developed along the bluffs of the Mississippi river, where its usual depth is from fifteen to twenty-five feet. Opposite Broadway, on West Hill, in Muscatine it is nearly forty feet deep, and this is its maximum thickness as far as known in the county. On the outer slope of the Illinoian drift plain it averages about ten feet, and on the Kansan drift plain it has about the same depth. On long and low slopes to lowlands and ravines it frequently is no more than five feet deep, but where there has been considerable cutting back on such slopes, producing abrupt bluffs, it is apt to be deeper. This circumstance, together with well records from the higher flats of the upland, indicates a greater development on the undissected flat uplands. On some terraces, and on the West Liberty plain, the loess-like superficial material is usually only a few feet in thickness. The formation occurs at levels, usually following the gentler slopes on the drift surface, and sometimes also the steeper slopes.

Four different phases of loess may be mentioned. A sticky and sandy phase has already been referred to as possibly con-

Navicula bacilliformis Grun. (Not common.) Rare in fresh water lakes.
Navicula viridis Kuetz. (Common.) Widely distributed, preferring quiet, shallow ponds and bogs fed by springs.
Navicula iridis Ehr. var. *affinis* (Ehr.) V. H. (Very rare.) Fresh water everywhere.
Navicula gibba (Ehr.) Kuetz. (Not rare.) Fresh water all over North and South America and Europe.
Navicula viridis (Nitzsch.) Kuetz. (Not common.) Fresh water everywhere.
Nitzschia palea (Kuetz.) Wm. Smith. (Very rare.) Frequent in creeks, rivers and ponds.
Pleurostauron autum (W. Sm.) Rab. (Rare.) Common in fresh water.
Suriraya ovalis Breb. var. *minuta* Breb. (Rare.) Rivers, cataracts and mountain streams
Tabellaria fenestrata (Syngb.) Kuetz. (Very rare.) Everywhere in fresh water

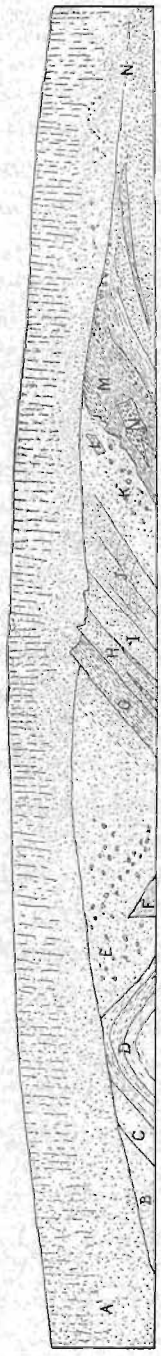


FIG. 38. Section of drift exposed in a railroad cut, in a low ridge, one and one-half miles east of Stockton.
A, loess; B, gray sand; C, ferruginous sand; D, faintly bedded silt; E, red sand and gravel; F, silt; G, yellow silt; H, red sand; I, yellow sand; J, cross-bedded sand and gravel; K and L, square blocks of fine silt imbedded in sand; M, fine silt, sand and gravel; N, sand changing upward into loess.

nected with fluviatile conditions attendant upon the early stages of Lake Calvin. It differs from the other phases in being thin and in having, at a few places, a small number of bowlders imbedded. Another phase is interbedded with the upper part of the Illinoian drift, and contains frequent snailshells. It seems to have formed on or near the Illinoian ice in its vanishing stage. One exposure of this kind is seen in the bluff along Hershey avenue, about two blocks west of Maine street, in Muscatine. It contains some pebbles in its lower part.* Another was seen in a fresh railroad cut across a low swell east of Stockton. Here there is, strictly speaking, no interbedding with the bowlder clay, but some highly tilted beds of silt, on the edges of which it rests, were observed to run up into the base of the loess with sharp, projecting edges, in such a manner that it appeared inconceivable that they should have been so imbedded unless the layers of silt were frozen at the time. The tilting of the underlying bedded materials suggests settled superglacial or englacial accumulations (Fig. 38). Still another phase of loess is coarser than the usual, and contains seams of fine sand and, in one instance, coarse sand and small pebbles. It is always evenly laminated, and at the same time free from clay or fine material. It is seen in the basal part of the loess,

* For fossils in this formation, see page 388.

and occurs along present or former large waterways. This is usually cut by slanting, straight joints into slightly faulted blocks, and changes upward into fossil-bearing, structureless loess. Typical exposures are seen near the crossing of Eighth and Pine streets, in Muscatine, and in the railroad cut in a small isolated hill, near the northwest corner of section 6, in Fulton township. At the latter place it rests on ferruginous gravel, into which some bent, vein-like protrusions of the base of the loess extend in a way that suggests extensive settling after deposition (Fig. 39). A little higher up it contains fossils, among which have been identified by Professor Shimek *Helicodiscus lineatus* (Say) Morse, *Pupa muscorum* L., *Bifidaria pentodon* (Say) Sterki, and *Succinea avara* Say. This phase seems also to be related to the Illinoian drift. Finally there is the floury loess without lamination, and uniform in composition. This is by far the most common phase, and into it all the other phases grade vertically or horizontally. It constitutes the usual upland veneer. It is occasionally fossil-bearing. In the city of Muscatine Professor Witter has collected from it the following mollusks:*

Helix striatella.
Helix fulva.
Helix pulchella.

*Proc. Iowa Acad. Sci., vol. I, pt. i, p. 16. 1880.

FIG. 39. Section of drift exposed in a railroad cut in a low hill three quarters of a mile west of Stockton.
A, loess of somewhat compact texture; B, loess, with fossils above and coarse streaks below, cut by slanting straight joints; C, pebbly sand; D, stratified gravel; E, blocks of silt; F, till; G, silt, resting on some ferruginous sand; H, blue till.

Helix lineata.
*Pupa blandi.**
Pupa corticaria.
Pupa muscorum.
Pupa simplex.
Succinea avara.
Succinea obliqua.
Helicina occulta.
Limnæa humilis.

Besides these mollusks he has also discovered teeth, bones and antlers of a species of caribou or deer, and a tusk and teeth of a mammoth or mastodon.

Opinions differ as to the origin of the loess. The usual view has been that it is an aqueous sediment, laid down at a time when the land was submerged. Chamberlin has lately advanced the hypothesis that it is in part an atmospheric sediment and in part a surface wash. Some of the features presented by the loess in this county seem to sustain such a view.

The greater part of the loess in this county was no doubt formed subsequent to the Sangamon stage, at the time when the Iowan drift was being deposited to the north of this region, as Calvin has shown. But some loess seems to be older than this, as where it is found interbedded with the Illinoian drift. Some may also be more recent. Professor Witter has reported the finding of chipped flints in the upper part of the loess exposed in a clay pit on Eighth street, in Muscatine. The author has found a river unio two feet from the surface of the loess on the bluff overlooking the Mississippi, in section 29, in Sweetland township. It was associated with chips of flint, and must have been brought there by human agency. Near the center of section 8, in Lake township, he accidentally found a nest of stones of a size suitable for hand hammers, lying one foot under the sod in

*The fossils from eastern Iowa usually identified as *Pupa blandi* are *Pupa pentodon*. *Pupa blandi* seems to be restricted, so far as the loess fossils of Iowa are now known, to the western part of the state. B. S.

the loess. There is no doubt that they had been placed there by human hands. It may be that at all of these places these relics of human work were purposely buried, but nothing has been observed to indicate that such was the case. An alternative view is that they were simply left on the surface of the ground and have been covered later by secular accumulation of atmospheric dust. If this be the correct view the surface loess in these places must be quite recent.

Terrace and Alluvium.—The deposits on the Cedar bottom are usually not very sandy. This bottom forms a belt about two or three miles in width, except near the north and south boundaries of the county where the valley of the river is narrow. At Moscow the town is situated on a terrace which appears more recent than the West Liberty plain. East of the railroad depot an excavation in this terrace, twenty feet deep, shows a structureless, yellowish, surface sand two feet deep, resting on a white or gray sand rather free from gravel. The Mississippi bottom land above Muscatine is narrow, and only a small strip next the river is subject to overflow. Above this the ground is a low slope up to the bluffs, in part at least formed by wash from the latter. This slope is never sandy. Below Muscatine, alluvium covers most of the island, and also the slope between the Muscatine slough and the bluffs. This slope largely consists of confluent fans of deposits from the creeks and ravines draining the uplands, and these fans are usually proportionate to the streams in size. Muscatine island is mostly covered by a rusty sand which in some places, as in sections 16 and 21, in Fruitland township, contains a large amount of gravel. On the south half of sections 33 and 34 there is a remnant of a terrace, known as the Sand Mound, rising from thirty to forty feet above the level of the island. It consists of rather fine, white sand, with very few pebbles. Some of the surface material on the island may have been derived from this terrace. Small alluvial tracts of land occur along the larger creeks in the county, especially along the Wapsinonoc, Mud creek and

Pine creek. From an alluvium which occurs in a small run just below Fairport, some snail shells have been collected. Part of the exposure is somewhat like a loess. Prof. B. Shimek has identified the following forms in the collection made:

Polygyra multilineata (Say) P. & J.
Zonitoides minusculus (Bin.) P. & J.
Succinea obliqua Say. ?
Pomatopsis lapidaria (Say) Try.
Limnea humilis Say. (?)
Pisidium abditum Hald. (?)

DEFORMATIONS.

The bed rock is slightly tilted to the south and west. The dip to the west is small. Near the east county line the top of the main dolomite, number 9 of the general Devonian section, is thirty feet above low water. Near the center of section 29, in Sweetland township, the top of the same ledge is about eight feet above low water. The two places are eleven miles apart from east to west. The fall of the river in the same distance is less than three feet. The total dip to the west in eleven miles is thus twenty-five feet, which is only a little more than two feet to the mile. The dip to the south is much greater. It has been made out along two lines. The elevation of the top of the Basal breccia (general section, No. 1), near the county line northwest of Moscow, is about 660 feet above sea level. The top of the Stromatopora breccia in Mad creek, in north Muscatine, lies at a level of about 560 feet. The former is seventy feet below the latter in the Devonian section. Hence there is a total descent of 170 feet in eleven miles, which is the north-and-south distance between these two places. This makes a dip of about sixteen feet to the mile. Near the north line of section 34, in Tp. 78 N., R. I W., the elevation of the base of the Strombodes ledges is 690 feet above sea level. The elevation of the top of the Stromatopora breccia west of Fairport and near Wyoming

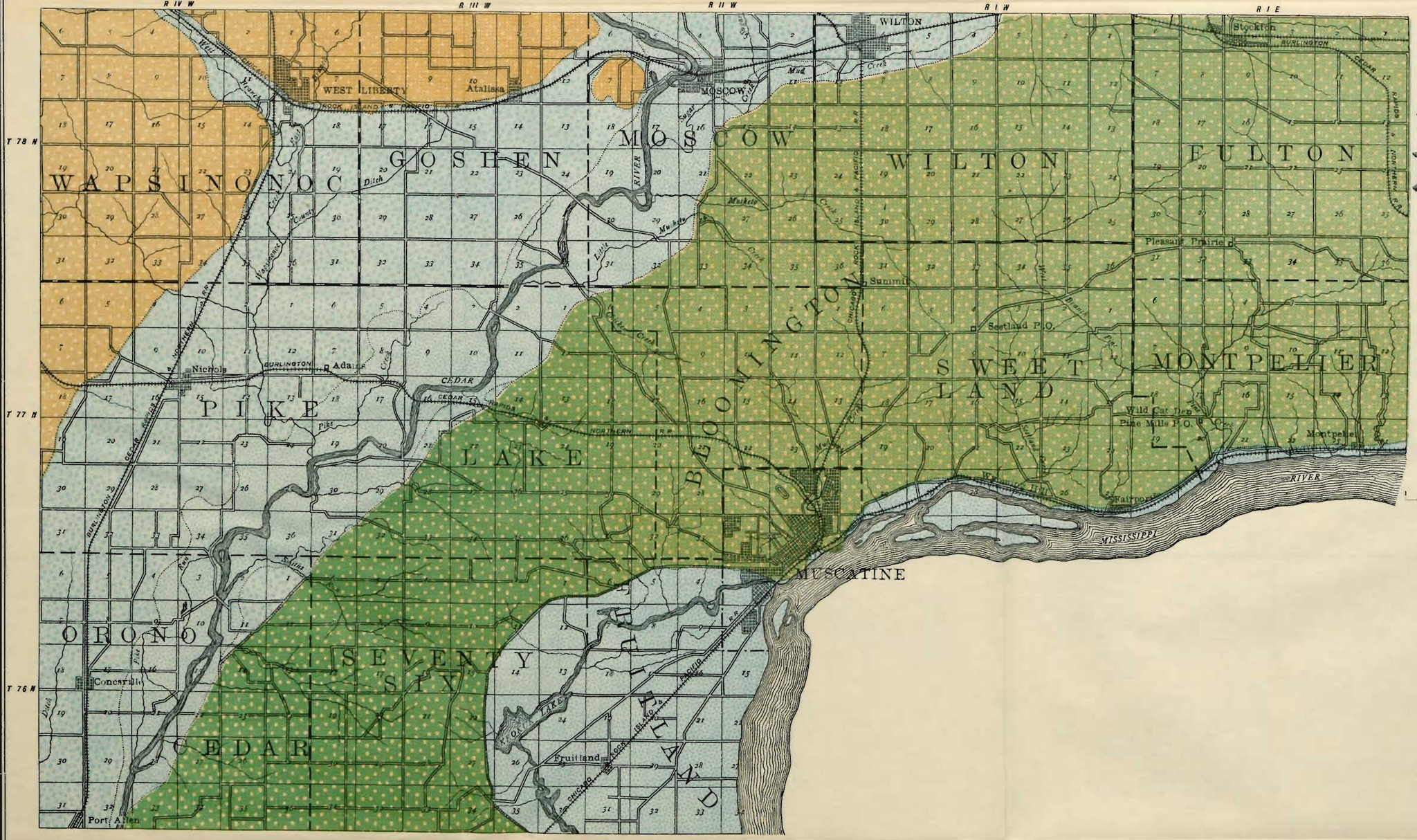
IOWA GEOLOGICAL SURVEY

MAP OF THE SURFACE DEPOSITS OF MUSCATINE COUNTY, IOWA.

BY

J.A.UDDEN

1899.



Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

- ALLUVIUM
- WEST LIBERTY PLAIN
- IOWAN LOESS OVERLYING ILLINOIAN DRIFT
- IOWAN LOESS OVERLYING KANSAN DRIFT

IOWA LITHO. CO.

DRAWN BY F.C. TATE

Hill is about 550 feet above sea level. The vertical distance between the two horizons in the section is forty-two feet, the Strombodes ledge being the lower. The north-and-south distance between the two places is nearly six miles, in which there is a total descent of 140 feet, or twenty-three feet per mile. Averaging these two measurements there is a dip to the south of about twenty feet to the mile. This would bring the top of the Cedar Valley limestone down to about 400 feet above sea level along the south boundary of the county, near the Mississippi river. Local variations and small folds are evident at some places. The south dip of the coal measures seems to be about four feet per mile less than that of the Cedar Valley limestone, indicating that the earth movements which produced this tilting had already commenced before the coal measures were deposited. That such was the case is known from evidence elsewhere in the state. No general faults or folds appear anywhere in the county.

JOINTS.

In most exposures of the bed rock two or three systems of joints can be observed. In the Des Moines sandstone all of these joints are generally nearly vertical. This is also the case in the most compact ledges of the Devonian limestone. In the softer ledges of the latter rock the joints are more apt to run at a considerable angle from the vertical, sometimes diverging as much as forty-five degrees, or even more. Some observations have been made on the bearings of these joints, and are given in the table below. It will be noticed that the joints cluster about two directions which intersect at right angles, one having an average trend about N. thirty-five degrees E., and the other of about N. fifty-five degrees W. (Fig. 40.) These directions coincide with the tilting of the rock, which is to the southwest, but more to the south than to the west, as already shown. The dip joints appear to be more frequent and more uniform in development than the

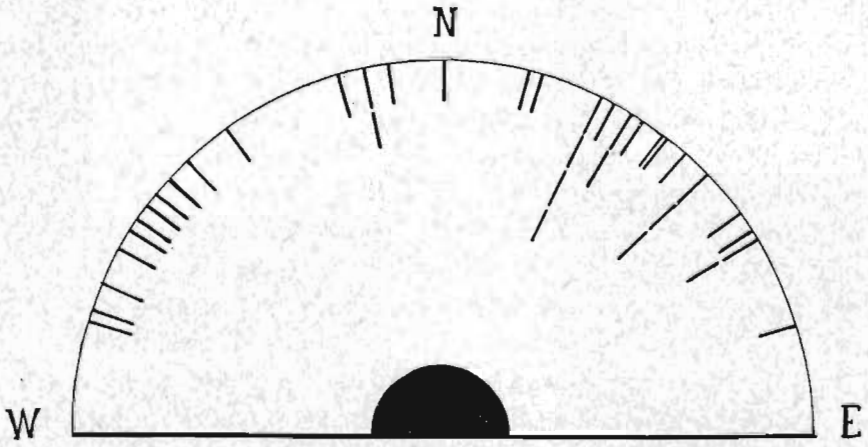


FIG. 40. Diagram showing the position of joint planes in the bed rock.

strike joints. The observations are too few to indicate any difference in the general direction of the joints for the different formations, if such difference should exist. The measurements were made with a small hand compass and were corrected for declination.

TABLE SHOWING DIRECTIONS OF JOINTS IN THE COUNTRY ROCK IN MUSCATINE COUNTY.

In the Des Moines Sandstone.

Montpelier creek	N. 27° E.			
Wild Cat Den	N. S.	N. 25° E.		
West Hill, Muscatine	N. 25° E.	N. 42° W.	N. 72° E.	N. 16° W.
Pappoose creek, Muscatine	N. 55° W.	N. 25° E.		
Branch of Pappoose creek	N. 70° W.	N. 40° E.		
Lowe's run	N. 50° W.	N. 8° W.	N. 30° E.	

In the Cedar Valley Limestone.

Montpelier creek	N. 45° E.	N. 53° E.	N. 57° W.	
Robinson's creek	N. 45° E.	N. 15° E	N. 12° W.	
Alteneder's quarry	N. 45° E.	N. 72° W.		
Fairport (landing)	N. 32° E.	N. 58° E	N. 12° W.	N. 25° E.
Sweetland creek	N. 37° E.	N. 43° W.		
Mad creek	N. 36° E.	N. 60° W.		
Gatton's quarry	N. 52° W.	N. 13° E.		
Pine creek	N. 32° E.	N. 35° W.		

In the Sweetland Creek Beds.

Robinson's creek	N. 58° E.	N. 66° W.

EARTH TEMPERATURES.

From a few observations made on the temperatures of well water, it seems that the underground temperature increases downward in this county at a rate somewhat near 1° Fahrenheit for 100 feet. This corresponds to the observed rate of increase at other places in this region. The data from Muscatine county are as follows:

Underground Temperatures.

	Depth in feet.	Temperature Fahr.
Average of several surface wells and springs...	50	51°
Frank Nettlebush's well	347	54°
Wilton artesian well	1,360	64°
West Liberty artesian well	1,768	65°

MINERALS.

Among the minerals found in the country rock *calcite* is the most common. It frequently occurs as Iceland spar, lining small crevices in the Cedar Valley limestone. Joints in this rock are sometimes filled with plates of a columnar structure. A white incrustation of this kind, an inch thick, was found lining a crevice in the Des Moines sandstone in Stark's quarry, in section 29, in Sweetland township. In Robinson's creek, in the uppermost weathered ledges of the Cedar Valley limestone underlying the coal measures, there are some small cavities which have been filled by a radiating variety of cone-in-cone, the bases of the cones next to the surface of the cavity occasionally consisting of pure transparent calcite. *Pyrites* is common in the Des Moines shales. It forms spherical concretions in the sandstone in the west part of Muscatine. It fills joints, sometimes an inch wide, in the eroded surface of the Cedar Valley limestone, under the coal measures in Sulphur creek. In similar situations it occasionally almost covers

the surface of the lower rock. About a foot above the base of the Sweetland Creek beds it forms a seam from half an inch to two inches in thickness. Higher up in this rock it forms spherical and lenticular concretions. A yellow effervescence of *copperas* is often seen on the black carbonaceous shale of the Des Moines. *Sphalerite* is sometimes found in small crevices in the Cedar Valley limestone, and has been observed near Montpelier. It was also seen in a silicified Devonian bowlder belonging to the basal conglomerate of the Des Moines at that place. *Gypsum*, or *selenite*, occurs as a disintegration product from pyrites in the Sweetland Creek beds, sometimes in dendritic forms in joints in the black shale. An incrustation of *epsomite* is now and then formed on exposures of the basal ledges of the same formation. A calcareous *limonite* forms the matrix of a conglomerate under the drift on West Hill in Muscatine. Concretions of impure *siderite* are quite frequent in the coal measures. *Bog manganese* forms a considerable ingredient in a black, mucky substance on top of the limestone in Wresley's quarry southwest of Moscow. A peculiar occurrence was noticed in a railroad embankment west of Stockton, near the county line. A Devonian bowlder lodged in fresh clayey drift had a powdery coating of this mineral measuring one-fourth of an inch in thickness. Large lumps of impure *hematite*, altered from Cedar Valley limestone, lie under the coal measures in the right bank of Pine creek about one-half mile from its mouth. Among the rare minerals of the drift *copper* may be mentioned. A piece weighing nearly twelve ounces was found in Mad creek some years ago, and is now to be seen in Mr. Weir's museum in Muscatine. A lump of *Galena* weighing five pounds has been found in the drift at the foot of the bluff west of Lake Keokuk. Dr. Otto Kuntze has recently discovered *Quenstedtite** near Montpelier, where it is found in dry seasons as an incrustation on an outcrop of Des Moines sandstone. Its composition is reported as follows:

* *On the Occurrence of Quenstedtite near Montpelier, Iowa*, by Otto Kuntze, American Geologist, vol. XXIII, No. 2, p. 119.

SO_3	29.01
H_2O	32.32
Al_2O_3	0.27
Fe_2O_3	26.86
$Si\ O_2$	1.77

ECONOMIC PRODUCTS.

COAL.

Coal has been mined in this county for more than forty years. The two localities which have been worked most extensively are West Hill, in Muscatine, and the old Hoor property, on section 30 in Sweetland township. The latter has been abandoned for some years, and the former long ago ceased to be productive. The mining was carried on mainly to supply the local demand. As to the nature of the coal taken out in Muscatine, Hall, in his report on the county,* says that "its quality was very poor, as it contained an unusually large proportion of iron pyrites mixed with it." The coal from the Hoor bank is said by Keyes to have been of excellent character and the seam was free from irregularities or clay seams. Another coal bank was operated successfully for many years, on a small scale, by Mr. Robert Henderson, in the northeast quarter of section 9, in Montpelier township.

Three years ago some drifts were opened on Mr. Frank Nettlebush's farm, in the northeast quarter of section 27, in Sweetland township. There are now several entries in the slope of a ravine, at a level of about 120 feet above the river. Two of these are worked, mainly by one miner. The coal is about twenty inches thick, with a "soapstone" and miners' "slate" for roof. The first season 2,000 bushels were taken out, and the year after the whole output was 5,000 bushels. The coal is sold to farmers in the neighborhood, and is considered to be of good quality. Some small drift mines are occasionally worked on the middle branch of Pine creek,

*Geology of Iowa, James Hall, vol. I, p. 277.

where this is crossed by the road following the west line of section 8, in Montpelier township. This coal rests on the Cedar Valley limestone, and above it there is first about eight feet of shale and then sandstone. These are all the mines now operated in the county.

Though the supply of coal seems by this time to be exhausted, it is not impossible that there may yet be found some local developments of veins which can be profitably worked on a small scale. But it is not at all likely that the feather edge of the coal basin which extends into this region has any extensive or thick coal veins. The rapid rise to the north of the underlying limestone causes the coal measures to run out in a distance of from two to five miles from the river. All observations on the beds containing the coal show that these are very changeable, and several circumstances have combined to render them unproductive. The bottom of the Carboniferous sea in which they were laid down was uneven. Contemporaneous unconformities indicate that the marginal waters in this sea occasionally cut away their own deposits. Recent erosion has extensively dissected the thin sheet of coal-bearing rocks which still remains in the region. Such veins as really do exist are apt to run out in short distances, and to have a poor roofing, for which reasons they prove unprofitable. Under such circumstances prospecting for coal will usually bring disappointment. The future of coal mining in this territory can best be told from the experience in the past. Many old "openings" are seen in the bluffs of the Mississippi river and along the creeks in Montpelier and Sweetland townships. Some of these have been worked for a season or two, but most have been failures. They were usually made at the expense of the land owners, who thought they could afford to risk a little sum on the prospect of a coal mine. That many hundreds of dollars have been spent uselessly in this way is quite evident, though the parties who have paid for the explorations usually are reticent as to particulars. There is just enough of a probable chance for a

profitable find occasionally to induce the land owners to engage in small speculations, but it is now a saying that no man has ever become rich by working a coal mine in Muscatine county. With much of the field exhausted and stronger competition in the market profits will no doubt be still less in the future.

BUILDING STONES.

In the west end of the county, and in the southern townships, there is no stone of any kind except a few bowlders. Over the east half of the county small quarries are quite frequent, especially along the rivers and the larger creeks. Good building stone is found, but not in such quantity or in such situations as to have encouraged extensive quarrying. Stone is taken out merely to supply local demand.

The Fayette Breccia.—The lower ledges in Gatton's and Wresley's quarries, southwest of Moscow, consist of the fossil-bearing upper part of the Fayette breccia. This is a strong, pure limestone, of compact texture, in heavy beds. The upper ledges are more brittle and more cut up by joints, and have been used by the Chicago, Rock Island & Pacific railroad for riprapping and ballast. The stone from Wresley's quarry was used in the construction of the old milldam in the Cedar at this place. Some of the lower unfossiliferous part of this breccia has been taken out for local use in the west bank of the Cedar above Moscow, and also in section 3, northeast of Moscow. This rock is a very pure limestone, and in Illinois it is crushed and sold to glass manufacturers, who use it as a flux.* Whether it would pay to furnish this rock for the same purpose from Moscow would probably

*An analysis of some of this rock from Rock Island, Ill., is given by James Hall in Geol. of Iowa, vol. I, p. 372. Dr. Hall remarks that it is one of the purest limestones which has been found in the whole western country. The analysis is as follows:

Insoluble in acid	.42
Carbonate of iron	.36
Carbonate of lime	98.77
Loss, alkalies, etc	.45
Total	100.00

depend on facilities for quarrying and handling, and on the cost for transportation.

The Cedar Vlley.—Other limestone quarries all belong to the Cedar Valley stage. Those on Pine creek are mostly in the calcareous and highly fossiliferous ledges, and yield a hard stone, sometimes in rather thin courses. The rock quarried along the bank of the Mississippi and in the creek east of Montpelier is a blue, dolomitic limestone, of an even texture, in heavy beds. It turns yellow and slightly harder on exposure. It has been used by the railroad for riprapping between Montpelier and Muscatine, and has lately been taken out on Mr. Charles Bar's property, near the mouth of Pine creek, by contractors, who transport it on barges down the river, where it is used by the government in the construction of wing-dams.

The Des Moines sandstone is soft, usually light brown or yellow in color, and quite variable in texture as well as in hardness and color. It is easily worked, and this perhaps in part accounts for its general use in Montpelier and Sweetland townships, where several farm houses and one small church have been built from it. It is quite durable, and the ferruginous ledges harden with age. Three quarries have been worked more than the other. One of these is in the west bluff, on the west branch of Pine creek, near the north line of section 18 in Montpelier township, on the land belonging to Mr. Charles Alteneder, who opened it many years ago. At this place the rock lies in heavy beds, some being four feet thick. The quarry wall now rises sixty feet from the bottom. The stone is rather fine in texture, and has some peculiar wavy, ferruginous bands, that seem to be due to infiltration of iron from percolating water. Another quarry is in section 21, in the river bluff in Sweetland township, and belongs to Mr. J. Stark. The stone is about the same kind as in Alteneder's quarry, but a little coarser in texture. At neither of these two places has much quarrying been done lately. More rock has been taken at the quarry on Lowe's run, in the north-

east quarter of section 32 in Bloomington township, west of Muscatine. The stone at this place is less ferruginous and of gray or yellowish-white color, with here and there a layer of darker shade. This quarry belongs to Mr. Jesse Oaks. Considering the quality of the stone from these and some other quarries in the Des Moines, it seems that it might with advantage be more generally used. Some imported sandstone is neither stronger nor more lasting than much of this rock. The chief objection that can be urged against it is that it is somewhat variable in each quarry, and the occasional delivery of stone of inferior quality may have prevented a more frequent use of the better kinds of the home product.

GRAVEL AND SAND.

Good gravel is scarce in this region. Some has been taken out along the railroad in the east bluff of Mad creek, near the northwest corner of section 25 in Muscatine township, and has been used for ballast on the roadbed. About one-fourth of a mile northwest of this place, there is another old gravel pit on the property of Mr. Samuel Sinnett. The deposit is about four feet deep, resting on a yellow till and overlain by loess. It is variable in texture, changing from sand to coarse gravel with large bowlders. A somewhat more extensive deposit of gravel and sand occurs under the Kansan till in the bluff near the center of section 6 in Fruitland township, on land belonging to Mr. Charles Warfield and to Mr. Charles Miller. This gravel is in part sand. Some years ago it was used in macadamizing the Hershey avenue road for a distance of three miles west of the city of Muscatine. In the railroad excavation recently made west of Stockton, a gravel was uncovered in the west side of a low, flat hill which lies to the south of the road, and it was used for ballast on the roadbed. The deposit was not far from twenty feet in depth at one place. Most of the pebbles consist of Devonian limestone. It changes into sand above. This gravel will no doubt become useful in the improvement of the roads in the vicinity.

Sand for mortar is usually obtained from recent and alluvial deposits along the streams. East of Moscow the Chicago, Rock Island & Pacific railroad has worked a sand pit for road ballast. This sand is white and rather free from gravel.

CLAY INDUSTRIES.

The Fairport Potteries.—More than a dozen kilns were at one time in operation in the production of stoneware in the town of Fairport. The place is still known among the river people as "Jugtown." At the present time there are only two kilns running. One of these belongs to Mr. John Feustel, and has recently been rebuilt. Mr. Feustel employs from five to twenty men. Most of the clay now used by him is hauled across the river from the Illinois side during winter, and costs about $14 a ton when laid down at the factory. A smaller quantity of clay is also taken on this side of the river from the bluffs near Pine creek. Jars, jugs, churns, milk pans, flower pots, hanging baskets and vases are manufactured. The ware burns to a cream-white color. About forty kilns are burned in a year, and the goods are in part shipped by rail and in part freighted to the cities along the river by a small boat. The other kiln is owned by Mr. John Shellhorn, who uses clay from a pit in the Des Moines shales north of the city. This is mixed with a red, ferruginous clay from the alluvium of the river just below the town. The ware produced is chiefly flower pots, hanging baskets and vases, which are of fine quality and have a beautiful pink-red color. About fifteen kilns are burnt in a year. The decline of the industry at Fairport in recent years seems to be due to a lack of suitable clay near the works and to the general introduction of enameled iron ware in the market.

Brick and Tile.—The Montpelier Brick and Tile works, which were running for nearly fifteen years, closed down at the end of the season in 1897. This factory made paving brick and tile, and also some crockery ware. The clay used was taken from a pit in the Des Moines shale. Another

industry which has been discontinued was the manufacture of hollow blocks for the construction of fire proof buildings by the Muscatine Terra Cotta Lumber company. The works were located north of the bluff road, southwest of the center of section 30 in Sweetland township. The factory was running from 1889 to 1892, and it also produced some paving brick. The clay used was a disintegrated coal measure shale.

Brick making is at present limited to the production of soft brick to supply the home market. Eight brick yards are located in Muscatine, and at West Liberty there is one. Neunhuis Brothers' yard is located below East Hill, north of Second street. The brick is made by hand, sun-dried and burned in open kilns. The output in one season varies from 500,000 to 1,000,000. The clay used is of two kinds, a laminated, calcareous silt, which underlies the Illinoian till, and loess. When burned alone or with a small admixture of loess, the silt makes a white, hard and strong brick. With a greater proportion of loess, the bricks turn red and do not become quite so hard. Both kinds are made.

The Muscatine Pressed Brick company's yard is located north of Woodland avenue, and east of Oak street. The brick is made by a Henry Martin soft mud machine, is dried wholly under roof, and burned in open kilns. The clay used is loess, which is excavated to a depth of sixteen feet. The upper six feet of this is compact and breaks into small cuboidal blocks, while the lower part of the bank is more open in texture. Some hard brick suitable for sidewalks is made from the upper clay, but the main product is a fine, soft, building brick. Usually about 1,500,000 bricks are made in a season. Mr. Carl Hagermeister operates a yard on Mulberry street, north of Woodlawn avenue. The brick is red, and made from loess clay, about 450,000 in a season. Hagermann & Koetting have their yard adjoining Hagermeister's on the same street to the north. The quality and the quantity of the brick made is about the same in both of these yards. The same kind of brick is also made from the same material by Mr. Charles

Samuels, near the junction of Cedar and Star streets, and by Fuller & Shoemaker near the crossing of Cedar and Eighth streets. Each burns about 300,000 bricks in a season. Mr. George Christopherson has a yard east of Mad creek on Second street and makes some 200,000 bricks in a season, using both the calcareous silt under the Illinoian till and loess, and making some white and some red brick. Brick and tile have been made for the last twenty-five years on the property now owned by Mr. J. W. Fuller, at West Liberty, southwest of the city. The clay used is a loess, rather more ferruginous than the loess at Muscatine. The brick is moulded by a Johnson Krieger soft mud machine, and dried under shelter. Some are burned in an open kiln and some in a down draft kiln which is also used for burning the tile. The usual output is 500,000 brick and 100,000 tiles.

The brick industry is thus represented by ten firms. These employ about thirty-two men during the summer season, and have a total output of about 5,000,000 a year. The price of the brick ranges from $5 to $6 per 1,000, and the total value of the brick made in a year is estimated to be about $27,000.

During the last few years about eight miles of streets have been paved with brick in the city of Muscatine. Most of the brick so used have been brought from Buffalo, in Scott county. Some have been imported from Galesburg and some shipped from Des Moines.

WATER SUPPLY.

The water works in Muscatine is owned by the Muscatine Water Works company. The first building of their plant was erected in 1875. At present there are twelve miles of water mains, from six to sixteen inches in diameter, with 117 hydrants. A reservoir is located on West Hill, and has a capacity of 2,000,000 gallons. The bottom of this reservoir has an elevation of 185 feet above low water in the river. The ordinary supply is furnished by pressure from this reservoir, but direct pressure can also be used. There are two

pumps, run by two low pressure condensing engines. The full pumping capacity is 5,000,000 gallons in twenty-four hours. The water is taken from the Mississippi river through a conduit which extends 700 feet out into the river. No filter has yet been found necessary. Should it prove desirable, artesian water may be obtained in this city at a depth of from 900 to 1,100 feet. It may be expected to rise some seventy-five feet above low water in the river.

The water works at West Liberty are supplied from an artesian well, 1,768 feet deep, made in 1888. The water-bearing rock in this well is the Saint Peter sandstone and the Oneota limestone. A Dean duplex force pump is used to raise the water into a standpipe sixteen feet deep and twenty-four feet in diameter, the bottom of which is fifty feet above the ground. The quantity pumped daily is 75,000 gallons. There are twenty-nine hydrants and 330 taps in the city. Professor Norton states that in the amount of alkaline carbonates the water from this well exceeds that from any other well in the state.* An analysis made by Floyd Davis gives the solid contents of this water as follows:†

		GRS. IN U. S. GAL.
1.	Sodium chloride	11.659
2.	Ferrous carbonate	Trace.
3.	Sodium carbonate	38.152
4.	Potassium carbonate	18.125
5.	Sodium sulphate	43.738
6.	Sodium chloride	9.302
7.	Magnesium phosphate	.077
8.	Magnesia	.019
9.	Silica	7.678
10.	Alumina	0 222

The town of Wilton had an artesian well made in 1891 and this now furnishes a sufficient quantity of pure water to its inhabitants. The main supply comes from the Saint Peter sandstone. The water is now pumped into a tank and distributed through two miles of water mains. About 56,000 gallons

*Norton, Artesian Wells of Iowa, Iowa Geol. Surv., vol. VI, p. 282.
†Norton, Artesian Wells of Iowa, Iowa Geol. Surv., vol. VI, p. 281.

can be pumped in a day. The water is said to be somewhat laxative and diuretic, and beneficial in case of rheumatism. An analysis made by Mariner and Haskins, of Chicago, gives the solid contents as follows:*

	GRS. PER U. S. GAL.
Calcium carbonate	10.47
Magnesium carbonate	6.45
Sodium chloride	18.56
Sodium sulphate	33.45
Iron oxide and alumina	Traces.

On the uplands of the drift shallow wells take their supply from the base of the loess or from a sand under the loess, but farmers now very generally have deep wells going down from 100 to 300 feet, with pumps worked by windmills. In the west end of the county such wells average 150 feet in depth and draw their supply from sandy strata in the drift. In the east end some such wells extend down 300 feet and draw their supply from the upper part of the Niagara limestone. Along Mud creek some wells of nearly the same depth draw water from sandy strata in the lower part of the drift. On the West Liberty plain water is obtained from pumps, which are driven from twenty to forty feet into a sand under the surface loess. When such pumps go down more than thirty or forty feet, the water is apt to have a strong mineral taste. On some low tracts around Nichols, temporary flowing wells have sometimes been obtained by boring through the hardpan which covers the surface in such places. Below the bluffs east of the Cedar in Moscow township, and west of the Mississippi in Fruitland and Seventy-Six townships, there are frequent springs from the drift. Some of these are copious, and most of them never dry up. In a few instances the water from these springs is conducted through pipes into the farmhouses, and along the Burlington wagon road, west of Muscatine, the flow is frequently conveyed into high troughs convenient of access to wayfarers. On Muscatine island water is every-

*Norton, same place.

where obtained at shallow depth, mostly by drive-pumps. The supply is so copious that it is pumped by engines in dry seasons for irrigating the melon crop.

Water Power.—At Pine Creek mills Mr. Michael Missel owns a flour mill which is partly run by water. The power wheel is a twenty-six-horse-power turbine. The dam in the creek is seventeen and a half feet high. Steam power is also used, the water being sufficient to run the mill for about half the time during the year.

NATURAL GAS.

A tract of some small gas wells is found just to the south of this county. The gas seems to come from vegetation which is buried in the deep drift in that region. It has been found in some wells in the south part of Cedar and Seventy-Six townships in this county. The highest pressure observed here registered a little more than nine pounds on a steam gauge. The only instance where it has been utilized is on the farm belonging to Mr. C. Hadley, near the center of the south line of section 36 in Cedar township. The other places where gas was found in measurable quantity are on Mr. J. O'Brien's farm, near the north line of section 26 in the same township, on Mr. J. Reed's farm in the southwest quarter of section 15 in Seventy-Six township, and on Mr. Lewis Eliason's farm west of the center of section 31 in the same township. On the farm of Mr. W. B. Verink, near the center of the west line of section 14 in Cedar township, a slight escape of gas from a deep well, seventy-five feet deep, is yet noticeable. The quantity is not sufficient to sustain a flame. In all of these wells the gas is reported as coming from a white sand, which in some instances is associated with peaty material and is covered by bowlder clay. Inflammable gas was also tapped some years ago by a well from a similar stratum in the drift on a farm near the southeast corner of section 7 in Fulton township.

SOILS.

Genetically, the soils of this county may be classified as loess, terrace material, and alluvium. The first makes the soil of the drift plains, and covers about two-thirds of the area of the county. This is the typical Mississippi valley corn soil, for which crop it is admirably well adapted. It forms a rich loam of uniform texture, inclined to be somewhat sticky in low places, but loose and open on higher ground. On the flat lands in the north part of Fulton township, the natural drainage is slow, and some sections were by the early settlers for some time considered unsuitable for tilling. This land has proved to be particularly well adapted for barley, though other crops also do quite well. It is now as productive as the best farming land in the county, and well repays the cost of tiling, which on some tracts has been very expensive. On the sandy hills on the Illinoian drift plain, the soil is sometimes so light that it drifts and injures the crops. In a few places this drifting prevents cultivation. The flat lands from which these small, sandy hills rise, and which lie between them, usually have a very rich soil that yields excellent crops. On the high slopes bordering upon the bluff lines in the east end of the county the loess surface is in some places subject to erosion from heavy rains, and this cuts deep gullies that prevent further cultivation. This erosion is of course limited to small tracts, and usually begins on fallows used for pasture. It is most common along the creeks and ravines in the south part of Bloomington, Sweetland and Montpelier townships.

On the west half of West Liberty plain the soil is like that of the uplands in texture, but it is usually deeper and contains a greater quantity of mould. Over several sections of land under the bluffs of the Kansan drift plain there were formerly extensive marshes and peat bogs. These have been drained by ditches and now yield rich crops of corn and other grains. On a few low places there is sometimes found a hardpan that is apt to interfere with the under drainage in wet

seasons and cause the soil to bake in times of drought. Partially successful attempts have been made to remedy this by boring through the hardpan and letting the water down into the sand below. Over the greater part of Orono township, and on that part of the plain which is nearest to the Cedar bottoms, the soil is more sandy. The veneer of loess runs out in this direction, and the underlying sand forms a typical terrace soil. Corn, oats and rye are the usual crops on this land, but in Orono township melons and sweet potatoes are also extensively raised. As a corn soil it is inferior to the uplands.

The bottom lands along the Cedar river are for the most part very fertile, but crops are occasionally damaged by overflow. Some low tracts have been protected by levees, and in other places the drainage has been improved by ditching. Corn, small grain and hay are the usual crops. The most productive soil in the county is probably to be found on some of the alluvial fans under the bluffs of the Mississippi river. These are frequently covered by a deep black loam, which yields from eighty to a hundred bushels of corn to the acre in good seasons, and on which failures are unknown. The soil on Muscatine island is entirely different, being coarser and sandy. Where the sand is coarsest and where the land is high corn cannot always be raised with profit. Nevertheless, this land has become very valuable in the production of melons, sweet potatoes and some other garden products. The Muscatine melon has become a staple article in the Chicago markets, and hundreds of carloads are shipped from this land every season. Some of the melon-soil in Fruitland township is really a gravel, but even this produces good or fair crops with favorable rainfall. The melon plant seems particularly sensitive to the conditions of the soil moisture, and a dry season prevents the melons from developing to their full size. Even the best melon land shows the effects of unfavorable weather, and the largest farms are provided with steam pumps

that irrigate the land from shallow wells, when rain is insufficient during the growing season.

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FOREST TREES AND SHRUBS OF MUSCATINE COUNTY.

BY FERDINAND REPPERT.

The timber area of Muscatine county is confined to the region along the Mississippi and Cedar rivers. Originally these forest belts were in the main unbroken and continuous along these water courses, and from four to six miles or more wide. Much of this area has been cleared of its timber and converted into farm and pasture lands. The original larger forest trees have almost disappeared, so that what is now seen are mostly "second growth" trees. There is very little, if any, timber cut for export or manufacturing purposes. There are frequent groves on the prairie farms, planted to protect the houses and live stock from wintry blasts. The soft maple (*Acer dasycarpum* Ehrh.) is the principal tree planted for this purpose; small groves of black walnut and evergreen trees are occasionally seen. The forest trees which most largely contribute to the timber supply are the white oak (*Quercus alba* L.), bur oak (*Q. macrocarpa* Michx.),

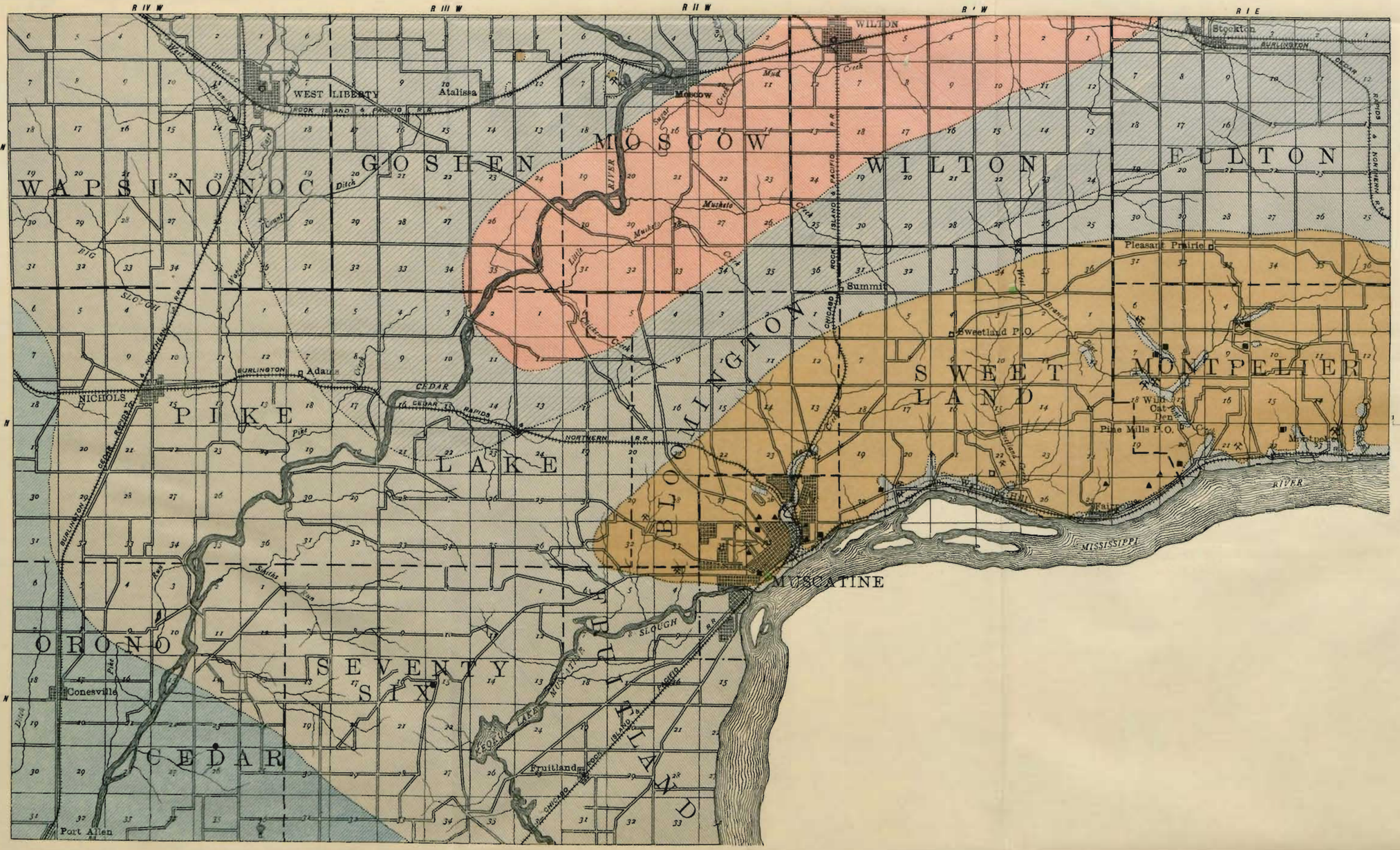
IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF MUSCATINE COUNTY, IOWA.

BY

J.A.UDDEN

1899.



LEGEND

GEOLOGICAL FORMATIONS

- PINE CREEK
- DES MOINES (Coal Measures)
- KINDERHOOK (NOT EXPOSED)
- SWEETLAND CREEK
- CEDAR VALLEY
- WAPSIPINICON
- NIAGARA (NOT EXPOSED)

INDUSTRIES

- QUARRIES
- CLAY WORKS
- ARTESIAN WELLS
- COAL MINES
- COAL MINES ABANDONED
- GAS WELLS NOT USED
- GAS WELLS BURNING

IOWA LITHO. CO.

DRAWN BY F.C. TATE

shell-bark hickory (*Carya alba* Nutt.) and mocker-nut hickory (*C. tomentosa* Nutt.). A few other species contribute more or less to the wood supply, but the six species above mentioned largely predominate.

Clematis virginiana L. Virgin's bower. Woody at the base. Climbing over shrubs, etc., twelve to fifteen feet or more. Borders of woods and thickets; frequent.

Menispermum canadense L. Moonseed, yellow parilla. Smooth, shrubby vine, eight to ten feet or more. In alluvial soil along streams, etc.; frequent.

Berberis vulgaris L. Common barberry. Shrub four to six feet high, cultivated as an ornamental shrub; sparingly spontaneous.

Hibiscus militaris Cav. Rose mallow, hibiscus. Plant three to four feet high, soft woody near the base; flowers large, flesh-colored, darker at the base, handsome. In alluvial soil along rivers and streams; frequent.

Tilia americana L. Basswood, white-wood. One of the larger forest trees in all rich woodlands. Not common; most frequent along the Cedar river. The flowers yield nectar abundantly; July.

Xanthoxylum americanum Mill. Prickly ash. In rock and sandy woods; frequent; shrub six to ten feet high; prickly and pungently aromatic.

Ptelea trifoliata L. Wafer-ash, hop-tree. Shrub eight to twelve feet high; in dry soil, borders of woods, etc.; infrequent.

Celastrus scandens L. Climbing bittersweet. A twining shrub, climbing over shrubs and small trees in open woods and thickets; not rare.

Euonymus atropurpureus Jacq. Wahoo. Shrub five to ten feet; in moist woods; frequent.

Rhamnus lanceolata Pursh. Buckhorn. Borders of woods and in thickets along Cedar river; infrequent.

Ceanothus americana L. Red-root, Jersey tea. Small, shrubby plant about two feet high; dry woodlands and sandy prairies; common.

Vitis cinerea Engelm. Downy grape. Along the Mississippi and Cedar rivers; not so common as the next.

Vitis riparia Michx. River-bank grape, wild grape. In all woodlands, thickets and fence rows.

Ampelopsis quinquefolia Michx. Virginia creeper. A common vine in all rich woods; also planted about dwellings for shade and ornament. In a general way it resembles the poison ivy, from which, however, it is readily distinguished by its leaves, which are composed of five leaflets, while those of the poison ivy are of three leaflets.

Acer saccharinum Wang. Hard maple, sugar maple. Medium to large sized trees; most frequent on the bluffs along the Mississippi river.

Acer dasycarpum Ehrh. Soft maple, silver maple. One of the largest trees; most frequent along the Mississippi and Cedar rivers. Largely planted for groves on the prairies and for shade along the streets.

Negundo aceroides Mœnch. Box elder. A small tree frequent along streams, also planted for shade, and very desirable where large trees are not wanted.

Staphylea trifoliata L. Bladder-nut. Shrub eight to ten feet, in moist woods; not common.

Rhus glabra L. Common sumac. Common in dry soil, four to six feet, sometimes tree-like ten to twelve feet or more.

Rhus toxicodendron L. Poison ivy. Climbing trees, also occurring in fence rows and thickets. It is frequently low and spreading along the ground; common. By contact it produces very disagreeable skin poisoning in many persons.

Rhus canadensis Marsh. Sweet sumac. Shrub three to four feet, in sandy soil, often forming broad clumps; rather common.

Amorpha canescens Nutt. Lead plant. In dry open woods and sandy prairies; quite frequent; two to three feet high.

Amorpha fruticosa L., False indigo. Shrub five to ten feet; frequent; banks of streams.

Tephrosia virginiana Pres. Goat's rue, cat-gut. Shrubby plant one to two feet; not rare; in dry soil and sandy prairies.

Robinia pseudacacia L. Common locust. A small to medium-sized tree, along roadsides and borders of woods. This otherwise valuable tree is too subject to the ravages of the locust-borer, *Cystus robiniæ*, a beautiful yellow-banded beetle common on the flowers of the golden-rod in September.

Cercis canadensis L. Red bud. Small tree twelve to twenty feet. Wooded hillsides along the Mississippi and alluvial sandy bottom lands of Cedar river; not frequent.

Gymnocladus canadensis Lam. Kentucky coffee-tree. A small to medium-sized tree, in alluvial soil along the Mississippi and Cedar rivers; not rare.

Gleditchia triacanthos L. Honey locust. Medium to large-sized tree, often planted for shade and ornament. Some of the trees are quite thorny while others are almost or wholly thornless.

Prunus americana Marshall. Wild plum. In woodlands along stream banks, etc.; frequent.

Prunus chicasa Michx. Chickasaw plum. On Muscatine island near the sand mound; local.

Prunus virginiana L. Choke cherry. Shrub or frequently tree-like, eight to twenty feet; in wooded ravines and borders of woods; frequent.

Prunus serotina Ehrh. Wild black cherry. A medium-sized forest tree, more or less frequent in all woodlands.

Spiræa salicifolia L. Meadow-sweet. Small shrub two to three feet, in wet soil along the Cedar river; not common.

Physocarpus opulifolius Maxim. Nine-bark. Shrub three to five feet, in hilly woods along streamlets, etc.; infrequent.

Rubus occidentalis L. Black raspberry. Frequent in thickets and fence rows.

Rubus villosus Ait. Blackberry. Borders of woods, thickets, etc.; common.

Rubus canadensis L. Low blackberry. Trailing extensively in neglected fields and borders of woods; fruits sparingly.

Rosa blanda Ait. Wild rose. Rocky, sandy soil; frequent; two to five feet high.

Rosa arkansana Porter. Wild rose. Common in dry soil; one to three feet high.

Rosa rubiginosa L. Sweetbrier. Along roadsides near old habitations; escaped from cultivation; not frequent.

Pyrus coronaria L. Wild crab apple. Tree, frequently twenty feet high, but generally smaller; often forming small thickets.

Pyrus americana DC. Mountain ash. This has been found in one or two instances along the border of woods, where the seeds were probably carried by birds.

Cratægus coccinea L. Hawthorn, red haw. Border of woods and in thickets; frequent.

Cratægus coccinea mollis Torr. and Gray. Red haw. Common; distinguished among our species by its large, bright scarlet fruit, one-half inch or more in diameter and edible.

Cratægus tomentosa L. Hawthorn, red haw. Not common.

Cratægus crus-galli L. Cockspur thorn. Cedar river region; not frequent.

Amelanchier canadensis Torr. and Gray. Juneberry. Small tree fifteen to twenty feet; in hilly woods; frequent; seldom has much fruit, although the trees bloom freely in early spring.

Ribes cynosbati L. Prickly gooseberry. Hilly woods; not common: fruit prickly,

Ribes gracille Michx. Missouri gooseberry. In open woods, etc.; rather frequent.

Ribes floridun L'Her. Wild black currant. Borders of moist woods; not frequent.

Cornus circinata L'Her. Round-leaved dogwood. Shrub six to eight feet; along Sweetland creek; infrequent.

Cornus sericea L. Kinnikinnik. Wet banks, etc.; shrub, four to eight feet; frequent.

Cornus asperifolia Michx. Dogwood. Tall shrub, often tree-like, twelve to fifteen feet high; in sandy soil; frequent.

Cornus alternifolia L. f. Dogwood. Tall shrub, or often tree-like, ten to fifteen feet high; hilly woods; frequent.

Sambucus canadensis L. Common elderberry. Along fences, borders of thickets, etc.; frequent.

Viburnum lentago L. Black haw. Along woodland streams, etc.; shrub, or often tree-like, six to fifteen feet high; not common.

Lonicera glauca Hill. Honeysuckle. Hilly woods and rocky ledges; frequent.

Diervilla trifida Mœnch. Bush honeysuckle. Rough or stony hillsides at Wild Cat Den; local.

Fraxinus americana L. White ash. Medium to large-sized trees; frequent, but becoming scarcer.

Fraxinus pubescens Lam. Red ash. Creek bottoms; probably infrequent; collected but once.

Fraxinus viridis Michx. f. Green ash. Along wooded streams; frequent; the most common ash.

Fraxinus sambucifolia Lam. Black ash. Along streams, etc.; not common.

Tecoma radicans Juss. Trumpet-creeper. Has escaped from cultivation more or less about old habitations.

Catalpa speciosa Warder, and probably unintentionally with it *C. bignonoides* Walt., have been largely grown and planted, but no escapes have so far been noted.

Ulmus fulva Michx. Slippery elm. In rich woods; not common.

Ulmus americana L. White elm. A very common and large tree in all river and creek bottom lands.

Celtis occidentalis L. Hackberry. Along streams in low ground; not common.

Maclura aurantiaca Nutt. Osage orange. Largely used for hedges; self-established specimens are seldom seen.

Morus rubra L. Red mulberry. Small tree fifteen to thirty feet high; not common; more frequent along Cedar river.

Platanus occidentalis L. Sycamore. Often a large tree; in alluvial soil along streams; not common.

Juglans cinerea L. Butternut. A rather small tree; rich woods near streams; not common.

Juglans nigra L. Black walnut. In rich soil along streams; frequently planted along roadsides near farm houses; native trees of much size have become rare.

Carya olivæformis Nutt. Pecan-nut. Infrequent; a few trees near Wyoming Hill, and in the "big timber" below Muscatine city, along the Mississippi.

Carya alba Nutt. Shell-bark hickory. In all upland woods; the most common of the hickories; not many large trees exist any more.

Carya sulcata Nutt. Big shell-bark hickory. In the "big timber" below Muscatine, and less frequently along Cedar river.

Carya tomentosa Nutt. Mocker-nut hickory. In nearly all upland woods, and rather frequent.

Carya amara Nutt. Bitter-nut hickory. River and creek bottom land; sometimes on upland; frequent.

Betula nigra L. Red birch. A small to medium-sized tree along streams; rather common.

Corylus americana Walt. Hazelnut. Common in open thickets and borders of woods; two to six feet high.

Ostrya virginica Willd. Iron wood. Hilly woods frequent; small tree.

Carpinus caroliniana Walter. Water beech. A small tree along woodland streams; not common.

Quercus alba L. White oak. One of the most common oaks; not many of the larger native trees are left standing.

Quercus macrocarpa Michx. Bur oak. Common in low and on high ground; very large trees not frequent.

Quercus bicolor Willd. Swamp White oak. In low ground along streams; frequent.

Quercus muhlenbergii Engelm. Chestnut oak. Hilly woods; not frequent.

Quercus rubra L. Red oak. A very common tree in all upland woods.

Quercus coccinea Wang. Scarlet oak. An abundant upland oak.

Quercus palustris Du Roi. Pin oak. Common in wet soil along the Mississippi and Cedar rivers.

Quercus imbricaria Mich. Shingle oak. A few small trees only in Cedar township.

Salix nigra Marsh. Black willow. Along streams, a small to medium sized tree.

Salix amygdaloides Anders. Black willow. With the former and very similar.

Salix alba vitellina Koch. Yellow willow. Small to medium sized tree with yellow branches and twigs; cultivated and self planted from detached twigs.

Salix longifolia Muhl. Long leaved willow. Very common along the shores of the larger streams, six to twelve feet.

Salix discolor Muhl. Pussy willow. Along the smaller streams and wet places; five to ten feet or more high.

Salix humilis Marsh. Prairie willow. In dry soil, two to four feet high; not frequent.

Salix cordata Muhl. Heart-leaved willow. Along streams, etc., five to ten feet high; frequent.

Salix purpurea L. Purple willow. Bank of Mad creek, near Muscatine city, four to six feet high; local.

Populus tremuloides Michx. Quaking aspen. A small tree in moist woods; not common.

Populus grandidentata Michx. Large-toothed aspen. Medium sized tree, in rich, moist woods; not common.

Populus monilifera Ait. Cotton-wood. Along streams; frequently a large tree.

Pinus strobus L. White pine. On rugged hills at Wild Cat Den, twelve miles above Muscatine; some of the trees still standing are two feet or more in diameter.

Juniperus virginiana L. Red cedar. Represented only by scraggy specimens on rock ledges; Wyoming Hill, Wild Cat Den, etc.

Note.

Gray's Manual, sixth edition, has been followed in the preparation of the above list.

I wish to express my thanks here to Prof. T. H. Macbride, for help and suggestions, and to Prof. L. H. Pammel for comparing specimens of Cratægus and Fraxinus, at the Missouri Botanical Gardens; and to C. R. Ball for determining specimens of Salix.

From the loess described on page 358, the following fossils have been collected, (identified by Shimek):

Helicina occulta Say.
Valvata sincera Say.
Polygyra multilineata (Say) Pils. (?)
Polygyra monodon (Rock) Pils.
Strobilops virgo Pils.
Bifidaria pentodon (Say) St.
Pupa muscorum L.
Cochlicopa lubrica (Müll) P. & J.
Pyramidula alternata (Say) Pils.
Pyramidula perspectiva (Say) Pils.
Pyramidula striatella (Anth) Pils.
Succinea obliqua Say.
Succinea avara Say.
Succinea ovalis Gld.
Limnæa caperata Say.