GEOLOGY OF CLAYTON COUNTY.

BY A. C. LEONARD.

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INTRODUCTION.

LOCATION AND AREA.

Clayton county is in many respects one of the most interesting counties in the state. Situated as it is largely within the driftless area, its surface is deeply trenched by the streams and its scenery is diversified and picturesque. There are few more attractive scenes along the Mississippi than those to be observed from the bluffs bordering the great river along the eastern boundary of this county.

The many deep valleys afford numerous outcrops and excellent opportunities for the study of the various formations. Three geological systems are represented by the indurated rocks, the Cambrian, Ordovician and Silurian, while the deposits left by the Pleistocene ice sheets belong to three widely separated periods of time and are very different in character. The soils of the area yield bountiful crops, while clays and building stones of excellent quality are abundant.

Situated in the northeastern corner of the state Clayton county is separated from the Minnesota line by Allamakee, is bordered on the west by Fayette and on the south by Delaware and Dubuque counties, while the Mississippi river forms the eastern boundary. It has an area of approximately 780 square miles which is divided into twenty-two civil townships.

The earliest settlement in Iowa, next to that of Julien Dubuque, was made near the point where North McGregor is now located. In 1795 Basil Giard obtained from the Lieutenant Governor of Louisiana a grant to a tract of land in the northern part of Clayton county, known as the "Giard Tract" or "Spanish Claim." This is still represented on many of the maps of the county. It contained 5860 acres and was occupied several years. When Louisiana was acquired by the United States a patent was issued to Giard by the Government, which was the first legal title obtained by a white man to land within the limits of Iowa.*

*B F. Gue, Hist of Iowa, Vol. I, p 116. New York City, 1903.

PREVIOUS GEOLOGICAL WORK.

The earliest geological investigations in the region of which Clayton county forms a part were carried on under the direction of David Dale Owen. With a large number of assistants he made an examination of the mineral lands of Iowa, Illinois and Wisconsin in 1839, the survey extending as far north as the mouth of the Wisconsin river. The field work therefore covered the greater part of what is now Clayton county and represents the earliest study of the rocks of the area. The report* embracing the results of the autumn's work was published in preliminary form without maps and illustrations in 1840 and later, in 1844, a revised edition appeared. In this report there appear detailed observations on the various townships, with brief descriptions of the timber, nature of the soils and kinds of rocks and minerals. Ten years later the region was again visited by Owen and his assistants and in his report of 1852 he describes briefly some of the geological formations occurring in the area under discussion, but there is no reference to localities in Clayton county.†

In 1855 James Hall, then State Geologist of Iowa, made a geological reconnoissance along the Mississippi river, for the purpose of studying the formations so well exposed near that stream. His report,‡ published three years later, contains references to various localities in the county and to the character of the rocks. Sections are given of the Trenton beds at Pikes Peak, opposite the mouth of the Wisconsin river, at the town of Clayton and at Guttenberg, as well as of the Galena strata at Elkader. Mention is also made of the Potsdam (Saint Croix), Calciferous limestone (Lower Magnesian) and Saint Peter sandstone occurring in the bluffs along the river.

J. D. Whitney§ has a brief account of some of the geological formations of Clayton county in the same volume, and in his discussion of the economic geology of the state refers to the occurrence of lead in the vicinity of Buena Vista and Guttenberg.

*House Rep. Exc. Doc., 26th Cong., 1st. Sess., No. 239, 161 pp. Washington, 1840
†Rept. of a Geol. Surv. of Wis., Iowa and Minn., pp. 48-76. Philadelphia, 1852.
‡James Hall: Report on the Geol. Surv. of Iowa, Vol. I, Pt 1, pp. 47-65, 1858.
§*Ibid.* pp. 297-302 and pp. 458, 459.

In the report of C. A. White on the Geology of Iowa there are a few scattered references to Clayton county in the chapters on general geology.*

Clayton county lies for the most part within the driftless area which has been described by Chamberlin and Salisbury.† It also forms part of the region discussed by W. J. McGee in his Pleistocene History of Northeastern Iowa.‡ The latter paper mentions certain topographic features of the area and gives several sections of the older drift.

The present writer visited in 1894 the different localities in the southern part of the county where lead has been mined and describes these briefly in his report on the lead and zinc deposits of the state.§

PHYSIOGRAPHY.

TOPOGRAPHY.

The greater portion of Clayton county is included within the limits of the driftless area, and its surface has not been affected by the ice sheets which modified so profoundly the topography of the entire state with the exception of this northeastern corner. Elsewhere the ice tended to level up the rough preglacial surface by wearing down the ridges and divides and filling the valleys with drift. But as it moved down from the north the ice sheet failed to override this area in northeastern Iowa and contiguous parts of Wisconsin and Illinois, and the surface was left as it had been sculptured by weathering and erosion.

Two very different kinds of topography are exhibited in the county. In the driftless area the surface features are the result of erosion acting on nearly horizontal strata of varying degrees of hardness. On the other hand the Iowan drift area in the southwestern corner has undergone very little erosion and the topography is constructional instead of erosional. The flat or gently rolling, bowlder strewn drift plain presents a sharp contrast to the deeply dissected driftless area with its steep-sided valleys and high intervening ridges.

*Rept. on the Geol. Surv. of Iowa, by C. A. White, Vol I, p. 167, 1870
†Sixth Ann. Rept., U. S. Geol. Surv., pp 199-322.
‡Eleventh Ann. Rept., U S G. S., Pt. 1, pp. 189-577.
§Iowa Geol. Surv., Vol VI, pp 51-53

THE DRIFTLESS AREA.

In this discussion the area covered by the Kansan drift is included with the driftless portion since that drift is in this region too thin to affect materially the surface features. From a study of the latter alone it would be difficult to discriminate between the driftless and the Kansan areas and hence they are naturally considered together.

The most prominent topographic feature of the region is the broad, bluff-lined valley of the Mississippi, while of only less importance are the deep trenches cut by the Turkey and Volga rivers. These valleys and their chief tributaries are sunk from 500 to 600 feet below the general level of the upland, the latter having an elevation of from 1100 to 1200, or 1250 feet above the sea. The difference in elevation between the bottom of the Mississippi valley just below Buena Vista, and the upland eight miles west, between Bluebell creek and Little Turkey river, is nearly 650 feet, or more than one-half as much as the relief of the entire state.

Another conspicuous feature in the topography of the county is the high ridge between the Turkey and Volga rivers. The road from West Union to Elkader follows this ridge, which extends southeast from Highland, near the Fayette county line, to within two miles of Communia. The road leading from Osborn on the Volga river, to Elkader on the Turkey, climbs 450 feet in crossing this divide between the two streams. From its summit one has a wide outlook for many miles in all directions, the view extending to the hills on the farther side of the broad depressions made by the above rivers.

North and east of the Turkey river, between that stream and the Mississippi, the surface is mostly upland. In the vicinity of the rivers this has been deeply eroded, and narrow gorge-like valleys have been carved in it. But away from the larger streams the upland is gently rolling. It may be seen from the railroad between Postville and Monona, and upon it are located the towns of National and Garnavillo. The surface is made up of a series of gentle curves convex toward the sky and with a gradual slope toward the drainage lines. The convex curves are the units of which the general surface is composed. There is scarcely an

IOWA GEOLOGICAL SURVEY

TOPOGRAPHIC MAP OF CLAYTON COUNTY IOWA

Topography from
Atlas Sheets of U. S. Geological Survey

Scale 1/125,000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

1903

ALLAMAKEE CO.
CLAYTON CO.
BOUNDARY LINE
Hardin
Luana
Monona
Watson
McGregor
Mo. Gregor
GRAND MEADOW
MONONA
GIARD
Boulah
Froelich
Giard
Wagner
Bismarck
Gunder
Farmersburg
MARION
WAGNER
FARMERSBURG
National
St. Olaf
Sny Magill
Clayton
FAYETTE CO.
CLAYTON CO.
Highland
Read
Clayton Center
BOARDMAN
HIGHLAND
READ
GARNAVILLO
Garnavillo
ELKADER
Ceres
Motor
Volga
Osborne
Communia
PERRY
COX CREEK
VOLGA
JEFFERSON
Guttenberg
Elkport
East Elkport
Osterdock
Mederville
St. Sebald
Strawberry Point
CASS
LODOMILLO
ELKPORT
MALLORY
MISSVILLE
Updegraff
Ryan
North Buena Vista
BUENA VISTA
Edgewood
Wood
DELAWARE CO.
CLAYTON CO.
DELAWARE CO
BOUNDARY LINE
CLAYTON CO.
DUBUQUE CO.
BOUNDARY LINE

Iowa Publ. Co. Davenport, Iowa.
TRI-CITY LITHO. CO. DAVENPORT, IA.

acre of perfectly flat land, but the gentle slopes lead down to the drainage channels which ramify to all parts of the surface. The streams divide, subdivide and divide again until they have modified by their erosion the entire area.

At several points flat-topped hills rise above the general level of the upland. These are outliers of Niagara limestone which have been left by the erosion of the surrounding strata. One of the most prominent of these hills of circumdenudation is one mile southwest of Gunder, in Marion township. It rises fifty to sixty-five feet above the adjacent region. Another is located four miles south of Postville on the western edge of Grand Meadow township and extends into Fayette county.

South of the Volga and Turkey rivers the country is very rough and much cut up by the many streams joining these rivers from that direction. The Niagara escarpment, produced by the outcropping edges of the beds of this formation, here forms a conspicuous topographic feature. It has been deeply incised by the numerous streams which have cut their valleys far back into the Niagara, making its line of outcrop a very sinuous one winding back and forth along the sides of the valleys and extending out in the ridges and divides between these. At the escarpment the surface rises abruptly from 100 to 200 feet. The precipitous slope is commonly wooded and covered by huge masses and blocks of limestone broken off from above. The roads often follow along near the base, and where they climb to the top they are steep and rocky.

The valley of the Mississippi has been mentioned as forming the most prominent topographic feature of the region. It has a width from bluff to bluff of from one and a quarter to three miles and the river flows now on one side, now on the other.

The preglacial valley was considerably deeper than the present one as shown by the record of the deep well at Prairie du Chien. In drilling this well 147 feet of sand and gravel were penetrated before striking the bed rock, showing that the river during glacial times filled its old valley to this depth with sediment.

The town of Guttenberg is situated on the flood plain and extends for more than two miles between river and bluff. One of

the common features of flood plains is well exhibited here, namely, the outward slope away from the river. During times of flood the deposition of sediment goes on most rapidly next the channel where the current is first checked, and therefore that portion of the plain is built up more than the remainder. The town is located largely on the higher part of the plain next the river and between it and the side of the valley the land is four or five feet lower. When there is high water this depression is overflowed to a depth of several feet. Where the Wisconsin river enters the valley of the Mississippi it has formed an extensive deposit of sand and has forced the main channel over against the Iowa shore. When the water is low large sand bars appear at this point.

The bluffs rise abruptly from the flood plain to a height of from 300 to 400 feet and then the surface has a gradual ascent to 600 feet and more above the river. On the Iowa side these slopes are for the most part heavily wooded, but on the Wisconsin side they are largely bare of timber, and the ledges of the indurated rocks are exposed. For some distance above and below McGregor the Oneota limestone is seen forming perpendicular cliffs, at the base of which the Saint Croix sandstone appears. In the vicinity of Clayton the Saint Peter sandstone outcrops toward the base of the slope and above it are cliffs of Galena-Trenton, or Galena-Platteville, limestone. This limestone composes the entire height of the bluffs at Guttenberg and also forms cliffs at many points between here and Buena Vista.

These rocky cliffs, fifty to one hundred feet high, with their talus slopes at the base, form a striking feature of the valley. Except where the strata outcrop to form perpendicular walls, the sides are covered with a heavy growth of timber, shrubs, ferns and other plants. One of the highest points along the river is Pikes Peak, two miles south of McGregor, opposite the mouth of the Wisconsin. It rises 450 feet above the water and standing on its grassy summit one looks out upon a marvelous picture. The broad valley of the Mississippi lies spread out beneath bordered by its picturesque bluffs. On the more distant Wisconsin shore the smooth slopes are verdure clad, except where cliffs stand out like giant walls of masonry against the

green background. Those nearer by are heavily wooded and only occasionally do the towers, pinnacles and crags of gray rock appear amidst the trees. The luxuriant vegetation of the river is a vivid green, with darker stripes of the same color formed by the fringes of timber along the edges of the water channels. Threads of blue intersect the level plain in a network of water courses which in places widen out into broad lakes and lagoons. Variety is added to the scene by an occasional river steamer pushing before it a huge lumber raft, or a scow heavily loaded with clam shells for the button factories farther down the river. The boats of the clammers dotting the surface of the stream appear as specks in the distance. Just opposite, the Wisconsin empties its waters into the Mississippi and brings down the sediment forming the sand bars which extend far out into the river. One can look for miles up the wooded valley of the minor stream bordered on the south by high, steep bluffs and on the north by low hills. Above the confluence and on the opposite side of the valley stretches the broad flat plain upon which is located the historic old town of Prairie du Chien. To the south of the town the land is divided into rectangular, cultivated fields, each a different shade of color and giving the plain the appearance of a huge checker board.

In striking contrast to the widely extended view obtained from Pikes Peak is the wooded glen known as "Pictured Rocks" which is reached by a winding and precipitous path following along the north slope. Clambering down through a tangle of ferns and wild flowers one reaches the bed of a small stream just below where it tumbles twenty feet over a lichen-covered ledge. The steep walls dotted with mosses, harebells and rock ferns, rise to such a height as to exclude all save the noonday sun and bury the gorge in fragrant coolness. The glen has been carved in the Saint Peter sandstone, which here has the exceptional thickness of 100 feet. The bright and varied colors of this rock add beauty and interest to the place. Numerous tints of red, yellow and gray shading into white prevail, arranged in bands or irregular patches.

At the mouth of Turkey river erosion has left a long, narrow, steep-sided ridge between the valleys of that stream and the

Mississippi. It extends for nearly three-quarters of a mile with its summit scarcely wide enough to afford space for a foot path, and on either side are perpendicular cliffs of Galena limestone from 100 to 200 feet high. Here and there are picturesque pinnacles, towers and battlements of the same rock, which has weathered into countless fantastic forms. The end of this ridge is shown in Plate V. The rocky and uneven summit is well seen from Millville station, two miles above the mouth of the Turkey river. A similar narrow ridge is found just below Guttenberg, at the mouth of Miners creek (Fig. 19). In both cases these

Fig. 19.—Ridge between Mississippi and Miner creek, Guttenberg.

sharp ridges are caused by the minor valley joining that of the Mississippi at an acute angle.

The valleys of the Turkey and Volga rivers are conspicuous features in the topography of the county. They have been cut to a depth of 400 or 500 feet, and in places the flood plain is more than one-half mile wide. Cliffs of Galena limestone outcrop along the sides at numerous points, with here and there isolated turrets or towering castle-like forms. These are well shown at Motor, on the Turkey river, and at Mederville, Littleport, Elkport and elsewhere on the Volga. Throughout most of their

extent the valleys have been eroded chiefly in Galena-Platteville beds, but toward the western border of the county the Maquoketa shale outcrops in the bottom of the stream-cut trenches. Where they have been cut in the soft shales of the Maquoketa there is a very noticeable broadening out of the valleys. This is best seen in the case of the Volga river, which, from a mile or more below the town of Volga to the Fayette county line, flows through a broad valley with gently sloping sides rising gradually to the Niagara cliffs one or two miles back from the river. At Mederville on the other hand the river flows in a narrow rock-walled gorge which is little wider than the channel itself. In this portion of its course the sides rise abruptly eighty or one hundred feet to the top of the Galena beds, whence there is a more gradual slope to the Niagara escarpment. But when the Maquoketa shales are reached in the vicinity of Volga, where the Galena-Platteville is below river level, these soft and easily eroded shales have enabled the stream to cut a much broader valley with gently sloping sides. The weathering of the shale is comparatively rapid and results in a widening of the gorge.

The marked difference in the character of the valley at Mederville or Littleport and Volga is therefore due wholly to the difference in the nature of the rock in which it has been carved. The same peculiarity is found in the valley of the Turkey river near the western border of the county, though the Maquoketa beds are not as shaly along that stream, and hence the change in the topography is less marked.

The valley of Bloody Run, at the mouth of which is located the town of North McGregor, though little more than ten miles long, forms a steep sided gorge 300 to 400 feet in depth, which is followed by the Chicago, Milwaukee and St. Paul railway in passing from the flood plain of the Mississippi to the upland 600 feet above. Toward the lower end of the valley the Oneota limestone forms picturesque, gray cliffs rising precipitously along the sides while farther up, deeply weathered crags and towers of Galena dolomite appear. In an expansion at its mouth, and within the limits of the town of North McGregor, a hill of circumdenudation rises 110 feet above low water in the Missis-

sippi and forty-five feet above the terrace of silt which partially encircles the knoll. The latter is composed, in part at least, of Oneota limestone which has been quarried on a small scale near the summit. At the time the terrace was being built the hill must have formed a rocky island about which the deposit of stratified silt accumulated in the quiet water near the shore. Similar hills of circumdenudation are not uncommon throughout the county, being found in the vicinity of Volga, Elkader, Motor and elsewhere. The Stoops quarry, at Elkader, is located near the top

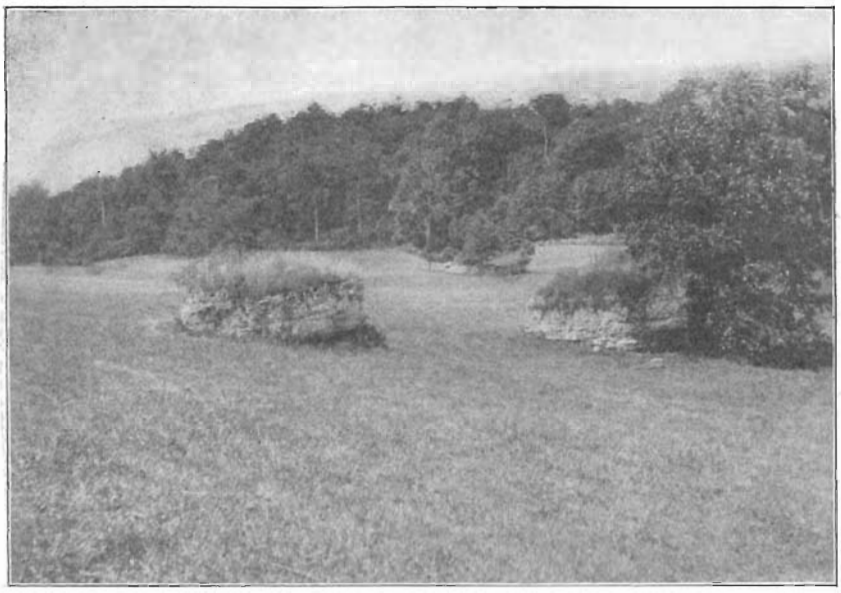

Fig. 20 Blocks of Niagara limestone which have slipped down the Maquoketa slope Elk creek valley, section 23, Elk township.

of such a hill which has been left between two valleys entering that of the Turkey within a short distance of each other. One of these is no longer occupied by a stream and is partially filled by river deposits and materials from the hillsides.

Little Turkey river and Elk creek have cut narrow, steep sided gorges far back into the Niagara escarpment to a depth of 300 to 400 feet. In the valley of Elk creek the difference in the topography of the Maquoketa shales and Niagara dolomite is especially well shown, though it is seen at numerous other points

south of the Volga, and also between that stream and the Turkey river. Four or five miles south of Elkport the shales occur in the bottom of the valley and rise some distance above until the heavy overlying limestone ledges are reached. Below, in the Maquoketa beds, the slopes are gentle, rounded, and occupied by cultivated fields and meadows. The Niagara, on the other hand, forms cliffs and abrupt slopes which are too steep and rocky for cultivation and are almost always heavily wooded.

Fig. 21.—Maquoketa slope leading up to Niagara escarpment, section 13, Sperry township.

Great masses of limestone (Fig. 20) have been broken off by undermining, by frost or other destructive processes and agencies, and have slipped down the smooth clay slopes of the Maquoketa until they are often found far away from the parent ledges. These huge limestone blocks, some of them as large as the ordinary country school house, are very characteristic of the Maquoketa slopes. They are frequently found in large numbers near the base of the Niagara escarpment, the masses being tilted at all angles, though sometimes the original horizontal position

of the beds has been maintained, even where the blocks have traveled long distances.

The roads often follow close to the base of the rocky, wooded and precipitous slopes of the Niagara escarpment, thus affording a broad outlook over the gently rolling Maquoketa surface with its fields, meadows and orchards.

Other localities where these topographic features are well shown are in section 13 of Sperry township, section 29 of Highland and in parts of Cox creek, Elk, Mallory and Millville townships. They are seen also in the vicinity of Volga, where the gently rounded slopes of the broad river valley are in the soft and easily eroded shales, while farther back the massive, heavy ledges of Niagara dolomite outcrop toward the summit of the hills.

From the foregoing it is evident, as previously stated, that the topography of the driftless portions of the county is the result of the action of erosion and weathering on nearly horizontal strata of varying degrees of hardness. The influence of the character of the rocks upon the results produced is well exhibited by the land forms occurring in the areas of the Galena-Platteville, Maquoketa and Niagara respectively. The cliffs, towers, crags and other fantastic forms assumed by the first named of these formations are seen in the bluffs of the Mississippi from Clayton to Buena Vista and below; along the Turkey and Volga rivers throughout their courses to within four or five miles of the western border of the county; along Buck and Miners creeks and many of the minor streams of the area. Where the Maquoketa is composed chiefly of clay shales, as in the neighborhood of Volga and south of the river of the same name, it is a region of low, gently rounded slopes which rise gradually from the Galena-Platteville beds to the Niagara cliffs. The sinuous outcrop of the latter, marked by abrupt, rocky slopes, produces the conspicuous escarpment which is such a marked topographic feature south of the Volga and Turkey rivers. It also caps the high ridge between those streams and forms the prominent hill near Gunder. The Niagara formerly covered a much larger area than at present and probably extended over the greater portion,

if not all of the county, but it has been very much affected by erosion. The Highland ridge was once continuous with the main mass of the Niagara south of the river, as were also the Gunder and other outliers, but the Turkey and Volga rivers have cut their valleys through the formation and left widely separated remnants. The escarpment is not stationary, but is constantly being pushed back through weathering and stream erosion.

The uplands and ridges represent an old peneplain in which the existing valleys have been cut. This was probably formed toward the end of the Cretaceous or possibly during Tertiary times. The former land surface was worn down by the streams into a comparatively level plain with only a few minor inequalities remaining. The streams had cut down to base level and flowed in broad, wide bottomed valleys with low and very gently sloping sides and flattened intervening divides. Later this old peneplain was elevated 600 or 700 feet, and the rivers began cutting their present valleys. These have reached a new base level, and their flood plains represent the beginning of a second peneplain which will be completed in the course of time if there is no elevation or depression before the cycle is brought to an end.

IOWAN DRIFT AREA.

The Iowan drift area occupies portions of Cass and Lodomillo townships in the southwestern corner of the county. The topography is here in marked contrast with that of the remainder of the area since it is constructional and produced by the accumulation of drift instead of being the result of erosion. The border of the Iowan drift is followed in a general way by the Chicago, Milwaukee and Saint Paul railroad, though northwest of Strawberry Point the boundary lies from one to two miles north of that road. Strawberry Point is located very near the edge of the drift sheet, and Edgewood lies one mile south, while the wagon road between these two towns follows the border closely the entire distance.

Throughout most of its course in this county, as well as elsewhere in the state, the Iowan border is marked by a ridge or a series of ridges and hills of drift and loess rising fifty to sixty

feet above the drift plain. For a distance of one mile east of Strawberry Point there is a single ridge, and it is upon this that the cemetery is located. Farther east the drift has been heaped up into irregular hills forming a belt about one-half mile in width. From some point of vantage on top of this ridge, as near the school house one mile east of town, or at the crossroads in the southwest quarter of section 27, or in the southeast quarter of section 28 of Lodomillo township, one may compare the drift plain on the inside with the driftless area outside the border. The surface of the Iowan plain is flat and poorly drained, with shallow depressions or swales and low, rounded elevations (Fig. 22). Scattered over it are numerous large, coarse-grained granite bowlders, many of which, however, have been gathered

Fig. 22—The Iowan drift plain near Strawberry Point.

from the fields and used in the construction of stone fences. The loess which mantles the surface elsewhere in the county is absent from this area and the soil is a rich black color.

Turning to the north and looking in the opposite direction the country exhibits a topography of an entirely different kind. Here the land is rough and cut by the streams into deep valleys and steep sided ridges, until little flat surface remains. The roads, instead of being straight, and laid out along the section lines,

follow either the divides between the streams or the bottoms of the valleys. A thick mantle of loess covers the bed rock and there is almost an entire absence of large bowlders. On this side are the erosional features of the driftless area, on the other the level drift plain, but slightly modified by erosion and resulting from the accumulation and heaping up of materials by the ice sheet. The streams have cut only shallow channels in the Iowan drift plain. The valley formed by the headwaters of the Maquoketa, for instance, has a depth of little more than sixty feet and is bordered by cliffs of Niagara limestone, the drift being thin in many places along the sides.

These two types of topography are so strikingly different as to attract the notice of even a casual observer, though he may not stop to inquire the cause. At many points along the border and just inside the ridge or belt of hills marking the boundary there is a low, swampy and poorly drained area. Such a swale may be seen at Edgewood, between the town and the bordering ridge lying to the north. Northwest of Strawberry Point the edge of the Iowan drift is not marked by a ridge of hills and is less easily traced since it has been modified by erosion of the streams flowing northeast into the Volga.

DRAINAGE.

The Turkey and its tributaries drain over three-quarters of the county; less than one-fifth of the area is drained by small streams flowing directly into the Mississippi; portions of Cass and Lodomillo townships are tributary to the Maquoketa, and a small strip along the northern border drains north into the Yellow river.

The Mississippi forms the eastern boundary and has influenced the drainage of the entire region. This major stream by cutting its valley to a depth of more than 600 feet has established a base level which controls the depth to which its tributaries have been able to cut their channels. Beginning at the north the following streams empty into the Mississippi: Bloody Run, Sny Magill creek, Buck creek, Miners creek and Turkey river. All of these flow in a southeasterly direction except the first named

which has a course nearly due east. Bloody Run rises on the upland near Monona and has a fall of about 550 feet before reaching its mouth, eleven miles distant.

The Turkey river enters the county nine miles from the northern border and crosses it in a general southeasterly direction to its confluence with the Mississippi not far from the southern boundary. The descent from the west county line to the mouth is 180 feet, or 3.6 feet per mile. The Volga after entering Clayton county has an average fall of almost six feet to the mile above its junction with the Turkey at Elkport. The chief tributary of the latter stream is Robert creek, which has its source in the northwestern corner of the area, near Postville, and with a very winding course flows first southeast and then almost due south until it joins the Turkey river a few miles below Elkader. Robert creek and its different branches, including Dry Mill creek and the other large tributary entering the Turkey from the north (Cedar creek) afford excellent examples of dendritic drainage systems. Their secondary and tertiary branches spread out in all directions like the limbs of a tree until they dissect and drain a large territory. Other streams of the area exhibit the same dendritic character, though perhaps not so perfectly and symmetrically. The principal tributaries of the Turkey river from the south are Elk creek, Little Turkey river and Bluebell creek, the head waters of all three being across the line in Dubuque and Delaware counties. The first named flows almost due north, the other two northeast.

The Volga also receives a number of important streams from the south, including Bear, Honey, Cox, Hewett and Nagle creeks, all of which have northeasterly courses. Their sources are close to the border of the Iowan drift plain, upon which they are slowly encroaching by the headward erosion of the streams. This process results in the extension of the valleys in that direction, and the divide is gradually being shifted to the south and west, since the streams flowing into the Volga have a greater fall and swifter current than those entering the Maquoketa. They are therefore enabled to erode more rapidly and are taking possession of the territory now draining south into the Maquoketa river. Hewitt and Spring creeks, the latter a branch of Cox

creek, have already extended their valleys some distance into the Iowan drift, the one near the west line of the county, the other just north of Strawberry Point. Between the last mentioned town and Edgewood the ridged border of the Iowan drift forms the divide separating the headwaters of the streams tributary to the Volga and those emptying into the Maquoketa. Three of the creeks, Bear, Honey and Cox, though they enter the major stream at points three to seven miles apart have their sources within a mile of each other in sections 21 and 22 of Lodomillo township.

STRATIGRAPHY.

GENERAL RELATIONS OF THE STRATA.

So far as known there is but one other county in Iowa, Winneshiek, which has so many geological formations as Clayton. There are no less than seven represented by the indurated rocks, and in addition to these, two drift sheets cover portions of the area, while other deposits dependent upon the ice invasion also occur. Then too the conditions are very favorable for the study of the strata of different ages. The deep valleys cut by the streams afford numerous outcrops in all parts of the county and the absence of drift over a large portion of the district adds to the number of rock exposures. Many of these afford vertical sections 300 to 400 feet thick and include beds belonging to several different formations.

No one of the twenty-two townships is without its outcrops, frequently continuous for long distances, and bringing to view the character of the various beds. The oldest strata, the Saint Croix, Oneota and Saint Peter are confined to the northeastern corner of the area, the two last named extending as far south as Guttenberg in the valley of the Mississippi. The Trenton, using the term in the sense in which it is used in the Dubuque county report, Vol. X, is confined almost wholly to the stream valleys and the same is largely true for the Galena, though this dolomite also forms the bed rock over several of the northwestern townships. The Maquoketa has a wide distribution and with the Niagara covers by far the greater part of the area. With the exception of several outliers the Niagara is confined to the

region south of the Turkey river, while the Maquoketa shales are found not only south of that stream but occupying a belt from six to ten miles wide north and east of the Turkey river.

In going up the valley of Bloody Run from its mouth to the station of Beulah one sees almost a continuous section extending from the Saint Croix sandstone at North McGregor through the Oneota, exposed in the numerous railroad cuts and in the cliffs, Saint Peter sandstone, Trenton and Galena limestones. The same succession of formations is found along the sides of the ravines in which is located the town of McGregor.

Though the Kansan drift is exposed at a number of widely separated points and covers considerable areas in the county it is so thin as to modify but slightly the preglacial topography. The Iowan drift is confined to the southwestern corner, where it exhibits all the characteristics which distinguish it in other parts of the state.

The following synoptical table shows the relations of the various formations:

GROUP	SYSTEM	SERIES	STAGE
Cenozoic	Quaternary	Recent	Alluvium
		Pleistocene	Wisconsin-terrace
			Loess
			Iowan drift
			Buchanan gravels
			Kansan drift
			Residual products
Paleozoic	Silurian	Niagara	Hopkinton
	Ordovician	Trenton	Maquoketa
			Galena
			Trenton
		Canadian	Saint Peter
			Lower magnesian
	Cambrian	Potsdam (Saratogan)	Saint Croix

In this table "Hopkinton" has been substituted for the term "Delaware" of the earlier reports, to designate the phase of the Niagara limestone which makes up the great basal member of the formation below the Le Claire and Anamosa phases seen

in Jones, Cedar and Scott counties, Iowa. The name "Delaware" was preoccupied, having been used by Orton in 1878 for a portion of the Devonian system of Ohio. The terms "Galena" and "Trenton" in the table, and, later in the text, the compound "Galena-Trenton", are used as they were employed by Calvin and Bain in the report on Dubuque county. The recent suggestion of Bain (U. S. Geol. Surv., Bulletin No. 256: *The Zinc and Lead Deposits of Northwestern Illinois*) to divide the "Galena-Trenton" stratigraphically is to be commended. If the suggestion is followed, all above the "Green Shales" of the Minnesota geologists will be called "Galena" regardless of lithological characters, while the "Green Shales" and underlying limestones will, together, be known as the "Platteville". In the earlier reports of this Survey the term "Oneota" was used as the exact equivalent of Owen's "Lower Magnesian Limestone". McGee, however, as indicated in the following Comparative Table, proposed "Oneota" for the lower member only of Owen's "Lower Magnesian", and the terms "New Richmond" and "Shakopee" have been accepted more or less generally for the upper members. It seems to some advisable to restore "Oneota" to the body of limestone for which McGee proposed it, in which case the three distinct units making up the formation covered by Owen's name will be designated by convenient terms, definite and precise. For the present the original term "Lower Magnesian" may be retained for the formation represented by the three units combined, until some more acceptable term has been proposed.

COMPARATIVE TABLE OF GEOLOGICAL FORMATIONS.

MINNESOTA	MINNESOTA	WISCONSIN	IOWA	IOWA (*Previous Reports*)
N. H. Winchell	Hall & Sardeson		McGee	Geological Survey
St. Peter	St. Peter	St. Peter	St. Peter	St. Peter
Shakopee limestone	Magnesian series: Shakopee	Lower Magnesian Limestone: Willow River	St. Peter	Oneota limestone
New Richmond sandstone	Magnesian series: New Richmond	Lower Magnesian Limestone: New Richmond	St. Peter	Oneota limestone
Main Body of Limestone	Magnesian series: Oneota	Lower Magnesian Limestone: Main body of Limestone	Oneota	Oneota limestone
St. Croix: Jordan sandstone	Magnesian series: Jordan	Potsdam: Madison sandstone	Potsdam Sandstone	Saint Croix: Jordan
St. Croix: St. Lawrence limestone	Magnesian series: St Lawrence	Potsdam: Mendota limestone	Potsdam Sandstone	Saint Croix: St. Lawrence
St. Croix: Shales	Potsdam	Potsdam: Calciferous sandstone	Potsdam Sandstone	Saint Croix: St. Lawrence
St. Croix: Dresbach sandstone	Potsdam	Potsdam: Shale	Potsdam Sandstone	Saint Croix: Basal Sandstone
Shales	Potsdam	Potsdam: Sandstone	Potsdam Sandstone	Saint Croix: Basal Sandstone
Hinkley sandstone	Potsdam		Potsdam Sandstone	Saint Croix: Basal Sandstone

CAMBRIAN SYSTEM.

SAINT CROIX SANDSTONE.

The Saint Croix sandstone is the oldest rock found in Clayton county and with one exception is the oldest in the state. It belongs to the Potsdam series, which is the upper or younger division of the Cambrian. The formation has been called the Saint Croix sandstone by N. H. Winchell.

The rock as exposed in Clayton county is a medium coarse-grained, massive sandstone often showing cross-bedding and of a prevailing yellow or buff color, though white, light gray, brown, chocolate, green and other shades are seen. When examined closely it is seen to be composed of clear, transparent, rounded grains of quartz with very little cementing material between them. The rock is thus for the most part a very pure sandstone with only small amounts of calcareous or ferruginous material. In places it forms a soft, incoherent bed of sand which can be removed with a shovel; in other places the grains are cemented together to form hard beds. The rock weathers irregularly, the softer layers wearing away more rapidly and leaving the harder portions projecting. Only the upper eighty feet of the Saint Croix are exposed in Clayton county but nearly the entire thickness has been penetrated by the deep wells at McGregor and across the river at Prairie du Chien. The record* of the well at the latter place shows the presence of the three members which compose the formation, namely the Basal Sandstone, Saint Lawrence limestone and Jordan sandstone of N. H. Winchell, Norton, Calvin and others, or the Potsdam sandstone, Mendota limestone and Madison sandstone of Irving. One of the wells at Prairie du Chien went down 1040 feet without reaching the bottom of the Saint Croix and the first well drilled at McGregor has a depth of 1006 feet in the sandstone, though it starts some distance below the top of the formation. This gives the sandstone a thickness of at least 1050 feet. It is only a part of the upper member or Jordan sandstone that is exposed above river level in this area. At the north county line it rises eighty

*Iowa Geol. Surv., Vol. VI, pp. 187, 188, Des Moines, 1897.

feet above the Mississippi, at McGregor seventy feet above low water and two miles below, at the mouth of the Wisconsin, the Saint Croix disappears beneath the river level.

This sandstone outcrops only in the northeastern corner of the county, in Mendon township, where it is seen in the bluffs of the Mississippi, along Bloody Run and the ravines in which McGregor is located. There are good outcrops just below North McGregor, along the wagon road between that place and McGregor, and at Point Ann, just south of the latter town. The rock is also well exposed on the north side of the main street of McGregor where it has been excavated to make room for buildings (Fig. 23).

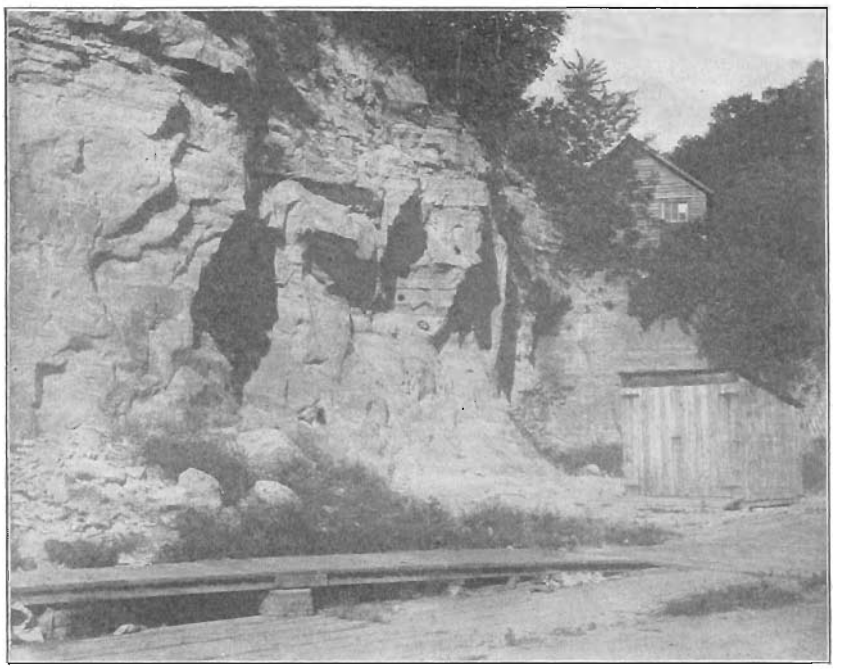

Fig. 23.—Saint Croix sandstone at McGregor.

No fossils have been found in the Saint Croix sandstone of this area and the conditions existing at the time of its formation were not favorable to the preservation of animal or plant remains. The sediments were accumulated near the shore and

the sands were subjected to the action of waves and currents, as is shown by the cross-bedding. Even the hard calcareous shells of the mollusks would be ground to powder and only occasionally would evidence of their existence be preserved.

ORDOVICIAN SYSTEM.

LOWER MAGNESIAN LIMESTONE.

(ONEOTA LIMESTONE OF PREVIOUS REPORTS,)

This limestone was first described by Owen and in his report of 1852 is termed the Lower Magnesian limestone. It will be seen by reference to the preceding comparative table of formations that the Oneota as formerly used in these reports includes the Main Body of Limestone, New Richmond sandstone and Shakopee limestone of N. H. Winchell, but does not correspond to the Oneota of McGee which comprises only the Main Body of Limestone. The present tendency is to restrict the term "Oneota" to this lower division, as defined by McGee. See Report on Winneshiek county, this volume.

As was shown by Calvin in his report on Allamakee county* no persistent sandstone formation is found in Iowa equivalent to the New Richmond of Minnesota and Wisconsin, but in places there seems to be an almost continuous succession of dolomitic beds extending from the top of the Saint Croix to the Saint Peter sandstone. Hence the name Oneota limestone has been employed by the present Survey in such wise as to include the entire assemblage of strata lying between the above mentioned sandstones and is equivalent to Owen's Lower Magnesian limestone. For the present it seems desirable to revert to Owen's name, and restrict "Oneota" to the lower member, as noted above.

The Lower Magnesian is not marked off sharply from the underlying Saint Croix, but there is a transition from the one to the other through from fifteen to twenty feet of calcareous sandstone or siliceous oolite. This rock is composed of clear, rounded grains of quartz cemented by lime carbonate. In some beds this cementing material is quite abundant, in others there

*Iowa Geol. Surv., Vol. IV, pp. 62-68, Des Moines, 1894.

is only enough to hold together the grains. The ledges vary in thickness from a few inches to two or three feet. This siliceous oolite is well exposed in an old quarry in the river bluff one and one-half miles above North McGregor. The transition beds are also seen in the section at Point Ann, just below McGregor. Here there are alternating layers of sandstone and limestone and some oolite similar to that described above.

The Lower Magnesian formation is for the most part composed of a massive, coarse, vesicular dolomite showing few bedding planes. Its color is light gray and white to bluff. The lower portion, for a thickness of thirty to forty feet above the Saint Croix, is in ledges two to four feet thick and has been quarried at a number of points. At some horizons, particularly toward the top, the strata contain abundant chert nodules. Some of the beds carry much crystalline calcite, filling the cavities in the dolomite. Above the quarry ledges the rock is more massive, coarse-textured and rough to the touch, and weathers with an uneven, pitted surface not unlike the Galena limestone.

Along Bloody Run several sandstone beds are exposed not far from the top of the formation. In the railroad cut one-quarter of a mile below Giard station and not more than twenty or thirty feet below the Saint Peter sandstone are three sandstone beds from eight inches to one foot thick separated by limestone layers. The rock is formed of clear quartz grains with little cementing material.

Near Clayton the upper fifty feet of the Lower Magnesian is seen to contain thin-bedded sandy and shaly layers. These have a thickness of about fifteen feet and are overlain by brecciated beds.

These arenaceous beds are doubtless the equivalent of the New Richmond sandstone of Minnesota and Wisconsin, but it will be noted that the sandstone member is here unimportant and the dolomitic strata form practically a continuous series between the top of the Saint Croix and bottom of the Saint Peter.

South of McGregor the Lower Magnesian limestone is often brecciated, but this feature was not observed north of that place. This brecciation is especially well shown in the ravine at the

sand pit just below Clayton. Here the upper ninety feet of the limestone are well exposed and the lower portion of the section is formed of the usual massive dolomite, here having a thickness above low water in the Mississippi of forty feet. Above this are fifteen feet of sandy and calcareous shales and earthy, impure limestone in thin, irregular beds. This rock is soft and weathers more rapidly than the overlying dolomitic strata, which form overhanging ledges.

Composing the upper portion of the Lower Magnesian section as here exposed are the brecciated and concretionary beds lying immediately below the Saint Peter sandstone and having a thickness of about forty feet. The angular fragments of the breccia vary in size from one inch to one foot in diameter. In some places what appear to be the original bedding planes are clearly seen and the layers, from a fraction of an inch to an inch and more in thickness, are much fractured. Portions of the rock are composed almost wholly of concretionary masses. The nucleus of the concretions is a very compact magnesian limestone and enclosing it are a number of concentric layers or shells one to two inches thick and less. The majority of these masses are from one to two feet in diameter, though some were seen with a diameter of six feet. Each one of the concentric layers is finely laminated and formed of alternately gray, compact bands and yellow bands, less compact.

Calvin, in his report on Allamakee county,* mentions similar concretion-like masses composing some of the beds near the top of the formation and notes their resemblance to some forms of Stromatoporoids.

The Lower Magnesian formation, including the Oneota proper, New Richmond and Shakopee, varies in thickness from 200 to 230 feet. In the ravines about McGregor it is not more than 200 feet, but two miles below, opposite the mouth of the Wisconsin river, it measures 230 feet. At no point is the entire thickness exposed in continuous section. Along the lower course of Bloody Run vertical cliffs of this dolomite, from fifty to 100

* Iowa Geol. Surv., Vol. IV. p. 67, Des Moines, 1894.

feet high, appear along the sides of the valley (Fig. 24). At the base of these cliffs, however, the beds are covered by talus, and the upper slopes are commonly overgrown with vegetation. At Point Ann, just below McGregor, there is a good section in the face of the bluff, where at least 100 feet of this limestone are exposed.

Fig. 24—Cliffs of Oneota limestone on Bloody Run two miles west of North McGregor.

This formation appears at the surface only along the valley of the Mississippi and its tributaries and therefore does not cover a large area within the county. It disappears below the level of the river near the northern limits of Guttenburg. At McGregor the dolomite rises 255 feet above low water in the Mississippi and at Clayton ninety feet, the average dip of the strata between these points being nearly eighteen feet to the mile. Perhaps the best exposures of this rock to be found in the area are in the numerous railroad cuts of the Chicago, Milwaukee and Saint Paul railroad in the valley of Bloody Run. The beds from top to bottom are well shown in these cuts between North McGregor and Giard. They are also exhibited in the

numerous ravines about McGregor, the lower quarry beds being well shown in the abandoned quarry near the park, and along Sny Magill creek. The excellent outcrops of the upper strata at the Clayton sand pit have already been described.

Fossils are extremely rare in this formation, and none were found during the course of the field work, although search was made for them. They have been found, however, by Mr. F. H. Luthe, formerly of McGregor, in the bands and masses of chert which occur in the upper half of the Lower Magnesian. Mr. Luthe's collection was studied and described by Calvin* who found the following forms: *Metoptoma alta* Whf., *Straparollus claytonensis* Calvin, *S. pristininiformis* Calvin, *Raphistoma pepinense* Meek, *R. multivolvatum* Calvin, *R. paucivolvatum* Calvin, *Holopea turgida* Hall, *Orthoceras primigenium* Vanuxem, and *Cyrtoceras luthei* Calvin. These were all collected from the formation in Allamakee and Clayton counties.

The large laminated, concretionary masses occurring in the beds of the upper part of the formation have already been mentioned. Their resemblance to some of the Stromatoporoids makes it possible that they may be of organic origin. N. H. Winchell has described somewhat similar but smaller masses from the same horizon in Minnesota and has referred the specimens to the genus Cryptozoon of Hall. But it has not yet been established that these structures are organic and they may be a kind of concretion.

It has been shown both on stratigraphical and paleontological evidence that the Lower Magnesian limestone is the equivalent of the Calciferous sandstone of New York. The fossils of the two areas are either identical or resemble each other closely and show that the formation in which they occur belongs to the Ordovician system.

SAINT PETER SANDSTONE.

Overlying the Oneota limestone and resting conformably upon it is the Saint Peter sandstone. This is a very pure and rather coarse-grained sand rock composed of more or less well rounded grains of clear quartz. The particles of sand are

*Bull from. Lab. Nat. Hist , of State Univ. of Iowa, Vol. II, No. 2, pp. 189-193 and Am Geol Vol X, pp. 144-148.

commonly very loosely held together and in many places the formation is little more than an incoherent bed of sand. With an increase of cementing material the rock becomes less friable and passes occasionally into quite a hard sandstone. At the sand pit below Clayton the material is so incoherent that large fragments are readily broken up with a pick, and the smaller pieces are disintegrated by turning upon them a stream of water from a hose.

At a few points the Saint Peter sandstone has sufficient coherence to be used for building stone, as near Guttenberg where the rock has been quarried on a small scale for this purpose. The sandstone has a wide range of colors, varying from the more common white or light gray through many shades of yellows, red, chocolate brown, etc. The coloring is due to small amounts of iron oxide which is deposited around and between the sand grains by percolating waters, the iron being derived from the overlying Trenton limestone. The colors are not distributed uniformly through the rock: sometimes they are arranged in alternating layers or stripes, giving the rock a banded appearance; sometimes they are in blotches or patches of various shapes and sizes. The tints of the Saint Peter are as a rule brighter than those of the Saint Croix.

As shown by the following analysis the Saint Peter is a very pure sand rock containing almost ninety-nine per cent of silica. The sample analyzed was from the sand pit at Clayton and the sand had been washed while being carried along the trough from the pit to the tank at the railroad. This washing has doubtless removed a portion of the more soluble impurities.

ANALYSIS OF SAINT PETER SANDSTONE.

Silica, ($Si\ 0_2$)	98.94
Alumina ($Al_2\ 0_3$) and ferric oxide ($Fe_2\ 0_3$)	.60
Calcium oxide ($Ca\ 0$)	.33
Magnesium oxide ($Mg\ 0$)	.14

J. B. WEEMS, Analyst.

In Clayton county the Saint Peter ranges in thickness from forty to eighty-five feet, with an average of probably sixty feet. At McGregor it is fifty feet thick; several miles to the northwest along Bloody Run, it shows a thickness of seventy feet and at the Clayton sand pit it is eighty-five feet.

The Saint Peter sandstone appears at the surface only in the bluffs of the Mississippi and along the valleys of Bloody Run, Sny Magill and Buck creeks and the ravines about McGregor and Clayton. Elsewhere it is covered by the Galena-Trenton and overlying formations.

The sandstone outcrops as a comparatively narrow belt along the valley sides, the area of the exposed surface varying with the steepness of the hillside, the widest outcrop occurring on the more gradual slope where it has considerable lateral as well as vertical extent. The areal distribution is difficult to represent on a small scale map since the width of the belt horizontally is comparatively insignificant and is necessarily somewhat exaggerated. At McGregor the base of the Saint Peter lies 255 feet above the river and the sandstone is found therefore well up toward the top of the hillsides. It occurs just below the bottom of Boyle's quarry and outcrops for some distance along the road leading west through West McGregor. This sand rock is not found in Point Ann or "The Heights" above McGregor, these points of the Mississippi bluffs not extending up to the horizon of this formation. The Saint Peter sandstone overlying the Shakopee division of the Lower Magnesian limestone is occasionally confused with the Saint Croix sandstone lying below the Oneota of McGee, and the two have been considered as one formation. But a brief study of any of the hillsides about McGregor will show that the two sandstones are separated by nearly 200 feet of dolomite. At Clayton the Saint Peter has descended to ninety feet above the Mississippi and at Guttenberg it disappears below water level near the south end of town. The sandstone extends up Bloody Run for a distance of five miles and at the school house near Giard Station it forms a vertical cliff thirty or forty feet high. The rock appears at many points in the bluffs along the Mississippi, particularly in the vicinity of Clayton and between there and Guttenberg. One of the best places to see this brightly colored sandstone is at the well known "Pictured Rocks" two miles below McGregor and opposite the mouth of the Wisconsin (Fig. 25). At this point a wooded gorge extends back from the river and along the sides

and bottom of this the many tinted sands are finely exhibited. The cool, shady glen, carved in the sandstone, with its clear tumbling brook, is a favorite spot for picnics, and is yearly visited by great numbers of people, who seldom fail to climb Pikes Peak, near at hand, and look upon the picture spread out before them from that elevated point. Reference has been made on a previous page to the view from here.

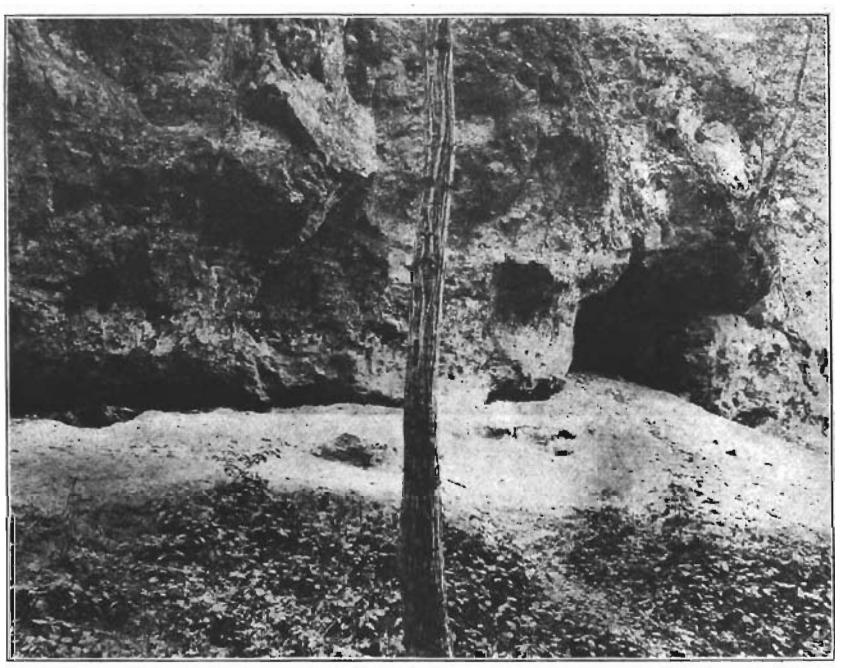

Fig. 25 —Cliff of Saint Peter sandstone at "Pictured Rocks."

Another excellent exposure of the Saint Peter is found at the sand pit just below Clayton where in a ravine opening into the main valley the sandstone has been quarried for many years. In the face of the pit a vertical section of over forty feet is exposed (Fig. 26), the sand here being white and quite free from all coloring matter.

This sandstone afforded no traces of organic remains and fossils are seldom found in the formation. Those listed by Sardeson* from the Saint Peter near Minneapolis are similar to the fossils of the Trenton and indicate that the sandstone is to be correlated with the Chazy of New York.

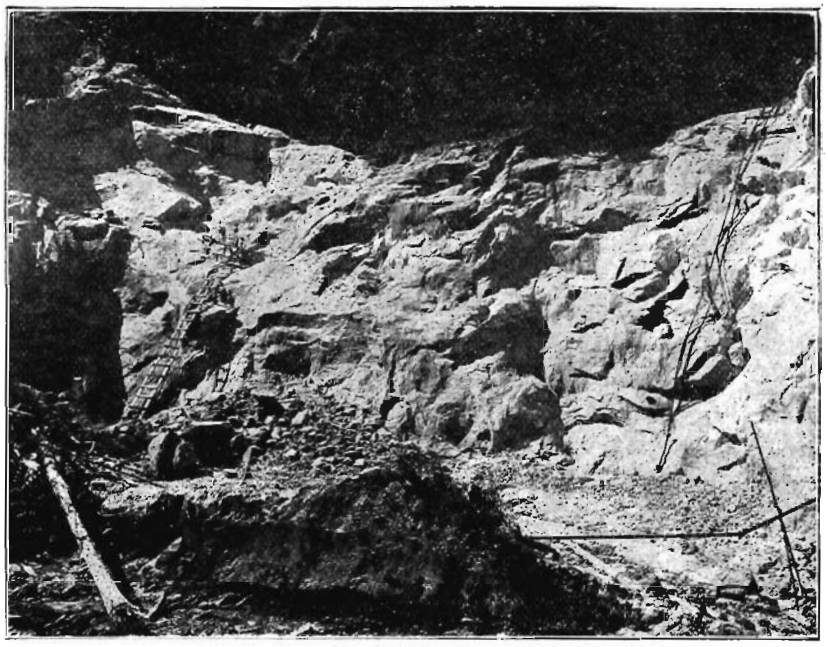

Fig. 26 - Sand pit in Saint Peter sandstone, Clayton, Iowa.

A discussion of the life of the Saint Peter sandstone is contained in the Allamakee county report† to which the reader is referred.

TRENTON AND GALENA LIMESTONES.

(THE GALENA AND PLATTEVILLE OF BAIN, SEE REPORT ON WINNESHIEK COUNTY.)

The Trenton Limestone.—At the top of the Saint Peter sandstone there is an abrupt change in the character of the rock and the Trenton limestone of most writers on the geology of the Mississippi valley, succeeds the sand formation without any intermediate transition beds. The line of contact between the

*Bull. Minn. Acad. of Sci., Vol. III, p. 318.
†Iowa Geol. Surv. Vol. IV, pp. 72, 73, Des Moines, 1894.

two is sharply marked and forms a very definite horizon. Ever since the name was first used by Hall in 1858 the Trenton has been applied to the non-dolomitic and rather thin-bedded limestones overlying the Saint Peter. It has also been customary to apply the term Galena to the heavy dolomitic beds occurring just above and to consider the Galena and Trenton as two separate formations. But it was pointed out by N. H. Winchell* in 1895 that there is a close relation between the Trenton and Galena as shown by a study of their fossils and that the latter is only a phase of the former. Much the same view was expressed by Norton† two years later, and he suggested that the beds designated as Galena and Trenton belong to a single formation to which the name Galena-Trenton was given. Abundant proof of the fact that we are dealing here with only one formation which has been more dolomitized at some points than others was found by Calvin and Bain in Dubuque county and for an exhaustive discussion of the relation existing between the Trenton and Galena the reader is referred to the report on that county†. The writer found in Clayton county much additional evidence of the wide variation in the amount of dolomitization which has taken place in these strata.

The non-dolomitic Trenton varies in thickness from eighty to 165 feet within a distance of fourteen miles or less, and in some parts of the county no portion of the Galena-Trenton has undergone dolomitization, the Galena dolomite apparently being absent. At a number of points the upper twenty-five to seventy-five feet of the formation are composed of pure, thin-bedded, non-magnesian limestone and if any of the strata have been changed to dolomite they lie a considerable distance below the Maquoketa.

At Clayton, and at Pikes Peak, opposite the mouth of the Wisconsin river, the non-dolomitic Trenton is only eighty feet thick, while at Elkader the thickness is 165 feet as shown by wells. The dolomitic Galena beds appear to be nearly, if not wholly, absent in Wagner and Marion townships and the upper

*Am. Geol., Vol. XV, p. 33, Minneapolis, 1895
†Iowa Geol Surv , Vol VI, p 146, Des Moines, 1896
†Iowa Geol Surv , Vol X, pp. 402-431, Des Moines, 1900

portion of the Galena-Trenton formation is represented by rather thin-bedded, non-magnesian limestones. These are well exhibited along Robert and Silver creeks in Wagner township and in the quarries in the vicinity of St. Olaf.

In section 14 of Wagner township non-magnesian strata have an exposed thickness of seventy-five feet and are seen to be overlain by the Maquoketa shales. Between six and seven miles to the south and at the same horizon the dolomitic beds are found at Elkader, with a thickness of at least 120 feet. At Volga the strata lying immediately beneath the Maquoketa are non-dolomitic, and along the Turkey river in Marion township similar beds are exposed at many points in the same position. At Osborne, only a little over four miles east of Volga, eighty feet of heavily-bedded dolomite are exposed just below the shales of the Maquoketa.

It is evident from these facts that we are concerned here with only one formation and that the Galena is simply the dolomitized phase of the Trenton limestone. The change in the character of rock has gone on unequally over the area. In some places little or none of the limestone lying between the Saint Peter and Maquoketa has undergone dolomitization, while at others the dolomite has a thickness of from 100 to 200 feet. The change usually begins at the top and progresses downward to a greater or less depth. But sometimes dolomitic limestones are found interstratified with the pure, unaltered limestones. Thus in the southwest quarter of section 9, Volga township, along the Turkey river, several ledges of dolomite occur beneath six to eight feet of typical, thin-bedded, compact and fossiliferous unaltered limestone. Above the latter the dolomitic Galena is seen in heavy beds. At this point the dolomitization did not affect all the beds but for some reason passed over several of them and attacked those below. In the lower part of the section exposed at the large springs in the northwest quarter of section 30, Read township, there are twenty feet of mottled, magnesian limestone in layers three to twelve inches thick. Lying above these are pure and unchanged beds having a thickness of fifty to seventy-five feet and overlain by typical Galena dolomite.

These examples illustrate in what an irregular manner the Trenton formation has been dolomitized and emphasize the fact that the Galena is simply a lithological phase of that formation and is not stratigraphically distinct.

Occasionally the change appears to take place first along bedding planes and joints. A bed two inches thick was observed which had been partially altered to magnesian limestone on the upper and lower surfaces while the inner portion was unaffected. In other cases the alteration had commenced in that portion of the rock immediately surrounding the fossils, an Orthoceras, for example, being encircled with a ring of magnesian limestone. In the instances just mentioned it seems probable that the dolomitization has been initiated where the percolating waters bearing the magnesium salt most easily had access, as along bedding planes and joints. Commonly, however, the magnesian portions are scattered irregularly through the rock, giving it a blotched or mottled appearance. The unchanged limestone is a light gray color, very compact and often quite fossiliferous while the magnesian patches are buff colored, contain eighteen per cent or more of magnesium carbonate and the fossils have been obliterated. These partially dolomitized beds were seen at many points in the county and always lay between the pure limestone usually called Trenton and the Galena dolomite. Rarely are they separated from the typical heavily bedded dolomite by non-magnesian strata, as was the case, already mentioned, in the Dry Mill creek section.

Though it will be convenient for the purposes of description to treat the Trenton and Galena separately, applying the former term to the pure, thin-bedded limestones and shales and the latter to the dolomitized beds, it should be borne in mind that they are parts of one formation. It was found impracticable to map them separately on account of the irregular way in which the Galena dolomite occurs and its absence from some areas of the Trenton. On the geological map accompanying this report they are therefore represented by the same color and are designated as the Galena-Trenton.

Lithological Character and Subdivisions of the Trenton.— The Trenton formation varies widely in character in different parts of the area. It is composed of limestones and calcareous shales and clays, the first named forming by far the larger part of the strata in this region. The limestones are mostly very fine-grained and compact, occurring in rather thin beds of uneven thickness, blue, gray or buff in color, and frequently rich in fossils.

At the base of the Trenton and resting immediately upon the Saint Peter sandstone are the Basal Shales of the Allamakee county report with a thickness of two or three feet. These are exposed at McGregor, Clayton and just above Guttenbery, where

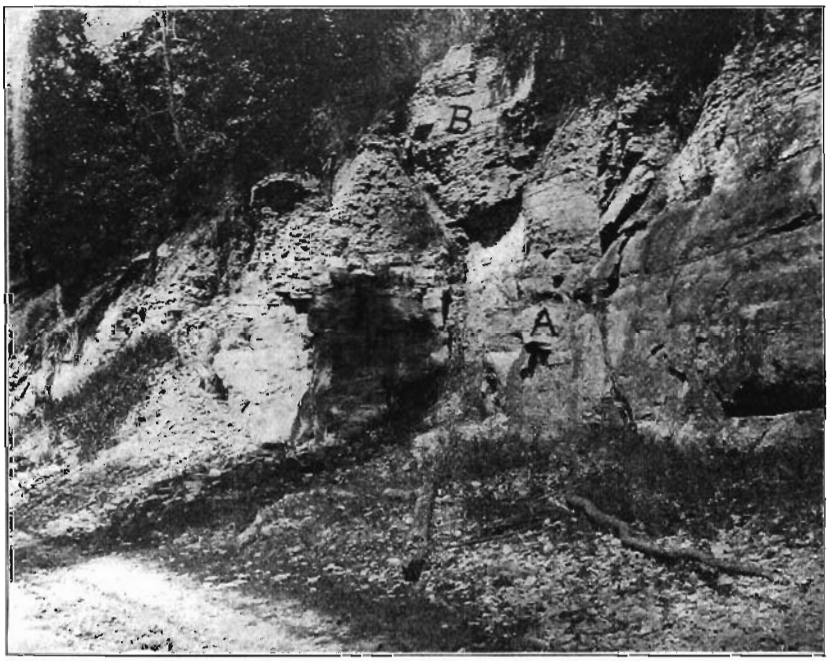

Fig. 27—Lower Buff Beds (A) overlain by thin bedded limestone (B) near Guttenberg. Platteville stage

the contact of the two formations is well exposed. Overlying the basal shales are from fifteen to twenty-five feet of maguesian limestone in beds eight inches to two or three feet thick, weathering to buff. These are the Lower Buff Beds of the Wisconsin geologists, and they seem to occur quite uniformly at the base

of the Trenton in Iowa, Wisconsin, Illinois and Minnesota. This compact magnesian limestone breaks readily into layers of almost any desired thickness and makes a very good building stone. In these beds are located the quarries at Guttenberg (Fig. 27) and McGregor. These are succeeded by thin-bedded, very fine-grained and compact fossiliferous limestone in uneven layers one to two inches thick. The rock is brittle, usually breaks with a conchoidal fracture and is light gray and blue. Sometimes the beds are separated by marly partings one or two

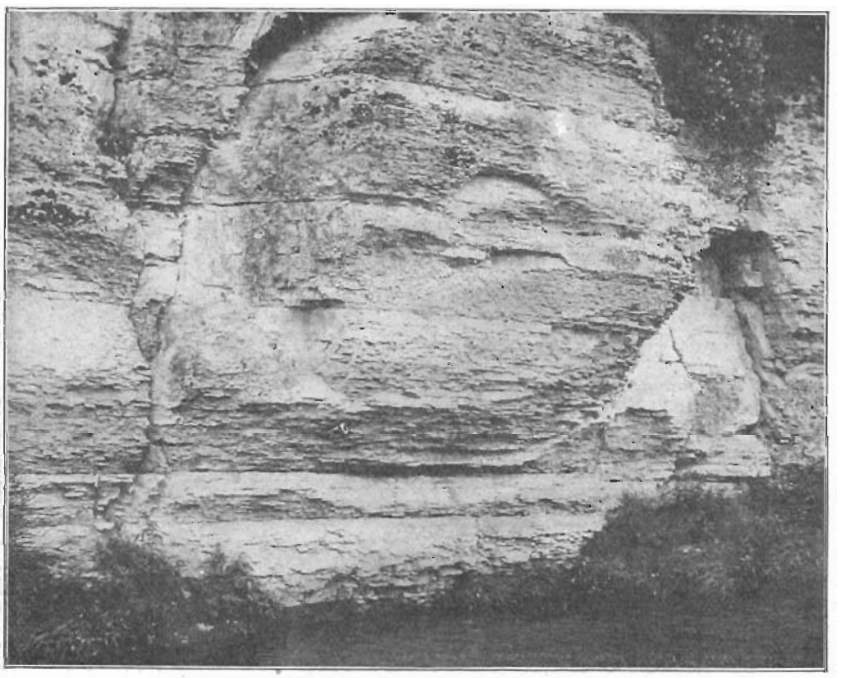

Fig. 28—Thin bedded Platteville limestone exposed on Dry Mill Creek, section 19, Read township.

inches thick. The irregularity in the thickness of the limestone layers is caused by the undulating bedding planes. Vertical or nearly vertical joints are frequently present and the thin-bedded character of the rock is especially well brought out by weathering. The thickness of this member of the Trenton varies greatly and in some places it makes up the main bulk of the formation above the Lower Buff Beds. The succession of strata

above the latter subdivision is not at all constant, but at least from twenty-five to thirty-five feet of the compact and thin bedded limestone is commonly present. Above this is frequently found a green shale five to six feet in thickness and lying about fifty feet above the Saint Peter sandstone. This is, in part at least, the equivalent of the "Green Shales" of the Minnesota geologists, though the formation seems to be much thinner here than farther north. The shale is often quite calcareous and contains lenses and bands of limestone rich in fossils. The most common species is *Orthis subaequata,* which is characteristic of the Green Shales of Minnesota and Dubuque county. Associated with this are branching monticuliporoids. This argillaceous member is well exposed in the ravines about McGregor, at Clayton, and one-quarter of a mile above Buena Vista, but it does not seem to be at all persistent, since it is absent in many sections. Thus at Guttenberg, where the entire thickness of the Trenton beds is present in the bluff, the shale does not appear, although the outcrop is almost continuous from top to bottom. Again, at Millville, five to six miles south of here, where nearly 120 feet of the thin-bedded Trenton limestone is exposed, no shale member is present. This serves to illustrate the variation in the character of this formation and the occurrence of strata in one locality which are absent from another.

The shale is succeeded by limestone in thin beds, compact, fine-grained and fossiliferous with a thickness of twenty-five to forty feet or more, and resembling that found below the argillaceous member. When the shale is wanting there is a succession of these limestone strata in beds one to six inches thick extending without interruption from the Lower Buff Beds to the Galena dolomite and even to the Maquoketa where dolomitization has not affected them. Mention has already been made of the fact that in Wagner and Marion townships these non-magnesian limestones extend up to the Maquoketa shale and compose nearly the entire Galena-Trenton formation.

The upper beds of the Trenton, overlain by the Galena, are well exposed at McGregor, Clayton, Guttenberg, Buena Vista, Millville, Elkader and near the mouth of Dry Mill creek. At Clayton they have a thickness of only twenty-five feet, at

McGregor of forty feet, and at Elkader they rise seventy-five feet above the Turkey river below the dam. At the latter place they form the ledges outcropping just above the stone bridge and in the old quarry near the creamery. This limestone of the upper Trenton is also well exposed along the small creek about one mile southwest of Elkader, where the beds contain abundant fossils.

From this locality the following species were collected in strata lying from ten to fifteen feet below the Galena dolomite and about 120 feet below the Maquoketa.

Rafinesquina minnesotensis N. H. Winchell.
Rafinesquina alternata Conrad.
Hormotoma trentonensis Ulrich.
Liospira vitruvia Billings=*Pleurotomaria lenticularis* or *Raphistoma lenticulare* of authors.
Orthis (*Platystrophia*) *biforata*.
Isotelus gigas DeKay.
Fusispira elongata H.
Calymene sp.
Illaenus americanus.
Trochonema umbilicata.
Clionychia lamellosa Hall (*Ambonychia*).
Fusispira inflata Meek & Worthen.
F. angusta Ulrich.
Oncoceras pandion Hall.
Orthoceras sp.
Ischadites iowensis Owen.
Cyrtodonta grandis Ulrich (?)
Parastrophia schofieldi Ulrich.
Anastrophia hemiplicata Hall.
Lophospira bicincta Hall.
Eccyliopterus sp.
Monticuliporoids (branching).
Bellerophon sp.

Ischadites iowensis is abundant at this locality and is confined to a layer two to three inches thick, in which large numbers are packed closely together. *Rafinesquina alternata* was observed at many localities and always near the top of the Trenton, only a few feet below the Galena dolomite. *Rafinesquina minnesotensis, Hormotoma trentonenis* and *Liospira vitruvia* were also found at several other localities in the same upper strata of the Trenton.

At the same horizon occur *Orthis testudinaria* Dalman, *Liospira lenticularis* Sowerby, *Strophomena rugosa* Raf., *Hormotoma salteri* Ulrich and *Lingula iowensis* Owen. *Orthis testudinaria* is also found near the top of the Galena-Trenton formation, just under the Maquoketa.

At the top of the Galena-Trenton, immediately below the Maquoketa shales, and at the horizon elsewhere occupied by the Galena dolomite, there are at some points dull gray, crinoidal limestones together with nodular or concretionary beds. These are described more in detail in the sections on succeeding pages. They are well exposed near Volga, on the Volga river; on the Turkey river in section 19 of Marion township, near the Fayette county line; on Robert creek and its tributaries in sections 9, 14 and 16 of Wagner township; in the vicinity of St. Olaf and elsewhere. Some of these strata contain *Lingula iowensis*.

The general character of the Trenton is shown in the following sections. The first is found in the ravine back of the town of Clayton.

		FEET.
8.	Green shale at the top of the Trenton	2-3
7.	Limestone, similar to No. 5	8
6.	Bluish green shale	2
5.	Limestone in regular beds four to eight inches thick, very fine-grained and compact, blue and buff in color. Occurs in thicker layers than No. 3	15
4.	Green calcareous shales containing lenses and bands of limestone rich in fossils. Among the most common are *Orthis subæquata* and branching *Monticuliporoids*	5
3.	Limestone, thin-bedded and compact, with marly layers one to two inches thick separating many of the beds. Latter are irregular in thickness and range from one to three inches. The marly partings do not always appear on fresh joint faces but stand out on weathered surfaces	25
2.	Limestone, dolomitic, compact, blue when fresh but weathering to buff on exposure, in even beds eight inches to two feet thick, contains few or no fossils. The quarry beds at Guttenberg and McGregor and the "Lower Buff Beds" of some writters	25
1.	Green shale immediately overlying the Saint Peter sandstone	2

No. 1 represents the "Basal shale" of the reports on Allamakee and Dubuque counties; the rest of the section belongs to the Platteville formation as defined by Bain No's. 2 and 3 are the "Platteville limestone," and No's. 4-8 represent the Decorah shale of Winneshiek county, the entire thickness of the Trenton at this locality is eighty-five feet.

A complete section of the formations exposed at Clayton is as follows:

		Feet.
4.	Galena dolomite (exposed)	150
3.	Trenton limestone (The Decorah shales and Platteville limestone of the Winneshiek county report)	85
2.	St. Peter sandstone	85
1.	Lower Magnesian limestone, exposed above low water in Mississippi	90

Section exposed in ravine near McGregor, in the northwest quarter of Section 33, Mendon township:

		Feet.
6.	Limestone, fine-grained, compact, blue and gray in color, very fossiliferous, in layers one to four inches thick	40
5.	Green calcareous shale with limestone bands very rich in fossils among which *Orthis subæquata* is common	6
4.	Fine-grained and compact limestone, light blue to buff in color, not so fossiliferous as No. 6	34
3.	Dolomitic limestone in ledges one to four feet thick, blue when fresh but weathering to buff, contains some fossils, the "Lower Buff Beds"	10-20
2.	Basal shale	3
1.	Saint Peter sandstone.	

Numbers 3 and 4 are well shown in Boyle's quarry, located well up on the side of one of the ravines at McGregor (Fig. 29).

SECTION OF GALENA-TRENTON AT GUTTENBERG.

		Feet.
5	Dolomitic limestone in heavy ledges, vesicular, coarse, buff colored, the typical Galena-dolomite	100
4	Magnesian limestone in beds two and three inches to one foot thick, mottled gray and buff, only partially dolomized and containing sixteen per cent of magnesium carbonate; part of the rock is very fine-grained, compact and gray colored, while other portions are buff and have a rough, coarser feel. Contains some chert in bands and scattered nodules. In these beds are located the quarries supplying rock for the limekilns at the base of the bluff	60
3.	Non-magnesian limestone, fine-grained, compact, in thin and uneven beds, gray. Lower portion not well exposed on the ridge, since it is partially covered with talus and soil	85
2.	Dolomitic limestone, blue when fresh but weathering to buff, beds eight inches to two feet thick. In these "Lower Buff Beds" the quarries are located	15
1.	Saint Peter sandstone, not exposed here, but known to rise ten feet above the river	

As stated on a previous page the upper portion of the Galena-Trenton is not dolomitic in some parts of Clayton county and the pure non-magnesian limestones of the Trenton series extend

up to the Maquoketa shale. These limestone beds outcrop on Robert creek, in the northwest quarter of section 14, Wagner

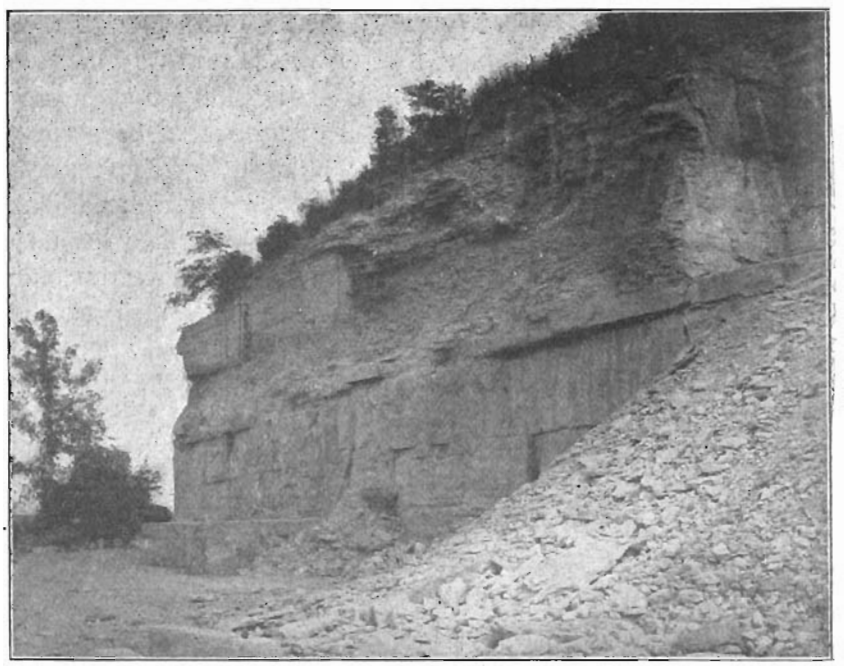

Fig. 29—Quarry in Lower Buff Beds, McGregor. Thin-bedded limestone is seen at top.

township, where they rise seventy-five feet above the creek in a steep cliff. Near this cliff, in a small gully washed in the hillside, the following section is exposed:

		FEET.
6.	Maquoketa shale.	
5.	Non-magnesian, gray limestone in beds three to twelve inches thick; the upper layers, lying immedtately beneath the Maquoketa, are dull, almost earthy in appearance	20
4.	Limestone, gray, in thin, flexuous beds one to three inches thick	15
3.	Non-magnesian, gray limestone in layers three to eight inches thick, not well exposed	25
2.	Beds containing abundant *Receptaculites oweni* and lying sixty feet below Maquoketa	1
1.	Gray limestone in beds three to eight inches thick	15

In sections 9 and 16 of Wagner township the Maquoketa shales are seen resting directly upon a dull gray, crinoidal limestone, compact and thin bedded. This rock is well exposed at the bridge over Robert creek in the north half of section 16,

Wagner township, where the limestone rises twenty-four feet above the stream and is overlain by the shales of the Maquoketa. These beds represent the non-dolomitic upper portion of the Galena-Trenton. The Thoresen quarry, three miles east of the above outcrop, in the northwest quarter of section 13, Wagner township, is in strata lying twenty-five to thirty-five feet below the Maquoketa. The rock is a blue and gray limestone occurring in beds two to fifteen inches thick, separated by marly partings from one-half to two inches thick, and of a reddish color. The latter contain many crinoid stems and other fossils.

The upper beds of the Galena-Trenton are exposed in an old quarry near the center of the south line of section 21, Marion township, where twelve feet of non-magnesian, gray, compact limestone appear in the face. The lower eight feet occur in layers three to six inches thick, separated by marly partings, while the upper ledges are nodular. These same beds are exposed along the small stream entering the Turkey river in the southeast quarter of section 19, Marion township, where immediately below the Maquoketa shale there are ten feet of nodular limestone of brownish color, overlying ten feet of thin and unevenly bedded gray limestone.

Distribution and Thickness.—The typical non-dolomitized limestone which has heretofore, regardless of its stratigraphic position, been called Trenton, has a wide distribution in Clayton county in the stream valleys. It is found along the Mississippi all the way from McGregor to the southern border of the area, being especially well exposed in the ravines back of McGregor and Clayton, and in the bluffs at Guttenberg. It outcrops in the valley of Turkey river throughout its course in the county and the beds are well shown in the vicinity of Elkader and on Dry Mill creek. They are also found at many points along Robert creek in Wagner township.

As previously stated the non-dolomitic limestone which authors have called Trenton, varies widely in thickness in this region. At Clayton it is eighty-five feet thick; at Pikes Peak, opposite the mouth of the Wisconsin river, eighty feet; at Guttenberg and McGregor 100 feet and at Elkader, where it rises

seventy-five feet above the river below the dam, its thickness is shown by wells to be 165 feet. The total thickness of the entire Galena-Trenton at Elkader is 285 feet.

*Galena Limestone**.—As previously stated, this is merely the dolomitized portion of the Galena-Trenton, or Galena-Platteville as the total assemblage of beds may hereafter be called, and is not to be considered a separate formation. But for convenience in discussion the dolomitic and non-dolomitic portions of the formation are treated separately. The change is usually not an abrupt one but there is a gradation through the mottled transition beds already described. These were observed in numerous localities where the base of the Galena dolomite was exposed. The quarries in the ridge back of Guttenberg, which supply rock for the lime kilns below them are in these transition beds, which here have a thickness of fifty to sixty feet. The limestone is mottled gray and buff and occurs in beds two or three inches to one foot thick.

An analysis of this rock† shows that it contains 80.81 per cent of carbonate of lime and 16.11 per cent of carbonate of magnesia. Above these mottled limestone beds is the more heavily bedded and true Galena dolomite, which extends to the top of the ridge. About two miles east of Garnavillo, at the old Dehn quarry on Buck creek, the same beds appear and have been quite extensively quarried. The rock is in ledges two to six inches thick and is readily separated along the bedding planes into thin slabs. *Orthis testudinaria* is a common fossil here. The limestone was broken into small fragments and the gray, compact portion resembling the typical Trenton rock separated from the buff and dolomite-like portion. Separate analyses were then made of each, and the one was found to contain 97.46 per cent of lime carbonate and 4.31 per cent of magnesium carbonate, while the other contained 60.97 per cent of lime carbonate and 18.28

*In this report as stated on a preceding page, the nomenclature of the report on Dubuque county has been followed. If the suggestion of Bain is accepted, the Galena limestone will be separated stratigraphically from the beds below it. The name will be applied to all beds of certain horizons without regard to lithological characters. The division will come at the top of the "Green Shales" of the Minnesota geologists, at the top of the 'Decorah Shales" of the report on Winneshiek county, published elsewhere in this volume. The beds below the line of division above indicated constitute the "Platteville formation" of Bain.

†Analysis made by Prof. J B. Weems of Iowa State College.

per cent of magnesium carbonate. Overlying this thin-bedded rock of intermediate composition lies 200 feet of dolomitic Galena of the Dubuque county type, while along the creek below the quarry the non-dolomitic phase appears.

There is an interesting outcrop of the mottled beds on Dry Mill creek in the northwest quarter of section 30, Read township, where 100 feet of Galena-Trenton strata are seen forming a vertical cliff. At the base of the section are twenty to thirty feet of transition strata. In these the unaltered gray limestone forms the bulk of the rock and the yellow magnesian patches form but

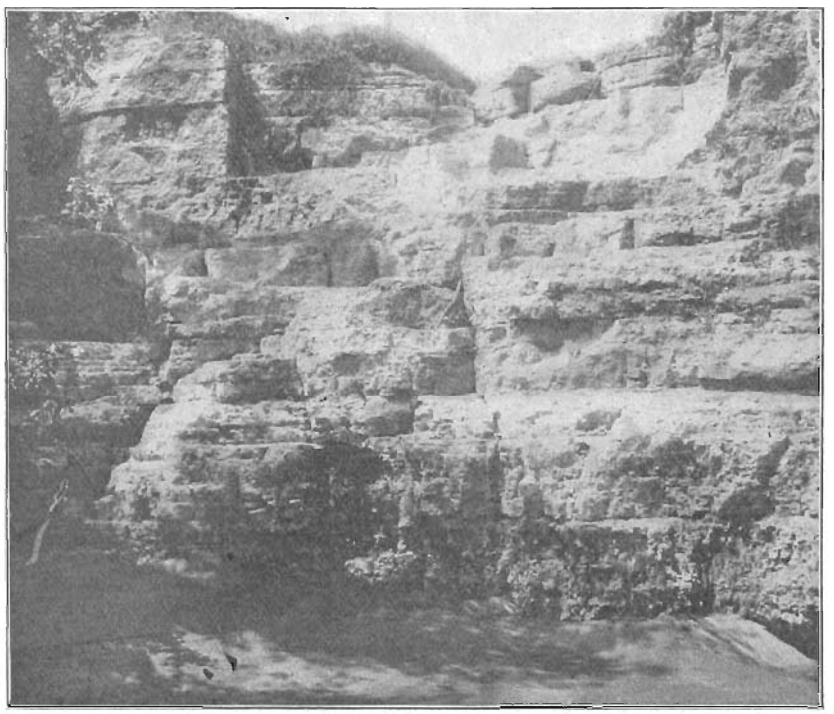

Fig. 30—Beds of Galena dolomite at Littleport, on Volga river.

a small portion of the mass. The beds are from three or four, to twelve inches thick. In the limestone portions of the rock the fossils are well preserved, but in the dolomitized parts they have been obliterated. *Receptaculites oweni* is common in these mottled beds, having been observed both here and on Miners creek. Above these partially dolomitized strata there are at this

point from fifty to seventy-five feet of unchanged limestone, thin-bedded, gray, compact and fossiliferous. The following species were found: *Hormotoma salteri* Ulrich, Isotelus sp., *Liospira lenticularis* Sowerby, *Liospira vitruvia* Billings (*Pleurotomaria lenticularis*), *Rafinesquina minnesotensis*, and *Rafinesquina alternata* Conrad. These sttata are overlain by typical Galena dolomite in ledges one or two feet thick. The mottled transition beds usually lie immediately below the dolomite, between that and the unaltered beds, and it rarely happens that any thickness of unaltered limestone intervenes, as in the above section on Dry Mill creek.

Fig. 31 Quarry in Galena dolomite, Elkader.

Throughout a large part of the county the upper strata of the Galena-Trenton are formed of heavily bedded dolomite in every way similar to that comprising the Galena around Dubuque. The rock where typically exposed is crystalline, rather coarsely granular, more or less vesicular, and of a buff color. It weathers very irregularly, which gives the dolomite its characteristic

rough, pitted surface when long exposed (Fig. 30). The beds vary in thickness from six inches to five feet and more, giving the Galena a massive appearance in striking contrast to the thin-bedded non-dolomitic limestone below. But the dolomite varies considerably in character at different horizons throughout its thickness, as is shown by the following sections.

The Galena is well exposed at Elkader, where it has been extensively quarried. In Stoop's quarry (Fig. 31) and below it to the river the following section is exposed:

		FEET.
5.	Light blue dolomite, rather compact and in ledges six inches to two feet thick. Some of the upper strata are separated by thin layers of reddish fissile shale.....	25
4.	Light gray to buff dolomite, containing many small cavities, ledges varying in thickness from one to five feet, most of them being over two feet thick.....	25
3.	Dolomite, buff, weathers irregularly, forming pitted surfaces, massive.....	70
2.	Unexposed	35
1.	Non-magnesian limestone in thin beds, compact, fossiliferous contains chert nodules arranged in bands, exposed to river.....	25

The quarry is in Nos. 4 and 5.

The strata near the top of the Galena are exposed in the quarry on Hickory creek, one-half mile north of Luana. The rock is here light blue or gray in color, is more compact and less vesicular and granular than the typical dolomite. It occurs in beds varying in thickness from four to eighteen inches.

The upper, thin-bedded part of the Galena is exposed along Cox creek in the southwest quarter of section 16, Cox Creek township, where the following section occurs.

		FEET.
3.	Dolomite in even ledges six to twelve inches thick, exposed in face of quarry.....	12
2.	Unexposed.....	20
1.	Heavily bedded Galena dolomite in ledges two to four feet thick, exposed to creek.....	10

The Maquoketa outcrops on the creek one mile above this quarry.

As shown by these and other exposures the upper portion of the Galena is composed of comparatively thin bedded dolomite and is not in such heavy ledges as the main part of the formation.

Reference has already been made to the absence of the Galena dolomite in Marion and Wagner townships where the strata for a thickness of fifty to seventy-five feet below the Maquoketa are formed of non-magnesian, very compact and thin-bedded limestone. These beds lying immediately beneath the Maquoketa shales are also well exposed in section 11 of Sperry township, along the river one to two miles below Volga. Near the east line of the section the Galena dolomite is seen rising about twenty feet above the Volga river. One-half mile west of here, near the railroad bridge, the following section is exposed along the small stream entering the river from the south:

		FEET	INCHES.
9.	Typical Maquoketa shale, blue when fresh, but weathering to yellow or buff; breaks with conchoidal fracture	20	
8.	Dull, gray limestone in uneven layers three to eight inches thick	5	
7.	Ledges of gray limestone		12-14
6.	Nodular or concretionary bed similar to No. 4, but the marly material in which the concretionary masses are inbedded is more abundant. The marl is a chocolate brown color	1	
5.	Gray limestone in two ledges four to six inches thick; contains abundant crinoid stems and other fossils		10-12
4.	Bed of nodular or concretionary limestone, dull and earthy, red to brown in color. Shows wavy lines due to laminæ bending around concretionary masses. Contains many brachiopods and crinoid stems		8-10
3.	Chocolate brown marl in undulating layer separating numbers 2 and 4		2
2.	Bluish gray limestone in beds four to six inches thick, with some marly partings. Contains *Lingula iowensis* Owen, and crinoid stems; also minute particles of iron pyrites	5	
1.	Unexposed to river but must be largely Galena dolomite which outcrops less than one-half mile east of here	10	

Distribution.—The dolomitic phase of the limestone, here called Galena, is found not only along the stream valleys but underlies a considerable area of the uplands along the northern and eastern border of the county. It forms the bed rock over most of Giard, Mendon and Clayton townships as well as a portion of Garnavillo, Monona and Grand Meadow townships. It is this rock which forms the picturesque cliffs, towers and pinnacles along the Turkey and Volga rivers and their tributaries and along Bloody Run, Sny Magill and Miner creeks. The Galena is well displayed along the Volga from Osborne to Elkport and below. At Mederville the river flows through a narrow,

rock walled gorge of dolomite which rises ninety feet above the river. The long, high, narrow ridge at the mouth of the Turkey river lying between the valley of the latter stream and the Mississippi, is formed almost wholly of Galena, as is the upper portion of the similar ridge back of Guttenberg. On Bloody Run between Beulah and Monona there are many outcrops of the same rock and it is a conspicuous feature of the Mississippi bluffs along the eastern border of the county. On the Turkey river there are good exposures at Motor and in the vicinity of Elkader, where the beds have been quite extensively quarried.

Thickness.- As may be inferred from the previous discussion the dolomitized beds vary in thickness from a few feet to 200 feet. The minimum measured thickness was near the northwest corner of Boardman township, where the dolomite is not more than 100 feet. Five miles northeast of here the beds for at least seventy-five feet below the Maquoketa are non-dolomitic, so that the dolomite is probably entirely absent. At Elkader it is 120 feet, and it has about the same thickness in Volga township. In the vicinity of Garnavillo the dolomite is 200 feet thick.

The uneven manner in which the dolomitization has progressed is shown by the fact that at Elkader the Galena dolomite extends up to the base of the Maquoketa while six miles north on Robert creek seventy-five feet of non-magnesian limestone is exposed directly below the Maquoketa. The same peculiarity is shown by an examination of the bottom of the formation. In Dubuque county heavily bedded dolomite begins directly on top of the "Green Shales".* At Clayton it is thirty feet and at McGregor forty feet above these shales, or eighty to ninety feet above the Saint Peter sandstone, while at Elkader the bottom of the dolomite is 165 feet above the sandstone. Still farther north in Allamakee county the dolomitized Galena begins about 240 feet above the Saint Peter†. But although the Galena is so variable the combined thickness of the two divisions of the Galena-Trenton formation is quite constant, where one is thick the other is thin and *vice versa*.

*Iowa Geol. Surv., Vol. X, p. 409

†Ibid, p. 409.

All the evidence bearing on the subject points to the conclusion that the Galena dolomite is derived from non-dolomitic limestone by alteration which has taken place subsequent to the deposition of the strata. This is the conclusion reached by Calvin and Bain from their studies in Dubuque county.* But the relations between the two portions of the Galena-Trenton formation are somewhat different in Clayton county from those in the counties adjoining on the north and south. In Dubuque county, for example, a bed of shale lies at the base of the dolomite and separates it from the unchanged limestone below. Such a shale, dividing the dolomitic from the non-dolomitic beds was seen in the area under discussion at only one locality, near the town of Clayton, though the bottom of the dolomite was exposed to observation at numerous points. Instead there were found the mottled transition beds already described which occupy a place intermediate, both in position and composition, between the dolomitic and non-dolomitic divisions of the formation. These furnish in themselves strong evidence of the secondary origin of the dolomite. The gray, compact, fossiliferous portions of the mottled rock contain only a little over four per cent of magnesium carbonate, while the buff, less compact and unfossiliferous patches contain over eighteen per cent of magnesium carbonate. It has been shown on a previous page that the alteration of the original non-dolomitic limestone has in some instances taken place first along bedding planes and joints where the magnesia-bearing waters would circulate most freely. The absence of these mottled beds from the adjoining counties is doubtless explained by the presence of the shale beds in the Trenton formation of those areas, which has prevented the waters from descending to a greater depth and has abruptly stopped the dolomitization at the horizons of the shale. These shales are largely absent from Clayton county and here the transition beds commonly occur at the base of the dolomite and there is thus a gradual passage from the altered to the unaltered

*Iowa Geol. Surv., Vol. X, pp. 492-497.

divisions of the Galena-Trenton formation. What it is that has limited the dolomitization below and why the change has extended to greater depths at some points than at others it is impossible to say.

The Galena dolomite contains few fossils; among those which are found *Receptaculites oweni* is by far the most common. *Maclurina cuneata* is also present.

MAQUOKETA.

It is doubtful whether any other geological formation in the state appears under such a variety of aspects as does the Maquoketa. In Dubuque county it is composed almost wholly of clay shales. At other localities it is formed of calcareous shales and non-magnesian limestones, while at still others it is represented by beds of true dolomite, often resembling those of the Galena or Niagara. It is therefore not always easy to separate on lithological grounds the Maquoketa from the formations above and below, although a careful examination commonly makes this possible, aided by the fossils characteristic of the Maquoketa.

In Clayton county the Maquoketa is distinctly calcareous and is in this respect very different from the beds as they occur farther south in Dubuque county. This calcareous phase of the formation is also strongly marked in Fayette county. The clay shales of the southern part of the region are thus found to be represented by limestone and dolomite toward the north and west. All phases of the Maquoketa are well represented in Clayton county, where the strata cover a large portion of the area and are deeply trenched by the streams.

The character of the formation is made apparent by the sections which follow. The best outcrops are found in the southern and western part of the county, in the vicinity of Volga and Strawberry Point and on the Turkey river in Marion township, near the Fayette county line.

ST. SEBALD SECTION.

This section, about one-half mile north of St. Sebald, is in the northeast quarter of section 33, Sperry township, on one of the small tributaries of Hewitt creek.

		FEET.	INCHES.
11.	Niagara limestone.		
10.	Blue and buff, impure dolomite in even layers four to twelve inches thick, the transition beds of the Maquoketa	25	
9	Blue clay shale which weathers into a plastic clay	12	
8.	Ledge of impure limestone		8
7.	Blue clay shale similar to No 9	2	
6	Calcareous shale in thin uneven layers, contains numerous fossils, including *Orthis Whitfieldi, O insculpta, O occidentalis. Rhynchonella neenah, Rhynchotrema capax, R. perlamellosa*	1	6
5.	Blue clay shale only slightly calcareous	3	
4.	Impure limestone, hard, in layers two to three inches thick	2	
3.	Clay shale, similar to No. 5	3	
2.	Impure argillaceous limestone in beds one or two inches thick, containing many fossils similar to those in No. 6	1	4
1.	Bluish green clay shales exposed at intervals along sides of the ravine	65	

It will be observed that over one hundred feet of the upper portion of the Maquoketa are here displayed and that below the dolomitic transition beds there are about twenty-five feet of alternating shales and limestones. At the base of the section there is a considerable thickness of nearly pure clay shales which appear to be quite free from calcareous beds. An analysis of this shale is given later under the subject of clays.

The impure dolomitic strata at the top of the Maquoketa (No. 10) appear at a number of points where the contact of this formation and the Niagara can be observed both in this and Dubuque county. They occur near the bottoms of the valleys of Spring, Cox and Bear creeks, a few miles north of the towns of Strawberry Point and Edgewood and are quite constant both in thickness and lithological character.

On Elk creek, in the northwest quarter of section 23 of Elk township, the beds near the base of the Maquoketa are well exposed. The Galena dolomite outcrops along the creek less than a mile below this locality.

ELK CREEK SECTION.

		FEET.
5.	Argillaceous limestone in layers three to twelve inches thick; breaks with conchoidal fracture; contains specimens of Orthoceras	15-20
4.	Ledge of impure limestone, dark brown color on fresh surface, contains many small cavities	2
3.	Dark brown, argillaceous limestone in several ledges separated by fissile shale	1
2.	Fissile shale, blue when weathered, chocolate brown when fresh: irregularly jointed; contains crystals of iron pyrites	7-8
1.	Gray limestone in uneven layers two to three inches thick, exposed in bed of creek	2

The basal portion of the Maquoketa is exposed at various points in Jefferson, Garnavillo and Volga townships. In these outcrops the rock is light yellow and contains many layers of indurated calcareous shale which often makes up the bulk of the beds. These yellow, stony, calcareous strata are characteristic of the formation in many parts of the area, the associated shales also having a yellow color upon exposure. The indurated layers, which are from three to eight inches thick, contain a rather high percentage of lime carbonate and some of them are impure limestones.

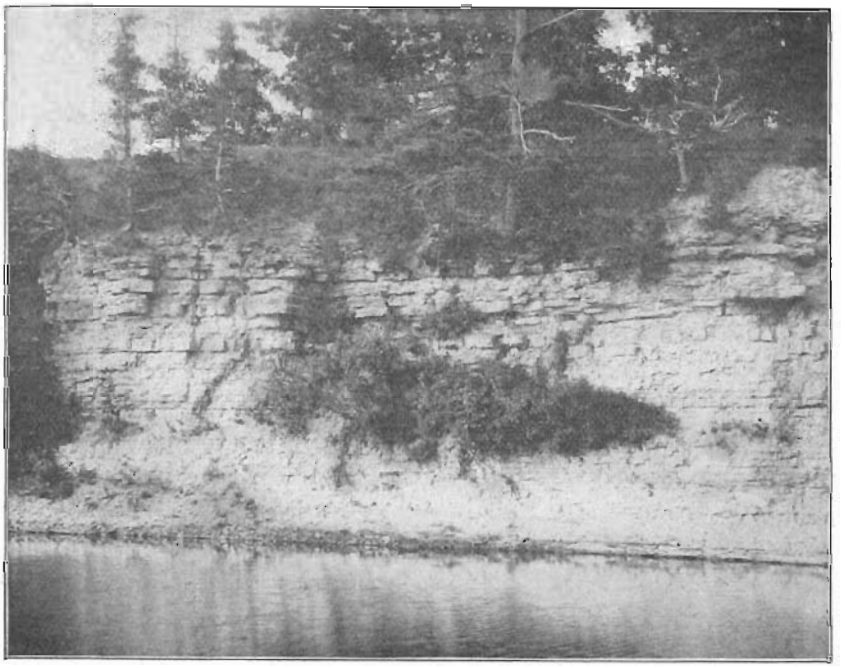

Fig. 32—Cliff of Maquoketa limestone and shale on Volga river at Volga.

The Maquoketa appears along the road just north of Osborne, where a thickness of eighty feet is exposed immediately above the Galena dolomite. The lower portion is composed of clay shales containing large numbers of iron concretions varying in size from that of a walnut to six and eight inches in diameter. When these are weathered they exhibit concentric layers and

finally break up into small fragments of impure limonite. The upper twenty to thirty feet of the section is formed of the indurated layers of calcareous shale.

The cliff (Fig. 32) which overhangs the river just above the dam at Volga affords an excellent opportunity to examine the Maquoketa strata. The upper ledges of the Galena-Trenton appear in the bed of the river below the dam and above these are seen over sixty feet of shales and limestones belonging to the overlying formation.

VOLGA SECTION

		FEET.	INCHES
15.	Blue clay shale, exposed	3	
14.	Unexposed	10	
13.	Limestone in ledges six to eight inches thick separated by thin shaly partings	10	
12.	Dark gray to brownish, weathering to buff, crystalline dolomitic limestone in well defined beds eight to eighteen inches thick	14	
11.	Blue and gray argillaceous limestone in layers one to two feet thick; where exposed in face of cliff the ledges are much weathered and the rock has a rough, pitted surface	10	
10.	Impure limestone, not occuring in well-defined beds, but in uneven and obscure layers of varying texture as seen on weathered surfaces. Some portions more crystalline than others and the crystalline patches are lens shaped and elongated parallel to the beds. This rock contains some crystalline calcite and calcareous nodules	7	
9.	Clay shale containing three bands of clacareous nodules similar to those of No. 8	1	4
8.	Thin seam composed of flattened calcareous nodules. These are white on outer surface and resemble chert nodules but when broken they are seen to be composed of very compact non-crystalline calcite		½
7.	Clay shale in single layer	1	3
6.	Blue clay shale which breaks into irregular fragments with conchoidal fracture	6	
5.	Calcareous shale in thin beds	1	
4.	Yellow clay shale		4
3.	Limestone ledge		4
2.	Clay shale	2	4
1.	Limestone exposed in bed of river. (Galena-Trenton.)		

The most noticeable feature of this section is the predominance of limestone strata, more than three-quarters of the beds being composed of this rock.

About one mile east of this outcrop the Galena-Trenton is seen overlain by twenty feet of clay shale, blue when fresh but weathering to a yellow color. Pieces of this shale are often blue

on the inside and yellow on the outside next to the bedding or joint planes. In places this shale shows a tendency to assume a concretionary structure. No calcareous layers appear in the shale at this point.

Perhaps the best locality in the county for the study of the Maquoketa formation is in the valley of the Turkey river in sections 18 and 19 of Marion township and adjoining parts of Fayette county. The beds are exposed at a number of points in the sides of the valley, which has here been cut through the Maquoketa to the Galena-Trenton. On the south side of the river in section 19, the lower part of the formation is well shown. The following section is not all seen at any one point but is formed by combining several outcrops in close proximity.

TURKEY RIVER SECTION.

		FEET.
4.	Yellow and gray calcareous shales and argillaceous limestones in layers three to eight inches thick; contain large numbers of siliceous and calcareous nodules which are rich in fossils-trilobites, gastropods and Orthoceratites being especially common. These nodule-bearing beds are very similar to those occurring above the dam at Volga. As at that locality the nodules are white on the outside but on being broken open the majority are found to be composed of gray calcite. Some contain a large percentage of silica. They are all very compact in texture, brittle, break with conchoidal fracture, and lie with their longest axes parallel to the bedding planes. These beds contain *Nileus vigilans* in considerable numbers and may therefore be designated the Nileus beds.....	20
3.	Indurated and highly calcareous shales interbedded with fissile shales. The indurated layers break readily into thin slabs and are separated by from six to eight inches of clay shale. The stony calcareous beds are rich in fragments of *Isotelus maximus* Locke and contain also Conularia, Graptolites and Orthoceratites.....	10
2.	Concretionary limestone similar to that observed near Volga and elsewhere at the top of the Galena-Trenton	10
1.	Thin and unevenly bedded, compact, earthy gray limestone resembling the non-magnesian portion of the Trenton limestone, exposed to river....	10

Numbers 1 and 2 of the above section undoubtedly represent the top of the Galena-Trenton formation, while the Isotelus beds (No. 3) form the bottom of the Maquoketa. These latter are characterized by the presence of great numbers of *Isotelus maximus*, the fragments of which fairly cover the surface of the slabs. It is seldom that an entire individual is found but head shields, pygidia and cheek spines are very common. The large eyes are often perfectly preserved and exhibit the facets clearly. These Isotelus beds are well exposed in the bed of the small

stream near the bridge in the northwest quarter of the southeast quarter of section 19, Marion township (Fig. 33). They were also observed four and one-half miles southeast of here, in the northeast quarter of section 35, at an elevation of 110 feet above the river, and also along the road between sections 22 and 23.

Fig. 33 Isotelus beds at base of Maquoketa, near center of Section 19, Marion township

Number 4 of the above section and the beds overlying it are exposed on the south side of the river in the dry run just across the line in section 13 of Fayette county.

COUNTY LINE SECTION.

		FEET
4.	Unexposed to base of the Niagara except some blue clay shales at bottom	90
3.	Buff dolomite in irregular beds, with much chert	30
2.	Greenish blue clay shale weathering into a plastic clay. Used in making brick at Clermont, exposed	10
1.	Very calcareous shales and argillaceous limestone which correspond in part to No. 4 of the previous section. Occurs in thin beds two to six inches thick and contains numerous impure cherty and calcareous nodules. The rock breaks readily into thin slabs along the lamination planes. The fossils observed were *Nileus vigilans* *Calymene senaria*, cystidean plates and Orthoceras. This member is not exposed continuously along the ravine and may be made up in part of clay shales similar to No. 2	100

The peculiar feature of this section is the presence of the cherty dolomite (No. 3) included between clay shales and the great thickness of calcareous strata at the base.

Numbers 1, 2 and 3 are well exposed near Clermont, Fayette county, between the town and the residence of ex-Governor Larrabee.. The road leading up the hill is cut through the Nileus beds, above which lies the blue clay used in brick making at Clermont. The latter is seen to be overlain by the dolomite of No. 3. This is heavily bedded, massive and very cherty. It has a coarse, uneven texture, is vesicular, buff in color and resembles the dolomite of the Galena or Niagara. But it carries characteristic Maquoketa fossils and lies between blue clay shales. The following fossils occur in the dolomite: *Orthis subquadrata, O. testudinaria, O. insculpta, Rafinesquina alternata* (of Maquoketa type), *Plectambonites sericea, Rhynchotrema capax, Leptaena unicostata* and Orthoceras.

There is another interesting exposure of the Maquoketa strata at Patterson's spring, four and one-half miles west of the Clayton county line, in the southwest quarter of section 20, Pleasant Valley township. Here below the Niagara limestone there are seventy feet of blue clay shales. But between the two several beds of non-magnesian, argillaceous limestone occur. These beds are three or four feet thick and very fossiliferous. The following species are common: *Leptaena unicostata, Orthis occidentalis, Tentaculites sterlingensis, Plectambonites sericea,* and Monticulipora.

The different outcrops occurring near the western boundary of Clayton county may be combined to form a general section of the Maquoketa formation as it appears in the northwestern part of the county. The following subdivisions are quite clearly defined.

GENERAL SECTION OF MAQUOKETA.

		FEET.
5.	Clay shales, not well exposed except near the top and bottom (well exposed at Patterson's spring in Fayette county)	90
4.	Cherty dolomite beds	30
3.	Blue clay shales, seen at county line section and the clay pit at Clermont	10-70
2.	Nileus beds, calcareous shales and impure limestones	40-100
1.	Isotelus beds forming the base of the Maquoketa, very calcareous, indurated shale	10

It is evident from the above section that in this vicinity from one-third to one-half of the Maquoketa is composed of calcareous shales, limestone and dolomite. Another noticeable feature is the rapid variation in the thickness of the several divisions of the formation. The Nileus beds appear to vary in thickness from thirty or forty to one hundred feet.

The foregoing sections bring out in a striking manner the variability in the lithological character of the Maquoketa. In the southern part of the county the upper portion of the formation is composed of buff, impure dolomite in even layers, the entire thickness of these transition beds being twenty-five feet. The presence in them of *Orthis testudinaria* leaves little doubt that they are to be included in the Maquoketa rather than the overlying Niagara. These strata were not observed in the northwestern part of the area and they are probably absent from that region.

Below these dolomitic beds of passage, or where these are wanting, below the Niagara, the formation is composed chiefly of clay shales, with some limestone layers at the top, having a thickness of from ninety to 100 feet. These shales appear in the St. Sebald and County Line sections. They may doubtless be correlated with the Upper Maquoketa of Dubuque county which is formed of "plastic clay shales with some indurated fossiliferous bands near the top", and including the transition beds has a thickness of 160 feet.*

The Lower Maquoketa of Clayton county on the other hand, is composed very largely of calcareous strata, and clay shales form an unimportant part of this division. Numbers 1 to 4 of the general section may be considered as belonging to this lower member of the formation.

*Geology of Dubuque County, Iowa Geol. Surv., Vol. X, p. 443, Des Moines, 1899.

At Osborne the basal portion is represented by fifty or sixty feet of clay shales containing abundant iron concretions, but less than five miles west, at Volga, the strata of this horizon are for the most part calcareous shales and limestones. The presence in this county of any considerable thickness of clay shale at the base of the Maquoketa is exceptional, since wherever observed the beds are commonly very calcareous and indurated.

The lithological differences between the Lower and Upper Maquoketa are here more marked than in Dubuque county and furnish additional grounds for the separation of the formation into two subdivisions, as suggested by Calvin and Bain.* The faunal differences are also quite noticeable and important, though some forms are common to both horizons.

The Isotelus beds are considered as marking the base of the Maquoketa since below them is both a lithological and faunal change. The strata underlying those containing the trilobite remains are pure limestones resembling the undoubted Galena-Trenton rock found near Volga and elsewhere. The Isotelus beds are distinctly argillaceous and shaly, the more indurated layers being only two or three inches thick, breaking readily into thin slabs and separated by fissile shale. The fossils, comprising *Isotelus maximus, Leptobolus occidentalis,* and numerous graptolites, are unlike the forms occurring in the underlying limestones. The small *Leptobolus occidentalis* Hall, which here occurs in dark shaly partings between the more indurated Isotelus-bearing beds, is a characteristic fossil of the dark shales in the lower part of the Maquoketa formation at Graf and elsewhere in Dubuque county. For these reasons the lower limit of the Maquoketa is placed at the bottom of these Isotelus beds.

The thickness of the formation varies from 200 feet in the southern part of the county to 240 feet in the northwestern townships. In Dubuque county the thickness is 200 feet and the formation becomes thicker toward the north and west.

The Maquoketa, as will be seen from a reference to the geological map accompaning this report,has a wide distribution throughout Clayton county. With the probable exception of several in the northeastern corner it is found in every township

*Ibid. p. 442.

in the area. It forms the surface rock of the uplands in Jefferson, Volga, Garnavillo, Read, Farmersburg, Wagner, Marion, Monona and Grand Meadow townships. Between the Volga and Turkey rivers it covers large areas where the overlying Niagara has been removed by erosion, and south of the Volga it occurs in the valleys cut back into the Niagara escarpment by the many tributaries entering into the major stream from the south. In the uplands back from the streams the Maquoketa is covered by the Niagara dolomite.

SILURIAN SYSTEM.

Niagara Limestone.

The youngest of the indurated formations occurring in Clayton county is the Niagara limestone which overlies the Maquoketa shale. It does not attain its full thickness in the

Fig. 31—Outcrop of Niagara limestone in the Gunder outlier, section 15, Marion township.

region under discussion, however, since the upper portion appears to be absent. The beds cover a large area in the southwestern part of the county but the exposures most favorable for study occur in the valleys formed by the headwaters of Spring,

Cox and Bear creeks, in the vicinity of Strawberry Point and Edgewood. Cliffs of the Niagara dolomite also form the sides of the valley of the Maquoketa river in the extreme southwestern corner of Cass township.

The character of the rocks shows considerable variation both vertically and horizontally but the typical Niagara is a yellow or buff, heavily bedded dolomite. It often resembles closely the Galena and might easily be mistaken for the latter formation were it not for its fossils and stratigraphic position. In outcrops which have been long exposed to weathering the beds usually have very rough and pitted surfaces, as shown in Fig. 34.

The basal beds of the Niagara are seen in Cass and Lodomillo townships and also in several outliers in Grand Meadow township, one of which extends across the line into Fayette county. As shown by these exposures the strata at the base of the formation are in rather heavy ledges two to four feet and more in thickness. These are well shown in "The Dolomite Quarries" four miles southwest of Postville and just over the line in Fayette county. The section here is as follows:

		FEET.	INCHES.
4.	Dolomite in a single bed with some chert nodules. Suitable only for rubble and broken stone.....	1	6
3.	Dolomite furnishing good quarry stone and quite free from chert.....	6	
2.	Ledge of dolomite very uniform in character and constant in thickness; rock resembles No. 1.		20
1.	Single ledge of even textured, finely granular, buff colored dolomite. In places has a clay parting one inch thick dividing the bed into two layers. Varies in thickness from five to eight feet, but where examined in face of quarry at time of the writer's visit it measured.....	6	4

No. 1 of the above section rests on the blue clay shales of the Maquoketa from which it is separated by a thin parting of calcareous shale. The beds contain *Platystoma niagarense*, Orthoceras and other fossils. Similar basal beds of the Niagara are exposed in the quarries near the section line between sections 10 and 15, Marion township, where heavily bedded, compact, buff dolomite overlies the Maquoketa shale.

In the southern part of the county the strata at the base of the Niagara are seen in the vicinity of Strawberry Point and Edgewood. They here rest on the calcareous transition beds of

the Maquoketa, already described in the discussion of that formation. Where exposed in the northwest quarter of section 14, Cass township, the rock is a heavily bedded, coarse-textured, crystalline dolomite. The ledges are three to four feet thick. The same strata are exposed along the valley in the northwest quarter of section 26, Lodomillo township. The thickness of these basal beds is from thirty to forty feet.

These heavy ledges at the base of the Niagara are succeeded by the quarry beds in which all the quarries in the southern part of the county are located. The character of the rock is well shown in these. In the Sousley quarry (Fig. 35), located in the northwest quarter section 15, Cass township, the following section appears:

		FEET.
2	Coarse-textured, buff dolomite containing chert nodules, in ledges eighteen inches to three or four feet thick	8-10
1.	Light gray, almost white, finely crystalline dolomite free from chert, in layers from four to eighteen inches and two and one-half feet in thickness. The thicker ledges can be split into any desired thickness along lamination planes. The rock is soft when first quarried and grows hard on exposure	6-8

In the northwest quarter of section 24, Cass township, the quarry beds have been opened on the land of Mr. F. Glass and exhibit the following section:

		FEET.	INCHES.
6.	Soil		
5.	Weathered, thin-bedded rock	2	
4.	Dolomite in layers two to six inches thick not suitable for building stone since the beds are too thin and cherty	2-3	
	3 Light gray and buff, fine-textured dolomite in four ledges ten, fourteen, fourteen and thirty inches respectively; the thirty inch ledge in places separated into three beds. These four ledges contain the best quarry stone	5	8
2.	Thin layers one to four inches thick containing much chert		14
1.	Ledge of dolomite at base of quarry		22

The same light gray to almost white, fine-grained and rather soft rock of the quarry beds is seen in the other quarries of this vicinity and it will not be necessary to duplicate the sections already given. This division of the Niagara has a thickness of twenty to twenty-five feet.

Above the quarry beds the strata, for a thickness of about fifty feet, are not exposed. They probably belong in part at least to the *Syringopora tenella* beds found to the south in Delaware county at about this horizon.

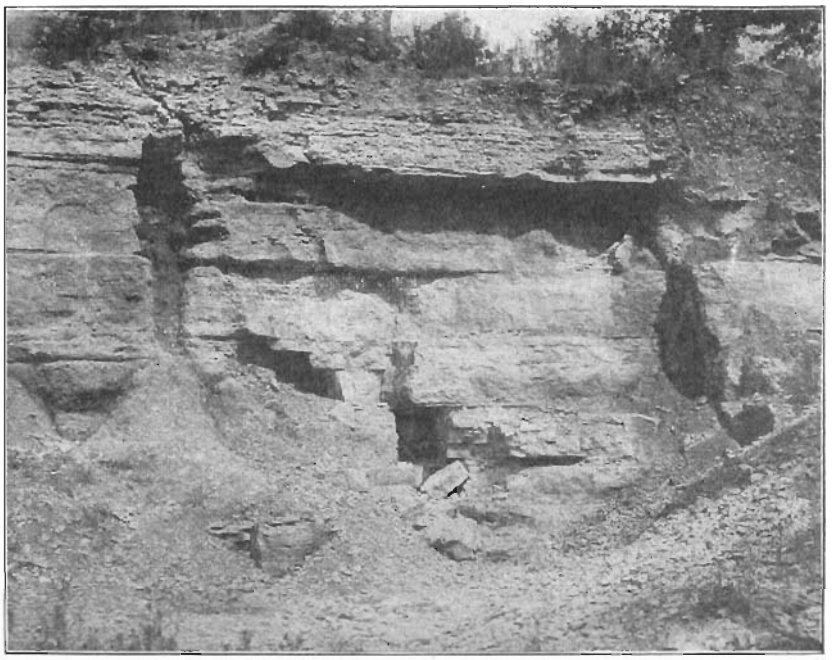

Fig. 35—Quarry in Niagara dolomite near Strawberry Point.

One mile north of Edgewood, along the road leading down to Bixby's Park, in the southwest quarter of section 26, Lodomillo township, the beds for 100 feet above the base of the Niagara are exposed. The rock is a very coarse grained, rough, vesicular and uneven textured dolomite, gray and buff in color and in heavy, massive ledges five, six, and eight feet thick. It contains many corals among which *Halysites catenulatus, Zaphrentis* probably *Z. stokesi* and Favosites are common. The weathered dolomite has the rough, pitted surface characteristic of the Niagara in many of its outcrops. The thickness of this division is about forty feet. Along the Maquoketa river in the extreme southwestern corner of the county, the cliffs forming the sides of the valley are composed of strata similar to those occurring

near Edgewood. The dolomite is massive, coarse grained, vesicular and contains the same corals. In addition *Pentamerus oblongus* occurs in the beds here. Between two and three miles to the south at the "Backbone" in Delaware county, about twenty feet of the *Syringopora tenella* beds and seventy feet of the *Pentamerus oblongus* beds are exposed.* The ledges forming the cliffs along the Maquoketa in Clayton county are believed to belong to the horizon of the *Syringopora tenella* beds as found in Delaware county. It is probable that the upper portion of the Niagara, the equivalent of the *Pentamerus oblongus* beds farther south, has only a slight thickness in this area. In northern Delaware county the latter beds begin 150 feet above the Maquoketa, while the total thickness of the entire Niagara formation in Clayton county is little more than this. The *Syringopora tenella* beds therefore probably form the upper member of the Niagara formation in the region under discussion.

The Niagara limestone covers a large area in the southern and southwestern townships, having a wider distribution than any other formation except the Maquoketa. It lies for the most part south and west of the Turkey river, occurring both between that and the Volga river and south of the latter stream. But several detached areas or outliers are present north of the Turkey. Two of these are in the vicinity of Gunder, in northeastern Marion township. The dolomite forms the top of a ridge rising fifty to seventy-five feet above the surrounding surface. Several quarries have been opened in the rock near the southern end of the ridge. Another outlier is found on the western edge of Grand Meadow township, extending across the line into Fayette county. In this is located the large "Dolomite Quarries" known also as the Williams quarry, to which reference has already been made.

The Niagara occupies a considerable area between the Turkey and Volga rivers. It forms the prominent ridge extending from Highland postoffice southeast almost to Communia. The streams have deeply trenched this divide and the dolomitic beds have suffered much erosion, exposing the underlying Maquoketa shale over a large portion of the region.

*Iowa Geol. Surv., Vol. VIII, p. 148, Des Moines, 1897.

The main body of the Niagara lies south of the Volga and Turkey rivers, occupying the uplands of the southern tier of townships and also of Sperry and Cox Creek townships. The prominent escarpment produced by the outcropping edges of the strata forms an extremely sinuous line extending north on the divides almost to the Volga, and south many miles from the river where the streams have cut valleys back five to ten miles into the Niagara limestone. The line of wooded cliffs which marks the edge of the formation constitutes a conspicuous topographic feature. At the base of these cliffs are huge masses of dolomite which have fallen from above and are tilted at all angles. Many of these blocks have moved down the gentle Maquoketa slopes and now lie at a considerable distance from the parent ledges. The cliffs are constantly being worn back by undermining and weathering and are thus slowly retreating.

The Niagara does not attain its full thickness in Clayton county, the upper beds either never having been present or having suffered removal by erosion. The maximum probably does not exceed 160 feet. The formation has about this thickness in the vicinity of Strawberry Point and Edgewood. In the ridge in Highland township, between the Turkey and Volga rivers, the dolomite is about 140 feet thick, and elsewhere it is less than this.

There is little doubt that the Niagara limestone formerly covered the greater part of the county and that what are now detached portions and outliers once belonged to a continuous area. But the streams of the region have cut their valleys through the formation, removing the strata over large areas.

The limestone weathers into a brown or red ferruginous clay filled with large numbers of chert fragments. The presence of the Niagara can frequently be detected by the occurrence of this cherty red clay even when there is no outcrop. It appears along the roads in many places, as in Highland, Boardman and Cox Creek townships.

RESIDUAL MATERIALS.

Prior to the glacial period and the invasion of the ice sheet the rocks of this region were subjected for many ages to the various weathering agencies. Through their action the strata were decomposed and became covered with a mantle of residual materials representing the products of decay.

In the case of the limestones and dolomites a large part of the substance of the rock (the lime carbonate) was dissolved and carried away in solution by the waters, leaving behind the insoluble constituents, consisting chiefly of clay. The rocks are commonly covered by a mantle of soil and subsoil resulting from their decay, the thickness varying from a few inches to many feet. Resting on the indurated beds of the county these residual materials are often observed, though they are usually covered by a younger deposit associated with the drift, the loess.

In those areas where the Maquoketa formation constitutes the bed rock, the decomposition product is a clay differing little in composition from the original shale. Since these shales weather and break down rapidly they are soon concealed by a covering of clay soil and good outcrops are not common. The Niagara limestone, as already indicated, weathers into a red or brown, ferruginous clay containing many chert fragments. These red, cherty residual clays, or geest, were seen at many points on the high ridge between the Turkey and Volga rivers, as well as south of the latter stream.

PLEISTOCENE SYSTEM.

KANSAN STAGE.

Kansan drift.—Although the Kansan drift covers a large portion of Clayton county it nowhere reaches any considerable thickness, seldom more than five or six feet. On this account it has had but slight effect on the topography of the area, the preglacial surface receiving only a thin veneer of Kansan drift and the topography of the entire county, beyond the border of the Iowan drift, is that of the driftless area. The surface features are the result of erosion and the glacial deposits are not thick

enough to modify these materially. In the discussion of the topography of this region the area of the Kansan drift has therefore been included with the driftless area, since there is little or no difference between the two.

When fresh and unweathered the Kansan is composed of blue till or bowlder clay, mixed with more or less sand and gravel containing large and small bowlders of igneous rock. Near the surface the drift is red and oxidized from long exposure and since it has no great depth in this county the till has this character wherever exposed. It is overlain by loess. Perhaps the best outcrops occur in the vicinity of Communia, in Cox Creek and Volga townships. Near the school house in section 12 of the former township the following section is exposed:

		FEET.	INCHES.
5.	Brown, sandy clay with small bowlders and pebbles..	2	
4.	Gray, rather sandy clay containing streaks and lenses of sand; also filled with numerous small bowlders of rotted granite.....	1	
3	Brown sandy layer		6
2.	Dark brown gravel, rather coarse and containing much rotted granite, diabase, diorite, etc....	1	6
1.	Gray, somewhat sandy clay similar to No 4, in which are bowlders of granite and other igneous rock.....	2	

The drift here shows planes of stratification which are evidence of water action, probably of the streams flowing from the melting ice. Granite bowlders one foot in diameter occur here, most of the rocks being in an advanced stage of decomposition. Southwest of this locality, in the east half of section 14 of the same township, there are exposed five feet of mottled gray and brown bowlder clay overlain by one foot of loess. Pebbles and small bowlders of granite, hornblende schist, diabase, chert, etc., were observed.

Drift outcrops in section 17, Volga township, where at the base there are four or five feet of coarse, brown ferruginous sand overlain by gray and brown mottled till, carrying pebbles and bowlders of granite, diabase, diorite and other material. The clay shows some lines of stratification. Only a short distance from here four feet of brown bowlder clay is exposed, above which there are two feet of coarse ferruginous sand. Many bowlders four to eight inches in diameter were seen here, some flattened, polished and striated on one or more sides.

IOWA GEOLOGICAL SURVEY

MAP OF THE

SUPERFICIAL DEPOSITS

OF

CLAYTON COUNTY

IOWA

BY

A. G. LEONARD

1903

Scale 1/125,000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

- Alluvium
- Iowan Drift
- Kansan Drift overlain by loess
- Driftless Area

ALLAMAKEE CO.

CLAYTON CO.

BOUNDARY LINE

FAYETTE CO

CLAYTON CO

BOUNDARY LINE

DELAWARE CO.

CLAYTON CO.

DELAWARE CO

BOUNDARY LINE

CLAYTON CO.

CLAYTON CO.

DUBUQUE CO.

BOUNDARY LINE

GRAND MEADOW

MONONA

GARD

MARION

WAGNER

FARMERSBURG

HIGHLAND

BOARDMAN

READ

GARNAVILLO

SPERRY

COX CREEK

VOLGA

JEFFERSON

CASS

LODOMILLO

ELK MALLORY

MILLVILLE

BUENA VISTA

Monona

Luana

Watson

Bradley Dix

N. McGregor

McGregor

Beulah

Frodtlich

Giard

Elkader

Wagner

Bismarck

Gunder

Farmersburg

National

Turkey River

St. Olaf

Highland

Read

Clayton Center

Garnavillo

Ceres

Motor

Osborne

Communia

Volga

Guttenberg

Medervillle

Littleport

Elkport

East Elkport

St. Sebald

Strawberry Point

Updegraff

Graham

Wood

Edgewood

Garryowen

Osterdock

Millville

North Buena Vista

Big Bend

Iowa Publ. Co. Davenport, Iowa.

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About one-half mile south of East Elkport, along the road leading up the hill in the southeast quarter of section 36, Volga township, the Kansan drift, with great numbers of bowlders, occurs. The till is brown, leached, highly oxidized and filled with pebbles and bowlders. A little ferruginous sand is mingled with the clay. At no other locality in the Kansan area are bowlders so numerous as here. Those two or three feet in diameter are common and some were observed four or five feet in diameter. Fine-grained granite predominates but diabase, hornblende schist, gabbro, diorite and greenstone are found. The drift covers the side of the valley from top to bottom, indicating that the latter was formed before the deposition of the drift and is therefore preglacial. In Mallory township brown bowlder clay is exposed along the road in the southwest quarter of section 21 and near the center of section 33. The drift is covered with loess which conceals it from view for the most part. The Kansan appears beside the road in the northwest quarter of section 14, Sperry township, less than two miles south of Volga. It outcrops near the school house two miles west of Garnavillo, where two feet of brown till containing pebbles and small bowlders of granite, diorite, greenstone, etc., were seen. One of the granite bowlders was one foot in diameter. The drift is exposed at several points in the vicinity of St. Olaf and Farmersburg. One-half mile north of the former town three feet of red bowlder clay occur overlain by five feet of loess. Bowlders six inches to one foot in diameter are present. Five miles north of here the Kansan drift appears in a railroad cut near the center of section 32 of Giard township. Five feet of brown bowlder clay containing pebbles of granite, greenstone and diorite are exposed. Some drift is found in Grand Meadow township but it is unlike the typical Kansan in being light colored instead of brown. It contains many small bowlders and is overlain by loess.

The margin of the Kansan drift in Clayton county is not marked by any ridge, due to the thickening of the deposit along the border, as in Dubuque county. The drift fades out so gradually that it is possible to determine only approximately where

the margin is located. The eastern and northern boundary as represented on the Pleistocene map which accompanies this report probably does not correspond exactly with the actual border, but the thinness of the drift and its covering of loess prevents any accurate mapping of the margin of the Kansan.

The drift is undoubtedly wholly absent from some portion of the Kansan area, since in this county it is everywhere thin and might readily be removed from considerable areas. It is not continuous but has an irregular, patchy border. In Highland township, and on the ridge in southern Boardman and northern Cox Creek townships, no drift was seen. At a number of points the residual clays of the Niagara appear at the surface or are covered only by a layer of loess. But since the extent of these areas within the Kansan border is unknown they have not been mapped as driftless, except in the case of the valley of the Little Turkey river where they are more clearly defined.

Buchanan Gravels.—When the ice sheet which had formed the Kansan drift began to melt and withdraw from the surface the streams flowing from it were loaded with sand and gravel. These materials were deposited and accumulated as beds of gravel resting on the older drift, or when the latter is absent, on the bed rock. These have been named the Buchanan gravels by Calvin from their occurrence in the county of the same name.* The best exposure of these found in Clayton county is a little over one mile south of Elkader, in the northeast quarter of Section 34, Boardman township. The gravel is reddish brown in color, is highly ferruginous, mixed with considerable coarse sand, and contains pebbles and small bowlders of rotted granite, diabase and other igneous rocks. Most of the pebbles are composed of quartz in the form of chert, derived no doubt from the Niagara limestone. From long exposure the deposit has become greatly oxidized and is deeply iron stained. So abundant is the iron that the gravel is in places cemented by it. The bed as exposed shows a thickness of ten to fifteen feet, extends along the road for 200 to 300 feet and lies nearly 200 feet above the Turkey river. It is covered by one or two feet of loess. The same coarse ferruginous gravel appears along the road one mile

*Iowa Geol. Survey, Vol. VIII, p. 241.

west of Volga, where it contains numerous small bowlders. It is seen resting on the Maquoketa shale in the valley of the Turkey river in the southeast quarter of section 19, Marion township. Many large Kansan bowlders, some four or five feet in diameter, occur along the creek near by. The Buchanan gravels were observed at other points in the region, always presenting the appearance of having been much weathered and oxidized.

IOWAN STAGE.

Iowan drift.—The Iowan drift covers only a small area in Clayton county, including parts of Cass and Lodomillo townships and one or two sections in southwestern Sperry. The area is represented on the Pleistocene map accompanying this report. The border lies from one-quarter to two miles north of the Chicago, Milwaukee & St. Paul railroad, the road following the level plain of the Iowan drift. As was stated in the discussion of the topography of this region, the margin is marked in most places by a ridge or a series of hills and ridges composed of drift and loess, rising fifty to sixty feet above the surrounding surface. The marginal ridge is well shown at Strawberry Point, in the eastern part of town, and continuing for a mile or more in the same direction.

The Iowan drift presents a very different appearance from the Kansan. It is gray in color, not having suffered the oxidation of the older till, its granite bowlders are fresh and little affected by weathering, it is not covered by loess, except near the margin, and its surface is characterized by the presence of numerous large bowlders of coarse-grained granite. The contrast between the two drift sheets is always striking. The reddish brown Kansan drift is covered by loess which forms a light colored soil, while that of the Iowan drift is black, the surface is dotted with large bowlders and there is no covering of loess. The older drift has undergone much erosion and streams have cut deep channels, while the younger has a level and poorly drained surface.

The character of the Iowan drift is well exhibited in several outcrops in the vicinity of Strawberry Point. Beside the road just north of town six feet of gray bowlder clay are exposed,

overlain by three feet of loess. The clay has suffered very little leaching and effervesces strongly with acid; its iron constituents are not oxidized and the granite bowlders are not decomposed. One composed of biotite gneiss was seen here with its feldspar and other minerals still fresh and bright. Only near the margin is the Iowan drift covered by loess, as in the above exposure, and elsewhere this gray mantle is absent. The light yellow bowlder clay is also seen just south of the school house on the line between sections 23 and 24 of Cass township, where the wagon road cuts through the marginal ridge. At this point the drift is overlain by ten feet of loess. The numerous large bowlders which are such a conspicuous feature of the Iowan surface are well displayed in section 6 of Cass township, along the roads southwest of Strawberry Point and elsewhere. In some parts of the Iowan area the drift is wanting, the Niagara limestone or its residual clay outcropping at the surface. Such small driftless areas were observed in sections 5, 6, 8, 9 and 16 of Cass township.

The thickness of the Iowan drift at some points near the border is shown by wells to be from 100 to 170 feet while at other points it is nothing. The well at Strawberry Point went through 125 feet of drift and loess before reaching the Niagara and another located on the ridge one-half mile east of town penetrated 172 feet of loess and till before striking bed rock. The thickness is probably somewhat less than this back some distance from the border where the drift has not been heaped up into morainal hills and ridges; and in some areas, as stated above, it is very thin and even absent. A well sunk about two miles north of the Iowan margin, in the northwest quarter of section 18, Lodomillo township, went through only fifty feet of loess and Kansan drift.

Loess.—The fine, light yellow, homogeneous silt known as loess forms the superficial deposit over nearly the entire county. In the driftless area it rests on the residual clays and sands while in that of the Kansan it overlies the reddish brown, oxidized till or the ferruginous Buchanan gravels. The only portion of the region from which the loess is absent is the Iowan

drift plain in the southwestern corner. This light colored deposit, which is fresh and unleached, presents a sharp contrast to the weathered, brown and oxidized clays on which it rests. It is believed that the loess was deposited during the time that the Iowan ice sheet was at its maximum development, or shortly after its retreat, and thus that it is of about the same age as the Iowan drift. The fine materials of the deposit were spread out over the surface beyond the Iowan margin either by wind or water or by the combined action of both agents. Recent investigations point to the wind as the chief factor in the transportation and deposition of the loess. The character of the fossils, which are almost invariably the shells of land snails, and certain peculiarities about the distribution of the deposit, lead to the belief that in many instances at least, if not in all, the wind was instrumental in the formation of the loess. Little evidence of stratification was observed in the loess in Clayton county. In thickness it varies considerably, ranging from zero to twenty feet. The average thickness is probably not over ten feet.

Terraces.—At many points along the Turkey and Volga rivers gravel terraces form conspicuous features of the valleys. They were formed when the streams had a larger volume than today and were loaded with an abundance of coarse sediment, such as sand and gravel. Through the deposition of these materials the floors of the valleys were built up. Later, when the rivers carried less sediment, they began to cut into their former flood plain deposits, leaving the remnants of the latter as terraces along the sides of the valleys.

On the Turkey river the broad and well preserved terrace near the Fayette county line has a height of fifty feet above the river. It is exceptionally well exhibited in the vicinity of Elkader, where it rises fifty-five feet above the water below the dam. The two cemeteries, the Court House and much of the town east of the river are built on this terrace. The sand and gravel pit near the railroad station is located in it. About three-quarters of a mile below town, along the railroad, the terrace has been cut into by gullies and has been badly washed by hard rains, so that the gravel and sand are excellently shown (see Fig. 36).

Many of the pebbles composing it are of igneous rock similar to those of the drift. In the bend to the west, just south of town, the stream is cutting into and undermining the gravel deposit. At Osterdock the terrace is sixty feet above the river.

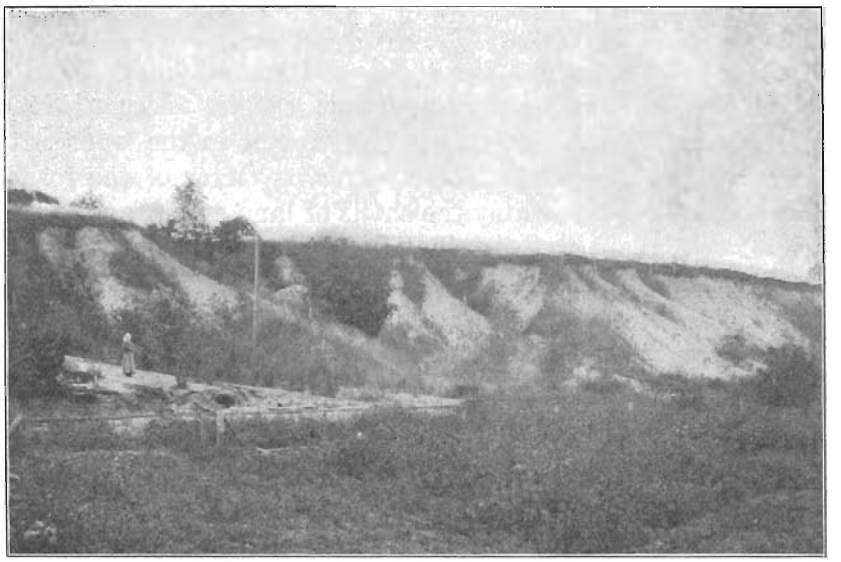


Fig. 36—Gravel terrace on Turkey river, one mile below Elkader.

Terraces appear at numerous points along the Volga. At the town of this name there is a broad and conspicuous terrace thirty feet above the stream and a lower one or second bottom, with an elevation of ten feet. Large numbers of agates here occur among the pebbles of the terrace. At Osborne it is forty-five feet, at Mederville fifty feet, and at Elport seventy-five feet above the river. Near the confluence of the Turkey and Volga, at Elkport, there is an upper and lower terrace, the one seventy-five, and the other forty feet high.

These gravels exposed along the Turkey and Volga rivers are probably of glacial origin but with what drift sheet they correspond in age is uncertain. They do not resemble the ferruginous Buchanan gravels since they are fresh and light colored. They are similar to the gravels of the Wisconsin ice sheet, but the latter did not invade the drainage areas of any of the Clayton county rivers except the Mississippi, so that the outwash

material of the ice sheet could hardly reach the valleys of the district. They did, however, fill the preglacial valley of the major stream to a depth of 147 feet, as shown by the deep well at Prairie du Chien. These Wisconsin gravels appear in the gravel pit just below Guttenberg, beside the railroad track.

ALLUVIUM.

Alluvial deposits are found on the flood plains of the larger streams, covering considerable areas along the Mississippi, Turkey and Volga rivers. These deposits are composed of the fine and coarse sediments laid down by a river on its valley bottom during times of flood. Occasionally the thickness of the alluvium deposited during a single flood is sufficient to raise the level of the plain very perceptibly. During the high water of the summer of 1903 the town of Elkport was several times flooded and when the waters receded the surface was seen to be covered by a layer of black, slimy mud from one to six inches and more in thickness, the thickest deposit being near the river. Where material had been washed down from the sides of the valley the addition to the flood plain was in places as much as two or three feet, half burying fences so that only the tops of the posts project above the mud layer. Over wide areas the thickness of the fresh alluvium was nearly a foot.

There are extensive alluvial bottoms along the Mississippi and narrower ones bordering the Turkey and Volga rivers along parts of their courses in Clayton county. Only the larger areas can be represented and these are shown on the Pleistocene map.

Deformations and Unconformities.

The strata of this region have been but slightly disturbed from their original horizontal or nearly horizontal position. They have a very gentle dip to the southwest and there are one or more low anticlinal folds. In the vicinity of Sny Magill creek, between McGregor and Clayton, the presence of a gentle anticline is indicated by the increased dip of the beds on one side and the lessened dip on the opposite side.

The indurated rocks form a continuous series conformable among themselves but between them and the drift there is a distinct unconformity. The Pleistocene deposits were laid down on

an old eroded land surface that for ages had been exposed to denudation. The two drift sheets are likewise unconformable between themselves, the Iowan drift and loess resting unconformably upon the Kansan.

ECONOMIC GEOLOGY.

Soils.

Several varieties of soil are found in Clayton county. Covering by far the larger part of the area is the loess, which forms a light, loose and porous soil. This rests either on the Kansan drift or on the residual clay of the driftless area. The porous and usually quite calcareous loess affords an excellent soil for agricultural purposes and is adapted to the growth alike of grasses, grains and fruits. The Kansan drift is everywhere covered by a greater or less thickness of loess and the same deposit forms the soil of the driftless area except where erosion has removed it from the steeper slopes.

The Iowan drift of the southwestern townships forms a rich, dark, loamy soil of great fertility. The level character of the surface of the Iowan makes its cultivation less difficult than the rough portion of the driftless area or even of the Kansan. Still a third variety of soil is furnished by the alluvium of the stream valleys. This is unexcelled for productiveness and its continual replenishment during times of flood causes it to maintain its fertility.

Building Stone.

Clayton county is abundantly supplied with excellent building stone, the Niagara, Galena-Trenton and Oneota formations all being quarried at a number of points. The attempt has not been made to locate all the quarries on the map, there being many which are abandoned or worked occasionally, and only the larger and more important ones are given.

Quarries in the Oneota.—The outcrops of the Oneota limestone are confined to the bluffs of the Mississippi and the tributary valleys in Mendon and Clayton townships. The rock has been quarried about one and a half miles above North McGregor, on Bloody Run, and in McGregor. The quarries

are located near the base of the formation thirty feet or less above the Saint Croix sandstone. A small opening has been made in these beds near the public park at McGregor, where there are six feet of excellent dolomite.

Quarries in the Galena-Trenton.—There are several horizons in this formation which furnish building stone. One of these lies near the base, in the "Lower Buff Beds". The rock is a fine-grained limestone, blue weathering to buff, lying in beds from eight inches to two, three, or four feet in thickness. It breaks readily along the bedding planes into slabs of almost any thickness and in places is cut by vertical joints. These lower beds are worked in the Boyle quarry at McGregor and in the quarries along the base of the bluff at Guttenberg. They have a thickness of from fifteen to twenty feet.

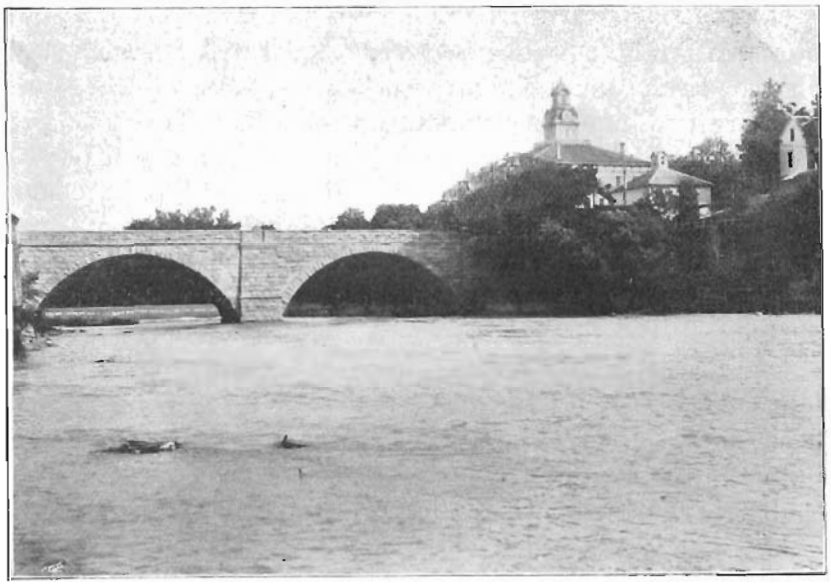


Fig. 37—Stone bridge at Elkader; built of Galena limestone.

The Galena dolomite is quarried at numerous points, most of the quarries being near the top of the formation. In this upper horizon are the Stoops quarry at Elkader, where the rock for the stone bridge (Fig. 37) was taken out; the Ferguson quarry one and a half miles north of Monona and that near Luana; the Stickfort quarry southeast of Garnavillo and the

Schoulte quarry one and a half miles north of National. The Thoreson quarry, about one mile west of Farmersburg, is in beds which lie twenty-five to thirty-five feet below the top of the Galena-Trenton and the Embertson quarry, east of St. Olaf, is about sixty-five feet below the Maquoketa shale. The rock in these two quarries is a blue and buff, compact, non-dolomitic limestone occurring in beds two to fifteen inches thick. Many of the layers are separated by reddish marly partings from a fraction of an inch to two inches thick. The Galena dolomite is quarried at several points in Cox Creek township; in the southwest quarter of section 16 and in the northeast quarter of section 20. The transition beds at the base of the Galena dolomite have been quarried at the old Dehn quarry, about two miles east of Garnavillo, and these beds also furnish the stone for the limekilns at Guttenberg.

Quarries in the Niagara.—The Niagara limestone is quarried at two different horizons in widely separated portions of the county. In the small Niagara outlier just southwest of Gunder there are two quarries belonging to Mr. R. L. Rierson. They are located in beds at the base of the formation and fifteen feet of dolomite are exposed. The rock is in heavy beds, compact and buff colored. The large Wilkes Williams quarry, five or six miles northwest of here and close to the line between Clayton and Fayette counties, is in these same strata immediately overlying the Maquoketa shale. At the bottom is a single ledge of even-textured dolomite ranging in thickness from four feet, eight inches to eight feet, with a one inch clay parting in places. Overlying this is a persistent twenty inch bed of very uniform character and constant thickness and then above are seven and a half feet of quarry beds, though the upper eighteen inch layer is cherty and suitable only for rubble and broken stone.

The quarries in the vicinity of Strawberry Point are in a horizon sixty to seventy feet above the base of the Niagara. The quarry of W. S. Sousley, which has been worked thirty-five years, is on the side of the valley formed by the headwaters of Spring Creek, in the northwest quarter of section 15, Cass township. From fifteen to twenty feet of rock are exposed in the quarry. The best stone lies at the base, where the dolomite is

almost white, free from chert and in ledges from three or four inches to one and a half or two and a half feet. This rock is soft when first removed but grows hard upon exposure. Above the white beds is a buff, coarse-textured dolomite containing some chert, and occurring in ledges from one and a half to four feet thick. The Glass quarry, which is in the same horizon, is located in the northwest quarter of section 24, Cass township.

Most of the stone quarried in Clayton county is used locally and little or none is shipped except from the Williams and Boyle quarries.

Clay.

Several of the formations occurring in the area under discussion furnish clays which are suitable for the manufacture of brick, tile and other clay products, but these are not at the present time utilized as much as they might be. The loess, alluvium and Maquoketa shale are used in the several brick yards. The Trenton limestones contain shale beds at several horizons, but these have not been made use of either in Clayton or any of the adjoining counties. From two to three feet of shale occur at the base of the formation and these are exposed at McGregor, Clayton and just above Guttenberg. They are not of sufficient thickness to be available for making brick. About fifty feet above the base of the Trenton series is a second shale member, corresponding to the shale at Decorah, five or six feet in thickness. This might furnish a good clay in some places but it commonly contains lenses and bands of fossiliferous limestone and calcareous nodules which render it unsuitable. It is well exposed in the ravines about McGregor, Clayton and one-quarter of a mile above Buena Vista.

The Maquoketa formation, on the other hand, furnishes clay of excellent quality for the manufacture of various clay products. The upper Maquoketa contains from sixty to ninety feet of shale and good outcrops of this occur near St. Sebald, three miles north of Strawberry Point; at Newberry Park, one mile and a half northeast of the same place; at Bixby's Park, one mile and a half north of Edgewood; in the vicinity of Volga and on the Turkey river near the Fayette county line.

The following is an analysis of the shale from near St. Sebald, in the northeast quarter of section 33, Sperry township, on one of the small tributaries of Hewett creek.

Silica	52.29
Alumina	20.64
Combined water	5.17
Clay and sand	78.10
Iron oxide	5.16
Lime	1 89
Magnesia	1.12
Potash	2.77
Soda	8 27
Total fluxes	19.21
Moisture, sulphur trioxide and carbon dioxide	2.76
Rational Analysis.	
Clay substance	70 65
Feldspar	2 57
Quartz	26.78
	100.00

This clay is well adapted to the manufacture of the common clay products but is especially well suited to the production of hollow ware.

Edgewood.—The brick and tile plant of Myron Mellon is located at Edgewood. Blue Maquoketa shale and loess are used. The shale is obtained two miles north of town just above Bixby's Park on Bear creek. It is from the top of the Maquoketa formation. This clay shale is mixed with varying proportions of loess procured from the ridge just north of Edgewood. For brick and three inch tile the proportion is one-third Maquoketa clay and two-thirds loess; for six and eight-inch tile it is one fourth clay shale and three-fourths loess. The more of the Maquoketa clay that is used the harder the brick or tile. This material alone makes an extremely hard brick.

The plant has a Brewer Brick and Tile Machine, a Penfield crusher, thirty horsepower engine and thirty horsepower boiler. The product is burned in a downdraft kiln, after drying in large drying sheds. The clay burns to a salmon red color and the brick and tile are hard and of good quality.

An analysis of the Maquoketa shale used here shows a composition differing considerably from that of the clay near St. Sebald. It is as follows:

Silica	44 39
Alumina	13.72
Combined water	12.18
Clay and sand	70,29
Iron oxide	7.80
Lime	7.88
Magnesia	6 05
Potash	1 56
Soda	5.29
Total fluxes	28.58
Moisture	0 89

Rational Analysis.

Clay substance	40 61
Feldspar	4.62
Quartz	28.00
Lime and Magnesia Carborate	26.77

It will be seen that this clay contains a strikingly high percentage of lime and magnesium carbonate but it produces a strong and durable ware when properly burned.

Monona.—The Monona Brick works are operated by George J. Jenkins and have been running twelve years. The plant is located in the west edge of town beside the Chicago, Milwaukee and St. Paul track. The material used is loess clay and twelve feet of this are exposed in the pit. The upper eight feet are yellow or buff and the lower four feet are blue and somewhat sandy. The brick burn to a red or dark brown color and are of good quality, being durable and keeping their color well. They find a ready sale in Monona and the surrounding region. A Quaker brick machine, made at Wellington, Ohio, is used and has a capacity of 16,000 brick a day. The moulds are sanded to prevent the clay from sticking to them, a fine river sand from Dubuque being employed. The brick are first dried on the ground in the sun and are later transferred to sheds open at the sides. They are burned in two dowudraft and two updraft kilns.

Guttenberg.—There are two brickyards near this place, both located around the point of the bluff in the valley of Miner creek. One of these is owned by Mr. M. Burr and has been in operation five years. An alluvial clay is used, part of it

obtained from the bottom along the creek and part from a terrace near by in which the material is a stratified clay and sand deposit. It is sandy towards the top but near the bottom of the pit is quite a stiff clay. These materials are mixed in the proportion of two-thirds of black alluvium to one-third of the sandy clay of the terrace. The brick are made in an Anderson brick machine manufactured at Anderson, Indiana, dried in two drying sheds and burned in a temporary kiln. The yard is operated five or six months of the year and employs seven or eight men.

The second brickyard, owned by I. K. Kohler, is located near the cemetery. The clay is here obtained from a terrace rising fifty feet above Miner creek and composed of a stratified sandy clay. The material exposed in the pit varies from a stiff clay, through sandy clay to almost pure sand. The brick are hand made, dried in sheds and burned in temporary kilns.

Lime.

Clayton county is well supplied with magnesian limestones suitable for lime, and these are burned at several points. There are two kilns at Guttenberg, one two miles northeast of Elkader, and lime was formerly burned by John Dehn at his place about two miles east of Garnavillo. At Guttenberg the rock used by Frank Stoeffler and George Koehler in their kilns is from the mottled transition beds lying between the non-dolomitic limestone and the completely dolomitized Galena. Analysis shows that the rock contains about 16 per cent of magnesium carbonate and is therefore intermediate in composition between true dolomite and pure limestone. The beds are quarried in the bluff above the lime kilns located at the base, are broken into small fragments and the rock is allowed to slide down the steep slope to the top of the kilns.

Charles Lee has a lime-kiln near Elkader and the limestone burned here is from the thin bedded Trenton formation.

The other magnesian limestone formations of the county would make good lime. The Oneota dolomite has been burned in Allamakee county, and the Niagara at various points in Delaware county, affording an excellent lime. The large and well

equipped plant at Eagle Point, Dubuque, uses forty feet of Galena dolomite lying fifty feet above the top of the "Green Shales".

Glass Sand.

The Saint Peter sandstone furnishes a sand of such purity that it is suitable for use in the manufacture of glass.

The following is an analysis of a sample from Clayton after the material has been washed:

Silica (SiO_2)	98.94
Alumina (Al_2O_3) and ferric oxide (Fe_2O_3)	.60
Calcium oxide (CaO)	.33
Magnesium oxide (MgO)	.14

The chief locality in Clayton county where the sand is obtained is a large pit near Clayton. This is located in a ravine a short distance back from the river where thirty to forty feet are exposed. The sand is easily dug with a pick and broken into fragments five or six inches in diameter. Then a strong current of water is turned on, which causes the pieces to crumble and the sand is washed into a long wooden trough leading to the railroad. As it is carried along this trough by the water it is thoroughly washed and is conveyed into a large tank. Here the water is drawn off and the sand is loaded directly on the cars.

This pit is owned by Mr. J. H. Buhlman and much material has been removed. There is a large abandoned pit just east of the one at present worked. Sand has been taken from this locality for thirty years. It is shipped to the glass factories at Clinton, and to Milwaukee for use in several malleable iron works there.

Throughout much of the extent the Saint Peter sand is colored by iron oxide but there are a number of places in the bluffs of the Mississippi where it is white and pure enough to furnish glass sand.

Road Materials.

Good materials for road building are found in many parts of the county, but little use has yet been made of them. The limestones of the Lower Magnesian, Galena-Trenton and Niagara when broken up would furnish stone for macadam and the

supply is inexhaustible. The glacial gravels are another source and these are ready for use. The ferruginous gravels near Elkader have already been mentioned; the iron is so abundant as to form a cement and the material packs well. The terrace gravels along the Turkey and Volga rivers could be used to advantage and have been employed to some extent at Elkader and elsewhere. There are two large gravel pits a short distance below Guttenberg. From the one just south of the railroad bridge over Miner creek the Chicago, Milwaukee and St. Paul road has taken large quantities of gravel for ballast.

Lead.

Lead has in the past been mined in considerable quantities at two points in Clayton county, Guttenberg and Buena Vista. At the present time it is mined only on a small scale. The work is carried on mostly by laboring men who have no other work during the winter months and put in their spare time prospecting for galena. Hardly enough lead is obtained to pay for the labor of getting it out

At Buena Vista mining was begun in 1851 in township 91 north, range I west, section 28, northeast quarter. Two nearly east and west ranges have been worked, and both are formed by three main parallel crevices with several minor ones. The ore in the south range occurred in a large body at the surface. The mine was on a side hill where the overlying strata have been eroded, leaving the deposit exposed. It was worked by an open cut and yielded lead in generous measure. The crevice was followed 700 feet west of the ore body, but without further discoveries. The fissure is open up to the surface, where it is from one to three feet wide, and is filled with clay and soil. One crevice in the north range has been worked by a level run into the hillside. Mining has been carried on here at intervals for over thirty years, and although no record has been kept, the mine is known to have produced large quantities of galena. Some zinc carbonate occurs in this same locality, but not in paying amounts. Several specimens of the lead carbonate, cerussite, were obtained here, and one of them analyzed by

G. E. Patrick yielded 69.67 per cent of lead. It occurs only in small quantities and has been derived by alteration from the galena. For many years little has been done in these mines, although some prospecting has been carried on from time to time. The deposits are lower in the Galena limestone than at Dubuque, but not at the base of the formation as at Guttenberg.

The Guttenberg mines are about three miles northwest of town on Miner Creek. The larger diggings were in section 7, township 92 north, range II west, but there were others in section 18, same township and range and in sections 11 and 12, township 92 north, range III west. The lead is found in the lower part of the Galena beds, occurring in the mottled, magnesian limestone forming the transition beds already referred to. Miner creek and its tributaries have cut deeply into the Galena formation, and the mines are located chiefly on the sides of the valleys which have in places cut across the east and west crevices. The partially dolomitized limestone is found along the creek as far as Mr. Rodenberg's place and some distance beyond.

For some years the Holmes mine was the largest in the district. The opening, which is in places fifty feet wide, was followed 2,000 feet. The cap rock forms a flat roof without fissure. The lead ore lay loose on the crevice material occupying the cavity, and was easily removed without blasting. Crossing the Holmes range was a "quartering" northeast and southwest, which was rich in ore. A north and south fissure close by also carried considerable amounts. The mineral in the Holmes, as not unfrequently occurs in the mines, "jumped" from one east and west to another parallel crevice of the same range. In this case the opening in the crevice followed became narrow and the galena gradually disappeared, but only to reappear in the other crevice. In all the specimens seen from the Guttenberg district the lead was crystallized not in simple cubes, but in combination forms of the cube and octahedron, the latter form often predominating or occurring alone. This locality formerly produced considerable lead, and two smelters were at one time in operation on Miner creek. After a few years' working the deposits gave out in the majority of the diggings and they are now practically abandoned.

About three miles southeast of Buena Vista and less than half a mile south of the Dubuque county line, the Fitzpatrick Lead Mining Company opened a mine in 1903. It is located in the northwest quarter of section 2 of Concord township, Dubuque county. Lead was discovered here by Mr. Fitzpatrick in 1900 and 36,000 pounds are said to have been taken out. The galena was about twenty feet below the surface and imbedded in clay in a ravine.

Water Resources.

An abundant water supply can always be assured by going down to the Saint Peter sandstone and in the central and northern portions of the county many wells have been drilled to this formation. Wells 400, 500 and 600 feet deep are not uncommon. On the ridge between the Turkey and Volga rivers one well has been sunk 666 feet to the Saint Peter, passing through the Niagara, Maquoketa and and Galena-Trenton formations. Water is also often struck in the Galena-Trenton beds, and many farm wells obtain their water supply from this source. McGregor secures its water from the Saint Croix sandstone, while Strawberry Point and the adjacent region draw supplies from the Niagara limestone. There are also shallow wells in the drift at many points.

Two flowing wells furnish Elkader with water. These are twenty-five feet apart and are 182 and 184 feet deep respectively. They extend thirty feet into the Saint Peter sandstone and give an abundant supply. The water is pumped into a reservoir on a hill nearly 300 feet above the town, giving a strong pressure in the mains. A third flowing well is at the Fair Grounds just below town.

McGregor has four flowing wells, the deepest a little over 1000 feet. The water supply for the town is obtained from a well less than 400 feet deep. The water is pumped into a reservoir on a hill and is very pure and free from mineral substance.

The following facts regarding the wells at McGregor and Prairie du Chien are taken from W. H. Norton's report.

WELLS AT McGREGOR.†

	WELL NO. 1.	WELL NO. 2.	WELL NO. 3.
Owner.	Town	Town.	J. Goedert.
When drilled.	1876-1877.	1899.	1889.
Depth	1,006 feet.	520 feet.	294 feet.
Diameter.	6 in. reduced to 3 in.	6 in. reduced to 3 in.	6 inches.
Elevation of curb.*	632 feet A. T.	618 feet A. T.	622 feet A. T.
Head of water.	694 feet A. T.	638 feet A. T.	644 feet A. T.
Flow per minute.	20 barrels.		
Temperature.	54° Fahr.	52° Fah3.	52° Fahr.

From this locality, including Prairie du Chien, on the Wisconsin side of the Mississippi river, there are reported some twelve artesian wells; and it is gratifying to learn that notwithstanding the great volume of water daily poured from the basin, well No. 1, one of the pioneer wells of the state, has suffered no preceptible change in its flow. In this well four-inch copper casing is used to a depth of forty feet, the original six-inch iron casing having been destroyed within two years by the corrosion of the saline water. No packing was used and it is thought that there is some leakage at the base of the casing. Well No. 2 was also recased, reducing the diameter from six inches to three inches, as the original casing was poorly done and the water leaked out through the joints. The second casing extends to 215 feet, and is packed at the base with a rubber gasket. In each of the wells the first flow was struck at 315 feet A. T., and from this to the base all sandstone beds were water-bearing. At a little over 520 feet from the surface brine was found in four feet of white sandstone. The two town wells supply fire protection, several public drinking places and the two finest fountains in the state. Three-eighths of a mile of pipe are laid through the business portion of the town, with five hydrants and a number of public taps. The water of the deeper well corrodes iron so rapidly as to be entirely unfit for steam purposes. Although somewhat saline it is palatable to most persons. The water of well No. 2 has no corrosive effect on boilers, but forms a slight scale.

†Reported by Mr. C. W. Walker and Hon. Horace Beach

*With the elevation of the Chicago, Milwaukee & St. Paul railway station at 612 feet A. T. according to Gannett as datum.

Several chemical analyses have been made of the waters of the McGregor artesians. The following by Joseph Henry of the Smithsonian Institution, is given as published in the North Iowa Times, March 15, 1887.

"The * * * * analysis of the water of the McGregor artesian well No. 1, is found to be a saline water, holding in solution in round figures 136 grains of solid matter to the gallon as follows:

Silica.	Potassium.	Sulphuric acid.
Iron.	Sodium.	Phosphoric acid.
Alumina.	Lithium.	Boracic acid.
Lime.	Chlorine.	Carbonic acid.
Magnesia."		

Scarcely more satisfactory is the analysis of the same well made by Hinrichs, January, 1879.

Specific gravity at 19½° C	1.0014
Total mineral matter, grains per gallon	157 0 gr.
Carbonate of lime, grains per gallon	22.4 gr.
Sodium carbonate and magnesium sulphate	134 6 gr.

"The water also contains a very small amount of lithium chloride, the lithium lines being visible but faint when the residue of the water is examined by means of the spectroscope."

Official Analyses.

	NUMBER 1.		NUMBER 2.	
	Grains per U. S. gallon.	Parts per million.	Grains per U. S. gallon.	Parts per million.
Silica ($Si O_2$)	323	5.571	.398	6 857
Alumina ($Al_2 O_3$) / Ferric oxide ($Fe_2 O_3$)	.348	6.000	.124	2.143
Lime (Ca O)	13.200	227,571	4.524	78.000
Magnesia (Mg O)	2.443	42.286	2.834	48 857
Potash ($K_2 O$)	...	.....	Trace	Trace
Soda ($Na_2 O$)	55 083	949.714	3.695	63.714
Chlorine (Cl)	56.136	967.857	2.088	36 000
Sulphur trioxide ($S O_3$)	22.504	388 000	2.618	45.143
Carbon dioxide ($C O_2$)	10.664	183.857	10.705	184.572
Water in combination ($H_2 O$)	1 069	18 428	1.732	29.857
Free ($C O_2$)	[9.305]	[160.428]	[4.350]	[75.000]
UNITED AS FOLLOWS.				
Calcium carbonate ($Ca CO_3$)	.....	.....	5.245	90.429
Calcium bicarbonate ($Ca H_2 (CO_3)_2$)	17.930	309 143	4.549	78.429
Magnesium bicarbonate ($Mg H_2 (CO_3)_2$)	.....	.....	9 868	170 143
Calcium sulphate ($Ca SO_4$)	17.002	293 143	.....	.....
Magnesium sulphate ($Mg SO_4$)	7.325	126,286	.332	5.714
Sodium sulphate ($Na_2 SO_4$)	13 539	233 428	4.276	73 714
Sodium Chloride (Na Cl)	92.634	1597.143	3.455	59.571
Alumina ($Al_2 O_3$) and Ferric Oxide ($Fe_2 O_3$)	.348	6 000	124	2.143
Silica ($Si O_2$)	.323	5.571	.398	6 8-57
Oxygen replaced by chlorine (O)	12.677	218.570	.472	8 143
Solids	161.778	2789 284	28 720	495.143

Analyst: Prof. J. B. Weems, Ames, Iowa. Date: June 16, 1896.

RECORD OF STRATA,

The following record of a well at Prairie du Chien* will illustrate the geological section at McGregor.

		THICKNESS.	DEPTH.
16.	Sand and gravel	147	147
15	Clay, fine, light blue	$\frac{1}{6}$	
14.	Limestone, hard arenaceous	2	149
13.	Grit, blue	6	155
12.	Shale, bluish green, arenaceous	107	262
11.	Sandstone, white, friable, alternating with hard streaks	118	380
10.	Grit, blue	35	415
9.	Slate rock	65	480
8.	Sandstone, reddish and yellow ochery	6	486
7.	Shaly rock	24	510

*Geology of Wisconsin, vol. IV, p. 61.

		THICKNESS.	DEPTH.
6.	Sandstone, white, carrying brine.....	4	514
5.	Slaty rock.....	75	589
4.	Sandstone.....	310	899
3.	Sandstone, red	45	944
2.	Conglomerate, white waterworn quartz pebbles.....	5	949
1.	Sandstone, coarse	10	959

The curb is near the summit of the Saint Croix. No. 16, the alluvial filling of the preglacial valley of the Mississippi, supplies the place of the upper sandstone of the Saint Croix, the Jordan. No. 14 is the remnant left after erosion of the Saint Lawrence dolomite. Nos. 12 and 13 are the Saint Lawrence shales. Preceding numbers represent the basal sandstone of the Saint Croix. Another well at Prairie du Chien was sunk to a depth of 1,040 feet without reaching the Algonkian.* †

Monona gets its water from a well 459 feet deep and reaching the Saint Peter sandstone. This well supplies the railroad and town in part. The water is pumped into the railroad water tank and some pressure is thus secured in the pipes. The town has three miles of mains. A portion of the supply is obtained from a large spring near by. The water is collected in three or four basins and from these pumped by wind mill and gasoline engine into a tank.

Strawberry Point is supplied with water from two wells 160 feet deep and ten feet apart. The water is pumped into a standpipe. The record of the wells shows that 125 feet of loess and drift were penetrated and thirty-five feet of Niagara limestone. The water is not very hard and is good both for drinking and for boiler use. About one-half mile east of town near the center of section 23, a well sunk on the ridge marking the border of the Iowan drift, passed through 172 feet of loess and drift. It went fourteen feet into the Niagara limestone, when a good flow of water was found. In the vicinity of Strawberry Point water is obtained in the Niagara at depths of from 160 to 250 feet.

*Iowa Geol. Surv., Vol. VI, 1896, p. 185-188.
†Private letter from Hon. Horace Beach.

Water Power.

The larger rivers of the county are capable of furnishing a plentiful water power and this has been utilized at several points. A dam on the Turkey river at Elkader supplies power to a large and well equipped mill. There is also a stone mill at Motor, between four and five miles below Elkader. On the Volga river power is secured for flour mills by dams at Volga City and Mederville. At the latter place the conditions for constructing a dam were especially favorable. The river here flows in a narrow rock-walled gorge, the sides of Galena dolomite rising abruptly from the water's edge. Two miles north of Strawberry Point is a stone mill with a turbine wheel run by water from a large spring near by. The stream flowing from the spring is dammed, and from the pond thus formed a sluice and iron pipe carry the water to the wheel pit.

Clams.

No account of the economic products of Clayton county would be complete without some mention of the clams of the Mississippi river which yield shells for the manufacture of pearl buttons. This has grown to be an important industry in many river towns of the upper Mississippi, and during the clamming season hundreds of men are employed in gathering the shells. For this purpose they are equipped with a boat and two iron rods made from ordinary gas pipe. From these rods at regular intervals are suspended short pieces of rope or stout twine to which hooks are attached. These rods are let down by ropes into the mud at the bottom of the river and dragged for a short distance. Whenever one of the hooks enters an open clam shell the two valves close tightly upon it. If the haul is a good one every rope will have a clam dangling from the end of it, and, since the rod has several dozen of hooks attached to it, each catch represents a large number of shells.

Clamming in the vicinity of McGregor began in the spring of 1898. In the early days of the industry one man could catch a ton of shells in a day, and these were carefully selected shells, for the poor ones were thrown back into the river. The clams

are now becoming much reduced in number and at present a man cannot catch more than 500 pounds at best in a day. The shells now (1903) sell for $20.00 a ton, whereas the price in the early days of clamming was only $6.00 or $7.00 a ton.

The season lasts about two months, since the clams do not "bite" well when the warm weather begins. The best time is from about the middle of April to the middle of June and this may be considered the clamming season. During these months the river is thickly dotted with the boats of the fishermen, and the shores are lined with their tents. They come here from places as distant as Ohio and Tennessee.

The clams are valuable not only for their shells but for the pearls and "slugs" they yield. These are found in the mantle or between the mantle and the shell. The pearls are discovered when the shells are being cleaned after having been first steamed to open the valves. They are felt for in the soft parts of the animal as these are being removed.

Many of the pearls equal the South Sea Island variety in luster and purity of color. They vary in color from the purest white to various shades of pink, and occasionally a black one is found. It is not uncommon to find pearls which sell for from $100 to $1000, and occasionally one is found which brings as high as $3000.

Those which are imperfect in any way, as in form texture or color, are known as slugs. These are the "baroque pearls" of the jeweler, which are now in such high favor. Some of these are of great beauty and may lend themselves to great variety and beauty of design. The pearls and slugs too small for other purposes are sold under the name of seed pearls. These are perforated by minute holes, strung on the finest thread and used in ornamenting lace and embroidery.

Acknowledgments.

The thanks of the Survey are due the many citizens of the county who showed their interest in and appreciation of the work by supplying whatever information was in their possession. The fossils were kindly identified by Professor Samuel Calvin and

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF CLAYTON COUNTY IOWA

BY
A. G. LEONARD
1903

Scale 1/125,000
1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometers

Topography from
Atlas Sheets of U. S. Geological Survey

LEGEND

GEOLOGICAL FORMATIONS

Niagara	Silurian
Maquoketa	Ordovician
Galena-Trenton	Ordovician
Saint Peter	Ordovician
Oneota	Ordovician
Saint Croix	Cambrian

INDUSTRIES

- Quarries.
- Brick Yards.
- Lime Kilns.
- Sand Pit.
- Lead Mines.

ALLAMAKEE CO.
CLAYTON CO.
BOUNDARY LINE
FAYETTE CO
CLAYTON CO.
BOUNDARY LINE
DELAWARE CO.
CLAYTON CO.
DELAWARE CO
BOUNDARY LINE
CLAYTON CO.
DUBUQUE CO.
CLAYTON CO.
BOUNDARY LINE

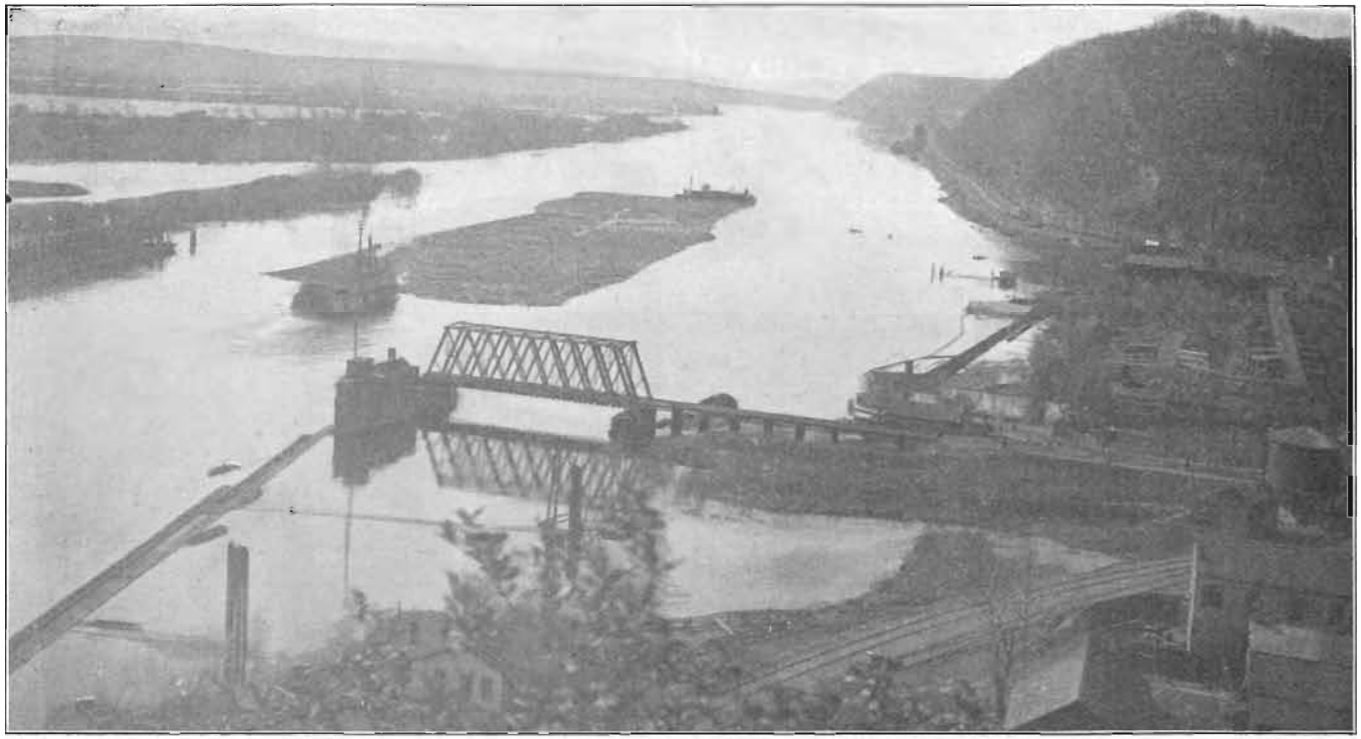
GRAND MEADOW
MONONA
GIARD
MARION
WAGNER
FARMERSBURG
BOARDMAN
HIGHLAND
READ
GARNAVILLO
SPERRY
COX CREEK
VOLGA
JEFFERSON
CASS
LODOMILLO
ELK MAILORY
MILLVILLE
BUENA VISTA

Luana
Monona
Watson
McGregor
Beulah
Froelich
Giard
Bismarck
Wagner
Gunder
Farmersburg
National
St. Olaf
Highland
Read
Clayton Center
Garnavillo
Elkader
Yorkshire
Volga
Motor
Ceres
Guttenberg
Littleport
Elkport
East Elkport
St. Sebald
Strawberry Point
Edgewood
Wood
Osterdock
Millville
Turkey River
North Buena Vista
Graham
Updegraff

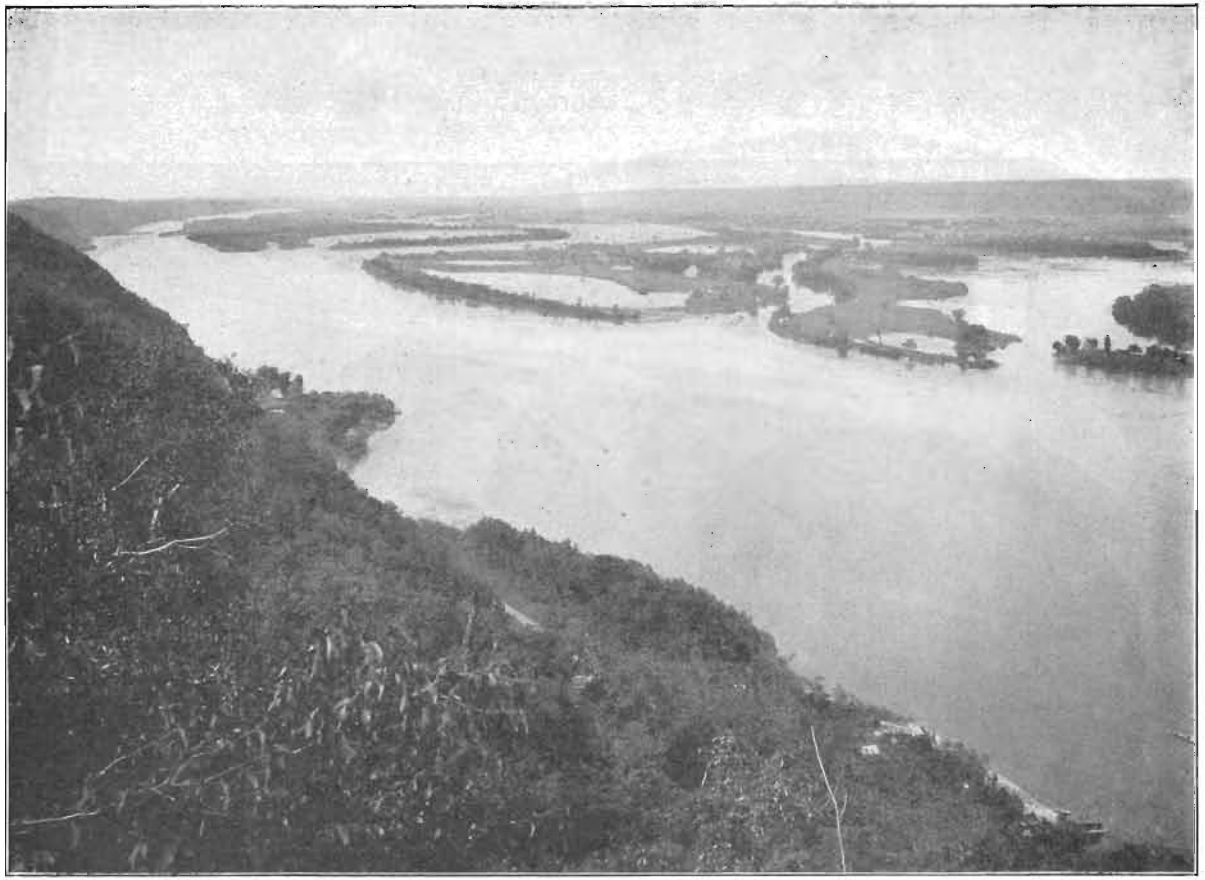
Iowa Publ. Co. Davenport, Iowa.

TRI-CITY LITHO. CO. DAVENPORT, IA.

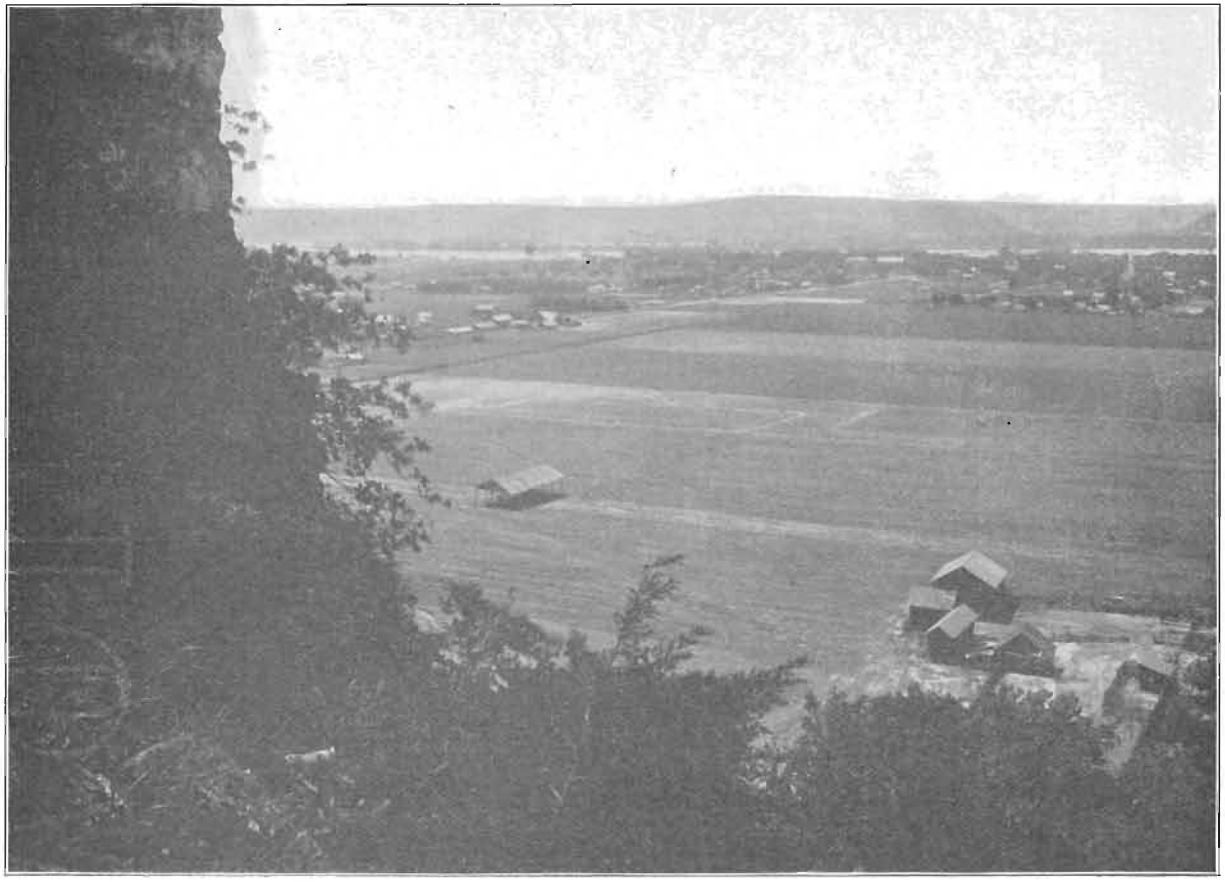
for this and many helpful suggestions the writer is under special obligation. Assistance was also rendered by Mr. J. C. Flenniken whose intimate acquaintance with many portions of the region made his help especially valuable and much appreciated. The great value of the topographic work of the United States Geological Survey should be here acknowledged. The topographic features represented on the accompanying maps of the county have been copied from the sheets of the United States Survey, and without these the mapping of the geological formations would have been a work of infinite labor.



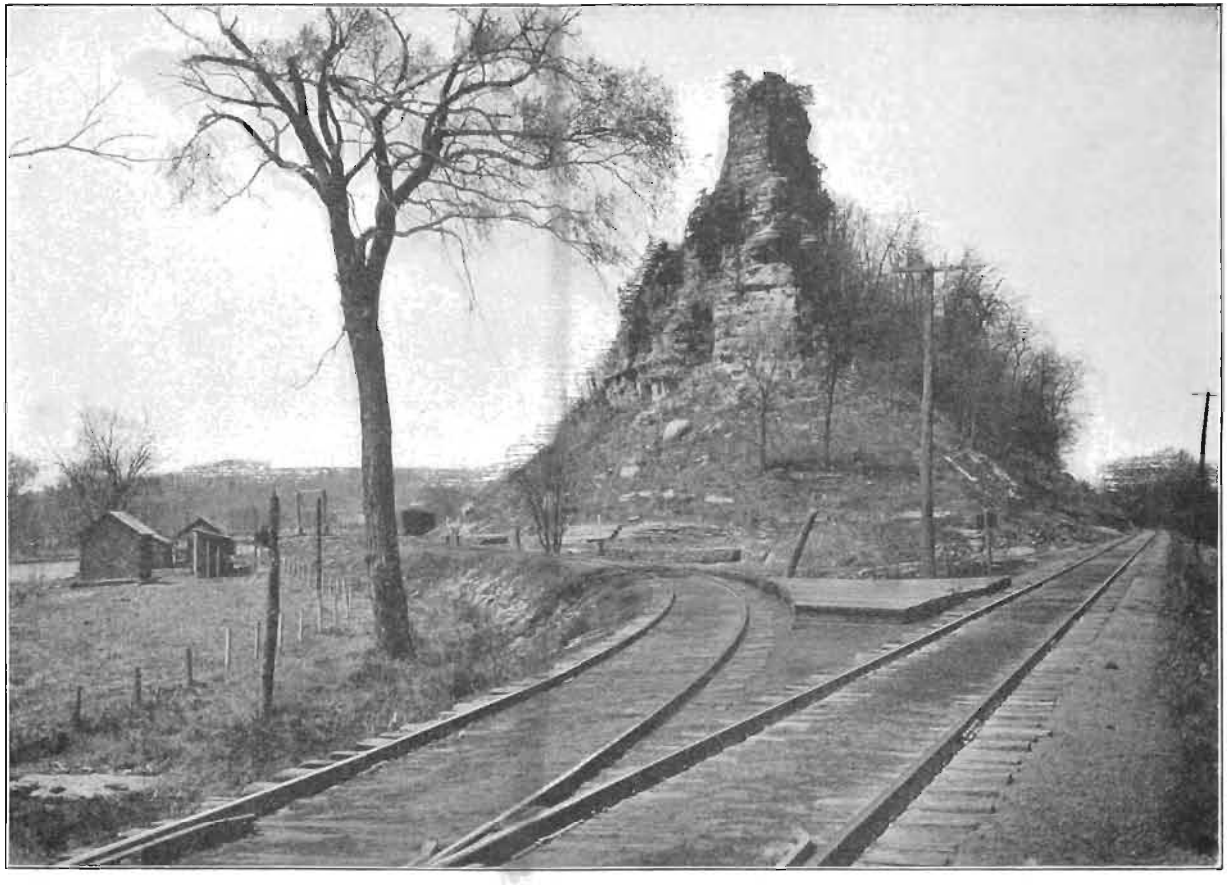
The bluffs of the Mississippi below North McGregor.



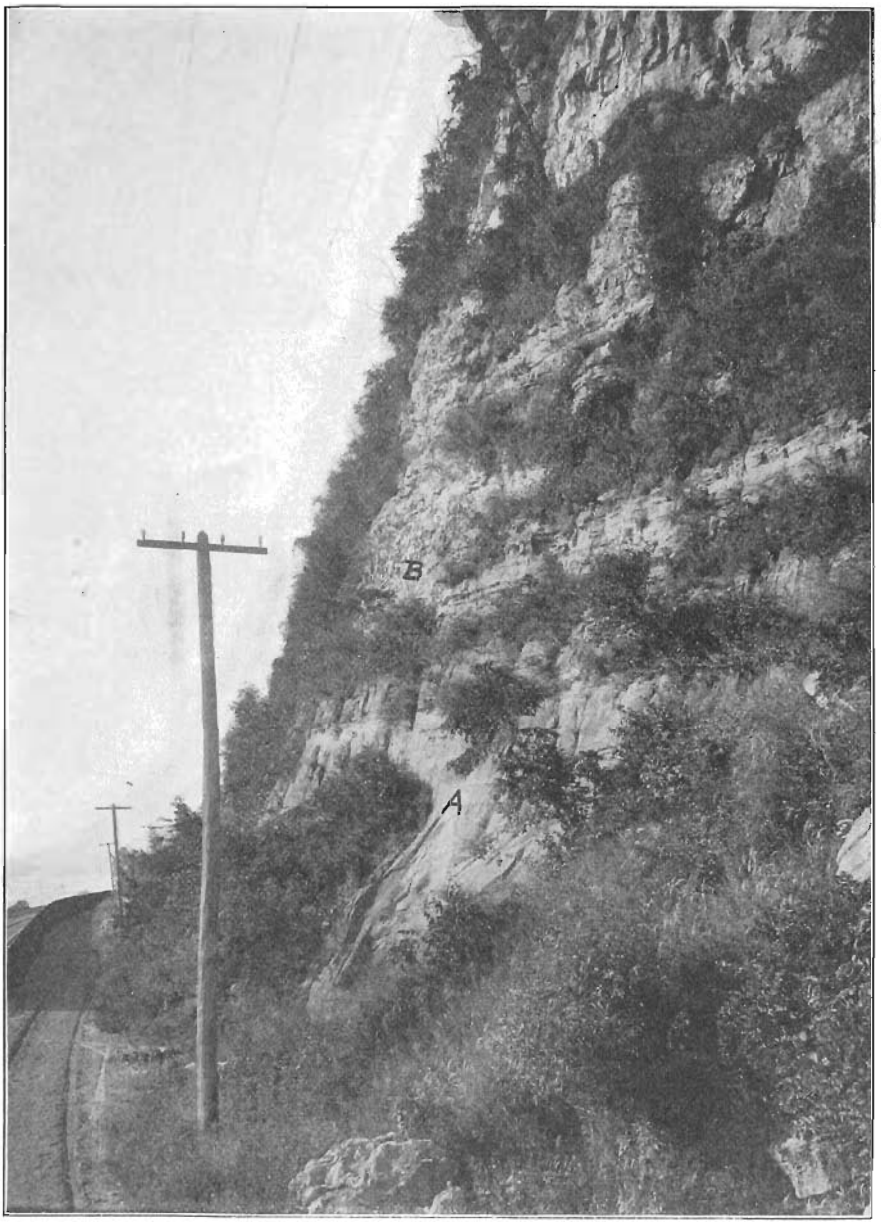
View looking up the Mississippi Valley from Pikes Peak, two miles below McGregor.



The broad flood plain of the Mississippi at Prairie du Chien, looking toward the Iowa shore



Narrow ridge formed of Galena-Trenton limestone at the mouth of the Turkey river



Point Ann, just below McGregor A is the Saint Croix sandstone B is the Oneota limestone