GEOLOGY OF WINNESHIEK COUNTY.

BY

SAMUEL CALVIN.

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CONTENTS.

INTRODUCTION.

GEOGRAPHIC AND GEOLOGIC RELATIONS.—AREA.

In some respects Winneshiek* is the banner county of the state. By virtue of its location it possesses a greater variety of soils and offers a greater range of agricultural possibilities than most of the other counties; it has more geological formations than any other; it presents an unusual number of scientific and economic problems for the consideration of the geologist. Geographically the county lies in the northeastern part of the state; it is separated from the Mississippi river by one county, Allamakee, which bounds it on the east; its northern boundary is the state line between Iowa and Minnesota, the parallel of 43° 30′ north latitude; on the south lies the great county of Fayette; while the counties of Chickasaw and Howard bound Winneshiek on the west. Winneshiek is one of the larger counties of the state, embracing, as it does, twenty congressional townships. The northern townships, however, measure only about five miles from north to south, each lacking the northern sections 1 to 6; the sections along the west side of Lincoln and Orleans townships are fractional; the area of the county is approximately 690 square miles.

Topographically and geologically the location of the county is such as to give this area unusual interest. Along its eastern border, and generally throughout the whole belt traversed by the Upper Iowa or Oneota river, the surface presents the rugged characteristics and conditions of the "Driftless Area" with its

*The spelling of the name of this county has varied fron *Winneshiek* to *Winneshiek*. The first spelling is not uncommon, especially on the older maps and in the earlier publications relating to this part of Iowa; but the second spelling is that authorized by the United States Board on Geographic Names and used in all the official publications of the Federal Government. See *Second Report of the United States Board on Geographic Names 1890-1899, Second Edition*, page 140, Washington, March. 1901.

deep, rock-cut valleys and stony, barren hills. The uplands in the northeastern two-thirds of the county are characterized by the strongly undulating topography which everywhere accompanies the old, eroded Kansan drift with its veneer of loess. In the west and southwest are gently undulating areas of the uneroded, younger Iowan drift. The ill defined border land between the driftless and drift-covered portions of the state passes through the county, and the county is also traversed by the rather sharply defined, sinuous line which marks the abrupt transition from the younger Iowan to the older Kansan.

The claim of Winneshiek to being, geologically, the banner county of the state might well rest on the number of distinct formations represented by the indurated rocks. In the extreme eastern edge of the county the Jordan sandstone. the uppermost member of our Upper Cambrian, occupies some small areas in the valley of Bear creek and along the Upper Iowa river, and this is followed in succession by the Oneota, the New Richmond, the Shakopee, the Saint Peter, the Platteville, the Galena, the Maquoketa, the Niagara, and, finally, the Wapsipinicon and Cedar Valley stages of the Devonian. Within the limits of our area the Maquoketa presents a number of unique features not seen elsewhere, and wholly unlike anything appearing at the type localities in Dubuque county. As a matter of fact the Maquoketa proves to be the most variable and versatile of all our geological formations, changing in lithological and faunal aspects from county to county in the most surprising and unexpected ways, and some of its most striking variations occur in Winneshiek. Here, in the middle of the formation, to give a single illustration, are forty feet or more of hard crystalline dolomite, cherty in places, so entirely different from the typical Maquoketa shales of White* that some very competent geologists have mistaken the beds for the Galena, and some for the Niagara limestone. The Niagara also presents some unusual characteristics. Lithologically it differs from the Niagara of the counties farther south, and it is quite erratic in its distribution. While it is present in some prominent knobs and higher uplands on the east

*Report on the Geological Survey of the State of Iowa, by Charles A. White, M.D., Volume I, page 180, Des Moines, 1870.

side of the Turkey river a few miles southeast of Fort Atkinson, it is entirely absent west of a line drawn through Fort Atkinson and Ridgeway. In this western part of the county the soft, magnesian Devonian—with its spirifers, productellas and other fossils represented by casts and clear cut impressions—overlaps on eroded Maquoketa. The complete disappearance of the Niagara and the unexpected relations of the Devonian to the Ordovician are features which, as already shown*, Winneshiek shares with Howard county.

The greater part of Winneshiek county is located in the small drainage area which is set off from the general drainage of the eastern slope of Iowa by the Cresco-Calmar ridge. The significance of this ridge and its relations to the drainage of northeastern Iowa are discussed in the report on the Geology of Mitchell County, pages 297 and 298, published in volume XIII of these reports.

PREVIOUS GEOLOGICAL WORK.

As compared with many of the other counties of Iowa, Winneshiek has received a fair degree of attention from official geologists. It is quite certain that the territory embraced within the limits of our area was visited by D. D. Owen in 1847. In his "Report of a Geological Reconnoissance of the Chippewa Land District, etc.", published in 1848, Owen, on page 24, mentions a bend in the Upper Iowa river "where the stream flows over solid ledges of magnesian limestone", which place he locates "eight or ten miles below the Big Spring, and by water about sixty miles above the confluence of the upper Iowa with the Mississippi." Reference is made to essentially the same locality on page 35 of the same report.+ Now the only points where the Upper Iowa river flows over ledges of the lead-bearing, magnesian limestone which Owen had in mind, are to be found between Decorah and the eastern border of the county. At Decorah the stream flows over the lower beds of the Platteville

*Geology of Howard county, by Samuel Calvin, pp. 25 and 38, Iowa Geological Survey, Vol. XIII, Des Moines, 1903.

+ This locality is mentioned in essentially the same terms on page 63 of the enlarged *Report of a Geological Survey of Wisconsin, Iowa and Minnesota* by David Dale Owen, Philadelphia, 1852. In this publication he ledges over which the stream flows are specifically stated to be "Lower Magnesian Limestone"; and the adjective part of the name of the stream is capitalized, making it the "Upper Iowa".

limestone and the upper beds of the Saint Peter sandstone. A few miles below Decorah the Saint Peter is cut through to the Shakopee or Upper Oneota, and before the east line of the county is reached the stream has cut through the whole thickness of Owen's Lower Magnesian limestone, down into his Lower sandstone, the Saint Croix. From the west line of Allamakee county to its mouth, the Upper Iowa flows in a channel cut in the Saint Croix sandstone.

In Hall's Geology of Iowa there is a report on "Winnesheik County" by J. D. Whitney* in which he recognizes a succession of strata "from the Lower Sandstone as far up in the series as the lower beds of the Galena." The hard crystalline dolomite at Fort Atkinson, now known to belong to the middle of the Maquoketa or Hudson-River stage, is spoken of as "undoubted Galena limestone." Nothing higher than the Galena is positively recognized in the county, but later formations are suggested by finding "in the extreme southwest corner of the county, an elevated ridge, running parallel with the course of the Little Turkey, in which no rock is exposed, but which, from its position and relations to the rocks known to exist in the neighboring counties, is undoubtedly the outcrop of the Niagara limestone."

In Dr. White's report on the Geological Survey of the State of Iowa, published in 1870, there are no references to Winneshiek county as such, but on page 80 of volume I there is a very good description of the ice cave at Decorah.

Winneshiek county is embraced in the area studied by McGee and reported on in detail in his *Pleistocene History of Northeastern Iowa*. In this memoir, which forms the major part of the Eleventh Annual Report of the United States Geological Survey, 1891, there are descriptions of the topography, drainage, soils, rocks and well sections of this county. The hard, Maquoketa dolomite at Fort Atkinson, however, seems to be counted as part of the Niagara escarpment.

Numerous articles on the Decorah ice cave have appeared from time to time in the newspapers and magizines. An article

*Report on the Geological Survey of the State of Iowa by James Hall, *State Geologist*, and J. D. Whitney, *Chemist and Mineralogist;* Vol. I, Part I, pp. 312-317, 1858.

by A. F. Kovarik in the *Scientific American Supplement* for November 26, 1898, is of especial interest. Mr. E. S. Balch refers at some length to the ice cave at Decorah in his exhaustive volume on *Glacieres or Freezing Caverns,* published in Philadelphia, 1900.

PHYSIOGRAPHY.

TOPOGRAPHY.

It is probably true that no county in Iowa presents a greater range of topographic forms than Winneshiek. The county lies within the limits of maximum preglacial uplift for this part of the Mississippi valley; and so, before the advent of the earliest glacial ice, the drainage streams had carved deep trenches and gorges in the indurated rocks. At least two of the great ice sheets from the Keewatin centers of dispersion—the Kansan and the Iowan—invaded the county, and each has left its impress on the topography. It was only the attenuated margins of these ice sheets, however, that reached the territory we are considering, and in each case the amount of detrital material carried was comparatively small. The result was that the very thin mantle of drift deposited over the county produced practically all of its effects on the uplands, so far as it was effective in modifying and disguising the old topography. Along the main drainage courses it was quickly swept away, leaving all the larger valleys, and the territory immediately contiguous to them, in possession of their preglacial characteristics. Preglacial topography, or Driftless Area topography, for example, is illustrated along the whole course of the Upper Iowa or Oneota river in Winneshiek county. The stream flows in a deep, rock-cut canyon from the point where it enters the county, near the northwest corner, until it takes its final departure, near the mouth of Canoe creek, in section 25 of Pleasant township. The part of the valley about Decorah and thence northwestward to the county line, is walled with bold, precipitous and picturesque cliffs of the Galena limestone, and all the tributaries entering the stream in this part of its course flow in steep-sided, rocky gorges. The bluffs about Decorah, rising sheer in places to hights of more than 100 feet,

and continuing to rise in rounded slopes for another 100 feet or more, are typical of those seen at other points along the upper courses of the river in this county. The general direction of the stream northwest of Decorah is nearly parallel to the strike of the strata, and for this reason the same beds and the same general type of escarpments recur at all the numerous points where cliffs are developed. Such variations as do occur in the appearance of cliffs arise from the fact that in following the windings of the river the cliff faces are sometimes parallel to the master joints that cut through the limestone in an east-west direction, and in other cases are at right angles to these joints. The very impressive, regular and smooth surfaced wall (Fig. 8) that rises sheer from the water's edge, layer upon layer, at Bluffton, coincides with a great joint face; while the more picturesque cliff above the bridge (Fig. 9), less than a mile away, and looking as if made up of massive, clustered columns, owes its striking peculiarities to the fact that its trend is at right angles to the joints. Weathering has eaten in along the joints, widening them, dissolving and trimming off the angles, and leaving the rounded, protuberant faces of the intervening blocks as semi-cylindrical pilasters supporting the massive wall. At Plymouth Rock, a few miles farther up the stream, there is another great cliff parallel to that above the bridge near Bluffton, and here, for the same cause, the same striking, columnar features are developed (Fig. 10).

A short distance below Decorah the stream turns at right angles to the course previously followed and flows in a direction opposite to the dip. The beds below the Galena are quickly cut through, one after the other, and each affects the width of the valley and the character of the bluffs. Owing to the presence of the friable Saint Peter sandstone, the valley widens out and the slopes are less steep for a short distance above and below Freeport. From section 9 of Glenwood township to the east county line, the Shakopee and Oneota dolomites form bold steep cliffs between which the river flows. At the mouth of Canoe creek, in section 25 of Pleasant township, the channel has been cut to a depth of thirty or forty feet in the Jordan sandstone, but the Oneota limestone asserts itself in the castellated crags and scarps that make up the greater part of the walls of the valley.

The same type of topography, unaffected by the drift and expressed in bold, precipitous, rocky cliffs due to preglacial erosion, occurs along Canoe creek in Canoe and Pleasant townships; and also along Bear creek in Highland township, from above Highlandville to the county line. In this northeastern part of the county the principal cliff-forming formation is the Oneota limestone. There are numerous low cliffs of Galena limestone along the gorges in the southern half of Glenwood township, and the upper beds of the Galena form a vertical wall twenty-five to thirty feet in hight in the banks of the Yellow river, near the county line, in section 13, Bloomfield township.

Throughout the eastern portion of the county there are occasional patches of typical, weathered Kansan drift on the uplands, but there are extensive areas in which no drift is seen, and the topography in general is that of the Driftless Area. The drift here is so thin, so patchy, so given to appearing in unexpected places, that, notwithstanding its inefficiency in modifying the preglacial topography, and notwithstanding the fact that over more than eight-tenths of the eastern half of the eastern townships the loess rests directly on dark residual clays, it is not deemed advisable to attempt to set off the driftless, from the drift covered parts of the county by a definite line.

The Saint Peter sandstone forms a number of conspicuous knobs, ridges and scarps in Highland, Hesper, Canoe, and Pleasant townships. The deposit, though very friable, is insoluble, and, if not exposed to mechanical disintegration, will stand indefinitely. One of the most conspicuous of the ridges occurs in section 8 of Highland township. In this case, however, there is a thin capping of the Platteville limestone on the highest points. The slopes are steep, rising abruptly from a comparatively level area which coincides very nearly with the upper surface of the Shakopee limestone. Practically the whole thickness of the Saint Peter is included between the base and summit of the ridge. An escarpment of the sandstone sends out very prominent and conspicuous salient in section 12 of Hesper township (Fig. 5). A few rods south of the Norwegian Lutheran church in the northern part of section 3 of Pleasant township,

there occurs a very characteristic sandstone ridge which rises abruptly from the level region on the north to a hight of sixty or seventy-five feet. Another equally good illustration of the peculiar topography, controlled by the Saint Peter sandstone, is seen in the great ridge running through sections 14, 15 and 16 of the same township, northwest of Sattre. Some prominent, conical knobs or monadnocks of Saint Peter are seen in section 21 of Pleasant township; while in Canoe township there are many knobs and ridges and other conspicuous topographic forms due to the presence of the Saint Peter sandstone. Some in the southern part of section 13 deserve especial mention. Knobs and ridges having the same structure and the same general characteristics are found north of the state line, in Minnesota; and it may be remarked that the presence of so many prominent remnants of a sandstone as friable and as ready to yield to mechanical disintegration as the Saint Peter, would indicate that the glacial ice which spread the scattered patches of drift so generally found in all of this region, was not very effective as an agent of erosion. The Jordan sandstone of the Saint Croix stage of the Cambrian affects but a very small area in Winneshiek county and is not an important factor in controlling the topography. Nevertheless, the stream valleys that cut into the eastern edge of sections 24 and 25 of Pleasant township and section 25 of Highland township, present decided, though low, vertical cliffs of the friable Cambrian sandstone.

The Shakopee and Oneota limestones are traceable in the topography over extensive areas in the northeastern part of the county. Along the stream valleys they, together, form bold, picturesque, vertical cliffs, as already noted; but in the interstream areas the Shakopee gives rise to wide, nearly level unbroken spaces which coincide with the upper surface of the formation and surround the abruptly sloping hills of Saint Peter sandstone. From the tops of some of the Saint Peter ridges the spaces controlled by the dolomite may look like very broad, flat bottomed valleys. The Shakopee limestone is capable of resisting both solution and mechanical erosion quite effectively. On the other hand the Saint Peter, when cut through by stream corrasion, recedes rapidly on account of the readiness with which it

yields to mechanical wear. This wear is always greatest on the steep slopes at the exposed edges of the body of sandstone; and so the flat spaces referred to as determined and controlled by the Shakopee are areas from which the sandstone has been progressively stripped off, down to the surface of the more resistant, underlying formation.

The Platteville and Galena limestones produce their most pronounced effects, topographically, along the stream valleys. They yield quite readily both to corrasion and solution. Their influence is not conspicuous in the surface configuration of the interstream spaces, except so far as they are responsible for the countless numbers of sink holes which occur in the eastern part of the area of their distribution, in a region where the drift mantle is comparatively thin.

The beds of the Maquoketa stage occupy a much larger area in Winneshiek county than any other formation of the indurated rocks, and throughout the greater part of this large area there are no very marked topographic features due to the presence of this formation. The beds, though much more indurated than the Maquoketa of Dubuque county, break down quite generally under the effects of weathering, and so cliffs, knobs or ridges of the Maquoketa stage are exceptional. Furthermore, the Maquoketa area has been covered with a comparatively thick mantle of drift which has modified and concealed to a large extent the effects of preglacial sculpturing of the bed rock. About the middle of the formation, however, there is in this county, as there is in Fayette, a series of hard, crystalline, dolomitic beds, the Fort Atkinson limestone (Fig. 12), forty feet in aggregate thickness, which gives rise to some conspicuous ridges and escarpments. The best example of the effect of the Fort Atkinson beds is seen in the high prominence on which stand the old buildings of the fort at the town of Fort Atkinson. The platform on which the village of Festina is built is held up by the Fort Atkinson limestone, and a very marked escarpment (Fig. 1) facing the small stream valley southwest of the village

Fig. 1–Steep slopes due to the Fort Atkinson limestone, seen along a small valley southwest of Festina, Washington township.

is due to the same formation. Along Ten Mile creek, in sections 7 and 18 of Madison township, there are some very unusual topographic forms. Here is found a unique and wholly unrelated assemblage of hills, prominent salients and steep slopes, rising from the narrow valley, and all constructed of the more shaly beds of the Maquoketa. Some of the hills stand well above the general level of the surrounding country, being remnants of strata once more widely distributed, remnants which, for some cause, have escaped the processes of denudation which brought the surrounding country to its present level. At present no explanation of the peculiar character and complete isolation of this strange bit of topography can be offered.

The Niagara limestone controls the character of the surface forms in the southeastern part of Washington township. In sections 35 and 36 the Niagara rises in a broad plateau 250 feet above the platform of Fort Atkinson limestone on which the village of Festina stands. Southwest of Festina, about on the line between sections 23 and 26, there is a point which rises even higher than the plateau to the south. This is part of an extensive mass or ridge of Niagara which, on its western side, runs

out into a series of bold and prominent salients facing the valley of the Turkey river in sections 26 and 27. A large isolated cone of Niagara in the western edge of section 35 is but another example of the characteristic topography controlled by the Niagara in this part of Washington township. There is another very prominent conical hill of this formation west of Festina, about on the line between sections 22 and 23 (Fig. 13). This cone stands apart from the other uplands of the Niagara, overlooking the lower plain which stretches away to the north, and is the most northerly outlier of this formation observed in Iowa. A long, elliptical hill in sections 28 and 33, with an elevation of 200 feet above the river valley, is the only marked bit of topography dependent on the Niagara, observed on the west side of the Turkey river.

There are some quite pronounced topographic features in the western part of the county, due to the Devonian limestone. In this region the Devonian overlaps on the Maquoketa. Beginning in the southwest corner of Fremont township and traversing the western edge of Orleans, are well defined, sinuous escarpments of Devonian, rising with convex, rounded slopes to a hight, in places, of fifty feet above the plain occupied by the more shaly underlying formation. In sections 1 and 12 of Jackson township there are some features characteristic of many of the hills around Fort Atkinson. Two nearly parallel and horizontal belts of rock (Fig. 16), due to the outcropping of harder ledges, appear on the slopes about twenty feet apart vertically. The upper one is the outcrop of dolomitized Devonian, the lower is produced by the uppermost ledges of the Fort Atkinson limestone belonging to the middle of the Maquoketa.

The effects of the Pleistocene deposits on the topography are much less in Winneshiek county than in parts of Iowa covered with a heavier mantle of drift. A comparatively small area in the western part of the county is occupied by drift of the Iowan stage. The remainder, and much the larger part of the county, so far as surface configuration is determined by Pleistocene deposits at all, shows the characteristic features of what has been called the Loess-Kansan topography. This type of surface is thoroughly drained and is carved by storm waters into an

intricate system of branching ravines with well rounded intervening ridges. On the uplands, outside the influence of the drainage courses, topography of the Loess-Kansan type is well illustrated throughout the greater part of the southeast quarter of Winneshiek county. The type is especially well marked on both sides of the railway between Castalia and Ossian. Another area of the same character embraces practically all of the townships of Hesper and Burr Oak with adjacent parts of Highland and Fremont.

The line between the Loess-Kansan and Iowan areas is very irregular and does not admit of ready description. The very erratic and curiously lobulate character of the margin of the Iowan ice sheet is well exemplified in this county. Beginning on the west side of the Turkey river at the point where this stream passes into Fayette county, the Iowan border line follows the river northward almost to Fort Atkinson. It passes a short distance west of the town named and then bears northward to Spillville. East of Spillville there is a short, broad lobe of Iowan which pushes southeast almost to Calmar, from which point the Iowan boundary passes around west of Conover, and thence northeastwardly to the southeast corner of section 35, Madison township. From the point last named the line extends northwest for a distance of twelve or thirteen miles when, near the middle of section 32, Orleans township, it makes a sharp curve and returns southeastwardly, parallel to its former course, to near the southeast corner of section 12, Lincoln township. Here, curving sharply to the northwest for a short distance and then looping back so as to form two small lobules of Iowan, it finally reaches a point near the northwest corner of section 35, Orleans township. With another very sharp curve the line turns to the southeast, which course it follows with but little deflection for a distance of about seven miles, to near the center of section 3, Madison; and then changing abruptly to the northwest it follows a rather simple, sinuous course of thirteen or fourteen miles to the west county line, in section 30 of Fremont. West of this line, the peculiarities of which will be best appreciated by reference to the map of Pleistocene deposits, the surface, so far as it is controlled by the drift, is characterized by the gentle undulations

of the uneroded, young Iowan till. The surface remains to-day essentially as it was left when the ice of the Iowan stage disappeared from the region. There has been no general erosion of the surface since; no loess has been deposited; there are many large, granite bowlders strewn over the area; where the Iowan ice deposited sufficient drift, the pre-Iowan topography is completely obscured; where the load carried and deposited by the ice was small, the effects of pre-Iowan, and, in some cases, of preglacial, erosion are still manifest. The escarpments of Devonian limestone in Orleans township, for example, are features of the surface due to rock sculpturing before the coming of the earliest ice, features which were not masked or destroyed by either of the drift sheets or by both combined. Another case of the same kind is seen north of the center of section 21 in this same township, where some steep hills are controlled by the cherty dolomite of the Fort Atkinson beds.

As usual, within the Iowan area and near its margin, there are many of the peculiar topographic forms called paha by McGee. These are loess-covered knobs or hills rising out of the Iowan plain and usually containing no Iowan drift. As examples there may be noted a chain of paha, blending in places into a practically continuous ridge, stretching across the north side of section 33, and another parallel chain a short distance north, in the adjacent section 28, Orleans township. The most symmetrical of these forms is a small, beautifully rounded paha which stands alone in the southeast corner of section 36, Sumner township.

There are some topographic features due to comparatively recent shifting of the mantle rocks which deserve attention. Throughout that part of the county lying east of the Iowan margin, there are evidences of a time of active aggradation of the small valleys, during which all were filled to a greater or less extent with clays and more or less angular rock fragments, some to depths of fifteen or twenty feet. The effect was to render the bottom of the valleys broadly concave, a feature that still persists in many instances. Quite recently, however, the drainage waters have been cutting deep trenches in the deposits referred to, and practically all the smaller valleys and upland sags in the surface show the effects illustrated in figure 2.

Fig. 2—Re erosion of an aggraded valley in the northeast quarter of section 21, Glenwood township.

When the county is looked at as a whole, there are a few topographic features of commanding importance. One of these is the Cresco-Calmar ridge to which reference is made in the Introduction. It is followed by the line of the Chicago, Milwaukee and Saint Paul railway as it crosses the county on the way from Postville to Cresco. The highest point of the ridge in Winneshiek, 1269 feet above tide, is reached at Ossian. The crest of the ridge forms a watershed, northeast of which lies the drainage basin of the Upper Iowa or Oneota river, another surface feature on a large scale, which may be taken as a single geographic unit. On the same side of the ridge, in the southeast corner of the county, is a small area which forms part of the Yellow river basin. Southwest of the ridge lies the broad basin of the Turkey river.

Following is a list of elevations above sea level, taken along the

ridge from Postville in Allamakee county to Cresco, Bonair and Lime Springs in Howard:—Postville 1195, Castalia 1245, Ossian 1269, Calmar 1257, Ridgeway 1209, Cresco 1300, Bonair 1309, Lime Springs 1246. Decorah, in the valley of the Upper Iowa, has an elevation of 875 feet, the Upper Iowa at the east county line, 760 feet. The highest point noted in the county occurs a short distance west of Hesper, with an elevation of 1360 feet. The maximum relief in Winneshiek county is about 600 feet.

DRAINAGE.

The drainage of the county is divided into two systems by the Cresco-Calmar ridge. A little more than two-thirds of the surface lies northeast of the ridge and is drained almost wholly by the Upper Iowa or Oneota river. From the northwest corner of the county the general course of the master stream is parallel to the ridge and at an average distance of about eight miles from the crest. From Decorah to the Allamakee county line the direction is nearly at right angles to that previously followed. The ridge on which Hesper is located constitutes the northeastern rim of the basin drained by the Upper Iowa. The two ridges are about equally distant from the axial stream; their sides are drained by a number of small creeks, none of which, under ordinary conditions of precipitation, attain any considerable importance. Canoe creek, which drains the larger part of Canoe and Pleasant townships, is the largest stream in the county tributary to the Upper Iowa. Nearly the whole of Highland township is drained by the initial branches of Bear creek, which becomes a stream of some importance before its confluence with the Upper Iowa in Allamakee county. Of the remaining streams on the north side of the basin Pine creek and Silver creek, which gather the storm waters from Burr Oak township, are most deserving of mention. South of the main river there are Ten Mile creek in Madison township, Trout creek draining Springfield township and the southern part of Decorah, and another Trout creek which drains most of Glenwood township and the northern part of Frankville. Altogether the tributary streams on both slopes of the Upper Iowa basin are small. Most of them are intermittent, all have steep gradients in some parts of their

courses and hence are found carrying destructive torrents on the occasion of heavy rainfall. During periods of drought the steep, stony beds are dry. Throughout all of this region the drainage is mostly underground. In times of normal precipitation the water quickly disappears from the surface, descending through countless sink holes, and in other ways, to passages in the much shattered and jointed underlying limestones. So much of this water as finds its way to the river emerges again in the many springs for which the valley is noted. The numberless terminal twigs of the upper branches of the Yellow river are spread out, fan-like, over the greater part of Bloomfield, and the southern sections of Frankville township, and carry off the surface waters from this small basin in the southeastern part of the county.

A narrow strip, embracing a few sections of land along the northern edge of Highland and Hesper townships, lies beyond the north rim of the Upper Iowa basin and drains into the Root river system in Minnesota. Southwest of the Cresco-Calmar ridge the surface is drained by the Turkey river, which flows almost parallel to the upper course of the Upper Iowa and, like the Upper Iowa, has few tributaries of any importance in Winneshiek county. Practically all of Jackson township and the western part of Sumner present the characteristic topography of the typical Iowan drift plain. There has been no erosion, and drainage is effected by the flow of surface waters along very broad, shallow sags, products of glacial moulding and not of erosion, which here take the place of definite stream courses.

STRATIGRAPHY.

Geographic Relations of the Strata.

Winneshiek county, as already noted, has a greater number of geological formations than any other county in the state; and owing to the fact that the drift mantle is thin or wholly absent along, or near to, the main drainage courses north and east of the Cresco-Calmar ridge, the rock exposures in this part of our area are numerous and in the main satisfactory. The greater

number of the formations have their outcrops in the northeastern part of the county. All the exposures from which our knowledge concerning six of the geological units recognized among the indurated rocks of this area is derived, are grouped in Highland, Hesper, Canoe, Pleasant, Glenwood, and Decorah townships. Two more formations, the Galena and the Maquoketa, have outcrops within these same townships, and so the remaining fourteen townships add but two additional units to the list, the Niagara and the Middle Devonian limestones.

Residual cherts and the dark, tough residual clays, called geest by McGee, are best developed in the eastern townships where the drift is thin or never was deposited. In the western part of the county the residual materials, which constituted the preglacial soils, were either scoured away by the earlier ice sheet, or were covered and concealed by the load of detritus which it carried and deposited. Kansan drift and loess, as surface deposits, are seen only east of the very irregular line which marks the border of the Iowan; the Iowan drift is thin, scarcely ever seen in vertical sections, and is limited, geographically, to the western portion of the county. Along the valley of the Upper Iowa or Oneota river below Decorah there are extensive valley trains and terrace deposits, some belonging to the time of melting of the Kansan ice, some of much later age to be correlated with the Iowan.

SYNOPTICAL TABLE.

GROUP	SYSTEM	SERIES	STAGE	FORMATION
Cenozoic	Pleistocene	Recent		Alluvium.
		Glacial	Iowan	Iowan loess.
				Iowan sand terraces.
				Iowan drift.
			Kansan	Post-Kansan loess.
				Buchanan gravels.
				Kansan gravel terraces.
				Kansan drift.
				Residual materials, Geest.
Paleozoic	Devonian	Middle Devonian	Cedar Valley	Lithographic limestone, etc.
			Wapsipinicon	Up. Davenport limestone.
	Silurian	Niagara	Hopkinton	Hopkinton limestone.
	Ordovician	Trenton	Maquoketa	Brainard shale.
				Ft. Atkinson limestone.
				Clermont shale.
				Elgin shaly limestone.
			Galena	Galena limestone.
			Platteville	Decorah (Green) shale.
				Platteville limestone.
		Canadian	Saint Peter	Glenwood shale
				Saint Peter sandstone.
			Lower Magnesian limestone of Owen	Shakopee limestone.
				New Richmond sandstone.
				Oneota limestone.
	Cambrian	Potsdam	Saint Croix	Jordan sandstone.

New Names Used in the Synoptical Table.—In the foregoing table some new names are used. The reasons for their introduction will appear in connection with the discussion of the individual formations to which they apply. The term Post-Kansan Loess is used for an old, altered loess deposit which lies on the Kansan drift, but is much older than the better known and more widely distributed Iowan loess. This old loess has been noted by Shimek in some recent papers, but this is the first time it has been recognized in these reports. The Hopkinton stage of the table is the same as the Delaware stage of earlier reports. Delaware, as a name for a geological formation, was preoccupied, having been used by Professor Orton for a member of the

Devonian system of Ohio, in 1878, and the term, Hopkinton, is here substituted for it as a designation for the phase of the Silurian represented in Delaware county, Iowa. The formation is well illustrated in the bluffs and quarries near Hopkinton. The unique development of the Maquoketa in Fayette and Winneshiek counties, as will appear from the general description of this formation in pages following, requires the use of four terms to denote the several units into which it is naturally divided in this part of Iowa. The persistent body of shale between the two parts of what has generally been called the Trenton limestone, is named Decorah shale from the city in which it is typically developed. Heretofore it has been recognized as a distinct geological unit under the name "Green Shales", first applied to it by the geologists of Minnesota. The term, Platteville, has recently been proposed by Bain to denote the lower part of the assemblage of strata for which the term, Trenton limestone, has been so generally used by Wisconsin, Minnesota, and Iowa geologists. The body of shale between the Saint Peter and Platteville, described as the "Basal Shale" in earlier reports and supposed to represent the initial phase of the Trenton series, is developed to a thickness of fifteen feet in Glenwood township, and there shows streaks and bands of sand which indicate relationship with the Saint Peter sandstone. The three units which in the earlier reports on the geology of Wisconsin and Iowa have been grouped under the single term of Lower Magnesian limestone, or Oneota limestone, are here recognized as sufficiently distinct to deserve separate names, and, following McGee and Bain, the term Oneota is limited to the lower division, and New Richmond and Shakopee are used for the other two units with the limitations given to them in the later reports on the geology of Minnesota. Owen's original name, the Lower Magnesian Limestone, which has so long been used and is so universally known among geologists, is tentatively retained for the stage represented by these three distinct units. This will occasion no confusion, and may be allowed to stand until some acceptable geographic term has been proposed as a substitute. All the other names in the table have been used in earlier reports.

Four systems of indurated rocks, the Cambrian, Ordovician,

Silurian and Devonian, are represented in Winneshiek county. Three of these, however, the Cambrian, Silurian and Devonian, are not here developed with any degree of completeness; the beds belonging to each are, in the aggregate, very thin, and the areas which they respectively occupy are relatively small. The main body of rocks in the area under consideration belongs to the Ordovician. The total thickness of the Ordovician sediments is more than 800 feet; the aggregate thickness of the other three systems, so far as they are developed within the limits of the county, does not exceed 300 feet.

CAMBRIAN SYSTEM.

Potsdam Series.

JORDAN SANDSTONE.

The Jordan sandstone, the upper member of the Saint Croix stage of the Upper Cambrian, is confined to two small areas in the eastern edge of the county. One of these is in the valley of Bear creek, in the eastern part of section 25, Highland township. For about one-fourth of a mile west of the county line the upper twenty or thirty feet of the Jordan is exposed at the base of the bluffs which rise from the edge of the water on the south side of the creek. On the north side of the valley the bluffs are some distance from the stream, the slopes are comparatively gentle, and the beds are largely concealed with rock waste and sod; but at one point, in the southeast quarter of the northeast quarter of the section named, the wagon road has cut into, and exposed the sandstone. In the lower part of the exposures the formation is composed of coarse, friable, quartz sand, without very definite bedding, imperfectly cemented, and dull and dingy in color. Higher up there are beds of sandstone alternating with limestone or dolomite, and there are other beds consisting of clean quartz sand, with grains well rounded and water worn, embedded in a calcareous matrix. These last beds constitute the "calcareo-siliceous oolite" referred to by Owen in his "Report of a Geological Survey of Wisconsin, Iowa, and Minnesota", pages 49 and 52. They are limited to a zone of about twenty feet immediately below the overlying Oneota magnesian

limestone, and represent the somewhat gradual transition from conditions favoring the accumulation of sandstone to the deeper, clearer, more quiet seas in which the formation of limestone became possible. At Quandahl, about a fourth of a mile east of the county line, the purely sandstone phase of the Jordan is exposed for a thickness of thirty feet. Owing to the fact that the valley of the stream descends rapidly to the east while the beds have a slight dip to the west, only a few feet of the sandstone below the transition beds are seen at this locality in Winneshiek county. In reality the strata in this part of the county have a northerly, as well as westerly dip. There are many springs along the south side of the valley of Bear creek in this immediate vicinity, but none on the north.

The second exposure of the Jordan sandstone occurs in sections 24 and 25 of Pleasant township. The upper fifty feet of the sandstone, including the transition beds, are exposed in the bluffs of the river, near the county line, in the northeast quarter of the northeast quarter of section 25 of the township named. The river bluffs here are simply an extension of the bluffs on the north side of the valley of Canoe creek, for at the point where the river receives the tributary, it turns so as to flow for a short distance parallel to the course of the smaller stream. The beds here dip strongly to the west, and in consequence the sandstone disappears in the bluffs of Canoe creek a short distance above its mouth. Exposures of the Jordan extend up the valley of the small stream that traverses section 24, almost to the center of the section, where, owing to the increasing hight of the valley and the westward dip of the formation, the sandstone passes out of sight beneath the basal ledges of the Oneota. The characteristics here are the same as in the valley of Bear creek. The Jordan sandstone has no economic significance; it has furnished no fossils in this county; it adds no special feature to the topography.

ORDOVICIAN SYSTEM.

Canadian Series.

ONEOTA LIMESTONE.

The Jordan sandstone, described above, is the upper part of the Potsdam of the earlier writers on the geology of Iowa and Wisconsin, the upper part of Owen's "Lower Sandstone", the upper part of the "Saint Croix Sandstone" of the more recent reports on the geology of Minnesota and Iowa. Between the top of the Jordan and the base of the Saint Peter sandstone there lies an assemblage of beds, mostly dolomites, all of which were included by Owen in his "Lower Magnesian Limestone." The term, Lower Magnesian Limestone, has been used in the same sense in which it was used by Owen in later works by Hall, White, Chamberlin and many others. The fact that the formation described by Owen under the designation noted was, in places, divided into three distinct units by the interpolation of a thin deposit of sandstone between an upper and a lower body of magnesian limestone, seems to have been overlooked by the earlier geologists. This arenaceous member, however, varies greatly in thickness, and in some cases it appears to be entirely absent; but when it is present it is the practice, in recent literature, to follow the Wisconsin and Minnesota geologists and call it "The New Richmond Sandstone." The body of dolomite between the New Richmond and the Saint Peter formations has been named "The Shakopee Limestone" in the geological reports of Minnesota, while McGee has proposed the name "Oneota Limestone" somewhat indefinitely, but apparently for the heavy deposits of dolomite lying between the Jordan and New Richmond sandstones. It is true that in his table of formations in the region covered by his memoir on *The Pleistocene History of Northeastern Iowa,* on page 334 of the *Eleventh Annual Report of the United States Geological Survey,* Part I, McGee uses the term, Oneota, as the equivalent of all the formations between the Potsdam and the Saint Peter, but McGee's Saint Peter is not the Saint Peter of Owen or of authors generally who have written on the geology of this part of the Mississippi valley. On page 332, and elsewhere in the work cited, he

extends the Saint Peter downwards so as to make it include the Shakopee and New Richmond formations, thus leaving only the lower member of the old "Lower Magnesian Limestone" to which the term Oneota was applied.

The Saint Peter sandstone, as defined by Owen, is a natural and consistent geological unit sharply set off from the beds both above and below it. It has nothing genetically or structurally in common with the Shakopee limestone on which it rests, nor has it anything more than the fact that it is composed of quartz sand to ally it to the New Richmond. Accordingly, in the recent reports on the Geology of Iowa, the term Saint Peter has been restricted to the definite and characteristically individual body of sandstone to which it was originally applied by Owen. At the same time, owing to the inconstancy of the New Richmond, its frequent entire absence, and the consequent occasional blending into one of the two bodies of dolomite between which it normally lies, McGee's term Oneota was extended to make it the exact equivalent of Owen's "Lower Magnesian Limestone." In Winneshiek county, however, as well as in many other portions of the area over which it is distributed, the New Richmond sandstone is very persistent, and in some places it attains a thickness entitling it to recognition as a distinct stratigraphic unit. For which reasons, as well expressed by Bain in his report on the *Zinc and Lead Deposits of Northwestern Illinois,* Bulletin No. 246, U. S. Geological Survey, page 18, "It seems well to go back to McGee's definition so far as restricting Oneota to the lower or main dolomite is concerned, and to adopt the Minnesota terms, New Richmond and Shapokee, for the upper beds." Following this suggestion, the term Oneota is here used to denote the great body of dolomite lying between the Jordan and the New Richmond sandstones. Thus limited, the Oneota limestone has a thickness in Winneshiek county of 150 feet. For thirty or forty feet above the base of the formation the dolomite is evenly and regularly bedded, is light buff in color, of fairly uniform texture, is easily shaped by the art of the stone cutter and may be obtained from the quarry in blocks of almost any desired dimensions ranging up to thirty inches in thickness.

The exposures of this quarry horizon in Winneshiek county are not numerous. The beds are seen in the bluffs facing the valley of Bear creek from Highlandville to the county line. Near the mouth of Canoe creek, in section 25 of Pleasant township, the beds are seen above the exposures of the Jordan sandstone, and from the east line to beyond the center of section 24 of the township last named, there are outcrops of the same horizon. The best exposures of the Oneota quarry beds in Iowa are to be found along Bear creek and its branches in Allamakee county.

At Highlandville, a few rods above the north bridge over Bear creek, the upper layers of the quarry beds are seen at the level of the stream. North of the village the higher portion of the Oneota limestone is exposed in a series of bold, vertical cliffs, a part of the system of picturesque scarps and towers and castles which crown the sides of the valleys, with practical continuity, from this point to the Mississippi river. The exposed portion of the limestone begins at the top of a steep talus slope, seventy-five feet above the level of the stream. The rock is a hard buff-colored, vesicular, crystalline dolomite, lacking uniformity, however, with bedding planes largely obscured or completely obliterated, and presenting an appearance of solidity and massiveness. It tends to break into shapeless pieces owing to lack of lamination or bedding planes. No fossils were observed. About ten feet above the base of the cliff there is a band, twelve to fourteen inches in thickness, characterized by numerous lens-shaped vesicles lined with drusy quartz. The vesicles are so arranged as to fall in definite horizontal planes and, at the same time, in vertical columns. Those in one plane are separated from the next above or below by laminæ from one-eighth to one fourth of an inch in thickness. This vesicular zone is continuous for a distance of forty or fifty feet, when it runs into the hillside and disappears. The hight of the cliff is about thirty feet. Above the vesicular layer the rock is more homogeneous and crystalline, and more resistant to the weather, than near the base of the exposure. There are some bands and scattered nodules of chert irregularly distributed through the limestone. The more crystalline parts of the deposit would make a good grade of lime.

In its distribution the Oneota is limited to the deeper valleys in Highland, Pleasant, and Glenwood townships. Exposures in Highland township occur along the north branch of Bear creek, beginning near the southwest corner of section 9; and along Bear creek itself there are many castles and cliffs of this formation, from the center of section 29 (Fig. 3) to the Allamakee

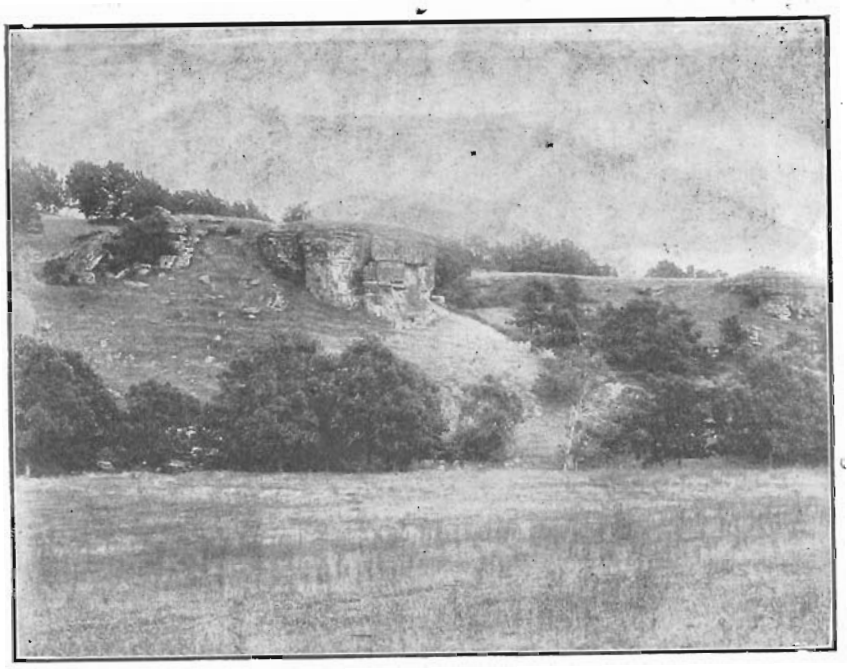


Fig. 3—Castles of Oneota limestone near the center of section 29, Highland township.

county line. In Pleasant township, in section 26, near the village of Canoe, there are characteristic cliffs of Oneota, among the best to be seen in the county. From this point exposures occur along Canoe creek to its confluence with the Upper Iowa river. The valley of the Upper Iowa is bordered by mural cliffs of this lower limestone in sections 25, 35 and 36 of Pleasant township, and in sections 2 and 3 of Glenwood. South of the Upper Iowa the only exposures of Oneota noted occur along the small valley in sections 2, 3, 11, 12 and 13 of Glenwood township.

NEW RICHMOND SANDSTONE.

Like the Oneota formation, the New Richmond sandstone is limited in its distribution in Winneshiek county to Highland, Pleasant and Glenwood townships. One of the best exposures of this sandstone occurs on the north side of the road, a few yards west of the wagon bridge crossing a small stream east of the center of the northwest quarter of the northwest quarter of section 13 in the township of Glenwood. West of the exposure the road ascends with a steep grade and in a short distance rises through the whole thickness of the Shakopee and Saint Peter formations and up into the Platteville limestone. Down the creek a short distance are picturesque precipices of the cliff-forming Oneota. At this point the New Richmond has a thickness of twenty-five feet. Unlike the Saint Peter sandstone, it is regularly and evenly bedded in comparatively thin courses, the courses ranging from two inches to nearly two feet in thickness. The surface of many of the layers is beautifully ripple marked. The whole formation is quite ferruginous, although in some of the thicker layers the iron staining is confined to an inch or two next to the upper and lower surfaces, while the middle portion of the beds is comparatively clean and white. The beds near the bottom are thinner and softer than those near the top of the exposure. Owing to cementation by deposition of dissolved silica in the interstices of the original layers of sand, some of the beds are quite hard, almost quartzitic. Fragments from all the beds sparkle in the sunshine in a characteristic way, due to the fact that, even in beds which are yet quite friable, all the sand grains have suffered secondary enlargement. Each grain became a nucleus around which silica was deposited from solution, and the new growth assumed the crystalline form, with regular crystalline facets. The myriads of such facets catch and reflect the sunlight, giving rise to the peculiar sparkling which distinguishes the New Richmond from all the other sandstones of Iowa. It is true that other sandstones exhibit this same peculiarity, but on a very small scale and in an exceedingly feeble way as compared with the New Richmond. The upper, thicker, harder beds, at the locality under consideration, show the effects of the secondary growth

of sand grains more perfectly than the softer, thinner beds below. In the valley of Village creek and along the other streams in the central and eastern part of Allamakee county, the New Richmond shows the characteristics caused by secondary enlargement even better than they are shown in Winneshiek.

There are good exposures of the New Richmond in the dry bed of an intermittent stream, a few rods southwest of the locality in section 13, Glenwood township, described above. Here the water has cut around masses of the sandstone, which show vertical faces six or eight feet in hight (Fig. 4). In the bed of

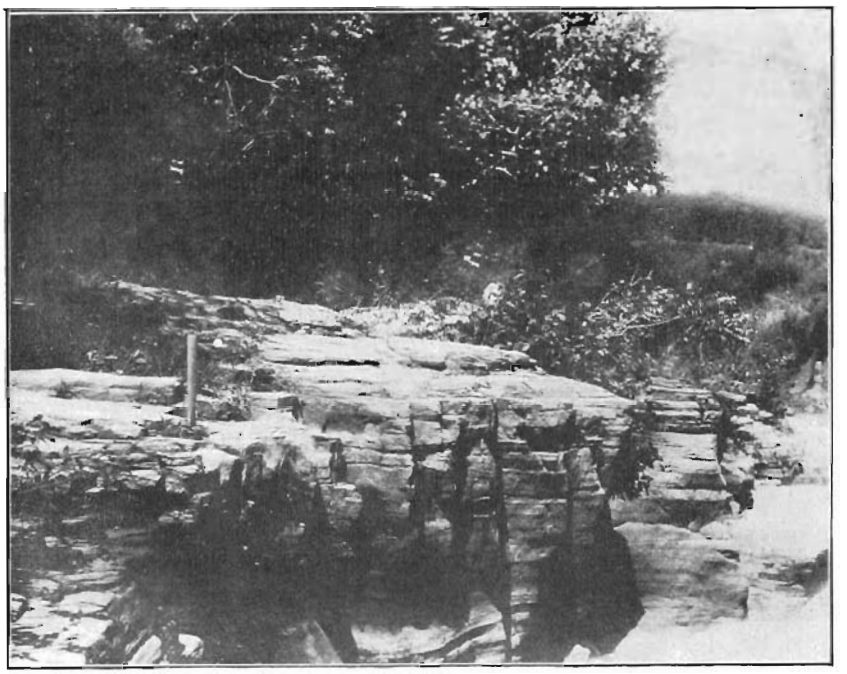


Fig. 4—Exposure of New Richmond sandstone in the northwest quarter of the northwest quarter of section 13, Glenwood township.

a small stream, east of the road, south of the center of section 33, Pleasant township, there is another typical exposure of the New Richmond sandstone. For some distance the sandstone forms the bottom of the channel, but near the line passing east and west through the center of the section it is cut through, and the water flows over the upper surface of the Oneota dolomite.

There is a thin shaly parting between the Oneota and the New Richmond. In the bottom and sides of the little stream channel the whole section of the sandstone is here well disclosed. As usual, it is very ferruginous, it is evenly bedded, ripple marked surfaces are common, and the effects of secondary enlargement of the sand grains are quite well displayed. About the middle of the section there is a calcareous or dolomitic band, four feet in thickness, which weathers very rapidly. It is composed, in large part, of layers in which there is a relatively small amount of clean, clear, quartz sand embedded in a calcareous matrix. The resemblance to some portions of the transition beds between the Jordan sandstone and the Oneota, is quite exact. Commingling and interbedding of arenaceous and calcareous layers occur toward the top of the sandstone, making a gradual transition from the New Richmond to the overlying Shakopee. There are good sections of the New Richmond on the north side of the small stream valley passing through the southwest quarter of section 10, Pleasant township.

There are numerous other exposures of the New Richmond sandstone in the county, most of which have been brought to light by the wash and wear along the public roads. Not very many of them, however, show the characteristics and thickness of the formation very satisfactorily. One near the village of Canoe, not far east of the center of the southeast quarter of the southeast quarter of section 27, Pleasant township, exhibits the pecularities due to secondary enlargement of the constituent grains rather better than most of the other outcrops. Probably the most westerly exposure of this sandstone is that in the southwest quarter of the northwest quarter of section 30, Pleasant township. In Highland township there are exposures of New Richmond as far west as the center of section 30, but these are fully one-fourth of a mile east of that noted in the next township south. North of Highlandville the New Richmond crops out at numerous points as the road ascends and descends the hills and the line of relief intersects the plane in which the sandstone lies. Of these the one near the northeast corner of the southeast quarter of the northeast quarter of section 21, shows the beds most perfectly. The exposures

near the center of section 30, Highland township, show a fairly good section of New Richmond, twenty feet in thickness. Here are all the usual characteristics of thin even beds with ripple marked surfaces and the others noted above. Toward the top the sandstone is interbedded with cherty limestone.

SHAKOPEE LIMESTONE.

The Shakopee limestone has essentially the same distribution as the Oneota and the New Richmond. Outside of the townships of Highland, Pleasant and Glenwood there are a few exposures in the valley of the Upper Iowa, in section 12 of Decorah township. In general the Shakopee resembles the Oneota in color, texture and composition. Everywhere it is dolomitic or strongly magnesian. In some cases, however, it is lighter in color, softer, less granular, less crystalline than the Oneota. It has no beds capable of furnishing a very desirable grade of quarry stone, and few that can be recommended for the manufacture of lime. On the whole it shows less tendency to form scarps and cliffs; it is more frequently rounded off into slopes covered with rock waste; owing to lack of cliff-forming qualities, good natural sections are very rare. In thickness it varies from fifty to eighty feet. The base of the Shakopee is not very sharply defined for the reason that, through a thickness of several feet, there are calcareous beds interstratified with beds of sandstone, or the limestone layers are composed of quartz sand embedded in a calcareous matrix. On the other hand, at the top of the Shakopee, in at least one instance—namely, a short distance west of the center of section 21, Glenwood township—the transition to the Saint Peter is made through a series of thin alternating calcareous and arenaceous layers.

In the bed and banks of a dry gully, where it is crossed by a bridge in the northwest quarter of the northeast quarter of section 27, Glenwood township, there are exposures which show the following succession of strata:

		FEET.	INCHES
9	Thin bedded dolomite, rather soft, non-crystalline...	2	
8	Dolomitic bed crowded with the peculiar problematic fossil which, in the report on Allamakee county, was referred to Hall's genus Cryptozoon	1	2
7	Thin bedded, soft, earthy limestone.....	3	
6	Soft, yellowish, earthy limestone in irregular layers, containing some specimens of Cryptozoon..... ...	2	
5	Thin band of shale.....		1
4	Sandstone, some of it quite hard, almost quartzitic in places, not uniform.....		3
3	Bluish green shale.....		6
2	Gray, porous, calcareous rock showing numerous small cavities about the size of sand grains.....	2	
1	Arenaceous shale.....	1	

Numbers 1 to 5 of the above section constitute part of the beds of transition from the New Richmond to the overlying dolomite. Beds 6 to 9 belong to the Shakopee. The peculiar structures referred to the genus Cryptozoon, which occur in Nos. 6 and 8, are quite characteristic of this lower part of the Shakopee in northeastern Iowa and the adjacent parts of Wisconsin and Minnesota. Each colony is made up of superposed, broadly and gently arching laminae, while each lamina is ornamented on its upper surface with numerous contiguous monticules which vary in different colonies from half an inch to two inches in diameter. Some of the colonies attain a large size, measuring six to eight feet in length and width and more than a foot in thickness. The general appearance is that of gigantic stromatoporoids.

Erosion by the wet weather stream which carries off storm waters from the little valley followed by the road in the west half of the southeast quarter of section 16, Glenwood township, has revealed the Cryptozoon bed, No. 8 of the foregoing section, and in the hillside, twenty to thirty feet higher are outcropping, thick ledges of hard crystalline dolomite in which are many pockets of calcite. Farther up the slope there are unsatisfactory exposures of the Saint Peter sandstone, but the Shakopee beds above and below the hard outcropping ledges just mentioned, are concealed by the mantle of waste.

The Shakopee limestone, with an indicated thickness of eighty feet between the base of the Saint Peter and the top of the New Richmond, is exposed in small isolated patches along the state

line road, on practically the north line of section 8, Highland township. The same thickness is indicated between outcrops of the two sandstones in sections 24 and 25 of the same township. In the northwest quarter of the northwest quarter of section 13, Glenwood township, there is only fifty feet of vertical space for the Shakopee between the two sandstones cropping out on the eastward facing hill slope, and in section 10 of Pleasant township the Shakopee appears to be reduced to even less than fifty feet in thickness. The formation is indeed quite variable in all of its characteristics.

SAINT PETER SANDSTONE.

The Saint Peter sandstone is one of the most consistent and most easily recognized of all the geological formations in Iowa. Normally it is made up of clean, transparent, well rounded and polished grains of quartz. Owing to the almost universal presence of a small amount of iron oxide in this sandstone in Winneshiek county, the color here is red, yellow or brown instead of the pure white, which prevails in the absence of any staining agent. Cementation is imperfect. Cohesion is so feeble that the deposit may be dug into with pick and spade quite as easily as in the case of some mantle rocks. Specimens collected for the museum are likely to crumble into loose grains of sand before reaching their destination. There is no definite lamination or bedding; the whole deposit, in many instances, may be looked upon as a single, homogeneous, massive bed of sand that was laid down without break or interruption between the beginning and the end of the process. Occasionally there are obscure indications of bedding planes at intervals of ten or fifteen feet, but there is no such division into definite layers as may be seen in the thin-bedded, ripple-marked New Richmond. Secondary enlargement of the sand grains is something very unusual.

The Saint Peter forms rather steep slopes at all of its exposures. For a few inches beneath the sloping surface exposed to the air the sand is dried, and a small amount of cementing material has been precipitated, with the result that the outer shell is a little firmer than the moister, deeper parts which have

been saturated with water ever since the sand was deposited. Wherever the sandstone is exposed, a sort of pseudo-lamination is developed nearly parallel to the sloping surface. Not infrequently this gives an appearance of cross bedding as a feature of the original structure, but it is due in all cases to a process akin to exfoliation. The dried, outer shells, of practically uniform thickness, scale off from the moister sand beneath. The upper surface of the Saint Peter, for a few inches or a few feet, may be firmly cemented with iron oxide. This is particularly true in areas from which the overlying Platteville and Galena limestones have been removed by solution. These limestones normally contain quite an amount of pyrite which, during the process of weathering and liberation by solution, is oxidized, and the oxide is carried downward and deposited in the upper portion of the insoluble sand. At the lower limit of the formation there is, in at least the one case noted in the discussion of the Shakopee, an interbedding of sand and dolomite.

At all exposures of the Saint Peter there is a bed of shale of variable thickness and texture between the mass of sandstone and the overlying Platteville limestone. Since this shale is usually quite smooth and plastic, without traces of sand, and in all respects identical with beds of shale found at various horizons throughout the Trenton, in the reports on Allamakee and Dubuque counties it has been regarded as the lowest member of the Trenton series. At Specht Ferry, twelve miles above Dubuque, this shale does not exceed three feet in thickness; in Allamakee it rarely has a thickness of more than five or six feet. At Minnehaha falls and in the gorge of the Mississippi below Minneapolis the shale bed is even thinner than at any observed point in Iowa. All the observations so far published indicate the most abrupt transition from the conditions recorded by the typical phase of the Saint Peter sandstone to conditions favoring the accumulation of sediments characteristic of the next overlying series. In the southeast quarter of the southwest quarter of section 6, Glenwood township, there is an exposure which shows some features of the upper part of the Saint Peter not heretofore recorded. The sandstone phase is overlain by a bed of shale fully fifteen feet in thickness, and the lower

eight or ten feet of this is highly arenaceous. Some thin bands at intervals of a foot or more are almost pure sand. The sand grains in the shale are of the same clear, worn and polished type as those making up the main body of the sandstone deposit. The upper part of the shale bed is quite free from sand and resembles the "basal shale" referred to the Trenton series in Allamakee and Dubuque. The lower arenaceous part should, without any doubt, be regarded as the closing phase of the Saint Peter stage. Owing to the unusual thickness which it here attains it seemed desirable, in order to show the exact succession of stratigraphic units, to give the shale a place in the column of formations in the synoptical table on page 60, and hence it appears under the name of Glenwood shale. The great development of arenaceous characters has led to placing it with the Saint Peter. Below the shale bed, sandstone of the normal phase of the Saint Peter is exposed for a thickness of about thirty feet. The deposit is all stained with iron oxide to a greater or less extent. Over parts of the exposed surface exfoliating laminae are developed; elsewhere the deposit breaks down into incoherent sand without passing through a laminated stage.

One-fourth of a mile north of the locality described above, the entire thickness of the Saint Peter is exposed in a steep ravine which, beginning on the west side of the road and extending to the east shows:

		FEET
11	Galena limestone in courses of variable hickness. Only the lower beds exposed	20
10	Decorah shales, gray, greenish or bluish in color, with embedded thin layers, lens-shaped slabs and nodules of limestone; near the top it contains Prasopora and related bryozoa, with *Orthis tricenaria*, *Orthis subaequata* and other "Green Shales" types farther down	15
9	Platteville limestone in a number of hard ledges ranging from three to eight inches in thickness	4
8	Thinner Platteville, brittle bluish layers with thin shaly partings, the "glass rock" of some authors	20
7	Platteville limestone represented by yellow magnesian layers rarely more than eight inches in thickness. The "Lower Buff Beds" of authors	5
6	Glenwood shale between the Platteville limestone and the normal phase of the Saint Peter sandstone, arenaceous toward the bottom, more purely argillaceous above. Should probably be divided into two parts, the upper to be classified as Platteville, the lower as Saint Peter	10
5	Iron-stained Saint Peter sandstone without definite bedding, presenting the normal characteristics of the formation except that there is more than the usual amount of coloring	30
4	Iron-stained Saint Peter sandstone, not separated from No. 5 by any definite bedding plane, but distinguished by the presence of great numbers of vermicular tubes one-fourth of an inch in diameter; some partly open, but generally they are filled with darker, more ferruginous sand	10
3	Iron-stained Saint Peter sandstone distinguished from No. 4 by the absence of the "worm burrows"	20
2	Basal part of Saint Peter, not well exposed	10
1	Ledges of dolomite belonging to the upper part of the Shakopee limestone	4

It is possible that No. 2 may not all belong to the Saint Peter sandstone, but in any event the thickness of the formation at this point is between sixty and seventy feet. Near the middle of the south line of the southwest quarter of section 10, Pleasant township, there is an exposure of the sandstone showing a thickness of seventy feet. At this point the formation contains a great number of cylindrical or fusiform concretions, a feature quite unusual in this county. In the northwest quarter of the northwest quarter of section 13, Glenwood township, the thickness of the sandstone, as ascertained by repeated barometric measurement, is only sixty feet. Near the northeast corner of the southeast quarter of section 20, Glenwood, there is a

good exposure of the upper part of the sandstone showing contact with the Platteville. The lower part is concealed in the long, gentle slope occupying the space between the steep bluffs in the eastern edge of section 20 and the stream which flows north through section 21. What appears to be the upper surface of the Shakopee limestone is exposed near the stream, a very good exposure occurring in the low, steep banks south of the road, and barometric readings show a difference of only fifty-five feet between the Platteville beds on the one hand and the Shakopee on the other. The apparent diminution in the thickness of the Saint Peter at this point is accounted for, in part at least, by the dip of the strata toward the south and west. At the other observed localities where the Saint Peter is exposed in this county, the thickness of the formation is not definitely indicated. Usually the upper surface is clearly defined, for, in general, the sandstone occurs in ridges or affects steep slopes, and may, or may not, be capped with the Platteville limestone; the contact with the underlying dolomite is generally concealed by the gradually thickening mantle of rock waste toward the foot of the declivity.

As to distribution, it may be said in general that the Saint Peter sandstone is exposed in an area lying southwest of the outcrops of the formations previously noted. The regular southwest dip of the strata, which prevails generally throughout eastern Iowa, is interferred with by a low anticline passing northwestwardly through Sattre and Locust in the northeastern part of Pleasant township. North of this axis the dip is toward the northeast; on the other side the dip is regular and throws the exposures of the Saint Peter toward the southwest. The belt in which the sandstone comes to the surface passes northwestward through the central part of Glenwood township, includes the northeastern corner of Decorah, the eastern part of Canoe and Hesper, the central parts of Pleasant, and the northwestern part of Highland. Owing to the reversal of the dip the Saint Peter is overlain by beds of the lower Trenton series in the northeast corner of Highland township. Outcrops of the Saint Peter sandstone have been already noted in sections 6, 13 and 20 of Glenwood township. Others were observed in the stream valleys in sections 21, 27 and 28. Northward to the Upper Iowa river, the

valleys are cut below the level of this formation; the higher land toward the south is occupied by the Platteville and Galena limestones. In Decorah township exposures of the sandstone begin in the bluffs of the river between Decorah and Freeport. A few rods northwest of the Freeport bridge there is a steep cliff made up in part of the Saint Peter and in part of the Platteville limestone. The top of the sandstone has an altitude of seventy feet above the water in the river, and the thickness exposed to the top of the talus slope is fully forty feet. The overlying shale bed is less arenaceous than in section 6 of Glenwood township, and the thickness is reduced to twelve feet. The lower part of the bed is leaner and more gritty than the "basal shale" of the counties of Allamakee and Dubuque. Red, yellow and brown colors prevail in the sandstone; very little of it is white. Other exposures of the sandstone in this township occur in the low valleys tributary to the river below Freeport. On the south side of the river there is quite a cliff of the sandstone parallel to the road in the northern and northeastern part of section 24. The southwest dip is here very strong, and though the sandstone rises seventy feet above the stream at Freeport, it has descended below the bottom of the river at Decorah. The sandstone is well exposed in the eastern part of Canoe township. The most extensive continuous cliffs of this formation seen anywhere in the county occur in the southern part of section 13 and the northeastern part of 15. The last exposure of the Saint Peter, toward the northwest, was seen in a little valley on the state line, in section 10 of Hesper township.

Some of the surface features controlled by the Saint Peter sandstone have been previously noted in the chapter on Topography. The prominent salient (Fig. 5) in section 12,

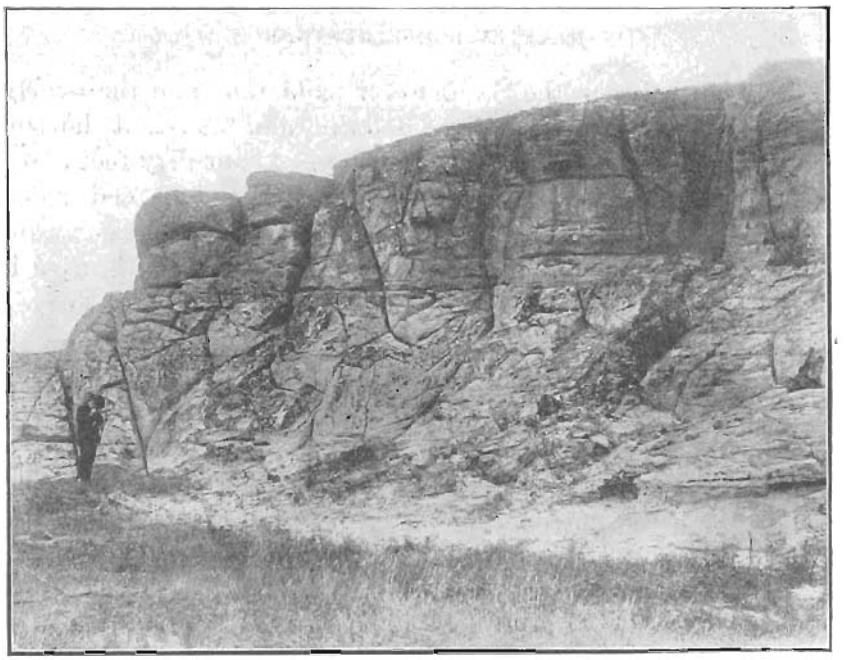


Fig. 5 Salient of Saint Peter sandstone, showing numerous joints, in the northwest quarter of section 12, Hesper township.

Hesper township, is from twenty-five to thirty feet in hight. It is jointed and seamed far more than is usually the case in this formation. It illustrates the tendency of this sandstone, uncemented and incoherent though it is, to form cliffs and steep slopes, to recede by wasting from the side rather than from the top. Extending for quite a distance all around the foot of the exposure, the soil is simply a bed of loose sand, and here flourish desert plants or sand-loving plants of kinds found nowhere else in Iowa except in waste from the Saint Peter sandstone.

From an economic point of view the Saint Peter sandstone of Winneshiek county has but little to offer. At none of the observed exposures was it free enough from staining matter to make it suitable for the manufacture of clear white glass, a use to which it is well suited and extensively applied in many other localities.

Trenton Series.

PLATTEVILLE LIMESTONE.

The shale between the Saint Peter sandstone and the overlying limestones marks a very definite and constant horizon throughout the upper Mississippi valley. About fifty feet above the top of the sandstone there begins another shale bed which, in the geological reports of Minnesota, has been generally referred to as the "Green Shales." The same name is used in the report on Dubuque county, Iowa; Iowa Geological Survey, Volume X. This second shale bed is equally constant and equally definite, and has the further advantage of being characterized by a distinct fauna of which Conrad's *Orthis tricenaria* and *Orthis subaequata* are perhaps the most common and most easily recognized types. Between the two shale beds lies a body of limestone; and a second, thicker body of limestone overlies the "Green Shales." Disregarding for the moment the first shale, which lies immediately on the Saint Peter, there are here three formations sharply set off one from the other, and having an aggregate thickness of approximately 300 feet. While the faunal relations of the three are quite intimate, they are each sufficiently distinct and sufficiently important stratigraphically to deserve rank as separate geologic units.

In the past there has been an unusual amount of confusion relative to the names which should be applied in this part of the geological column, either to the assemblage of strata as a whole or to its several parts. In the report on Dubuque county, Volume X, pages 402-411, the reader will find a discussion of the discrepent views expressed by geologists concerning the limits within which certain terms may be applied, together with the probable causes which have led to such remarkably wide differences of opinion. While the work of Hall in Iowa and Wisconsin, with its masterly insight into paleontological relationships, led, properly enough, considering the state of the science at that time, to the almost universal practice of calling some or all of these beds Trenton, it is not now certain that all together, or any part of them, can be regarded as the exact equivalent of the Trenton limestone of New York. Furthermore, as will be seen

by a perusal of the literature cited in the report on Dubuque county, the "Trenton" as defined in one state or county in the Mississippi valley, has not always been the exact equivalent of the "Trenton" as defined in some other state or county not far away. The body of limestone above the "Green Shales" varies greatly in lithological characters, a fact that seems to have been overlooked by the earlier workers. In places it is a heavy-bedded, crystalline dolomite throughout its entire thickness, in other places only part of it is dolomitic; in still others it is a thin-bedded, unaltered limestone from top to bottom. Where completely dolomitized, as in the lead-bearing region around Dubuque, it was separated from the "Trenton" and called Galena limestone, a name that seems to have been based at first on lithology rather than on life zones or on any definitely recognized stratigraphic limits. Accordingly the term, Galena, has been used with as much indefiniteness as the term, Trenton. The more recent work of Winchell, Norton, Bain and others has made it clear that the three stratigraphic units referred to above, while individually showing quite a range of variation in thickness and lithological characters, are yet stratigraphically clearly defined and easily recognized throughout the entire area of their distribution in the upper Mississippi valley. In the interest of clearness it is greatly to be desired that a definite name should be applied to each of these definite units.

Bain has led the way toward definiteness by proposing to divide the assemblage of strata to which the names Galena, Trenton, or Galena-Trenton have been more or less vaguely applied, calling all below the top of the "Green Shales" Platteville* and all above that very definitely marked horizon the Galena limestone. In the region about Platteville, Wisconsin, whence the name, Platteville, is taken, the shaly member seems to be more calcareous than in Iowa or Minnesota, and so the term is made to cover both the shale and the underlying limestone. While retaining the term in the sense in which Bain has used it, it is yet desirable to distinguish between the calcareous

*Zinc and Lead Deposits of Northwestern Illinois. By H. Foster Bain, U. S. Geol Surv., Bulletin No. 246, pp 17-20 Washington, 1905

and the argillaceous parts of the deposit, and for the present the limestone member will be called the Platteville limestone, and the overlying argillaceous beds the Decorah shales.

The limestone member of the Platteville is divisible, somewhat arbitrarily, into three parts,—(1) Lower Buff Beds, (2) Thin, Brittle Beds, (3) Thicker, Quarrystone Beds. As a whole, the Platteville limestone is much thinner in Winneshiek county than in Dubuque. The lower Buff Beds, which near Specht Ferry are from sixteen to twenty feet in thickness, are here limited to five or six feet, the individual layers rarely exceeding eight inches; while in Dubuque county, as shown in Plate 5, opposite page 412, some of the beds have a thickness of almost as many feet. The heaviest courses in the Lower Buff Beds in Winneshiek county were seen near Freeport where layers two feet in thickness are found directly above the Glenwood shale. These beds are highly magnesian, yellowish or buff in color, rather soft and earthy as compared with the typical dolomitic phase of the younger Galena but still capable of offering admirable resistance to the disintegrating effects of the weather. Where they have greater thickness and are favorably located with respect to market, they deserve attention as a source of good building stone. No fossils have been found in this portion of the Platteville limestone in Iowa.

The lower Buff Beds are followed by limestone in thinner layers, which are rarely more than three inches in thickness. These beds are bluish in color on fresh fracture; though weathering to gray; fine grained, hard and brittle; not so highly magnesian as the beds below, and quite fossiliferous. The prevailing fossils are small forms of *Rafinesquina alternata* Conrad, and normal forms of *Plectambonites sericea* Sowerby. All the fossils are firmly embedded in the fine grained limestone. Shaly partings of varying thicknesses separate the individual layers. The total thickness of these thin, hard, brittle beds is about twenty feet. They are quarried at a few points, the most important being a large opening at the base of the bluff on the north side of the river at Decorah, but they have little of economic importance to recommend them.

A series of layers varying from four to eight feet in thickness, overlies the thin brittle beds just described. The stone here is evenly bedded as shown in figure 6. It is bluish in color, fine

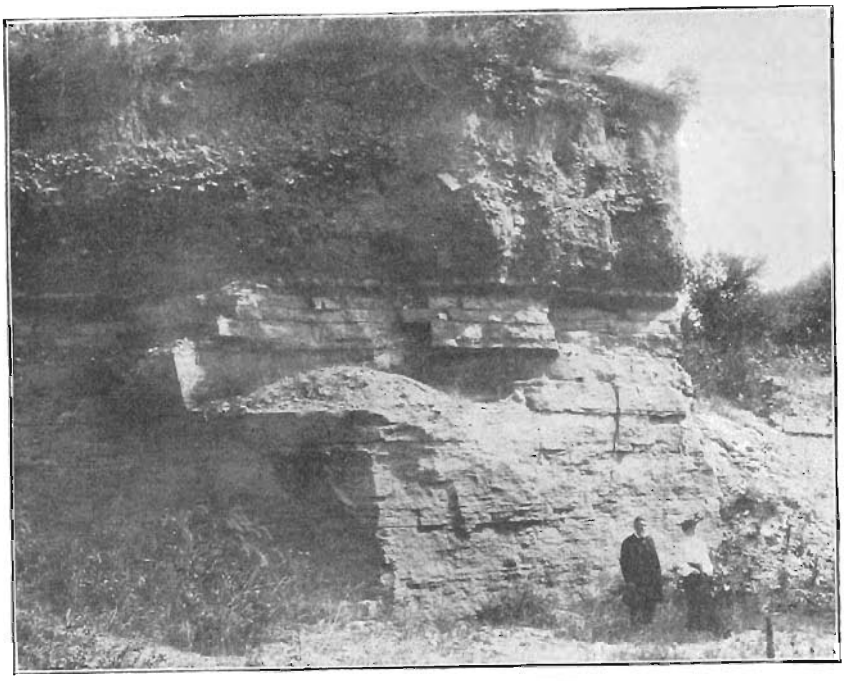


Fig 6 Quarry face in the Platteville limestone; showing the regular bedding toward the top; a small amount of undisturbed Decorah shale overlies the limestone; the upper part of the section is made up of rock waste and loess. Near the north end of the Ice Cave bridge, Decorah.

grained, hard and compact, and is capable of withstanding the disintegrating effects of the atmosphere or alternations of temperature. The layers range in thickness from six to eight inches, and owing to the uniform character of the individual beds and the comparative freedom from joints it is possible to obtain pieces of almost any desired surficial dimensions. In some respects this is the most important quarry horizon in the Trenton series in Winneshiek county. It has been worked quite extensively on the north side of the river at Decorah, in the northeast quarter of section 16. One of the quarries operated by M. T. Halloran in the northeast quarter of section 15, makes use of these same beds. There are a number of quarries worked at

this horizon in the vicinity of Hesper, the most active operations at the time the region was visited being carried on at the Weber quarry south of the village. Mr. Weber has been quarrying here for about twenty years, taking out stone at the rate of 250 to 300 cords a year. Since the aggregate thickness of the workable beds is not very great, the area worked over is, consequently, quite considerable. At all the localities where this phase of the limestone is worked, the large orthoceracone which is usually referred to *Endoceras proteiforme* Hall*, occurs not infrequently. Some of the individuals of this gigantic species must have attained a length of twelve or fifteen feet. A fragment of one of these great shells, donated by Dr. Fordyce Worth of Hesper, is five feet in length, ten inches in diameter at the larger end and five inches at the smaller. The entire fragment belongs to the septate part of the shell, no part of the living chamber being included. The depth of the air chambers is relatively small; from twenty-seven to thirty occur in the space of one foot. Another fragment collected near Decorah is three feet long, seven and a fourth inches in diameter at the larger end, and tapers at the rate of one and one-fourth inches to the foot. A piece more than two feet in length, fitting on to the larger end of this specimen, was left in the quarry, and disappeared with the ordinary rubble stone before it could be cared for. Other determinable fossils are rare. The beds are composed chiefly of finely comminuted and firmly cemented brachiopod shells. On the north side of the river near Decorah, large blocks of the compact stone from this horizon were formerly sawed into thin slabs and polished by machinery, the power being furnished by the waters of a large spring which issues from the hillside, thirty feet or more above the level of the valley. The product was a very pleasing quality of "marble" suitable for table tops and interior decorations.

DECORAH SHALE.

Within the limits of the city of Decorah, at numerous points within a short distance of the city, and at practically all the localities where the limestone last described comes to the surface, the shaly member of the Platteville stage is well exposed. The

*In *The Geology of Minnesota, Vol. III, Part II, of the Final Report*, page 777, Professor John M. Clarke refers this species to Conrad's genus Cameroceras.

Decorah shale ranges from twenty-five to thirty feet in thickness. It is everywhere very calcareous, with numerous bands and nodules of limestone distributed through it. A very typical exposure of the shale (Fig. 7) is seen at the foot of the bluff on

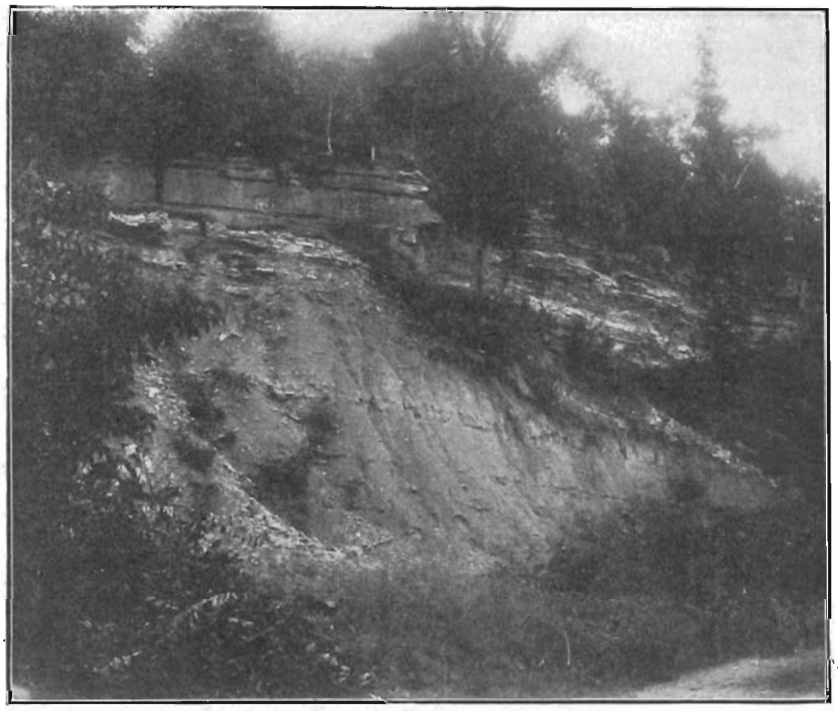


Fig. 7 Exposure of the Decorah shale with the overlying basal ledges of the Galena limestone, at the Dugway, Decorah

the left of the "Dugway", the road leading southwest along the river from the west end of Main street. Practically the whole thickness of the beds is here shown. The deposit is more argillaceous toward the base of the section, and becomes quite calcareous toward the top. The contact with the firm, well-bedded, overlying Galena limestone appears in the upper part of the view. Fossils are numerous in the shales. The species noted embrace *Streptelasma corniculum* Hall, *Prasopora simulatrix* Ulrich, and other species of monticuliporoids, some hemispherical, others branching, Lingula, represented by fragments which render specific identification uncertain, *Strophomena incurvata*

Shepard, *Plectambonites sericea* Sowerby, *Orthis tricenaria* Conrad, *Orthis testudinaria* Dalman, *Orthis subaequata* Conrad, *Orthis plicatella* Hall, *Rhynchotrema inaequivalvis* Castelnau, Liospira, species undetermined, and an undetermined species of Orthoceras. The Prasopora is most abundant in a zone, two or three feet in thickness, immediately below the Galena limestone; brachiopods are more common in the middle and lower part of the section.

The Decorah shales were exposed in grading Winnebago street east of the court house, and quite a portion of the deposit may still be seen at this point; they were also cut into during the progress of street work in other parts of the city. They come to view on the north side of the river at and near the mouth of the Mill spring ravine. A short distance east of the ravine, near the residence of John O. Vold, the shale is much more argillaceous, more slippery and sticky and more impervious to water than at the Dugway, and a number of small springs, coinciding in position with the upper surface of the shales, issue from the hillside. The shales overlie the limestones in the west quarry of Mr. Halloran, east of the Ice cave bridge. They are seen at the east end of North street in West Decorah, where they have been exposed by the grading of the roads leading out of the city. There is a good exposure along the roadside in the southwestern part of section 9, Decorah township, and another excellent outcrop is seen near the center of the northeast quarter of section 5. Near the center of the southwest quarter of the northeast quarter of section 20, Glenwood township, and at the same level around the valleys converging towards the central portion of this township, there are numerous points where these shales come to the surface. There are also many exposures of the shales in a belt extending northward through the central part of Canoe township; and in Hesper township the outcrops are many. The lower part of this deposit, underneath some glacial material and local rock waste, occurs above the quarry stone in the Weber quarry, just south of Hesper. The characteristics here are more like those seen in these shales near Waukon in Allamakee county. The shaly part is quite argillaceous, and the calcareous constituents take the form of thin lenses of lime-

stone in some cases composed almost wholly of the unbroken valves of brachiopods cemented together. The very perfect valves of *Orthis subaequata* are by far the most common. *Orthis tricenaria* occurs occasionally; *Orthis testudinaria* and *Plectambonites sericea* are not rare; while very conspicuous, though less numerous than some of the other species, are detached valves of *Strophomena incurvata* and *Strophomena planumbona**. In some instances the limestone lenses are made up of compacted masses of branching monticuliporoids. It is possible that, by proper management, the Decorah shales might become economically valuable in the manufacture of Portland cement. Otherwise, as far as known at present, they are without commercial importance.

GALENA LIMESTONE.

In point of thickness and areal distribution the Galena is the most important body of limestone in Winneshiek county. Its firm, relatively thick basal ledges are sharply set off from the underlying Decorah shales. As a geological unit it is fairly uniform in characteristics throughout our area and throughout its entire thickness. There are some local departures from uniformity to be noted later, but they do not affect the general statement. As a rule the bedding is thin; layers equalling a foot in thickness are rather exceptional. The total thickness of the formation will average about 225 feet.

All the bold, picturesque cliffs facing the valleys around Decorah, are composed of Galena limestone, for the shales below the base of the Galena rise but little above the platform on which the city is built. From the northwest corner of the county to Decorah the Oneota or Upper Iowa river flows, in general, in the direction of the strike of the strata, from which fact it would result that, were it not for the grade of the stream, the floor of the river valley would lie in a plane practically parallel with the base of the Galena. As it is the water in the river and the lower beds of the limestone are at the same level a short distance above Decorah, and from this point northwestward the stream level

*By many authors the *Strophomena planumbona* Hall, has, of late years, been regarded as identical with *S. rugosa* Rafinesque, but the reason for so regarding it is not convincingly apparent.

rises very gradually above the base until, at Florenceville in Howard county, it coincides with the upper beds of the Galena formation. One of the results of the relation existing between the course of the river and the strike of the beds is that the great vertical cliffs which rise at intervals along the sides of the valley between Decorah and Kendallville are all repetitions of a single section; all reveal essentially the same horizons and pass through the same life zones.

In the matter of distribution the Galena limestone appears at the surface in two areas in Winneshiek county. One of these is very small and unimportant, and occupies only a few acres in the valley of the Yellow river, in the northeast corner of section 13, Bloomfield township. The other area is much larger and lies in the northern and northwestern part of the county. The great trench which forms the valley of the Oneota or Upper Iowa river has been cut in this area near its southwestern edge. The belt on the south of the stream is rather narrow; the dip is at right angles to the main course of the valley, and the formation soon disappears beneath the shales and shaly limestones of the Maquoketa stage. In section 9 of Frankville township and section 10 of Springfield the larger area of the Galena reaches its greatest extension toward the south and southeast. North of the river the area, on the average, is wider. It extends to the state line in Fremont and Burr Oak townships, and on northward into Minnesota. Toward the northeast it includes the village of Hesper.

Lithologically the Galena limestone of Winneshiek county differs from the typical Galena around Dubuque in being composed almost wholly of non-dolomitic limestone. There are a few exposures in the northwestern part of the county in which this formation is magnesian and assumes the general aspect of the massive, buff colored, completely dolomitized beds of Galena in the mining regions of Dubuque county, but these outcrops are few and the area in which they occur is quite limited. One of the outcrops is seen a rod or two east of the county line and not far from the south line of section 18, Fremont township. This occurrence is noted in the report on Howard county, Vol. XIII, page 43. Other good examples of the dolomitic phase of the Galena

occur in the same township near the southeast corner of section 7. In general, however, the Galena limestone in the northern part of Iowa is not a dolomite. In texture the non-magnesian part of the formation is of much finer grain than the coarsely granular Galena of the lead mining regions farther south. In color it ranges through varying shades of blue, drab or dark gray on freshly broken surfaces, but it weathers to lighter gray, or even buff, under protracted exposure. With the exception of an occasional stratum, or small group of strata, the several layers in the non-magnesian phase of the Galena tend, on exposure to weather or alternations of temperature, to split up into very irregular, thin laminae, which break again transversely into small, shapeless chips. Some portions of the old retaining wall around the court house square in Decorah illustrate this tendency. In the southeast quarter of the southwest quarter of section 9, Bluffton township, there is an exposure showing a few layers of Galena limestone ranging from twelve to fourteen inches in thickness. These show practically no effect of weathering; they are capable of furnishing a very desirable quality of building stone. The heavy ledges just noted are interbedded with shale, one of the shale bands being fully twelve inches in thickness. In the last twenty or thirty feet of the formation toward the top, the layers quite generally show a curiously mottled appearance due to the presence of irregular, yellowish spots, from an inch to an inch and a half in diameter, mingled with the prevailing drab or blue. While this feature is not strictly limited to the upper zone, it is more common there than at other horizons. The stone in these spots is granular and vesicular, easily broken down, and differs conspicuously from the fine grained, compact portions of the limestone surrounding them. In localities where this phase of the limestone has been long exposed, these softer, porous portions have been washed and weathered away leaving the beds marked by irregular pits and caverns and curious tortuous channels. Wherever the observer finds this phase of the Galena limestone well developed, he may be sure that he is not far from its upper limit, from its contact with the overlying Maquoketa.

Good sections of parts of the Galena limestone may be seen in all the bluffs along the river and its few tributaries, from

Decorah northwestward. At no place is the whole thickness to be found in a single exposure. In the vertical scarp at the "Dugway", in the city of Decorah, the basal portion of the formation is seen; and in the slopes above the scarp there are outcrops at intervals up to 160 feet above the base. The highest beds coming to the surface in this vicinity belong to the Gastropod zone described in the report on Dubuque county, and furnish such diagnostic species as *Maclurea bigsbyi* Hall, and *Hormotoma major* Hall. *Receptaculites oweni* Hall, occurs in loose fragments at the gastropod horizon. There are from fifty to sixty feet of the upper part of the Galena not exposed in and around Decorah. Probably the most impressive section of this limestone is to be seen at Bluffton. Here, on the south side of the river, is a great vertical cliff (Fig. 8) more than 100 feet in hight.

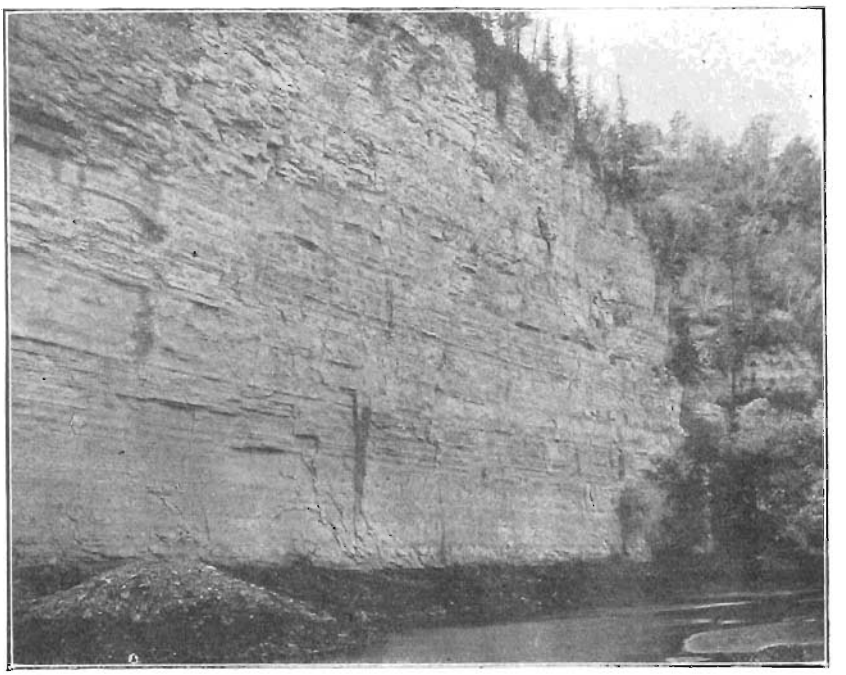


Fig. 8—Cliff of Galena limestone at Bluffton. The face of the cliff coincides with the face of one of the master joints which cut the formation.

It rises sheer from the edge of the water in the river, and its base is only about twenty-five feet above the top of the Decorah

shales. The flat, even, vertical face of the scarp coincides with one of the great east-west joints which divide the limestone into massive blocks. The stone is fairly homogeneous throughout the whole front of the cliff, all showing about the same color and the same effects of weathering. There are, however, some softer bands that recede faster than the rest, and between forty and fifty feet above the base there occur the firm, heavy ledges interbedded with shale, noted above as seen in the southwest quarter of section 9. Following the Bluffton-Cresco road, the

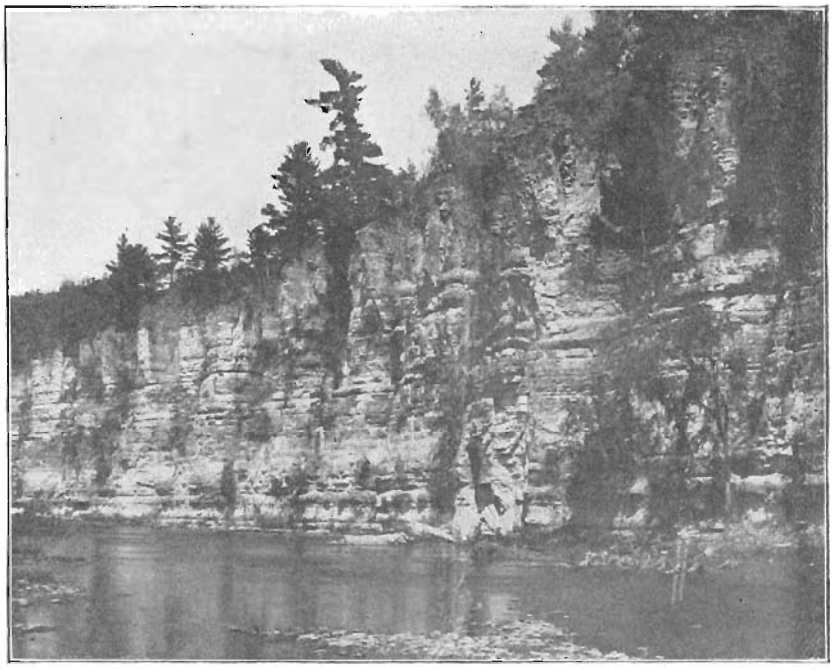


Fig. 9—Cliff of Galena lime tone above the bridge northwest of Bluffton, showing the effects of joints at right angles to the face of the cliff.

gastropod zone with its large forms of Maclurea, Maclurina and Hormotoma, is encountered in the northwest quarter of section 16, at an elevation of 150 feet above the river. *Receptaculites oweni* Hall, occurs here at the same horizon. At the angle of the road, one-fourth of a mile west of the center of section 16, the top of the Galena is reached, and the overlying Maquoketa attains a thickness of forty feet between the plane of contact with the Galena and the summits of the surrounding knobs and

ridges. Above the bridge west of Bluffton there is a cliff of Galena trending north and south through the middle of the east half of section 9, in which the limestone is developed into strikingly regular columns on account of solution and weathering along the east-west joints which here cut the face of the cliff at right angles. The effect of these joints will be appreciated if this cliff (Fig. 9) is compared with the one trending east and west (Fig. 8) a short distance below. East of the village of Plymouth Rock, in section 35, Fremont township, the river flows southward at the foot of a cliff (Fig. 10) having the same direc-

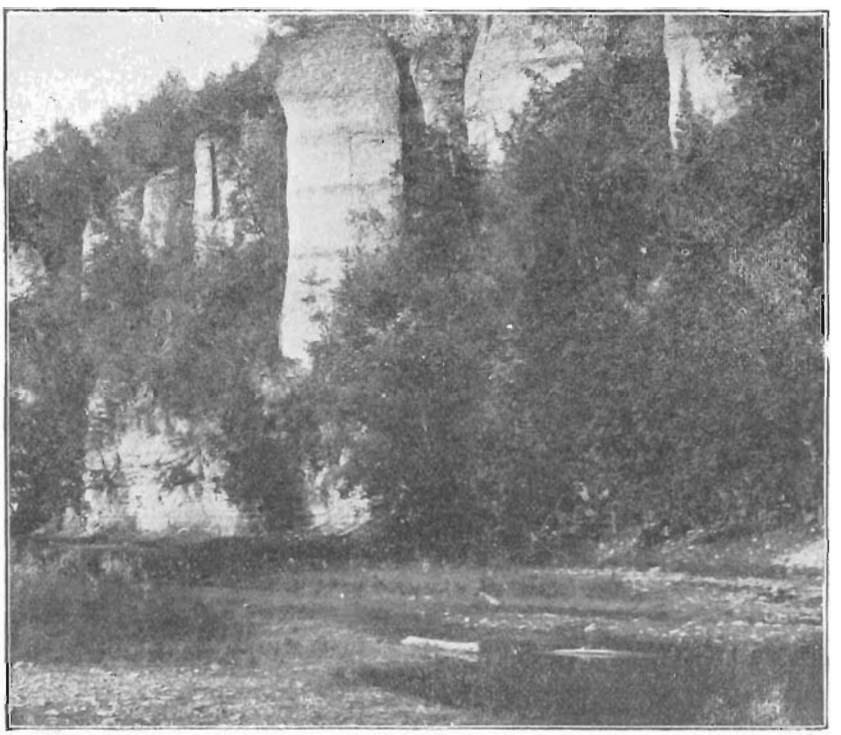


Fig. 10—Columns of Galena limestone at Plymouth Rock, produced by weathering along joints which cut the rock at right angles to the face of the cliff

tion and the same general appearance as that above the bridge at Bluffton. The great rounded columns, due, as in the preceding case, to the influence of joints which cut the beds at right angles to the cliff face, are, in some respects, even better

developed than at the locality farther down the stream. As usual the beds show only very slight differences in characteristics from top to bottom of the section; the greatest departure from the prevailing type of fine grained, light gray or pale buff limestone is found in a zone fifteen feet in thickness, ranging from sixty-five to eighty feet above the base of the cliff, in which the rock approaches a dolomite in general appearance. The contact of the Galena with the Maquoketa, which may be seen in a number of erosion gullies on the slopes east of the brow of the cliff and is well displayed about the middle of the west line of section 36, occurs at an elevation of 120 feet above the level of the river. This would leave about 100 feet of the formation unexposed below the bed of the stream.

In the badly weathered layers near the foot of the cliff, at Plymouth Rock there are a few corals belonging to the genus Streptelasma and an occasional specimen of *Hormotoma trentonensis* Ulrich & Schofield. Thirty feet above the base there are beds containing *Fusispira elongata* Hall, and *Hormotoma major* Hall. The upper Receptaculites zone begins about ten feet higher, and the species, *Receptaculites oweni* Hall, ranges through a thickness of fifteen feet. Some specimens of Maclurina occur in beds overlying the zone of Receptaculites.

There are a few rather conspicuous and persistent life zones ranging through the Galena limestone in Winneshiek county. Two of these are characterized by the abundance of *Receptaculites oweni* Hall. The lower Receptaculites zone occurs between fifty and sixty feet above the base of the formation. It is well exposed in the upper quarry of Mr. M. Halloran, north of the center of section 15, Decorah township. The colonies are unusually large and well developed for this lower horizon; as a rule they are smaller and less numerous here than in the upper zone. Specimens more than a foot in diameter are abundant in some of the layers of the quarry, and many are weathered out on the adjacent slopes. The same horizon may be recognized in the vertical face of the cliff above Mill spring on the north side of the river at Decorah, and it will be found again in the steep ravines which make it possible to study the successive beds which make up the lower and middle portions of the Galena formation

above the "Dugway." The upper Receptaculites zone occurs from 150 to 160 feet above the top of the Decorah shales, from fifty-five to sixty feet below the top of the Galena limestone. This upper zone is much better developed in Dubuque county than in Winneshiek; throughout the city of Dubuque it is crowded with robust colonies of this peculiar fossil, while in the lower zone specimens are decidedly rare. *Ischadites iowensis* Owen, occurs about midway between the two zones. In some instances it is present locally in very large numbers, but it is far less persistent than its larger relative.

Ten feet below the upper Receptaculites bed there is a zone rich in gastropods, among which the more conspicuous forms are *Maclurea bigsbyi* Hall, *Hormotoma major* Hall, *Trochonema umbilicata* Conrad, *Fusispira elongata* Hall, and *F. inflata* Meek & Worthen. *Rafinesquina alternata* Conrad, and *Plectambonites sericea* Sowerby, come up from the Platteville limestone and range through the Galena and on to the top of the Maquoketa. Near Bluffton there is a small zone about seventy feet above the base of the Galena, which is unusually rich in Plectambonites. Of the two persistent brachiopods mentioned the evidence at hand would indicate that they were not uniformly distributed at any particular time over the old sea bottom, but seem to have been grouped more or less in local colonies. It must be said, however, that fossils are not common in the Galena limestone of Winneshiek county.

MAQUOKETA BEDS.

The Galena limestone ends abruptly and is followed in ascending order by the formation, 200 to 240 feet in thickness, which, since 1870, has been called in works on Iowa geology the Maquoketa shales. The formation was first recognized by Hall, and in his report on the Geology of Iowa it was called the Hudson-River group. This name, or some of its equivalents, such as Hudson-River shales or Hudson-River formation, has been used almost exclusively in the geological reports of Wisconsin and Minnesota. In the reports on the Geology of Illinois, 1866 to 1890, Meek and Worthen's name, Cincinnati group or Cincinnati shales, has been employed for the beds which are equivalent

to the Maquoketa shales of Iowa. The term, Maquoketa shales, was used by White in his report on the Geology of Iowa, 1870, on the assumption that the beds, as developed in Iowa, represented only some "particular epochal subdivision" of the Cincinnati group of Meek and Worthen. That the formation under consideration is not the exact equivalent of the "Cincinnati group" or of the "Hudson-River group", as these are known farther east, becomes apparent when the numerous local variations and peculiarities of this most erratic assemblage of geological strata are studied in the field. Furthermore, it is not possible to correlate the Maquoketa of Iowa, or the corresponding beds in states adjacent, with any particular subdivision of the upper member of the Ordovician system, which may be recognized in the type localities of Ohio or New York. More than that even, it is not possible in Iowa to correlate the horizons of the Maquoketa as seen in one locality with those of some other locality only a few scores of miles away. The Ctenodonta and Orthoceras beds of Dubuque county, for example, have no equivalents, either lithologically or faunally, in Fayette and Winneshiek. On the other hand the Isotelus beds near Elgin possess peculiarities that are not exactly duplicated, even at the same stratigraphic horizon, outside of a radius of a few miles, while the heavy beds of dolomite at Clermont in Fayette county (Iowa Geol. Surv., Vol. XV, p. 476, Fig. 41) or at Fort Atkinson in Winneshiek county (Fig. 12) have no representative in the type region for the Maquoketa about Graf. Not a single feature of the lower half of the formation as it is seen in Dubuque county is repeated, even approximately, in Fayette and Winneshiek. At what would seem to be the same stratigraphic horizon the beds are lithologically and biologically so different that it is impossible to say that they were contemporaneous in age or that one in any way represents the other. Since, therefore, it is not possible, within the limits of a single state, to correlate the Maquoketa horizons of different but not very widely separated localities, it would seem useless to attempt correlations between the formation in Iowa and any part or parts of an assumed stratigraphic equivalent in Ohio or New York.

A local name is needed for the peculiar assemblage of beds lying between the Galena and the Niagara limestones, a name that is non-committal concerning eastern equivalents, and the term Maquoketa, which has been in use since 1870, may be allowed to stand for the latest sediments of the Ordovician system in the region bordering the Mississippi river.

So long as the conception of the formation under discussion was based on the characteristics displayed at the type locality along the Little Maquoketa river in Dubuque county, the name "Maquoketa shales" possessed no element of incongruity; but studies in Fayette and Winneshiek counties have shown some seventy feet of limestone and dolomites—some shaly, some of average purity and induration—making up the basal portion of the formation*. Separated from the basal calcareous beds by ten to fifteen feet of bluish plastic shales there are heavy beds of dolomite aggregating forty feet in thickness, which furnish a fair quality of building stone and are quite extensively quarried (Fig. 12). In view of the prevalence of limestones and dolomites in the lower and middle portions of the formation the lithological part of the old name is no longer appropriate, and the less restrictive term, "Maquoketa beds", is here employed.

In the matter of distribution in Winneshiek county it may be said that, with the exception of two or three square miles in the southeastern corner of Fremont township, the sediments of the Maquoketa stage are all found in a large, irregular area south and southwest of the Upper Iowa or Oneota river. The general trend of the line of contact with the Galena limestone is nearly parallel with the stream and, in the northwestern part of the county, is separated from the stream by only a few miles at most. The distance increases toward the east, and on the Allamakee county line the northern edge of the Maquoketa area is more than six miles south of the river. Excepting the very small area of Galena in section 13 of Bloomfield township, the Maquoketa is spread continuously over the four southeastern townships south of a line passing through the northern part of Springfield

*Fayette county offers more satisfactory exposures of the northern phases of the Maquoketa than any other, and for a full detailed description of this formation as it occurs in Fayette the reader is referred to the report of Savage, *Geology of Fayette County*, Iowa Geological Survey, vol. XV, pp. 463 to 486.

and Frankville. The Cresco-Calmar ridge is capped with a narrow tongue of overlapping Devonian, but between the crest of the ridge and the Upper Iowa the Maquoketa extends in a broad belt having an average width of about four miles. Nearly all of Washington township has some phase of the Maquoketa for the bed rock immediately beneath the mantle of loose materials which constitute the soils. Some small outliers of Niagara break up the continuity of the Maquoketa area in the southeastern part of the township, while over a few square miles in the southwest the formation in question is overlain unconformably by the Devonian. The Maquoketa extends up the broad valley of the Turkey river to a point about on the line between Winneshiek and Howard. The area thus covered is larger than that over which the Galena limestone is distributed, and these two formations together form the bed rock over much the greater part of the county.

It is not easy to describe the lithological characters of the Maquoketa in Winneshiek county for the reason that it varies greatly in this respect at different horizons, and beds holding the same stratigraphic position may take on quite different characteristics in passing from one locality to another. There are, however, but very few good sections of the Maquoketa in Winneshiek county, and a very large proportion of the exposures that are available for study are singularly barren in the matter of fossils. By reference to the excellent general section given by Savage on pages 484-486 of Volume XV of these reports, and based on studies made in Fayette county, it will be seen that the formation in this northern part of the state is naturally divided into four members as follows:

4 *Brainard Shales.*—Blue and bluish-gray shale, with some intimately associated beds of limestone at the top and bottom of the division. Includes numbers 11-13 of the General Section. It is proposed to designate this member by the name of the small railway station in Fayette county near to which it has its most typical development. Thickness about 120 feet.

3 *Fort Atkinson Limestone.*—Massive, yellow, cherty dolomite and associated beds of limestone. Numbers 7-10 of Savage's section. The corresponding beds are well developed in Winneshiek county, the best exposures occurring at Fort Atkinson (Fig. 12). Thickness forty feet.

2 *Clermont Shale.*—Bluish colored, plastic, fine grained shale, well developed below the Fort Atkinson limestone at Clermont in Fayette county, where it has been extensively used in the manufacture of brick and tile. Number 6. Thickness fifteen feet.

1 *Elgin Shaly Limestones.*—Limestones, dolomites and shaly limestones with beds of calcareous shales and thin partings of bluish, less calcareous clays; quite variable in character and fossil contents, but generally yellowish, decidedly calcareous and more indurated than the blue, plastic shales of 2 and 4. Includes numbers 1-5 of the section by Savage. Near Elgin the Isotelus beds at the base of this member are largely blue, hard, fine grained limestone. Thickness of entire member seventy feet.

Near Elgin the lower fifteen or twenty feet of the Maquoketa is composed of rather hard, bluish or drab colored, calcareous beds, some of which would rank as a fairly pure limestone and others as a very calcareous shale or shaly limestone. The more indurated layers are separated by partings of dark colored shale, and some of the partings are rich in the small linguloid species, *Leptobolus occidentalis* Hall. Most of the indurated beds are crowded with pygidia and other parts of the dismembered skeletons of *Isotelus maximus* Locke, the form described by Owen as *Asaphus* (*Isotelus*) *iowensis*. The corresponding beds are exposed at many localities in Winneshiek county. They are everywhere, however, yellow in color, much softer and more argillaceous than in Fayette, and the more indurated layers are separated by yellow, marly, non-plastic shale. As in Fayette county the beds are cut by two systems of joints which intersect at oblique angles, and the harder layers may be taken out in large, even surfaced slabs ranging from two to six inches in

thickness. Figure 11 shows the characteristic appearance of these beds as they are seen in a roadside gully one-half mile east of Nordness, near the southeast corner of the northwest quarter of section 11, Springfield township. The base of the view is not more than three or four feet above the top of the Galena, which last is well exposed in a large quarry at Nordness and appears along or near the road almost continuously between the village and the exposure illustrated by the view. Fossils of

Fig. 11—Exposure of Isotelus beds, Maquoketa stage, one-half mile east of Nordness.

any kind are rather rare in the beds here exposed. There are some imperfect impressions of a small Lingula resembling *L. riciniformis* Hall, and an occasional glabella or pygidium of *Isotelus maximus*. One fairly perfect specimen of this last species was found here, but on the whole the scarcity of the remains of this trilobite is in striking contrast with their remarkable profusion at the same horizon around Elgin. A section forty feet in thickness may be studied here, and the great

horizontal range of the exposure, together with the very large number of loose slabs and fragments, afford unusual facilities for observing the fossil contents, provided there were any; but with the exception of the rare occurences above noted, the whole deposit here is remarkably barren. All the beds, whether belonging to the Isotelus horizon or lying above it, present the same yellow color; all, even the more shaly portions, are decidedly calcareous.

The Isotelus beds are seen at many points along the border line between the Maquoketa and Galena areas; at all the outcrops the same yellow color prevails; everywhere there is the same alternation of indurated beds with soft marly shale; the same clean cut joints divide the deposit into rhombic blocks. In the southwest quarter of the northwest quarter of section 9, Madison township, there is an outcrop of the Isotelus beds which split readily into thin laminae and disclose numerous impressions of graptolites associated with *Lingula riciniformis* Hall, and detached plates from the armor of *Isotelus maximus*. Some of the beds furnish great numbers of *Leptobolus occidentalis* Hall, a form which is very abundant in some of the dark, slaty, carbonaceous shales at the type localities near Graf in Dubuque county. The graptolites are biserial, belonging to the genus Diplograptus, and may be referable to the species *D. peosta* Hall, but they are too imperfectly preserved for exact determination. This is one of the most satisfactory exposures of the Isotelus beds in the county. The specimens of Lingula, the numerous graptolites, and the great numbers of Leptobolus recall some of the features of the section at Graf, but the lithological characters are very different, and the presence of Isotelus introduces a feature wholly unknown at this horizon in Dubuque county.

Near the northwest corner of section 20, Bluffton township, the Isotelus horizon is again exposed, but no specimens of the trilobite were found; Lingula is more common here than at the other exposures mentioned; graptolites are also present; there are many specimens of *Conularia trentonensis* Hall; and there is at least one species of Orthoceras. An outcrop of the Isotelus beds, which is typical of many others throughout the county,

occurs in the bank of an intermittent creek near the center of the northwest quarter of section 18, Springfield township. At this point the yellow calcareous rock has been quarried in a small way, and quite an amount of it was piled up near the breast of the opening. The rock comes out in slabs three to four inches in thickness. The intersecting joints are the same as elsewhere at this horizon. The stratigraphic position and the lithologic features leave no doubt that these beds belong to the Isotelus zone, but the most careful search failed to reveal a single fossil of any kind.

Beds practically barren of fossils, but lying at the stratigraphic level of the Isotelus zone, as determined by the lithologic characters and the near by outcrops of the upper surface of the Galena limestone, occur in the bed of a small creek in the southeast quarter of section 25, Madison; in the northeast quarter of section 18, Springfield; and in the northwest quarter of section 15, Frankville. About the middle of the line between sections 11 and 12, Bloomfield township, there is a good outcrop of the Isotelus zone with some of the overlying beds, and there is another south of the bridge over the Yellow river in the northeast quarter of section 13, but the absence of fossils is one of the most striking characteristics. The upper surface of the Galena is exposed at the south end of the bridge, and the contact with the Maquoketa occurs only a few yards farther south. For eight or ten feet above the contact the Maquoketa is a soft, yellow, marly shale, but this is followed by the typical indurated and jointed layers of the Isotelus zone.

The cases noted in the foregoing paragraphs are sufficient to show the general features possessed by the Maquoketa of Winneshiek county in the zone which includes the first twenty feet above its contact with the Galena. This part of the formation is fairly uniform throughout the county so far as color and lithology are concerned; but there are marked variations in the faunal characteristics; in certain localities there are no records of life; elsewhere the beds are fossiliferous, but at the best fossils are never abundant, and the list of species from one outcrop may not be the same as that from any of the others. When comparison is made with the Isotelus zone as it is developed

near Elgin in Fayette county, the differences are strikingly great; when the comparison is extended to the corresponding beds in Dubuque county, it is almost impossible to find any resemblances whatever. Diplograptus, Leptobolus and Lingula embrace about the only life forms common to the Dubuque and Winneshiek outcrops of this basal part of the Maquoketa; lithologically these beds in the two counties named could scarcely present more decided differences.

Throughout the greater part of the area in which the Maquoketa is distributed the beds of the Elgin formation that lie above the Isotelus zone, are soft, yellow, marly shales interbedded with harder layers which, in some instances, are firm enough to rank as limestones or dolomites. Over entire townships there may be scarcely a trace of a fossil except occasional impressions of *Plectambonites sericea* Sowerby. This barren phase is particularly marked in Madison and adjacent townships. Unfossiliferous beds of this horizon, aggregating twenty to forty feet in thickness, may be seen in disconnected outcrops on many of the hill slopes in Madison township. A good example occurs on the line joining the centers of sections 5 and 8. Another, but less satisfactory, occurs on the road passing south from the middle of the north line of section 26. Others may be seen in sections 13, 21 and 35. The most remarkable exposures of this horizon of the Maquoketa are found along the southern edge of section 7 and in parts of the adjacent section 18. Here are curious hills and knobs of uneroded Maquoketa, more than 100 feet in hight, facing the broad, flat bottomed valley of Ten Mile creek, and rising well above the level of the surrounding uplands. The tops of the knobs are rounded and sodded over, but a continuous section more than thirty feet in thickness is exposed on the north side of the road passing between the two sections named. The whole deposit here is yellow, calcareous shale or a partly dolomitic shaly limestone. *Plectambonites sericea* occurs very sparingly and was the only fossil recognized. A short distance west, near the northwest corner of section 13, Lincoln township, the same yellow, granular, shaly limestones and marly shales appear, but fossils are now, individually at least, much more numerous and include such common forms as *Plectambonites*

sericea and *Orthis testudinaria* with occasional individuals of a small variety of *Orthis* (*Platystrophia*) *biforata.* Passing toward the northwest from the point last noted, in the direction of the strike, there is encountered, near the southeast corner of section 17, Orleans township, an outcrop of Maquoketa which shows a wide departure from the ordinary phase of the Elgin formation. The beds here are a non-magnesian, crinoidal limestone, but some of the thin layers are crowded with well preserved shells of *Plectambonites sericea.* There are also some branching monticuliporoids and an occasional pygidium of Isotelus. An outcrop similar to the one just noted occurs on the east side of the road between Winneshiek and Howard counties, near the middle of the west line of section 30, in Fremont township. This was described in the report on Howard county, Volume XIII, pages 48 and 49. The deposit, as in the preceding case, is non-magnesian, largely crinoidal, but some of the layers carry fossils of types found near Lebanon and Morrow, Ohio. The large, well marked forms of *Rafinesquina alternata* Conrad, together with the variety *nasuta,* occur here, and there are also typical individuals of *Rhynchotrema capax.* The universal Ordovician species, *Plectambonites sericea* and *Orthis testudinaria,* are also represented. The crinoidal remains are not perfect enough for identification. In the report on Howard county this exposure was regarded as belonging to "the very uppermost beds of the Maquoketa." They are, in fact, the uppermost for this locality, for only a few rods to the south they pass beneath beds of Devonian age. Their real position, however, is below the middle of the Maquoketa. The enormous erosion and the consequent length of the great time gap representd by the unconformity between the Ordovician and the Devonian in this part of Iowa, are very much greater than was realized when the Howard county report was written.

So far as relates to Winneshiek county, the best exposures of the upper part of the Elgin substage occur near Fort Atkinson. East of the bridge over Rogers creek, at the south end of Tenth avenue, there is a good section of yellow shales and shaly limestones overlain by gray, drab or bluish shales of the Clermont substage. The harder limestone beds here contain large and

small forms of *Rafinesquina alternata* and occasional specimens of *Strophomena planumbona, Orthis testudinaria, O. subquadrata, O. whitfieldi* and *Hormotoma gracilis*. A single example of an Orthoceras, three inches in diameter, was observed, and fragmentary remains of *Isotelus gigas* were noted. South of the bridge over the same creek east of the town, there are layers with large and beautifully preserved individuals of *Rafinesquina alternata* indistinguishable from the robust forms found in the Cincinnati shales of Ohio and Indiana. In addition to the species named the ubiquitous *Plectambonites sericea* and *Orthis testudinaria* are present, together with a few individuals of *Orthis insculpta*. Near the level of the water there are beds of hard, blue limestone; one layer about three feet above the base of the low cliff is charged with fragmentary remains of a trilobite which seems to be referable to *Nileus vigilans*. Stem segments of crinoids are common, and mingled with them are some plates of cystids. All the fossils, except occasional brachiopods, are too imperfect for specific identification. Mud cracks on some of the layers, the comminuted condition of most of the fossils and a certain irregularity in the bedding would indicate that the formation at this point represents an old beach deposit.

One mile east of Fort Atkinson, above and below the bridge crossing the river in the northern part of section 16, Washington township, there are other good exposures of the Elgin phase of the Maquoketa. The horizon is lower than that seen on Rogers creek; the beds are harder; some of the ledges are twelve inches in thickness. Fossils are rare or entirely absent in the lower part of the section. The rock is partly dolomitic, but it is not homogeneous; the bedding surfaces are very irregular, nodular, knobby and uneven; the prevailing color, as usual, is yellow; thin shaly bands are interstratified with the harder layers. The Nileus layer, with the armor of the trilobite reduced to small fragments, occurs on the hillside east of the bridge, about thirty feet above the level of the stream. The Elgin beds crop out at intervals in the valley of the Turkey river all the way from Fort Atkinson to the Howard county line. They appear on both sides of the narrow tongue of Devonian which caps the Cresco-Calmar ridge.

The Clermont shale is not well exposed in Winneshiek county. The lower part of it is seen overlying the Elgin beds along Rogers creek near Fort Atkinson. It comes to the surface in the valley of a small creek, less than one-fourth mile north of the center of section 15, Washington township. Its whole thickness of twenty feet is exposed, though imperfectly, along the road in the northeast quarter of the southwest quarter of section 4 of the same township. It is seen at a number of points in the southern part of the township, one of the best exposures occurring in the eastern part of section 28. The shale is indicated by springs and gentle slopes, as well as demonstrated by actual outcrops, along the roads and in the stream valleys in section 1 of Jackson township and sections 19, 30 and 31 of Calmar. In the banks and beds of the streams which traverse the southern sections, 31 to 35, of Military township, the blue, plastic Clermont shale is seen in small outcrops at a great many points. It is usually the upper part of the formation that is here exposed, a thickness of a few feet only appearing from beneath the protective covering of hard dolomite belonging to the Fort Atkinson limestone. It is only in proximity to the scarps formed by the underlying Elgin beds, or the overlying Fort Atkinson, that the Clermont shale appears in natural exposures. On the intervening slopes the shale is soon concealed by the mantle of waste. As a concrete illustration, typical of many others in the southern part of Military township, the exposure near the center of the southwest quarter of section 33 may be cited. Facing a ravine at this point there is a steep scarp due to the Fort Atkinson limestone, and at the foot of the scarp, and, for a short distance, in the bottom of the ravine, the blue Clermont shale is exposed. Crumbled by exposure to the weather and continually moistened by escaping spring water, it is reduced on the surface to a soft, slippery, plastic clay. The overlying Fort Atkinson, as at a number of other points in this and adjacent sections, is quarried for building stone. In Winneshiek county no fossils were found in the Clermont shale, a fact probably due to the lack of thorough and systematic search. In Clayton and Fayette a number of the

common species having a wide geographic range in the upper part of the Ordovician system, are found at this horizon. The shale is not developed economically at any point in Winneshiek.

The Fort Atkinson limestone overlies the Clermont shale. It is composed of magnesian beds varying in thickness from two or three inches to three feet or more. Nodules of chert disposed in more or less regular bands are common, and in some cases, as at the quarry three-fourths of a mile southwest of Ossian, the chert may form thin continuous layers extending from side to side of the exposure. The thickness is forty feet, and the rock is firm enough and thick enough in some of its layers to be used for massive permanent masonry. There is nothing in the typical Maquoketa section near Graf and Lattners in Dubuque county to correspond in any way to this hard crystalline dolomite. Its presence in the midst of a formation that only a short distance toward the south is made up wholly of shale, has led to errors of correlation on the part of a number of geologists. In Hall's Report on the Geology of Iowa, page 314, Whitney correlates the limestone at Fort Atkinson with the Galena and says that "It possesses all the characteristics of this rock as exhibited in the lead region; its color is the same and it weathers in the same irregular, ragged manner." On page 80 of the report on Allamakee county, published in volume IV of the present series of reports, the writer was led into the same error and correlated the buff, dolomitic Fort Atkinson limestone with the Galena near Dubuque. All the statements in the Allamakee county report relating to the Galena limestone, need modification to bring them into harmony with present knowledge of the structure of the Galena and Maquoketa formations. On pages 324 and 385 of the *Eleventh Annual Report of the United States Geological Survey,* in his memoir on *The Pleistocene History of Northeastern Iowa,* McGee evidently correlates the massive Fort Atkinson dolomite with the scarp-forming Niagara limestone.

The type exposure of the limestone under consideration is the quarry west of the old fort at the town of Fort Atkinson (Fig. 12). The rock is a buff colored granular dolomite resembling some phases of the Niagara in Delaware county, or of the dolomitized Galena about Dubuque. As shown in the view, there are

from twenty to thirty feet of the limestone exposed in the quarry. The clean cut vertical faces of the quarry are due to some of the numerous joints which cut the formation vertically. Near the bottom of the quarry face the layers, comparatively free from chert, range from two to four feet in thickness; near the top the thickness varies from two to four inches. Chert is more abundant in the middle and toward the upper part of the

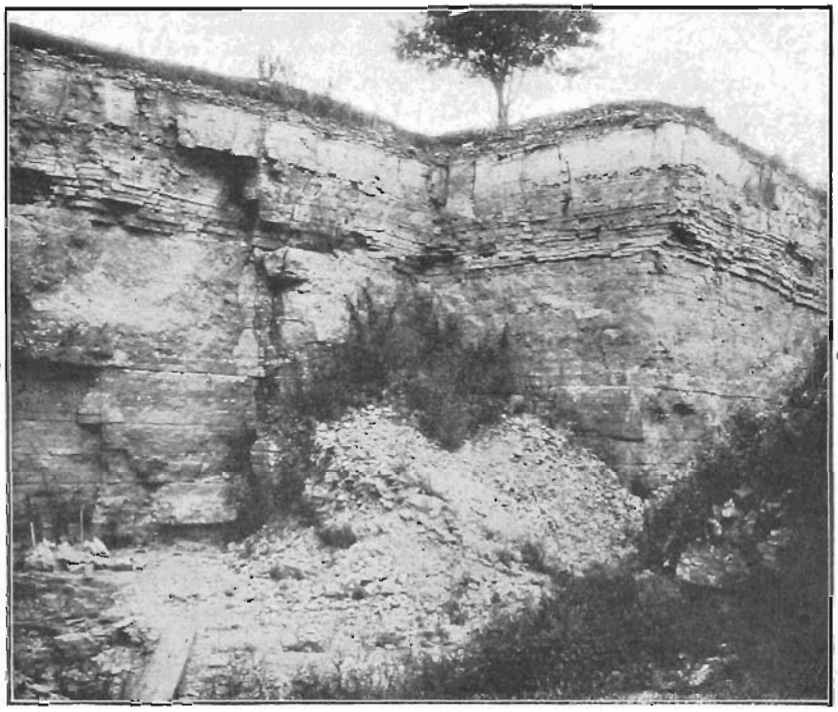


Fig. 12—Quarry in the Fort Atkinson limestone, at the town of Fort Atkinson, a few rods west of the old fort.

quarry. Fossils are not very plentiful; the most common species are *Rafinesquina alternata, Plectambonites sericea* and *Rhynchotrema capax. Orthis insculpta* occurs, but very sparingly. At a quarry in this limestone, near the center of the southwest quarter of section 33, Military township, the beds in the lower part of the working are from six to ten inches thick, bluish in the center and buff colored toward the bedding surfaces. In

the upper part of the quarry the layers are thin and cherty. The fossils include *Rafinesquina alternata, Orthis testudinaria, O. insculpta, O. plicatella, O. subquadrata,* a small Orthoceras like *O. sociale,* and a large, Orthoceras unnamed. There are many exposures of the Fort Atkinson limestone in the southern sections of Military township and along the streams flowing down the slope from the Cresco-Calmar ridge. The profile of the surface on this slope coincides very nearly with the southward dip of the strata. A quarry is worked in the northern part of section 15, about three-fourths of a mile southwest of Ossian. The beds here are composed of coarse dolomite with more than the usual amount of chert. A thickness of fifteen feet is exposed. A solid band of chert, four inches thick, runs through the quarry about ten feet from the base. Among the fossils are many stem segments of crinoids with some body plates of Glyptocrinus, *Lingula iowensis, Rafinesquina alternata, Orthis insculpta, O. testudinaria, Rhynchotrema capax,* a large annulated Orthoceras and a pygidium of Calymene. There are other exposures of the Fort Atkinson in section 8 of Military township, some of which have been quarried on a small scale. The Fort Atkinson is seen at a number of small outcrops on the northeastern slope of the ridge, notably at some quarries in the northwest quarter of the northwest quarter of section 5, Bloomfield township. Quite an amount of fairly good building stone has been taken out at this point. The organic remains are rather fragmentary, but it is possible to recognize the body plates of Glyptocrinus, the shells of *Rafinesquina alternata, Plectambonites sericea, Orthis insculpta, O. subquadrata, Rhynchotrema capax,* and *R. perlamellosa,* together with parts of the armor of a large *Isotelus gigas.* On the whole, however, the Fort Atkinson limestone is found to become softer and to undergo decomposition more readily as it is traced northward and eastward from its typical exposures near Fort Atkinson.

The Brainard shale is present at only a few points in Winneshiek county. At Patterson's Spring and other of the type localities near Brainard in Fayette county, this shale and associated beds attain an aggregate thickness of fully 100 feet. At no point

in Winneshiek county, so far as observed, does its exposed thickness exceed ten or fifteen feet. One of the best of the natural outcrops noted occurs along the roadway in the southeast quarter of the southeast quarter of section 1, Jackson township. The shale here lies between two dolomites, the Fort Atkinson limestone below, and the Devonian limestone above. Throughout the western part of the county the Maquoketa is overlain unconformably by beds belonging to the Wapsipinicon stage of the Devonian. The unconformity is one of overlap due to the transgression of the Devonian sea upon an extensively eroded surface. During the interval of erosion the upper part of the Maquoketa was cut away to such an extent that in some places the overlapping Devonian rests on beds belonging to the middle of the Elgin substage; in other places it rests on Fort Atkinson limestone; in section 1 of Jackson township there are ten or fifteen feet of Brainard shale between the Devonian and the Fort Atkinson. Near the southwest corner of section 5, Calmar township, this shale is seen between the same two limestones, but the thickness is reduced to three or four feet. It occurs in the same relations to the limestones near the middle of the north line of section 33, Lincoln township. It is quite probable, indeed almost certain, that the full thickness of this upper shale still persists beneath the small patches of Niagara limestone in the southeastern part of Washington township, but no outcrops were seen on the long slopes between the Fort Atkinson and Niagara limestones. In general it is represented in this county by nothing more than a few scattered remnants. Normally it is blue, fine grained, plastic, unfossiliferous. The few remnants observed have no commercial value, but large bodies of it might easily be opened up on the hill sides below the outliers of the Niagara.

SILURIAN SYSTEM.

Niagara Limestone.

The Niagara limestone is represented in Winneshiek by a few small outliers in the southern and southeastern part of Washington township, all of which may be referred to the lower or Hopkinton stage of the series. A prominent knob of Niagara

(Fig. 13), covering less than forty acres, stands out prominently on the line between sections 22 and 23, about three-fourths of a mile west of Festina. The village is built on a plaform of Fort Atkinson limestone. A long slope due to the presence of the Brainard shale leads toward the summit of the knob, and at a level 100 feet above the level of the platform there is an old quarry which has been worked in a hard, granular dolomite identical in characteristics with some phases of the Niagara farther south. The summit of the outlier rises about twenty feet

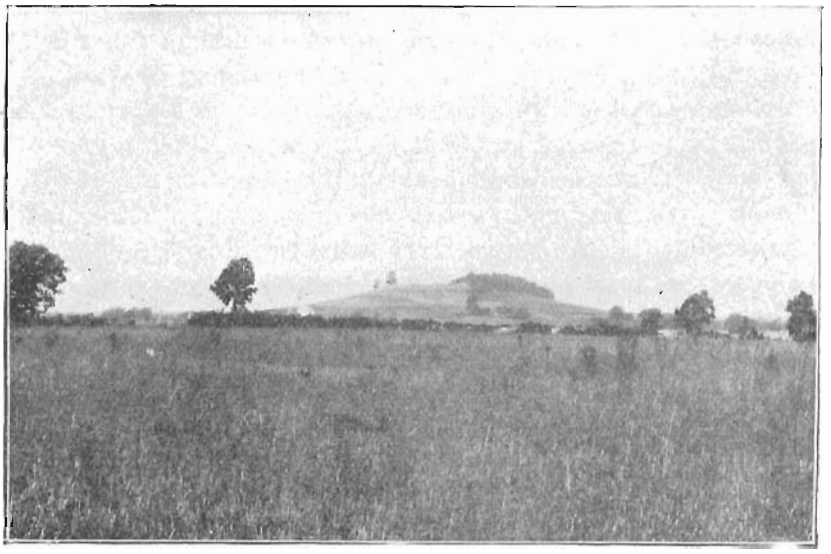


Fig. 13—Conical knob, the most northerly outlier of Niagara limestone in Iowa, one mile west of Festina, Washington township

above the top of the quarry. The exact plane of contact with the Maquoketa could not be made out, but the thickness of the Niagara at this point is not more than forty feet. No fossils were found, a fact not surprising, however, for in Dubuque, Delaware and other counties where the basal part of the Niagara may be studied, the lower zone is practically unfossiliferous. This outlier has the distinction of being the most northerly exposure of the Niagara limestone in Iowa.

The largest of these outliers in Washington township begins about a mile south of Festina and occupies portions of sections

25, 26, 35 and 36. The greatest thickness of the Niagara, approximately 75 feet, occurs near the northeast corner of section 35. The road in the northwest quarter of section 35 angles around a very characteristic cliff of the Niagara limestone (Fig. 14), and a bold salient of this limestone (Fig. 15) faces the valley of the Turkey river in section 26. This larger area forms a flat topped mesa with steeply sloping sides. Its outline is quite irregular; its total area does not much exceed a single square mile. A

Fig. 14—Cliff of Niagara limestone north of center of section 35, Washington township Photo by Lees.

ridge capped with Niagara, trending northeast-southwest, begins in the northeast quarter of section 27 and extends to a point east of the center of section 23. A very symmetrical conical outlier, occupying only a few acres, rises from the level of the valley in the southwest quarter of section 35; and another, which forms an elongated butte with flat top and steep sides, extends obliquely across the line between sections 28 and 33. This last is the only known remnant of Niagara in this county on the west side of Turkey river.

In the main the Niagara here is a cream colored, magnesian limestone; though in the larger area, in section 35, there is a bed of soft, yellow dolomite, ten feet in thickness, about forty feet from the top; and some of the layers in the old quarry at the outlier west of Festina, are composed of hard, buff, crystalline dolomite matching the best type of this limestone in the counties of Dubuque and Delaware. At the cliff in the northwest quarter of section 35 there are some obscure stromatoporoids about the middle of the section, and an imperfect glabella resembling that

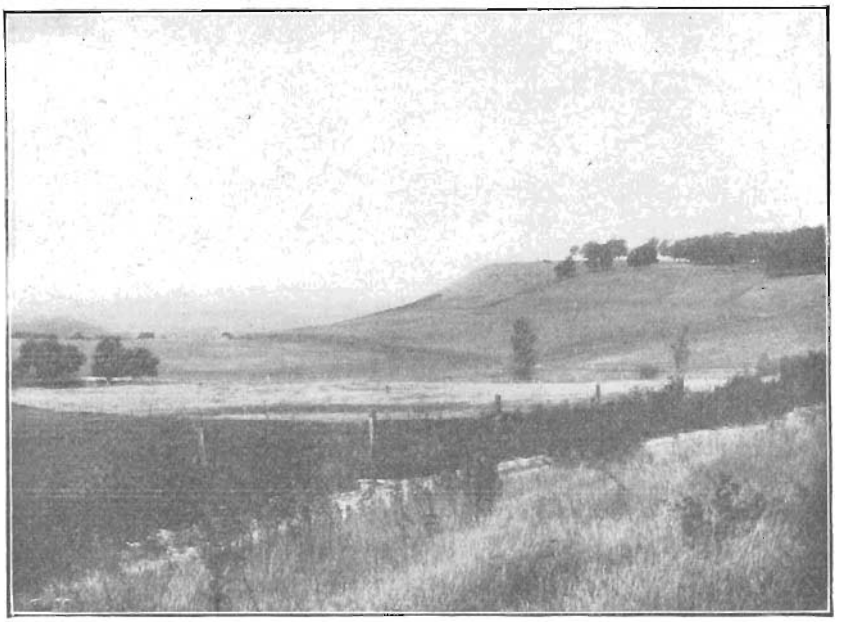


Fig 15 Salient of Niagara limestone facing the valley of the Turkey river in the southwest quarter of section 26, Washington township.

of *Illaenus insignis,* was found in the upper beds. The grounds on which these outliers are referred to the Niagara are chiefly lithologic and stratigraphic; but the evidence from these two criteria finds strong support in the geographic relations of the outliers to the Niagara of Fayette county, which, toward the south, is continuous with the great Niagara area, and toward the north is found to diminish rapidly in thickness and areal distribution. The last remnants of the formation in Iowa, toward the northwest, are found in these small isolated areas.

DEVONIAN SYSTEM.

Middle Devonian Series.

WAPSIPINICON AND CEDAR VALLEY LIMESTONES.

Beds belonging in part to the Wapsipinicon stage, and in part to the Cedar Valley stage of the Middle Devonian occur in the western part of Winneshiek county. Owing to the small size of the individual exposures and the scarcity of fossils, it is not possible to separate the two stages with any degree of definiteness. The area occupied by the deposits of the Devonian period includes practically all of Jackson township, the greater part of Sumner, and portions of Lincoln, Orleans and Fremont. A narrow tongue of Devonian enters Winneshiek from Howard county and extends as a capping along the Cresco-Calmar ridge as far as Calmar. As noted above in this report, the Devonian lies unconformably upon an eroded surface. There was an eastward transgression of the Devonian sea after the beginning of the period, and our territory was not reached till near the close of the Wapsipinicon stage. The earliest beds of the Iowa Devonian—the Otis, Independence and Lower Davenport—are accordingly missing in this part of Iowa, and the beds which come in contact with the Maquoketa belong to a horizon above the Gyroceras zone at Independence. The most characteristic fossils of the lowermost strata of the Devonian in Winneshiek county are *Productella subalata* Hall, and *Spirifer pennatus* Owen. A small Spirifer like *S. subumbonus* Hall, is occasionally found near the line of contact.

The exposures of the Devonian in Winneshiek county are numerous, but the formation is distributed in the part of the area covered with the deepest drift and is seen on the surface only in small, isolated patches. Unless distinctive fossils are present, the correlation of one outcrop with another is not always possible. Nearly the whole formation, as it appears in this part of the state, is a soft, yellow, earthy, magnesian limestone, or imperfect dolomite, in which the embedded life forms are preserved, if at all, in the condition of internal casts. It is

not quarried at any point in the area studied, nor is any of it suitable for quarrying. Where it has been stripped and cut into by erosion, instead of forming cliffs which might be studied in detail, it breaks down into rock strewn slopes, with the more persistent ledges asserting themselves in a feeble way, as shown in figure 16. The view shows the hard Fort Atkinson limestone near the foot of the slope, with some of the harder beds of the

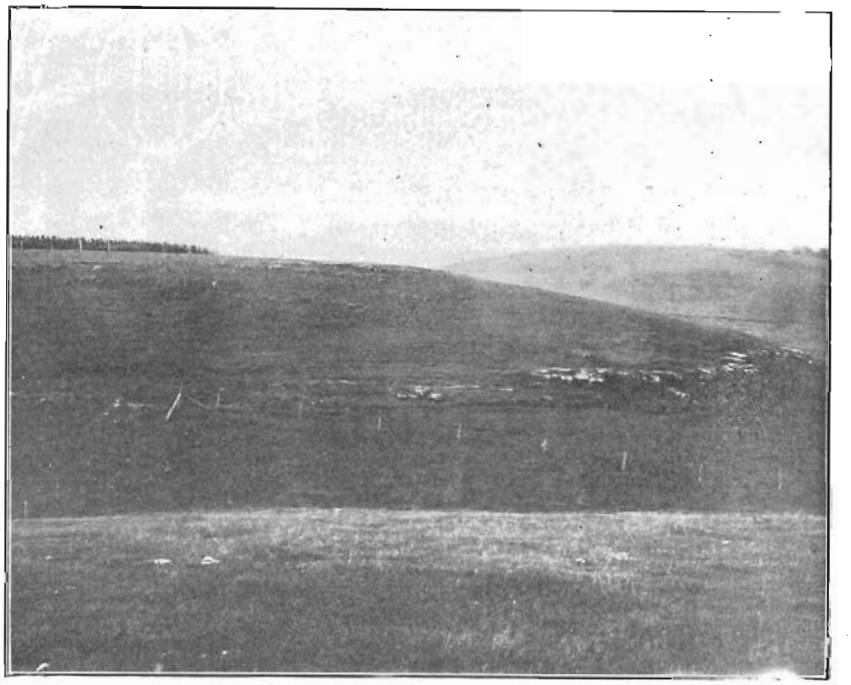


Fig. 16 -View near Fort Atkinson showing outcropping of Devonian dolomite near the top of the hill, and Fort Atkinson limestone, of the Middle Maquoketa, near the base. There are ten or fifteen feet of Brainard shale between the two limestones, but no Niagara. Photo by Lees.

Devonian expressing themselves in ragged, fragmentary outcrops toward the top. Ten or fifteen feet of Brainard shale separate the two limestones, but its presence is not indicated by the topography. Fragments of weathered Devonian limestone are sprinkled over the entire hillside. The Devonian at the point shown in the illustration, near the southeast corner of section 1

Jackson township, is, as usual at this horizon, soft, yellow, magnesian, not very fossiliferous, but yielding to persistent search the casts of *Productella subalata* Hall, *Spirifer subumbonus* Hall, and *Spirifer pennatus* Owen.

The same Productella beds are seen in numerous small outcrops—wherever, in fact, the drift is absent—on the west side of the valley of the Turkey river, all the way to the Howard county line; they are present on both slopes of the Cresco-Calmar ridge in Calmar, Madison and Lincoln townships; they appear in contact with the Lower Maquoketa in the small Devonian areas which enter our county from Howard in Orleans and Fremont townships. For a few concrete illustrations there may be noted the outcrops of Devonian crowded with casts of Productella, which occur in the road between sections 15 and 22, Lincoln township. The best locality is just west of a small valley passing through the sections named. Devonian outcrops are more or less continuous for three-fourths of a mile farther west, but near the middle of the south line of 16 the Fort Atkinson dolomite appears from beneath the Devonian in the gentle descent toward the Turkey river. Between the point last named and the stream, the Maquoketa is seen at intervals, carrying such fossils as *Lingula iowensis*, *Leptaena unicostata*, *Plectambonites sericea*, *Orthis whitfieldi* and *O. testudinaria*. The Devonian, only a few feet higher, furnishes casts of two Atrypas, one large Spirifer, *S. pennatus* Owen, *Cyrtina hamiltonensis* Hall, and *Paracyclas elliptica* Hall, in addition to the common Productella. Less than a quarter of a mile west of the river the Devonian again appears above the Maquoketa, good exposures being found near the southeast corner of section 17 and along the east side of 20. At the bridge over the Turkey river on the line between Howard and Winneshiek, there is a good example of the Productella beds, which was noted in the report on Howard county. The deposit presents the usual lithologic characteristics, but the grading for the road has exposed a section of several feet in thickness and afforded better opportunities than occur at the natural exposures for an investigation of the fauna. Fossils, in the first place, are not abundant, and, secondly, the obscure casts that do occur are not always identifiable. It is possible, however, to make out the Productella and large Spirifer which prevail at this horizon,

and in addition are casts of *Stropheodonta demissa, Atrypa reticularis, Spirifer subumbonus, Cyrtina hamiltonensis,* some undetermined gastropods and the pygidium of Phacops. Shales of the Maquoketa stage occur in the bed of the stream immediately below the bridge.

In Howard county the Productella zone is overlain by beds almost barren of fossils, but characterized by the presence of occasional colonies of Acervularia and great numbers of irregular pockets filled with calcite. Following down the stream from the county line bridge referred to above, the Devonian limestone is found to be continuous in the bluffs in the southern part of section 6, Lincoln township. The slopes are strewn with loose fragments of the soft, earthy, magnesian limestone, and quite a number of these contain *Acervularia davidsoni* Ed. & H. The corals were not seen in place, for the upper part of the bluffs is rounded back and covered with a heavy mantle of detritus; but it is clear that the beds above the Productella zone are present in this locality. Beds of this overlying horizon, with its irregularly shaped masses of calcite, may be seen in places near the northeast corner of section 16, Jackson township, and in the southwest quarter of the northwest quarter of 28, Calmar. Beds belonging to the next higher zone occur in section 31 of Jackson township. In the road passing south from the center of this section, a few rods north of the Fayette county line, there is an exposure showing from eight to ten feet of soft, yellow, earthy dolomite containing *Dielasma iowensis* Calvin, *Atrypa reticularis* Linne, and *Spirifer subvaricosus* Hall & Whitfield. In the northeastern part of the section the same horizon is indicated by the same fauna at the crossing of the creek one-fourth of a mile southwest of Navan, and again in the railway cut a short distance west of the small station.

The highest beds of the Devonian in Winneshiek county are seen on the east side of the county line road, less than a fourth of a mile south of the northwest corner of section 7, Orleans township. They were not noted at any other locality. Here the limestone is non-magnesian, light gray or white in color, fine grained or lithographic in texture. Some of the beds are very much crackled as if they had been exposed to air drying while yet soft and plastic.

The fossils are mostly stromatoporoids of the types found associated with the lithographic zone from Johnson county to Mitchell. Colonies of a small digitate Favosites occur with the stromatoporoids, an association that is practically universal in Iowa. In Johnson county the lithographic limestone lies practically at the top of the Cedar Valley stage; but if these beds in section 7 of Orleans township are traced toward the southwest, they will be found in Howard county to pass beneath heavy, magnesian layers such as are seen in the quarries on the higher ground around Vernon Springs. By reference to the report on Chickasaw it will be found that in the county south of Howard there are fifty feet of these magnesian beds above the lithographic horizon. In Mitchell county, in the Lewis quarry and at the Chandler cliff section for example, there are some soft, yellow magnesian beds, a few feet in thickness, above the lithographic limestone, which may be regarded as remnants of the heavy, overlying layers in Howard and Chickasaw. These upper beds seem to have no equivalents at Iowa City or elsewhere in the southern part of the Devonian area. The light colored, lithographic, non-magnesian phase of the Devonian attains its greatest known thickness in the vicinity of Mason City, as may be seen by reference to the report on Cerro Gordo county. Samples taken from this horizon in Mitchell county were analyzed by A. B. Hoen of Baltimore and were found to contain only a trace of Aluminum-iron oxide and but .07 of one per cent of Magnesia. Such a stone is especially well fitted for use in the manufacture of Portland cement. There is not enough of the non-magnesian zone in Winneshiek county to be of commercial value, but the great development which these beds attain in the counties south and west of the area under consideration renders them worthy of careful consideration by the makers of Portland cement, and places them high in rank among the important geological resources of the state.

THE MANTLE ROCKS.

RESIDUAL MATERIALS—GEEST.

The mantle of rock waste forming the soils and subsoils of Winneshiek county, may be divided into (1) Residual Materials or Geest, and (2) Transported Materials which make up the

many phased deposits of the Pleistocene System. The geest belongs to no one age or period, but is a product of destructive processes which have been in continuous operation throughout all the periods since northeastern Iowa first rose above the sea. It does not occur in large bodies at any points within the limits of the county, corrasion and removal have been able to keep pace with the processes of production. The residues resulting from the disintegration of local bed rock vary with the composition of the beds, but it may be said that the characteristic geest of this county is that derived from the decay of limestones. This is usually a very dark colored ferruginous clay enclosing numerous fragments of chert and occasional fragments of undissolved limestone. Geest is best seen in the eastern part of the county, in the regions where the drift is thin or wholly absent. It cannot be said that the geest mantle is continuous even in regions of no drift; it occurs as mere remnants of a mantle, often in fissures in the bed rock. In the drift covered regions it has been quite effectually swept away, the greater part of that which remains being protected in fissures into which it had been worked before the coming of the glacial ice. Among the largest and most typical bodies of residual materials are those seen near the center of section 26, Glenwood township. These bodies are of dark red residual clay, in some cases two or three feet in thickness, in and upon which are large quantities of residual chert. The chert represents insoluble nodules in the Galena limestone, and the great amount of it would indicate the removal by solution of nearly the whole thickness of this formation.

Residual materials from the Oneota limestone, a crystalline dolomite, may be seen a short distance east of the center of section 19, Highland township. Here are all stages of rock decay from partly disintegrated bowlders of the Oneota to gray dolomitic sand and dark, ferruginous residual clay. All the crystalline dolomites, such as the Niagara in Delaware county, the Galena around Dubuque, and the Oneota in the northeastern counties, break down, by solution of the cementing substance, into loose granules representing the constituent crystals of the deposit. The product resembles ordinary, incoherent sand. Decayed Galena in Dubuque county, and Niagara in Delaware,

have given rise to considerable bodies of loose, dolomitic sand many feet in thickness; and here in section 19 of Highland township, as well as at many other places in Winneshiek county, the Oneota is seen passing through the same phase of decomposition. The final result in all such cases, however, is the solution of all that is soluble in the granules and the conversion of the finer insoluble constituents of the dolomite into a dark red, ferruginous, tenacious clay in all respects like that derived from the non-magnesian phase of the Galena. The residual clays from the Maquoketa beds are, on the whole, less ferruginous than the geest from the Galena and Oneota limestones. The residue from the Saint Peter sandstone is simply a bed of incoherent quartz sand practically equal in volume to the body of sandstone that has suffered disintegration. A typical illustration of such geest occurs around the base of the salient of Saint Peter (Fig. 5) in section 12 of Hesper township.

PLEISTOCENE SYSTEM.

KANSAN STAGE.

Kansan Drift.—Only two drift sheets have been recognized in Winneshiek county, the Kansan and the Iowan. The drift mantle, even where both sheets are present, is comparatively thin. The older Kansan, weathered, iron stained, deeply eroded and covered with loess, is found in the eastern two-thirds of the county. In the eastern one-third there are areas of considerable extent where the drift occurs in patches; in the intervening vacant spaces the loess rests directly on bed rock or on residual clays and cherts. The heavier and more continuous bodies of Kansan drift are found on the uplands. North of the Oneota river the drift is well developed along the high divide passing through the northern townships, a fact that is apparent in the western part of Hesper township and the northeastern part of Burr Oak. South of the river the most typical and characteristic areas of the Kansan occur on the high ground in Springfield, Frankville, Military and Bloomfield townships. The drift is thin, patchy, or wholly absent over considerable areas about the headwaters of the Yellow river in Bloomfield and Frankville townships. The same statement may be made relative to the whole

of Glenwood and Pleasant townships, and to the greater part of Decorah, Canoe and Highland. In Bloomfield township, for example, there is the large area of Kansan on the upland of which Castalia is the center. This is continuous with the main body of the formation toward the west and northwest; but among the numerous branches of the Yellow river the drift is reduced to mere shreds and isolated remnants, as is well illus-

Fig 17—Driftless hills in sections 23 and 24, Pleasant township. The slopes are covered with waste from the Oneota limestone.

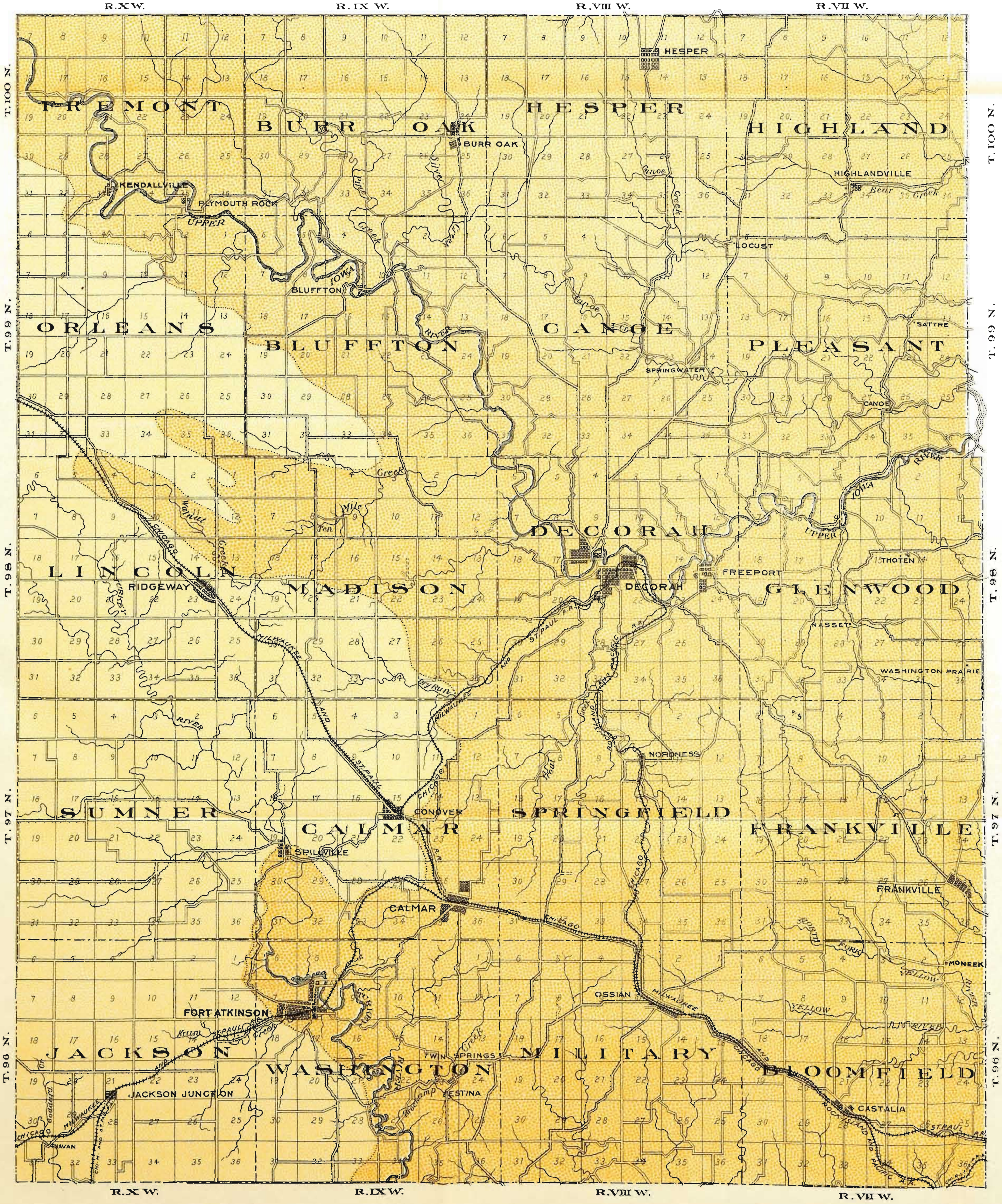
trated by the detached body occupying a small ridge near the center of section 13 and another near the northwest corner of section 12. In Canoe township there is a detached mass of drift of considerable extent and several feet in thickness, south of the center of section 2. In Pleasant township there is quite an area of the older drift south and east of Locust Lane, but in the small valley traversing sections 23 and 24, the hill slopes are covered with local waste (Fig. 17), and there is no evidence that

glacial ice had ever invaded the region. In general it may be said that, in the eastern third of the county, the valleys, even of the smaller, intermittent streams, have the topographic features and surficial mantle of the Driftless Area, while the divides, even the smaller ones, show some traces of the Kansan drift. It is possible that the whole region, embracing both valleys and uplands, may have been covered to an equal extent with the Kansan glacier, and that erosion during, and subsequent to, the period of ice melting may have carried away from the valleys whatever detrital material the ice deposited. On the other hand it is probable, at least possible, that the ice coming from the higher lands to the northwest, moving here in the direction of the drainage, and very much attenuated at its margin as it approached the Driftless Area, pushed out on the ridges, its continuity with the main body of the living glacier uninterrupted, while it broke down and became dead at the heads of the valleys. The ridges were in fact a continuation of the surface to the westward, upon which the ice moved as an unbroken sheet; but the valleys, all of them preglacial, were depressions below that surface, and the thin margin of the ice broke down into detached, dead fragments wherever, in this critical part of its area, such depressions were encountered. According to this view these valleys never were invaded by living glaciers, never received any mantle of drift. The same conditions are indicated by the distribution of the Kansan in the marginal part of its area in Dubuque county.

At all the exposures of Kansan drift noted in Winneshiek county the formation is weather stained and oxidized throughout its whole thickness. The color is red, not infrequently quite brilliant. The smaller remnants in the eastern part of the county are very pebbly or sandy, and in some cases they grade into deposits which might be classed as Buchanan gravels. This pebbly phase of the Kansan is well illustrated at many points along the road passing north and south through sections 21 and 28, Decorah township; but the feature is so common, especially throughout the eastern townships, as practically to include all observed exposures, and further mention of particular cases is unnecessary. The normal, blue, unweathered phase of the

Kansan was not seen in any of the outcrops during the progress of the survey, but McGee in his *Pleistocene History of Northeastern Iowa*, page 519, publishes the record of a well located in section 7, Orleans township, which showed—pebbly yellow clay, 6 feet, and compact, laminated blue clay with striated pebbles, 10 feet. This well is located in the western edge of the county where the glacial deposits are thickest, and in an area where both drift sheets are present. The yellow clay undoubtedly belongs to the Iowan stage; the blue clay presents the normal aspect of the unweathered Kansan. Another well reported by the same author is located in section 16, Burr Oak township. Here the record shows—loess, 14 feet; laminated sand, coarser below, 10 feet; gravelly and sandy brown clay, 6 feet. In the last case the well is located in the loess covered Kansan area, some distance beyond the extreme limits of the territory covered by the later Iowan ice. The drift is overlain by stratified sands of the age of the Buchanan gravels. The brown color of the glacial clay indicates profound weathering of the deposit, and the presence of the weathered zone shows that the surface has not been disturbed by glaciers since the materials were deposited and exposed to the air. In the erosional topography which is so prominent a characteristic of this locality, in the weathering and complete oxidation of the drift, and in the overburden of loess there may be recognized the features which everywhere distinguish the loess-Kansan portions of the great drift-covered area of Iowa.

Buchanan Gravels.—When the Kansan glaciers were melting and making their final slow retreat from this part of the state, large volumes of water flowed out from the margin of the ice upon the region which the ice retreat had just laid bare. This water was loaded with detrital material, coarse and fine, and the load was sorted and deposited along the courses followed by the streams. Sheets and trains of gravel were thus laid down, some of them upon the surface of the Kansan drift more or less remote from the major drainage courses, some of them strewn along the larger valleys. Two distinct phases of these gravels have been noted in previous reports, one the upland, the other the valley phase. The probable genesis of the two phases is



IOWA GEOLOGICAL SURVEY

MAP OF THE

SUPERFICIAL DEPOSITS

OF

WINNESHIEK

COUNTY

IOWA.

BY

SAMUEL CALVIN

1906

Scale $\frac{1}{125,000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

Iowan Drift

Kansan Drift
Partly Driftless
Overlain by loess

TRI CITY LITHO CO. DAVENPORT IA.

discussed in the report on Howard county, volume XIII, page 67. Both types occur in Winneshiek, the upland gravels being found at a number of points in almost every township in the county, the valley phase, so far as observed, being best developed along the river in the southwest quarter of section 7, Glenwood township. For concrete illustrations of typical exposures of the upland gravels reference may be made to the deposit a short distance south of the northwest corner of section 22, Hesper township, to the gravel ridge in the southwest quarter of section 36, Madison, and to the sheet of gravel on the upper slopes of the high bluffs, on land belonging to Mr. Halloran, in the northeast quarter of section 15, Decorah township. At the point named in Hesper township a section of gravel, five feet in thickness, has been laid bare by the cutting of a gully along the side of the road. The material is very ferruginous, rusty, weather stained, and many of the pebbles and cobbles are in an advanced state of decay. In the Madison township example there is a mixture of coarser and finer fragments, a condition that is very commonly observed wherever the materials have been deposited in close proximity to the edge of the ice. The assortment is always better where the load had been carried for longer distances. Pebbles, cobbles, and small bowlders up to a foot in diameter, occur together at the same level. The beds, as usual, are very ferruginous, and a large proportion of the rock fragments are badly decayed. The materials have been used to some extent in improving the local roads. On the Halloran land the gravels occur 100 feet above the river and lie in a broad sheet which in places attains a thickness of fourteen feet. The very rusty appearance of the deposit led to the making of a number of test pits by encouraging the hope of finding a bed of iron ore. Remnants of similar beds are found on the slopes of the bluffs at numerous points around Decorah.

At the locality mentioned above in the southwest quarter of section 7, Glenwood township, the road, for some distance, has been cut through a broad sheet of rather fine gravel which occupies the bottom of the valley of the Upper Iowa or Oneota river. The deposit, which typically illustrates the valley phase of the gravels, occurs at intervals for a number of miles up and down

the valley. It is composed of pebbles which have an average diameter of half an inch. These are mostly smooth, well rounded, polished quartz. There is quite a proportion of sand mixed with the pebbles, and the deep ferruginous stain indicates that rock fragments containing iron bearing minerals were primary constituents of the deposit. Nearly all the mineral species except the quartz are partly or wholly decomposed.

Deposits of Uncertain Age, Probably Kansan.—The history of the Kansan drift and the intimately associated Buchanan gravels is fairly clear, but there are some deposits in the larger valleys, possibly belonging to the Kansan stage, which it is more difficult to understand. The gorge of the Upper Iowa and all the other stream trenches of any consequence in the county are preglacial in age. The Kansan drift comes well down into the valley on the sides of the bluffs around Decorah, and some of the gravels deposited by floods from the melting Kansan ice, lie in the very bottom of the gorge. The valley was not only completely excavated before the Kansan, but it was even deeper than it is to-day; for during the time of the Kansan floods aggradation took place to a depth of not less than fifteen or twenty feet. Now from Decorah eastward to the county line there are extensive terraces of sorted and stratified materials, well up on the sides of the valleys, from thirty to fifty feet above the present flood plain. The materials composing these terraces differ markedly from those making up the Buchanan gravels in that they are largely of local limestones and cherts. In most cases less than ten per cent of the fragments are of crystalline rocks. Along the river from the county line westward, in the southeast quarter of section 36, Pleasant township, the terraces are well developed. Not far from the line the stratified terrace materials have been undercut by the river so as to show a fresh section forty feet in hight. Near and below the middle of the section there are many coarse blocks from the Oneota and Saint Peter formations, but the main body of the deposit consists of rounded fragments of chert and local limestone, with some pebbles of quartz, diorite, granite and other northern crystallines, all embedded in quartz sand. Some small streaks made up almost exclusively of northern pebbles and quartz sand are iron

stained and resemble the ordinary Buchanan gravels. Between section 36 of Pleasant township and section 16 of Decorah, there are many remnants of the same terrace deposits. In section 12 of Decorah the terrace has been cut into by a small wet weather tributary exposing a fresh surface of the same materials found farther east. The deposit is well stratified. Some streaks of clay are intermingled with the gravels. There is also a considerable amount of quartz sand; and rounded fragments of crystalline rocks occur, varying from small pebbles a fraction of an inch, to cobbles eight or nine inches in diameter. The major part of the material, however, consists of fragments of sedimentary rocks from the local formations. The larger crystalline cobbles are very rare. On the left bluffs of the river opposite Decorah, between Mill spring ravine and the Ice cave, the terrace material takes the form, in part at least, of irregular, only partially worn chips of limestone arranged in definite bands, with what seems to be washed residual clay in the interstices; while mingled with the local fragments are small numbers of crystalline pebbles. Toward the base of the deposit the limestones are worn and well rounded; foreign pebbles are present in larger proportional numbers than higher up; all the fragments are embedded in clean quartz sand; and the whole is bound together with calcareous cement into a firm conglomerate. The base of the terrace is here thirty feet above the present flood plain, and on a platform between the terrace and the river are many remnants of very much weathered, ferruginous Kansan drift.

Along with the deposits of uncertain age one at the mouth of Mill spring ravine should perhaps be mentioned. While some of the materials here are the same as those composing the terraces described above, it is very probable that the deposit is due to the working over and re-deposition of a variety of materials at a much later date. The section exposed occurs at the side of the road and is twenty feet in hight. The arrangement of the materials is without definite order. Small bodies of stratified, oxidized, iron stained gravels are shown; there are irregular local masses of gravel composed of limestones and cherts; large blocks of calcareous tufa, probably a precipitate from the springs of the immediate neighborhood, are disposed without

order throughout the face of the section; there are yellowish and ashen silts, some containing such land shells as Succinea and Polygyra; and there are others containing the shells of aquatic types such as Physa. Impressions of leaves resembling those of the modern elm and hazel are found in some of the blocks of calcareous tufa. The whole appears to be but a remnant of a much larger deposit that once may have filled the ravine from side to side for some distance above its mouth.

Post-Kansan Loess.—There are evidences of two distinct loess deposits distributed throughout the county. Between the two the differences in age are very great. The older loess is related to the Kansan drift, though the time of its deposition may have been very much later than the appearance and withdrawal of the Kansan ice. Its exact age can not be determined from the knowledge now at hand. It lies on an eroded surface of Kansan till, which would imply that its deposition did not immediately follow the disappearance of the Kansan glaciers; that this loess was old, weather-stained and altered before the second, or Iowan loess was laid down upon it, is also clearly indicated. The old loess is blue or gray in color. It is much more plastic than the yellow Iowan loess. Evidences of age and alteration before it was covered by later deposits are found in the segregation of the iron in the form of large, ferruginous, concretionary "pipes", and in the great numbers and large size of the loess kindchen which indicate the leaching and re-deposition of the calcareous constituent. Where the deposit is trenched by rain cut gullies, the ferruginous "pipes" are shown to be not only very numerous, but to be hard enough to bear complete separation by washing from the softer matrix and resistant enough, for some time, to cumber the bottom of the trench by scores and hundreds. The concretionary process evidently began around plant roots, but it went on, building up concentric rings, until diameters ranging from three to five inches were attained. Shimek* has referred to the particular case observed near the northwest corner of section 20, Bluffton township. In 1903 one of the best exposures in the county was to be seen at this point. The older loess was exposed in a steep sided trench to a depth of four feet,

**The Loess and the Lansing Man.* By B. Shimek, *Bulletin from the Lab. Nat. Hist. of the State University of Iowa*, Vol. V, p. 340. Iowa City, November 19, 1904.

and above it was a bed of fresh, yellow, Iowan loess having a thickness of eight or ten feet. The locality is on a hillside sloping to the north, and both loess deposits are thickest near the top of the slope. The older deposit, in fact, thins out and disappears in a short distance, and before the middle of the slope is reached the younger loess rests directly on yellow shaly limestones belonging to the Maquoketa stage. Both older loess and Kansan drift had been removed by erosion before the last episode of loess deposition began. The alteration of the older loess was all finished before the deposition of the later, for the overlying bed of ten feet in thickness would effectually protect the lower from further change. Except at the surface, there are no evidences of change in the upper bed since it was laid down. The locality noted above is but one of scores showing the same relations of two distinct beds of loess. When seen in a clean vertical section, the line between the two deposits is quite sharply drawn as shown in figure 18, reproduced from a view by Shimek taken in section 3, Decorah township.

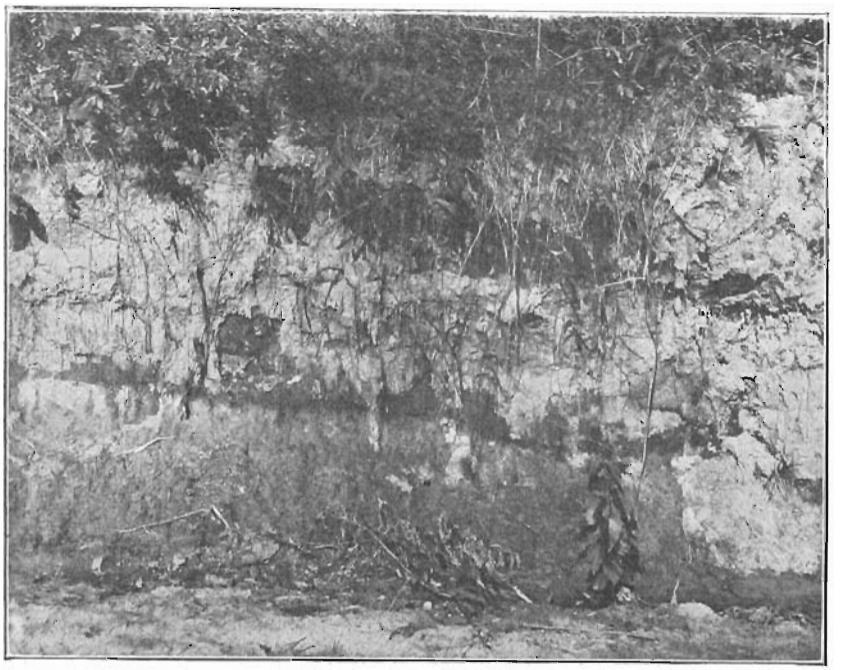


Fig. 18.—An older and a younger loess in section 3, Decorah township. The dark band below the middle of the view separates the two deposits. Photo by Shimek

IOWAN STAGE.

Iowan Drift.—The Iowan drift covers less than one-third of the total area of Winneshiek county. It pushes over into Winneshiek from Howard and Chickasaw and terminates quite abruptly along a very irregular line before advancing far, at any point, beyond the limits of the western townships. The erratic line which marks the extreme east[ern] limits of the Iowan ice sheet, is described in the chapter on topography, and is shown on the map of the Pleistocene deposits. West of this line the surface is, in general, a very gently undulating plain, contrasting strongly with the deeply dissected surface of the Kansan drift, or of the region in which the present topography is due to preglacial erosion. The inequalities of the Iowan surface are not due to water sculpture in post-Iowan time, but to the irregular manner in which the drift materials were deposited by the Iowan ice. In Winneshiek county, as elsewhere, the Iowan drift is very thin near its margin and fails in many cases to conceal the effects of pre-Iowan erosion, but in general this younger drift plain, with its broad, shallow sags and low, flat, intervening swells, shows none of the characteristics of a water carved surface. The deposit under consideration is characteristically developed over the major part of Jackson and Sumner townships and the west central part of Orleans.

The Iowan till is yellow, comparatively free from cobbles and pebbles, moderately calcareous, and its surface is strewn with large, coarse grained, light colored granite bowlders. Usually the Iowan area has no loess; the till shows scarce any signs of oxidation or leaching; its bowlders are fresh; its surface has not been modified in any appreciable degree by erosion; its materials remain practically as the retreating Iowan glaciers left them.

Along its border the Iowan drift plain is usually abruptly set off from the Kansan by a conspicuous ridge of loess. The Kansan area is always loess covered; the surface is carved by drainage waters into a branching and re-branching system of ravines which diminish in depth and importance as the number of branches is increased, and finally fade into scarcely perceptible, shallow depressions on the divides; over the ridges and ravines

loess is spread as a veneer, showing that the erosion was complete before the yellow loess was deposited; the upper surface of the till is reddened by oxidation which took place during the long pre-loessial period of exposure; the lime carbonate has been leached from the upper zone; many of the few small bowlders which occur are so far decayed as to crumble of their own weight or under very slight mechanical force; the contrast between the old, eroded, weathered and loess covered Kansan and the young, fresh, uneroded Iowan is very great, and it is all the more striking when the two areas are seen in close proximity, as along the Iowan margin. The differences are sufficient to arrest the attention of any intelligent observer.

Iowan Sand Terraces.—Deposits of fresh, white, clean sand are strewn along the valley of the Upper Iowa, and are particularly well displayed in sections 13 and 24, Decorah township, and 7, 8 and 18, Glenwood. The sand overlies the rusty Buchanan gravels, in areas of some width, on the east side of the road leading from Freeport to the bridge in section 7 of Glenwood; but it seems to have been deposited chiefly in comparatively narrow belts along the lower slopes of the bluffs. It is referred to the time of flooded streams connected with the melting of the Iowan ice on the basis of its fresh appearence, its stratigraphic relations to the old, weathered Buchanan gravels and its evident identity with sand beds of Iowan age in counties ranging from Johnson to Mitchell. In connection with the record of sand trains along the main drainage course of the county, it will be appropriate to note a number of Iowan bowlders in the northeast quarter of section 21, and the northwest quarter of 22, Fremont township, at some distance from the Iowan border. There is here a sharp curve in the river changing the flow from the northeast toward the southwest, and on the outside of the curve there is a low, flat area extending eastward for a distance of half a mile. The bowlders, fair in size and more than a dozen in number, are located on this flat space upon which the stream would be projected at high water. It is easy to see that floating masses of Iowan ice carrying bowlders would be swept out of the main channel and stranded at such a point, when the swollen

stream was transporting and depositing the Iowan sands. At its maximum, the Iowan ice lay deep in the valley of this river, and in all its drainage basin, west of Foreston in Howard county, and it was from this region that the bowlders near the northeast corner of section 21, Fremont township, came.

Iowan Loess.—Intimately related to the coming and going of the Iowan ice sheet was the deposition of the young, fresh, yellow loess which begins at the Iowan border and is spread to indefinite distances over the region lying outside of that margin. The whole county, excepting the area of Iowan drift, is covered with it. The loess is very young as compared with the other phenomena of the area upon which it lies. It varies in thickness from a few inches to ten, fifteen or twenty feet, but in general it conforms to all the erosional inequalities which had been developed on the surface before the time of its deposition. If, therefore, it could all be swept away, the topographic features of the region would not differ essentially from those of the present. This loess is a fine, yellow dust, evidently derived from the yellow Iowan till to the westward, often containing numerous fossils in the form of the fragile shells of land snails, and furnishing occasional small limy nodules, the loess kindchen. The more extensively and thoroughly the loess is studied, the stronger grows the evidence that it is simply wind-blown dust, a true aeolian deposit. Usually the formation shows no evidence of stratification, but bedding planes are indicated in not a few instances. When seen at all, they conform to the surface slopes or present the irregularities sometimes seen in drifts of snow or bodies of aeolian sand. A case of very complex bedding is seen near the center of the west half of the northwest quarter of section 33, Calmar township.

Alluvium.

Fine alluvial deposits occur in the valleys of the principal streams. In that part of the Upper Iowa or Oneota valley between the northwest corner of the county and Decorah there are many small areas and narrow belts of alluvium, well shown at Plymouth Rock, Bluffton, and other points where the walls of the valley recede from the stream and true flood plains are

developed. Below Decorah there are a number of similar areas, but the coarser sands and gravels connected with the effects of melting glaciers, have choked up the valley and preoccupied the space which might have been covered with alluvium, to a much greater extent below Decorah than above. Alluvial plains of no very great size occur along Bear creek and Canoe creek in the northeastern part of the county, and along the Turkey river in the southwest.

Soils.

The soils of Winneshiek county are very varied. There are stony residual soils without loess in the hilly driftless portions of the county, in the eastern parts of Glenwood, Pleasant and Highland townships, as illustrated in figure 17; in the same part of the county there are residual deposits covered with loess; in the central and western portions of the Kansan area the soil is loess underlain by Kansan drift; in the Iowan area the soil is a dark loam derived directly from the Iowan till, without loess; and in the stream valleys there are the small areas of alluvial deposits, furnished with the most fertile and most desirable type of soil in the county. Large bodies of superior farming lands, with loess-Kansan soils, are found in the county in two distinct areas. One of these includes the northern parts of Fremont, Burr Oak, Canoe and Pleasant townships, together with the whole of Hesper and the western part of Highland. The other covers the central part of Frankville township; from fifteen to twenty square miles in the eastern and central parts of Madison; and the uplands on the summit and sides of the Cresco-Calmar ridge from the Iowan border near Calmar to the southeast corner of the county. In these areas the surface is more or less rolling and naturally well drained, the soil is loose and mellow, free from rock fragments, easy of cultivation. The slopes are not so steep but that a fertile loam is developed. In the other parts of the loess-Kansan area, in proximity to streams, the surface is characterized by steep sided ravines and narrow intervening ridges, the land is easily trenched and gullied by rains, humus is washed away as fast as developed, and the soil is less fertile and less easily cultivated than on the uplands farther from the drainage courses.

Iowan drift soils are found in the western portion of the county, over the whole or part of Orleans, Lincoln, Calmar, Sumner and Jackson townships. The surface is less rolling than in the loess-Kansan area, for which reason the surface drainage is not so universally perfect. A deep, black, fertile loam is developed, rich in lime carbonate as well as in organic matter. There is sand enough to make the soil warm, mellow and easily cultivated. Granite bowlders are scattered over the surface, but they are not sufficiently numerous to be troublesome. Lack of drainage in very wet seasons is the only disadvantage which these soils have as compared with those of other parts of the county, and this is nowhere serious. It is probably true that the most valuable farming lands of Winneshiek are found in the area of Iowan drift. The distribution of the small areas of alluvial soils has been noted under the head of Alluvium.

Unconformities.

In discussing the stratigraphy of the county reference was made to the very pronounced unconformity between the Productella beds of the Devonian and the Maquoketa formation of the Ordovician. The Silurian is absent. The Niagara limestone may never have been deposited in the northern part of the county, or it may originally have been very thin and, in this area, was removed by erosion before the beginning of the Devonian. The few small outliers of Niagara in Washington township would indicate that the Niagara probably was present, at least in the southwest part of our area, and that erosion must be reckoned as one of the factors in accounting for its absence between the Maquoketa and the Devonian at points only a few miles from the outliers, on the west side of the Turkey river.

The unconformity here is due to overlap. During the Silurian the shore line was moved westward to an unknown distance, and at the beginning of the Devonian the sea was still remote from Winneshiek county. At the most it was only the lower part of the earlier division of the Niagara that was deposited in this area before the waters receded to the west. The greater part of what has been called the Delaware stage of the Niagara is

absent, as well as the whole of the Gower, which is so conspicuously developed and attains its maximum thickness in Scott, Cedar and Jones counties. On the other hand the lower part of the Devonian is missing. During the time represented by the Otis, Independence, Lower Davenport, and most of the Upper Davenport beds, as these have been described by Norton in reports on Linn, Scott, and Cedar, the region was still undergoing erosion. The Devonian horizon that lies in contact with the Maquoketa in Winneshiek and Howard counties is that of *Productella subalata* Hall, and *Spirifer pennatus* Owen, a horizon equivalent to that of the city quarry and other quarries in and around Independence, a horizon well above the Fayette breccia, even above the Gyroceras beds of the Upper Davenport. The uplift which caused the waters to recede probably came to an end about the beginning of the Devonian, and a slow subsidence allowed a transgression of the sea upon an eroded surface. The movement reached its maximum about the close of the time represented by the Upper Davenport beds of Norton. The crustal warping which made the transgression possible faded out toward the southeast; there are no indications of it in Cedar county where the several divisions of the late Silurian and early Devonian seem to follow each other without any break, but the abnormal eastward trend of the Devonian margin in Muscatine and Scott counties may be indicative of some corresponding movement in the region south of Cedar.

The other unconformities in the county are connected with the deposition of the successive formations belonging to the Pleistocene. The Kansan drift is unconformable on all the formations of the Paleozoic rocks with which it comes in contact. The Iowan drift was spread over a deeply eroded surface of the older Kansan. The Iowan loess is unconformable on Kansan drift in some localities, and on the older indurated rocks in others.

Economic Products.

BUILDING STONE.

Winneshiek county is fairly well supplied with building stone. The lower part of the Oneota limestone as exposed in the valley of Bear creek from Highlandville to the east county line, is capable of furnishing a superior grade of quarry stone, and all it lacks is development. The same beds come to the surface

along Canoe creek in sections 25 and 26, Pleasant township, and a mile farther north, in a small valley which traverses sections 23 and 24, they are again exposed. The stone is a light cream colored dolomite in very regular layers, durable, easily worked and suitable for use in the construction of the higher grades of public and private buildings. Owing to distance from markets no effort has been made in this county to operate quarries at this horizon; but it should be known that the formation is, in all respects, the same as that which, in Minnesota, has won deserved reputation under the trade name of Kasota limestone.

Most of the quarries about Hesper and Decorah are worked in the upper beds of the Platteville limestone. For a thickness of five or six feet below the base of the Decorah shales (the "Green Shales" of authors) the Platteville lies in regular beds from three to eight or ten inches in thickness. The stone is not dolomitic, but is firm and compact, with fine even grain, gray or drab or bluish in color on fresh fracture, but bleaches to lighter shades on exposure to the weather. Stone from layers at this horizon is quite durable and has been used extensively, particularly in the construction of the earlier buildings, in Decorah. In the neighborhood of Mill spring, and between the spring and the Ice cave, a large amount of good building material has been taken from these beds. The lower quarry of Mr. Halloran, located northeast of the city, is worked in the Platteville limestone. Another quarry near the north end of the Ice cave bridge (Fig. 6) has furnished quite an amount of material from the same formation. Joints are so distributed that pieces ten to twelve feet in length and nearly as many feet in width may be taken from the quarries, and the superior resistance of the rock to weather and mechanical wear fits it admirably for door steps and flag stones.

A number of quarries have been opened in the Platteville limestone around Hesper. The one which has been worked most constantly is located south of the village and is operated by Mr. E. H. Weber. Several hundred cords are taken out annually and sell at the quarry for $4.50 a cord. Mr. Weber has been operating here for twenty years. The lower part of the Decorah shale is in position above the quarry stone and has to be stripped in

carrying on the work. In the species and grouping of the fossils, the shale here resembles that near Waukon in Allamakee county more than that near Decorah. Only the beds for a few feet in thickness below the shale are taken out by the quarrymen, and, during the many years of operation, the stone has been removed over an area of some acres.

In the lower part of the Platteville formation the beds are thicker and more magnesian than in the quarries described. There are found here the "Lower Buff Beds" of the Wisconsin and Iowa geologists. This horizon is capable of furnishing a superior grade of building stone, especially suited, where the beds are thickest, for bridge piers and other heavy structures. In point of durability and resistance to weather the Lower Buff beds have few superiors. At no points in the county have these beds been utilized to any considerable extent. Individually and in the aggregate their thickness is much less in Winneshiek than in Dubuque county. The heaviest ledges of the Lower Buff beds in Winneshiek county were seen in the valley of the Upper Iowa in the vicinity of Freeport and farther east.

A number of quarries have been opened in the Galena limestone, above the level of the Decorah shale. Many are small and were operated only temporarily to supply some immediate local need. At no point does quarrying in the Galena assume commercial importance. The upper quarry of Mr. Halloran is worked at the level of the lower Receptaculites zone, about fifty feet above the Decorah shales. The quality of the stone is not as good as that from the upper part of the Platteville. The bedding is not so regular; the texture is less uniform; much of the stone is liable to split into small chips on long exposure to the weather. There is a large quarry at Nordness which is opened in the upper beds of the Galena. The Maquoketa begins only a few feet above the exposure. The upper beds are badly checked and weathered, but below these there are some quite firm ledges varying from ten to fourteen inches in thickness, with which there is associated a ten inch band of shale. About the middle of the quarry face there is a belt of irregularly bedded concretionary limestone, three feet in thickness, altogether lacking in the homogeneity requisite for good quarry stone. Below this belt

there are six feet of more regular and more homogeneous beds, with some of the individual courses fully ten inches in thickness. Another quarry at the same horizon as that at Nordness is opened on the south side of the Yellow river, in the north half of the northeast quarter of section 13, Bloomfield township, on land belonging to the estate of Mr. Melvin Green. The characteristics are the same as at Nordness except that there are several bands of shale, ranging from two or three, to ten inches in thickness, interstratified with the limestone. Another quarry which includes the uppermost beds of the Galena is located on the south side of the diagonal road in the southwest quarter of section 17, Bluffton township. There are other small quarries, worked temporarily or intermittently to supply the purely local demands, near Kendalville, Plymouth Rock and Burr Oak. In the southeast quarter of section 7, Fremont township, are some small quarries opened in beds of dolomitized Galena, a phase of the formation resembling that at Dubuque. Dolomitization here is local, being restricted to an area of three or four square miles. The many other small openings in the Galena limestone are too numerous to be individually noted.

Much of the Galena limestone is very unreliable. When quarrying has been carried into the hillside beyond the zone of weathering, the ledges may appear to be thick, firm, durable, suitable for any kind of construction; but after being placed in walls and exposed to alternations of temperature and the chemical effects of air and moisture they split into thin laminae and eventually break up into small, irregular chips. The effect is well shown in the portions of the old retaining wall still standing around the court house square.

Quite an amount of quarrying has been done in the Maquoketa formation. The Isotelus zone is very regularly and evenly bedded, and in a few instances it is firm enough to serve for building stone. One quarry at this horizon, located in the northeast quarter of Springfield township, was noted in connection with the general discussion of the Maquoketa beds. In some cases the strata lying between the Isotelus zone and the Clermont shale are capable of furnishing a fair grade of building material for rough walls and foundations; but the principal

quarry horizon in the Maquoketa is that of the Fort Atkinson limestone. This, not infrequently, is a hard, granular, crystalline dolomite comparable to some phases of the Galena limestone in Dubuque county. At Fort Atkinson quarries have been worked in this formation for many years, and one of these, located a few yards west of the old fort (Fig. 12), is capable of yielding blocks of any desired dimensions up to three feet in thickness. Another quarry in the same limestone, on the east side of the fort, has been operated intermittently for some time and has furnished quite an amount of fairly good material. In the southwest part of Military township there are many quarries and natural exposures in the Fort Atkinson beds. The small quarry near the center of the southwest quarter of section 33 and that near Ossian in the northwest quarter of section 15, will be found noted with some detail in the part of this report which treats of the Fort Atkinson limestone. On the north side of the Cresco-Calmar ridge the Fort Atkinson formation comes to the surface and is quarried near the center of the southwest quarter of section 27, Springfield township, and about sixty rods south of the northwest corner of section 5, Bloomfield. At the point last named the rock is yellower, softer, less crystalline than at Fort Atkinson. The rocks of this horizon become more earthy or shaly toward the northeast, and gradually lose the qualities of a pure dolomite which distinguish them at the type localities in Fort Atkinson and Clermont.

A small amount of material has been taken out at a few points from the Niagara limestone. The old quarry in the small Niagara outlier west of Festina, near the northeast corner of section 22, Washington township, has been noted in discussing the Silurian System. No stone for any useful purpose has been taken from any phase of the Devonian.

Lime.

While no lime is now manufactured in Winneshiek county, the materials for making a high grade product are not wanting. The upper two-thirds of the Oneota is particularly well suited for this purpose. This is a hard, granular, crystalline dolomite of much the same character as the Galena limestone which is so

successfully made into lime at Eagle Point, Dubuque. At Waterville in Allamakee county lime is made and shipped extensively, and the stone used is the Oneota, the same stone that is so well developed at Highlandville and Canoe, and along the river below Freeport, in Winneshiek county. The non-dolomitic Galena formation in Winneshiek would make an excellent lime if it were used soon after it is burned, but it will not keep as well as lime made from the Oneota dolomite. It is liable to deteriorate by becoming air slaked if kept in stock for even a comparatively short time, and, if in this condition it is used for mortar, it is easily crumbled and washed out of the joints. The greater part of the Niagara limestone should make a good grade of lime. There is nothing in the Devonian that can be recommended for lime making, unless it may be the small amount of the lithographic phase in section 7 of Orleans township.

Clays.

There are two brick yards operated in Decorah, and these make practically all the clay products manufactured in the county. The raw material used is loess. This clay is worked as it is taken from the pit. The brick are sand moulded and dried on the yard. About 500,000 are made annually. The loess is abundant and widely distributed throughout the county, being found everywhere except in the small area of the Iowan drift. Loess clay might be used in making a high grade of pressed brick. The Maquoketa clays, the Clermont and Brainard shales, are not used at any point, though it should be possible to obtain Clermont shale with little difficulty in the vicinity of Fort Atkinson. This is the clay that has been used for many years in making brick and tile at Clermont in Fayette county.

Road Materials.

Materials for the improvement of the country roads and village streets are abundant in the form of limestones and gravels. Limestone, easily crushed to form macadam, may be found convenient to almost every locality in the county; but the natural stores of road materials occur in the beds of Buchanan gravels

which are so widely and generally distributed as to be present in practically every neighborhood. The most abundant deposits of these gravels, as already noted, are along the stream courses, beds notable for their extent occurring in the valley of the Upper Iowa below Freeport.

Water Supplies.

Streams and springs, the natural sources of water supplies, are well distributed throughout the county. Shallow wells in the surface deposits are important sources of supply in portions of the county where the drift mantle attains considerable thickness, and the deeper wells drilled in the underlying rock are usually successful at moderate distances from the surface. The great aquifer, the Saint Croix sandstone, which underlies the whole state and supplies the greater part of our artesian waters, may be reached at any point in Winneshiek county with no great amount of drilling.

With a few possible exceptions along Bear creek, the springs of the county are all fed by ground waters which have never reached a depth of more than a few score of feet beneath the surface. For example, the most important spring horizon is at the base of the Galena limestone. This formation is cut by numerous intersecting joints along which the ground waters move with great freedom. The large number of sink holes that pit the surface over much of the area where the Galena is the bed rock, constitute one of the ways whereby water finds access to the fissures referred to. The descent of the waters below the base of the Galena is stopped by the impervious bed of Decorah shale. When valleys are cut below this horizon, the waters find exit, and always on the side where the rocks are dipping toward the valley. Cold spring, a few miles northwest of Bluffton, are Mill spring, on the north side of the river opposite Decorah, are among the noted springs of the county, whose position is determined by the Decorah shale. In both cases the waters come to the surface a few feet above the level of the shale horizon. There are a few small springs along the plane between the Glenwood shale and the Platteville limestone.

There are springs of the shallow type represented by those from the Galena limestone in the eastern part of section 1, Jackson township. At this point, however, the jointed limestone is the Fort Atkinson, and the impervious bed beneath is the Clermont shale. At least one spring in Washington township, in the northeast quarter of the northwest quarter of section 35, is due to ground water in fissures in the Niagara limestone finding exit on top of the Brainard shale.

The contact plane between the Jordan sandstone and the Oneota limestone is another horizon along which springs occur. The spring at Highlandville, and other springs between Highlandville and Quandahl, are due to waters from the Jordan sandstone, which probably rise as a result of hydrostatic pressure and flow out because corrasion of the valley has cut into the upper part of the aquifer.

Water Powers.

The streams of Winneshiek county are capable of furnishing a large amount of water power. Power has been developed on the Oneota or Upper Iowa river at Kendallville, Plymouth Rock, Bluffton, Decorah and Freeport. Some of these plants have been allowed to fall into decay, but the possibilities are there still, and in the future all available sources of water power are certain to be in demand. There are good power properties on the Turkey river at Spillville and Fort Atkinson. Along the smaller streams, such as Bear creek and Canoe creek, there are opportunities for developing and maintaining water powers very much greater than have yet been realized. Mill spring near Decorah is an example of a fair sized stream issuing on the hillside, many feet above the valley, and affording head sufficient to do quite an amount of useful work.

Gold.

Winneshiek is one of the counties in which reports of the discovery of gold in the stream gravels have been in almost constant circulation since the earliest occupation of the territory by the white man. Quite an amount of work was done in attempts to recover gold between 1855 and 1865, and there was

a very active interest in the subject as late as 1903. No substantial basis for the remarkable claims made by the gold hunters could be discovered, and it is safe to say that none ever existed. A few flakes of gold may possibly occur in sands and gravels derived from the drift, the precious metal having been brought from the auriferous ledges of the Rainy lake region by the glacial ice; but it would require unusual patience and persistence on the part of the prospector to discover even a single "color." The citizens of Winneshiek may rest assured that neither in their county nor in any part of Iowa will gold mining in any form ever become a profitable industry.

Caves.

The Galena limestone is notable for the great number of fissures and caverns which it contains. Openings in the formation appear in the faces of bluffs, and their presence is indicated over extensive areas of upland by the great numbers of sink holes which pit the surface. Enlargement of fissures has given rise to caverns or caves.

The Glenwood cave is typical of its kind. The location is in the face of a bluff, less than one-fourth of a mile south of the center of section 34, Glenwood township. There is here a large grotto forty feet high in front and diminishing rapidly in hight to about eight feet, at a distance of sixty feet from the entrance. At this point the cave proper ends, and the opening beyond that is reduced to a comparatively small fissure. The mouth of the cave is a pointed arch which is nearly thirty feet wide at the base. The limestone forming the roof and walls is shattered to small chips by weathering, and the appearance is somewhat rough and ragged. The floor of the cave is not far above the level of the Decorah shale, which appears in the bed of the creek a short distance to the north. The lower zone of *Receptaculites oweni* Hall, is involved in the walls and roof, fragments of the fossil being found amongst the fallen waste which strewed the floor. The cave affords exit for one of the numerous underground streams which traverse the fissures of the Galena limestone.

Mill spring at Decorah issues from a somewhat similar cave, but tumbled blocks from the walls and roof obstruct the entrance. The geological horizon is the same as at the Glenwood cave. The floor is a few feet above the Decorah shale, and *Receptaculites oweni* is seen in the face of a bluff a short distance above the level of the spring pool. Cold spring, a few miles northwest of Bluffton, flows out of a low roofed cavern in the Galena limestone.

The Decorah Ice cave is the most noted of the caverns in this county, the most noted in the state of Iowa. The location is in the face of the bluff on the north side of the river, opposite Decorah. The cave is entered from a recess at right angles to the trend of the cliff, and the direction taken by the chamber is practically parallel to the outer surface. The opening is in fact an enlarged fissure, one of the numerous east-west joints which cut through the Galena. The cliff face is merely a joint face, and the cave is opened along the next parallel joint. The mass of limestone between the cavern and the front of the cliff has settled and slipped outward at the base, the movement being due to the yielding of the underlying Decorah shale. A short distance east of the Mill spring ravine, not far from the home of Mr. John O. Vold, there is an exposure of Decorah shale, and on the slope above the shale there is a great column of Galena limestone which has crept out at the base on the yielding, slippery shale and assumed a nearly horizontal position. The relations of the strata involved in the displaced mass remain practically undisturbed. The widening of the Ice cave is due to similar creep, but the amount of the movement has been very much less.

The Ice cave has attracted attention from the fact that the walls are dry and bare in the late autumn and the first two months of winter, and are coated with ice during the spring and early summer. Ice is formed commonly on the north wall. The amount varies greatly from year to year, but generally the maximum thickness is attained between the first and the middle of June. Later in summer the ice is gradually melted, and it may disappear completely early in August. No two seasons, however, are necessarily just alike, so far as relates to the thickness of the ice, or the times of its appearing and disappearing.

Much depends on the intensity and duration of the cold of the preceding winter. Dr. C. A. White, when serving as State Geologist of Iowa, visited the cave on June 1, 1869, and he records in his report, Vol. I, page 80, that "the ice seemed dry and well frozen, and was evidently accumulating at the time of our visit." On the 22nd day of July, 1877, the writer found the north wall covered with a thick sheet of ice, and, under the conditions of very low temperature then existing, several weeks must have elapsed before the ice was all melted. Some of it may have been present until well on into September.

Between July 1, 1897, and July 16, 1898, Mr. A. F. Kovarik of Decorah carried on a series of observations on the Ice cave, the most important that have yet been made. The results of his work were published in the Scientific American Supplement, No. 1195, issued for November 26, 1898. From this paper I quote freely the facts which follow. The cave divides into two branches at a distance of twelve meters from the entrance, one branch leading southward into a small chamber having an opening upward to the outer air; the other leading westward into the ice chamber. At six meters from the division is the point where the ice accumulates to the greatest thickness, a point called by Mr. Kovarik the "Locus Glacialis." According to the excellent report before me the greatest thickness in 1897 was attained July 1, when it was about 25 cm., or ten English inches. From then the thickness gradually decreased, so that July 17, it was only 15 cm.; July 24, 10 cm.; and by September 3 all the ice had disappeared. After September 3, the temperature gradually rose until October 16, when it reached its highest point, +8.3° C., or about the temperature of a cold spring; from thence, a gradual decrease in temperature continued till the time of the lowest point. This was February 26, 1898, when the thermometer showed —6.6°C. In 1898 the ice at Locus Glacialis first appeared about May 29. Two weeks before that time water was dripping from the crevices between the north and south walls. Beginning with May 29, the ice rapidly increased in mass, and by June 12, the time of maximum quantity, the ice covered the wall for a width of nearly two meters, having the greatest thickness of 29 cm. The decrease was rapid in 1898; July 16, only a small

quantity was found, and by August 1 all the ice had disappeared.

The following table is quoted from the paper of Mr. Kovarik; the temperatures are given in degrees Centigrade.

TIME.	IN THE VALLEY. (SHADE)	DIVISION.	LOCUS GLACIALIS.	END.
July 1, 1897	+33.3	+ 2.2	0.0	0.0
July 27, 1897	+21.1	+ 5.0	0.0	0.0
August 14, 1897	+32.2	+ 5.8	+3.1	0.0
September 3, 1897	+32 2	+ 7.2	+3.1	+8 3
September 18, 1897	+33.9	+ 8 6	+6.1	+8.3
October 16, 1897	+ 24 0	+10.0	+8.3	+8 3
October 30, 1897	+ 10.0	+ 7.2	+4.7	+5.0
December 11, 1897	— 2.2	— 2.7	—1.1	—2.2
January 8, 1898	0.0	— 2.7	—3.9	0.0
January 22, 1898	— 5.0	— 6.1	—3.9	—3.9
February 26, 1898	0.0	— 6.6	—6.6	—5.0
March 12, 1898	+ 2.8	— 1.6	—2.7	—2.7
March 26, 1898	+ 8.8	— 1.7	—1.6	—1.1
April 16, 1898	+25.6	— 1.4	+1.1	—1.1
April 30, 1898	+13.9	+ 1.1	—1.1	—1.1
May 28, 1898	+17.2	+ 1.7	—0.3	0.0
June 9, 1898	+25.0	+ 1.7.	—0.3	0.0
June 18, 1898	+28.3	+ 1.7	—0.2	0.0
July 16, 1898	+35.0	+ 7.2	0.0	+2.2

From this table it will be seen that the popular notion that ice melts in the cave in winter and freezes in summer is not quite correct. It is true that freezing does take place in the summer, but the table shows the impossibility of anything like melting in the winter. Early in the winter the temperature in the cave reaches the freezing point, about as early as it is reached in the air outside; and with rare exceptions a freezing temperature is maintained until late in the following summer. After the ice disappears in late summer the temperature rises above the freezing point, and so long as this condition lasts no ice can be formed. By the middle of December, when the temperature of the cave has fallen below freezing, all moisture near the surface has been sealed by frost, circulation is stopped, no water finds its way into the cave, no ice is formed, though the temperature is low enough to congeal water if only it were present. The formation of ice begins when the ground thaws in spring and the released waters can percolate into undergound fissures and caverns. The cold that freezes ice in May or June is the cold of

the preceding winter. The walls of the caverns may be chilled for some distance from the surface to a temperature many degrees below the zero of our ordinary Fahrenheit thermometers and water may be congealed by simple contact with such a surface. The Ice cave, however, is but a part of the great system of intersecting fissures and caverns that cut through the Galena limestone in many directions, the master joints being here, as elsewhere, east and west. There are miles of these joints connecting one with another in the hills about Decorah, and they represent millions of cubic feet of air space. If the winter should be severe and the cold protracted, these spaces may be filled with air having a temperature below zero Fahrenheit. With the advent of warm weather the colder, denser air flows out and may maintain a low temperature in the openings through which it escapes for some time after summer has fairly set in. As shown by McGee, the rapid expansion of this air as it issues from an orifice, would tend still further to reduce the temperature as in the case of an artificial ice machine, but the main cause of the freezing observed in glacieres like the Decorah Ice cave will be found in the stored up "cold" of the preceding winter.* That there is a movement of air into the cave in winter and outward in summer is confirmed by the observations of Mr. Kovarik. On July 1, 1897, he found a cold breeze coming from the cave, which was noticeable thirty meters from the entrance. At the entrance the breeze was so strong as to make it impossible to light an ordinary match, and, near the floor, it would blow out the flame of a candle. From December 11, 1897, till February 26, 1898, he found the air flowing into the cave. In this way we

*For explanation of the phenomena of Freezing Caverns, and especially of the Decorah Ice Cave, the reader may consult the following references:

WHITE.—Report on the Geol. Surv. of the State of Iowa, By Charles A. White, M. D., Vol. I, page 80. Des Moines, 1870.

KOVARIK.—The Decorah Ice Cave and its Explanation, By Alois F. Kovarik. Scientific American Supplement, No. 1195, page 19158, November 26, 1898.

BALCH.—Glacieres and Freezing Caverns, By Edwin Swift Balch, pages, 88, 89, 177. For general discussion of causes of subterranean ice, see pages 136-161. Philadelphia, 1900.

KIMBALL.—Ice Caves and Frozen Wells as Meteorological Phenomena, By H. H. Kimball. Monthly Weather Review, Vol. XXIX, page 366. Washington, 1901.

McGEE.—Ice Caves and Frozen Wells, By W J McGee. The National Geographic Magazine, Vol. XII, page 433. New York, 1901.

KIMBALL—Ice Caves and Freezing Wells, By H. H. Kimball. Monthly Weather Review, Vol. XXIX, page 509. Washington, 1901.

can imagine the great limestone chambers were filled with air at a temperature below the freezing point. The later outward movement of this stored up winter air maintained in the cave a temperature at, or near to O °Centigrade, throughout the months of spring and early summer.

Acknowledgments.

In prosecuting the survey work in Winneshiek county the writer had the assistance of Professor M. F. Arey of the State Normal School during the season of 1903, and of Mr. J. H. Lees of the University of Chicago in 1905. Many citizens of the county have, for many years, taken an intelligent interest in their local geology, and these have been able to render valuable service by directing the representatives of the Survey to characteristic outcrops and typical exposures. Of these, Dr. F. Worth of Hesper deserves especial mention. As acknowledged in the preceding pages, free use has been made of the excellent paper on the Decorah Ice Cave by A. F. Kovarik. The limitations of the working season preclude the possibility of making continuous observations for a sufficient length of time, by members of the staff of the Survey, and such work as that done by Mr. Kovarik is a contribution to knowledge of the greatest value. The Survey is indebted to Professor B. Shimek for the following excellent paper on the Botany of Winneshiek county. The paper represents a large amount of painstaking work, and the part relating to the trees and shrubs which are adapted to the soils and climate of the county will be found especially valuable. It is a pleasure here to acknowledge the value of the topographic work done by the United States Geological Survey. Free use has been made of advance proofs of the topographic sheet of the Decorah quadrangle, both in the field and in the office. Without this work as a base, the mapping of the geological formations would have been practically impossible. To the individuals and organizations contributing to the success of the survey of the county, the writer acknowledges his obligations and extends sincerest thanks.

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF WINNESHIEK COUNTY, IOWA.

BY
SAMUEL CALVIN
1906

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

LEGEND
GEOLOGICAL FORMATIONS

Cedar Valley, Wapsipinicon		Middle Devonian	
Niagara		Silurian	
Maquoketa		Trenton Series	Ordovician
Galena, Decorah, Platteville			
Saint Peter		Canadian Series	
Lower Magnesian			
Saint Croix, Jordan		Potsdam Series	Cambrian

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