GEOLOGY OF WORTH COUNTY.

BY

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CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Worth is included in the northern tier of Iowa counties, and accordingly lies next to Minnesota along its northern border. It has Winnebago on the west and Mitchell on the east, while Cerro Gordo lies next to the south. In common with the other Minnesota border counties, Worth county has a row of fractional townships along the northern line. In comparison with the average county of Iowa it is unusually small in size, possessing only twelve townships, while each member of the northern row of these lacks more than a mile of having its full north-south dimension of six miles. With the deficiency in area above mentioned, Worth county contains approximately 400 square miles, about 256,112 acres.

PREVIOUS GEOLOGICAL WORK.

In the records of early geological observations in Iowa very little has been written directly concerning the region under consideration. Pioneer explorers found subjects of only passing interest in the broad expanse of grassy prairies, here and there modified by rows of prominent hills and knobs, and not yet obscured by the numerous artificial groves with which they are now so copiously dotted. To the early scientist Worth county presented few geological phenomena to attract more than momentary attention on account of the almost universal drift covering, and hence merited the expenditure of little space in the several reports that have been made on northern Iowa geology.

David Dale Owen,* in his report on the geology of Wisconsin, Iowa and Minnesota in 1852, makes bare mention of the Devonian rocks exposed along the banks of Shell Rock river, as also of the fact of their being quite generally buried beneath the drift.

In 1858 A. H. Worthen,† under the direction of Prof. James Hall, first state geologist of Iowa, traversed the area drained by the Cedar river and its branches and referred the country rock of Worth and Cerro Gordo counties to the Hamilton group.

In the final report of Dr. C. A. White,‡ 1870, are recorded the most detailed observations yet published. In his discussion of the geology of Worth and Cerro Gordo counties, the extreme thinness of the drift along Shell Rock river is spoken of and comment made on the remarkable difference in surface features between the eastern and western portions of the county. The rock exposed along the Shell Rock was referred to the Devonian; but the magnesian layer was not recognized in Worth county. Several analyses of peat taken in the vicinities of Northwood and Silver Lake were made, and the results were included on page 398 of the same volume.

The terminal Wisconsin moraine (now known as the Altamont) was traced across the county by Upham§ and in his report on "the terminal moraine in Iowa," published in 1880, its course is accurately described. Further study of the surface will, however, necessitate some rectification of the position of the ice margin as mapped by Upham.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface of Worth county presents two extremes of topographical development; one, the area covered by the hills and ponds of the Altamont moraine, the other, the mild drift plain

*Owen's Geol. Survey of Wisconsin, Iowa and Minnesota, p. 78.
†Geology of Iowa, Vol. I, Part 1, p. 396.
‡Geology of Iowa, Vol. II, pp. 249-253.
§Ninth An. Rep. Minn. Geol. & Nat. Hist. Surv., p. 389, 1880.

of the Iowan stage. The former occupies essentially the western half of the county, while over the eastern half the Iowan drift predominates. A line separating these two areas or, in other words, in a general way tracing the edge of the Wisconsin drift, would enter from the north, between six and seven miles east of the middle, and, continuing across the county in a general southwest trend, pass into Cerro Gordo an equal distance west of the middle point of the south county line. The sudden break from rugged to mild surface features is very noticeable to the traveler going from west to east across the county. Marked differences are apparent in the condition of the streams, as to both the present stage of development of the systems and the history and age of the separate streams. In accordance with the relative ages of the two till sheets, the drainage is less perfect in the newer Wisconsin than on the older Iowan.

WISCONSIN DRIFT AREA.

So recent in geological time was the recession of the Wisconsin, the last ice sheet which infringed upon any portion of Iowa's territory, that the consequent streams thus originated have had a very insufficient length of time in which to subdue their genetic relatives, the lakes, ponds and marshes. Evidence of the youth of these streams is found in the scarcity of side branches, the high gradient, and their indefinite courses among the hills. In this category would be included Beaver and Winan creeks in Fertile township, Goose creek flowing across the northeast corner of Hartland, the two branches of Elk creek in Bristol township, as well as numerous other small tributaries not of sufficient importance to merit a name.

Those rivers of sufficient size to remove the material as rapidly as it was furnished by the melting ice succeeded in maintaining their old channels entirely or in part. Among the rivers of Worth county Shell Rock is the only one that has retained its pre-Wisconsin course entire. The upper part

of the old Elk creek valley is filled in and practically obliterated so far as its relation to the present Elk creek is concerned. It is quite plain that Lime creek, at some stage during the presence of the Wisconsin glacier, was diverted from a portion of the channel occupied by it previous to the advent of that ice.

By inspection the region of Wisconsin drift may be divided into two areas, the division being based upon the prominence of development of morainal features. Including nearly the northwest one-half of Northwood township, the outer morainal region would embrace the whole of Hartland and Brookfield townships and a generous three-eighths of Danville in triangular shape off the northwest corner. Although typically morainic the pronounced topographical characters are not here exhibited on so large a scale as they are on the inner morainal tract to the west. Warren Upham, in "Exploration of the moraine in Iowa,"* gives the following accurate description:

"In Worth county the eastern belt of this moraine enters Iowa in sections 8 and 9, Northwood, and extends four miles southwest with a width of about one and one-half miles, to section 24, Hartland, and then three miles south to the northeast corner of Brookfield. It consists of uneven swells and hills thirty to forty feet above the intervening hollows, and fifty feet above Northwood, which is situated one and one-half miles southeast, on a plain of valley drift about twenty feet above the Shell Rock river. Next this belt appears to be broken and removed by an offset six miles to the west; and thence its course is south through the east part of Bristol, and through sections 2, 11, 14, 23, 27 and 33, Fertile, its southeast border being about one-third mile northwest of Rhodes' Mill, in section 34. In these townships the formation is in knolls, hillocks and short ridges, trending to the south or southwest, and thirty to sixty feet high."

*Ninth Ann. Rep. Minn. Geol. and Nat. Hist. Survey, p. 389.

It will be noted that after reaching the northern edge of Brookfield the moraine is spoken of as removed by an offset six miles to the west. If traced southward the extreme margin would lead along the eastern edge of Brookfield and across Danville, as before outlined. What is here spoken of as an offset to the west is apparently an opening in the Altamont moraine, exposing an inner moraine here six miles west of the Altamont, and marking an extended halt in the ice retreat. This inner moraine is well defined southward through Bristol and into Fertile township, where it unites and coincides with the outer range of hills which here assumes a more southwesterly direction. Again, from Mr. Upham's report:

"At the southwest corner of this county these morainic hills become more abundant and abrupt, and form a very rough wooded belt two or three miles wide, for a distance of six miles west from Rhode's Mills to Pilot mound. This tract includes parts of four counties, and is bounded on the south by Lime creek."

This row of hills may be followed northward into southern Silver Lake township where its prominence is less marked, but where it nevertheless maintains its strictly marginal characteristics. Its individuality is somewhat obscured by a merging into the maze of hills and peaks with which the whole area of Hartland and eastern Silver Lake is well supplied.

Viewed broadly, it would appear that the Wisconsin ice invasion of Worth county consisted of a lobular ice border, with, perhaps, many local advances and retreats. How long a time, or how numerous the minor oscillations, are matters of conjecture only.

It is obvious that the region most recently deserted by the ice would present the most youthful characteristics. The region of lakes, including Silver, Bright and Rice lakes, is bounded on the east by the range of hills, the inner moraine. Silver lake seems to have been caught immediately within this confining wall. Rice and Bright, while not so near

the edge, are the direct results of this temporary halt in the ice motion. During the final period when the ice prevailed over the three western townships, Silver Lake, Bristol and Fertile, those previously occupied, Hartland, Brookfield and portions of Northwood and Danville, were divested of their frigid mantle and probably overrun with water, laden with debris from the thawing glacier's edge. The retreat of the ice west-northwestward was more or less continuous, with minor intermittent pauses, to the position of the Altamont moraine proper in Winnebago county, which culminates at the southern border of the county in Pilot Mound, a heap of glacial detritus more than 180 feet high.

The topographical disparity between these two areas of Wisconsin drift is one of degree of development only. So far as the difference in time since their deposition is concerned, geologically it is not of sufficient length to be taken into account in a consideration of subsequent denudation of the land. What is observed on the one is found much exaggerated in the other. The face of the country in general is one of ice moulding rather than water sculpture.

The presence of knobby, rounded hills unaffected by water erosion, and ponds and kettle holes situated at high elevations and in apparently most unstable positions are conspicuous features over the whole morainal area. In Northwood township these forms predominate, though subdued, the most prominent points reaching elevations of from twenty to twenty-five feet above the level of the adjoining Iowan drift plain. In Hartland they assume greater proportions, reaching heights of thirty to forty feet. South into Brookfield they extend in elongated ridges, but diminishing in size. At the eastern edge of Brookfield, in the old valley of Elk creek, now occupied by that stream, are developed some of the most unique morainal features in the county. The scale of the ice architect was small in fashioning these heaps of debris, but here is displayed, in miniature, what elsewhere in the county appears with greater magnitude. Some of the forms

observed are nicely rounded kame-like knolls, not more than thirty feet high, and apparently of not more than twice this distance in basal diameter, with surfaces strewn with small bowlders; some are more elongated and of the nature of the esker, while others, locally known as "hog's-backs,"

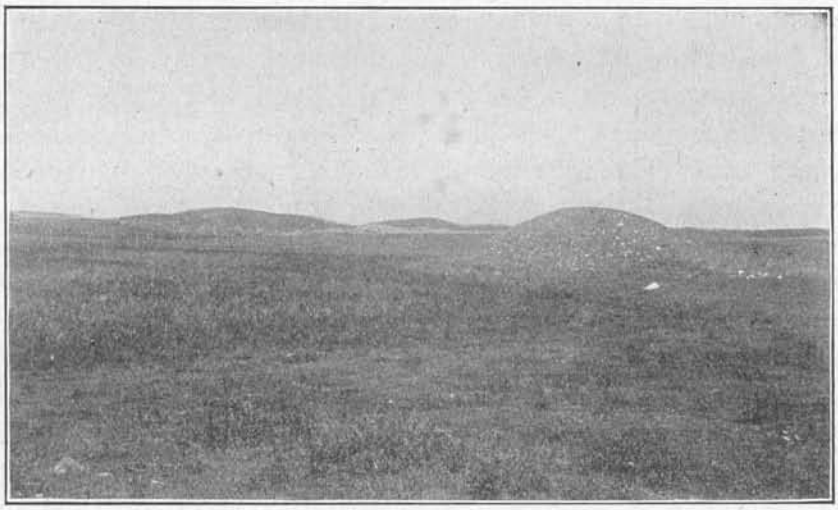


FIG 37. Morainal knobs in eastern Brookfield township, in the old valley of Elk creek. The bowlders are almost exclusively limestene.

are distinctly drumloid in character. The broad preglacial valley of Elk creek appears to have been a convenient place for the eastward extension of a narrow tongue of ice, which modeled and built these conspicuous land forms at its leisure, sometime after the main body had receded. In its course across Danville this marginal tract is not specially pronounced, the rolling, hilly country giving way to the mild surface of Iowan drift.

At the offset to the west in Brookfield township, mentioned by Upham, the immense ridge of drift which extends north and south between Bristol and Brookfield into Fertile township is a very conspicuous topographical feature. Approached from either the east or the west it rises before the traveler

until at the summit, at an elevation of about 130 feet, he overlooks wide stretches of county in both these directions. Southward it eventually blends into the miscellaneously arranged mass of hills in the southwest corner of the county. Lime creek breaks through this morainal belt at Fertile and for more than two miles east along nearly the remainder of its course in the county it is bounded on the south by high bluffs of Wisconsin drift. This is only another instance illustrating the lobular, irregular nature of the ice border. The region west of Fertile, which is part of a larger area extending into Cerro Gordo, Hancock and Winnebago, and which reaches its climax in Pilot Mound at the northern border of Hancock county, presents perhaps the most typically developed ice-moulding in the county. Here are exhibited with striking prominence hills and eminences, some rounded and steep, others elongated with steep sides, and showing flattened tops. Some are connected in series assuming a general north and south direction, while others are isolated in position and often surrounded by low wet ground or even a pond or peat bog. These latter, with occasionally a small stream, are the only variations in the monotony of hill and hollow, and the public highway must often diverge a mile or more from its proper location in order to avoid swamps and miry places. Natural conditions, assisted by the agency of man, are at work draining these places, for within the space of the last twenty years areas now passable and even under cultivation were covered with water during spring and early summer, and so wet as to be quite unfit even for pasturage the remainder of the year.

In the western part of Bristol and Silver Lake townships there is a general slope to the west. The surface features are prominent, but not so characteristic as to the east and south.

Rice lake, so called from its supporting a luxuriant growth of wild rice around its marshy borders, is so situated as to lie mostly in Winnebago county, only an elongated tongue-like projection extending into Bristol township of Worth

county. Of the approximate two hundred acres within Worth county no portion may be said to be covered with water the year round. It has an average width of one-fourth mile, but rapidly widens to more than one-half mile where it crosses into Winnebago county. The basin occupied by the lake embraces an area considerably larger than that actually inundated. The major portion of the large depression is overspread with a heavy accumulation of peat, which sustains growths of rushes, wild rice and other water-plant life. At no point in the water-covered portion is the depth more than a few feet, as a thin reedy vegetation is always present in the most open places. It is surrounded by low hills of drift, which appear to have been modified but little since they were deposited by the ice. They often barely separate from the main depression other depressions in the drift surface which lack entirely the first vestige of drainage. This would indicate that the origin of Rice lake is the same as its kettle hole relatives. From such a hollow there would be no outlet for water except through evaporation and seepage. The comparative mildness of the topography to the south may be illustrated by the fact that an attempt was recently made to drain the lake in that direction by ditching and tiling.

Silver lake, somewhat north and east of the center of Silver Lake township, is a small body of open water confined within walls of glacial drift. It is nearly a mile long and one-half as wide. It has no outlet. In periods of excessive precipitation its overflow is discharged through a small stream with only a poorly defined channel northeastward across the line into one of its genetic relatives in Minnesota. To the west and east the lake extends out to a swamp covered with rushes and swamp grass. To the north and south where the open water is immediately bounded by banks of till, conspicuous levees have formed through the action of the ice pressing shoreward. There are no inlets of any importance. A few V-shaped ravines, originating only a short distance from the shore among the hills, have served to enlarge but slightly the

catchment area as it was left at the final retreat of the ice. A conception of the limited extent of this area may be gained from the fact that numerous ponds containing water are found only a few rods from the edge of the lake itself. A notable example of this kind is presented at the south edge of the lake, along which the wagon road passes. The road here follows for some distance along the crest of a ridge, "hog's-back," of drift fifteen to twenty feet above the water. This acts as a partition between a peat swamp to the south and the open water of the lake.

Bright lake, near the northwest corner of Silver Lake township, and hence, near the northwest corner of the county, is another small lake of glacial origin. It is surrounded by the knolls and rounded hills of the Altamont moraine. Within these it is entirely enclosed, with the exception that an attempt has been made to produce artificial drainage to the northwest. Local surface drainage is the chief source of the water supply. Except in seasons of unusual rainfall, no outlet is necessary. The amount of evaporation is sufficient to maintain an equilibrium, and even in exceptionally dry periods to produce complete desiccation, so that portions of the area included in the lake basin are almost yearly under cultivation.

Deserted lake basins are not infrequently found. In Fertile township, less than a mile north of the town of Fertile, is an old lake bottom now covered with a thick layer of peat. It includes the west central portion of section 26, practically the north half of section 27, and triangular areas off the corners of 21, 22 and 28. It is not beyond the remembrance of the old settlers of the neighborhood, that this basin known as "Goose lake," was perennially covered with water. This broad flat is now mantled with a thick growth of marsh grass, and although not yet sufficiently subdued to admit of cultivation, pasturage and the natural filling in from the surrounding hillsides are rapidly converting the springy, miry peat soil into one of a more firm and stable character, suitable for purposes of agriculture.

The material of these deposits as shown in a road cut across Goose lake is light brown in color near the top, grading downwards through different shades of brown to nearly black at a depth of four or five feet. In the upper portion the moss fibers are distinct, forming a closely interwoven spongy mass, while a few feet below, where the plant fibers are somewhat altered, a more compact earthy aspect is presented.

IOWAN DRIFT PLAINS.

That part of the county lying east of the Wisconsin drift margin, as described in the early part of this paper, belongs to the region of Iowan drift. This till sheet was deposited over all northeastern Iowa, with the exception of the "Driftless Area" in the northeast corner, and presumably it underlies the later deposits of Wisconsin drift which cover the western part of Worth county. Owing to its thinness and the lack of a distinct morainal margin, its southern border has not yet been worked out in detail, but, in a general way, the limit would be a line taking a southeasterly direction from a point in southern Hardin county, where it appears from under the Wisconsin, through Marshall, central Tama, Benton, northern Johnson, Cedar and Scott to the Mississippi river. As the order of superposition determines the relative age of deposits, it will be obvious that the time of deposition of the Iowan drift must ante-date the deposition of the Wisconsin. This is, however, not the only test to be applied in determining the matter of relative age. The person of only ordinary habits of observation cannot but be impressed with the more mature aspect presented by the broad level plains and gentle swells of eastern Worth as compared with the hummocky undrained surface configuration of the western portion of the same county. The one presents some of the characteristics of an erosional topography while the other is a geologically young and ice-moulded topography.

The characteristic features of this till sheet as displayed here, are very similar to those elsewhere studied and described. Although universally overlain with Iowan drift, the

present greater inequalities of the surface are not entirely due to the material of this drift sheet. In fact it would seem that nearly if not quite all of the prominent variations in relief are the expressions of a pre-existing surface of water erosion. Over the major portion of the area this undoubtedly depends directly upon the land forms of the next older drift sheet, the Kansan, so called from its having reached its maximum southern extension in Kansas. But along the streams, and the Shell Rock in particular, the country rock determines largely the land contour. At several outcroppings of the indurated rocks along the lower Shell Rock, except for the prevalence of bowlders, the presence of any glacial drift whatever would scarcely be recognizable.

From the contact line with the Wisconsin in Northwood township a typical level drift plain widens out to the south and east. Northwood is situated on this plain between twenty and thirty feet above water in Shell Rock river. So extremely flat is the region, and from lack of gradient so little chance have the erosive agents had to do effective work, that drainage is almost entirely wanting. As a consequence the rain-waters accumulate in the slightest depressions, where they either evaporate or disappear through seepage. This state of affairs so close to the edge of the Wisconsin drift may in some measure be due to clogging up of drainage ways by the over-wash material from this drift sheet; or as is the case in other parts of the county, the lack of drainage appears to be due to the original level condition of the drift surface.

Eastern Worth in general is a series of these plains with a gradual slope to the south and east. The greater portion of Barton township, with eastern Kensett, is, with the exception of occasional mild undulations, a broad, level expanse stretching southward so as to embrace also the northern third of Union. Over parts of this area, in Barton township north of Bolan, in exceptionally wet springs, square miles have been known to remain practically under water for some days. So slight is the relief and so low the gradient, the water appar-

ently hesitated in doubt whether to seek egress through Deer creek to the northeast or Shell Rock to the southwest.

Another striking surface irregularity that is encountered at times, quite frequently in Union township, is the presence of what appear to be at first sight kettle holes of glacial origin. These are usually more or less circular in form, often filled with water, and present generally the characteristics of the glacial pond. They vary from three to ten rods in diameter and from three to six or eight feet in depth, while sometimes two or three may be connected by a narrow channel-like depression. Cultivation of the land has done much towards obliterating many of these, but considering their position on this relatively old drift sheet, as also the proximity to the surface of the limestone underlying this region, a possible explanation may be found in a process more characteristic of a limestone region than that of ice moulding. Wells in the country east of Shell Rock river indicate distances to rock of from three to forty feet. Where the limestone is so near the surface, and covered only with a thin layer of pervious drift material, percolating waters would have a very solvent effect upon the limestone thus exposed to their action. Should the water on reaching the rock surface chance to find a crack or fissure it would, on account of the solubility of the rock substance, begin at once to enlarge the opening, and eventually find its way out through subterranean passages. With the process once started, allow it to operate for ages, and there will be formed an inlet to a subterranean stream with gradually increasing proportions as the processes of disintegration, solution and transportation continue. Environment in general goes to indicate that these "sink holes,"* as they have been designated, have formed through this process. Clogging up of an underground water way would evidently, by further accumulation, result in a pond which would resemble in many respects the kettle hole of a new ice topography.

*Rocks, Rock Weathering and Soils, G. P. Merrill, p. 259.

That portion of Deer Creek township, north of Deer creek, which divides the township diagonally from northwest to southeast, takes on a more rugged aspect, which character persists eastward into Mitchell county. This, as also the more dissected area in southern Union township, seems to be in part the results of a more vigorous water action. Although streams of any importance are scarce, what few small drainage ways are present have eroded their channels, in most cases, to the rock surface. Though all have had an equal length of time in which to accomplish this erosion, it is evident that those passing through regions of comparatively thick drift covering will cut more rapidly into this loose superficial material than those which encounter the indurated rock strata at a depth of only a few feet. The deeply eroded stream channels correspond in a general way with areas of thick drift and hence produce the rougher topography.

DRAINAGE.

In harmony with the two types of land surface represented in the county are the drainage systems developed. In efficiency of drainage a similar comparison may be made as between the youthful and more mature drift surfaces. Not only is complete drainage a sign of an old topography, but a mature land surface is to a great extent the result of the work of water as an erosive agent. The Iowan drift is, therefore, more nearly perfectly drained than the newer Wisconsin, although the river systems, as ordinarily considered, lack much of typical development, even on the older drift sheet. Shell Rock river, Elk creek, its largest confluent, and Lime creek, the three largest and most important streams of the county, all flow in preglacial valleys in parts of their entire courses.

*Lime creek**—True to its name, that portion of Lime creek included within the boundaries of Worth county, flows over a limestone bed, and its channel is usually limited by walls of this same material. Could the person who named it have observed it at the beginning of the last ice invasion, or even

*Iowa Geological Survey, Vol. VII, p. 136.

before the advent of the Iowan ice, he might have as appropriately assigned to it this appellation, for it occupies a well defined preglacial valley, bounded by rock-supported terraces.

Pursuing a general northerly direction after its random windings among the knobs and hills of western Cerro Gordo county, it enters Fertile township near the middle of section 34. Continuing northward for a little more than one-half mile to the town of Fertile, it makes a bold turn of nearly 90° to slightly south of east, which general trend it maintains to the east edge of Fertile township, where it comes to the south county line. Eastward along southern Danville it meanders, as though reluctant to depart, and crosses the county line seven times within a distance of one and one-half miles before making its final exit into Cerro Gordo at the middle point of the southern boundary of section 32.

Below Fertile the creek skirts the eastern bluffs which bound its valley, here nearly one-fourth mile wide and narrowing southward. The confining hills range from twenty to thirty-five feet in height. The valley floor is strewn to the water's edge with drift material which often stands out in low ridges or mounds. Bowlders are plenteously scattered over the surface of the drift. The stream has here cut a maximum depth of six to eight feet into the limestone, which depth gradually lessens southward until at the south county line the dip of the strata carries them beneath the level of its bed. In changing its trend towards the east or southeast it assumes the normal direction for the strike streams of northern Iowa. Lime creek, at the point where the direction of its course becomes normal, passes into the region of Iowan drift, and at once a series of terraces, of which two are especially prominent, appears. These terraces are mainly developed on the north side of the stream. On the south are high bluffs of Wisconsin drift as far as the middle of section 31 of Danville township, where less pronounced hills of Iowan take their place. The stream holds quite closely to the southern border of its ancient valley along the whole of its eastward course.

In fact, at no point was there observed any terrace development to the south. This may in part be accounted for from the fact that Lime creek is a strike stream, one that runs parallel to the strike, and consequently at right angles to the dip of the underlying sedimentary rock strata. The dip being to the southwest, the gravitational tendency of the stream in corrading its channel would be to work gradually in that direction. Another factor which might come in to accentuate this process is the relative rapidity of weathering in the two walls of the valley. The north wall, exposed to the direct rays of the sun during the day, is thus subjected to the greatest daily extremes of temperature. The same differences will hold with respect to the seasonal variations. The rock ledges, following the physical law that heat expands bodies and cold contracts, would absorb heat during the warm parts of the year, and at the same time take in considerable moisture. As the temperature is lowered during fall and winter, the stored up heat is given off, and the contraction alone would be sufficient to accomplish much in rending the rock mass by cracking and fissuring. But here enters as an effective aid to the contraction of the rock mass the expansion of the included moisture on a lowering of temperature. Water is an exception to the above mentioned law of contraction and expansion, as is well known by the phenomenon of freezing. The small particles of moisture held in the interstices and cavities of the rock upon freezing exert perhaps a greater force in rock-breaking than any other agent. Thus are the processes of insolation and expansion, cooling and contraction, united and at work upon all rocks wherever such conditions exist. It is obvious that although the same conditions would obtain in the south wall of the valley of Lime creek, the extremes of temperature would not be so great, owing to the oblique angle at which the rays of the sun would strike it, if at all. Other active influences would be weakened in proportion. Therefore, it is not unreasonable to conclude that these secularly operating agents have been instrumental

in bringing about the state of affairs that to-day exists in the valley of Lime creek.

The history of the stream, which has been recorded in full by Dr. Calvin in his report on the geology of Cerro Gordo county,* would hold good for that portion of it that traverses Worth county territory, for it both enters from, and makes its exit into Cerro Gordo. South of Fertile and before making the bend to the east, Lime creek has evidently done considerable work towards making a valley for itself, the greater portion of which was excavated during the latter part of the Wisconsin ice epoch. It is not an alluvial valley, but one partly drift filled and sprinkled with bowlders. Some time during this stage of glaciation, and evidence at hand would point to an early stage, Lime creek was diverted from its preglacial valley at Fertile where the abrupt change in direction has already been noted. Had this diversion taken place late during the sojourn of the Wisconsin ice, the stream in this morainal region would not have the width of valley which it exhibits to-day; for the subsequent lapse of time has not been sufficient. Further, in the history of any stream, valley making does not proceed to any extent without a consequent deposition of alluvial material, but there is here no alluvium; the peculiar conditions of low bowldery mounds and ridges extend in this part of the valley to the very margin of the channel. It is probable that a late ice advance has strewn the alluvial valley, cut during early Wisconsin times, with drift detritus, thus making clear the present somewhat anomalous state of affairs.

In its course eastward this stream skirts the northern edge of a lobular eastward extension of Wisconsin drift which it is reasonable to suppose may have narrowed the old Lime creek valley more or less by a process of filling in which gradually pushed the stream northward. Lime creek has cut a maximum depth of twelve feet into the limestone since the retreat of the Iowan glaciers which spread a thin sheet of till over hill and hollow of probably the entire county. From the immediate

*Ann. Rep. Iowa Geol. Surv., Vol. VII, p. 137.

bank of the stream extending back with a gentle ascent sometimes one-half mile or more, but usually only a few rods, is a low plain covered with a thin layer of Iowan drift and strewn with conspicuous Iowan bowlders. This is bounded to the north by a sudden rise of twenty to thirty feet which initiates a broad terrace plain, also sloping slightly toward the stream, and stretching away to the north often more than two miles, where it is again bounded by a well defined ascent of twenty to twenty-five feet. Beyond this hills of Iowan drift assume the role of surface deposit and thus bound Lime creek's ancient valley. On the level of the second terrace, broad swales extend northwestward, with very gentle inclination, even to the edge of the Wisconsin drift. These are occupied by stream channels that are dry most of the year and which originate in some peat marsh or pond on the edge of the morainal area. Such an instance is noted with its beginning in section 21 and including portions of 22 and 27 of Danville township, also one originating in section 20 and embracing part of 29 of the same township. These appear to have served as broad waterways accommodating sluggish flows from the edge of the melting ice.

The history of the stream cannot be more clearly stated than by inserting a quotation from Professor Calvin:*

"The preglacial valley had a width reaching from the south bank of the present stream to the line of hills which form the northern border of the second plain noted above. The sub-Aftonian, if it was ever deposited in this region, cannot be differentiated from the Kansan, but it is certain that, at the close of the Kansan stage, the old valley was only partially filled with detritus, and an important drainage stream of the subsequent interglacial stage followed the old depression and in part re-excavated the old valley. At the beginning of the Iowan stage the re-excavation was far from complete, its amount being represented by the space between the south wall of the valley and the first terrace north of the present

*Iowa Geological Survey, Vol. VII, pp. 137-8.

stream. The Iowan glaciers deposited only a very thin sheet of drift over this region; but they carried numerous bowlders that are scattered over the whole surface of highlands and lower plains. The plain between the terrace and the channel, and rising only a few feet above the level of the water, is

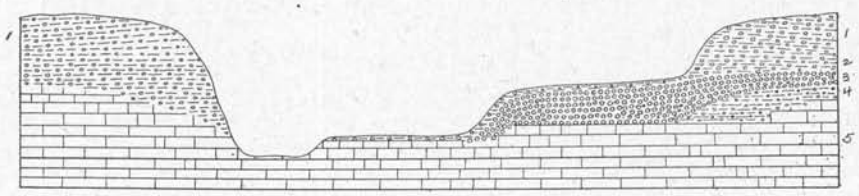


FIG. 38. Profile across the valley of Lime Creek in western Danville township. 1. Wisconsin drift. 2. A thin layer of Iowan drift which overlies both terraces. 3 Buchanan gravel. 4. Kansan till. 5. Codar Valley limestone.

thickly strewn with large Iowan bowlders that have not been disturbed since they were deposited at the level at which they now lie. The present channel is a shallow trough cut in the Iowan drift of this lower plain and represents the inconsiderable amount of erosion since the withdrawal of the Iowan ice."

At the edge of the moraine in the region of Fertile these terraces gradually lose their identity, although the widely excavated ancient valley may be traced in a continuous northwest direction nearly to Winnebago county. It is quite disguised in places by the hills and ridges of the drift which partly fill it, while at other points its limits are still very evident. In general, this preglacial valley appears as a broad depression, which the Wisconsin glacier failed to obscure in dumping its load of rock detritus. Beaver creek, a small postglacial stream, flows through this partly filled trough. Originating among the hills and ill-drained ponds of Winnebago county, it joins Lime creek at Fertile. Although it effects the drainage of that portion of western Fertile which is drained at all, so meagrely is this developed that the catchment area would scarcely exceed the width of the depression that marks the old Lime creek valley. The stream has accomplished some down-cutting, but it has not eroded the entire valley which it occupies. Its bed in many places seems

to be made almost entirely of the smaller rock fragments of the Wisconsin drift. Just at the point where it joins the present Lime creek valley is found a rather anomalous collection of larger bowlders resembling much those characteristic of the Iowan till sheet. Veined and crumpled gneisses, granites and greenstones are here clustered together in a manner not at all characteristic of the newer drift; they probably have been derived from a remnant of the older Iowan.

Lime creek receives two small tributaries—Winan creek at the southwest corner of Danville township, and Willow creek at the point where it leaves the county at the south edge of section 32.

Winan creek has its source in the neighborhood of Rice lake, Bristol township, in the swales and ponds of the moraine. Meandering diagonally across Fertile, it escapes upon the Iowan drift practically as it reaches the upper terrace of Lime creek valley in section 25. Rock is not exposed in its banks, but after leaving the Altamont moraine it flows at about the rock level in the upper terrace of Lime creek. Except an occasional ill defined slough or low swale, it has no branches of importance and drains only a narrow strip of the morainal country through which it passes. In its lower course springs, which flow out at the base of the post-Kansan gravels, occur along its banks. This is usually at the surface of the limestone, but may represent the contact line between these gravels and a layer of Kansan till proper.

Willow creek is a stream of minor importance so far as drainage is concerned. It originates among the ponds of western Danville township, and has a well defined channel southward from the middle of section 18 to its confluence with Lime creek. Ledges of limestone appear in its banks along the road in the western part of section 20 and the eastern part of 19. Eight to ten feet of rock are seen more or less covered with talus. The coral reef, as found along Lime creek, is exposed underlain by a crystalline dolomitic limestone. Below this point no stratified rocks are exposed, although the

stream has cut somewhat below the level of the surrounding country rock. The valley is quite generally strewn with Iowan bowlders.

Shell Rock river.—With the exception of Deer Creek township, which is drained by Deer creek, Shell Rock river and its confluents drain the whole of the region of Iowan drift. Shell Rock also receives important branches from the region of Wisconsin drift, and through these tributaries effects the drainage of a considerable portion of the morainal tract. The river enters the county from Minnesota in the northeastern part of Hartland township and, after clipping off a small triangular area in the corner, crosses into Northwood township. Following a general east-of-south direction it traverses diagonally Northwood and Kensett townships and cuts off from the northeast corner of Lincoln a triangular area of about one and one-half square miles, and from the southwest corner of Union a similarly shaped area of practically three square miles, beyond which it passes into Cerro Gordo county. From its entrance into Hartland township to its exit from the Altamont moraine at Northwood, it has a somewhat winding course through a broad drift valley twenty-five to thirty feet below the general upland to the east. Through this region it is generally bounded by low boggy or marshy banks. The depression through which the stream flows averages more than half a mile in width. It is partly filled with hills of Wisconsin drift, which appear as low elongated mounds in the vicinity of Northwood, but have a more abrupt and pronounced character farther up the stream, so that the outlines of the broad valley are more or less obscured in the edge of Minnesota. Beginning in the upper part of section 12, Hartland township, and gradually widening southward to a maximum of one quarter mile at the south line of this section, is a low flat terrace skirting the west bank of the stream. This platform ranges from ten to twelve feet above the water and disappears in the southern part of section 13. The material composing the terrace, as exposed in the river gorge just north of the bridge,

on the road through the middle of section 18, Northwood township, is a gravelly bowlder clay.

Immediately west of Northwood this partially filled valley increases in breadth to nearly a mile, but it narrows considerably within the city limits. Although it has no marked boundary on the east, it is represented quite continually by a flat bottom land to the west of the stream. The bottom land is bounded by hills of bowlder clay and gravel for a distance of two or three miles south of Northwood. This wide valley is gradually lost and beyond this, in the remainder of its course in the county, Shell Rock river occupies a shallow rock-bound pre-Iowan valley which has been only partially filled with Iowan drift. This shallow trough is not generally well defined, and often, on account of its drift disguise, is not noticeable; but numerous instances are found, especially in the eastern part of its course in the county, where the river is unmistakably bounded some distance back on either side by walls of limestone, the intervening space between which is covered with a thin layer of drift and sprinkled with bowlders. The stream has cut into the rock a short distance, usually from four to six feet. This ancient valley is not conspicuous north of the center of Kensett township where rock exposures cease in the banks of the stream. The first striking evidence of it is found in section 27, Kensett, where the wagon road crosses the stream. West of the bridge a few rods, and separated by a ridge from the present channel, is a notable depression which, followed to the north or south, joins the present stream valley. This appears to have been once the bed of the river, which now takes a more direct course. Again, on the township line between Kensett and Lincoln is observed a like instance to the east of the river. Limestone outcrops on the road on the dividing ridge ten to twelve feet above the water, thus making the evidence of a preglacial channel here stronger than in the former case. A low terrace of limestone overlain with drift material quite generally bounds the valley to the east, often twenty to thirty

rods back from the stream, which usually occupies the western side of its preglacial valley and which, on account of its impinging against this side, causes the more abrupt appearance and greater number of rock exposures.

A somewhat exaggerated section across Shell Rock river in section 32, Union township, above the county line bridge, would show the following profile.

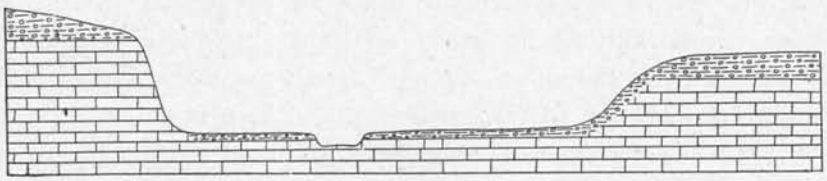


FIG. 39. Profile of Shell Rock river valley in southern Union township. The limestone trough is overspread with Iowan drift to the water's edge and sprinkled with Iowan bowlders.

It seems not unreasonable to conclude that a stream of considerable size must have occupied this channel for some time previous to the Iowan ice. Shell Rock has very few tributaries. With the exception of Mad creek, a small and insignificant stream in western Union less than a mile long, it receives no tributaries whatever from the east. From the west it has only two of importance as drainage lines, Elk and Goose creeks, both of which originate in the region of the moraine.

Elk creek is formed by the confluence of several small branches, the two principal ones joining in section 10, Bristol township. In the whole of its course across Brookfield township and to its confluence with Shell Rock, it is a sluggish stream with low marshy borders. It occupies a broad depression from one-half to three-quarters of a mile wide and from thirty to forty feet deep which, as has been mentioned, apparently once accommodated a much more important stream than Elk creek. This wide hollow is partly filled with Wisconsin drift which, at some places, has somewhat obliterated its borders, but never completely filled it. It passes beyond the limits of the Altamont moraine in eastern Brookfield, and

emerging upon the Iowan this ancient valley is finely displayed by a broad level terrace bounding the stream to the north. The terrace is best developed in section 19, Kensett township, where it rises fifteen feet above the stream. This gradually decreases to the east, giving way to a more or less well defined flood plain along the southern side of which the stream meanders. Although no well data furnishing information concerning the amount of material deposited in this old valley are available, it would seem that the limestone is not far below the surface. West of the road a few rods, in the middle of section 24, Brookfield township, is a small rather abruptly-rounded mound, in appearance not unlike a morainal hill. On closer inspection it was found to be not only rock supported but its mound-like form was partly due to a ledge of limestone which outcropped beneath a cap of gravelly material eight to ten feet above the water. This is evidently a mound of circumdenudation as no other outcrops are found at this level in the vicinity.

Goose creek is a small stream issuing from the marshes and ponds of the moraine. Its headwaters are in Minnesota, and, to within two miles of its junction with Shell Rock river, it is merely a series of connected peat marshes. In its lower course it has a quite well defined valley, but it is narrow and no sensible amount of alluvium has been deposited.

As to the history of Shell Rock river little more can be said. In the upper part of its course the country rock is entirely obscured by glacial drift, and indications are that the river previous to the Wisconsin, and even before the Iowan, had not cut to the underlying rock. The wide drift channel was only partly clogged by the Wisconsin ice, and the stream at present winds among low mounds of drift which it has made little attempt to remove since the ice retreat. The rock-walled, pre-Iowan valley observed in Kensett, Lincoln and Union townships, may be the result of the confluence of two large streams at the point where Elk creek now joins Shell Rock. Preglacial Elk creek was a more important stream

than the present, comparable at least with present Shell Rock river. The old gorge is evidently due to more vigorous water action than is to-day characteristic of the present stream.

Deer creek, the only direct representative of the Cedar river system, is fed principally from the region of the moraine. Both the moraine and the stream enter Iowa at nearly the same point in northwestern Deer Creek township. This creek has cut a shallow channel in the Iowan drift, and reaches the rock surface near the east edge of the county, where it has a narrow drift valley. Deer creek effects the drainage of Deer Creek township, and some small branches carry off the surplus waters from northern Barton township.

GEOLOGICAL FORMATIONS.

GENERAL DESCRIPTION.

The indurated rock strata which underlie Worth county are quite generally hidden by the more or less complete mantle of drift. Save an occasional deep well, the only opportunities for the study of these deposits are found in the shallow gorges of Lime creek and Shell Rock river.

Of the Pleistocene series two formations are represented as surface deposits—the Wisconsin and the Iowan. Although Kansan drift has not been observed in section, its presence is indicated in several ways which will be mentioned under that heading. The sedimentary rocks belong to the Devonian system, and so far as determined are practically continuous over the whole county, with perhaps a gentle dip to the southwest.

In the attempts that have been made to correlate the Devonian strata of Iowa with those of New York, several classifications have been proposed. A certain bed in Iowa would, for example, be found to present similar characteristics to one in the formations of New York, so far as the physical properties were concerned, but with so great a disparity in the fauna contained that a parallelism could not be established. As Professor Calvin has said, so distinct are the

two regions geographically that the conditions of sedimentation were different, and for the same reason the order and succession of faunal conditions were not the same. So that, although the beds of any given epoch in the Devonian period were deposited contemporaneously, the fossil remains may vary widely.

Dr. Owen, in his geologic work on the Devonian rocks of Iowa, correlated them in a general way with the Hamilton, Corniferous and Onondaga groups of New York. In treating of the rocks of the Cedar river and its tributaries, he did not, however, apply any specific name but used the somewhat noncommittal terms, "Formations of Cedar Valley" and "Limestone of Cedar Valley." Following Owen, W. J. McGee in his memoir on "Pleistocene History of Northeastern Iowa," has suggested the name Cedar Valley Limestone for the whole thickness of Devonian sediments between the Lime creek or Hackberry shales above and the Independence shales below. Further study of these rocks in Iowa has led to a division in the old "Cedar Valley Limestone" and to the adoption of the title Wapsipinicon stage, including the Independence shales and those layers below the *Spirifer pennatus* beds of Calvin, thus restricting the name "Cedar Valley" to the beds of limestone below the Lime creek shales down to the upper Davenport beds of Norton.

The exposed layers of Devonian rock in Worth county are referable to the upper portion of the Cedar Valley stage. The several geological periods which are represented are grouped and their relations shown in the following table:

GROUP.	SYSTEM.	SERIES.	STAGE.	DEPOSITS.
		Recent.		Peat. Alluvium.
Cenozoic.	Pleistocene.	Glacial.	Wisconsin.	Till.
			Iowan.	Till.
			Buchanan.	Gravel and sand.
			Kansan.	Till.
Paleozoic.	Devonian.	Middle Devonian.	Cedar Valley.	Equivalents of Mason City sub-stage of Calvin.

DEVONIAN SYSTEM.

CEDAR VALLEY LIMESTONE.

A prominent characteristic of the Cedar Valley limestone in Cerro Gordo county, and a more or less constant feature wherever the corresponding horizon is exposed in the state, is the zone of Stromatoporoids. This interesting reef is present at nearly every outcrop of any importance in Worth county. So continuous is it that it is often a very helpful "landmark" in connecting strata from one exposure to another. The distinguishing character of this bed is the presence of the spheroidal and branching stromatoporoids, which even in the incipent stages of weathering present a peculiar and distinctive aspect. The spheroidal forms are the most generally prevalent, and where disintegration of the ledge has gone on to some extent, these being somewhat harder than the matrix stand out, giving a nodular appearance. Often when the matrix is entirely broken down, these spherical bodies, still intact and apparently unaffected by weathering, may be picked up from the material of the talus slope. This layer appears near or at the top of most of the quarries

of Mason City in Cerro Gordo county, but is of very little account economically. Traced up stream along Lime creek it is a constant member at all exposures showing the complete section to water level. In northwest Lincoln township, Cerro Gordo, and southern Danville of Worth county, it crops out about ten feet above the water in Lime creek, and at places forms a low terrace some six or eight rods back from the bank of the stream. Beyond this point it does not appear along Lime creek, but along the banks of Willow creek, a tributary stream from the north, an extensive outcrop appears along the line between sections 19 and 20 of Danville township.

Again, it is found usually capping the low bluffs of the Shell Rock, except where removed by preglacial erosion. Besides the characteristic stromatoporoids, a few genera of corals, with several different species, are found at this horizon. Excellent specimens of these fossils are obtainable at numerous points along the public road running north from the county line between sections 31 and 32, 30 and 29. The outcrops are close to the west border of the Shell Rock valley, and are sufficient to fully establish the location of the ledge in the Cedar valley series. The rocks exposed in the gorge of the river contain no fossils, yet the characteristic nodular appearance of the weathered ledge above is enough to unmistakably settle the question of the identity of the terrane.

Paleontologically the remaining strata of the Cedar Valley terrane are quite barren. Small cavities, which are probalby fossil moulds filled with calcite, are found in some layers, but the organic structure is so entirely destroyed that practically no forms could be recognized with certainty.

The Cedar Valley strata which outcrop along Shell Rock river may quite generally be recognized as continuous from one exposure to another. But because of numerous small folds which characterize these rocks in this region, the thickness of any given stratum may vary greatly in a distance of only a few rods. Hence the impossibility of assigning definite

thicknesses to the strata. Along this river the beds of limestone may be observed with a maximum thickness of twenty feet, from the railroad bridge to section 1, Lincoln township, to their disappearance beneath the drift in the vicinity of Northwood, and with a minimum thickness of three or four feet near the south county line. This variation in the exposed thickness does not appear to be due to a widespread flexure in the strata with its crest in the northern part of Lincoln township, but is rather due to the fact that the stream impinges against the low walls which restrain the valley at this point and thus exposes a greater thickness of beds. Where it pursues a direct course, holding strictly within the bounds of its ancient valley, it has cut into the rock usually to a depth of four to eight feet since the retreat of the Iowan glaciers. But where, in its meanders, the stream had cut into the confining walls of its pre-Iowan valley the maximum height of rock exposures is the result.

TYPICAL SECTIONS.

At the county line bridge across the Shell Rock in southern Union township, a low ledge of limestone, which may be traced northward in a series of low folds, flanks the stream and shows the following section:

		FEET.
2.	Very coarse gravel with numerous limestone bowlders	15–20
1.	Hard, compact limestone, containing some calcite concretions and badly weathered at the top	5

In a low fold about one-half mile south of Foster's mill, near the northwest corner of section 29, a layer not noted in any section previously observed north of the county line bridge, is brought into view. This consists of a dark-colored, argillaceous and more or less crystalline rock of uniform texture. It is here barely shown above the water in the arch of the fold and disappears in both directions in a few rods. At Foster's mill a total of eighteen feet is exposed:

		FEET.
4.	Weathered limestone, crystalline, and containing numerous calcite cavities	10
3.	Compact, light-colored, dolomitic limestone, heavy bedded	4
2.	Very close-textured limestone, lithographic in appearance, hard and breaking with conchoidal fracture. Has a very characteristic ring when struck with the hammer	3
1.	Argillaceous, dolomite layer, exposed to water below dam	1

The weathered stratum at the top appears sandy and is an advanced stage of disintegration, and for this reason is usually spoken of as sandstone. But from the fossil stromatopores found in the road directly west of this exposure, and only a few feet higher, and the characteristic nodular weathering, it is seen to be referable to the stromatoporoid beds of the Mason City section.* It is here more or less dolomitized and presents the same distinguishing characters as in Cerro Gordo county. The dividing line between beds four and three is usually quite marked, while often between three and two no sharp line of contact can be made out. Gradations from one to the other occur, and sometimes a thin layer of earthy dolomite is found intercalated between layers of hard, light-colored limestone. Number three from its general appearance, weathering and relative position in the series, may be correlated with the layer of limestone appearing below the stromatoporoid reef in the Mason City section. While in some of the quarries at Mason City this stratum reaches a thickness of fourteen to fifteen feet, it does not at any outcropping in Worth county attain to more than eight or nine feet, and it often thins down to one foot and a half. The lower member of the section following the same sequence is the equivalent of the Mason City dolomite in Calvin's section for Cerro Gordo county.

Below Foster's mill the strata have a decided dip to the south, while north of the mill they dip in the opposite direction. The mill is situated just south of the crest of a fold (a

*Iowa Geol. Surv., Vol. VII, p. 169.

natural mill site) which is followed to the north by several perceptible oscillations with crests only a few rods apart. This exposure is terminated to the north by a V-shaped ravine evidently cut into the rock previous to the deposition of Iowan drift, as it is partially filled with this material.

A short distance above the wagon bridge, on the section line road above Foster's Mill, is a small quarry in which the white limestone (No. 2 of Foster's Mill section) appears about four feet above the water and attains a thickness of two feet. Above this is a thin layer of the more or less dolomitized limestone as observed at Foster's Mill. This is covered at the surface with a foot and a half of alluvial material containing some small pebbles. At water level is a somewhat argillaceous dolomite, lighter colored than that below the mill, but in position its equivalent.

In Lincoln township, just above the point where Shell Rock enters section 13, is a quarry in which is exhibited four to five feet of compact limestone which grades downward into a coarser textured white limestone. Below this to water level the beds are covered with talus. The upper dolomitic limestone is represented by a few feet of weathered rock with an almost arenaceous structure and containing fragments of fossils. One good specimen of spheroidal stromatopora was found.

The middle layer of white limestone is here prepared for road material by crushing, and a considerable amount has been removed for this purpose. Although occasionally employed as a building stone, it is very unstable for structural purposes. Weathering has a very marked effect upon it even when it is exposed for short periods of time. Especially is it liable to injury by the action of frost. Sudden changes in temperature cause it to spall or chip off, and, when viewed in exposed ledges, it is often broken up into polygonal blocks by a series of transverse and vertical cracks; its most persistent splitting being along lamination planes.

A few rods north of the bridge on the section line between 12 and 13, Lincoln township, a gentle fold brings the stratum of argillaceous dolomite above the water in the same relative position as below the mill. Only one foot of light colored limestone is present between the darker dolomite below and the more or less dolomitized layer above. All are unfossiliferous, but the upper member often shows a slight brecciation. The bedding of the argillaceous layer is usually in ledges from eight inches to a foot or fifteen inches thick. The peculiar brown color seems to be partly due to the process of weathering rather than to the stage of dolomitization. Where the bedding is heaviest, the central portions of the ledge, or that part farthest from bedding and joint planes, is usually of a dark bluish cast. Along these planes water percolating from above, with organic matter in solution, has a chance to act upon the rock substance, thus modifying its composition wherever it comes in contact. Where this rock is exposed to the direct action of running water the outer surface is altered to a dark rusty brown color and forms a thin protecting coating through which disintegration progresses more slowly than where exposed more generally to all the atmospheric agencies. The wearing away is due more to the attrition of particles carried in suspension in the water than to rock decay.

On the east side of the road bounding section 1, Lincoln township, on the west, on the Jewett farm, is a small rock exposure in the side of a shallow ravine. Six feet of the compact limestone are in view, the upper two feet of which are badly shattered by weathering. This upper portion is quite filled with the stem-like cyathophylloid corals, which are also sparsely present through the lower strata of the outcrop. Stromatoporoid growths were found, but in a poorly preserved condition. Aside from doubtful casts, this is the only outcrop of the Mason City limestone in Worth county, at which fossil remains were not unquestionably found in place.

Beginning in the northwest quarter of section 1, Lincoln township, is a continuous outcrop for about one-third of a

mile where Shell Rock river flows close to the west edge of its valley and at the foot of the exposure. From a short distance below the railroad bridge it extends northward across the line into Kensett township. The following is the somewhat generalized section:

		FEET.
5.	Bowldery drift	2
4.	Badly weathered limestone, rusty red in color, no fossils, nodular in appearance, bedding obscure on account of disintegration	6
3.	Fine textured limestone of light color, non-fossiliferous and containing much crystalline interstitial calcite, heavy bedded	3
2.	Slightly argillaceous magnesian limestone, grading downward into the darker variety, breaks with earthy fracture but is very hard, bedding 8 to 12 inches	2–3
1.	Argillaceous dolomite, that portion not adjacent to joint or bedding planes a dark blue, good building stone, to water	6

No. 5 of this section is the equivalent of the upper member in the Foster Mill section. Although no fossils are found in place, the characteristic weathered face is sufficient data for the correlation. Below the railroad bridge a layer of calcareous sandstone eight inches thick appears between Nos. 3 and 2. This is very susceptible to the weathering agencies, and its breaking down forms a re-entrant in the quarry face.

The entire exposure is a series of gentle flexures, but broadly the dip is slightly to the south. At the extreme north end of the outcrop, north of the wagon bridge on the township line, a rather abrupt dip brings the limestone stratum No. 4, nearly to the level of the water, where it disappears beneath the drift. This limestone cliff serves as a natural abutment upon which the west end of the bridge is anchored.

An interesting example of the manner in which a stratum may sometimes "feather out" is exhibited just north of the wagon bridge. Here a thin bed of limestone, No. 4, is intercalated between layers of the argillaceous dolomite near the center of the quarry face. An abrupt bend in the strata

occurs at this point, displacing each one more than a foot almost vertically. At the crest of this fold the intercalated layer has its uniform thickness of eight to ten inches. Immediately north of the crest, and down the limb of the fold, it rapidly thins, feathering out completely in the short

FIG. 40. Rock exposure in northern Lincoln township, Stromatoporoid zone a thin stratum of compact limestone beneath, which is the dolomite. The hammer marks a low fold due to rapid thinning of a certain layer.

space of two or three feet and before reaching the synclinal limit of the flexures. Other cases of this kind were noticed at different exposures but none so strikingly conspicuous as the above. The river here comes from the northeast and is undoubtedly the causal agent which has produced the escarpment. Some stone has been quarried, the lower dolomitic layer being the most important as a building stone.

A little south of the road through the middle of section 26, Kensett township, and a short way east of the river bridge, is an artificial exposure from which a small amount of stone has been removed. The rock here quarried is the lower magnesian limestone of previous sections. A depth of four feet taken out makes the bottom of the exposure about water

level in Shell Rock. The close textured limestone, No. 2, of Foster's Mill section, is barely represented by a layer so thin and badly broken that it can with difficulty be found in place.

Outcrops in the bank of the stream showing low folds are found north of the above mentioned bridge. Phases are here observed that have not been present in any previous exposures. These folds usually have at the top a thin layer of the light colored limestone, No. 2, of Foster's Mill section. Beneath this is a six to eight inch stratum of light brown dolomite containing a few cup corals. To the water, two or three feet, is a very fine-grained and magnesian limestone which is decidedly brecciated. The matrix is a fine, close-textured limestone, while the contained fragments appear to be dolomitic.

A small quarry has been opened in the northern part of section 14, Kensett township, and some stone removed to supply a local demand for the purpose of rough masonry. The argillaceous dolomite has here been quarried to a depth of six feet. A thin layer of sandy, shaly and weathered limestone occurs between strata of the dolomite. All the layers shown at this exposure now suffer more or less from weathering and are of little value as building material.

No other exposures north of the point last described were observed. Limestone bowlders along the bank, and the character of the bed of the river, indicate that the stream has eroded the rock slightly, nearly as far north as the northern boundary of Kensett township.

At Northwood no limestone is visible in place, but all indications imply that the Shell Rock here runs at about the level of the indurated rock surface. Wells in Northwood average from twenty to thirty feet to rock, which is about to the level of the bed of the river.

It will be noted from the map that all of the rock exposures of any consequence along Shell Rock river, and those for which the stream is in any measure responsible, are found along the west bank. The same causes seem to be at work

here in determining the position of this river relative to the boundaries of its old valley, as are active in the valley of Lime creek. Less resistance is encountered in corrading its channel down the dip of the rock strata and in the direction of the planes of stratification. Shell Rock is another example of a strike stream, and the usual tendency with such drainage lines is to widen their valleys in the direction of the slope of the country rock. As in the case of Lime creek, the factor of differential weathering in the two sides of the shallow trough-like valley might also aid in producing the observed conditions, but probably is not so important a factor as with the former stream.

Along a small stream which flows through southern Lincoln and joins the Shell Rock at Plymouth, in the edge of Cerro Gordo county, both No. 2 and No. 1 of the Foster's Mill section are exposed. The stream has cut four or five feet into this limestone in its meanders along the county line in the southern part of section 36 of Lincoln township. The upper layer is much shattered at the surface, breaking up into small polygonal blocks. The magnesian limestone is barely exposed at the bottom of the creek.

Limestone has been taken from the bed of Deer creek below the wagon bridge, near the south line of section 35, during seasons when the creek has been dry. There are no exposures along its banks, showing that the stream, in its lower course in Worth county, flows at the surface of the rock, into which it gradually deepens its gorge as it proceeds across Mitchell county to the east. Only a small fragment was obtainable to show the nature of the beds removed. This showed a dark color and coarsely crystalline texture so much weathered as hardly to be fairly representative of the parent ledge. It is probably referable to the lower dolomitic phase in the sections along Shell Rock river.

A railroad well at Manley, in southern Lincoln township, furnishes the following section from drillings collected by Mr. D. Knowles:

		FEET.	FEET.
21.	Alternating layers of gravel and quicksand....	50	50
20.	Limestone, blue-gray, compact; brittle, more or less uneven fracture, and tendency toward mottling.....	5	55
19.	Same as above, except mottling.....	5	60
18.	Limestone with fragments of dark, gray-blue, porous, dolomite, drillings much mixed.....	5	65
17.	Limestone, light-gray; drillings sharp.....	5	70
16.	Dolomite, blue-gray, saccharoidal, with minute caverns.....	5	75
15.	Same as above, but darker, and becomes more earthy and cavernous; quartz, pebbles and angular fragments probably from above.....	5	80
14.	Same as 15.....	5	85
13.	Same as 15.....	5	90
12.	Dolomite, dark blue-gray, mottled with black; finely saccharoidal in texture.....	5	95
11.	Same as above, lighter in color.....	5	100
10.	No sample.....	5	105
9.	Same as 11.....	5	110
8.	Dolomite, very dark in color.....	5	115
7.	Same as No. 11.....	5	120
6.	Dolomite, gray, sub-crystalline, the same as 16.	5	125
5.	The same, with limestone fragments and crystalline calcite.....	5	130
4.	No sample.....	5	135
3.	Limestone, gray, with pieces of marly limestone.....	15	150
2.	Limestone, light-gray; chert abundant.....	25	175
1.	Same as above, no chert in sample.....	10	185

This is the only well in the county in which so great a thickness of the Devonian rocks has been penetrated. It is of special interest as showing the entire thickness of the Mason City dolomite in Worth county, of which forty feet are exposed in Cerro Gordo county. Samples five and sixteen, inclusive, show alternating zones of light and dark-gray dolomite to a thickness of fifty-five feet. Below the dolomite is a limestone which probably corresponds with the Lower Devonian limestone indicated in Norton's section of the Mason City deep well† and represents the base of the Devonian for the region.

Limestone of the Cedar valley stage, into which the stream has eroded its shallow channel, is exposed along Lime creek.

†Iowa Geol. Surv., Vol. III, p. 188.

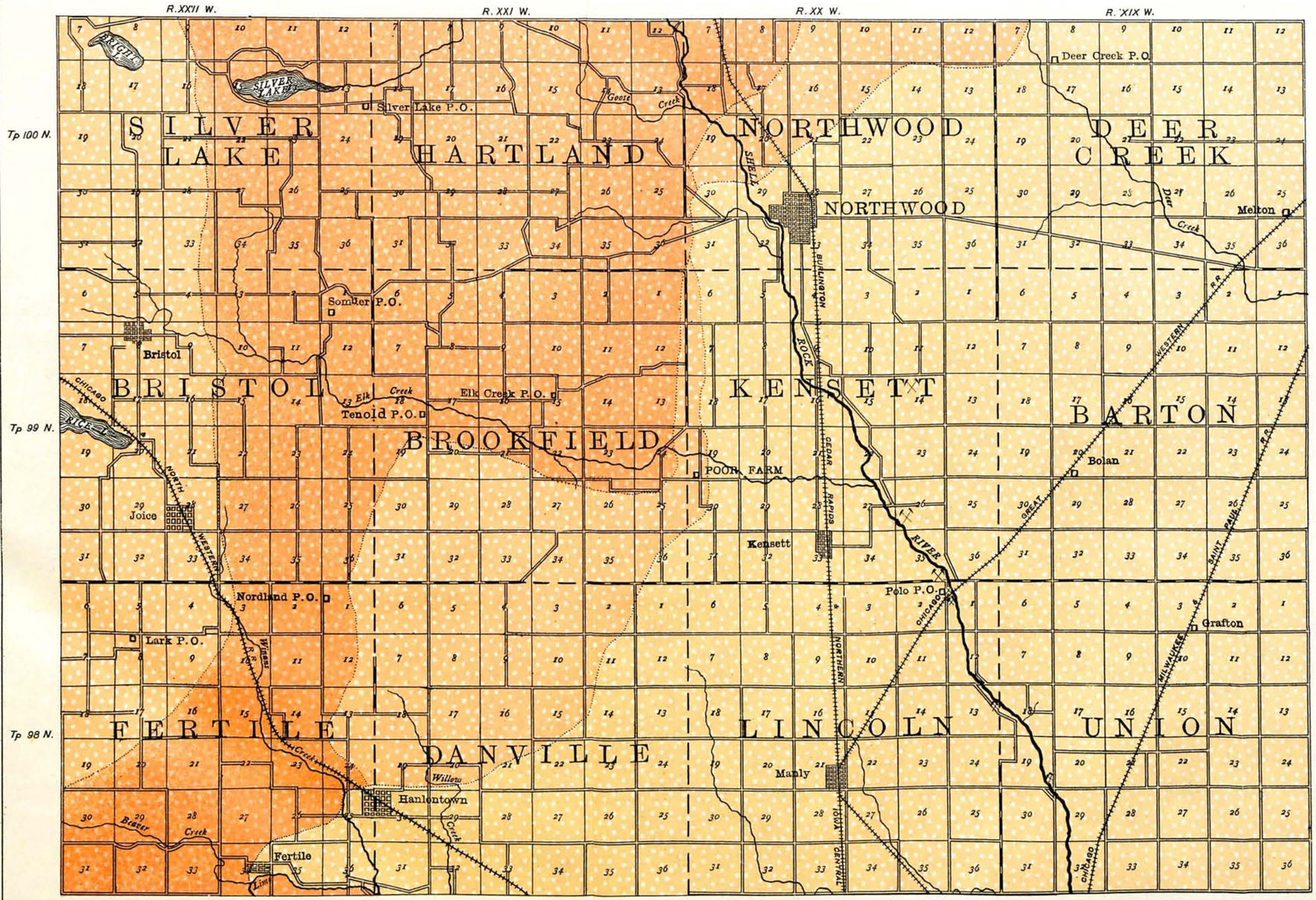
Near the southern line of section 31, Danville township, where the stream channel crowds closely the northern limit of its valley, is a low outcrop of four to five feet, showing an arenaceous, weathered and more or less crystalline limestone underlain by a layer of thinly bedded, light-colored lime rock to water level.

At Fertile an outcrop in the south bank of the stream, below the wagon bridge, gives the following section:

		FEET.
3.	Hard limestone, badly shattered into small blocks by weathering	4½
2.	Arenaceous shaly limestone, very slight effervescence with dilute HCl	8
1.	Heavy bedded, sub-crystalline, dolomitic limestone to water level	5

Bed No. 2, giving way much more readily to weathering than the other members, is conspicuous as a re-entrant along the face of the exposure. At a level about six or eight feet higher than the bridge at the east end of the main street of Fertile, stone containing numerous cavities filled with crystalline calcite, outcrops in the road. Many of the cavities are probably fossil casts, but so poorly preserved as not to be certainly recognizable as such. South from Fertile, in the banks of Lime creek, the same sequence of strata is shown. The thin shaly layer here weathers into a plastic light-blue clay. The upper layer is a partly crystalline rock with small calcite cavities and presenting a sandy appearance when weathered. Beneath the clayey stratum is a dark-colored, argillaceous limestone weathering to a bluish cast. It is readily affected with hydrochloric acid and effervesces freely. The strata here dip quite perceptibly to the south, so that layers appearing a few feet above water may be traced southward until they disappear below the bed of the river.

These are the highest and, therefore, youngest indurated beds observed in Worth county. In the Devonian column they would come above the reef of stromataporoids and probably be included in No. 6 of Calvin's "Generalized section of



IOWA GEOLOGICAL SURVEY

MAP OF THE

SUPERFICIAL DEPOSITS

OF

WORTH

COUNTY,

IOWA.

BY

IRA A. WILLIAMS.

1900.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

WISCONSIN DRIFT

ALTAMONT MORAINE

IOWAN DRIFT

INDUSTRIES

QUARRIES

DRAWN BY F. C. TATE

IOWA LITHO. CO.

Cedar valley limestone in Cerro Gordo and adjacent counties."*

LIME CREEK SHALES.

There has not yet been found any certain evidence of the presence of these shales in Worth county. Projecting the line of strike from known exposures in Cerro Gordo county, it would lead across the southwest corner of Worth, and it is probable that beds of shale may underlie the heavy deposits of drift by which all the indurated rocks are obscured in western Fertile township. Wells sunk in this section do not go to rock for their water supply, so that no information can be gained by this means. It is believed that the broad valley of Lime creek, widely excavated in the country rock, may, in part, account for the absence of these shales, if they ever were present.

PLEISTOCENE SYSTEM.

Members of this system representing at least four different stages are present in Worth county. These may be grouped into three of glaciation or times of drift deposition, and one interglacial stage or time of deglaciation. Deposits referable to the first stage of glaciation anywhere recognized in Iowa, the sub-Aftonian,‡ are certainly not found in this region, but well sections at different points reveal the presence of bowldery material below that which is directly referable to the Kansan, and suggests the possibility of an earlier drift sheet. The presence of Kansan drift is indicated by well sections in different parts of the county. The time following the Kansan period of glaciation to which the name Buchanan has been given from typical deposits of that age in Buchanan county, is represented by quite extensive deposits of gravel and sand. This age was brought to a close by the on coming of the Iowan ice, and material from Iowan glaciers is abundant over the greater portion of the region under consideration. No deposits are found in the area of Wisconsin drift referable

* Ann. Rept. Iowa Geol. Surv., Vol. VII, p. 160.
‡Iowa Geol. Surv., Vol. VII, p. 171.

to the interglacial stage, Peorian, between the Iowan and the Wisconsin ice. Practically half of the county, as outlined on the map, is occupied superficially by the heterogeneous materials of the Wisconsin drift.

KANSAN DRIFT.

The relations of the Kansan drift sheet in Worth county to the overlying Iowan are such that it is difficult to distinguish the one from the other. There are, however, several things which point to the presence of Kansan drift. Worth county is included within the area over which the ice moved and deposited its load during the early and maximum advance of the Keewatin glacier. For this reason bowlder clay and gravel underlying the Iowan, which is usually only a few feet thick, may reasonably be referred to the Kansan stage for want of better evidence for referring it to a still earlier till. As has been pointed out by Calvin,* the deposits of gravel along Lime creek and other small streams, overlain by a layer of Iowan till, represent the interglacial period preceding the Iowan stage of glaciation. These deposits necessitate the presence of a pre existing drift sheet from which they were derived. In the boring of wells over the eastern part of the county, pieces of partly decayed wood are often encountered at varying depths. Where found between layers of drift clay, these may represent an old forest bed of interglacial growth; or, they may be found incorporated in the body of the Iowan material, in which case they may have been transported some distance. Nevertheless, they are indicative of a pre existing soil. It is admitted that the evidence is far from conclusive, but, when taken in connection with other facts, it favors strongly the assumption that this was a glacial soil. In the region of Shell Rock river where Iowan drift is often observed lying directly upon the country rock, and where no older glacial deposits are present, the drift seldom exceeds eight or ten feet in thickness, and this where apparently no erosion

*Iowa Geol. Surv., Vol. VII, p. 171.

has taken place since deposition. The Iowan drift, wherever studied, although covering hill and valley alike, is known as a relatively thin sheet in comparison with other till sheets; a mere veneer over the surface of the country. In southern Union, Lincoln and Danville townships thicknesses of drift ranging from forty to one hundred feet are found above rock and consist of alternating beds of clay, gravel and sand. Allowing twenty feet for Iowan, which is more than an average, the lower layer, in part at least, may be correlated with the Kansan.

On the farm of H. H. Schulte, on section 26, Danville township, a well drilling shows the following sequence of strata:

		FEET.
1.	Soil	2
2.	Yellow clay	18
3.	Sand, water	1
4.	Blue clay, mixed	59
5.	Sand, water	4
6.	Soft blue clay	4
7.	Alternating sand and clay	10
8.	Coarse gravel	7
9.	Rock encountered	
	Depth	105

One and three are undoubtedly Iowan drift. Three to seven, inclusive, are probably Kansan. Eight, pre-Kansan gravel which may be due to an older drift. Other wells, over the Iowan area, encountered the so-called hard-pan, or gumbo layer, which sometimes defies all efforts to sink a drive well through it, and often is an impediment to progress with the ordinary auger. It is a very compact blue clay, and may represent the upper surface of the Kansan drift.

BUCHANAN GRAVELS.*

Gravels of this age are found in the terrace which bounds Lime creek, and underlie an area in southern Danville and Fertile townships within this valley, varying from one-half to more than a mile in width. They are underlain by a terrace of limestone which is somewhat above the present stream

*Iowa Geol. Surv., Vol. VII, pp. 172-211.

valley. These are usually composed of very coarse material, and the bowlders are more or less weathered and broken down, so that many of them crumble readily. The gravel is used for road building, and is removed for this purpose along Willow creek in the middle of section 29, and at the southwest corner of the same section, Danville township; also in the banks of Winan creek south of the road through the center of section 25, Fertile township.

During recent excavations for a railroad line these gravels were exposed at several points in sections 30, 32 and 33 of Danville. In a cut in the southwest quarter of 33 four feet of very coarse gravel are in view, overlain by a thin stratum of soil. Above the schoolhouse in the southwest corner of section 32 the following order of strata is shown:

		FEET.	INCHES.
3.	Iowan drift, the upper two feet modified to brown soil	5	
2.	Coarse gravel, iron stained and weathered	1	6
1.	Coarse, clean gravel	5	

The railroad is here laid on the plane of the upper terrace, and in its course across section 30 is ballasted with Buchanan gravel, which was usually found beneath only a few feet of Iowan drift, and taken out quite continuously from the side of the road bed.

Gravels of Buchanan age are probably represented along Elk creek, outside of the Altamont moraine, in the terrace which skirts this stream to the north, but their relation to the two drifts here present cannot as yet be definitely stated.

The retreat of the Kansan ice was attended with floods of water which filled to overflowing all of the depressions marking the former courses of streams. That these were swift currents carrying large volumes of water is evidenced by the coarseness of the material carried and laid down by them, and also by the fact that these deposits are only irregularly stratified. The deposits consist of fragments of rock from fine sand to slabs measuring more than six inches across. In the exposures examined these are dumped in together, with little

of the order that is generally characteristic of water-laid deposits.

IOWAN DRIFT.

Materials from the Iowan ice sheet are almost universally present over that portion of the county which is not occupied by the Wisconsin drift. They generally constitute a thin sheet of till which, so far as can be made out for Worth county, varies from naught to twenty feet in thickness. Exposures showing the complete section of Iowan drift above the Kansan were not seen, so that in discriminating the two, well data must be depended upon, which, as has been indicated, are not altegether reliable. The Iowan is thinnest in the region of Shell Rock river, where it may be seen lying uncomformably upon the sedimentary rocks. In places along this stream channel the large and conspicuous granite bowlders are often the only indication of ice invasion. In the eastern part of the county wells show that the depth to rock varies from three to ninety feet. Within the limits of Barton township forty feet is the maximum limit, but a thicker layer of drift material is found in southern Union and Deer Creek townships. In no place, however, is the blue clay more than fifteen feet below the surface. Accepting the blue clay as Kansan drift, the Iowan drift is then represented by a comparatively attenuated layer varying from a few inches to fifteen feet.

In western Lincoln and Danville townships the total thickness of drift varies from forty at Manly to more than 100 on section 26 of Danville, as has been mentioned under Kansan drift. But of this assemblage of clay, gravel and sand quite generously spread over the surface of the land, only the uppermost layer of yellow bowlder clay, which scarcely exceeds twenty feet, can be referred to the Iowan stage. In the old valley of Lime creek Iowan drift forms a thin coating over the surface of the Buchanan gravels. It is never more than three or four feet thick, and often not sufficient to hide

bowldery gravel which crops out in road beds and on side hills.

The materials of this drift are porous bowlder clay interspersed with pockets of gravel and sand. The color varies little from the dark yellow several feet below the surface to the light

FIG. 41. A field of Iowan bowlders in northwestern Lincoln township.

brown immediately beneath the soil layer. It is rich in calcium carbonate and effervesces with dilute hydrochloric acid even in the surface layer of soil. Perhaps the most conspicuous surface feature is the large granite bowlders. Where none have been removed these often present an appearance not incomparable to a distant flock of sheep, and many acres are strewn with rock fragments from one or two feet to many feet in diameter. The prevailing type is the red granite. These are usually coarse-grained, and sometimes show striated or glacial planed surfaces. A large rock of this species is located in the northern part of section 14, Kensett township. It rests almost directly upon the limestone. It is made of large flesh-colored crystals of orthoclase feldspar with quartz. The dimensions were not accurately determined, but it is somewhat more than twelve feet high, twenty feet long and

ten to twelve feet wide. Among a certain class of inhabitants of the immediate neighborhood the question whether or not a large deposit of gold might be found in the interior of this monster is a prevalent one. Gray granites are common, and specimens of the darker basic rocks are not exceptional.

WISCONSIN DRIFT.

It was during the latest ice epoch recorded in Iowa that the hills of the Altamont moraine were built, and the glacial material strewn over western Worth county. So short a time have the agents of degradation acted that the existing land forms are essentially those fashioned by the retreating glacier. Modification of the material thus laid down has progressed to only a slight extent. In general it consists of a yellow clay containing many bowlders of all sizes, all textures, and all species. So unweathered and unleached is this bowlder clay that when first exposed, as in a new road cut, its extremly light yellow color, often nearly white, makes it conspicuously visible at some distance. With dilute hydrochloric acid effervescence takes place almost as freely as with a pure limestone, thus indicating the source of the material making up this sheet of till. All grades of fineness are found from the comminuted limestone clay to the beds of coarse gravel.

Near the margin of the Wisconsin drift the surface is very much broken. Knobs and ridges are very common, often separated by ponds and swales. The salient features are usually composed of compact bowlder clay, showing little if any stratification. In a railroad cut through a prominent rounded knoll in section 24, Fertile township, the unstratified condition is clearly shown, as also in numerous road cuts at other places in the morainal tract. From the fact that true kames and eskers are rather rare, the few examples which do occur are of more than ordinary interest. In the old valley of Elk creek these types of land forms predominate as has been stated under topography. North of the middle of section 10, Bristol township, was observed a small section of a

kame-like ridge composed entirely of gravel and sand. These materials were plainly interstratified, thus giving a definite clue to the agent that aided in their deposition. In this and in others observed in this region the bedding of the strata is not horizontal, but dips in each direction from the crest of the ridge. Cross bedding in a single layer is also more or less obvious, showing that the conditions which existed when these deposits were laid down differed from those that surround our streams to-day. These deposits are probably due to subglacial streams which were confined above and to either side by walls of ice.

An exposure of drift in the northeast quarter of section 15, Fertile township, furnishes a section which is of interest, not alone from the sequence of layers displayed, but as showing certain structural features as well. A morainal hill is here dissected for a railroad track. This is a somewhat rounded knoll bordering the low marshy swale through which Winan creek flows. About twenty-two and one-half feet are exposed in the following sequence:

		FEET.	INCHES.
5.	Bowldery soil	1	6
4.	Gravel, imperfectly stratified	6	
3.	Sand, apparently somewhat stratified	5	
2.	Very fine sand, grading from 3 into a homogeneous, unstratified material containing numerous root casts composed of $Ca\ Co_3$	8	
1.	Arenaceous light-blue clay to road bed	2	

The upper layers of soil, gravel and sand are laid symmetrically with the present contour of the hill, but from 3 to 2 of the above section, although apparently a gradation, the bedding shows two low rounded mounds which are fused into one by the upper layers. The material responsible for these subcontours is a very fine, calcareous, silty substance not unlike the loess of central Iowa; practically no pebbles larger than sand grains are found below the gravel stratum. The sand of 3 contains numerous rounded clay bowlder balls from one to six inches in diameter. These, when dry, may be crushed with the pressure of the hand. All the layers below 4 contain

root casts made of pure calcium carbonate, most numerous, however, in the layers of No. 2. They are sometimes hollow, but often contain the root fragment around which the concretion has formed. The light-blue clay at the bottom is arenaceous, but also effervesces very freely when tested for lime

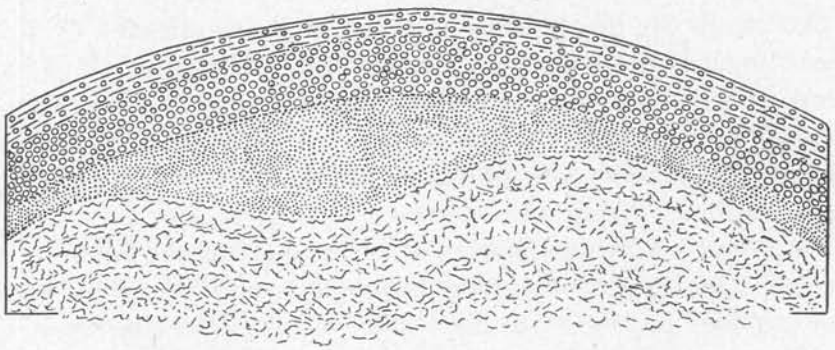


FIG. 42. Section of morainal till on section 15, Fertile township.

Extending through all layers below the gravel, sometimes vertical, but usually inclined, and often intersecting

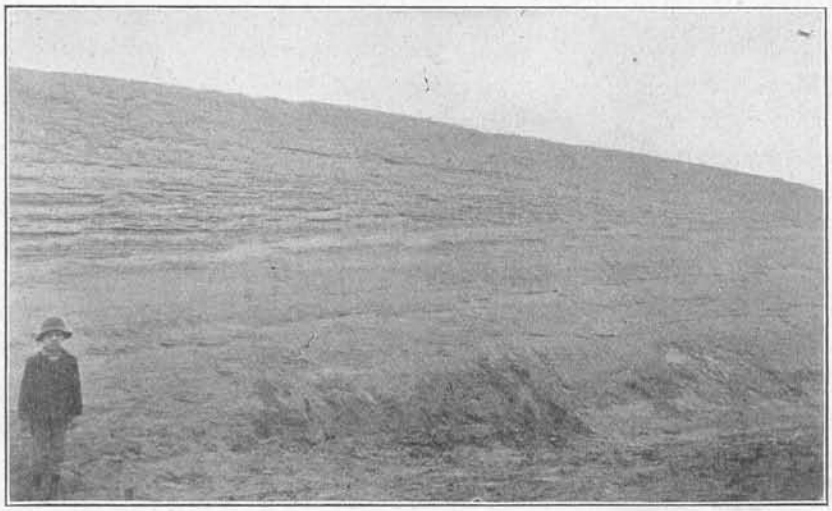


FIG. 43. Faulting in Glacial clay. It is shown best at the extreme right.

each other, is a series of faults which have in some cases displaced individual layers more than a foot. This displacement

is made evident by the alternation of wet and dry strata in the lower part of the exposure. The following figure will illustrate the faulting observed in a portion of a single wet band a little to the right of the center of the section and at the crest of the broader subundulation:

Although the upper beds of loose sand are affected by this faulting, it is not so evident on account of slipping, which has more or less obliterated all structural features. Along these fault planes appear the greater number of root casts, probably because the roots of plants found here a place of easy penetration. These casts also appear scattered promiscuously throughout the whole mass, and, on account of the removal of material by the wind, often protrude from the surface from one to two inches as minute hollow cylindrical columns of calcium carbonate.

Although no definite contact line which would mark an interruption in the deposition of the material of the hill can be made out, it seems probable that here are represented two stages of deposition, and possibly the work of two different agents. Two small undulations are here developed with a later deposit of gravel and sand, making a single rounded knoll. It is not probable that the non-horizontal position of the strata is due to the later melting of included bodies of ice, for in this case any irregularity would be expressed at the surface. This, however might account for the faulting, but when considered in conjunction with the character of the lower material, root casts, etc., this explanation is rendered insufficient. In comparison with the material of the loess deposits of central Iowa, this is of a coarser sandy texture, and is, perhaps, more calcareous. No molluscan remains, such as are quite generally characteristic of the loess of Story, Marshall* and other central counties, were found. With these slight variations it is very similar to ordinary loess. From the prevailing presence of root casts, many of which contain the woody fibres of the roots themselves

*Iowa Acad. Sci., Vol. VI, pp. 98 and 117.

and which almost universally assume a more or less vertical attitude, it may be inferred that these are remains of plants *in situ* and not transported. In short it would appear that here are exhibited deposits representing two stages of Wisconsin glaciation. The lower portion of this section may be due to loess-depositing agents, be they wind or water, or the two combined. The section may record (1) a retreat of the ice sufficiently long to allow of plant growth, and (2) a readvance which may have scoured off any accumulated soil, and which deposited the upper layers of sand and gravel. The balls of bowldery clay in the layer of coarse sand were undoubtedly frozen when deposited, for otherwise they would not have withstood the rough usage to which they were subjected. It will be observed that the direction of the planes of faulting bear no constant relation to each other. Although in a general way somewhat parallel, they often intersect at high angles. These may be the result of the pressure of the superincumbent ice, or may be due to differential settling.

The aggregate thickness of drift deposits over the area covered by the Wisconsin ice scarcely ever exceeds 125 feet. A creamery well on section 18, Hartland township, gives the following record:

		FEET.
5.	Soil	2
4.	Yellow clay	15
3.	Coarse gravel with water	4
2.	Gravelly blue-clay	60
1.	Rock, cherty	30

Wells in Silver Lake township show a greater distance to rock, but it is exceptional to find more than 150 feet of drift deposits. The Iowan, if present, cannot be differentiated from the Kansan in well sections. Neither the Wisconsin nor the Kansan reach here the thickness which they attain in the central part of Iowa, where the Kansan alone often exceeds 200 feet, and the Wisconsin more than fifty feet on the general upland.*

*Iowa Geol. Surv., Vol. VII, p. 229; also Vol. IX, p. 198.

In distinguishing the Wisconsin drift from the Iowan, aside from topography, two principal points of difference may be noted. First, the character of the contained bowlders. While on the Iowan the prevailing type is the red granite, with a relative scarcity of the darker rocks, on the Wisconsin

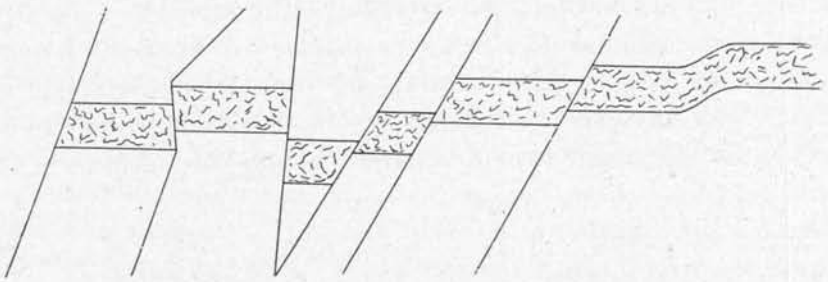


FIG. 41. Diagrams showing displacement by faulting in a single layer of clay, slightly over a foot in thickness.

the gray granites predominate, and, although comparatively fewer in number, the red and pinkish granites are not rare; but neither reach the prevailing large size of the Iowan bowlders. In the Iowan drift limestones are common, but not in the proportion that they reach in the Wisconsin. At any exposure of the latter drift numberless fragments of limestone may be found from the size of a pebble to that of a slab several feet long, and in some cases these seem to predominate, with an almost total absence of other species of rocks. It seems probable, therefore, that the greater portion of the rock debris carried by the Wisconsin ice was derived from the limestone areas over which it passed. Pieces of sandstone are frequently found, and both limestone and sandstone fragments are sometimes fossiliferous. Members of the dark colored basic rocks, greenstones, diabase, gabbros, etc., are quite numerous, but do not often occur above the size of the cobblestone. One instance was observed where a dark brown micaceous bowlder, exceeding a foot in diameter, had been severed in making a road cut, leaving half of the bowlder still imbedded in the matrix of yellow clay. The larger bowlders of this group are usually more or less crumbled from weathering.

While in one drift section it might be impossible to tell, after applying the diagnostic tests for each, whether the drift be Iowan or Wisconsin, in general the bowlder clay of the Wisconsin is more compact, contains less sand intermixed, and is more impervious to water. Although oxidation and leaching of the soluble constituents have not gone on to any extent in the Iowan, in comparison with the Wisconsin it is usually more or less iron stained and the calcareous contents partly removed by percolating waters, so that in distinguishing the two drifts it is seen that the more recent is unleached, has the ferreto zone little developed, and has a shallower soil.

ALLUVIUM.

With the exception of a very small amount of alluvial material at places along Shell Rock river, probably laid down during stages of high water, and a perceptible amount spread over the floor of Elk Creek valley outside of the Altamont moraine, there are no bodies of alluvium sufficient for mapping in the county.

ECONOMIC PRODUCTS.

SOILS.

In the broad extent of fertile soils lies the greatest and most enduring wealth of Worth county. As in other prairie regions, much of the progress and comfort of that small proportion of the population engaged in other occupations depend upon the tiller of the soil. The soil, as a source of wealth, is not yet developed to its full capacity. In areas of timber growth, with which the Wisconsin drift is more generally characterized, a great deal of the farming has been made possible only through long processes of "grubbing" and clearing, and large fields have thus been brought under the plow. After a few years of cultivation these cleared farms become very productive, rivaling the open prairie soils for the raising of small grain, and even surpassing them in the production of the universal and most important crop, corn. It was the grass covered prairies that, as a farming country, attracted the early

settlers to northern Iowa. At present the level plains of the Iowan drift region, which occupy the eastern half of the county, and which, in "days gone by," presented the most typical prairie aspect, are nearly universally under cultivation. An occasional strip of native prairie grass, occupied by a swale or slough, is seen, but it is quite unusual to find an area of any extent unaffected by the processes of agriculture unless on account of the physical conditions of the soil itself.

In general, the soils of Worth county belong to the drift type. In the neighborhood of Shell Rock river, where in places the drift is exceedingly thin, the underlying limestone has undoubtedly lent more or less to the process of soil formation, but not in sufficient amount to be appreciable in the elements necessary to plant growth. Here, as elsewhere over the county, the miscellaneous materials of glacial debris are almost entirely responsible for the constituents of the soil. Atmospheric agencies at the surface, water working its way down through the clayey till, the roots of plants and decaying vegetable matter, with its humus accumulating year after year, are the principal influences that have been at work upon these glacial deposits since they were laid down by the ice.

It is, therefore, evident that the older drift would show a soil more highly modified, and developed to a greater depth, than a newer till sheet. In the two drifts exhibited as surface deposits in Worth county such is found to be the case. On the Iowan in places where it has apparently undergone no loss by denudation, nor been added to by transported material, the process of oxidation and leaching has gone on to a depth of several feet, and the plant roots have usually penetrated a considerable distance beyond the depth stirred by the plow. The true soil layer is usually a black loam, rich in calcium carbonate, and grading into a porous, clayey subsoil. Small bowlders and pebbles are included, but these near the top are somewhat decayed and more or less comminuted so that they offer no hindrance to tilling of the land. It is especially

adapted to the cultivation of the cereals. The prosperity of the people on this productive soil is attested by the many fine farm houses, large and well constructed outbuildings and seldom a field of any size that is not surrounded by a well kept wire fence.

The soils of the western part of the county, in the region of the Altamont moraine, are relatively newer. Modification of the surface has not progressed to any depth and the soil through which the farmer drives the plow is very little altered from the original bowlder clay. On the steeper slopes any loose material is readily washed into the hollows by the rains, so that between and in the lower slopes of the hills is usually accumulated a layer of dark sandy loam containing only the smallest pebbles and having a high percentage of calcium carbonate. Some of the knolls are composed almost entirely of gravel and bowlders, and it is not unusual to see several of them within the scope of a single view, with summits almost completely barren of vegetation of any kind. Where the material is the true bowlder clay, it is so much more compact than the Iowan drift that the tendency is rather to shed the water falling upon it than to absorb it. Plant roots likewise find difficulty in penetrating to any depth, but it is here that the tools of agriculture should intervene as a valuable aid to the natural agents. By stirring deeply, the earth becomes aerated, water readily soaks in and plants extend their roots downward without opposition.

The only serious obstacles to the farmer are the numerous bowlders encountered both below, and at the drift surface. Experience has, however, shown that by perseverance these may be effectually removed and and it is not an extraordinary spectacle to see heaps of them gracing fence corners or lined along the public highway. They vary in size from a few inches to several feet in diameter, and in weight from one or two pounds to a number of tons.

It may be interesting to note an advantage the farmers of Iowa, or the farmers of any region covered with glacial

deposits, have over those who live on soils derived alone from the underlying country rock. The material brought down by the flowing ice is a mixture of earth and rock fragments gathered from over a large area measured in latitude by the distance from the point of accumulation in the frigid north, southward to the place of deposition. It is composed of all species of rocks from the hard crystalline granites, greenstones and porphyries, to the finely ground rock meal of the softer limestone. Thus when disintegration of these bits begins, each yields slowly its characteristic product which contributes something necessary to plant life. By these contributions from innumerable decaying pieces of rock all the elements which are essential to the growth of different crops and which the process of continuous cultivation tends to take away from the soil, are supplied. Each year something is added to the soil by such continuous decay, and it is due to this that bowlder clay soils usually have a remarkable endurance to repeated cropping without becoming exhausted, as is often the case with residual soils. Should successive crops of the same grain tend to decrease the fertility, it is only necessary to practice rotation of crops for a few years, and thus, through rock decay and modification of the clay subsoil the degenerated soil becomes again enriched with the exhausted constituents.

In this way may probably be explained the state of affairs that has existed for the last few years over northern Iowa with regard to the cultivation of wheat. When the wild prairie soil was first tilled enormous crops of wheat were grown yearly, and the farmer relied much upon the yield of this cereal. After a series of years of repeated cropping the yield began to fall off until the wheat crop could no longer be depended on to supply even domestic needs. The soil was undoubtedly overtaxed, and some of the elements necessary to the growth of wheat exhausted. In distinction from the other cereals wheat requires a larger proportion of the element phosphorus, and as compounds of this substance

are relatively scarce in the soil-forming rocks, it is probably owing to the partial exhaustion of this element in an available form that the folling off of wheat production is due. After resting the soil for several years, thus allowing a recuperation of its lost constituents, wheat may be planted with reasonable hopes of an average crop.

The soil developed within the valley of Lime creek contains much sand and is much more susceptible to drought than the upland soils. This may in part be due to its sandy nature, but more to the perfect under-drainage through the Buchanan gravels which underlie the upper terrace.

BUILDING STONES.

Limestone is quarried at several points along Shell Rock river, as has been mentioned under Cedar Valley limestone. The amount removed is limited by a very small local demand, and this local demand is usually determined principally by wants of the owner, upon whose territory the quarry is located. The time is just lately passed when the outcropping ledges along the banks of Lime creek and Shell Rock river were public property, and every one was free to "baul his few loads of stone" whenever occasion demanded. The almost universal advent of the barbed wire fence has, perhaps, accomplished more towards doing away with this friendly traffic than any other factor, but it is at present only necessary to gain permission to enter a neighbor's field or pasture, the latter granting for little or nothing the use of his private quarry. Practically all of the limestone is taken out from the compact, light-colored stratum, and from the underlying, dark magnesian layer as given in the sections along the Shell Rock. The former is a very poor building material because of the serious effects of weathering upon it, especially the action of frost. This may be observed in quarry faces where the cracked and fissured character of this stone stands in contrast with the unweathered dolomite. The non-elastic property of the white limestone, together with its hardness, which is

somewhat above the average, recommend it for road material and concrete. The dolomite referred to is the equivalent of the Mason City dolomite, which is considered one of the best and most durable building stones taken from any of the several quarries in the Cedar Valley limestone of Cerro Gordo county. This has been utilized to some extent in Worth county, the largest exposure being in the northern part of Lincoln township, where the Great Western railroad crosses the river. There are here exposed ten to twelve feet of dolomite of the same character as that quarried in Cerro Gordo county. These beds have been worked intermittently and only a small amount of stone has been taken out.

Obviously the hindrance to more extensive quarry operations in Worth county has been the lack of proper facilities for transportation. Team hauling has been the only method of conveyance, and little of this stone ever finds its way more than a few miles from the place quarried. The excellent character of the stone and the small amount of stripping necessary, on account of the extremely thin sheet of drift along Shell Rock river, are both favorable conditions to the development of the quarry industry. Considering the proximity of the Great Western railroad in northeastern Lincoln township to one of the best rock exposures in the county, it would seem that here are conditions very favorable to the working of these quarries.

These limestones both produce an excellent quality of lime, as they have been used in its manufacture at Mason City in Cerro Gordo county. The dolomitic limestone gives a higher grade of lime than the purer varieties. This magnesian lime does not air slack readily and for this reason may be shipped long distances from the place of manufacture without suffering deterioration. In this branch of the quarry business, Worth county has facilities equal to any of its neighboring counties. A small amount of capital applied under competent supervision would do much to develop these resources at present lying dormant.

The greater portion of the building stone is derived from the igneous rocks of the drift. These are almost universally employed in the western half of the county in constructing walls for houses, barns and outbuildings. The process of splitting these so-called "hard heads" into blocks of desirable shape seems to be an art in which only those who have grown old at this sort of masonry are skilled. In breaking the larger bowlders, a stone drill and blasting powder or dynamite are made use of. When broken sufficiently small to be transported they are moved to the place where the wall is to be built, where further shaping into rectangular blocks is done with the ordinary stone hammer and chisel. Although requiring more work in dressing than limestone, where the latter is not readily available, the extra expenditure of labor is compensated for by the greater durability and the much more comely appearance. The blending of different shades and the contrast between colors in a wall of these hard crystalline rocks present an aspect very pleasing to the eye of those unused to beholding these species in larger masses than our prairie bowlders. The supply of these rocks is practically unlimited, and those at the surface are yearly being added to by bowlders heaved upwards by the frost. The great ice sheets have been the means of laying at our doors free of all charges this material for which importation would be very expensive.

PEAT.

Bodies of peat are accumulating in many of the pondy depressions of the Wisconsin drift. These deposits are continually increasing by the growth of certain species of mosses and the vegetal remains brought in by the wind and water. Although of value as a fertilizer, and in some localities used for fuel, the peat bogs in Worth county are generally regarded as impediments to agricultural progress and much is being done to eliminate them.

WATER SUPPLIES.

The county is well provided with a supply of potable water. In the western part of the county it is drawn almost exclusively from the beds of sand and gravel of the Pleistocene. These furnish a sufficient amount for stock and farm purposes. A goodly, and in many cases quite constant, supply is often obtained by sinking shallow wells into the clay at the edges of glacial ponds or peat marshes. This water is usually contaminated and is used for live stock principally. Wells on the gravel terrace of Lime creek in some cases are sufficiently supplied from these gravels, but quite often it is necessary to go below the level of Lime creek into the underlying limestone.

Along Shell Rock river, and over most of the eastern part of the county, the indurated rocks are generally penetrated to some depth for water. The aquifer is some member of the magnesian strata below those exposed along Shell Rock. Small springs frequently occur, issuing generally at the rock surface, and it is from this source that Mad creek of western Union township is almost entirely supplied. Northwood draws the city supply of water from the base of the Pleistocene deposits, which are here between thirty and forty feet deep.

WATER POWER.

On the Shell Rock river there are two mills, one at Northwood and one at Foster's mill in the southern part of Union township. The former is situated just inside of the Wisconsin border and has a fall of seven and one-half feet, which, with a seven-foot turbine, is capable of developing seventy horse power. Foster's mill has a head of six feet, and when two forty-inch wheels are employed about fifty horse power can be developed. The average slope of the river is less than seven feet per mile, but the volume of water is usually sufficient to run eight or nine months in the year.

On Lime creek Rhode's mill at Fertile is the only one in operation. This mill has a fall of eleven feet, and can develop seventy horse power. The flow is more constant in Lime creek than in Shell Rock, and during years of ordinary rainfall the mill is idle only during the winter months on account of the ice.

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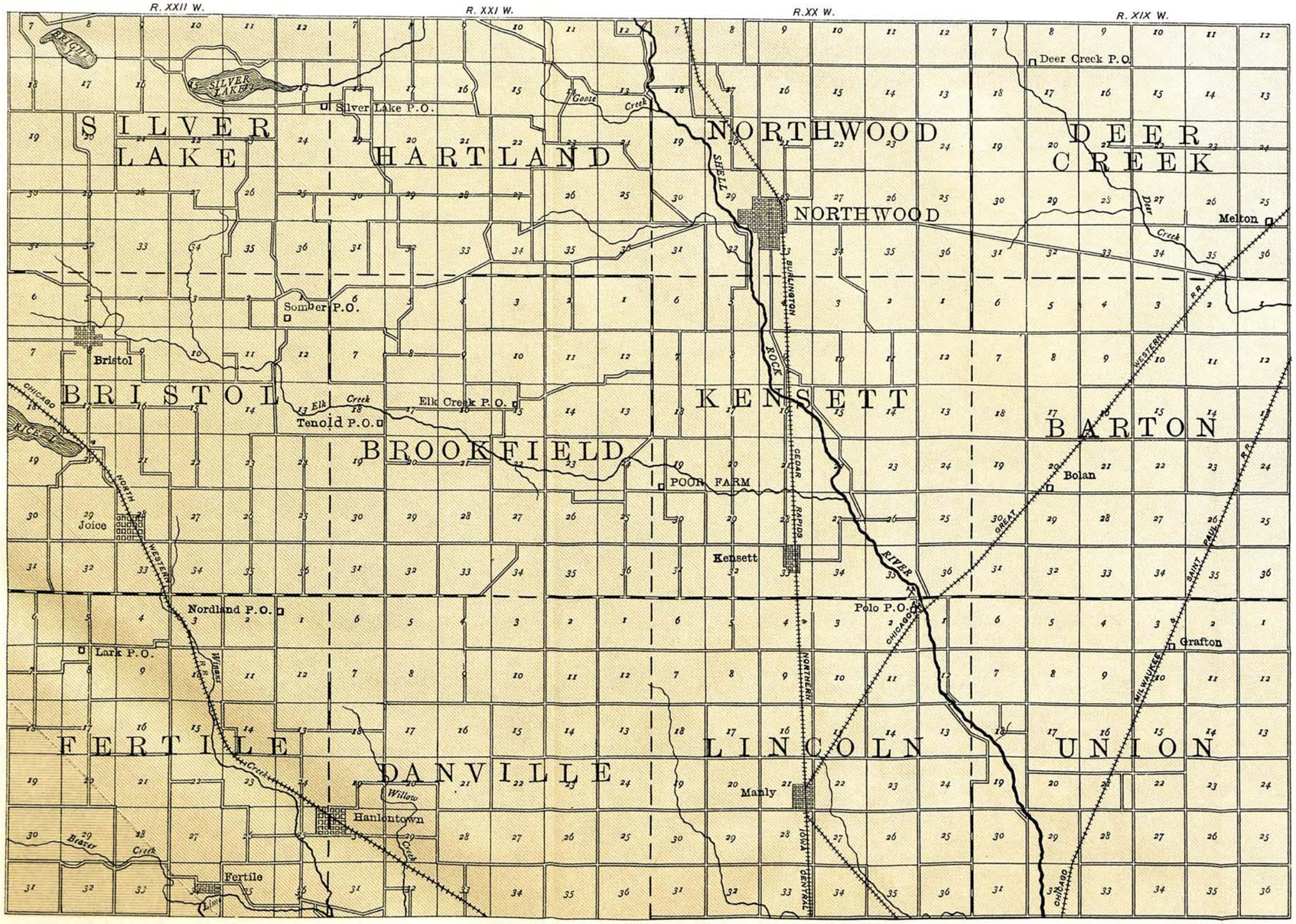
IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF WORTH COUNTY, IOWA.

BY

IRA A. WILLIAMS.

1900.



Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

LIME CREEK

CEDAR VALLEY

INDUSTRIES

QUARRIES

DRAWN BY F. C. TATE

IOWA LITHO. CO.