# GEOLOGY OF CEDAR COUNTY.

BY

WILLIAM HARMON NORTON.

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## CONTENTS.

## INTRODUCTION.

### SITUATION AND AREA.

The district mapped and described in the following report comprises an area twenty four miles square, situated nearly midway the state from north to south, and in the second tier of counties west of the Mississippi river. It is bounded on the north by Jones county, on the east by Clinton and Scott, on the south by Muscatine, and on the west by Johnson and Linn. It lies mainly in the doab between the Wapsipinicon and Cedar rivers. The former transects the northeast corner of the area. The latter, from which the county takes its name, crosses it from northwest to southeast, leaving five townships in part or whole on its right bank.

### PREVIOUS GEOLOGICAL WORK.

Beyond the immediate valleys of the trunk streams mentioned, outcrops of the indurated rocks are infrequent. The topography of the county, with its drift plains and rolling prairies, presented no salient features to attract the notice of the early students of physiographic geology. There is therefore no long list of scientific papers relating to this area. The earliest geological survey within the limits of the county, that of David Dale Owen* in 1848 and 1849, the final report being published in 1852, records the presence of Silurian, Devonian, or Carboniferous strata at some nine different places in the county. In the survey of Hall and Whitney† less than ten lines are allotted to the county, and these are references of a general nature to forest, prairie and soils.

In the reports of Dr. C. A. White‡ no mention is made of Cedar county, except in certain analyses of peat, the whole attention of this survey being devoted to other regions of the state.

Cedar county is included in the large area whose glacial geology is described by W J McGee in the Pleistocene History of Northeastern Iowa§. References to localities within the county will be found on pages 202, 218, 223, 341, 357, 404, 407, 463.

The present Survey has already recorded a number of features in the geology of the county. Houser‖ has written on the economic conditions of the lime and building stone industries, and Norton¶ has noted the presence of Devonian and Carboniferous outliers and has described the geological section of the Tipton deep well.

Thus the geological work already done in the county is limited in amount and easily summarized. The indebtedness of the present investigation to it is comparatively slight. But it is impossible to place here on record the amount to which we are indebted to the geological work of the present Survey done elsewhere in the state. The mapping of strata,

*Rept. Geol. Sur. Wisc., Iowa, and Minn., D. D. Owen, Philadelphia, 1852.
†Rept. Geol. Sur. State of Iowa, Hall and Whitney, Des Moines, 1858.
‡Rept. Geol. Sur. State of Iowa, C. A. White, Des Moines, 1870.
§U. S. Geol. Sur. 11th Ann. Rept., Washington, 1890.
‖Iowa Geol. Sur. vol. I. pp. 199-207.
¶*Ibid*, vol. III, p. 121.
¶*Ibid*, vol. III, pp. 197-200 and vol. VI, pp. 261-262

the description of deposits, and the elucidation of difficult problems in other counties afford a body of knowledge, experience, criteria and methods of attack of which we have availed ourselves to the utmost. The diagnostics, for example, of the distinct ice invasion called the Iowan, which have been so fully worked out by Calvin in Johnson, Delaware, and other counties, have been carried over into Cedar and applied to similar phenomena here; and, to mention a much less important instance, it would have been far more difficult to interpret the Devonian section in Cedar were it not for the more extensive outcrops already studied in Linn.

## PHYSIOGRAPHY.

### RELIEF.

A measure of only about 325 feet separates the highest from the lowest elevations in the county. The maximum height is attained in the northwestern part at something over 960 feet, the minimum in the valley of the Cedar on the Muscatine county line at 635 A. T. Omitting from consideration the trenches of the streams, this area of twenty-four miles square forms a fairly even surface which gradually rises towards the northwestern corner from an elevation of 740 feet A. T., at the southwest, 760 at the southeast, and 860 feet at the northeastern corner.

Slight as is this relief when compared with the mountains of Colorado, or the canyons of Arizona, it nevertheless comprises the various records of different geological agènts acting through times almost inconceivable in their length. It possesses, therefore, an historic interest which may equal that of the most stupendous scenery. The historic interest of an ancient document does not depend on the size of its letters, nor are the geological values of the landscapes in Cedar county lessened by the faintness of the characters in which their story is engraved.

On the north lies a narrow plain which we shall know as the Clinton lobe of the Iowan drift plain. This slopes eastward from a height of 900 feet A. T. near Lisbon, to 820 A. T. near Massillon. On the left bank of the Cedar a similar plain, which may be termed the Tipton lobe of the Iowan plain, stretches from the Linn county line to within a fraction of a mile of Tipton, with a maximum elevation of about 800 feet A. T. With the exception of these lobes and an anomalous area at Rochester where constructional contours prevail, the remainder of the county may be described as an upland, everywhere overlooking the Iowan plains, retaining in places, as near Sunbury, much of its initial level surface, but elsewhere worn by long rain wash and stream erosion to a gently undulating prairie, as about Red Oak, or deeply carved into a maze of steep hills, as near Cedar Valley. This is termed the Kansan upland, and it will be more fully described under the head of the Kansan drift. It stands at 960 A. T., south of Mechanicsville, at 900 south of Stanwood, at 860 south of Clarence, and at 840 A. T. near Lowden. In Gower township its altitude is from 800 to 820, and it descends to 760 and 740 in Springdale township, a descent of over 200 feet from the marginal hills overlooking the Clinton lobe of the Iowan drift plain. In Sugar creek township the crests of the Kansan upland are about 800 feet above sea, declining to 760 in Farmington.

The following table gives the elevation above tide of the towns of the county, Gannett's Dictionary of Altitudes in the United States being authority:

| | FEET |
|---|---|
| Bennett | 742 |
| Buchanan | 750 |
| Centerdale | 725 |
| Clarence | 829 |
| Downey | 683 |
| Durant | 720 |
| Lowden | 721 |
| Massillon | 733 |
| Mechanicsville | 899 |

| | FEET |
|---|---|
| Plato | 703 |
| Stanwood | 851 |
| Tipton | 805 |

## DRAINAGE.

*The Wapsipinicon River.*—The two master streams of the county are the Wapsipinicon and the Cedar rivers. The former transects the extreme northeastern corner, leaving hardly more than two square miles of the county on the left bank. While its drainage area comprises about one hundred and fifty square miles, its course within the county is only some four miles in length. But even within this short distance it presents both the types of river valleys common in eastern Iowa and in glaciated regions. Where the Wapsipinicon crosses the Jones' county line, it winds over a sandy alluvial plain more than a mile in width. At Massillon it enters a narrow rock-bound valley, in which ledges of Niagara limestone stand thirty feet above the water, the hills on the right bank rising to twice that height above the same datum. At the Clinton county line it escapes from this constricted valley and flows out on a wide flood plain, silt filled to unknown depth. These sharp contrasts are clearly due to glacial interference. A stream flowing over rocks of uniform resistance will excavate a valley homogeneous throughout in width, in depth, and in contours. In such rocks, differences in valley width express corresponding differences in age. Since every stream cut valley must needs be narrow before it is wide, and shallow before it is deep, the gorge at Massillon must be far younger than is the wide silt filled valley above the town; and we must conceive that the stream has been diverted here from its ancient path to the gorge which it has excavated in comparatively recent times.

The method by which a river widens its channel in massive rocks is well illustrated at Massillon. The Gower limestone of the ledges is obdurate in the extreme. It does not break into chipstone under frost, and its laminæ, though etched by the weather on the surface of the cliffs, remain coherent, and the ledges remain horizontal indefinitely. But these limestones, like all indurated rocks, are affected with joints, or natural fissure planes, which here are vertical and distant, cleaving the ledge from top to bottom. They form channels for percolating water, which gradually widens the joint seam by dissolving the limestone along its sides. It is in this way that the "wells" are formed which are found on the top of the ledges, and are as much as five feet in diameter. Thus by

Fig. 16. Ledge of Gower Limestone on Wapsipinicon river, Massillon.

the percolation of water down the joints great blocks are detached from the rock-mass. They are gradually undercut by the river flowing at the base of the ledge, and when undermined, slip, as is shown in figure 16, fall and at last are carried away piecemeal by the stream.

*Tributaries of the Wapsipinicon.*—The eastern and the northern tier of townships pay tribute, for the most part, to the Wapsipinicon. Its affluents gather the storm water over the larger portion of the Clinton lobe and the northeastern part of the Kansan upland. Pioneer creek flows southeast from the southern margin of the Iowan plain northwest of Mechanicsville, where in wet weather water stands in shallow pools. It receives the drainage of the Kansan island in Secs. 1, 2, and 3, Pioneer township. A branch called Picayune creek, rises at the edge of the Kansan southeast of Mechanicsville, and breaking through the paha ridges south of the village, joins Pioneer creek near the Jones county line. Here the creeks traverse a marshy flood plain a mile wide lying forty feet below the Iowan plain adjacent. A small stream known as Sybil creek drains the Iowan plain north of Stanwood. Mill creek gathers its head waters west of Clarence and maintains a southeast course across the Iowan plain and through a narrow upland of Kansan south of Oxford Mills.

The eastern part of the Iowan plain is drained by two creeks whose course is east and southeast. The northern one drains the country north of the great Lowden paha, and discharges in Clinton county below Massillon. The other, Yankee run, occupies an ancient valley whose floor of rock is buried an unknown distance below the surface. West of Lowden the valley plain is over a mile wide and falls with distinct slope to the southeast. A south branch of Yankee run is of wholly different type. Rising southwest of Lowden and flowing nearly east, it drains an intricately dissected Kansan upland, in which it has cut a comparatively narrow channel. The same upland is penetrated by the headwaters of Rock creek, and south of Bennett, where it shows scarcely a trace of stream cutting, it pays tribute to Walnut and Mud creeks. The longer courses of these three creeks lie in Scott county, and their physiognomy has been described in that report.

*The Cedar River.*—In its diagonal course across the county the Cedar exhibits the same alternation of wide and ancient, with narrow and recent valleys shown by the Wapsipinicon. Where it crosses the Linn county line it winds down a flood plain two miles wide in meanders, the radius of whose inner curve is three or four times the width of the stream. Above the flood plain rise the steep forest-crowned hills of the Kansan upland on the right bank, while on the left there is a gradual ascent from sandy terraces to the rolling prairie of the Tipton lobe of the Iowan drift plain. At Cedar Bluff the river swings to the left, and sweeping against the hills, which here rise eighty feet to the Iowan prairie, washes their bases of Gower limestone. At the village it breaks directly through a rocky spur projecting from the left bank, thus forming an isolated hill some fifty feet high and about 1,000 feet in length, which rises abruptly from the river on the one side and on the other from the wide flood plain. The present channel of the Cedar where it transects the spur is 600 feet wide, rock-floored and completely filled by the stream. So recently has the river been diverted from the flood plain to the right of the island, that practically no stream-cutting has taken place below the level of the plain, and the farm lands upon it are protected by a levee from high water. The walls of the gorge cut in the soft and laminated Anamosa limestone are still vertical.

The extraordinary behavior of the stream in thus leaving the wide and easy way to the west and climbing, as it were, over the hills on the east, has aroused the attention of the intelligent people of the vicinity, and so striking is the example of a phenomenon not common, that it may be well to consider the ways in which such isolated hills on flood plains are made. Projecting spurs may be formed and afterwards transected in the normal development of meanders. As the stream cuts its curves more and more deeply convex, as it alters its open curves to horseshoe bends and constantly narrows their necks, it, at last, may cut completely through the neck of the inclosed spur, leaving its former crescentic channel slowly to fill with alluvial deposits, and ultimately to be aggraded to the level of the flood plain. If we attempt to apply this theory to the case in hand, and imagine the Cedar as once swinging to the left of the knob in a great horseshoe curve, and cutting the present path of the stream from both above the "island" and below, we shall see at once that the latter does not exhibit the requisite form. Its longer axis is not aligned at right angles to the course of the stream, as it should be if formed in this way, but lies parallel with it.

Such isolated hills on broad flood plains are found also where a narrow tongue of land, intervening between a river and the lower course of a tributary, is cut through by lateral sapping, the master stream thus becoming diverted to the channel of the affluent. If this hypothesis is applicable here we must suppose that the small creek mouthing one and three quarter miles above Cedar Bluff once fell into the trunk stream below the village, and that the ridge once intervening has been wholly consumed with the exception of the rocky "island" under discussion. If this is the case, the valley of the creek, the left bank of the Cedar from the creek to the island, and the channel at the island onght all to present the same topographic forms since they are all of the same age. But the contours of these courses are markedly different. The channel at the island presents every evidence of extreme topographic youth in its floor of rock and its narrow and vertical walls. The others are evidently older, being bounded by hills of moderate slope in which rock but rarely appears. A cogent fact which contradicts both of the theories is this: the valley of the Cedar has not developed in a regular and uninterrupted cycle. The depth of the ancient fluvial floors of rock beneath its wide flood plains forbids us to connect with the cycle to which they belong such a channel as this at Cedar Bluff.

Other solutions of the problem being closed there remains the agency of the great ice invasions of Pleistocene times. When the broad valley of the Cedar was still filled with glacial ice, a superglacial stream finding its way as best it might would here and there discover its ancient channel, while here and there it would be let down upon some rocky spur across which it would cut a narrow gorge such as this at Cedar Bluffs.

It would be expected, also, that for long stretches the ancient strath so filled with glacial ice would be so blocked with ice and land waste that the river would be diverted to a new track. Such is the path of the Cedar from below Cedar Bluff nearly to Rochester, a rectilinear course in a narrow valley cut to a depth of 140 feet in the Kansan upland, bordered with steep bluffs covered with forests and disclosing here and there vertical palisades of Gower limestone.

From Rochester to the south line of the county the valley of the Cedar is of the type described above Cedar Bluff. The river swings from side to side of a flood plain a mile in width. On the right bank the Kansan upland lies about 100 feet above the river. On the left bank the Kansan lies lower, being from sixty to eighty feet above the same datum on the prairies east of Lime City.

The breadth and sloping sides of the wide reaches of the Cedar are evidences of great age, but in themselves alone these characteristics do not imply a preglacial or pre-Kansan origin. Valleys as broad in southwestern Iowa have been found to be post-Kansan by the geologists who have studied that field. But, while the latter are cut in drift, the former are cut in solid rock in large measure. Taking into consideration both the quantity and the hardness of the material excavated, and, in especial, the fact that the drift lies unconformable on the slopes of rock which form the sides of the valley, the conclusion is inevitable that the wide valleys of the Cedar are at least pre-Kansan in age, and may, perhaps, be even pre-glacial.

*Terraces of the Cedar.*—These remnants of ancient flood plains are well marked on the broader reaches of the Cedar. They testify to the great volume of water, derived from the melting of the ice sheets of Pleistocene time, which once poured through this channel. Connecting with the terraces described in the report on Linn county,* these benches continue without interruption to Cedar Bluff, being more sharply defined on the left bank of the stream. A narrow upper terrace, standing about twenty feet above the lower bottoms and thirty-five feet above the river is marked by a clean scarp and

*Iowa Geol. Surv., vol. IV, pp. 176, 177.

level floor, and its surface is composed of either a yellow, loess-like loam, a rather stiff, yellow joint clay, or of sand.

A typical section is afforded in Cedar township, Sec. 17:

| | | FEET |
|---|---|---|
| 8. | Clay, yellow, slightly arenaceous | 2 |
| 7. | Clay, reddish, sandy, more or less indurated, graduating into No. 6 | 1 |
| 6. | Sand, stratified, yellow and white, from fine to coarse, with some gravel | 4 |
| 5. | Clay, white | 2 |
| 4. | Ochreous accumulation, indurated | $\frac{1}{6}$ |
| 3. | Sand, light yellow and gray, interstratified with laminæ an inch or less in thickness of white clay | 3 |
| 2. | Gravel, stratified, with yellow sand | 6 |
| 1. | Concealed to floodplain | 3 |

The lower bottom land which for the most part stands well above the present floods of the river, is about a mile in width and varies in its superficial deposits from sandy stretches to fine silt and black humus.

In the narrows from Cedar Bluff to Rochester terraces are either inconspicuous or wholly absent, but from the latter station to the Muscatine county line the remnants of these ancient fluvial floors form a most striking topographic feature, everywhere bounding the wide alluvial bottom lands with their sinuous and sharp escarpments. Rochester stands upon a bench of stratified sand and gravel about twenty-five feet above the river, which sweeps southwestward, forming a selvage about the hills as far as the mouth of Crooked creek. About the town benches occur to a height of twenty feet and more above this terrace. These are composed of sand and are rendered indistinct by dunes which surmount them and by their blending with the northwest-southeast ridges of the district. South of Rochester the main terrace on the right bank stands at about twenty-five or thirty feet above the present flood plain of the river. With a width in places of over one-fourth of a mile, it extends nearly to the Muscatine county line where the river swings across the flood plain and impinges on the base of the bluffs of the western bank.

The structure of this bench is shown in many gullies. Below about six inches of humus lies a rather stiff, reddish jointed clay, four feet thick, resembling weathered loess, which passes by interbedding into stratified yellow sand affected with the common brownish bands denoting an admixture in these layers of some clay.

In color, depending on age and degree of ferrugination, and in composition and structure, these terrace deposits agree with those of the age of the Iowan drift, and are taken to have been laid down at the time of the melting of the Iowan ice sheet.

### TRIBUTARIES OF THE CEDAR.

*Clear Creek.*—This large creek drains the Kansan upland in the northwestern part of the county. Two branches draw their head waters, northeast of Lisbon, from the Iowan plain, over which they flow in shallow trenches. Entering the hills of the Kansan they soon descend to a depth of 100 feet beneath these loess-capped summits. The east fork of Clear creek rises south of Mechanicsville on a divide where storm water gathers in temporary ponds, and flowing west and joining the west forks, takes a southwest course through the Kansan upland in a tortuous valley bordered here and there by ledges of Gower limestone which reach a height of about fifty feet. The excellent mill sites thus afforded were early utilized by the erection of three of the largest mills in the county. Within about one-half mile of the Linn county line Clear creek leaves the Kansan and flows out upon the comparatively low area of the Tipton lobe of Iowan drift, and upon this it continues with high terraces until it falls into the Cedar at a normal angle.

Between Clear creek and Cedar Bluff two unimportant streams flow southwest into the Cedar over the Iowan plain. The western of these is diverted in its lower course along the flood plain of the river by its natural levees. The ravines of the head-waters of the eastern of these streams trench through Kansan till and uncover the Gower limestone at about 800 feet A. T., and in section 14, Linn township, the creek has cut some 40 feet in the same beds, the slopes of the rock being covered with Kansan till and loess.

Below Cedar Valley there debouch into the Cedar on the left bank three relatively important streams,—Rocky run, Rock creek and Sugar creek. These all rise on or near the frontier of the Clinton lobe of the Iowan, and pursue southeasterly and southerly courses, changing to southwesterly when within about two miles of their trunk stream. In the plain of Iowan drift west of Tipton, the tracks of Rocky run and Rock creek are deflected, corresponding to the southeastward movement of the Iowan ice.

*Rocky Run.*—This stream rises south of Mechanicsville, on the Kansan plain, here undissected. Flowing south through Red Oak township, it occupies a channel about five feet deep in a valley lying about thirty-five feet below the summits of the adjacent hills. Across the Iowan plain its strath is in places bowlder strewn. Entering the Kansan upland in Center township, it holds a very narrow, winding valley, which reaches the depth of 140 feet below the level of the upland. The Gower limestone is disclosed at many points, and on the slopes cut by the stream in the rock the loess and the Kansan till descend well down to the present level of the water.

*Rock Creek.*—The Iowan area directly north of Stanwood and the rolling Kansan area about Red Oak discharge their storm water into the valley of Rock creek. Near Tipton the creek bends to the west about a heavy ridge of Kansan drift, and again to the southeast along the margin of the Tipton lobe of the Iowan. Entering the Kansan again southwest of Tipton, its valley is wholly similar to that of Rocky run in the same area. Near Rochester it leaves the upland and turning abruptly west along its margin falls into the Cedar.

*Crooked Creek.*—This name is applied to a stream which rises on the flat divide north of Tipton and flows southward through a wide valley cut only in the drift. East of Rochester it crosses a region where the country rock rises nearer to the surface, and here the valley narrows. As the Devonian limestones here traversed are comparatively weak, the narrows are less constricted and less steep of side than the gorges of the streams which cross the resistant limestones of the Niagara.

*Sugar Creek.*—This is the largest creek of the county. Its course extends from the margin of the Clinton lobe of the Iowan drift south of Clarence, southward to Muscatine county, a straight line distance of eighteen miles. Until it reaches Sugar Creek township, the valley of this creek is cut wholly in the loess and the drift, and over the lower portion of this track is a much wider valley than that of the Cedar from Cedar Bluff to Rochester. From the summits of the Kansan upland one looks across a sunny valley from a mile to a mile and a half wide and eighty feet deep. All the enormous amount of material, a bulk sufficient to refill the valley, has been washed away by the creek and delivered to the river for transport to the sea, and all by the slow processes of erosion now in progress. But the age of the valley cannot antedate the deposition of the drift sheets in which it is excavated. How long is it, then, since these were laid down by the Pleistocene glaciers? Long enough for Sugar creek to have washed out and away each clay-flake, sand-grain and pebble of the bulk which once filled this wide valley.

At the north line of Sugar Creek township the stream passes into a region of much shallower drift, and encountering the resistant rocks of the Gower, has accomplished a much smaller measure of erosion. The strath at once constricts, and from here to Lime City is similar to the valleys of the other creeks of the county cut in the same limestone. A mile south of Lime City the stream emerges upon the drift and flows over wide flood-plains bordered by gently sloping hills southward across the Muscatine county line and enters the old channel perhaps once occupied by the waters of the

Mississippi, designated in the report on Scott county as Durant channel. This broad and ancient waterway transects the southeastern corner of Cedar county. The course of the channel and its relation to the Illinoisan ice have been set forth in previous reports* In Cedar county the channel is now occupied by Big Elkhorn creek, and is about one mile in width and flat bottomed.

Farmington township is drained in part by two creeks which flow south over the southward sloping Kansan plain and empty into Durant channel. Both occupy wide, flat, silt-filled valleys in their lower reaches and shallow swales toward their head-waters, and both lie wholly in drift.

The tributaries which fall directly into the Cedar on the right bank are comparatively short. The most northern of them is Nicholson creek, which presents all the usual characteristics of the smaller streams in Kansan drift. It has cut through into the Gower limestone in its lower course and falls into the river above Cedar Valley.

The southwestern townships of the county are drained by the three forks of Wapsinonoc creek. They occupy wide drift cut valleys with well graded flood plains and well marked dendritic system of subordinate drainage channels. Flowing south across the Muscatine county line the creek traverses the wide alluvial plain of Lake Calvin and empties into the Cedar south of Nichols.

*Sinks.*—All the drainage of the county is subaerial, except a short underground course of a storm water stream in the southeastern corner of Iowa township. This phenomena is so rare in this region that it may be described in some detail. To one approaching from the south, the sink appears as a normal, narrow, steep-sided little valley, directing its way toward the Cedar. In a distance of eighty rods the ravine descends some sixty-five feet below the upland. Here the water course, strewn with fragments of Devonian rocks, ends

*Udden, Iowa Geol. Sur., vol. IX, p. 344.
Norton, Ibid, pp. 410, 420, 421.

abruptly against a low wall of heavily bedded limestone, and turning to the left plunges through a rock portal about four feet wide into the tunnel through which it finds the remainder of its way to the Cedar. The entrance is now choked with debris, but it is said that the cave, a mere cleft for the most part, but in one place widening to a passage five feet wide and seven feet high, has been followed a distance of 150 feet. From the south, east and west shorter ravines descend to pit-like sinks at about the level of that described, nine of these being counted in a radius of twenty rods. The longer ravine is at right angles to the river, from which it is separated only by a steep and narrow ridge of the same height as the land on either side. The outlet of the sink was not seen.

It is characteristic of some of the streams whose courses lie north-south that the west bank is both higher and steeper than the east. On Sugar creek north of Tipton the hills of the west bank rise rather steeply to a height of seventy to ninety feet above the stream, an elevation reached on the opposite side only at a distance of from two to four miles from the creek. Less markedly the same difference obtains on the branch which empties into Sugar creek near Wilton, on Crooked creek and on the course of Rock creek above Tipton. In so far as the difference may be due to unequal initial depth of loess, another problem is added to those still unsolved as to the origin and distribution of that formation.

*The Preglacial Drainage.*—Before the advent of the Great Ice the drainage channels of this region were by no means as they are today. Midway the present valleys of the Wapsipinicon and Cedar lay a preglacial channel broader and deeper than are the post-glacial valleys of these rivers. Toward this central trough, here called Stanwood river, the rock surface sloped from either side so that in the immediate valleys of the present rivers it stands 200 feet above the rock cut path of the ancient stream. Another deep preglacial channel lay near the Johnson county line, west of Downey, probably connecting with the depressions found by Calvin* in Johnson county, in Cedar and Scott townships.

Nothing in the present topography gives the slightest hint of the existence of these buried river beds. Their discovery is due to the well drillers of the county, who, in these belts, find that their drills pass through scores of feet of river sand before they grind on the rock 300 feet below the surface of the ground.

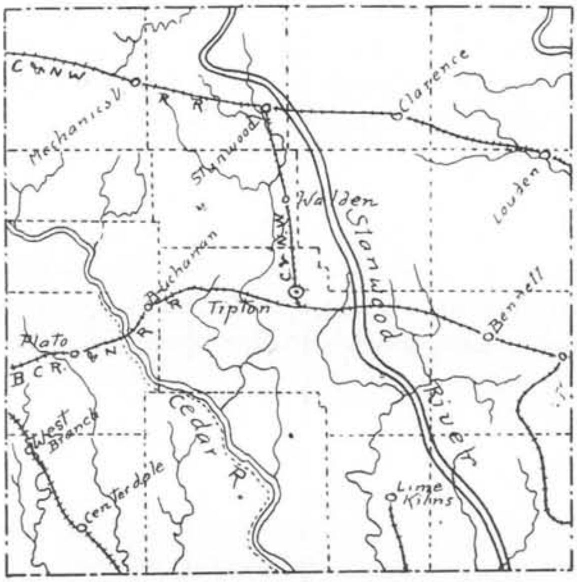



Fig 17. Course in Cedar County of Stanwood River.

Stanwood river enters the county in Fremont township, and, curving strongly to the west, passes southeast to Stanwood. Trending southward east of Tipton, it follows down the east side of Sugar creek nearly to where that stream enters the rocky gorge two and one-half miles north of Lime City. Here it bends to the southeast, and while its course in Farmington township is not well made out with the data at hand, it

*Iowa Geol. Surv., vol. VII, p. 91.

is well nigh certain that it joins near Durant the ancient buried river which passes south through western Scott county, described in the report on that county under the name of Cleona channel.

At Stanwood the rock floor of Stanwood river is 544 A. T. Five miles southeast, at Geo. Kinney's (Sec. 17, Fairfield Tp.), it has declined to 500 A. T., the rock here being struck 320 feet below the surface. Fourteen miles southeast of Stanwood, at John Helmer's (Sec. 23, Center Tp.), it has fallen to 440 A.T., a gradient of seven feet to the mile, as steep as that of the swift Colorado. Cleona river, into which Stanwood river empties, has a fluvial floor in southern Scott county of not higher than 400 A. T. This channel continues, as has been shown by Leverett, to the southeast county of Iowa. To Mount Clara, eighty miles south of Durant, the fall of the floor of this buried waterway is but twenty-six feet. From Durant north, by Cleona channel and the Maquoketa and Mississippi, to the rock floor of the Mississippi at Sabula, is a rise of but nineteen feet in sixty miles. Stanwood river was clearly a tributary of this axial stream, a preglacial Mississippi as it may have been. Data are not at hand to show clearly the character of the preglacial valley further than the general slope toward the trough. Measured from crest to crest, its width is at least seven miles at Tipton, with a sharper descent to a thalweg perhaps two miles wide. Three miles north of Tipton the inner trough, a mile wide, lies 120 feet below a wider one, at least two and one-half miles wide, and rising more than 100 feet higher. If precipitous walls exist, such as those of the bluffs of the Mississippi, in northeastern Iowa, there is no evidence of the fact in the records of the wells. So far as appears, the character of the transverse profiles points to a river at least well on toward maturity. This is in such strong contrast with the steep gradient that the question at once suggests itself how far the gradient may be due to differential uplift. If this is the case, it has not affected to any marked degree the preglacial channel of the Mississippi. The question is a much larger one than Cedar county, and we need do no more than place the local facts on record to be taken into account with those from other districts in reaching general conclusions for the entire region.

The channel of Stanwood river is aggraded with river sand. At Stanwood it is thus filled to a height of 116 feet above its rock floor. Three miles southeast, at Henry Britcher's, drillers report 144 feet of sand overlying the rock, and one report names a figure considerably higher. In a few wells in the channel these deep sands were replaced by glacial tills, as in this section of a well in Fairfield Tp., Sec. 22:

| | THICKNESS. | DEPTH. |
|---|---|---|
| Yellow clay | 30 | 30 |
| Blue clay, tough | 126 | 156 |
| Sand | 10 | 166 |
| Blue clay | 66 | 232 |
| Sand, to rock | 1 | 233 |

Such heavy sands are found in wells at some distance from the central line of the trough. For example, at the well of Adam Birk, to the northeast of Tipton, probably two miles from the median line of the valley, and more than 100 feet higher than it, sand 100 feet deep was penetrated below seventy-five feet of yellow clay, the former resting directly upon the rock.

In these channels sands are usually fine of grain. They could have been laid down by streams discharging the waters of the advancing glacier, and overloaded with its silt, or, far more probably, a subsidence in early Pleistocene times diminished the gradient and thus lessened the capacity of the stream to carry its load.

## STRATIGRAPHY.

The indurated rocks of the county were deposited during three long, successive cycles of geologic time known as the Silurian, the Devonian, and the Carboniferous. Shales reported in a single deep well sunk in the preglacial channel of Stanwood river, if authentic, belong without much question to a still earlier cycle, the Ordovician, and this age may therefore be placed in the list.

During the long eras after the emergence of the region from the sea, an event wholly accomplished at the end of Paleozoic time, the rocks of the county weathered to residual clays, known as geest. Remnants of this mantle which remain can thus be assigned to no particular age. The incoherent superficial deposits belong to a time notable for the exceptional development of glacial ice in the northern hemisphere and known as the Pleistocene.

The areas of outcrop of each of these formations may be seen by consulting the maps which accompany this report. It will be noted that the larger part of the county is underlain by the Silurian. A much smaller area, lying chiefly in the southwestern townships, is assigned to the Devonian, and here the rocks are for the most part deeply buried beneath the drift. The Devonian limestones are weaker than the Silurian and with preglacial weathering may well have sunk to a somewhat lower relief, allowing upon them a deeper accumulation of glacial drift than would lodge on the harder and higher rocks of the Silurian area.

The succession of the groups and systems of the rocks of the county with their subdivisions is set forth in the following table:

SYNOPTIC TABLE OF FORMATIONS IN CEDAR COUNTY.

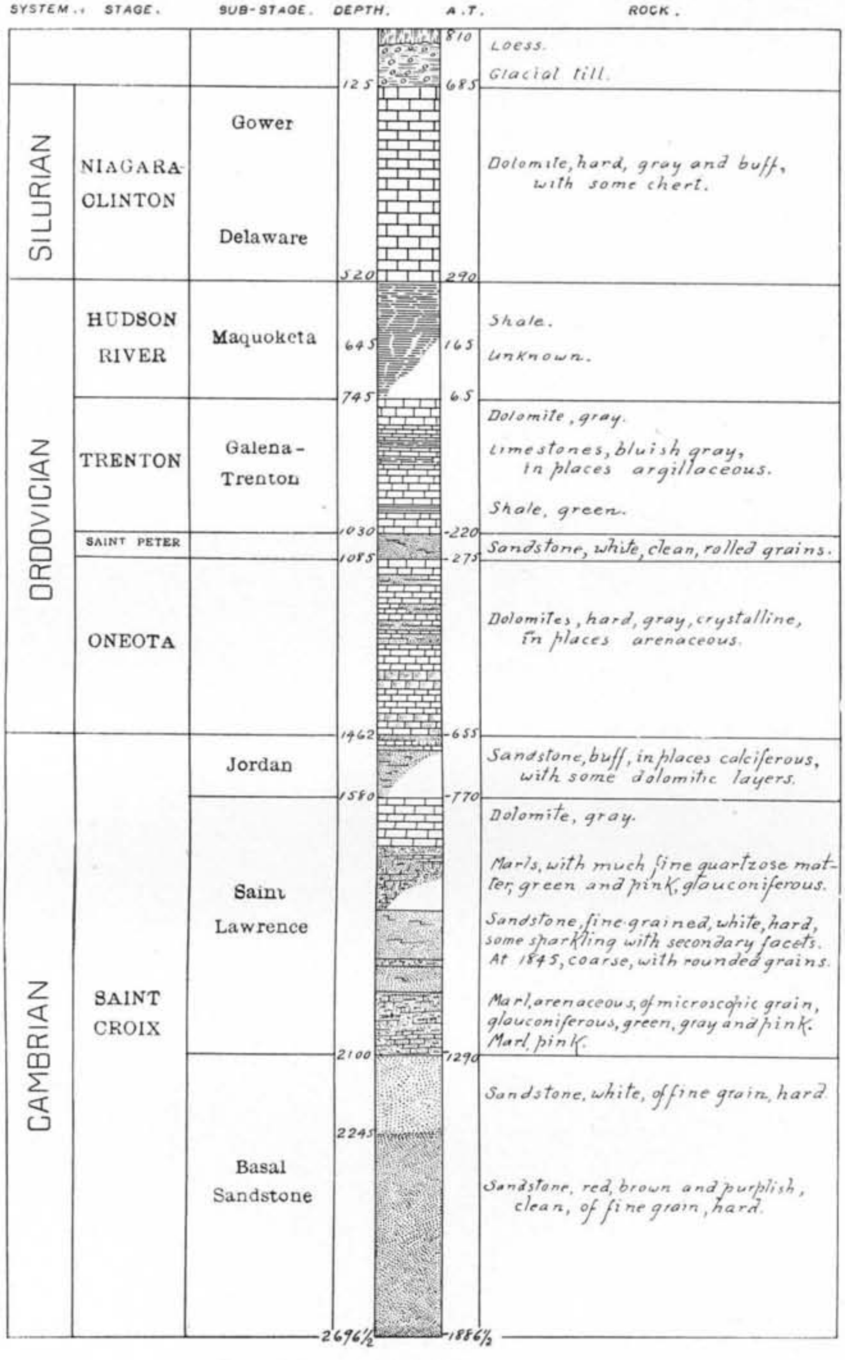
| GROUP. | SYSTEM. | SERIES. | STAGE. | SUBSTAGE. |
|---|---|---|---|---|
| Cenozoic. | Pleistocene. | Recent. | Alluvial. | |
| | | Glacial. | Iowan.<br>Yarmouth.<br>Kansan.<br>Aftonian.<br>Pre-Kansan. | |

SYNOPTIC TABLE OF FORMATIONS IN CEDAR COUNTY—CONTINUED.

| Residual Clays, or Geest. | | | | |
|---|---|---|---|---|
| Paleozoic. | Carboniferous. | Upper Carboniferous. | Des Moines. | |
| | Devonian. | Middle Devonian. | Cedar Valley. | |
| | | | Wapsipinicon. | UpperDavenport |
| | | | | LowerDavenport |
| | | | | Independence. |
| | | | | Otis. |
| | | | | Coggan. |
| | Silurian. | Niagara. | Gower. | |
| | Ordovician. | Trenton. | Maquoketa. | |

THE DEEPER STRATA.

The outcropping rocks within the limit of the county can hardly represent a vertical measure of more than 250 feet, an amount inconsiderable in comparison with the thousands of feet of stratified rock upon which they rest. Of the nature of these deeper strata much is known, both from their outcrop in areas to the northeast and from deep borings. One of the most interesting of these is the Tipton artesian, one of the deep wells of the United States. The samples of drillings, carefully saved by different citizens of Tipton when the work was in progress, tell in a satisfactory manner the nature and




Geological section of the Tipton artesian well.

thickness of the underlying formations. A report of these has already been published by the Survey.*

During the present investigation a set of samples was obtained much fuller than the incomplete ones used in previous studies. Of the sixty additional samples thus secured, the larger number were of use only in corroboration of the record and section already made out. Several, however, bridged serious gaps, and made it possible to correct the previously published reports. The succession of formations, their thickness, and the character in brief of the rock is exhibited in plate VII.

### Ordovician.

According to the log of the well at the tile factory at Stanwood, as reported by Mr. G. W. Sisler, of that village, there was found at the depth of 296 feet, and immediately beneath Pleistocene deposits, 44 feet of black, hard, tough clay, which dried like shale. Any deposit which would answer to this description at this place and depth would in all likelihood be the shale of the Maquoketa. The conclusion is fairly probable that Stanwood river here cut through the Silurian limestones into the shales of the Ordovician. At the town well of Mount Vernon, fourteen miles west of Stanwood, where the Niagara would presumably be at its thickest, beds of shale intercalated with limestone were penetrated from 300 to 325 feet from the surface, the main body of shale not being reached. At Anamosa, where the Gower is well developed, the Maquoketa was found 360 feet from the surface. At H. Britcher's, two and one-half miles south and two miles east of Stanwood, the drill was still working in limestone at 363 feet from the surface at the completion of the well. The question must be left in some doubt, with the probability in favor of the presence of a shale at Stanwood and its reference to the Ordovician.

*Iowa Geol. Surv., vol. III., pp. 197-200.
*Ibid*, vol. VI., pp. 261-262.

### Silurian.

## NIAGARA.

The lower beds of the Niagara, the Delaware stage of Calvin, have not been found in the county. Some of the exposures in the northeastern part of the county, where the Delaware stage might be expected to occur, if at all, carry so few fossils that their assignment to any stage is somewhat uncertain. But in the absence of the coralline and pentamerous beds characteristic of the Delaware, they are placed with the higher stage of the Niagara, the Gower, with which their lithological characteristics very well agree.

### GOWER LIMESTONE.

The Gower limestone receives its name from Gower township, Cedar county, where its various lithological phases are

Fig. 18 Gower Limestone, Anamosa Type, Cedar Bluff.

well developed, and where it is more extensively quarried in the Bealer quarries, at Cedar Valley, than at any other point in the State. It includes the beds which have been designated as the Anamosa in the earlier reports of the Survey, together with those long known as the LeClaire. The former phase consists of soft, laminated, light buff, granular limestones with gentle quaquaversal dips, and often approximately horizontal. The texture is porous or vesicular, and the lustre dull, relieved by occasional shining facets of minute crystals. Bedding planes are even and parallel, and commonly the rock quarries to dimension stone a foot or less in thickness. Joints are distant and vertical. Fossils are exceedingly rare. Fucoid markings are sometimes seen, and surfaces are not infrequently covered with small, rod-like, flexuous bodies, whose nature is a matter of conjecture.

Found in immediate connection with the Anamosa are beds so different that they were long supposed to belong to a distinct and earlier stage, named the LeClaire. Hall, indeed, who assigned it its name, placed these two phases in different geological series, referring the LeClaire to the Niagara and the Anamosa to the Onondaga Salt Group.

The LeClaire facies is a hard, brittle, gray or bluish gray limestone, sometimes oxidized to buff. It is subcrystalline, and in places of trachytic harshness on account of vesicularity due to the removal of minute fossils. Moulds and casts of fossils abound. These are often gregarious, and while no complete list of species has been made out, the fauna is known to represent that of the Gault of Canada.

The LeClaire occurs in places in mounds fifty feet high and over, in which little semblance of stratification is to be seen. Here the rock is brecciated or conglomeratic. The matrix may be so nearly of the same color and texture as the fragments, that it is with difficulty that the real nature of the massif is made out, or it may consist of a buff, friable, granular limestone sand, distinctly impairing the value of the outcrop, both for lime kiln and for crusher. On the sides and upper surface of these mounds stratification planes are usually seen dipping outward in either direction at high angles. At first obscure, inconstant, and blending with the lumpy rock of the mounds, these bedding planes become comparatively well defined as they pass outward. This is illustrated in plate VIII., taken from the lime quarry at Cedar Valley, and is typical of many exposures in several counties.

A second aspect of the LeClaire is thus presented, in which it is distinctly stratified. Retaining its crystalline texture and hardness, it may even rival the Anamosa in closeness of lamination and evenness of bedding, as at Lime City, where this facies is quarried for building stone. In this phase the layers may lie as in the Anamosa, nearly horizontal, but commonly they are inclined or tilted, and sometimes at angles surprisingly high. As a rule these stratified layers hold their highest dips in juxtaposition to the mounds, gradually decreasing to horizontal with increasing distance therefrom. Where any considerable horizontal section is afforded, they are seen to form synclines between the massifs.

The forces and conditions under which these phenomena of the LeClaire were formed is confessedly one of the difficult problems of Iowa geology. Any theory deserving acceptance must explain the following salient facts.

The dip is seldom constant over any considerable distance. Within a fraction of a mile, or even a few rods, it lessens or increases its angle, and changes or reverses its direction. Some outcrops lead us to believe that the normal dip is radial rather than anticlinal, *i. e.* the layered limestone lies in basins rather than in troughs. Where no great vertical thickness is exposed the slant may appear fairly uniform from top to bottom, but in deep exposures the dip is seen to diminish downward, forming synclinal curves. An inclined layer remains, as a rule, of uniform thickness. This is specially noteworthy in highly inclined and finely laminated layers.

From many observations in Cedar and adjacent counties to the east, north and west, the composite impression remains that the higher angles of dip usually lie between 10° and 30°. But much higher angles have been measured, in Cedar county

Agglomerate mound of Gower limestone with bedding plains on flank.

as high as 70° and in Linn for short distances 90° in the case of small folds (plate IX).

Layers finely laminated are locally flexed and, in rare cases, display abrupt folds with fracture (Fig. 19).

Inclined strata may alternate horizontally within a few feet with brecciated beds, the dip of the separated layers remaining about the same. The fragmental beds are sometimes made of unrolled, angular fragments of massive limestone; while the tilted beds adjacent are finely laminated. Brecciated beds usually form the centers of anticlines of stratified limestone.

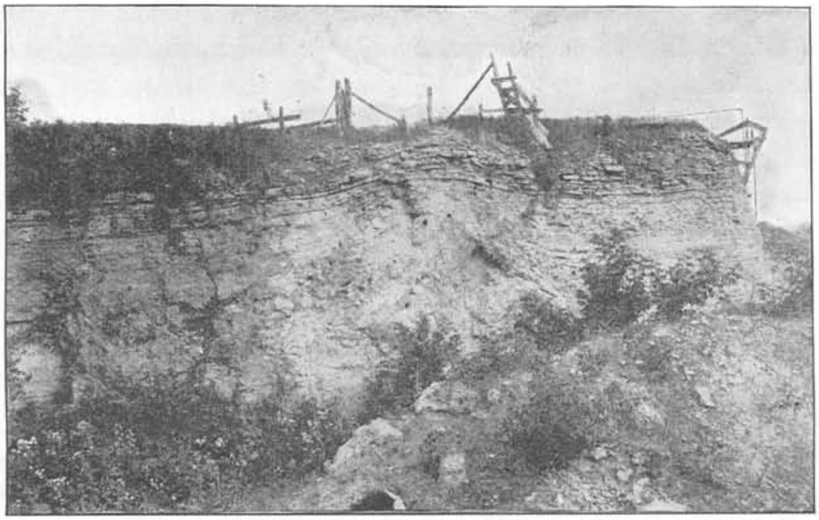


Fig. 19. Massif of Gower Limestone at Lohmann's Quarry, near Lowden.

Planes of cleavage are in all cases coincident with fossil zones, when such occur. In no case has cleavage been seen to pass transversely through a zone of fossils. Even on the most steeply inclined bedding planes, fossils lie as if they had there lived and died, no evidence being seen of their having been swept thither by currents. Thus layers of rhynchonellas, crinoid stems, pentameri, spire-bearing brachiopods, and of rod-like bodies unclassified are affected with the same abnormal dip as are unfossiliferous limestones.

While the law of parsimony requires that all these phenomena be expained by as few causes as possible, it is difficult to relate them all to any one causal process. The theory that these inclined planes are of the nature of slaty cleavage is disproved by the fact that they correspond with the natural bedding planes as shown by the lie of fossils.

The theory which at once suggests itself of folding under lateral pressure, accounts for the position of the massifs in the centre of anticlines, for the brecciation there found, for the flexed and broken strata, and for the variant angles of dip. Radial dips and the thickness of the strata are difficulties on this hypothesis.

The third theory is one suggested in part by Hall, and worked out with painstaking fidelity in the Wisconsin field by Chamberlin. It has been used as a working hypothesis by the Iowa Survey in the reports on Linn, Jones and Scott counties. It is here assumed that at the close of the Niagara huge mounds and ridges were built on the bottom of the shallow Silurian sea, in part by the accumulation in situ of corals, crinoids and molluscous shells, and in part by the drift of calcareous sediments under strong currents. That these reefs were near the surface during their building is attested by their conglomeratic character, due to the same wave action as coral breccia to-day. The fact that massifs are commonly highly fossiliferous is thus explained, as is the steepness of their slopes, and the intercalation on the sides with bedded deposits. That the shore was distant is shown by the purity of the limestones, their freedom from admixture with clays and sands derived from the wash of the land. That the sea was shallow is further implied in ripple marks, mud wash and mud cracks, with which the laminated limestones are sometimes affected.

While these mounds were in building, calcareous mud settled upon their steep sides, forming layers of limestone

Tilted Gower limestone at bridge crossing Rock creek.
Township 80 N., Range 3 W., Section 23, Se. ¼ of Sw. ¼.

dipping outward at various angles and directions, corresponding to the slopes of the mounds. With increasing distance from the mounds, the slant of the strata would decrease until horizontality was reached. Where mounds were in close proximity, steep synclines would result from the gradual filling of the trough, in the manner of cross-bedded deposits laid on initial slopes. Where they were more distant, stretches of obliquely-bedded limestones might be built out from them in the path of a current; and where their influence diminished to zero with increasing distance, beds would be laid down with practical horizontality. Such calcareous sediments would be in places coarse enough to constitute a sand-rock, made of cemented grains of limestone sand. Elsewhere the material might be so fine that it would accrete to a dense and ringing limestone.

All types of the Gower are thus accounted for, and the rapid alternation at the same levels of the LeClaire and Anamosa.

The hypothesis fails to account for the higher inclinations that have been measured. Under the theory of oblique lamination no angle of dip could exceed the angle of repose of calcareous silts under water. While this is no doubt a high angle on account of the property of rapid cementation they possess, it falls far short of the 70° seen at the crossing of Rock creek, on the Tipton-Rochester road, to say nothing of still higher angles.

Even in more gentle dips it seems that there should be at least some slight thickening of the laminæ downward, if deposited as sediments at the present angle of slope. This does not occur; even with laminæ of a fraction of an inch they maintain a constant thickness throughout.

Nor does it account for sharp flexures, folds with vertical limbs, and folds broken at sharpest change of direction. These phenomena, observed at the new quarries in these beds at the Upper Palisades, near Mount Vernon, are, it is true, somewhat exceptional, and they are confined to small areas of a few feet in length. Nevertheless they demand explanation.

So far as the steep angle of slope is concerned, it is possible that on the theory of oblique lamination, these may be explained if we conceive that the steep mounds of the massifs were sometimes undercut by currents. That subaqueous erosion actually occurred in Gower times there can be no doubt. The record is left in channel cuttings such as that noted at LeClaire by Calvin. Thus extensive slides may have taken place, by which large blocks of strata were left at higher angles than those of their original deposition. When these masses show a curvature, there is implied also a flexibility in the fallen blocks.

*Thickness of the Gower.*—As the base of the Gower is nowhere seen in the county, its full thickness cannot be measured. Cliffs of the LeClaire, a few miles east of the Linn county line, on the Cedar river, measure ninety feet. The Gower is quarried at Cedar Valley to a depth of 116 feet, the maximum thickness observed in Iowa.

*Weathering.*—The Anamosa stone weathers to thin, detached laminæ, or spalls, but so slow is the process that it need not be taken into account in weighing the value of the Anamosa as a building stone. Wherever the zone of weathering reaches any considerable depth, such as eight to twelve feet, evidence is at hand that the decay is preglacial, and involves immense lengths of time.

The LeClaire stone, when heavily bedded, weathers to deeply-pitted, cavernous surfaces. So uniform is the composition of the limestone, that this exceedingly irregular decay cannot be due to local differences in material, such as the presence of argillaceous matter. Nor is it proven that the pitting is due to local differences in the proportion of calcium and magnesium carbonate, any spot being especially vulnerable where the former was in undue excess. On a rock so uniform in texture and composition, and one which does not break down into chipstone under the action of frost, such cavities may well be formed by the localization of agents of decomposition. Where a lichen takes root, where a mould of a fossil allows water to penetrate, wherever any agency of disintegration or chemical decay is localized, there such pits will result on a stone whose face is consumed only by the detachment of grain after grain. On a differently constituted limestone the face would be broken down before these depressions would have time to form.

It is seldom that a finer illustration of honeycombed limestone is found than that of the rock represented in figure 20, on the road from Tipton to Mount Vernon, on the crossing of Baldwin creek.

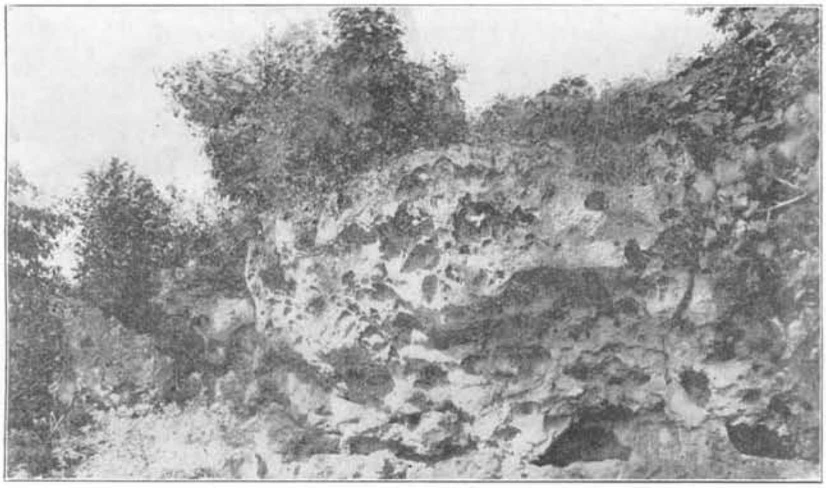


FIG. 20. Weathering of Gower Limestone, Baldwin Creek.

*Chemical Composition.*—The following analyses, made at the chemical laboratory of Cornell College, under the supervision of Dr. Nicholas Knight, show the exceptional purity of the Gower limestone, and its near approach to a typical dolomite.

BUILDING STONE QUARRY, LIME CITY

| | PER CENT. |
|---|---|
| Calcium carbonate, $CaCO_3$ | 55.3 |
| Magnesium carbonate, $MgCO_3$ | 43.0 |
| Ferric and aluminum oxides, $Fe_2O_3$ and $Al_2O_3$ | 1.4 |
| Silica, $SiO_2$ | 0.6 |
| | 100.3 |

BUILDING STONE, BEALER'S QUARRY, CEDAR VALLEY.

| | PER CENT. |
|---|---|
| Calcium carbonate, $CaCO_3$ | 56.4 |
| Magnesium carbonate, $MgCO_3$ | 42.6 |
| Ferric and aluminum oxides, $Fe_2O_3$ and $Al_2O_3$ | 0.7 |
| Silica, $SiO_2$ | 0.4 |
| | 100.1 |

LIME QUARRIES, CEDAR VALLEY.

| | PER CENT. |
|---|---|
| Calcium carbonate, $CaCO_3$ | 51.27 |
| Magnesium carbonate, $Mg CO_3$ | 48.09 |
| Ferric oxide, $Fe_2O_3$ | 0.35 |
| Silica, $SiO_2$ | 0.225 |
| | 99.935 |

This analysis shows a remarkably high per cent of magnesium carbonate, about 2½ per cent more than a normal dolomite.

### *Sections of the Gower.*

1. BEALER'S QUARRY, CEDAR VALLEY.

| | | FEET. |
|---|---|---|
| 9. | Limestone, buff, magnesian, very soft, Coggan stage. | 14 |
| 8. | Limestone, weathering into chipstone, in layers up to six inches | 1½ |
| 7. | Limestone, light gray, rough, massive, very vesicular. | 3 |
| 6. | Limestone, fragmental, argillaceous | 1 |
| 5. | Seam of blue argillaceous material extending for 180 feet along quarry face | 0.2 |
| 4. | Limestone in thin spalls, hard, dense, "flinty" | 5½ |
| 3. | Limestone, hard, rough, buff, crystalline, highly vesicular, with moulds of spire bearing brachiopods, the spires often remaining in casts | 5 |
| 2. | Limestone in layers from two to eight inches, laminated | 4 |
| 1. | Limestone, light buff, granular; lustre dull, homogeneous in grain, slightly vesicular, destitute of silica in any form, fracture even, soft when first quarried, rapidly hardening on drying, bedding planes horizontal, even and comparatively distant, laminated, joints distant, master joints running south-southeast. All quarried for building stone, together with Nos. 2–8, Gower stage | 94 |

A further description of this section will be found on a subsequent page. The quarry whose section has been given above lies just south of the bridge on the right bank of the river. Going up stream, we have an interesting series of exposures which exhibit the rapid change in lithologic types, structure, and attitude so characteristic of the Gower. Ten rods north of the bridge occurs limerock of the LeClaire phase at the same levels, highly tilted to the southwest at angles of from 30° to 45°. Fifteen feet up the side of the cliff lies a layer of spire bearing shells similar to those mentioned in No. 3 of the preceding section. Eight rods to the north the dip has declined to 11° W SW. in a heavily bedded, but finely and for the most part coherently laminated limestone, the softer laminæ being etched out by weathering but not detached. Thirty feet further the rock dips sharply to the northwest at an angle of 12°. Eight rods up stream the rock has assumed the texture of the Anamosa and has been quarried for building stone. Vermicular rod-like bodies occur on the even, smooth faces of the stone. The dip is here 10° W SW. at the southeast end of the quarry. For twelve rods the rock is now concealed. It reappears with a dip of 12° S SE., declining to nearly horizontal within a rod. Thirty rods up stream, at the entrance of the lime quarries, finely laminated crystalline limestone is tilted to 41° S SE., resting apparently on the steep side of a massif of unstratified crystalline limerock a rod away. Twenty rods further on occurs a strongly conglomeratic outcrop which passes on the further side into layered limerock dipping N NW. At the quarry fifty feet of typical limerock is exposed, a hard, brittle, light bluish gray, crystalline limestone with a tendency to break along vertical planes to long, splintery or rectangular fragments. In the center of the quarry the rock is a massif, but from this mound there pass outward and downward bedding planes dipping at high angles. The passage from the layered limestone is shown in plate VIII. The dip varies, the layers gradually lessening their inclination from 40° to nearly horizontal. At the north end of the quarry the following northeast dips were measured near the summit, 36°, 38°, 47°, 49°. Here the crystalline rock again becomes laminated to two and four inches. It is stated by the foreman of the quarry that as these layers continue outward and downward, where now concealed, they pass into granular rock useless for lime.

Near the base of the section a sharp contrast was seen where, in a vertical distance of five feet, were found, between typical limerock above and below, layers of soft granular limestone underlain by four inches of "flinty" laminæ. The fossils observed, *Amplexus* and Favositid corals, *Rhynchonella* and one or more crinoids, were of the LeClaire.

North of the quarry, across a small ravine, cliffs face the river composed of semicrystalline, finely laminated limestone, nearly horizontal, or dipping at low angles to the northwest.

2. EXPOSURES OF THE GOWER ON SUGAR CREEK.

Where Sugar creek leaves the deep, preglacial channel, here known as Stanwood river, and enters the region of the indurated rocks, in Tp. 80 N., R. II. W., Sec. 34, Se. ¼, its channel at once contracts, and from this point to Lime City exposures are frequent along its banks. Immediately at the crossing of the creek between Sec. 34 and the section to the south, Sec. 3, Sugar Creek township, nothing is exposed below the Coggan, which here lies eight feet above the water, or about 700 A. T., according to the United States topographical survey. One mile below, eight feet of gray mottled magnesium limestone, in part fragmental, and difficult to assign to any definite horizon, appear on the left bank, at the bridge. On the right bank (Sec. 10, Sugar Creek township, E. ½), the limerock of the Gower fronts the creek in ledges twenty-five feet high, in which tilted layers are seen to merge into structureless massifs. Further down the stream the finely laminated phase comes into view in the Sw. ¼ of the same section, dipping from 15° to 23° SE., and intermediate in texture between the granular and the crystalline phases. These rocks are in some layers quite fossiliferous, but with a restricted number of species. Eight rods further down stream a quarry has been opened. The dip has here decreased to 7°, and the stone has assumed for the most part the granular Anamosa facies. Twenty feet is exposed of these evenly-bedded layers, which weather to detached laminæ for a zone of twelve to fifteen feet from the surface. Short, flexuous, rod-like fossils cover the faces of some of the laminæ, and about five feet from the base is a zone in which casts of an ostracod crustacean are abundant. One-half mile south a building stone quarry has been opened on the farm of E. Hinkhouse, and at the same distance west, rock at about the same level has been quarried for lime. The next exposures are those a quarter mile south, at Lime City.

### 3. LIME CITY.

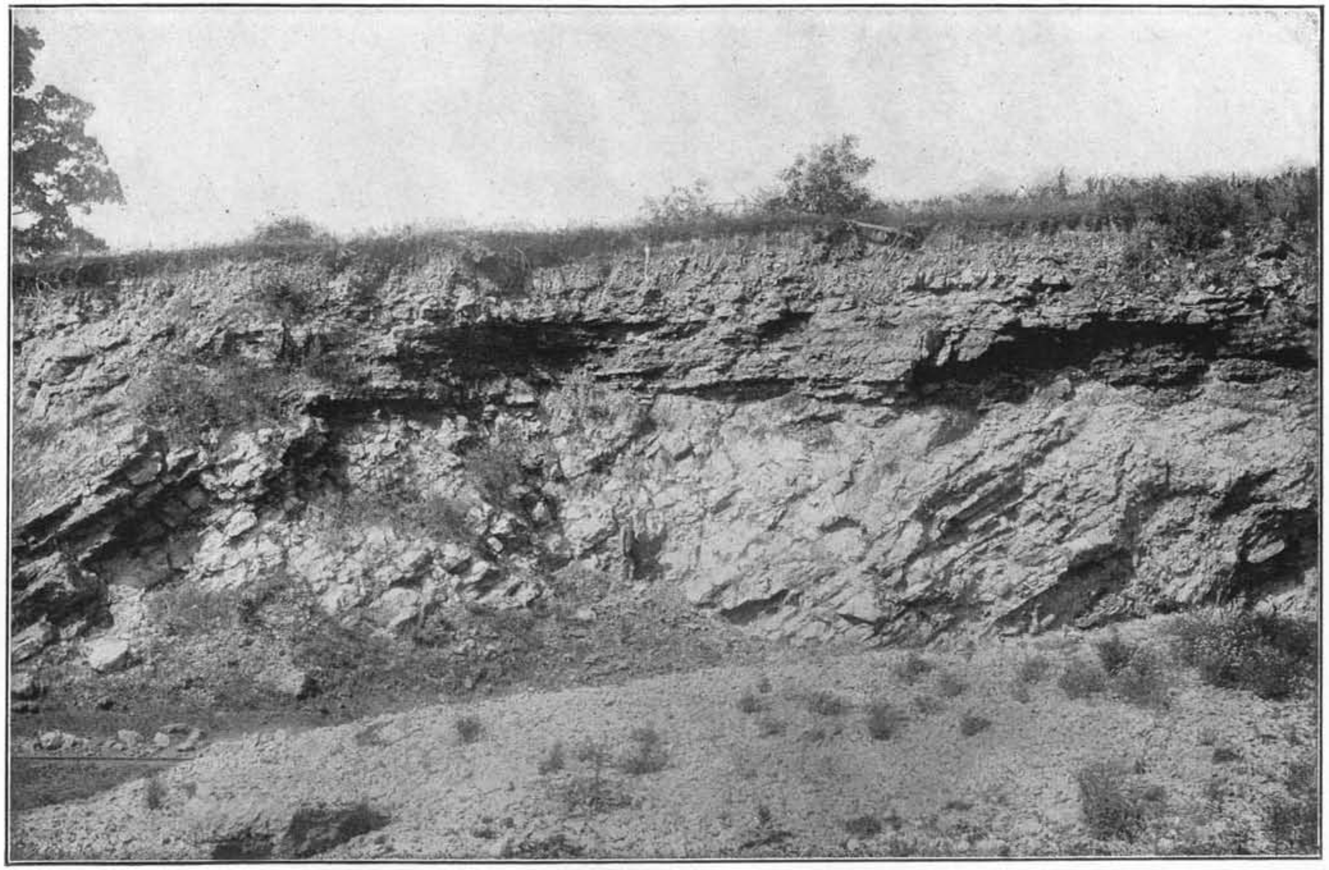
Here extensive quarries have been opened on the right bank of Sugar creek, along a circuit of about one-half mile. The usual rapid horizontal transitions in the limestone encourage lime and building-stone quarries in adjacent outcrops, and a still larger portion is quarried and crushed for railway ballast. To the north the stone is limerock, lying for the most part in confused or structureless mounds. South of these it dips heavily outward and downward from them. Twenty-five feet of Gower is here exposed, a hard, gray, subcrystalline limestone in layers, destitute of lamination, varying in thickness from one-half to two feet. The rock is fossiliferous in places, with moulds and casts of Gower fossils, the planes of highly fossiliferous layers coinciding, as is customary, with the dip of the strata.

Across the small ravine, in which the kilns are situated, the dip has decreased to 28° E SE., the stone continuing of the same type described. On the further side of a little gully the limestone dips 13° SE., and while still hard and crystalline, is now finely laminated. Four rods east a large quarry is opened for building stone. At the west end the dip is 10° SE., and in twenty paces this has become horizontal. The rock does not assume the granular Anamosa facies, although it is as finely laminated and as evenly bedded. The uppermost layers are of the Coggan and transition layers to the higher Devonian terranes. The section is as follows:

| | | FEET. |
|---|---|---|
| 3. | Coggan and Otis limestones | 20 |
| 2. | Limestone, hard, bluish gray, tough, ringing under the hammer, crystalline, finely and coherently laminated, in courses up to three and one-third feet, but readily splitting to layers of six, eight and twelve inches | 14 |
| 1. | Limestone, gray, vesicular, in heavy courses, rough surfaced | 8 |

From this trough of the syncline the strata rise gradually to the east, dipping 7° SW. a few rods further on. At a distance of 500 feet east of this the dip has increased to 21° SW. At this point, the last quarry to the east, the rock lies in parallel, fairly even courses, varying in thickness from one foot or less, the common dimension, to two and three feet. It is here also finely laminated and crystalline. The hardness of the stone makes it admirably suited to the use of railway ballast, to which it is put.

At several points along the line of the quarries the heavy layers were seen to be marked on their upper surfaces and vertical joint faces with ramifying, or inosculating, shallow channels from 1 millimeter to 2 centimeters in width. The origin of these was not discovered. The upper surface of the Gower at these quarries along a circuit of one-half mile on Sugar creek is even and regular. The structureless mounds, the layers dipping at high degrees and various directions, and the horizontal strata, rise alike to the same plane at which they are bevelled by the horizontal layers of the Goggan (plate X).



Horizontal Coggan beds overlying the oblique-bedded, LeClair phase of the Gower limestone at Lime City.
*—From a photograph by Houser.*

4. CROSSING OF ROCK CREEK, TP. 80 N., R. III W., SEC. 23, SE. ¼ OF SW. ¼.

This section is of special interest in that it presents the Gower more highly tilted than has been seen elsewhere, with such dips, in fact, that it is impossible to account for them by any theory of cross bedding. At the same time it exhibits the usual rapid change in dip both in direction and amount and a radial dip which may be typical, though not so well seen in any other recorded outcrop. The course of the creek

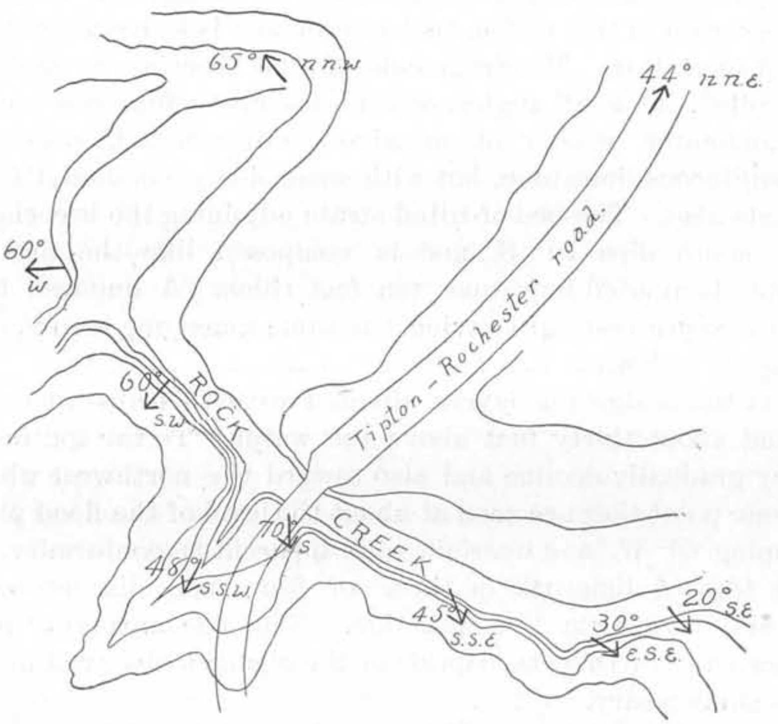



FIG. 21. Sketch map showing variant and radial dips of Gower Limestone. Rock Creek, Tp. 80 N., R. III W., Sec. 23, Se. ¼ of Sw. ¼. Contour interval, 10 feet. One-half inch=10 rods.

along the crest of the anticline is also worthy of note. This and the various dip are shown in the accompanying sketch-map. Rock creek has here cut to a depth of thirty feet in a dome or anticline of the Gower. This is overlain with twenty feet or more of limestones of the Wapsipinicon stage of the Devonian.

At the bridge the roadway scarps the side of the hill and exposes two or more beds of hard, gray, crystalline limerock, laminated to a fraction of an inch. The bed nearest the bridge is fifteen feet thick and tilted at an angle of 58° S. From the second it is separated by a bed of breccia, or scree, eighteen feet wide in which the matrix is soft, granular limestone sand. Considerable argillaceous material also occurs, and in one place a stiff, unctuous, greenish or yellowish clay so much resembling the pockets of Carboniferous clay not uncommon in this region that it probably is to be assigned to that formation. The fragments of this breccia are angular, unrolled, set at all angles, of all sizes up to fourteen inches in diameter, mostly of massive non-laminated, vesicular, fossiliferous limestone, but with some finely laminated fragments also. The bed of tilted strata adjoining the breccia on the south dips 70° S. and is composed like the first of thinly laminated limestone, ten feet thick. A hundred feet to the southwest, up a ravine, the same limestone recurs, dipping 48° S SW.

At the bridge the layers affected with this abnormal dip stand about thirty feet above the water. To the southeast they gradually decline and also toward the northwest where at one point they are seen at about the level of the flood plain dipping 60° W. and overlain with apparent unconformity, by ten feet of limerock in three or four rude discontinuous layers, forming a low anticline. The accompanying map makes any further description of the changes observed in the dip unnecessary.

5. LOHMANN'S QUARRY, TP. 81 N., R. 1 W., SEC. 4, NW. ¼.

Two miles west of Lowden, on a branch of Yankee run, an important quarry has been opened for a number of years, and is now owned by Mr. Lombard Lohmann. Limestone of the Anamosa type has been quarried to a depth of forty-five feet. Joints are distant, the master joints running N. 20 E. The strata are disposed in a distinct anticline. At the south end of the quarry they dip 3° N NW.; at the north, 14° E NE. The following is the succession of layers:

| | | FEET. |
|---|---|---|
| 6. | Spalls, weathered into thin plates | 8 |
| 5. | Flagging, about four inches thick | 8 |
| 4. | Limestone, rough, massive, once used for lime | 3 |
| 3. | Building stone, in layers up to one foot | 15 |
| 2. | Flagging | 2½ |
| 1. | Building stone, in layers from 5 to 14 inches | 6 |

No. 4 thickens and thins in a most interesting manner, rising as a lens shaped mound twenty-five feet in diameter, at about the center of the quarry, retaining elsewhere the thickness as stated (See plate IX). This mound is obscurely fragmental and the fragments are themselves in places arranged in obscure layers dipping outward as high as 45°. The upper layers of fine grained rock in part pass into and merge with the unstratified mass, and, in part, rise on its flanks. The mound of rough rock is clearly contemporaneous with the even bedded granular building stone on which it rests and by which it is surrounded. The phenomenon of distinctly different lithologic types of limestone formed under slightly different conditions in the same area, at the same time, is here exhibited as in a hand specimen, and it may well be taken to illustrate the relation between the LeClaire and the Anamosa phases of the Gower.

On the creek, a few rods distant to the north, the same layers are seen to dip west and south, forming the northern limb of a syncline.

## The Devonian.

The Devonian series in Cedar county comprises several terranes which are grouped under two stages—the Wapsipinicon and the Cedar Valley. The former, named from the excellent section along the Wapsipinicon river, in Linn county, embraces the lower beds of the Iowa Devonian and has been subdivided into several sub-stages—the Upper Davenport, the Lower Davenport, the Independence and the Otis. To these is now added an inferior member, the Coggan, which in earlier reports was classified as Silurian.

### THE COGGAN.

The lithological affinities of this limestone are wholly with the Silurian. It is a soft, granular, magnesian limestone, vesicular, often of earthy lustre, differing in appearance from the Anamosa limestone principally in its heavy bedding and absence of lamination. Under the hammer it frequently emits a distinct bituminous odor. Nodules of dark flint may occur in it and these occasionally unite to form a thin continuous layer. At some exposures it takes on a harder and more crystalline aspect.

The composition of the normal type in Bealer's quarry is as follows, according to an analysis made in the chemical laboratory of Cornell college, under the direction of Dr. Nicholas Knight.

| | |
|---|---|
| $Ca\,CO_3$ | 58.2 |
| $Mg\,CO_3$ | 39.5 |
| $Fe_2O_3$ and $Al_2O_3$ | 0.9 |
| $Si\,O_2$ | 1 2 |
| | 99.8 |

In this dolomite the proportion of calcium carbonate is but two per cent higher than in the Gower dolomite of the Silurian used for building stone and taken from the same quarry.

In the Coggan is found gregarious a small spire-bearing shell, which, in the report on Linn county,* is stated to resemble *Spirifer subumbonus*, Hall. Occuring in the Coggan only in moulds and rare casts, and belonging to a type of wide range, and one difficult to identify in imperfect specimens, it did not seem safe, at the time, to refer it without qualification to this species. Since the publication of the report just cited more perfect specimens, collected over a larger area, have sufficed to conyince all who have examined them of their identity with the species named, a well known Devonian type,

*Geology of Linn County, Iowa Geol. Surv., vol. 4, p. 140.

and one found in Iowa only, so far as now known, in the Devonian beds, the Otis, immediately above.

Along with *Spirifer subumbonus* have been found in the Coggan several pygidia of a trilobite. These, together with the brachiopod mentioned, were referred to Dr. John M. Clarke, State Paleontologist of New York, who considers it "a species not far removed from the *Dalmanites erina*, which occurs sparsely in the Onondaga limestone of both New York and Ohio. So far as the specimens indicate, the species has little affinity to typical Silurian forms and its relation to the species cited indicates the Devonic." A small cheek of a *Proetus*, an unidentified *Conocardium*, and a little spiral gastropod complete the fauna of the Coggan beds so far as now known.

It thus becomes necessary to shift the Coggan across the Siluro-Devonian frontier, and to enroll it as the basal member of the Wapsipinicon stage. This position is in accord with the strong apparent unconformity at Lime City and Cedar Valley, where its horizontal beds rest on the highly tilted layers of the Silurian. The magnesic character of the terrane is entitled to no consideration except as corroborating other evidence. The Devonian even of the Cedar Valley stage is dolomitic in the northern counties of the state. Along the forty-second parallel in Iowa the stratigraphic division between the Silurian and the Devonian would seem to be drawn where calcareous sediments change to argillaceous, as at the summit of the Otis, or where dolomites change to non-magnesian limestones, as at its base. Drawing the line as we have done at the base of the Coggan makes against each of these classifications by lithological affinity, but is in accord with the far weightier evidence of fossils.

## THE OTIS.

This terrane was first discriminated in Linn county, where it is well marked in the valleys of the Cedar and Wapsipinicon rivers by its position between the argillaceous Independence above and the dolomitic Coggan beneath, by its lithological facies, and by its fossils. It has also been found in Scott county in a narrow strip at the eastern edge of the Devonian area, adjoining outcrops of the Niagara, and immediately underlying the Independence. In Cedar it is less well developed than in Linn, but its outcrops are more numerous than in Scott. It is seldom that it here clearly indicates its place in the Devonian succession, and in only one locality could it be identified by its fossils. The Otis exhibits considerable variety in its lithology. Typically it is a limestone carrying so slight a per cent of magnesia that it effervesces readily and actively at a touch of cold dilute HCl. But its passage beds downwards into the dolomitic Coggan indicate a larger and larger per cent of magnesium carbonate in their composition. It is also a fairly pure limestone, and shows no outward trace of argillaceous admixture. But in several localities it is difficult to draw the line of demarkation between it and the Independence shale.

The most common lithologic type of the Otis is a drab limestone weathering to lighter tints, hard, brittle, ringing, with conchoidal, irregular or splintery fracture, and of fine grain. It is frequently crackled and fragmental, the fragments being small and in apposition, and of the same color and texture as the matrix when this can be distinguished. In this aspect it is heavily bedded, reaching sometimes a thickness of layer of five feet, and is unevenly laid and roughly surfaced. Frequently it is laid in thinly laminated layers. In either case it may be fossiliferous. These types were the only ones discovered in Scott county, but both in Linn and in Cedar considerable lithologic diversity prevails, introducing crystalline, saccharoidal limestones, compact or friable, of various colors, highly crystalline brown or drab layers which break with calcite cleavages, layers mottled with greenish argillaceous material, and others containing fragments or nodules of dark flint or of crystalline silica. In Linn this diversity was diagnostic of the formation as the boundaries of it were there drawn, and the same variant types recur in Cedar at the same horizon.

The thin-shelled, smooth-surfaced little brachiopod, *Spirifer subumbonus* Hall, which, with an obscure coral found by Prof. J. A. Udden, forms the entire known fauna of these beds, is gregarious in the fine-grained phase and occurs also in the granular. It is found from central Linn to the Mississippi. Since the little spirifer of the Coggan beds is identified with the same species, it is probable that further evidence may warrant uniting these two sub-stages. Meanwhile their lithologic facies are so different that, as a matter of convenience for field work, they are still ranked as distinct terranes.

The following analysis, made under the supervision of Dr. N. Knight, is of a pink, saccharoidal, crystalline limestone, a type occurring at a number of localities in the county. The extremely small amount of magnesium carbonate will be noted, showing strong contrast with the Gower dolomites of the Silurian.

| | PER CENT. |
|---|---|
| Silica, $SiO_2$ | 0.24 |
| Ferric oxide, $Fe_2O_3$ | 0.34 |
| Calcium carbonate, $CaCO_3$ | 96.73 |
| Magnesium carbonate $MgCO_3$ | 2.94 |
| | 100.25 |

Another analysis of Otis limestone, from the Sw. ¼ of Sec. 25, Tp. 80 N., R. III. W., was as follows:

| | PER CENT. |
|---|---|
| $SiO_2$ | 1.52 |
| $Fe_2O_3$ | 0.58 |
| $CaCO_3$ | 93.61 |
| $MgCO_3$ | 4.20 |
| | 99.91 |

## THE INDEPENDENCE.

No exposures were seen in Cedar county of the fine, fissile, fossiliferous shale found in a shaft at Independence, and given the name of that town by Calvin. At the same horizon in Linn county occur buff, argillaceous limestones, and it is in this form that the Independence is seen in Cedar. These are often marked by irregularities of deposition, channel cutting, lenses of calcareous material, and rapid lateral change in form and constituents of the rock. Occasionally the dark buff, dingy, impure limestone contains angular, small, sparse fragments, either of the same nature as the body of the rock, or of the aspect of the fine-grained, drab limestone of the Otis or Lower Davenport. The latter seem to have been more soluble, and when dissolved away have left angular cavities. Angular fragments of silica are seen frequently, and weathered surfaces may be rough, with a flinty, angular sand left in relief. Siliceous nodules are usually found on all outcrops of these beds, and so peculiar are these that they are diagnostic of the Wapsipinicon stage of the Devonian. The lenticular masses may reach a foot in diameter, and a microsection shows that they are not composed of flint, but of crystalline silica intercrystallized with calcite. The surfaces, therefore, where the calcite has dissolved, have a characteristic rough and carious aspect, and masses may have a harsh vesicularity resembling pumice. The silica resembles gangue quartz in the great number of micro-cavities it contains. The Independence was thus recognized at one point, Sec. 4, Sugar Creek township, in the log of a well driller, who reported a number of "balls of flint, from the size of a hickory nut up to a base ball." At Independence, and at Lafayette, in Linn county, thin seams of coal and coaly shale were found in this formation. Coal reported near Rochester, in a well on the farm of J. D. Ridenours, Tp. 79 N., R. XI. W., Sec. 5, Sw. ¼ of Sw. ¼, may belong to the Independence rather than to any outlier of the Carboniferous. It is said that three and a half feet of coal was struck at a depth of 120 feet and beneath sixty feet of rock. The thickness of the vein is altogether exceptional, unless it includes black shale. The well curb is something more than 100 feet above the outcrop of the Otis on Crooked creek southeast, and of the Independence on Rock creek northwest.

The ordinary appearance of the Independence in Cedar is a rather soft, buff, speckled, magnesian limestone of earthy lustre where weathered, and often so argillaceous that it breaks down into a clay. As one of the weaker Devonian terranes it is a slope maker, and its exposures are rare. Its presence may often be inferred from slopes below ledges of the Lower Davenport or above those of the Otis.

The following analysis of a more siliceous layer of the Independence, exposed on Sugar creek, Sec. 3, Sugar Creek township, was made under the direction of Dr. Nicholas Knight. Macroscopically the limestone was buff, earthy and friable from weathering. The siliceous residue under the microscope displays a field of minute, angular, quartzose matter, with a few larger grains polarizing in high colors:

| | |
|---|---|
| Silica, $SiO_2$ | 18.66 |
| Ferric oxide, $Fe_2O_3$ | 2.00 |
| Calcium carbonate $CaCO_3$ | 58.21 |
| Magnesium carbonate, $MgCO_3$ | 21.00 |
| | 99.87 |

THE LOWER DAVENPORT.

The lithological characteristics of this unfossiliferous limestone are identical with those described in the reports on Linn and Scott counties. So similar is the limestone in all its outcrops that hand specimens from the Volga, the Wapsipinicon, the Cedar, and the Mississippi could not be told one from another were the labels removed. It is a hard, compact, fine-grained limestone, non-crystalline, breaking with irregular, conchoidal, or splintery fracture. Massive in places, it is also found in places weathering to thin plates. In Linn county it is completely brecciated. In Scott it is but little disturbed. In Cedar its condition is intermediate. Retaining here and there its initial attitude, as at Rochester, it is in places partially or wholly broken into breccia.

When brecciated it presents the appearances noted in previous reports. Specimens are seen where the laminæ retain much of their parallelism although slightly separated. Fine and close lines of lamination are sinuous and flexed sometimes in a hand specimen, and compound brecciation is not infrequent. The common appearance of the breccia of the Lower Davenport is that of a mass of small fragments set close at all angles, the edges remaining sharp and even splintery, the matrix scanty and of much the same material as the fragments, but more granular and slightly lighter colored. Silicious nodules occur similar to those of the Independence, but smaller and in much fewer numbers. Large blocks of laminated limestone are occasionally seen set at all angles, and where the bracciation has commingled higher beds, fossiliferous lighter colored fragments of the Upper Davenport may be in juxtaposition. When massive there is apt to be exhibited on weathered surfaces a crackled or fragmental structure.

Lithologically these beds are very like the drab limestone of the Otis; and except where the intervening argillaceous Independence is present it is hard to tell them apart. Were it not for the clearer sections in adjoining counties, the outcrops in Cedar would hardly suffice to demonstrate the separation of the Lower Davenport from the Otis and its relation to the other terranes of the Wapsipinicon stage. Still, on the right bank of the Cedar at Rochester and south to the county line it directly underlies the Upper Davenport, and in one or more outcrops is superimposed on argillaceous limestones of the Independence. The Otis, on the other hand, directly succeeds the magnesian Coggan, and is overlain by the argillaceous Independence. But no single exposure exhibits both beds of drab, non-magnesian limestone, the Otis and the Lower Davenport, separated by the buff, shaley Independence.

The following analysis made by Dr. Nicholas Knight is in all probability a representative one. The sample was taken from the ledge of the Lower Davenport outcropping above

Rochester on the right bank of the Cedar. The extremely small per cent of magnesia and the comparative freedom from insoluble impurities are strongly marked features of the limestone well exhibited in the analysis:

| | |
|---|---|
| Silica $SiO_2$ | 0.86 |
| Ferric oxide $Fe_2O_3$ | 0.30 |
| Calcium carbonate $CaCO_3$ | 96.91 |
| Magnesium carbonate $MgCO_3$ | 1.93 |
| | 99.70 |

THE UPPER DAVENPORT.

Where these beds were first recognized under this name, in Linn county, they form a distinct terrane of a tough, semicrystalline, heavily bedded limestone, whose characteristic fossils are *Pentamerus comis* and *Orthis macfarlanei*. This is the horizon of the Gyroceras beds of Calvin, a life zone recognized earlier in Buchanan county as the lowest of the fossiliferous Devonian in Iowa above the Independence. The same beds recur in Cedar at the same horizon, immediately overlying the Lower Davenport. The lithological characters are persistent, and the same species are found in the same relative abundance. The exposures of the Upper Davenport are seen on the divide between Crooked creek and Rock creek in rare outcrops, and on the right bank of the Cedar from the Muscatine county line northward to within three miles of Rochester.

The beds of this terrane in Linn county were seen to be the equivalent of the beds at Davenport, called the Corniferous by the paleontologists of the Davenport Academy of Science; and under the impression that there was here a marked change in fossils, the summit of these beds was made the line of contact between the Wapsipinicon and the Cedar Valley stages. In the survey of Scott county a closer study of the Upper Davenport showed that along with the characteristic species of the beds in Linn county were others, which in Johnson and Buchanan counties occupy a higher place.

Thus in the Scott county report the life zones of *Phillipsastrea billingsi*, and species of Acervularia are included in the Upper Davenport. At Davenport there overlies this terrane a shaly limestone in which *Spirifer pennatus* is common, and this horizon was made the lowest in the Cedar Valley stage. In Muscatine county Udden found it difficult to differentiate the Phillipsastrea beds from those of *Spirifer pennatus* and the Gyroceras, terming all the Phillipsastrea beds. In the two or three fossiliferous exposures in Cedar county in which anything higher than the horizon of *Pentamerus comis* appears, the line of separation between the latter and the higher zones was not clear in the unworked quarries and with the brief time given to the collection of fossils. The *S. pennatus* beds, if distinct, are but little higher than the Phillipsastrea beds, since both fossils occur in the chipstone of the small quarries near Atalissa. There is no doubt that *Orthis macfarlanei* and *Pentamerus comis* are here basal in the fossiliferous series, but it is not clear that *S. pennatus* and Phillipsastrea did not appear at the same time toward the south of the Iowa Devonian era, while in the central portions their life zones are distinctly separate. It is thus difficult to draw the upper limit of the Upper Davenport and the line of demarkation between the Wapsipinicon and the Cedar Valley. If, with Calvin, this line is placed at the top of the *S. pennatus* beds, all the fossiliferous outcrops in Cedar county may be regarded as Wapsipinicon. If the original line is retained, the horizon of abundant *Spirifer pennatus* will go to the Cedar Valley. On the whole, it seems best to leave the definition of the Upper Davenport to await a final decision after the sequence in the northern counties, such as Fayette and Howard, is ascertained. Either the life zones observed in some counties fail of demarkation in others or their stratigraphical equivalents are elsewhere barren. The latter seems inadmissible, since the horizon of *Pentamerus comis* and *Orthis macfarlanei* is constant, and immediately succeeds the Lower Davenport, a terrane well marked through the entire Devonian area in Iowa, so far as studied, both in its lithological characters, in the stresses to which it has been subject, producing brecciation, and in its superimposition on the Independence.

## *Devonian Sections.*

### COGGAN SUBSTAGE.

#### 1. CEDAR VALLEY, BEALER'S QUARRY.

| | | FEET. |
|---|---|---|
| 5. | Limestone, hard, dense, yellowish gray, breaking into large, rhombic chipstone by diagonal cracks about 6 inches apart ............................ | 1 to [illegible] |
| 4. | Limestone, laminated, of similar texture to No. 5, spalls 1 to 4 inches thick ......................... | 1 |
| 3. | Limestone, soft, granular, laminated, with minute moulds of brachiopods ......................... | 1 |
| 2. | Limestone, soft, light buff, with occasional lenses of dark flint, fossiliferous with minute moulds, in layers up to 1 foot ........................... | $2\frac{1}{2}$ |
| 1. | Limestone, in massive layers about 3 feet thick, soft, earthy, buff, with some flint nodules, and with many characteristic Coggan fossils, *Spirifer subumbonus* Hall, and trilobite pygidia ......... | 7 |

No. 1 rests conformably on horizontally-bedded limestones of the Gower stage.

#### 2. CEDAR VALLEY, LIME QUARRIES.

| | | FEET. |
|---|---|---|
| 2. | Limestone in horizontal layers, not breaking into thin spalls, but breaking down into clay, with boulderets of disintegration of irregular form, soft, earthy, light gray, speckled (Coggan) ....... | 3 |
| 1. | Gower limestone, of LeClaire phase, either in calcareous massifs or in highly tilted layers ........ | 50 |

#### 3. TP. 80 N., R. III. W., SEC. 4. NE. ¼, ON ROCK CREEK.

The thickness of the following members is estimated from several outcropping ledges.

| | | FEET. |
|---|---|---|
| 5. | **Limestone, hard, flinty, close-grained, in part laminated, non-fossiliferous, in spalls ..............** | **10** |
| 4. | **Limestone, soft, granular, buff, in layers 9 inches and over ......................................** | **2** |

| | | FEET |
|---|---|---|
| 3. | Limestone, massive, granular, grayish buff, highly vesicular, with numerous casts and moulds of *Spirifer subumbonus* (?) of larger than ordinary dimensions (with layers above referred to Coggan) | 12 |
| 2. | Gower limestone, LeClaire phase, exposed ....... | 1 |
| 1. | Concealed to creek .............................. | 8 |

4. LIME CITY, BUILDING STONE QUARRY.

| | | FEET. |
|---|---|---|
| 7. | Limestone, saccharoidal, slightly pinkish, laminæ up to 4 inches in thickness ..................... | 1 |
| 6. | Limestone, white, saccharoidal, with close coherent laminæ ..................................... | 2 |
| 5. | Limestone yellowish gray, soft, earthy luster, weathering to layers 2-4 inches thick .......... | 2½ |
| 4. | Limestone, saccharoidal, pink and yellowish gray, decaying into crystalline limestone sand. This changes laterally into a brittle gray rock, in layers 1-4 inches thick, breaking into rhombic chipstone of dull, earthy luster. In places also the same transition occurs in one foot vertical, the "sandy" crystalline rock above graduating into brittle dense "flinty" rock beneath ............ | 6 |
| 3. | Limestone, light buff, saccharoidal, in heavy laminated courses weathering to fine crystalline sand ......................................... | 5 |
| 2. | Limestone, massive, highly vesicular, with moulds of Coggan fossils. All the above layers are practically horizontal, magnesian, useless for building stone and are well named "sand rock" by the workmen .............................. | 3¾ |
| 1. | Limestone, Gower hard, crystalline. ............ | 22 |

5. LIME CITY, BETWEEN BUILDING STONE QUARRY AND LIME KILNS

| | | FEET. |
|---|---|---|
| 5. | Limestone, magnesian, more or less fragmental, fragments small, mottled, dull, earthy buff and light brownish, weathering to irregular surface caused by relief of harder fragments ......... | 2 |
| 4. | Limestone, magnesian, light pinkish buff, saccharoidal, laminated ........................... | 3 |
| 3. | Limestone, magnesian, crystalline, saccharoidal, white or light gray, in heavy layers ........... | 5⅝ |
| 2. | Limestone, earthy, buff vesicular, Coggan lithologic type, in layers of 26, 18, and 26 inches... | 5¾ |
| 1 | Gower limestone, to railroad tracks ............. | 12 |

6 LIME CITY, LIME QUARRIES.

At these quarries, but a few rods distant from the exposures just described, the same beds recur which we refer to the Coggan. They are, as usual, horizontal and are thus in strong contrast with the Gower limestone on which they rest, which is highly inclined, or in unstratified massifs. Unconformity could not be more strongly simulated or exemplified. The Coggan beds are here of light buff color, non-laminated, soft and earthy, useless for any economic purpose except riprap, with strong petroliferous odor when struck with the hammer, and contain an occasional minute mould referred to the characteristic fossil brachiopod of the Coggan. Layers are commonly from six to twelve inches in thickness. The upper rock surface is but little decayed, but for a depth of three feet the upper layers are broken to chipstone by weathering, and are covered with two to three feet of red geest in which glacial pebbles are commingled. In these beds occur flint nodules up to one foot in diameter. The total thickness of these layers referred to the Coggan is here eighteen feet.

7. OUTCROPS ON ROCK CREEK.

The relation of the Coggan to the underlying Gower is seen at several stations on Rock creek. One mile northeast of Rochester (Tp. 80 N., R. III.W., Sec. 36, Sw. ¼ of Se. ¼) typical Coggan beds, massive, soft, granular, and with characteristic moulds of fossils, are exposed with a thickness of some seven feet, the layers being horizontal, and ranging from one to three feet in thickness. They directly overlie highly tilted beds of the LeClaire lithological facies, dipping 44° east in heavy, non-laminated layers, which extend to the water in creek, a thickness of five feet. One-half mile east of this station, and about twenty-five feet higher, higher beds of the Devonian are disclosed on a small branch of the creek.

One and one-half miles north several outcrops on the same creek (Tp. 80 N., R. III. W., Sec. 25,) exhibit the relations of the Coggan with the Silurian beneath, and with higher beds of the Devonian above. Here there is seen toward the head of the ravines, at a height of about fifty feet above the bed of the creek, a dark brown, non-magnesian limestone, identical in appearance with outcrops of the Otis at Cedar Rapids and elsewhere. In the road, about ten feet higher, occurs heavily-bedded granular limestone, weathering white, non-fossiliferous, and whose facies is not characteristic of any particular horizon. Further down the draw north of the road the following section appears :

| | FEET. |
|---|---|
| 3. Limestone, soft, buff, vesicular, in layers about 18 inches thick, of Coggan facies. Exposed at two horizons within a space of | 8 |
| 2. Limestone, buff, horizontally bedded, fine granular. The horizontal face exposed in the bed of the ravine shows interlacing weather seams and imbedded angular bowlders of the LeClaire beneath, up to two feet in diameter, with small imbedded fragments of the same | 2 |
| 1. Limestone, hard, gray, crystalline, of typical LeClaire facies, in heavy beds, dipping as high as 30°, in recurring ledges to water in creek | 20 |

8. SUGAR CREEK TOWNSHIP, SECTION 3.

On Sugar creek the succession of the Lower Devonian strata is more clearly seen. At the bridge between Sec. 34, Tp. 80, and Sec. 3, Tp. 79, R. II. W., about at the level of the bridge floor, eight feet above the water, rock occurs apparently in place, of typical Coggan appearance, and with characteristic moulds of Coggan fossils, and about one and a half feet thick. For three feet above this no exposure is seen, when there appears a thin layer of Otis limestone, carrying, as so frequently in other counties, *Spirifer subumbonus*, Hall.

### THE OTIS LIMESTONE. INDEPENDENCE SHALE. LOWER DAVENPORT LIMESTONE.

No exposures were found in Cedar county exhibiting the Otis beds in any force. This was the more unexpected, inasmuch as this formation is well developed in the counties both to the east and the west.*

9.—The only locality where the Otis has been found in Cedar in its typical fossiliferous beds is on Sugar creek, at the bridge between Sec. 3, Tp. 79, and Sec. 34, Tp. 80. While the section displayed here in the wagon road to the west of the bridge is not well shown on account of the weathering of the rock and the lack of any distinct ledges, it is yet possible to make out fairly well the succession. Nos. 8 and 9 are probably a Coal Measure outlier inset in an ancient channel, and with this exception the beds above No. 6 conform in facies to that of the Independence beds in Linn county in their usual less argillaceous aspect.

| | | FEET. |
|---|---|---|
| 12. | Limstone, buff, argillaceous, weathering to calcareous clay, with some harder layers of buff, dense, dark speckled limestone, some finely laminated, all briskly effervescent in cold dilute HCl., with lenticular nodules of silica having carious surfaces from dissolution of intercrystallized calcite | 18 |
| 11. | Limestone, buff, earthy, breaking into rhombic chipstone; at base a layer of green clay one half inch thick | 2½ |
| 10. | Limestone, buff, soft, more or less crackled | 2 |
| 9. | Shale, black, argillaceous | ⅛ |
| 8. | Sandstone, brown | ½ |
| 7. | Limestone, buff, earthy, crossed with parallel cracks about three inches apart, dipping about 10° N. Briskly effervescent, but apparently magnesian | 5 |
| 6. | Limestone, soft, buff, dark speckled, earthy, dipping as above | 1 |
| 5. | Limestone, brown, crystalline, non-magnesian, in thin calcareous plates, with *Spirifer subumbonus.* Hall. Otis beds | ¾ |
| 4. | Limestone, gray, earthy, dipping 10° N., perhaps over a lens, Otis | ½ |
| 3. | Concealed | 4 |
| 2. | Limestone, Coggan | 1½ |
| 1. | Concealed to water in creek | 8 |

*Norton, Report on Geology of Linn Co., Iowa Geol. Surv., vol. IV.
Norton, Report on Geology of Scott Co., Iowa Geol. Surv., vol. IX.

10. At the crossing of Crooked creek (Tp. 79 N., R. II W., Sec. 8, Se. ¼), there are exposed in the road about eight feet of rock of Devonian facies. At the summit lies a white saccharoidal limestone, and at the base one of brownish buff color and earthy luster. For the most part the rock of the exposure is thinly bedded. It is slightly flexed, forming low arches. There is considerable difference in the appearance of the layers, but all contain so little magnesia that they readily effervesce in cold dilute HCl. Among the forms noticed are a light gray earthy limestone, one dark drab and crypto-crystalline, and a saccharoidal white limestone, mottled with irregular greenish yellow argillaceous laminæ, the white portions containing considerable clear quartz in minute detached perfect crystals. Carious silicious nodules also occur. The horizon is that of the Otis in the layers which form the transition to the Independence.

11. Ten feet above the summit of the last section as measured by the barometer there is well displayed in the road on a hill a few rods west, a section twenty-five feet thick of typical Lower Davenport limestone, non-magnesian, of finest grain, conchoidal fracture, and for the most part closely laminated. At the base lies a foot or so of light colored saccharoidal limestone. Stresses of various strength producing more or less perfect brecciation are in evidence. Some layers, especially toward the base, are massive and finely fragmental or crackled, the fragments remaining in juxtaposition, and disclosed only on weathered surfaces. There is also considerable breccia of ordinary Lower Davenport type, the "second phase" recognised in the report on Linn county*, where numerous small fragments are set in a scanty and lighter colored matrix. In certain layers the close coherent laminæ are sharply flexed within the limits of a hand specimen. Here and there are large fragments of laminated limestone set at all angles. Another type is seen where the laminæ are detached and separated, but retain

*Iowa Geol. Surv. vol. 4, pp. 158, seq.

within the matrix considerable of their original parallelism. Lenticles of silica occur.

12. A mile north of Rochester on the right bank of the Cedar a little above the mouth of Rock Creek (Tp. 79 N., R. III W., Sec. 3, Se. ¼ of Nw. ¼) a striking ledge of the Lower Davenport overlooks the river:

| | | FEET. |
|---|---|---|
| 3. | Limestone, non magnesian, drab, weathering to lighter tints, hard, of lithographic fineness of grain, breaking with conchoidal fracture; in places crackled and fragmental in massive layers two feet thick and more, here and there graduates laterally from such layers into thin calcareous plates a fraction of an inch in thickness | 10 |
| 2. | Limestone, non-magnesian, gray, semicrystalline, soft, retreating under No. 3 by weathering | 2 |
| 1. | Unexposed to flood plain of river | 25 |

13. Directly across the river from Rochester the same ledge appears at nearly the same height. A miner's shaft was sunk here some years since which apparently began in this stratum and shows to a certain extent the nature of the strata beneath, concealed in the preceding section by talus. In position and in composition the following numbers readily fall into the Independence, except perhaps the basal layer, which probably is Otis:

| | | FEET. |
|---|---|---|
| 8. | Upper portion of shaft, not observed | 7 |
| 7 | Limestone, rough, brown, crystalline | 2 |
| 6 | Limestone, brown, soft, earthy luster, ferruginous and argillaceous, briskly effervescing in cold dilute HCl. | 6 |
| 5. | Limestone, buff, earthy, speckled with darker spots, thin layered | 1 |
| 4. | Limestone, bluish, non-magnesian, in part crystalline, in part earthy | 4 |
| 3. | Limestone, pale buff, argillaceous, weathering to chip-stone | 3 |
| 2. | Limestone, buff, dull earthy luster, laminated, in even layers 2 to 6 inches in thickness | 1 |
| 1. | Limestone, white, saccharoidal | ½ |

A similar succession is seen imperfectly on the hillside where, from the base up, outcrop in different places a white, soft, crystalline, granular limestone, a brown, crystalline, granular limestone, limestone weathering to thin, drab, calcareous plates, and the heavy ledge stone of the last section.

From the base of the shaft is said to have been taken a massive bluish drab limestone, subcrystalline, with cavities lined with drusy spar. A special interest attaches to this layer, since it is currently believed to contain large percentages of silver. By those interested in Rochester, names are given of chemists in Chicago and in Iowa who, twenty years ago and more made analyses of the rock showing as high as $247 of the white metal to the ton. The analyses themselves are not extant. On this basis there has been considerable labor expended and some money in the exploitation of this "vein." Besides the sinking of the shaft described, a driller was kept at work for some weeks, and several openings have been made in the hillsides adjacent. Neither the rock itself nor its relations and surroundings give the faintest suggestion of any metallic content except pyrite. The following analysis, made at the chemical laboratory of Cornell college under the direction of Dr. Nicholas Knight, is less valuable therefore in disproving the local theories of the rock than in showing the relative amount it contains of lime and magnesia carbonates:

| | PER CENT. |
|---|---|
| Calcium carbonate, $CaCO_3$ | 78.75 |
| Magnesium carbonate, $MgCO_3$ | 20.16 |
| Ferric and aluminum oxides, $Fe_2O_3$ and $Al_2O_3$ | 0.10 |
| Silica, $SiO_2$ | 0.40 |
| Manganese oxide, $MnO_2$ | 0.20 |
| | 99.61 |

14. TP. 79 N., R. II W., SEC. 6, NW. ¼.

North of Rochester a section of special interest is shown in the bed and sides of a little branch of Rock creek. Only about twelve feet is exposed, but three different lithological types occur and in a relation not easy to decipher.

The base of the section at the road bridge and the larger portion of the outcrop consists of a soft, dark buff, or brown, speckled, argillaceous limestone, of earthy lustre, often in laminæ an inch or less in thickness. These are in places flexed, and brecciation is not infrequent, small fragments of dull, speckled, brown limestone being set in a matrix of similar material. In places fragments are of hard, light drab, fine-grained, laminated limestone. These fragments are usually small, and none of the type were seen near the base of the section.

A few rods up stream from the bridge the floor of the shallow trench discloses extremely irregular layers of hard, dense, ringing, drab limestone, often thinly laminated, occurring in lenses and masses up to eight to ten feet in length. The lower layer exposed is about three feet thick, and is fissured and crackled, the fractures being filled with calcite. No brecciation was seen. Above this, masses of the same lithologic facies display considerable brecciation, and the matrix commonly consists of dingy brown, earthy limestone, similar to that outcropping beneath. The upper surface of the drab limestone shows a bluish clay, a geest, three to six inches thick. Overwrapping this limestone of the Otis type, recurs the earthy limestone already described.

The summit of the section is formed of a peculiar pinkish limestone, cemented of small calcite crystalline grains, rather loosely coherent, which produce a somewhat oolitic appearance on weathered surface. This forms a lenticular mass about twelve feet long and five feet thick, from which a surface layer of the same material extends up stream for half a rod. This pink, crystalline limestone is separated from the brown limestone beneath by a thin selvage of plastic, bluish clay.

The general horizon of the outcrop is unmistakably near the base of the Wapsipinicon stage of the Devonian. The brown, earthy limestone is clearly Independence, of the facies of the calcareous beds at Kenwood, Linn county. The brecciation it displays has been described under the so-called first or lowest phase of the Fayette breccia in Linn county. The section at Kenwood, above Cedar Rapids on Indian creek, shows on a large scale similar channel cutting and contemporaneous erosion and similar irregularities of deposition. The lens-like structures of the lighter limestone are altogether similar to those of the Otis limestone as seen in Linn county, and its facies and composition is of that substage.

15. TP. 80 N., R. III W., SEC. 4, NE. ¼.

The most northern outcrop of the pink crystalline limestone just described was found at the locality named above in a road section, at about the hight of the summit of section No. 3, described on a previous page.

| | FEET. |
|---|---|
| 2. Quartz, highly vesicular, resembling nodules in Independence. | ½ |
| 1. Limestone, massive, crystalline, pink, gray and drab, in places forming a fine grained saccharoidal "sand rock," in places a mass of interlocking crystals about one-eigth inch in diameter. In the midst of this ledge are many masses and fragments of black flint. Fragments are also seen of buff and drab close textured laminated limestone. These are most numerous immediately below the upper silicious layer, No. 2, but occur even to the base of the section. Some of these limestone fragments are clearly imbedded fragments. In places on the hill other masses seem to be disintegrated portions of a layer or lenticle | 15 |

16. TP. 80 N , R III W., SEC. 23, SE. ¼ OF SW. ¼.

The variant and abnormal dips of the Gower limestone of this interesting section at the crossing of Rock creek on the Tipton-Rochester road have been already noted. In almost immediate contact with these highly tilted strata of the Silurian lie nearly horizontal beds, which on lithological grounds we have referred to the Devonian. On the right bank of the creek and above the bridge the following sequence is seen:

| | | FEET. |
|---|---|---|
| 3. | Limestone, massive, macrocrystalline, rough surfaced on weathering, buff, rapidly effervescent in cold dilute acid, dipping from 5° to 10° SE. | 3 |
| 2. | Not exposed | 4 |
| 1. | Dolomite (Gower), laminated, crystalline, lying at angles exceeding 45° to creek, estimated | 30 |

Below the bridge on the same side of the creek the Gower gradually descends and the overlying strata correspondingly thicken. No beds of Coggan type were noted. Opposite an old mill a few rods below the bridge the ledge is more accessible, and presents the following section:

| | | FEET. |
|---|---|---|
| 4. | Limestone, briskly effervescent, irregularly bedded, in part massive in bed five feet thick, without trace of stratification and with imbedded fragments of fine grained, yellow magnesian limestone. Abutting on this in places, limestone, drab and dense, weathers to layers about one inch thick. Elsewhere it appears in heavy courses two feet thick, on fresh surfaces showing lines of lamination picked out in different tints, highly crystalline, pink and yellowish green in color. Upper layers are brownish, macrocrystalline, as if compacted of crystalline grains | 11 |
| 3. | Limestone, reddish, crystalline, saccharoidal, approximately horizontal, briskly effervescent, in two layers | 2 |
| 2. | Contact of Nos. 3 and 1 not observed. | |
| 1. | Limestone, Gower, dipping 30° S SE.; by barometer. | 20 |

The facies of this pink crystalline limestone is very similar to some found in the Otis at Cedar Rapids, below well marked outcrops of the Independence, and it is to the Otis, therefore, that it is referred, together with the various limestones associated with it.

### SECTIONS OF THE UPPER DAVENPORT.

Higher beds of the Devonian than those already described outcrop along the right bank of the Cedar below Rochester.

At this village the highest ledges seen in the bluffs belong to the Lower Davenport. Three miles due south these beds have sunk to the level of the upper terraces of the river. The following section is seen in an abandoned road in Tp. 79 N., R. III W., Sec. 23, Sw. ¼ of Se. ¼:

SECTION 17.

| | | FEET. |
|---|---|---|
| 3. | Limestone, hard, tough, gray, a coquina of minute fragments of shells, valves of *Gypidula comis*, Owen, very abundant, ten individuals being counted on a surface 6 inches square. Upper Davenport......... | ½ |
| 2. | Breccia, fragments large, non-fossiliferous, up to one foot in diameter, and near surface one noticed 2¾ feet long and 1 foot thick. In several places the matrix is abundant and contains sparce, small fragments. Lower Davenport................................... | 6 |
| 1. | Breccia, fragments dark drab and mostly small, those with diameter of four inches being exceptional. Matrix abundant, coarser grained than fragments, and of a light yellowish color. Lower Davenport .. | 2½ |

18 TP. 79 N., R. III W., SEC. 26, SW. ¼ of SE. ¼.

A mile south of the exposure last described, the Lower Davenport appears at the level of the present flood plain, at the base of a hill fronting the river. Three feet are here seen of finely laminated limestone, brownish drab, with conchoidal fracture, the laminæ often curved. On the hillside to the northwest an old quarry shows ten feet of tough, hard limestone, drab and gray in color, irregularly bedded, in part a coquina, and fossiliferous. The following brachiopods were collected:

*Gypidula comis*, Owen.
*Stropheodonta demissa*, var, *plicata*, Hall.
*Atrypa reticularis*, Linn, winged.
*Atrypa aspera*, var, *occidentalis*, Hall.
*Rhynchonella intermedia*, Barris, (?) immature.
*Spirifer pennatus* Owen

19. IOWA TOWNSHIP, SEC. 35, N. ½.

Here is exposed in the roadway a highly fossiliferous stratum, although the number of species represented is not large. A somewhat higher horizon is indicated than that of the quarry just described. *Spirifer pennatus*, Owen, in large specimens, *Orthis iowensis*, Hall in its ordinary form not approaching *O. macfarlanei*, Meek, *Stropheodonta demissa* of the large normal type, *Atrypa reticularis* and *A. aspera* were the only species collected.

20. QUARRIES NORTH OF ATALISSA.

The highest Devonian exposures in the county are found a few rods north of the Muscatine county line on the right bank of the Cedar one mile and a quarter southeast of the outcrop just described. In the channel of a small creek near water level in the river the Lower Davenport appears in typical hard, dense, brown, non-magnesian limestone, in laminæ from a fraction of an inch to two or three inches in thickness. Only one foot is here exposed, but a little distance up stream and about ten feet higher there outcrops one and three-fourths feet of the same lithologic type, but here brecciated. The matrix is scanty but distinct, and the fragments are many of them parallel and in places still in juxtaposition. Across the creek and about twenty-five feet higher, two small quarries have been opened in the overlying fossiliferous beds. In the western of these, eight feet of fossiliferous, light gray limestone are exposed in layers from one to two feet thick, more or less irregular in bedding and lenticular, intercalated with highly fossiliferous shaly limestone layers six inches thick. In abundance of the species represented *Orthis iowensis* ranks first, *Atrypa reticularis*, second and *Spirifer pennatus* third with about one-third as many specimens as the species first named. Besides these occur *Atrypa aspera occidentalis*, *Stropheodonta demissa* in normal form and in the smaller quadrate and strongly plicated variety, *Crania crenistriata*, Hall and *Phillipsastrea billingsi*, Calvin.

The floor of the quarry adjacent to the east lies eight feet lower than that of the one last described.

| | | FEET. |
|---|---|---|
| 4. | Limestone, hard, compact, gray and buff, mottled, in layers from 2 to 4 inches thick, overlain with red geest | 1½ |
| 3. | Limestone, shaly, yellow | ⅛ |
| 2. | Limestone, yellowish drab, splitting into irregular layers from 2 to 6 inches thick | 3 |
| 1. | Limestone, tough, hard, gray, evenly bedded, resistant to weathering in two or three layers | 3½ |

All these layers are fossiliferous, but owing to the hardness of the stone specimens are difficult to disengage. *Orthis macfarlanei*, was observed in No. 1 and *Spirifer pennatus* in No. 4. Chipstone of the quarry supplied specimens of *Gypidula comis*, *Stropheodonta demissa*, var. *plicata*, an Acervularia and *Phillipsastrea billingsi*, Calvin, *Ptyctodus calceolus* and *Cyrtoceras*.

About thirty-five feet above the base of the hill layers of a comparatively barren limestone have been opened up. In the five feet here exposed no fragments large enough to identify were found. The stone is yellow, breaking up into chipstone.

### The Carboniferous.

Sandstones which probably belong to the Coal Measures, to the Des Moines stage of the Upper Carboniferous, are found at a number of localities over the county, but each in a very limited area. Those on Clear creek were described by the writer in volume III of the reports of the present Survey, p. 121. In all these outliers the sandstone is of moderately fine grain, and of various tints of buff and reddish brown, rather friable, but with indurated surfaces, either by secondary deposit of silica, or by deposit of the ferric oxides. Ledges very seldom appear, scattered bowlders of disintegration along hillside or in some draw being alone in evidence. Commonly these are found well down in present valleys, and in one instance on the level of the flood plain of the creek.

The location of several of these is sufficiently well shown on the accompanying map, and doubtless there are many which are not thus recorded. One outlier deserves perhaps more definite mention, that on Rock creek, Tp. 79 N., R. III W., Sec. 1, W. ½. Here on the outer edge of the flood plain a branch has cut through some two or three feet of a laminated, gray and reddish, friable sandstone, indurated on exposed surfaces with purplish brown crusts of ferric oxide, and containing in places finely comminuted fragments of brachiopod shells, too small for identification. In the midst of the laminated sandstone occurs a layer four inches thick, which contains numerous pebbles of clear quartz up to six inches in diameter, and of irregular form and smooth surface. Below there is exposed a few inches of fine, bluish, non-calcareous, plastic clay, destitute of fossils.

The story which is read in these outliers is of special interest. After the deposit of the rocks of the Devonian, this area was slowly lifted from the sea and during the Mississippian suffered long erosion. With the incoming of the Des Moines stage. a subsidence brought the waters of the Carboniferous ocean either far outspread over the area, or, at least, passing far up the river valleys of the time. In either case, siliceous sands were laid down in these valleys, unconformable with the country rock, and it is these sands which are here and there brought to light by the present streams.

## The Pleistocene.

### PRE-KANSAN AND AFTONIAN.

The ground moraine of the earliest of the great ice sheets which invaded Iowa in Pleistocene times is, in Cedar county, buried out of sight beneath later glacial deposits. In other counties, where it is exposed by erosion and its physical characteristics have been noted, this stony clay is a dense till, nearly black in color when moist. In well drillings and well records it can hardly be discriminated from the deep, unweathered Kansan till, which normally succeeds it, unless they are separated by the silts, the soils, or the vegetal deposits of the intervening interglacial epoch, the Aftonian. According to some of the well-drillers of the county, such old soils and peat beds, recognizable by their dark color, their texture and odor, are sometimes met with, especially in the "deep country," as the well-men term it,—the deep, preglacial, buried channel of an ancient stream, known in this report as Stanwood river. It is said that these vegetal accumulations are found in the the midst of the blue till, dividing it into two members, of which the lower, the pre-Kansan, is the thicker.

In the record of the well at the tile factory at Stanwood, two blue tills are parted by sands, which may correspond to the Aftonian gravels:

| NO. | | THICK-NESS. | DEPTH. |
|---|---|---|---|
| 9. | Yellow clay, Loess | 20 | 20 |
| 8. | Blue muck, Ashen loess | 7 | 27 |
| 7. | Green, bright, hard clay | 1 | 28 |
| 6. | Yellow clay, Kansan? | 7 | 35 |
| 5. | Blue clay, pebbly, Kansan | 65 | 100 |
| 4. | Sand with fragments of wood, first five feet very fine, coarser below, Aftonian | 15 | 115 |
| 3. | Blue clay, hard, pebbly, Pre-Kansan | 65 | 180 |
| 2. | Sand | 116 | 296 |
| 1. | Clay, black, hard, tough, dries like shale, (Maquoketa shale) | 44 | 340 |

### THE KANSAN DRIFT SHEET.

The Kansan drift extends over the entire county. In the Kansan areas it is reached by every gully which descends below the loess. It underlies the Iowan drift plain and forms the nucleus of the paha hills which rise upon it. Indeed, few exposures of till are found in the county which upon grounds of physical characteristics can be referred to any other formation.

In its normal aspect the Kansan till is a dense clayey till, jointed, and bluish drab in color. Pebbles a fraction of an inch in diameter are plentiful; cobbles and bowlders are rare, except where, as in the immediate vicinity of streams, the till has been washed. It effervesces freely in acid from the considerable amount of limestone flour and meal it contains, derived from the grinding of calcareous rocks in the glacial mill. But so deeply is the Kansan decayed since the remote age of its deposition that few exposures are found in the county where it presents its normal unweathered facies. Two such sections are here given:

SECTION ON CREEK, TP. 82 N., R. IV W., SEC. 30, NE. ¼ OF NE. ¼.

| | | FEET. |
|---|---|---|
| 6. | Alluvium, on flood plain, sandy.................... | 2 |
| 5 | Sand, with some clay and an occasional pebble....... | ¾ |
| 4. | Clay, loess-like, gray, non-calcareous, with ferruginous concretions.................................... | 2½ |
| 3. | Sand and gravel........................................ | ¼ |
| 2. | Till, brown, jointed, in rhombic blocks, leached of lime for ten inches from the surface, graduating into No. 1...................................... | 2½ |
| 1. | Till, blue, calcareous pebbles small, those of chert and limestone numerous, some of coal; cobbles few, one of pink granite undecayed; cobbles in creek washed from this till, chiefly greenstones, a number faceted. ...................................... | 5 |

SECTION ON CREEK NORTH OF BENNETT, TP. 81 N., R. I W., SEC. 33, SE. ¼ OF NE. ¼.

| | | FEET. |
|---|---|---|
| 4. | Humus, on side of low hill............................ | ¼ |
| 3. | Till, brownish yellow, calcareous to within one to two feet of the ground surface, in places carrying a moderate number of large pebbles; a few discontinuous thin veins of sand near base.............. | 3 |
| 2. | Till, brownish drab, calcareous, crumbling readily in hand when moist, not jointed, of the same constituents as No. 1, and graduating upward into No. 3... | 2½ |
| 1. | Till, typical unweathered Kansan, dark drab, traversed by joint cracks at distances of a few inches, hard, dense, predominately clayey, containing many small pebbles, rarely so much as an inch in diameter, a few fragments of coal observed, graduating into No. 2; to water in creek....................... | 6 |

A few feet above this section gray loess appears on the hillside, overlain with loess of the ordinary buff type.

With such rare exceptions as these just described, the exposures of the Kansan till in Cedar county are deeply and thoroughly weathered. By percolating waters, its constituent lime and magnesia carbonates have been taken into solution and carried downward to form calcareous nodules at depths rarely exposed to observation. By the roots of trees and grasses and growing crops, they have been carried upward and built into vegetal tissue. The texture of the till has been altered by frost and by decay so that it crumbles readily into small particles. Still more conspicuous are the superficial changes due to the alteration and the accumulation of the iron compounds of the till. To a depth of from six inches to two or three feet, the Kansan on certain areas has been so heavily rusted that it has turned to a deep terra cotta red, and to this zone of marked ferrugination Bain has applied the felicitous term, *the ferretto.*

Below the ferretto lies a zone in which the till has weathered to reddish yellow, to a yellow distinctly brighter than that of the loess, and to brownish drabs which pass by insensible gradations downward into the bluish drab of the unaltered till. These changes due chiefly to oxidation are most pronounced where the access is most ready to waters charged with atmospheric gases. They are least where the till is densest and most impermeable. Thus even where the mass of the till is unaltered and of normal color, a film is embrowned along the faces of each joint crack, and seams of sand are reddened by rusting.

*The ferretto.* The significance of the ferretto of the Kansan drift was not fully weighed until the recent work of Calvin and Bain on the glacial deposits of Iowa. It has long been known that the deep red soils of the United States south of the glacial border, the *terra rossa* of southern Europe, and the laterite of the Dekkan, were formed by the decay and oxidation, through vast periods of time, of rocks and clays containing iron in some of its compounds as a constituent. But the salient fact had not been seen that, were the loess removed from the upper Mississippi valley, there would be brought to the light over much of the Kansan area a soil as vividly colored as the red soils of Tennessee and Georgia.

Taking it for granted, then, that the ferretto is a true *terra rossa*, a red *geest* formed on the Kansan Drift, by secular decay, the thickness of the ferretto becomes a measure of the length of time during which the Kansan was exposed to the weather between the time of its deposition and that of its covering with the mantle of the Iowan loess. That this time is exceedingly long and can be measured only in tens of thousands of years is seen in the fact that the Iowan and Wisconsin drift sheets, whose origins are so remote that they must be reckoned in milleniums are still comparatively unleached and unrusted.

Emphasis should be placed, however, not so much on the comparatively narrow zone of greatest ferruginous accumulation, where the clays are dyed the deepest of terra cotta reds, as upon the wider zone in which the primitive color of the till is more or less altered by oxidation. The former depends upon other factors besides the lapse of time, and is not wholly a measure of the length of subaerial decay. It is produced also by the accumulation of ferric oxides in certain strata to which they have been brought by the movement of ground water. Thus from the porous loess there must be a continuous carriage of these oxides downward to the less permeable clays of the Kansan beneath. Even the basal layers of the loess are in places similarly affected, and thus in the midst of the silt an ancient weathered surface may be simulated. The deceptive appearance of a buried soil is added sometimes by the accumulation in the same way of the black oxide of manganese. In the alluvial clays of the creeks of the county a bright red ferretto not infrequently is seen to develop upon an impermeable clay lying beneath heavy humus.

The geographic distribution of the ferretto—using the word in its narrower sense—depends upon much besides age. The relief of the region is an important factor. In Cedar county it is not found on the Kansan drift except on hillsides where the local relief is considerable. On level tracts, and over gently undulating country, the Kansan till is yellow or reddish yellow in color, but the deep red ferretto is absent. On the other hand, it is seldom wanting wherever the Kansan is deeply dissected, as west of Clear creek, north of Bennett, and in the rugged country about Plato and Cedar Valley. This marked difference seen on surfaces of a single drift sheet cannot be due to local difference in age caused by difference in rate of erosion in the two topographic districts. It might be conceived that where the relief is greatest and the present drift surfaces are the youngest, the red ferretto would have been removed as fast as formed, since erosion has been there most rapid, and that it would lie the deepest and reach its darkest shades of color on the level tracts where the processes of removal are most slow. But on the contrary it is where erosion is least that the red ferretto is absent, and where its agents are most active that it is thickest and reaches its deepest dyes.

A control which suggests itself for this distribution of the deep red ferretto is that of the movement of ground water. It is on level or gently rolling tracts that ground water will remain comparatively stagnant and its level comparatively high. It is here that the oxidation of ferruginous constituents will be longest delayed and therefore the ferretto slowest in forming. On the other hand, on the steep hillsides of well dissected districts the movement of ground water is rapid. With every alternation of wet and dry weather alternate couches of water and air descend through porous soils, and the processes of oxidation are accelerated. Not only will the oxidation of the till be carried to its highest degree, but there will be effected a relatively large transference to it of the iron of the loess above.

As a subordinate factor the relative thickness of the loess is worthy of investigation. It may not be found to obtain elsewhere, but in Cedar county there is some connection, which may in part be a casual one, between the red ferretto districts and the exceptionally heavy loess which covers them. To what extent the iron of the ferretto is derived from the superjacent loess is undetermined.

Applying the term ferretto to the wider zone in which oxidation of the till has been effected to any appreciable degree, the factors of relief, movement of ground water, and superior terrane, become wholly secondary, and its cause can only be a subaerial secular decay. The ferretto thus becomes a demonstration of the long interval between the Kansan ice invasion and the later ones known as the Iowan and the Wisconsin, and therefore of the diversity of the Glacial epoch.

The Kansan has been superficially affected by the action of water in two ways, complementary each of the other. By the removal of the finer ingredients of the till there is left a thin zone, oftenest seen on the slopes leading down to streams, in which pebbles are more numerous than in the till beneath. And by a deposit of the finer ingredients washed from the till there results a reddish clay containing more or less sand and gravel, usually not over a foot thick, graduating into the overlying loess, with whose formation it probably was contemporaneous.

A special facies of the Kansan may be mentioned, one developed near the surface, a gray, stony, non-calcareous clay, often with a slight greenish tint.

A typical section is that of Tp. 80 N., R. IV W., Sec. 15, Sw $\frac{1}{4}$:

| | FEET. |
|---|---|
| 2. Loess, vertical thickness to summit of hill ............ | 10 |
| 1. Till, whitish, flaky, pebbles rare, a stiff clay containing considerable sand. Contains so little iron that it changes color but slightly before the blowpipe. Upper surface reddened to a depth of one to three inches, and in places forming an ocherous crust by infiltration from above. Transition to loess abrupt. Exposed in road a vertical distance of .................. | 5 |

TP. 80 N., R. I W., SEC. 4, NW. ¼.

| | FEET. |
|---|---|
| 4. Loess, exposed at cut about twenty feet below top of hill .............................................. | 3 |

| | | FEET. |
|---|---|---|
| 3. | Red ferretto of Kansan till | 2 |
| 2. | Till, gray, in places slightly greenish, mottled buff where more sandy, a stiff, flaky clay, reddening but slightly on heating | 2 |
| 1. | Till, yellow to base of exposure | 4 |

Nos. 1, 2 and 3 are wholly alike in absence of lime, and in kind and size of included pebbles. These are for the most part small, those over three inches being rare. Limestones and cherts not abundant. Small greenstones common and often faceted and scored.

The following exposure is exceptional, in that it shows a calcareous till overlying the gray clay described :

TP. 81 N., R. II W., SEC. 16, NE. ¼, ON LOW HILL OVERLOOKING BRANCH OF SUGAR CREEK.

| | | FEET |
|---|---|---|
| 4. | Loess, buff, graduating into No. 3 | 6 |
| 3. | Loess, ashen gray, with red ferruginous stains, bulls' eyes, and minute calcareous tubules. Toward base a ferretto of undulating ferruginous layers 2 to 3 inches wide | 3 |
| 2. | Till, calcareous, yellow, clayey, pebbles small, rather numerous, limestone and flints rare, no distinct reddening of upper surface | 4 |
| 1. | Till, gray, non-calcareous, otherwise similar to No. 2. | 4 |
| | To flood plain of creek, concealed | 5 |

A few feet further down the hill the loess thins to two feet and the underlying till is non-calcareous. Here the ferretto is clearly derived by leaching from above, instead of by weathering, and the calcareous admixture in No. 2 may have the same origin.

TP. 81 N., R. I W., ON ROAD BETWEEN S. ½ SECS. 11 AND 12.

An interesting section showing zones of ferruginous and manganesic accumulation forming a ferretto.

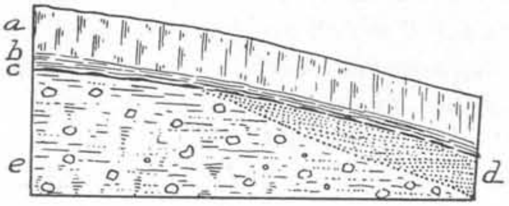



FIG. 22. Section Showing Zones of Ferruginous and Manganesic Accumulation at Base of Loess.

*a*. Loess, yellow.
*b*. Loess, ashen, laminated, graduating into c.
*c*. Ferretto, a reddish stain on upper surface of till, or a few inches below upper surface, width, one inch. This passes out upon "c" as a reddish yellow, ocherous layer three inches thick, overlying and mingling with a thinner black manganesic zone.
*d*. Stratified sand and sandy clay. Immediately below ferretto is so sandy as not to be plastic.
*e*. Till, brown, jointed, clayey, Kansan facies.

TP. 81 N., R. I W., SEC. 9, NORTH ROAD.

A section exhibiting an uncommon aspect of the Kansan where lime is carried downward to form calcareous concretions.

| | | FEET. |
|---|---|---|
| 4. | Humus | ½ |
| 3. | Loess | 2½ |
| 2. | Clay, transition from loess to till, intermediate in color and texture of clay | 1 |
| 1. | Till, reddish brown, jointed, a stiff clay with no cobbles; its included pebbles rarely one inch in diameter, non-calcareous to depth of six feet where there is a zone of hollow, round, calcareous nodules | 6½ |

Further down this hill ashen loess lies above No. 2, and through it runs a ferretto three inches wide of limonite crusts.

*Topography of the Kansan.*—The origin of the present topographic forms of the Kansan drift sheet will be most easily understood if the entire area of the formation is conceived in its initial aspect of a fairly even and undissected drift plain. The inequalities which need be postulated are few. While the initial surface probably had the slight depressions, the low swells, which are found on drift plains of later age, no trace has been discovered of the more salient features of glacialogic relief, such as the great morainic hills of the later drift. Distinct drumlinoid ridges, however, fluted it in places and here and there a continuous sag indicated the line of a preglacial river in whose valley the drift had settled by compression and condensation. Conceiving that the Kansan area was originally, then, a plain of very slightly diversified relief, it follows that the present topographic contours are those developed by erosion. At the greatest distance from the streams where the work of running water is still slight, the initial plain remains apparently little changed. For two miles north of Tipton, for example, the divide between Sugar creek and Rock creek is a tabular narrow area so level, so unscored by drainage channels, that in a wet season, as that of 1899, storm water lingers in small pools within hailing distance of the ravines leading steeply down to the creek to the east. Within the city limits and for a half mile south this level upland, only nibbled on the edges by the streamlets, is a model at hand in the teaching of physiography in the high school at Tipton. Examples of the initial upland plain on a much larger scale occur on the Cedar-Wapsipinicon divide from Sunbury north, nearly to Clarence. This area is an extension of the New Liberty plain described in the report on the geology of Scott county*. This gradually passes into the gently undulating country of Farmington and Fairfield, and with a deepening of every streamway with increasing distance from the divide, passes by insensible gradations into the rugged region south of Lowden.

It is in the same upland whose remnant levels have been mentioned, that the deep and intricate dendritic systems of ravines have been carved which characterize tracts of considerable size in different parts of the county. These maturely dissected regions occur wherever the upland stands

*Norton Iowa Geol. Surv., vol. IX, p. 410

high above near base levels, where the streams have been able therefore to cut it well to pieces. A single description will suffice for all these tracts,—for Center township southwest of Tipton, for Gower township about Plato, for Springfield township south of Lowden, for Pioneer township southwest of Mechanicsville, and for a little island of Kansan drift a mile north of the last named village. In each the residue of the original levels of the upland mav be seen in the even sky-line of the crests, and the initial surface may be restored in imagination by refilling the valleys with the material which has been washed out and away to the river and the sea. In each the long crests of the ridges rounded to the weather curve are so narrow that they sometimes afford scant space for roadway. Rarely have they been broken up into detached hills by the meeting of the heads of the gullies which trench their flanks. Along these even winding crests are laid out excellent roads, smooth, well drained, and underlain by the loess, in dry weather an admirable elastic pavement. Sooner or later one must descend to the level of creek or river, and here the road follows out on the spurs which buttress and rebuttress the stem lines of the divides, like the pinnules of a compound pinnatifid leaf. At the head of the ravines the descent is quite too steep for a road.

No dubitation is permitted the raindrop which anywhere falls in these regions. Its easy path has long since been fixed for it. It courses down the steep hillside, taking with it a modicum of the soil; it runs down the gully into the ravine and out along the way of a wet weather stream to creek and thus swiftly on to the river. Thus these areas are incised with a system of drainage channels which join one another as twig joins stem, and branch the tree trunk. This arborescent system is so complete that it would be difficult to find room where another ravine could be inserted, a fact painfully in evidence on roads laid out with that undeviating rectitude so pleasing in conduct, but so uneconomic in roads.

In considering the contours of these dissected uplands it must be remembered that the Kansan drift is here covered with a mantle of loess, and that it is in this soft yellow silt that the ultimate branches of the erosion system are developed. The loess was laid down, however, after a large portion of the dissection of the upland had been accomplished. It follows down the till slopes of hillsides, and the undisturbed lamination of it within a few feet of the present flood plains proves that its presence there is not due to creep.

FIG. 23. Loess-Kansan landscape south of Lowden.

Indeed, some considerable part of the excavation of these valleys is pre-Kansan, if not preglacial. For where they are cut in rock, till rests on the long decayed rock with its mantle of geest descending to the water way with a slope and surface apparently unaltered by ice invasions.

A characteristic loess-Kansan landscape with spatulate ravines is presented in figure 23, but as with much of the work of the camera, the impression is lost of depth of valley which is received in the presence of the object.

The larger portion of the Kansan is much less deeply and intimately dissected than the areas we have described. Here the drainage system is indeed complete, the whole area is reduced to slope, but these slopes are gentle. The rounded crests of the undulations too low to be called hills, reach the initial level of the upland in which they have been carved, and thus afford an even sky-line. Everywhere the loess forms the subsoil, but the drift will be found at no great distance from the surface, except near the margin of the Iowan.

Thus one initial plain of Kansan till but recently mantled with loess, gives rise according to the degree of its dissection by runing water to the level tracts above Sunbury, to the gentle rolling prairie of Fairfield township, and to the maize of steep hills south of Buchanan.

*Advance and Retreat of the Kansan.*—With variations of climate the front of a glacier may retreat and again advance. During its retreat glacier water will throw down silts and sand upon the ground moraine laid bare by the removal of the ice. Upon the readvance of the ice these water laid deposits may be covered by another ground moraine, and the stratum of stratified silt interbedded between the glacial tills, forms a lasting record of the backward and forward movements of the ice front. The only instance which so far has come to the notice of the Survey in the case of the Kansan, was found at Carey's quarry south of Tipton (Tp. 80 N., R. III W., Sec. 13, Sw. ¼ of Nw. ¼). Where the like has been seen elsewhere in Iowa, the upper and lower tills are so markedly dissimilar that they are referred to distinct ice invasions and the intercalated deposits to an interglacial epoch. But in this case both tills are Kansan in facies, as is shown in the appended section. The inference seems safe of a local readvance of the Kansan, although it is possible that the lower till may be an altered pre-Kansan, and the interstratified deposits Aftonian.

| | | FEET. |
|---|---|---|
| 8. | Brown, stiff, sandy clay | 3 |
| 7. | Clay, less sandy, resembling loess | 2 |
| 6. | Clay, reddish brown, jointed | 1 |
| 5. | Kansan ferretto, reddish brown, highly oxidized | ½ to 1 |

| | FEET |
|---|---|
| 4. Kansan till, stiff, non-calcareous, jointed; pebbles small, few reaching 1 inch in diameter; till reddish yellow mottled with gray, sandy and highly oxidized at base | 8 |
| 3. Clay, light buff, sandy, with an occasional pebble, loamy, non-calcareous, merging into a gray and light buff pulverulent loess-like silt, in places stained orange and red, stratified, flexed and crumpled | 3 |
| 2. Sand and gravel, heavily ferruginated, indurated but not cemented, dark reddish brown, with pebbles up to 5 inches in diameter of which the granites are rotten | 2 |
| 1. Till, non-calcareous, completely oxidized, like No. 4, but carries larger pebbles and cobbles, small fragments of coal and limonite nodules, resting on limestone | 3 |

## THE PAHA.

The drumlinoid hills of eastern Iowa, loess-capped, with an inflexible trend from west-northwest to east-southeast, were named paha by McGee.

While the work of the survey in Cedar county has certainly not solved the riddle of the paha, it has added some salient facts, which must be met by any theory of their origin.

In distribution we may discriminate three areas on which paha are found: an area peripheric to the Iowan frontier, in part within the Iowan drift, and in part situated on the Kansan overlooking the Iowan plains below, and an area upon the Kansan too remote from the Iowan border to have been under the control of the glacier ice of that invasion.

An example of the latter is found in Iowa township. The interstream area between the Cedar and Wapsinonoc creek includes flat, tabular tracts, and these may occur within half a mile of the river. As the upland descends below 750 A. T., it is traversed by long, distant, parallel swells of pahoid orientation. From twenty to forty feet high, they are comparatively broad, and their sky-line is often fairly even, although the eye may catch here and there the curve of the convex lens. These extend into Muscatine county, where their origin is attributed by Udden to glacio-fluvial action accompanying the Illinoian invasion. Similar low pahoid swells are seen on the Kansan upland in Fairfield township, on the divide between Sugar creek and the affluents of the Wapsipinicon, at right angles to the ridges which would normally be produced by the erosion of a dendritic system of drainage. In Red Oak township indistinct pahoids flute the Kansan upland between Rock creek and Rocky run. Southwest of Mechanicsville the Kansan undulates in similar swells, numerous and well defined.

Whether these flutings represent drumlins of Kansan drift, covered with an even veneer of loess, or are silt bars of loess laid in some ancient body of water, or wind rows of this light loam, or whether they are hills of erosion, the modeling or sculpture of their forms can hardly be referred to the present order of erosion, but must belong to the same order of events which produced the paha of the Iowan border, which they so closely resemble. The pahoids just described have attracted little attention even from students of land forms. On the other hand the paha, which are peripheric to the Iowan, are among the most striking reliefs in eastern Iowa, and may well give name to their region, the Land of the Paha, as McGee has termed it. It is because they are so closely associated with the Iowan that they have heretofore been treated as a phenomenon of that drift. Where they override the Kansan upland, they have been classed in the category of the heavy loess, which fringes the Iowan as with a moraine. Where they rise isolated from the Iowan drift, they have been treated as genetically related to that ice invasion, but the paha are so closely associated with the Kansan on this border that they may be treated as detached portions of it, even when entirely surrounded by the younger drift. Within the Iowan area paha are limited to the margin. So far as the topographic sheets of the United States Geological Survey indicate, the instances are rare indeed where paha are found at any considerable distance from the loess covered Kansan. In Cedar county the interior of each lobe of the Iowan stands clear of paha, while they cluster in the lee of the Kansan upland and fringe its sides. In Bremer county unpublished notes of these northern paha show that they preserve there their trend, and affect in all instances the immediate vicinity of the Kansan. In Linn a low, isolated paha stands on the wide drift plain north of Marion, an exception without a parallel in the observation of the writer.

The concord in height between the Kansas upland and the paha which fring it may not be without significance, nor the fact that both alike are covered with loess. Considering the difficulty in distinguishing tills, it is probably of less consequence that so far as seen in the few sections afforded of the nuclear till of paha, this has been of Kansan facies.

From the west county line pahoid hills surmount the edge of the Kansan from Lisbon to Mechanicsville. In the writer's report of Linn county, this belt of hills was termed the Lisbon paha ridge, a designation that the progress of the survey has not shown to be of any particular utility. No topographic contrast could well be stronger than that here brought to view in a walk of a few rods across the frontier which separate the areas of the younger and older drift, when one leaves the low and level plain with an occasional bowlder, its roads black with deep humus, its fields covered with grains and grasses, and climbs the boat shaped hills to the south, crowned with the primeval forest of white oak and maple, the road yellow with the loess, and looks down on the two contrasting topographies, the labyrinth of steep hills to the south, whose larger streams lie in broad deep valleys, and the levels to the north where the same streams head in sloughs and take their courses in channels indenting the level of the prairie by perhaps less than twenty feet. Paha also skirt the Kansan for some three miles west of Mechanicsville, lying north of the tracks of the Chicago & Northwestern railroad. From

Mechanicsville east, a low, narrow, and fairly even topped ridge separates the two areas. East of Clarence the paha become more conspicuous, their crests standing eighty and 100 feet above the Iowan, here descending the valley of Yankee run. South of Lowden paha occur abutting on the Kansan, but not rising to its summit level. The line of these remarkable hills continues east to the Wapsipinicon river, and with some interruptions to the Mississippi. The physiognomy and structure of the belt in Scott county is described in the report of that area in volume IX of the present Survey.

On the north the Clinton lobe is bordered by a line of lenticular hills which enter from Linn county and extend to north of Mechanicsville. They stand about forty feet above the plain and the county road which runs along their bases gives their orientation. This ridge skirts a beautiful little island of Kansan lying north of Mechanicsville, and in its lee to the southeast cluster a bevy of these drumlinoid hills, as characteristic perhaps as any in Iowa. Most striking of them all is the one to the northeast, named Stanwood paha by McGee. The length of this ridge is two and one-half miles, and this may be increased by one mile if we may add another ridge to the northwest in direct alignment and separated by a gap of only twenty rods, the channel of Picayune creek. The width is not more than a quarter mile, and its height some ninety feet. The crest is slightly undulating, and the lateral slopes, which descend at an angle of 7°, are smooth and but slightly eroded. Of the terminal slopes, that to the southeast is the more gentle, the ridge tailing out in this direction upon the marshy drift plain. The higher crests of the hill are made of typical pulverulent loess. As it declines to the southeast the loess contains disseminated grains of sand, and one or two knobs are said to be sandy. Where Picayune creek divides it, stratified sand of the usual type underlies the loess, and at the extreme northwest there is exposed in the road, about twenty feet above the base, ten feet of till, yellowish brown, rather sandy, non-calcareous, with small pebbles. By analogy with other paha we may infer that till rises much higher than this, and may constitute much of the bulk of the ridge. There is no trace of rock nucleus. In a boring near the base, at the house of Mr. O. S. Burleigh (Sec. 9, S. ½ Fremont Tp.), the drill passed through 146 feet of glacial deposits, mostly blue till, without encountering rock. As the well curb is about 830 A. T., the rock surface cannot here rise above 684.

Stanwood paha is but one of a series of parallel hills of similar form which extend south to the Kansan line at

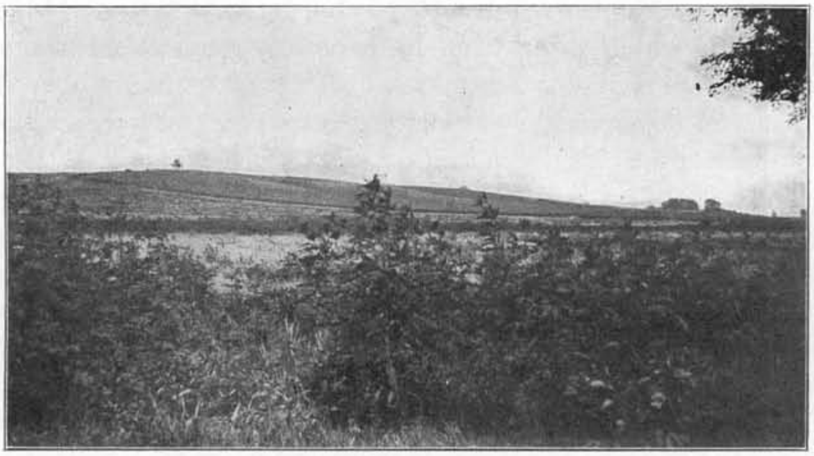


FIG 24. Stanwood Paha, southeast end looking east.

Mechanicsville. On some of these the loess mantle is thin reddish till of Kansan aspect appearing well up toward the summits. On others the loess is wanting, the whole hill, so far as appears, being composed of Kansan drift. Around these hills wraps the Iowan area, often marshy to their bases. North of the Stanwood paha two or three short paha rise about twenty feet above the wide marshy flood plain of Pioneer creek. To the northwest across the creek lies an upland as high as the summits of the paha. This upland, which seems to have been the main path of the Clinton ice lobe whose vestiges remain in many large bowlders and a sandy till, descends to the creek in lobes of pahoid orientation composed of reddish Kansan till with perhaps a thin veneer of Iowan in places.

Northeast of the Stanwood paha the north margin of the Clinton lobe lies in Jones county. A detached paha near the north line of the county overlooks Mill creek from a height of over 120 feet. The south slopes of this bold ridge are lobate, and at the northwest, about forty feet below the crest, a till of Kansan aspect is found in excavations for cellars, the loess being here absent.

In the northeast part of the county an island of Kansan topography, loess covered and intimately dissected, extends from Massilon on the right bank of the Wapsipinicon nearly to Oxford Mills. The margin of this upland breaks into narrow pahoid crests and a series of paha flank it to the south and southwest. Some of these, sixty feet high, are wholly destitute of loess and are composed of a brownish, non-calcareous till either accreted around a rock nucleus or at least resting on a rock foundation. In the Kansan upland the drill reaches the Niagara limestone at from 750 to 760 A. T. On the sides of the detached pahoids, rock outcrops at from 750 to 780 A. T. A number of hills of this group show sand and loess on their summits.

South of this cluster of paha the Iowan plain passes into Clinton county through three gateways, each from a mile to a mile and a half wide, separated by two massive ridges with the orientation of paha. The northern of these is much the larger, and it forms one of the most interesting topographic forms of the state. In bulk it is king of paha, if it may be classed among them. In length it is over six miles, and in width ranges from a third of a mile to a mile and a half. On the south side it is well dissected or lobate and its contours here are similar to those of the Kansan areas well matured. Ramifying lobate spurs strike southwest from the central ridge. The crest is complex, with inosculating loess boat-shaped hills, which rise 160 feet above the plain at the south.

On the northeast the slopes are more simple. The sky-line is shown in figure 25, a view taken from the Iowan plain to the north. The bowlder in the foreground, one of the largest seen in the county, measures 7 by 4 feet and is of pink granite.

Sections on both sides of the ridge prove a till nucleus which rises within at least forty or fifty feet of the summit. On the southern spur, in sections 26 and 27, Massilon township, this till exhibits the normal Kansan characters, being

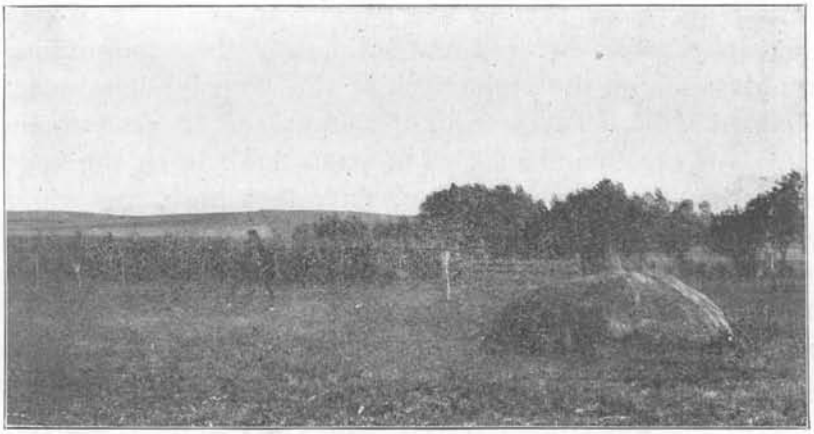


FIG. 25. Sky-line of pahoid ridge north of Lowden from Iowan plain to north.

a very stiff clayey till, reddish yellow in color, with but few cobbles, and leached of lime to a depth of seven feet from the surface. On the north side the roadway section shows the common relation of loess and till seen on deeply dissected Kansan regions. Typical yellow pulverulent loess, weathered brown superficially, is the only deposit seen for about thirty-five feet from the top of the hill. At this point the basal layer of the loess is transected—a pinkish loam, more or less distinctly laminated, with ferruginous concretions and tubules, reaching a vertical thickness of a foot or more. Overlying this basal loess is an irregular black layer of manganesic accumulation from one to three inches thick.

About fifty feet from the top of the hill a shoulder of till is crossed by the road exposing ten feet in vertical measure. The upper one foot on which the pink loess rests is a clayey reddish till with sparce pebbles, passing downward into reddish non-calcareous till in which small pebbles are plentiful, but predominantly clayey.

Little information as to the structure of the ridge was obtained from well records.

The following wells are along the crests:

John Weibe, Sec. 21, Se. ¼, depth 144 feet; to rock, 85 feet "all in solid yellow pebbly clay." (This record does not distinguish the loess from pebbly tills.) No sand or gravel, rock at 755 A. T.

Ernest Schleuter, Sec. 27, Nw. ¼ of Nw. ¼. Yellow clay (loess and yellow till) 40 feet, blue hard pan 132 feet, total depth 172 feet, a little sand and water at 110 feet. Rock surface not over 688 A. T.

Luis Heuser, depth 222 feet; elevation of curb 810 A. T. Sec. 26, Se. ¼.

Chas. Kramer, Sec. 28, depth 183 feet; to water 180 feet.

Parallel with ridge just described lies a much shorter paha, which also extends from the drift plain near Clarence, and terminates two miles west of Lowden. Its crests are distinctly convex and reach about the hight of the Kansan upland to the south.

The paha of the Tipton lobe are less numerous and striking than those of the area we have described. They are inconspicuous or absent on the Kansan margin on the right bank of the Cedar, but at Buchanan several short elliptical paha form with their flowing contours an impressive and beautiful feature of the landscape. They are scarcely one half mile in length and rise 100 feet above the creek at their base. They are heavily mantled with loess, and no drift appears upon their sides. Three miles west of Tipton the plain marked on the map as Iowan forms a lobelet extending south between Rock creek and Rocky run. This is skirted by paha and along it run narrow sands ridges, some of them less than ten feet high, aligned with the paha of the region.

In the immediate vicinity of Tipton there occur well within the Kansan, both west and south of the town, fine ridges of this class, but with rather flat tops. So far as the structure of these is shown they consist of loess underlain by stratified sand. In one distinct ridge of northwest-southeast trend south of Tipton, lines of lamination dip conspicuously outward as seen in fig. 26.

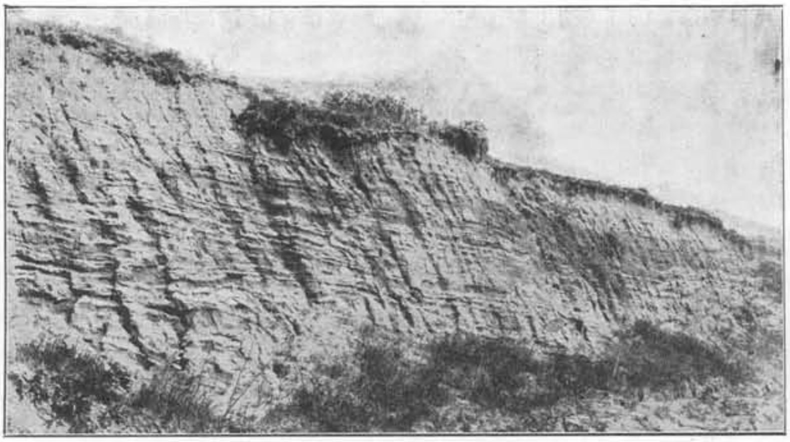


FIG. 26. Stratified sand and loessid silt in pahoid ridge, south of Tipton.

No very distinct paha mark the north border of the Tipton lobe. In Cedar township, in especial, occur sandy ridges with hummocky summits and with the pahoid trend near the margin, and about 150 feet above the Cedar river.

A tract at Rochester extending east to Crooked creek presents some difficulties in classification. Constructional profiles so prevail that it was a question whether it should not be included in the Iowan. It stands well below the Kansan upland to the northwest, and the parallelism of its reliefs is in contrast with the dendritic drainage of that area. The higher paha have as usual a nucleus of Kansan till and are mantled with loess. The low parallel ridges are mantled with sand and a brownish sandy clay, or consists of the same, recalling the aspect of the Iowan near Cedar Bluff. Though no bowlder dotted drift of Iowan facies was found on this tract, it would probably have been mapped as Iowan, had it been possible for that ice sheet to have had access to it. It is surrounded by typical Kansan areas, and it does not appear that the long, narrow gorge of the Cedar below Cedar Bluff would have made a practicable path for glacier ice.

*Origin of Paha.*—With our present limitation and uncertainty of knowledge any extended discussion of the origin of these unique and enigmatic reliefs would be useless. The parallelism of their axes at once suggests a genetic kinship with drumlins. Their form points in the same direction, but such rounded contours would obtain by weathering on any hill capped with so soft a silt as the loess. Assuming that they are loess-mantled drumlins of Kansan drift, raises the difficult question why they should congregate around the borders of a far later ice sheet. Where the margin of Iowan and of Kansan coincide, as about the driftless area, this may be expected, but surely not where the margins are separated by the width of the state, as in Cedar county and west. On the other hand, the assumption that the cores of the paha are drumlins of the Iowan drift is confronted with as serious objections,—the involved assumption of a virtual Iowan peripheral moraine composed of drumlins, the presence of the Kansan drift in the paha, and the pahoid ridges on Kansan areas. The second of these could be met by the admission of the essential similarity of the tills of both drift sheets, and the impracticability of discriminating one from the other in most cases. The third would be avoided were the Iowan border extended for about fifteen miles to the south, under the assumption that the normal topographic features of that drift sheet were here masked by the loess, or by the hypothesis that the direction of both flows was the same.

The hypothesis is attractive that paha are eskers of loess, or that they are silt bars laid down wherever caught by snag of rock, or hill of drift. The absence of loess on certain pahoid hills closely associated with paha seems to prove that the direction of their major axes was given by the constant and rectilinear movement of ice, rather than by currents of water and of wind. The presence of loess on their summits may be attributed to whatever causes are responsible for its presence on the Kansan upland. The absence of loess on the Iowan plain is explained by the protection afforded by the mantle of Iowan ice at the time when the loess was laid down. The cores of the paha may at this time either have been islands in the *mer de glace*, or, being overridden by the ice, they may have caused long crevasses in which, or because of which, loess was deposited on the summits below.

### THE BUCHANAN GRAVELS.

It has been discovered by Calvin in his work in Buchanan and Delaware counties that the retreat of the Kewatin glacier in northern Iowa was attended by the deposition, on uplands and in valleys, of heavy gravel trains which in the long lapse of time that has since elapsed have become reddened by rust, decayed, and leached of their lime. These water laid deposits contemporaneous with the Kansan are termed the Buchanan gravels. One exposure was found in the county which possesses the characteristics of this formation.

Tp. 81 N., R. IV W., SEC. 15, Ne. ¼ of Se. ¼

| | | FEET |
|---|---|---|
| 3 | Clay, pale buff, with disseminated sand merging into No. 2 | 1½ |
| 2 | Sand, yellow, with disseminated rare pebbles | 1 |
| 1 | Sand, dark red, with disseminated pebbles. Upper surface with more abundant gravel, slightly undulating and conforming to slope of hill. Junction with No. 2 sharply distinct, stratified, pebble lines and lines of coarser sand irregular, discontinuous and apparently often backset at angle of 6° to 8° toward hill. Pebbles mostly below 1 inch, but some cobbles, these angular, often rotten, sometimes striated and faceted, limestones and cherts comparatively few. In places so indurated as to be cut with trowel with difficulty, but in general friable | 5 |

Toward the base of the hill the red sand and gravel thins with a corresponding increase in thickness of the yellow sand above. Eight feet above the creek No. 1 is overlain by an ashen loess-like silt 20 inches thick which passes upward into the a yellow loessial loam two feet thick. This grades into the yellow sand of No. 2 by interstratification. This sand at the edge of hill is 15 feet thick.

In the above section we may consider No. 2 as the loessial sands so often found associated with the Iowan border. No. 1 which has every mark of greater age will then fall into the Buchanan gravels.

It is a noteworthy fact that such exposures are exceedingly rare. Sand is not common even in the immediate vicinity of streams, and a fine clay usually overlies the Kansan on the uplands. There is thus marked a considerably less slope to the Kansan surface at the retreat of its parent glacier in Cedar county and therefore a slacker drainage than that which obtained in the counties to the north, where the Buchanan was first studied.

## THE IOWAN DRIFT.

Just west of the Linn county line the Iowan drift sheet divides, one lobe—that designated in this report as the Tipton lobe—passing south along the left bank of the Cedar and the other and larger—the Clinton lobe—extending across the northern townships of the county. In the latter the Iowan drift reaches its greatest extension to the southeast.

The topography of this drift sheet in each of its lobes in Cedar county corresponds with that of other areas described by Calvin in the reports of the present Survey and in his monograph upon the subject in the Bulletins of the Geological Society of America.

On a well nigh featureless plain of glacial till, which slopes gently to its borders, or at least to its border on the south, the streams have cut shallow troughs. Interstream areas are so largely undrained that some ponds still survive the gradual decrease of ground water during recent decades. At the time of the settlement of the country sloughs were common, and large tracts were so marshy that the occupation of this portion of the county was considerably delayed. These initial depressions have nearly all yielded to ditch and tile, but a few shallow ponds still linger in wet weather, one at the edge of Mechanicsville, and others on the plain west of that village.

*Bowlders.*—The bowlders of the Iowan area in Cedar are neither so large nor so numerous as those left in Delaware, Buchanan and Bremer counties by the Iowan ice field, but in these repects they resemble those of the Marion till plain in Linn, with which the lobes in Cedar are continuous. The distribution is far from uniform on either lobe. They are rarely seen on the Clinton lobe, from the Linn county line, as far east as Clarence. Thence to Clinton county they are more plentiful, and they are specially numerous in the lobelet southeast of the village, where they may be counted by the dozens, many more than three feet in diameter.

On the Tipton lobe they are, on the whole, more common than on the northern area, as perhaps would naturally follow from its lower altitude and connection with the great drainage channel of Cedar river. They are specially numerous north and west of Cedar Bluff. In the interior of the lobe, from Cedar Bluff to Tipton, they do not impress one as being more numerous than the Kansan would probably show, were the loess removed.

The natural habitat of the bowlder is the low ground of swale or meadow. Rarely are they seen on hilltop or high on hillside. From their natural "station" they have been largely removed to the roadside, a place most convenient for the farmer and for the passing geologist. Many also have been buried to make way for the mower, and many have been built into abutments for bridges and foundations for barns and houses. In a few decades these important witnesses to the Iowan ice invasion will be beyond reach of ready summons.

Lithologically they are for the most part of a pinkish or flesh colored granite or gneiss. Traps are not uncommon, and the reddish crust which forms upon some of them by the rusting of their ferro-magnesian constituents sometimes takes the tinge of the pink granites when seen at a distance.

The bowlders are usually more or less rounded, at least on exposed faces. In other words their form is that of bowlders of disintegration. This process is uninterrupted. Crystals of feldspar, flesh red and flat faced, are ever being detached and scattered at the base. But so exceeding slow is the process that it is reasonable to suppose that these rounded forms were assumed by long weathering on their parent granite ledges in Minnesota and Wisconsin, whence they were brought by the ice, the earliest emigrants into the state.

Where large Iowan bowlders have been broken up, it is often found, according to Calvin, that they rest comparatively near the surface of the ground on surfaces planed by the abrasion of the rocks over which they have been dragged by the ice. Smaller stones so planed and scored are sometimes so set that the surfaces affected are exposed to view. Such bowlders cannot belong to a superglacial drift, unless they were thus beveled on their parent ledges before their journey to Iowa was begun.

Little is seen on either of the lobate areas of the Iowan of typical pale yellow, clayey, calcareous till, described by those who have studied the Iowan in the counties to the north of Cedar. The following is the only instance within the areas of a till which when tested reacted for lime within the depth of the exposure, and this was found below a layer of loess:

CUT ON B., C R & N. RY., TP. 81 N., R. III W., SEC. 34 Sw ¼.

| | | FEET. |
|---|---|---|
| 5. | Humus, and humus colored sandy clay .............. | 4 |
| 4. | Sand, pale yellow, moderately fine.................. | 1 |
| 3. | Clayey sand, reddish brown......................... | ½ |
| 2. | Loess, buff........................................ | 2 |
| 1. | Till, sandy above, clayey below, calcareous, destitute of bowlders and cobbles, rather loamy and loose of texture and resembling loess in color.......... | 3 |

But over large tracts there lies a deposit which seems eminently characteristic of the Iowan, though not yet recognized as such so far as is known to the writer. This is a sandy till with many pebbles and cobbles, and an occasional bowlder. It is traced in sandy humus and is corelated with the sands which near the Iowan frontier underlie the loess.

It is in the prevailingly arenaceous nature of its deposits that the Iowan stands in conspicuous contrast with the Kansan. Sand is rarely seen on Kansan areas, except near the frontier of the younger drift. Even along water ways the loess usually graduates downward into a reddish clay which rests upon the ferretto of the till. But near the border of the Iowan the loess passes downward by interbedding into heavy, yellow, stratified sands. This peripheric sub-loessial sand is one of the most valuable means of tracing the border of the Iowan ice from which the streams bearing these sands were discharged.

With the exception of this superficial arenaceous layer the till exposed on Iowan areas has not been discriminated from the Kansan by the writer. It is not to be expected that tills of different ice invasions will be so markedly unlike that their age can be told by their structure and composition. And it may be assumed that an overlying drift sheet will contain much material reworked from the older one subjacent. It is not proven therefore that the clayey till resembling Kansan on those areas referred to the Iowan does not belong to the Iowan stage. A few typical sections of the drift of these areas are now given.

FREMONT TOWNSHIP, SEC. 4, Se. ¼ OF Ne. ¼. EXCAVATION FOR CELLAR.

| | | FEET. |
|---|---|---|
| 4. | Humus | 1 |
| 3. | Humus colored sandy clay | ¾ |
| 2. | Clay, sandy, stiff, hard | 1¼ |
| 1. | Till, non-calcareous, reddish yellow, predominantly clayey, pebbles small | 2 |

At a well a few feet distant, blue, hard, stony clay was struck at a depth of twenty-four feet, sand fourteen feet thick at eighty-eight, and rock at 120, overlain with blue clay.

LINN TOWNSHIP, SEC. 15, Nw. ¼. AT BRIDGE OVER WET WEATHER STREAM.

| | | FEET. |
|---|---|---|
| 2. | Humus and humus colored sand | $2\frac{1}{2}$ |
| 1. | Till, yellow, predominantly clayey, non-calcareous, pebbles small and comparatively few, forming a vertical wall of stiff clay | 2 |

In the bed of the gully lay four bowlders, three of them granite, from one to two feet in diameter. As bowlders lie on the surface in an adjacent field, it may be taken that these belong on top of No. 1.

DAYTON TOWNSHIP, SEC. 14, Ne. ¼ OF Ne. ¼.

At the quarry at this locality on Mill creek a pit five feet in diameter contains tills of distinctly different appearance, as shown in figure 27.

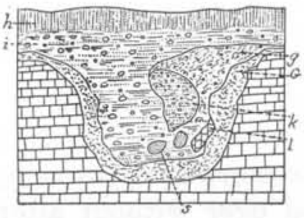



FIG. 27. Cavity formed by weathering and filled with drift.

*G* Lining the cavity formed by weathering is an unctuous clay of finest grain, formed by decomposition of the adjoining rock and is preglacial.

*g* Less dark in color, and containing rare pebbles of the drift, is also a residual clay, somewhat kneaded by glacial action.

*i* A yellowish brown, sandy till, and from its composition and place in the pit may be regarded as Iowan.

*k* A rounded mass of till, reddish brown, clayey, containing rotten pebbles, evidently a bowlder of Kansan till thrust by the Iowan glacier into the pit.

*s* Rounded masses, ten inches in diameter, of yellow-brown sand handled when in a frozen condition by the Iowan glacier.

*l* Fragment of adjoining limestone.

*h* Humus.

*The Tipton Lobe.*—The rock surface beneath this area is much more uniform than that beneath the Clinton lobe, and is everywhere found at no great depth. All the shallow creeks which cross the plain have chiseled their channels in the rock, and wells reach it from ten to fifty feet from the surface.

On the Tipton lobe the evidence of the action of glacier water is specially conspicuous, and here the influence may be traced of the nearness of the great drainage channel of the Cedar. Sand is a common constituent of the soil. It is found in hummocky ridges and low swells, often of pahoid trend, and occasionally occurs, as north of Cedar Bluff, in small tracts of little dunes.

This lobe presents an exception to the usual undissected character of the Iowan surface, where northwest of Cedar Bluff two creeks and their branches which head in the Kansan, cross it on their way to the Cedar. In this limited area the aspect of the topography is abnormal in the depth of the rock-cut valleys, the width of flood plains, and the amount of dissection. The bowlders scattered over the surface and the fact that it lies in the direct and only path to the typical Iowan area west of Tipton, are, perhaps, sufficient reasons for mapping this region of western Linn township as Iowan, although the ice here passed over without altering to any marked degree the lie of the land. Here no clear marginal ridge marks the separation from the Kansan to the north and it is hard to draw the line of demarkation except by the border line of the loess and the height of adjoining Iowan areas.

East of Cedar Bluff the Tipton lobe conforms with sufficient closeness to the normal Iowan drift plain. To the north the line of juncture with the loess-covered Kansan is so marked that it has been followed by a diagonal road in Red Oak township, the main thoroughfare from Tipton to Mechanicsville. The Kansan border here rises from twenty to forty feet above the Iowan, perhaps a little more than the thickness of the loess, although this is here comparatively thin. To the south the sinuous line of forest covered Kansan hills forms an impressive frame to the broad Iowan prairie. This appearance is in part due to the fact that near the margin the Iowan slopes somewhat rapidly southward to the valleys of Rock creek and Rocky run. For in its central portions the prairie is as high as the hilltops of the Kansas upland which lies to the south and east. If the heavy loess were removed from the latter, it would stand at a lower level than the Iowan to a degree probably corresponding to the general southward and eastward descent of the surface in the county. Thus here at least it is unnecessary to suppose that the Iowan ice sought out areas of lower ground in the preexisting land surface, or that it excavated that surface to any extent by its advance. The difference in height between Kansan upland and Iowan plain is due to the presence of loess upon the former.

*The Clinton Lobe*—to now take up some of its characteristic features in detail—stretches across the northern portion of the county, the line of the Chicago & Northwestern railroad marking approximately its southern limit. From the Linn county line to Stanwood the railway runs close under the front of the Kansan upland. From Stanwood to Lowden the lobate outline of the Iowan carries at one place nearly two miles south of the line of the railway. Geologic and glaciologic control is seldom more strikingly illustrated than here where the front of an ancient glacier determines the line of a transcontinental highway of commerce. Along the Iowan plain the line is run in tangents at the minimum of expense for cuts and fills. A mile or so to the south, across the comparatively hilly country of the Kansan, the expense of construction and of operation would have been much greater.

Several possible causes suggest themselves of the origin of this plain as a topographic feature. The initial preglacial rock surface may have been left so slightly eroded that it has controlled the later deposit of drift upon it. Or, although deeply chiseled by erosion, it may have been leveled by the earlier drift by filling its depressions. And the Kansan drift plain formed in either way, by the smooth veneering of a preglacial rock surface, or by plastering full its depressions, may either have remained unscored by erosion until overrun by the Iowan, or it may have been closely gashed by long erosion, as is seen today in the deep valleyed Kansan about Plato, and then have been leveled by the invasion of the Iowan ice, its valleys filled with Iowan drift, and its hills perhaps cut down.

Of these different possible explanations, the one which seems to meet the case is that which places the present plain under the control of a previous drift plain of the Kansan. That it is not under the control of the rock surface is clear, since this varies widely in its relief. From Mechanicsville west, the Niagara lies everywhere near the surface at an elevation of about 890 A. T., and is disclosed by all the shallow creeks which cross the plain. From Clarence east rock is reached at a depth of a few feet. But this subsurface of rock is crossed in Fremont township by a deep preglacial valley whose rock floor lies nearly 300 feet below the surface of the Iowan plain.

Nor can we attribute the plane surface of the Iowan to any considerable extent to either erosion or aggradation by the Iowan ice. The Iowan drift is typically scanty and thin. No proof is found that the ice planed away preexisting hills of the Kansan. If such planation is assumed it cannot be granted that it passed below the weathered superficial surface, for many facts go to prove that the present weathered zone of the Kansan is pre-Iowan, and the Kansan drift or drift indistinguishable from it, is often found deeply weathered on Iowan areas. Nor is any proof at hand that the Iowan filled preexisting depressions to any considerable extent in the county. In the few cases in the county where excavations have been seen in present depressions, the aspect of the drift has been Kansan with the possible exception of a thin veneer of Iowan.

We are then left to the assumption that the region was originally a Kansan drift plain, left little scored by erosion on account of distance from local base levels of erosion, a drift plain diversified perhaps by drumlins, but otherwise resembling the level Kansan tracts about Bennett and Sunbury.

The question remains as to the relative elevation of the Iowan and Kansan. To the traveler on the great railway which passes along the southern margin of the plain, the line of hills with their pahoid summits which marks the Kansan frontier at once give the impression that the Iowan occupies a region of lower altitude. But if the loess were removed the difference in height of the two drift sheets would be inconsiderable. At Lisbon where the Iowan is highest the crests of the hills to the southeast overlook the plain from a height of only 40 feet. At Mechanicsville the difference is 60 feet. From Stanwood to Clarence, where the altitude of the Kansan decreases, the difference is from 20 to 40 feet. About Lowden, where the Iowan follows down the broad descent to the Wapsipinicon now occupied by Yankee run, the hills of the Kansan rise over 100 feet above the plain. Therefore with the exception of the eastern end of the plain in Cedar county, it stands little, if any, lower than the Kansan drift would appear if the loess, whose thickness here may be taken to be about 40 feet, were removed.

*The Loess.* The distribution of this yellow siliceous silt is presented in the map of Pleistocene deposits. Its greatest thickness is adjacent to the Iowan margin, where it is at least 40 feet deep. In the interior of the Kansan area drift appearing on the hillsides often shows that it cannot exceed a thickness of ten or fifteen feet.

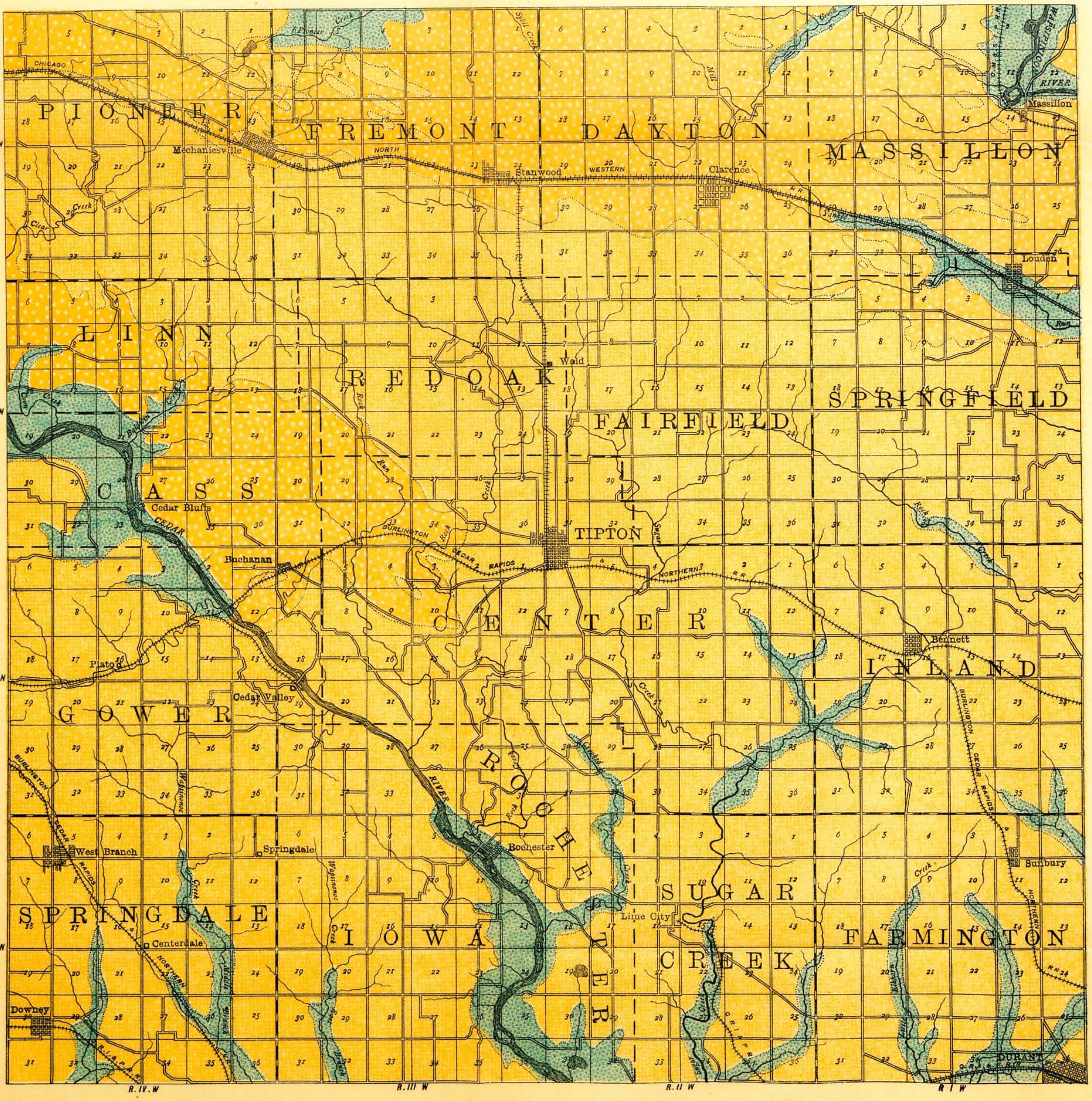
The different aspects of the loess, its graduation beneath into a bluish gray, more pervious, calcareous and fossiliferous silt, often laminated, and its weathering superficially into a finer and darker clay, have been fully described in the reports of the Survey, and no detailed account is thought necessary.

As in Scott county it graduates near the Iowan margin downward, and sometimes laterally, into stratified sand, and on the Kansan passes often into a basal layer more clayey and redder owing to wash from the till beneath. A few sections are appended.

BEALER'S QUARRY.

| | | Feet. |
|---|---|---|
| 6 | Weathered loess, brown, fine of grain and in part finely jointed, traversed with narrow parallel sinuous bands which when wet show darker than the remainder, conforming in general direction with slope of hill....... | 5 |
| 5 | Loess, typical light buff, pulverulent, breaking down in great blocks along vertical cleavages; towards base interstratified with thin, tortuous, discontinuous veins of fine white, orange and red sand, dipping with the hill.............................................. | 14 |
| 4 | Loess, fine, pulverulent, with brownish spots and lines.. | 4 |
| 3 | Loess, finely laminated, laminæ of thickness of fine cardboard, slightly undulating, picked out by weathering and readily detaching in hand specimen, darker in color and more clayey than the loess above into which it graduates by imperceptible gradations............ | 7 |
| 2 | Red geest, and red till, either composed in part of geest, or weathered to same color, with pebbles of northern rocks.............................................. | 1½ |
| 1 | Rock, rotten. | |

In other parts of the quarry the rock is overlain by eight feet of till, the upper five feet of which is highly oxidized, the surfaces of joint blocks an inch and less thick being deeply stained red, the lower three feet being yellow and yellowish gray. Although but few cobbles and bowlders appear in situ, a number are left on the rock surface after hydraulic stripping, the largest observed being two feet in diameter. The till is here leached to within one foot of the underlying rock. Upon the till rests a distinct pebble layer one half to one foot thick, the maximum diameter being five inches; and upon this a zone of reddish clay stiffer than loess and sandy beneath, on which true loess rests, with distinct change of color at line of parting.




IOWA GEOLOGICAL SURVEY

# MAP OF THE SUPERFICIAL DEPOSITS OF CEDAR COUNTY, IOWA.

BY

**WILLIAM HARMON NORTON**

1900.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

ALLUVIUM

IOWAN DRIFT

KANSAN DRIFT
OVERLAIN BY IOWAN LOESS

DRAWN BY F.C. TATE

IOWA LITHO. CO.

*Remains of the Mammoth.* Several finely preserved teeth of *Elephas primigenius*, the Mammoth, were found on the farm of A. T. Whitnell, Sec. 6, Springfield Tp. Se. ¼ of Se. ¼. These were found in a "washout" in a small creek. Above the washout a bed of white alluvial clay is overlain by gravels. In which of these the teeth occurred is impossible to say. Two of them were kindly donated to the museum of Cornell college.

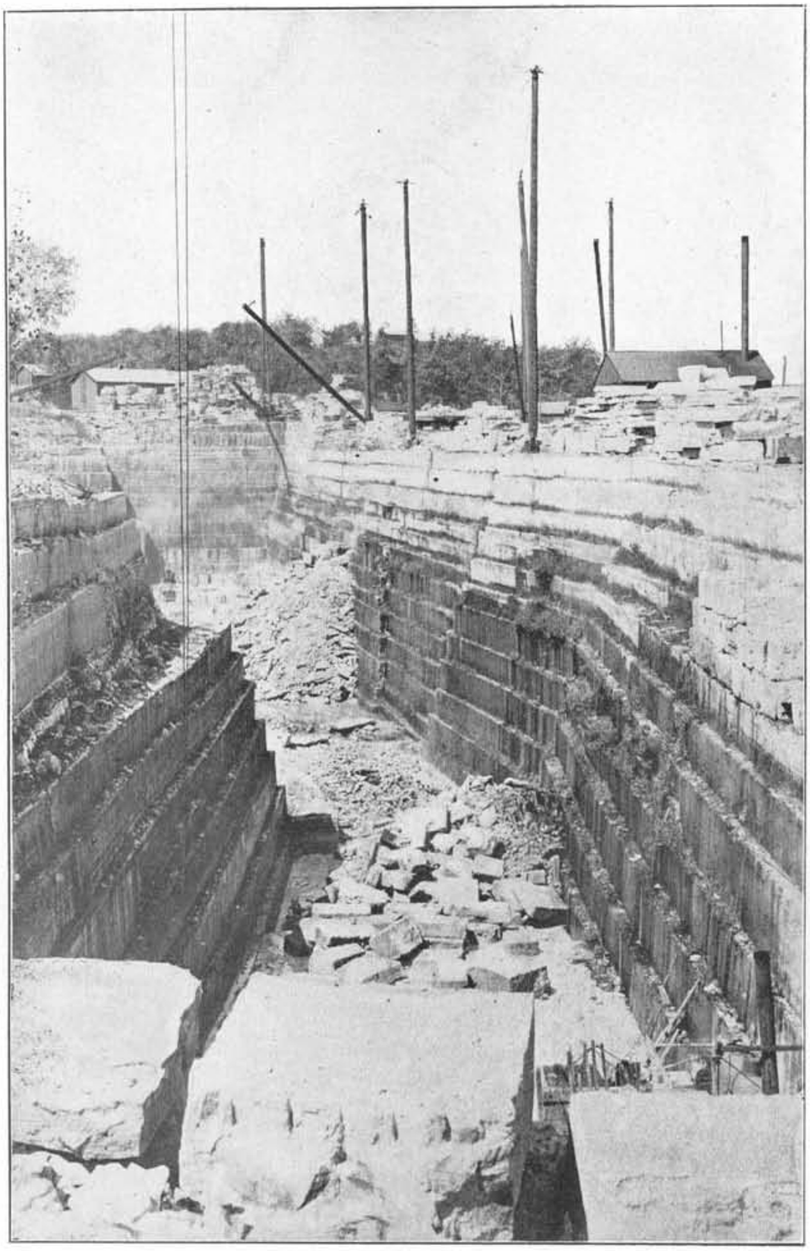
## ECONOMIC GEOLOGY.

### Building Stone.

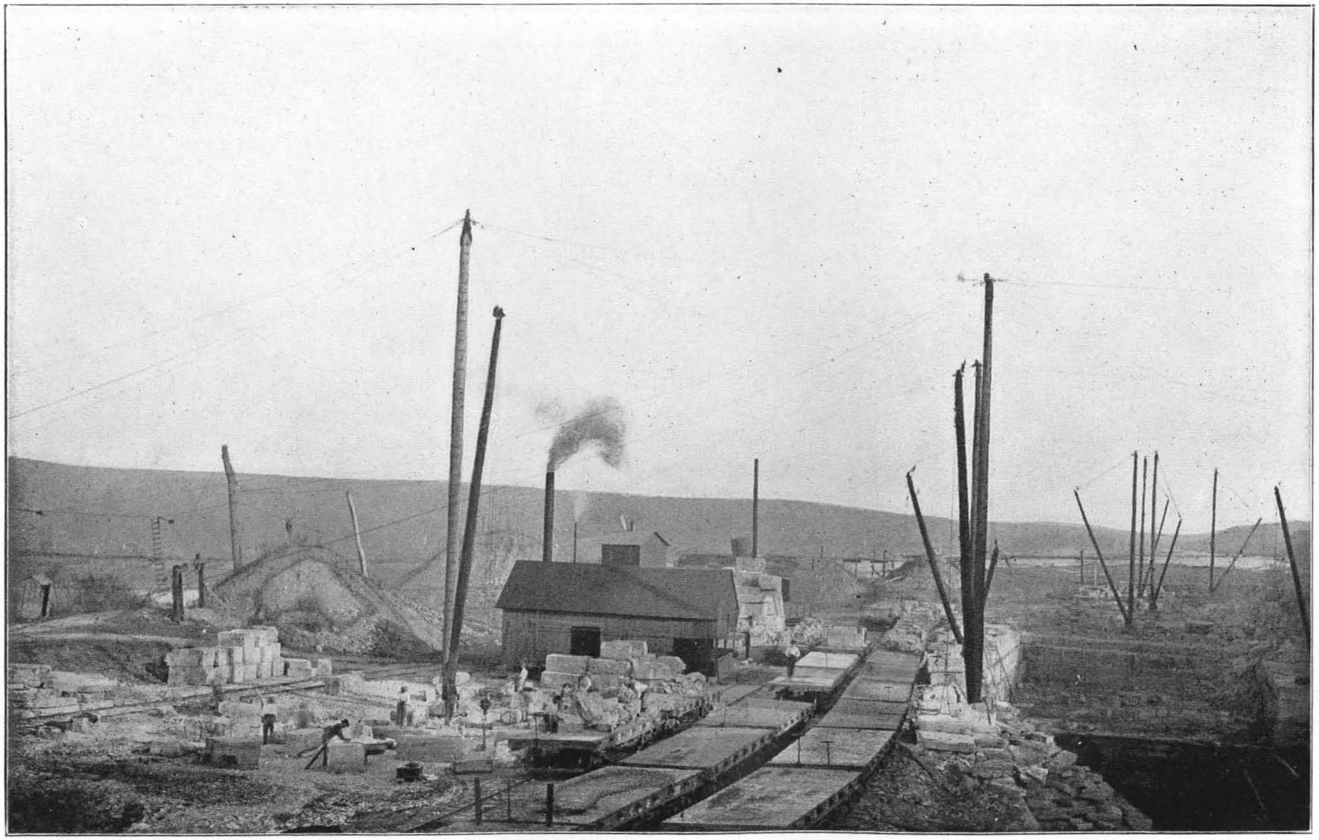
Cedar ranks easily first among the counties of the state in the value of the yearly output of building stone, a preeminence due chiefly to the quarries at Cedar Valley and Lime City. Building stone of excellent quality is found widely distributed over the county and while the small quarries which have been opened in almost every township do not greatly add to the large amounts contributed by the two quarries mentioned, yet their value and convenience to the rural districts and neighboring towns is greater than mere statistics could show. There is hardly a section in the county where a farmer or townsman can not get a load of cheap good stone within easy hauling distance. Thus in Pioneer township there are quarries at Peet's Mill and elsewhere on Clear creek; in Cedar township at Cedar Bluff and two and one-half miles north of that village; in Gower township at Cedar valley and Plato; in Center at several quarries south of Tipton; in Rochester along Rock creek; in Iowa near Atalissa; in Sugar creek at Lime City and a number of quarries north of that village; in Springfield southwest of Lowden; in Massilon along the Wapsipinicon, and in Dayton township near Clarence. Nearly all of the building stone quarried in the county is furnished by the Gower stage of the Silurian, the only exception being that of the Devonian quarries in Iowa township near the Muscatine county line. The good qualities of the Anamosa phase of the Gower limestone have long been recognized and have frequently been set forth in the countv reports on the counties of eastern Iowa. Its even and smooth bedding, its uniform grain, its comparative softness in working with saw and chisel when fresh from the quarry, and its hardness when recementation has taken place on drying, its obduracy to all chemical agencies of rock decay, and its resistance to frost, its pleasing color and the absence of any injurious minerals which might weaken, strain or impair its ease of working, all these characteristics contribute to make the Anamosa one of the best building stones of the West.

*Bealer Quarries.*—In value of output, and perfection and cost of machinery, these quarries are the most noteworthy in Iowa and are among the largest of the Mississippi valley. They are located some six miles southwest of Tipton on the right bank of the Cedar. The village which has sprung up about them is called Cedar Valley, and a spur connects with the Cedar Rapids-Clinton line of the Burlington, Cedar Rapids & Northern Railroad near Plato, about two miles northwest.

The quarries were opened seventeen years since by Mr. E. J. C. Bealer, who, as a practical bridge architect, saw the great value of the stone at this point for bridge piers and all heavy masonry. The chief quarry now in operation was opened in November, 1894, and no expense has been spared to equip it with modern and effective machinery. A levee costing $20,000 has been built along the river front for protection against floods. Railway tracks in the quarries are so built that the force of gravitation is utilized to the utmost and no locomotive engines are required to make up the train of loaded cars which in busy seasons is sent out daily. The stripping of the quarry, consisting of twenty-five feet of soft silt known as loess, and less than ten feet of pebbly glacial clay, is cheaply and expeditiously handled hydraulically by means of a high duty steam pump, capacity three quarter million gallons per day, and suitable pipes and hose. In quarrying the stone there are employed one single and three double steam channellers and four steam drills. One of the



Bealer's Quarry, Cedar Valley. Main pit.



Bealer's Quarries, Cedar Valley. General view.

channellers used in the quarry holds, it is claimed, the championship record in its line of work. "It has been made to cut 400 feet in five hours, and for ten hours its record is 750 feet." The plant includes also four eighty horse-power engines, two forty horse-power, and five engines of fifteen horse-power, one steam pump, low duty, capacity three quarter million gallons daily, and three pumps each of one quarter million gallons capacity, one pumping to reservoir and the others for general purposes. There are fourteen derricks in operation, ten of which are supplied with steam hoists lifting from four to twenty tons each. A large machine shop is well equipped for repairing and rebuilding the tools and machinery of the plant.

The usual force at work aggregates 100 men, constituting with their families an industrial colony of more than usual prosperity, if one may judge by appearances. They occupy neat cottages of good size and kept in repair, situated on both sides of the river and commonly with a small allotment of land. Most of these properties belong to the owner of the quarries, and a just pride is evidently taken in the sociologic as well as the economic success of the enterprise.

With the present force and equipment forty-five cars per day can be loaded and shipped without difficulty and the full capacity of the plant is often taxed to the utmost.

The output consists chiefly of bridge stone of three grades. The proprietor contracts for completed bridge piers and has a large force employed in their construction. Dressed dimension stone are cut in the yards and crush stone, rip-rap, rubble and curb stone are included in the products of the quarry.

The quarries were opened in natural ledges fronting the river in the face of bluffs rising about 120 feet above the stream. These ledges have been quarried away over an area of several acres, and on the platform thus formed a pit 300 by 125 feet has been sunk to a depth of sixty feet below the level of water in the river, and another of like dimensions has recently been opened. The lower ninety-four feet is used for bridge and dimension stone, the stone becoming of finer grain and better quality, it is said, with increasing depth to the present quarry floor. Above this lies a ledge twenty-two feet thick used only for rip-rap, rubble, railway ballast, and macadam, for which it is admirably adapted. It includes hard, fine grained spalls, a four foot layer of hard, highly vesicular, crystalline limestone, and four feet of laminated limestone in layers from two to eight inches thick. On this ledge rests a bed of about twelve feet of soft earthy limestone, called the Coggan, wholly worthless for any industrial purpose, and constituting a part of the stripping.

The quarry stone belongs to the Silurian system, Niagara series, and to a stage which the writer has called the Gower, from the township in which Bealer's quarries are situated. Other things being equal, a geological formation is best named from the locality where its industrial uses are most fully developed, and the coincidence of scientific with commercial names is desirable whenever it can be obtained. Unfortunately in the present case the stage could not be termed the Cedar Valley after the village, since that name has already been applied to a stage of the Devonian. No locality in Iowa, whose name is at all available, so fully represents the different phases of this important formation as does Gower township in Cedar county.

Of the Gower limestone there are several phases, representing different modes and circumstances of deposition. Most important of these is the phase quarried at Bealer's, a laminated, light buff, granular, even bedded building stone. Nowhere in the state is it found of greater thickness or better suited to the purpcses to which it is put. As a dolomite, it withstands chemical decay indefinitely, while its texture makes it resistant to frost to a high degree. So few are open bedding planes that in the deep pit mentioned there were found but two or three pervious to water. When this excavation was made, it was put down in two pits separated by a wall of stone left for the time unquarried. One of these pits being left for a while unpumped, water stood in it twenty-five feet above the floor of the adjoining pit, and even under this head there was no seepage.

In the distance between the bedding planes this stone differs from many outcrops of the same formation. The rock, however, is laminated throughout and may be split along these planes to layers one foot in thickness without difficulty, and in places to eight and nine inches. On natural outcrops adjacent long weathered outcrops often show close lines of lamination, but these are strongly coherent, beyond the usual in this formation, and permit the quarrying of permanently solid blocks of as great thickness as called for. The common size of the blocks raised from the lower part of the quarry is six and one half feet long and three and one quarter feet wide and thick, weighing each something more than four tons.

In some of the outcrops of the Anamosa phase of the Gower stage there are found, especially toward the summit, thin layers or laminæ of a compact, drab, fine grained limestone, called by workmen "flint" on account of its hardness, brittleness, and fracture. Such seams are a direct injury; under the weather they break into small rhombic chip stone. Since their coefficient of expansion is different from that of the adjoining layers, they tend to form in time a horizontal cleavage of the block of which they form a part. At Bealer's quarry these seems are practically absent, and the stone free from this element of weakness as well as of all deleterious accessories, can be strongly recommended as of the highest durability.

*Cedar Bluff.*—Immediately above the bridge at this village, a ledge of Anamosa stone has been quarried to some extent for local supply. The face of the ledge is here some thirty-five feet. The upper seven or eight feet are weathered to thin spalls. In the middle lies a stratum of seven feet of fine grained, light yellow limestone of pure Anamosa type. Below this the stone shows an alternation of harder and softer laminæ, the harder being of finer grain and more brittle. The best building stones are said to be taken from the bed of the river at the base of the ledge.

Below the village the same formation outcrops on both sides of the river in ledges up to fifty feet in height, showing the same granular laminated limestone, horizontally bedded in even courses, weathering in places to thin calcareous plates, but for the most part standing in undivided layers up to two feet in thickness.

*McLeod's Quarry*, Tp. 82 N., R. I W., Sec. 12, Sw. ¼.—On the left bank of the Wapsipinicon, less than one half mile below Massilon, this quarry shows a face of twenty-five feet of vesicular, semicrystalline limestone, the upper fifteen feet massive or obscurely bedded, the lower ten feet in rough layers from eighteen to thirty inches thick, all buff in color and sparingly fossiliferous. Just below the village on the right bank of the stream, the same layers form a picturesque ledge about thirty feet high.

*Frink's Quarry*, Tp. 82 N., R. II W., Sec. 14, Nw. ¼ of Se. ¼. The following section is here shown

| | | FEET. |
|---|---|---|
| 4. | Limestone, rough, in layers from one half to one foot thick, weathered | 4 |
| 3. | Limestone, in eight inch layers | 2 |
| 2. | Limestone, exceedingly rough, crystalline, deeply pitted with rounded cavities up to five inches in diameter | 2 |
| 1. | To creek level, not exposed | 13 |

The layers here form a gentle syncline dipping 2° north at south end and 6° south at the north end.

*Burrough's Quarry*, Tp. 80 N., R. III W., Sec. 22, Sw. ¼.—The Gower is here quarried on a small scale on the left bank of Rocky run. For 8 feet above the creek, a very fair granular building stone lies in layers from 7 to 18 inches thick, weathering superficially to spalls 2 to 4 inches thick. The dip to the southeast is perceptible. An adjacent ledge reaching a height of 20 feet above water level is composed of laminated limestone, hard, gray and crystalline. A few rods away an old pot kiln attests the possibilities of the stone as a lime maker. Here a layer identical with No. 4 of Whann's quarry is found above the limerock. Across the creek and down the stream on the same farm, about 50 feet of this hard, crystalline, laminated limestone is displayed in overhanging ledges and hillside outcrops. Toward the base the rock weathers to thin spalls, but above the laminæ are coherent, and the cliff breaks down in immense blocks. About 15 feet above the limestone a few fragments of yellow sandstone were seen in a shallow ravine, but no distinct outcrop was found. All the limestone in this section resembles the Anamosa stone in its lamination and in its horizontal or nearly horizontal bedding. Nowhere is it disturbed, tilted, or conglomeratic, as is so commonly the case with the LeClaire. And yet in their hardness, color, and crystalline texture, these beds on Rocky run are distinctly of the LeClaire type.

*Wallick's Quarry*, Tp. 81 N., R. IV W., Sec. 16, Ne. ¼ and Se. ¼.—Two and one half miles north of Cedar Bluff the Anamosa phase is here quarried for local uses. The rock rises to the surface in the low hills, so that no stripping, except of weathered spalls, is necessary. The rock is of the ordinary phase of the finely laminated, fine grained, light buff building stone of the Gower. It is in thin layers, dipping 11° SE., and shows a face of twenty feet.

*Hecht's Quarry*, Tp. 82 N., R. II W., Sec. 14, Ne. ¼ of Ne. ¼.—The following section is seen at Hecht's quarry:

| | FEET. |
|---|---|
| 3. Limestone, spalls, irregularly shaped chipstone, buff, resembling conglomerate of harder centres with matrix of limestone meal | 4 |
| 2. Limestone, rough, semicrystalline, cores gray, weathering to buff | 1 |
| 1. Limestone, for the most part evenly bedded, buff or gray, thickness of layers from above downward in inches: 8, 18, 10, 15, 19, 24, 12, 18, 18. At west end a dip of 3° W., in centre slightly S.; at east end a perceptible dip SW | $11\frac{5}{6}$ |

*Cary's Quarry*, Tp. 80 N., R. III W., Sec. 13, Sw. ¼.—About two and three-fourths miles southwest of Tipton two quarries have been opened on Rock creek. Mr. M. C. Cary here quarries a face of 15 feet in layers mostly of the thickness of flagging, but some reaching 9 inches. At the west end of the quarry the stone is hard and crystalline, of the LeClaire phase, in layers 6 inch thick and upward and dipping 12° S SE. Two rods east this has passed into the Anamosa phase, but slightly harder and more crystalline than typical, dipping 3° E., the juncture being now concealed.

Twenty-five rods southwest of this section a small quarry has been opened showing a mound of hard limerock at the north end, and, the juncture again being obscured, at the south Anamosa stone, some layers being soft and granular, and others harder and more compact. The layers here run from 1 and 2 inches to 9 and 12, and dip from 30° W NW. to 38° N NW.

*Whann's Quarry*, Tp. 80 N., R. III W., Sec. 14, NE. ¼ of NW. ¼.

| | | FEET. |
|---|---|---|
| 5. | Limestone, light buff, hard, fine grained, luster earthy, resembles Bertram beds of Linn county | 2 |
| 4. | Limestone, buff, softer, with numerous branching vertical tubes one to two mm. in diameter | 1 |
| 3. | Limestone, hard, gray, crystalline | 1½ |
| 2. | Limestone, buff, more or less vesicular, in layers from 8 to 30 inches thick, with bands of harder crystalline gray rock | 5 |
| 1. | Limestone in layers as above, buff, granular, laminated | 6½ |

The dip here is a gentle one to the southwest. A few rods up stream the ledge is seen to form a low syncline.

### Lime.

Rock of the highest excellence for the manufacture of lime is as broadly distributed over the county as is good building stone. This is due to the many areas where the Gower limestone is exposed by erosion, and to its rapid alternation at the same horizon between its two lithological phases. At no great distance from the quarries of the granular, evenly bedded Anamosa stone, there will be found outcrops of the crystalline, massive or obliquely bedded dolomite, which takes its name from LeClaire, the town in Scott county where its typical features were seen and described by Hall nearly fifty years ago. Thus, at Lime City and at Cedar Valley, lime and building stone quarries are in close proximity. It is to these two places that the manufacture of lime is at present restricted. This is not due to any special advantage in the quality of their limerock over that of other localities in the county too numerous for mention, but to the facilities with which the rock can be handled and the product placed on the market. In almost all portions of the county the explorer of outcrops of the country rock finds the white heaps of half burned lime and the ruined walls left to show the place of pot kilns. During recent years of business depression all of these have been abandoned. With the increasing prosperity of the building interests we may expect that the pot kiln will again become a local rival of the large plants equipped with patent draw kilns, as has already taken place in adjoining counties.

The upper beds of the Silurian furnish a limerock of the highest degree of excellence. It is from them that some of the largest kilns in Ohio, Wisconsin, and Illinois, as well as Iowa, draw their supply. The lime burned in Cedar county is identical with that of the well know kilns at Racine and Port Byron. Its preeminence depends upon its chemical and physical qualities. It is notably free from silica in all its forms, and from argillaceous or ferruginous impurities. The large per cent of carbonate of magnesia present makes it a cool lime, slow to set, slow to slack, and it is to such limes that architects, masons, and plasterers now invariably give preference over the so-called hot limes burned from non-magnesian limestone. The hardness and durability of mortars made from this lime approaches that of cement. Buildings are seen in which it was employed, where, after thirty-five years of weathering, the joints seem as fresh as when struck. Wholly minor advantages are the brittleness of the rock, which aids in its breaking to suitable dimensions for the kiln, and its vesicularity, which gives more ready access to heat in burning and to water in slacking.

The purity of the Gower dolomite is demonstrated in the following analysis made in the chemical laboratory of Cornell college under the supervision of Dr. Nicholas Knight:

LEDGE ON ROCK CREEK, TP. 80 N., R. 3 W., SEC. 23, SE. ¼ OF SW. ¼.

| | |
|---|---|
| Calcium carbonate, $Ca Co_3$ | 55.76 |
| Magnesium carbonate, $Mg CO_3$ | 43.85 |
| Ferric oxide and aluminum oxide, $Fe_2 O_3$ and $Al_2 O_3$ | 0.26 |
| Silica, $Si O_2$ | 0.12 |
| | 99.99 |

The total impurities of this specimen of the dolomite used in lime making throughout the county are but little more than one-third of one per cent.

*Lime City.*—The quarries of this plant are situated on the right bank of Sugar creek, five miles northwest of Wilton, a spur of the Chicago, Rock Island & Pacific connecting them with the main line at that junction. The rock is of the usual LeClaire facies. Dynamite is used in blasting, and the stone is sent to the kilns by a tram running on a trestle. Four patent draw kilns are in operation, and the lime can be loaded from the sheds directly on the cars. Some years since petroleum was used as fuel in one of the kilns, but only wood is now employed for calcination. The region about Sugar creek is forested, and wood is obtained at moderate expense. The output finds ready market along the lines of the Chicago, Rock Island & Pacific railway in Iowa and the states west. The amount of stripping is very slight. The beds of the Coggan, which overlie the limerock, are shipped for riprap and ballast, being wholly unavailable for lime or building stone.

*Cedar Valley.*—The lime plant at Cedar Valley consists of three patent draw-kilns, each with a capacity of 120 barrels, and the usual storage and cooper sheds. Of the quarry face of sixty feet scarcely any is unavailable for lime, and the expense of stripping is inconsiderable. The rock is economically handled, and the lime is loaded on the cars of the Burlington, Cedar Rapids & Northern railway. It has found a wide market over Iowa and the states adjacent to the west. Wood is employed as fuel, and is brought in from the heavily wooded hills of the Kansan upland on both sides of the river.

## Clay.

*Brick and Tile.*—No shale of economic importance is found in Cedar county. The only clay utilized in manufacture is the loess, and this extends so widely over the county that material for brick and tile exists in close proximity to every town. It is utilized at present only at the county seat, whose central position gives it an advantage as a distributing point. The brick and tile factory at Stanwoad was burned recently and has not yet been rebuilt.

Brick and Tile Factory, G. H. Kettell, Tipton.—This plant is situated in the south portion of the town, and comprises three kilns, two of them down draft, with a capacity of 95,000 brick; two Bennett clay machines, with a capacity of 14,000 brick and 10,000 three-inch tile per day, operated by a twenty horse-power engine, and drying sheds holding 125,000 brick.

The brick turned out are the common machine pressed brick, and are of excellent quality, of even texture, dense and ringing, and of good color. The tile are made of the same material and are equally good.

The clay pit shows from six to twelve feet of stiff, yellow loess loam, not readily friable when dry, and destitute of clay dogs and fossils. Where thinnest it is underlain by non-calcareous, yellow till, and where deepest by sandy layers and the bluish loess silt. Besides supplying the local demands of the largest town in the county, the factory ships over the Burlington, Cedar Rapids & Northern and the Chicago & Northwestern railways. The station of the latter is only a few blocks distant, and a switch of this railway enters the yards.

### Road Materials.

The clays of the county offer an inexhaustible supply for burning for ballast. It hardly seems probable, however, that their use for this purpose will ever be necessary, considering the fact that the county abounds in a stone unexcelled among limestone in hardness and durability as road metal. Crushed stone of the Gower limestone is used in large quantities as ballast on the lines of the B., C. R. & N., and the C., R. I. & P. railways, the former taking it from the Bealer quarries at Cedar Valley, and the latter from the quarries at Lime City. It can be obtained at reasonable expense from either of these places for county roads and town streets, and in the majority of the towns of the county a crusher could be set at work on rocks of the same formation and of equal value exposed in the vicinity.

The movement for good roads in the county has hardly more than begun. Scarcely a city or village street has been redeemed from the primitive dirt road of the early settlers. But the near future will no doubt witness rapid progress in municipal paving and road making in the area, and the facility with which good road metal can be obtained will greatly hasten this movement. It is of prime importance to remember that no stone, however valuable, will make a good road unless some intelligence is used in its construction. The traditional method of dumping rock of any and all sizes on an ungraded and undrained roadway, has long been proven the shortest way to its permanent ruin. From the beginning such a dump makes an execrable road, rough with loose stones, and it fast goes from bad to worse. In towns it is often impracticable to use it as foundation for any superstructure and its removal is too expensive to be considered. It thus postpones indefinitely the laying of a good street, either of brick paving, asphalt, or macadam.

### Sand.

This valuable material for building is obtained along the rivers of the county at little if any more than the cost of hauling. A somewhat inferior grade is found in the sands beneath the loess near the Iowan margin. Occasionally sand is taken from dunes and pahoid ridges on the Iowan area.

### Water Power.

The larger creeks of the county are perennial streams affording considerable water power, which has in the past aided largely in the development of the region. Commonly they traverse rock-cut reaches giving excellent sites for dams. Of these there were utilized early in the history of the county three on Rock creek, one on Pioneer, one on Sugar, and three on Clear creek. Several of these mills were large structures and well fitted for the part that they had to play, using power equivalent in some instances to twenty horse-power. With the rapidly changing conditions of the milling industry, and the shrinking and less constant volume of water at disposal, these water powers which so long and faithfully served the needs of the pioneers fell into disuse. The last dam was washed out in 1899 and the last mill using water power abandoned. It is quite impossible to say how distant is the day when in an age of electricity these creeks will again be harnessed to serve the needs of the people.

No dams have ever been built across the Cedar or Wapsipinicon within the county limits. On the former power could be obtained economically and in large quantity in the narrow reaches from Cedar Bluff to Rochester, but the distance to any town of size makes its utilization indefinitely remote.

### Soils.

The fertility of the soils in Cedar county is well known far beyond its limits. In the average assessed valuation per acre of its farm lands it is surpassed in Iowa only by Scott and Polk counties, in each of which these values are enhanced by large urban populations. This high value is due in part to a number of causes other than geologic, such as the length of time that has elapsed since the settlement of the county and the character and skill of its citizens. But a leading factor in the agricultural prosperity of the area is the abounding fertility of its soils.

None of the soils in the county is the result, at least directly, of that commonest of soil making processes, the secular decay of underlying rocks. Here and there, however, may be seen remnants of the ancient soil which covered the county before the episode of the great Ice Invasion, a soil formed by the decay in place of the limestones of the region. This is a stiff, unctuous, reddish clay, often seen directly overlying the rock. Compared with the glacial tills which now cover it, this residual clay, or geest, must be considered a very poor soil or subsoil indeed, and a large measure of the prosperity and wealth of the region must be referred to the successive invasions of vast sheets of ice in the yesterday of geologic history, which buried the geest beneath richer deposits or removed it entirely. In pre-Pleistocene times the agricultural advantages of the region were distinctly inferior to those of the present, and it is perhaps fortunate that the agriculturist had not then made his appearance upon the scene. It was the slow but resistless movement of immense bodies of glacial ice which ground to powder the rocks in their path from the region of the far north, and commingled the component minerals of limestones, shales, sandstones, granites and other igneous rocks into one heterogeneous ground moraine, which embraces every valuable constituent which rocks can supply to soils and growing crops. And because this drift is for the most part finely comminuted—a commixture of rock flour and rock meal, with sand, gravel, and an occasional bowlder—it breaks down rapidly into a most fertile soil. Water penetrates it, oxygen, carbon dioxide and the humic acids permeate it, the roots of trees and plants push their way down through it, earthworms and other animals burrow in it. So soon as it was laid down Nature with her multifarious agencies began to develop upon the bare, gray surface of the ground moraine the deep rich soils which to-day are the delight of the farmer.

Furthermore, by wash of water and perhaps also aided in part by the wind, particles intermediate in size were selected from the drift and laid down in a silt too fine to be called sand and too coarse for clay—the loess. This yellow loam spread widely over the area contains all the mineralogic richness of the glacial tills, and is, moreover, far more porous and accessible to soil making agencies. Brief, then, as has been the time since these deposits of till and loess were laid, it has sufficed for the production upon them of soils of a depth and richness unsurpassed in all the Mississippi valley.

Ever since glacial times there has also been in progress a redistribution of soils. The season of 1899 supplied a striking illustration of the movement of soils ever to lower levels, and at last by way of the creek and the river to the sea. The heavy rains of the spring of this year washed the plowed land on the hillsides to an extent seldom seen. At the lower end of each little gully was outspread thin alluvial fans of the blackest and richest soils, in places covering several acres. All the creek bottoms received an accretion of soil mingled in places with corn stalks and various debris washed by the floods from higher up the stream.

Thus the soils developed on glacial till and loess have been washed down to lower levels for thousands of years to form the deep alluvial soils of the creek and river flood plains, but never, at least before the settlement of the country, at a rate sufficient to remove the soils of the uplands faster than they were formed.

Thus the soils of the county may be divided into two classes, those of primary derivation developed directly by the decay of subsoils and subjacent rock, and those of secondary derivation, produced from the primary soils by wash of water.

Primary soils may be further classified according to the geological nature of the underlying formation from which they have been developed. Thus we have in Cedar county the soils of the Iowan areas developed on the Iowan drift and its washed and blown sands, the soils developed on the Kansan till, and the soils produced on the loess loam.

Judging by the value at which farm lands are held in different parts of the county, the most desirable of these soils are those of the loess where it is comparatively thin and where it is but slightly dissected. A thickness of from ten to twenty-five or thirty feet of the loess secures an adequate underdrainage and at the same time allows water in dry weather to rise easily to the surface by capillary attraction from the couche lying upon the impermeable till beneath.

The fertility of a soil depends largely upon its nitrogenous constituents and these are derived from the decay of organic matter. It is the organic matter, or humus, which, mingled with the finely comminuted earthy material derived from the decay of rocks, gives its black or dark color to the superficial layer commonly known as the soil. The amount of humus present depends on the ratio between the rate of its accumulation and the rate of its removal by rain wash and other agencies. Where the latter is practically zero it accumulates indefinitely in peat bog and marsh. Where the latter comes to be in excess of the former, as on steep deforested hillsides, the humus is soon entirely washed away. The availability of any soil for agriculture depends also on its drainage. On level or undrained tracts soils are exceedingly rich in humus, but they are too wet for profitable farming. Steep slopes are well drained, but the humus, because so rapidly washed away, is scanty and the soil is infertile. The golden mean is found where erosion has been sufficient to reduce the region to slope, but where the slopes are as yet very gentle. It is here that, in the accurate language of the farmer, "the land lies just right."

It is well drained, and at the same time is covered with deep, black humus soil, rich in all the ingredients which go to the feeding of crops.

The golden mean just described is reached over extensive tracts in Cedar county, especially over the loess covered Kansan. In Fairfield township, where land is said to be held at the highest price per acre, in Farmington, Iowa, Springdale, Inland, Red Oak, and in parts, in fact, of every township included in the Kansan area, the wealth of the soil and the ease with which it is cultivated, is reflected in the large and well kept farms, commonly of 160 acres and more, supplied with every convenience of farm machinery. Commodious houses, well painted, and comparing not unfavorably with the average houses in the towns of the county, have replaced the humble homes of the pioneers, these relics of a bygone stage in social evolution being set to one side to serve as granaries or tool sheds. Rows and clusters of shade trees, belts of wind-breaks of soft maple, or more rarely of conifers, well grassed and well fenced door yards bright with flowers, orchards of apple, cherry and plum, with an occasional experimental peach tree or apricot, large, well built barns and sheds for the stock, for which the county is famous, deep, unfailing wells, equipped with wind engines, and sometimes affording a house supply under hydrostatic pressure,—all these are evidences of the fertility of the soil, which must not escape the attention of the geologist. Not infrequently an abandoned farm, abandoned to a tenant by its owner who has moved to town, where the rental yields an adequate support without labor, is a further proof of a long continued prosperity, dependent at last analysis upon geologic and climatic conditions.

In unpleasing contrast are the deeply dissected regions of loess-Kansan topography which have been frequently mentioned in this report. Here land values are comparatively low, being sometimes not more than half that of farms where the same geologic formations have suffered less erosion.

Under the plow the soil fast washes down the steep hillsides. Gullies start with heavy rains, and, rapidly deepening, soon escape the control of the careless farmer. In a few years it is imperative to refurnish the soil with nitrogen by seeding to clover, or to turn it to pasture. At the worst this is a region of from two to ten acre allotments, of the log cabin and the two or three room shack of the clearing. At the best it is farmed in prosperous sheep and cattle ranches of hundreds of acres. On these the roughest land is retained in its native timber. In such large tracts some excellent plow land is always found, and the remainder is used for pasture.

These two types of farming lands, so markedly different and producing such divergent sociologic conditions, have after all precisely the same subsoils. The loess underlies each, and the difference between the two types is at bottom merely a difference in angle of slope, dependent upon distance from local base levels of erosion and on preglacial conditions.

In each certain advantages accrue from the absence of native stone or glacial bowlder in the way of plow or mower, and still more in the looseness of the texture of the loess which permits roots to go deep to draw moisture and food. Acting as a sponge, the loess rapidly absorbs moisture in wet weather and when not too deep gives it back in dry by capillary attraction to surface layers. It has long been recognized that it is unsurpassed as a subsoil for vineyard, orchard, and all vegetation whose roots strike deep.

*Iowan Soils.*—The typical Iowan till and its high value as a subsoil has been fully described by Calvin in his reports on the counties where it is extensive. Rich in the salts demanded by the grains it is better adapted to the culture of wheat and oats than is the loess.

The sandy till which represents the Iowan in Cedar county forms a deep, warm, mellow soil suitable to all crops. The Iowan area forms some of the best farming land in the county, and the description of the farms on the best of the loess-Kansan will apply also to the best of the Iowan. Upon the whole, however, the Iowan farms are not valued so highly as are those on the gentle rolling Kansan. On account of the immaturity of the Iowan plain the natural drainage is imperfect. This is now remedied for the most part by ditches and tiling, but the evident disadvantages of the undrained tracts delayed the settlement of considerable of the area. The land has not yet had time to produce the improvements seen in districts longer farmed, and its market price is therefore still somewhat less.

The bowlders of the Iowan are not plentiful enough to form any special embarrassment to farming operations. A very small per cent of the labor required in New England for this purpose would here suffice to remove them all. And in no case is the plow compelled to work in a heavily stony till. It is rarely that the plow discovers the till beneath the deep soils which overlie it. The nearness, however, of the till brings the level of ground water high on all tracts where its movement is not accelerated by slope, and on such levels the land is cold and wet until tiled, when it becomes of the best. On the Tipton lobe especially, and near the terraces of the Cedar river, sandy soils occur which have all the advantages and defects of such soils everywhere. In the season of 1899 the large rainfall in spring and early summer gave these soils a distinct advantage over the clayey soils of the loess, and when the field work of the survey was finished in July there was nowhere in the county a better stand of corn than on the sandy soils of the Iowan plains. In dry seasons the relative advantages of the two soils is reversed. In a drought crops may suffer severely on the sandy knolls and ridges, while they are uninjured on lower ground where the humus is deep, and on large areas where a sandy clay, probably of the same age as the loess, overlies the till.

A class of soils geologically distinct from those described are the alluvial soils of the flood plains of the streams. The ancient flood plains of the rivers which now stand as terraces twenty feet and more above the water are underdrained by basal beds of sand, and therefore, like all such old fluvial floors, are apt to suffer in times of protracted drought. Where a few feet of reddish, sandy clay underlies the humus, as is frequently the case, drought is less severely felt than where the humus is spread on strata of sand.

The lower bottoms and the flood plains as a whole embrace along with these sandy tracts many square miles of excellent farm land. So deep is the rich, black alluvium that it is often two feet and more in depth before a change in color can be be detected. The map of the county exhibits the distribution and the great width of these alluvial tracts along reaches of the Cedar and Wapsipinicon rivers and the larger creeks.

In the valleys of the smaller creeks the change in regimen due to cultivation can sometimes be seen. The peaty humus of the swale is overlain with a few inches of lighter colored soil washed from the adjacent hill sides since the country was settled.

On the whole corn is the staple crop of all the areas of the county, Kansan and Iowan as well, but the latter is more largely given over to pasture meadow and the smaller grains than is the former.

IOWA GEOLOGICAL SURVEY

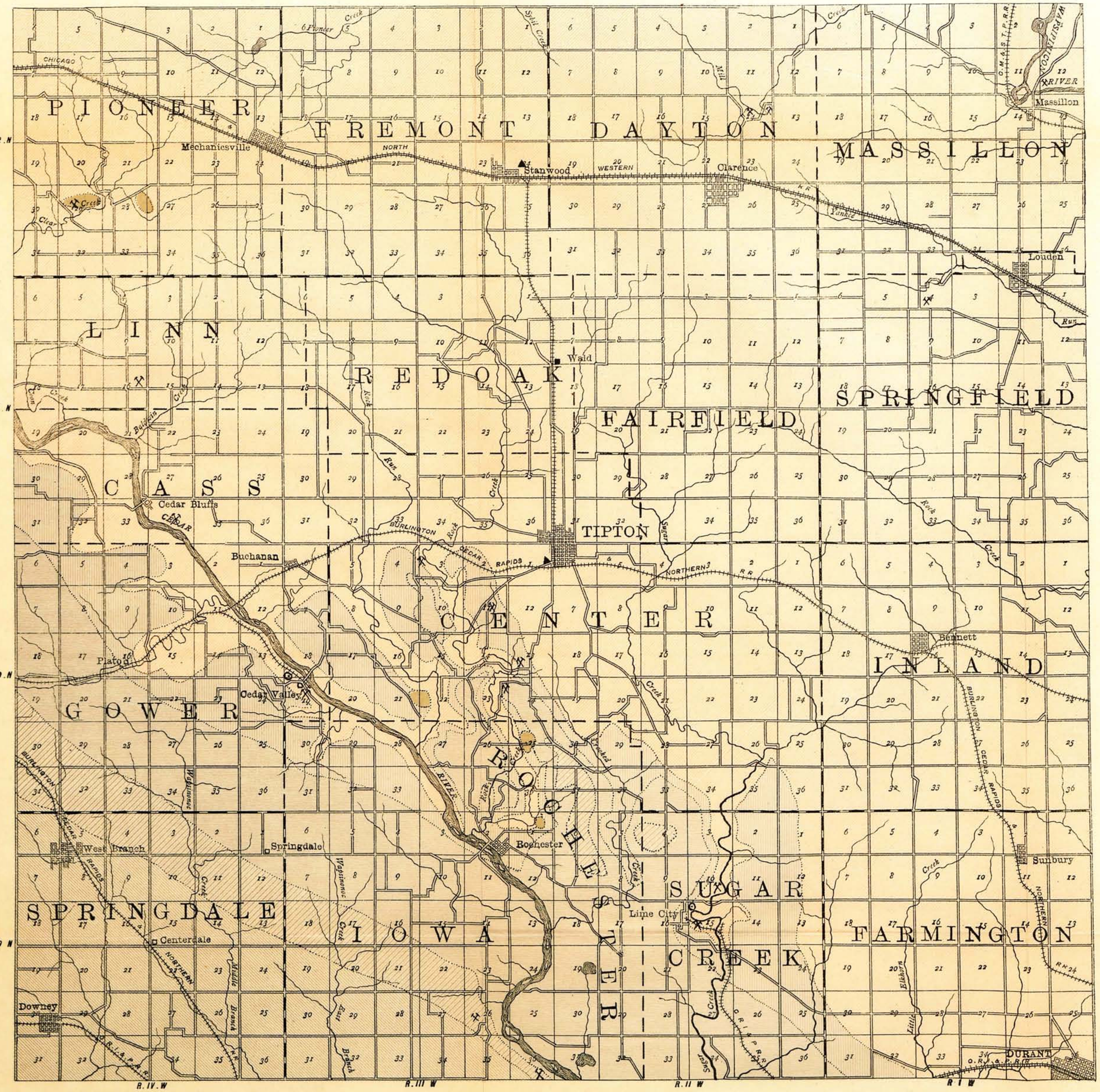
# GEOLOGICAL MAP OF CEDAR COUNTY, IOWA.

BY

WILLIAM HARMON NORTON

1901.

Scale $\frac{1}{125000}$




## LEGEND

### GEOLOGICAL FORMATIONS

| | |
|---|---|
| DES MOINES | CARBONIFEROUS |
| CEDAR VALLEY | DEVONIAN |
| UPPER DAVENPORT | DEVONIAN |
| OTIS, INDEPENDENCE AND LOWER DAVENPORT | DEVONIAN |
| COGGAN | DEVONIAN |
| NIAGARA | SILURIAN |

### INDUSTRIES

CLAY WORKS ▲

QUARRIES ⚒

LIME KILNS ⊙

DRAWN BY F. C. TATE

IOWA LITHO. CO.