
GEOLOGY OF BENTON COUNTY.

BY

T. E. SAVAGE

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INTRODUCTION.

LOCATION AND AREA.

Benton county is located in the east-central portion of Iowa. It lies across the middle line of the state from north to south while its eastern border is about seventy-two miles from the Mississippi river. It is a rectangle in form, thirty miles in length in a north and south direction, twenty-four miles in width, and embraces an area of 720 square miles. The extreme southwestern portion of the county is cut by the channel of the Iowa river, and the northern part is crossed diagonally by the valley of the Cedar.

Benton is bordered on the north by the counties of Black Hawk and Buchanan, on the east by Linn, Iowa county touches it on the south, and Tama joins it on the west. Of these areas Buchanan county has been described by Professor Calvin in a previous volume of the Iowa Survey reports. Linn county has been discussed by Professor Norton, and Tama has been investigated by the present writer. The county includes twenty congressional townships—townships 82-86 north and ranges IX-XII west. It is divided into twenty civil townships, fifteen of which are of the usual size while the other five—Cedar, Harrison, Polk, Taylor and Benton—which are located towards the the northeast corner, are more or less irregular in size and form owing to the fact that their boundaries are in part determined by the winding channel of the Cedar river.

Benton is pre-eminently an agricultural county. It is situated in the midst of the finest agricultural portion of our peerless state. The larger part of this beautiful area lies within the region covered by the Iowan ice sheet, and the drift of this age furnishes to the county a soil that is unsurpassed in depth, fertility and productiveness. Well tilled farms of ample size; beautiful homes with attractive surroundings; numerous farm buildings, large and commodious; these are the evidences which lend a substantial air of thrift and prosperity to the inhabitants of this fortunate region.

EARLIER GEOLOGICAL WORK.

Benton county lies outside of the main area of the Coal Measures of Iowa, and consequently the history of the early exploitations of that mineral did not involve this particular portion of the state. No valuable mineral deposits of any kind and no large areas over which the indurated rocks are exposed attracted the practical students of geology to this region. The problems of the superficial deposits did not appeal to workers in the science of geology until recent years, hence the chroniclers of early explorations in Iowa rarely give to our county even passing notice.

The pioneer geologist *Dr. D. D. Owen does not mention the county by name but he might well have referred to her billowy surface when he thus described the rural beauty of a portion of the state: "Undulating prairies interspersed with open groves of timber and watered with pebbly or rocky-bedded streams, pure and transparent; hills of moderate height and gentle slope; here and there, especially toward the heads of the streams, small lakes as clear as the rivers, some skirted with timber and some with banks formed by the green sward of the open prairies; these are the ordinary features of the pastoral landscape."

In Hall's† Geology of Iowa, published in 1858, Professor Whitney speaks of an exposure of limestone of Hamilton age near the town of Shellsburg. He also mentions a few places near Vinton where outcrops of the rocks of the same age occur.

In another place Mr. Whitney‡ discusses the probability of local beds of Carboniferous strata underlying the superficial materials of the area under consideration.

In the report on Iowa Geology by Dr. C. A. White not a word is said with respect either to soils or topography, or to the indurated rocks or the Pleistocene deposits that occur within the borders of Benton county.

W J McGee,§ in his Pleistocene History of Northeastern Iowa, refers in a general way to the drainage, and the behavior

*D. D. Owen: Report Geol. Sur., Wisconsin, Iowa and Minnesota, p. 100, 1852.

†Hall and Whitney: Geology of Iowa, Vol. I, Pt. 1, pp. 262 and 263. 1858.

‡*Ibid.*, p. 264.

§McGee: Eleventh Ann. Rept. U. S. Geol. Surv. p. 221 *et seq.* 1891.

of some of the streams. He also mentions deposits of loess and sand that occur at various points within the area, and gives a few sections of wells put down in this particular region.

In discussing the Paleozoic strata of Northeastern Iowa Prof. W. H. Norton* describes sections which show the different formations that were penetrated in putting down two deep wells in the town of Vinton. Again, in his report on the Artesian Wells of Iowa, Mr. Norton makes a detailed description of these wells and gives an analysis of their water.† In the latter report Professor Norton also discusses the Jumbo well at Belle Plaine.‡

Professor Chamberlain has published an account of the well at Belle Plaine which for a time after it was drilled provoked an unusual amount of discussion.§ A few years later Mr. Call described the Belle Plaine artesian well and attempted to explain the source of the water.|| In 1898 Mr. Roy Mosnat presented an excellent account of the Artesian wells of the Belle Plaine area in the present series of the Iowa Survey reports.¶ This area includes the southwest portion of Benton county together with the southeast corner of Tama, a small area in the northwest corner of Iowa county and the northeast corner of the county of Poweshiek.

PHYSIOGRAPHY.

TOPOGRAPHY.

General description.—Over the greater portion of Benton county the topography is what physiographers designate as a prairie plain. The indurated rocks that underlie the superficial materials are of Devonian age, and have practically a horizontal position. There are no very great differences in altitude between the valleys and uplands, nor in general is there any great diversion from the gently undulating character of the prevailing landscape.

*Norton: Iowa Geol. Surv., Vol. III, pp. 192-195. 1893.

†Norton: Iowa Geol. Surv., Vol. VI, pp. 266-267. 1896.

‡Norton: Iowa Geol. Surv., Vol. VI, pp. 350-352. 1896.

§Chamberlain: The Artesian Well at Belle Plaine, Iowa, Science Vol. VIII, p. 276.

||Call: Iowa Artesian Wells. Weather and crop service, Vol. III, March, 1892.

¶Mosnat: Iowa Geol. Surv., Vol. IX, pp. 523-526. 1898.

The county as a whole, however, embraces topographic phenomena of exceeding interest for the reason that the surface features over one portion of the area have been developed through the destructive processes of erosion, while those over another part of the region have been moulded by the constructive agency of ice.

The entire surface of the county is drift covered with the exception of small areas of fluvial deposits along the flood plains of the larger streams. The drift of the county has been derived from two different ice sheets, which, in time, are separated by an exceedingly long interval. The two topographic areas mentioned above are coincident with the areas over which the drift of these respective ice sheets are spread out at the surface. The older portion of the region, that over which the uppermost till is of Kansan age, embraces a little more than the south half of Iowa township, the south part of Leroy and a small area near the south side of the township of Saint Clair.

The history of this ancient surface is one of long continued exposure to the processes of weathering and the agents of erosion. It is recorded in the chemical and physical changes that have been accomplished in the superficial portion of the drift. It is revealed in the deeply carved and thoroughly dissected divides. It is reflected in the depth of the stream channels and in the great width of their flood plains. In general it is depicted in every feature of the landscape, which is typical of a water sculptured region approaching the conditions of topographic maturity.

The area over which the later or Iowan drift was spread embraces the most of the county with the exception of the older portion outlined above. That the topography of this area was impressed upon it by the ice is shown by the gentle curves and slight inequalities in the surface; by the scant development of definite stream channels and the absence of any widely extending series of secondary branches; by the presence of innumerable swales or saucer-like depressions which lie between low, rounded elevations, and which have not yet been obliterated either by filling or by drainage or by both of these means combined. The above are glacial phenomena and

they clearly testify to the recent retreat of the ice mantle and to the extreme topographic youthfulness of this portion of the county.

The Iowan-Kansan border.—The sinuous line of irregular elevations that marks the southern limit of the extension of Iowan ice in Benton county begins, on the west side, at the town of Belle Plaine. To the west and south of this place there is evidence that a tongue of Iowan ice pushed down the broad valley of Salt creek and for some distance overspread the flood plain of the Iowa river. To the north of Belle Plaine, for a distance of two miles, the line of hills passes near the west side of sections 17 and 8 of Iowa township. Not far from the northwest corner of section 8 it bends to the eastward for one-half mile across the north side of this same section. It then bends southward along the west side of section 9, forming for some distance the conspicuous bluffs in the west bank of Stein creek. In the northwest part of section 16, this line again bends eastward and continues in a sinuous manner not far from the north side of sections 16 and 15, and on to nearly the middle of section 14. Bending southward it passes diagonally across the southeast quarter of section 14, the southwest corner of section 13 and down to near the center of section 24. Turning eastward for nearly one mile it crosses a little to the north of the middle of section 24 of Iowa township, and thence passes towards the northeast a short distance south of the town of Luzerne. It continues towards the northeast across the northwest corner of section 19 of Leroy township, and on to the northeast corner of 18. From this point it bends eastward for three-fourths of a mile and then continues in a general southeast direction across the northeast corner of section 17, the southwest corner of section 16, the north end of section 22, the southwest corner of section 23 and the northeast corner of section 26. See figure 1. Continuing in a direction a little south of east, about one mile south of the town of Blairstown, it passes diagonally across the middle of section 25 of Leroy township and enters the township of Saint Clair, a few rods north of the southwest corner of section 30. From this point it continues in a general southeast direction near the south

side of section 30, and diagonally across the north side of section 32. It passes eastward near the middle of section 33 and then crosses diagonally the south half of section 34. It crosses the Benton-Iowa county line a little east of the middle of the south side of section 35 of Saint Clair township. This line of moraine-like ridges continues in a southeasterly direction across the northeast corner of Iowa county where it forms a conspicuous border of hills overlooking the south side of section 36 of Saint Clair township and sections 31, 32, 33 and 34 of Florence. From section 35 its trend takes it so far south into Iowa



FIG. 1. Iowan-Kansan border near the middle of Leroy township. These elevations also form the south bank of the valley of Prairie creek.

county that it appears as an indistinct line almost on the horizon's rim; and from the south side of section 36 it has entirely disappeared from view, being obscured from sight by the presence of intervening swells. In the townships of Saint Clair and Leroy the Iowan border is beautifully preserved and is very conspicuous. As one approaches from the north, the line of hills rises abruptly to a height of fifty to seventy feet above the comparatively level Iowan plain. In Iowa township the margin is less distinct. The Iowan surface is here much

more broken; the pre-Iowan topography not having been greatly altered. For this reason the contrast between the surface of the Iowan plain and the line of hills that borders it is not so clearly marked in Iowa township as it is further east, in the townships of Leroy and Saint Clair. To the careful observer of land forms, however, the subdued and rounded character of the elevation, together with the choked condition of the stream channels over this portion of the Iowan area will be quite readily discriminated from the higher, and more deeply sand or loess covered hills with sharper contours and the more open waterways which are presented in the region of the Iowan-Kansan border in Benton county.

These elevations can scarcely be called a moraine as that term is usually understood, for they contain no proper unspread Iowan drift. In fact, the Iowan glacier deposited scarcely any pebbles or finely pulverized detritus over this portion of the region which it invaded. It would seem probable, also, that the ice became so exceedingly thin at its southern margin in Benton county that its onward flow was obstructed where the stronger hills were encountered, the ice continuing to advance further where the movement was over level areas of prairie or flood plain.

As an obstruction the hills may have acted in part in the nature of a barrier to the glacier's advance, and again their presence would be a cause of the much more rapid melting and destruction of the ice, owing to the partial breaking up of the attenuated mass as it moved over the very uneven surface. Thus it seems possible that the presence of such hills may have determined the particular line of lower limit reached by the Iowan glacier in this portion of the state. The hills immediately adjacent to the ice margin would receive the deepest deposits of loess or sand which was swept from the surface of the melting glacier by the agencies of wind and water. It is the presence of these deep deposits of loess or sand overlying the ancient hills of Kansan drift which increases to such an extent the altitude of the elevations along the Iowan border above that of the hills over the unmodified portion of the Kansan drift plain, and which makes the transition from the com-

paratively level surface of the Iowan plain to that of the Kansan so abrupt and conspicuous. That the presence of hills determined in some measure the particular line to which the southern margin of the Iowan ice advanced would seem probable from the fact that around the most of its southern border such a line of hills bounds the Iowan plain. Where the ice moved over a level area it advanced further southward, as is shown in the lobe which occupied the valley of Salt creek in the western portion of the county. The cores of the bordering hills are composed of till of Kansan age. In the upper portion of this drift, immediately beneath the covering of sand or loess, there is a zone in which the drift is thoroughly leached of its lime constituent and in which the contained iron is highly oxidized, coloring the till a dark reddish-brown to a depth of two to four feet, the transition being gradual down to the unchanged blue color of the drift below. Recent erosion has in numerous places exposed this leached and oxidized horizon which in all cases conforms to the present contour of the hills. These facts would indicate that the bordering hills were carved by erosion long before the invasion of the Iowan glacier or the deposition of the overlying mantle of loess or sand; that they were present at the time of advance and opposed the onward movement of the Iowan ice.

If they did determine in some measure the distance southward which the Iowan glacier attained, the ice near the margin must have been exceedingly attenuated for its flow to be influenced by such slight inequalities in the surface. If the Iowan ice movement was thus influenced near the margin by the presence of hills we have a possible explanation of why, within a few miles of its border, there are left paha-like hills and pre-Iowan island areas, both overlain by loess, such as appear near the towns of Garrison, Watkins and Norway, and which occur at other places along its southern margin; of why the Iowan border presents such a large number of narrow, digitating lobes, as at Salt creek and at numerous points to the east of Benton county; of why its margin in so many places coincides for some distance with one of the bordering banks of a pre-glacial stream as in the case of Deer creek and Salt creek

in Tama county, and Stein and Prairie creeks in the county of Benton; of why in other cases the Iowan ice seemed to avoid the immediate vicinity of the larger streams, and why it should follow parallel with, but at some distance from, the valley of the Iowa river through the counties of Benton and Iowa.

The Kansan area.—The portion of Benton county over which the superficial drift is of Kansan age has been outlined above. It embraces about forty square miles, twenty-five thousand six hundred acres, in the extreme south and southwest portion of the county. The northern border of this area follows a sinuous line that is approximately parallel with the channel of the Iowa river, and which has an average distance from that stream of about five miles.

As would be expected from its proximity to the river, the Kansan plain is here deeply gashed and trenched by an intricate system of stream channels so that no large undissected upland areas are left in this portion of the county. The wagon roads have in many places no relation to the section lines, but follow the channels of the streams, or wind in a zigzag manner along the tops of the narrow divides. From these ridges the traveler looks off on either side over an almost endless series of hills and ravines. The tops of the elevations rise sixty to eighty feet above the deeper valleys. The slopes are quite steep. The bottom of the smaller runnels are open and their sides are sharply angular, testifying to the activity of erosion at the present time. A comparatively mild type of Kansan drift topography is shown in figure 2.

As is usual throughout a belt some miles in width around the immediate margin of the Iowan plain, the Kansan surface is mostly covered by a heavy deposit of homogeneous, unconsolidated material which is usually composed of loess or occasionally of rather fine-grained, yellow colored sand. This material varies in depth from a few inches to fifteen or twenty feet. All of the area of Kansan drift in Benton county has been modified by the presence of this more recent deposit. At numerous points over the area, the streams have cut their channels through the covering of loess and revealed the presence of the underlying Kansan drift. Such exposures may

be seen along the roadway between sections 13 and 14, and again between sections 14 and 22 of Iowa township; also along the south part of section 34 of Leroy township and at very many other places over the area. These exposures reveal the fact that the loess forms a mantle over the old and deeply eroded Kansan surface duplicating more or less perfectly the configuration of the surface of this underlying drift.

The profound erosion which the region has suffered was practically accomplished during the long period that intervened between the withdrawal of the Kansan ice sheet and the deposition of the loess.

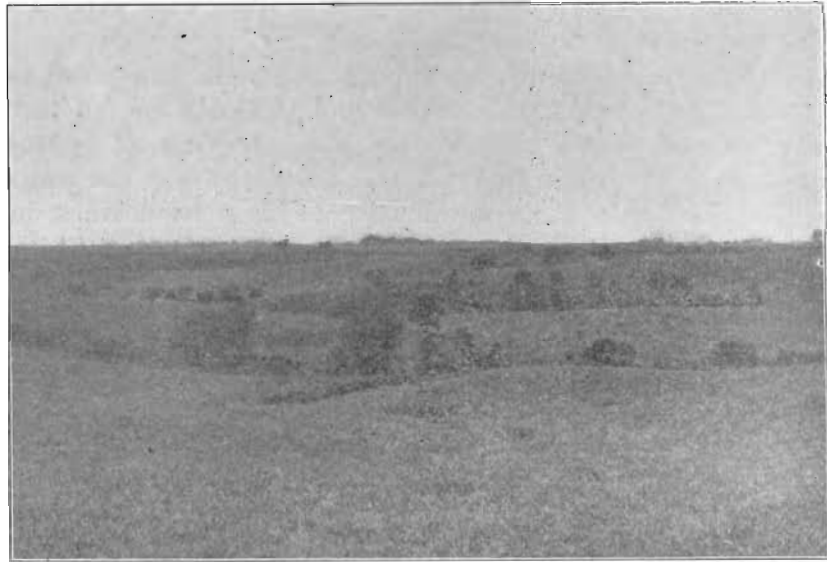


FIG. 2. Mild erosional topography of the Kansan drift area in section 26, Leroy township, one and one-half miles south of Blairstown.

The loess is not of a perfectly uniform depth over the summits and the slopes. Usually the thickness is somewhat greater near the crests of the hills but, as far as the topography is concerned, its presence serves only to enhance the abruptness of the curves, the steepness of the slopes and the height of the hills.

The larger streams of the region flow in valleys of pre-Kansan age. Their waters have swept from side to side in broad curves

and expanded their channels into wide flood plains. The Iowa river in Benton county has developed such a flood plain more than two miles in width. Stein creek flows in the midst of such a plain which is three-fourths to one mile broad, while the smaller streams follow valleys that are exceedingly wide in proportion to the volume of water which they carry.

The Iowan area.—The area in Benton county that was covered by the Iowan ice sheet includes the most of that portion lying to the north of the bordering line of hills traced above. It embraces very much the greater portion of the county. In this region the topography is that of an undulating prairie over which gentle swells and grassy swales alternate in almost endless succession.

Over the most of this region the streams have not yet succeeded in cutting definite channels, nor have they developed any complex system of tributaries. The storm waters escape along ill defined, concave depressions of a marshy character. These have their sources in the saucer shaped basins which are more or less inclosed by the irregular disposition of the swells. Water courses in the form of sloughs or marshes are typical of the Iowan drift topography, and are in striking contrast to the deep and open ravines that form so constant a feature of the Kansan drift surface.

Over all of the Iowan area in Benton county solitary boulders of light colored granite are not infrequent. Some of these are of large size, but usually they are not so numerous or so large as to constitute topographic features of any great importance. Along the western portion of the county the surface is gently rolling, and in the townships of Monroe and Homer it passes into a very slightly undulating, almost level, plain. This type of surface is shown in figure 3. In the southern part of Kane township, the northern portion of Iowa and the northwest corner of Leroy, the surface becomes quite broken. The hills are somewhat subdued and in some places have received a deposit of loess several feet in thickness. Such a deposit of fossil bearing loess is exposed in a cut along the roadside between sections 12 and 13 of Iowa township. Over this area Iowan boulders are quite numerous. The hills are plainly of pre-Iowan origin.

Pre-Iowan erosion was strong here on account of the proximity of the Iowa river. The thin sheet of Iowan ice that invaded the area was not of sufficient depth, it did not carry sufficient materials, nor did its flow continue for a sufficient length of time to level down this deeply sculptured section over which it moved. The loess covering would suggest that the ice disappeared from these hills earlier than it withdrew from the adjacent portions of the Iowan plain.

In Cedar township the undulating prairie surface, dotted with frequent bowlders of respectable size and having numerous marshes occupying depressions between the low, rounded

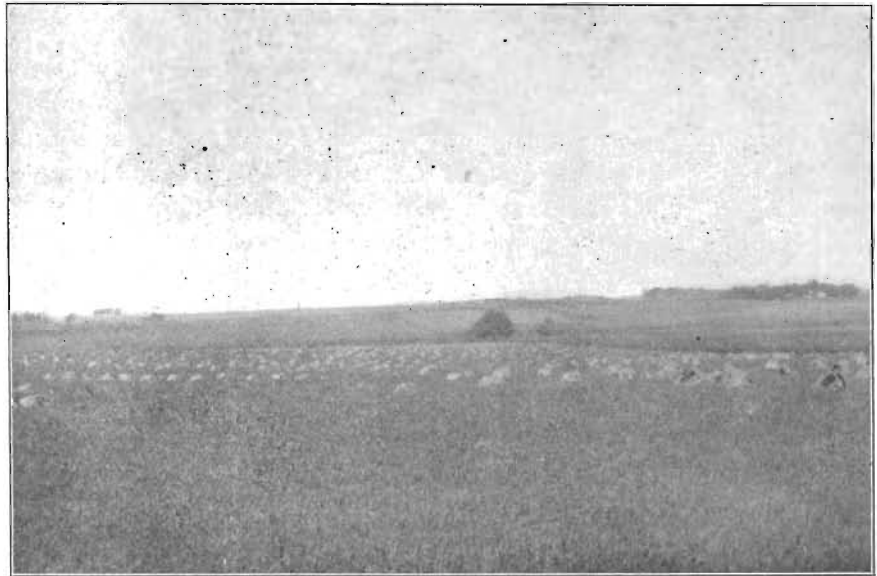


FIG. 3. Prairie landscape over the Iowan drift plain; northwest of Keystone in Kane township.

prominences, extends right up to the bluff that overlooks the west bank of the Cedar river.

In the east-central portion of Monroe township there is an elongated area, embracing about five hundred acres, that appears like an island of loess-covered Kansan standing in the midst of the typical Iowan plain. The long axis of this area extends from the northwest towards the southeast. Its topography is similar to that of the eroded Kansan plain such

as is encountered south of the Iowan margin. The slopes and crests of the hills are mantled with loess, and there is no trace of Iowan drift or Iowan boulders or Iowan ice action to be seen upon it.

Another such peculiar area rises abruptly out of the Iowan plain in the northeast quarter of Big Grove township. This area is more than two miles in length and has a width of one and one-fourth miles. Its axis trends in the same general direction as that of the former. Like the former, too, this area is deeply dissected. The tops of the hills stand forty or fifty feet above the ravines and sixty to seventy feet above the general Iowan surface. Like the former area, also, there is a deep deposit of loess covering the summits and sides of the hills, and there are no Iowan boulders and no indications of any kind to suggest that it had been covered by a glacier since the Kansan age.

When the early settlers came to this county they found these areas forest covered. Groves of native timber still remain over the steeper hillslopes. The presence of such a woodland area within its borders, in the midst of the treeless Iowan prairie, suggested for Big Grove township its name.

These island areas of Kansan features, that were surrounded but not submerged by the Iowan ice, form a part of a discontinuous chain of hills that extends in a southeasterly direction from near the middle of Monroe township to the northeast corner of the township of Florence. The abrupt elevations that overlook the town of Garrison from the northwest are members of this interrupted series. An area of very broken country, one-half mile to one and one-half miles in width, continues this line of hills from near the town of Newhall, in Eldorado township, to the valley of Prairie creek, in the northeast corner of Florence township. These latter hills rise sixty to eighty feet above the general altitude of the Iowan surface. They bear a thin mantle of loess, but, in the main, the rounded character of their contours and the presence of occasional boulders of respectable size testify to a transient visit of a very thin body of Iowan ice. The presence of this peculiar belt of hills extending across the county would indicate that the ice

which moved over that particular area was so thin that it failed to overflow the island areas at all, and that it did not move over the other hills of this belt in sufficient depth and for a sufficient length of time to efface to any great extent their pre-Iowan features.

It is possible that the trend of this chain of hills represents the direction in which the ice-flow advanced and that this line is the result of a single attenuated portion near the frontier of the icy sea. However, it seems certain that the Iowan glacier became generally very thin towards its margin from the frequent occurrence of paha which are but another phase of the phenomena described above.

Paha is a name applied by McGee to isolated prominences that occur near the margin of the Iowan plain, and which were surrounded but not covered by the Iowan glacier. They rise abruptly out of the level prairie. The nucleus of these elevations in Benton county is a hill of undisturbed Kansan till. This drift is buried beneath a mantle of fine-grained, pebbleless material similar to that which crowns the hills along the Iowan border. Such prominences are not uncommon in Benton county and they are even more frequent to the eastward, in the counties of Linn, Cedar and Delaware.

A short distance northwest of the town of Norway an elongated paha ridge, one and one-half miles in length and one hundred rods in greatest width, extends from near the east side of section 13 of Saint Clair township in a southeast direction across section 18, and to near the middle of section 17 of the township of Florence. This conspicuous elevation stands about eighty feet above the surrounding plain. Its axis is a ridge of drift which at the top shows the leached, ferretto character of the old Kansan surface. At the northwest end of this hill the drift is overlain by a bed of loose sand six to ten feet in depth. Passing towards the southeast the material of this mantle becomes finer so that the covering of all but the upper end of the paha is typical loess. From the loess bank at the east end of this ridge Mr. Trojorsky obtains clay for the manufacture of brick and tile.

About one mile northeast of the town of Watkins there is a similar ridge having a trend in the same direction. This paha is fifty to sixty feet in height, three-fourths of a mile in length, and forty rods in width. Near its summit strongly oxidized boulder clay with abundant gravel appears within two feet of the surface, while a mantle of loess, in places seven feet in depth, covers the lower portion of the slopes. In the case of each of these paha, like that of the larger Kansan island areas described above, the ice seems to have been divided by the obstructing hill of drift which at these points probably stood higher than the general altitude of the region. In this manner long crevasses may have been formed in which fine detritus was deposited by wind and water upon the exposed summits of Kansan hills. These isolated prominences would thus escape the leveling action of the Iowan ice, and so be left like a chain of coast islands along the margin of the frozen sea. Under such conditions they would receive their mantle of loess in a manner similar to that of the hills along the Iowan border.

The eminences above described are the only exceptional elevations that break the monotony of the undulating surface in the townships of Florence, Fremont, Big Grove, Jackson and Cedar. Also in Bruce, Union, Eldorado and Eden townships the only digressions from the billowy character of the landscape are the valleys where the larger streams follow pre-Iowan courses which the Iowan drift failed completely to fill. The same may be said of Saint Clair township, with the exception of the small Kansan area in the extreme southern part. The northern portion of Leroy presents similar surface features, as also do the south half of Canton and the north half of Kane townships.

In the northeastern portion of the county, in the proximity of the Cedar river and its larger tributaries, there is an area over which the present topography has been largely determined by æolian agencies. The surface is here quite broken. The hills in many places are crowned with fine-grained materials and rise to a height of fifty to sixty feet above the lower lands. This region is embraced in the Iowan plain, but its surface is modified by exceptional erosion and by the presence of abun-

dant deposits laid down by the winds. In many places numerous large, gray granite boulders are scattered quite thickly over the lower lands and on the flanks of the hills. Boulder-strewn fields are more conspicuous topographic features over this portion of the Iowan drift plain than at any other points in the county. These large granite masses appear incongruous among the trees that still cover the steeper slopes. An example of one of these large boulders, near Shellsburg, is shown in figure 4. The timber groves of white oak and red oak, of elm,

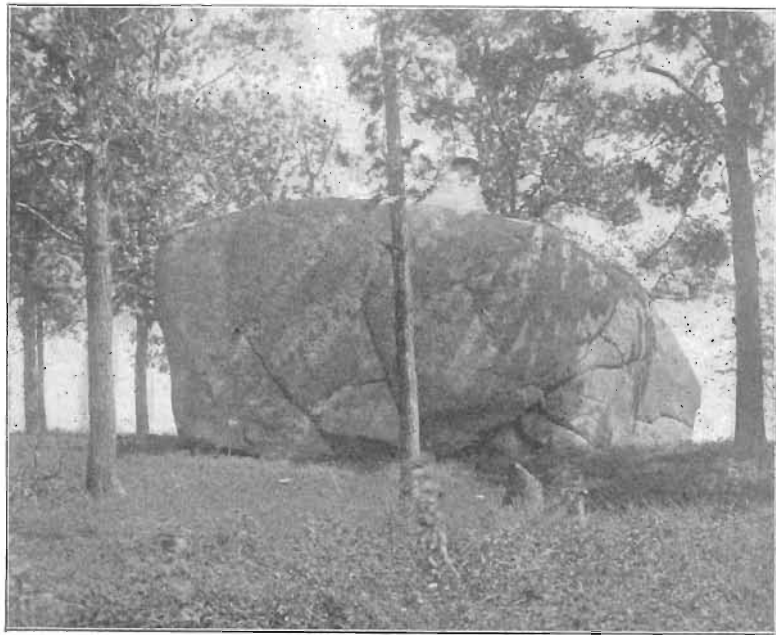


FIG. 4. These large granite masses appear incongruous among the trees which still cover the steeper slopes, near the middle of section 14, Canton township.

hickory, basswood and butternut seem to thrive not a whit less perfectly over this portion of the Iowan plain than on the clay ridges over the rougher portion of the Kansan.

The sand-capped hills have little regularity of form or arrangement, and not infrequently the sparkling water of a beautiful lakelet is nestled at their feet, and mirrors the trees and grasses that fringe their foothills. In Polk township hills of sand occur west and south of the town of Urbana to the

Cedar river, and east and southeast to the Benton county line. In some cases the ridges extend in a general east and west direction and seem to be, in part at least, of the nature of dunes formed by obstructions which checked the velocity of dust laden currents of air during the time of retreat and since the withdrawal of the Iowan ice.

North of Urbana, in Polk township, the level surface of the Iowan plain stretches unbroken up to the northern border of Benton county. South of the Cedar river there is a rugged area lying between that stream and the main line of the old Burlington, Cedar Rapids and Northern railroad, embracing a part of Taylor township, the whole of Benton and the northern portion of Canton. The tops of the sand or loess crowned hills rise fifty to sixty feet above the marshes or basins or valleys that lie between them. In many of these deposits the loess contains fossils. A good exposure of such a fossil bearing bed may be seen in the east-central part of section 34, Benton township.

Where the surface is the most broken a fine forest of second growth timber covers the hills, and it would be well for the people of the county if the woodlands that yet remain might be judiciously preserved. While there is little in the topography of this region to suggest that it had suffered an invasion of the Iowan glacier, yet large bowlders of granite, gray or pink in color, are not rare over portions of this area. Such granite masses may be seen a short distance east of the wagon road near the west side of section 33 of Benton township, and they are especially abundant in the fields on either side of the road passing across the middle of sections 14 and 15 of the same township.

There is an abandoned river channel, one-half mile to one mile in width, that extends in a southeasterly direction from the site of the old town of Benton city, on the Cedar river, to the southeast corner of Benton township. It meets the present channel of the Cedar river again about one-half mile east of the Benton-Linn county border. This old valley is known locally as "Sand Prairie." Beds of sand like river bars abound over the lowlands, and deposits of similar materials crown the summits

of the bordering bluffs that rise to a height of seventy or eighty feet on either side. The Cedar river doubtless occupied this waterway at one time, but for some reason its waters have since carved a deeper and more circuitous channel through resistant Devonian limestone, leaving this abandoned valley a witness to the changes, but affording slight explanation as to the cause of such desertion.

Between Sand Prairie and the Cedar river circular mounds and oblong earthworks of some prehistoric inhabitants are con-



FIG. 5. Lake in the Iowa drift area, section 15, Benton township. The low, bordering hills were, until recently, covered with forests.

spicuous. Numerous stone hatchets, flint arrowheads, scrapers and other implements of early man have been found over the region by Mr. Thomas Carver, of Shellsburg, and other enthusiastic collectors. Near the northwest corner of section 15 of Benton township there is a glacial lake that covers an area of three and one-half to four acres, and which formerly was of much larger size. See figure 5. It is surrounded by low, forest clad hills and is situated one hundred feet above the flood plain of the Cedar river and twenty rods south of the bluff that

borders the valley. About three-fourths of a mile southwest of this lake there are a number of mounds composed of rather fine-grained sand, and disposed in a line along the crest of a divide that is bordered on either side by a deep ravine. Another group consisting of ten or twelve circular mounds arranged about an oblong ridge six or seven rods in length occurs a short distance to the southeast of the lake mentioned above. Excavations in these mounds have furnished a few poorly preserved fragments of human bones. The mounds are probably tumuli where men of a departed race, with a keen sense of the beautiful withal, built the graves of their fathers beside the quiet waters of this charming lakelet, and overlooking the valley of the river where picturesque bluffs of woodland and scarped cliffs of limestone make beautiful its bordering banks.

The area embraced between the bend of the Cedar river and the abandoned valley of Sand Prairie is the scenic portion of the county. For purposes of tillage the land can not be compared with the deep, black soil of the wide prairie that surrounds it at some distance on every side. The steep hillslopes and sand covered crests should never be deforested, nor should the plow of the too enterprising farmer be allowed to convert these uniform slopes into angular trenches and rain washed gulleys. If the more densely wooded portion of this area, so convenient to the towns of Vinton, Shellsburg and Urbana, could be preserved as a picnic ground or public park, accessible to all for purposes of pleasure and recreation and for the beneficent influence which objects of natural beauty so graciously afford, it would prove a constant source of satisfaction and enjoyment to the enlightened people of Benton county.

ALTITUDES.

The following table of elevations, compiled from Gannett's Dictionary of Altitudes in the United States, gives the height above tide of the roadbed at the railway station in the most of the towns of Benton county:

NAME OF STATION.	FEET.
1. Shellsburg	774
2. Atkins	841
3. Norway	792
4. Walford	806
5. Vinton	810
6. Newhall	877
7. Watkins	812
8. Mt. Auburn	863
9. Garrison	859
10. Van Horn	951
11. Blairstown	839
12. Luzerne	897
13. Keystone	883
14. Belle Plaine	824

From an examination of the table of altitudes it will be seen that in the northern part of Benton county the surface slopes towards the southeast, while in the southern portion the inclination is almost due eastward. The highest point of the area is probably in the western part of Monroe township, on the divide between the Cedar and the Iowa rivers. At the town of Dysart, just across the line in Tama county, the altitude is 968 feet. From this point the line of greatest elevation extends in a general southeast direction to Van Horn, thence east to Newhall. It then bends a little south of east, passing about one and one-half miles south of the town of Atkins.

The Shellsburg topographic sheet, published by the United States Geological Survey, gives the altitude along the flood plain of the Cedar river in the eastern portion of Benton county as about 760 feet above the mean sea level, and the elevation of the tops of the hills in that portion of the county at 960 feet. It seems probable that the measure of the extreme range between the highest and the lowest elevations in the county would not much exceed 210 feet.

DRAINAGE.

Two master streams, the Cedar river and the Iowa, control the drainage of Benton county. The northeastern and the southwestern portions of the county are pretty well dissected by stream channels, and consequently have a fairly thorough surface drainage. Over a large portion of the intervening area, however, marshes are not infrequent. Many of the sloughs have not yet been converted into corn fields, nor have all of the swales been properly tiled and put under the plow.

These marshes are the contracted remnants of once larger glacial lakes. They represent the last stages in the passing of these lakes from which the water has been banished by the development of slight drainage, by the shrinking of the ground water, by filling with material borne by the winds and washed by the rains from the bounding slopes, and by the accumulation of the imperfectly decomposed remains of moisture loving plants which for many generations flourished around the shallow margin of these prairie pools.

Some of the marshes still furnish congenial conditions for the growth of cat-tails and rushes. The most of them, however support a luxuriant growth of swamp grass and sedges. During the summer months the uniformly rich, green color of these grassy patches is broken only where a solitary water hemlock spreads aloft its delicate umbels or a swamp milkweed unfolds its purple flowers. Such areas are usually left for native meadow, or fenced and utilized for purposes of pasturage.

The Iowa river.--The Iowa river receives the run-off from an area of about seventy-five square miles in the southwest corner of the county. It enters Benton from Tama county about the middle of the west side of section 31 of Iowa township. It cuts across the southwest corner of this section and enters Iowa county about the middle of the south side of the same section. After passing south for a distance of one-fourth of a mile the channel bends northward and once more enters Iowa township near the southwest corner of section 32. It meanders near the south side of this section for one-half mile, then bending further southward it again leaves Benton county and returns no more to its borders.

Along this portion of its course the river flows in a channel of pre-Kansan age which was probably carved in the indurated rocks before the advent of the Glacial epoch. Wells that have been put down over the flood plain of the Iowa in Benton county show that the preglacial channel was more than two hundred feet deeper than the bed of the present stream. The width of the ancient valley has not been definitely ascertained, but well borings would indicate that it was probably not less than five or six miles. The waters of the present river flow in a broad flood plain nearly two miles in width. The valley is bordered by bluffs of Kansan drift that stand sixty to eighty feet above the bed of the stream. At none of the numerous meanders of the river has the current cut away the bordering hills to such an extent as to expose the indurated rocks which formed the banks of the preglacial valley.

Stein creek.—The only tributary to the Iowa river whose waters are largely collected from Benton county is Stein creek. This stream rises in the ill drained swales of the Iowan plain near the southern border of Kane township. It flows in a southeasterly direction across Iowa township, crossing the county line near the southwest corner of section 36. It drains a few square miles along the south side of the township of Kane, and the greater portion of the surface of Iowa township. Its waters flow in a pre-Kansan valley bordered by hills of drift of Kansan age. At no point in this portion of the county are indurated rocks exposed in the banks of the stream. The channel of Stein creek has a flood plain three-fourths of a mile in width and it is bounded by bluffs sixty feet in height. The hills that form the west bank of the valley are higher and more precipitous than those that border it on the east.

The Cedar river.—The Cedar river enters Benton county, from Black Hawk, near the northwest corner of section 6, township S6 north, range 10 west. It flows for about two miles in a direction a little south of east and then bends nearly due south for a distance of three miles. Along this portion of its journey the waters are confined in a comparatively narrow channel which is bounded for much of the distance by abrupt ledges of limestone. Near the middle of the west side of section 21 of

Harrison township the river bends westward, debouching in a broad, drift bordered valley one and one-half to two miles in width which it follows down to the city of Vinton.

This broad valley continues toward the southeast from Vinton past the town of Shellsburg and beyond the limits of the county. It is bordered on the north by rather abruptly sloping hills, but on the south the bed of the channel merges by a gentle gradient into the undulations of the Iowan plain. Instead of following the direct course in the channel already formed, the bed of which is only a few feet higher than its own flood plain, the Cedar river swings northward at Vinton and continues to flow in that direction up to the southeast corner of section 9 of Taylor township. It then changes to a southeasterly trend for two and one-half miles, when it again bends to the northeast for one mile, and then with a swing to the southeast and east it reaches the old town of Benton City, about the middle of the west side of section 20, Benton township. At this point once more an opportunity was presented for the Cedar river to appropriate an old preglacial channel, the Sand Prairie described above. With inexplicable perversity it again turns aside from the ready formed waterway and choosing the longer course and more difficult route, it swings in a broad curve two and one-half miles farther north, carving a new channel one hundred and twenty-five to one hundred and fifty feet in depth in the hard limestones of the Cedar Valley stage. The river leaves the county near the middle of the east side of section 13 of Benton township. It again meets the preglacial channels not far from the town of Palo, a short distance east of the Benton county line. By the erratic course which it follows from Vinton to Palo the river traverses a journey of eighteen miles to shorten the distance to its mouth by one-half that number of miles. It carves a channel to a depth of more than one hundred feet in hard limestones in order to avoid the shallow cutting and ready erosion that would have been required by the more direct route.

In this peculiar action the Cedar exemplifies the anomalous behavior of many of the rivers of eastern Iowa portrayed so graphically by McGee.* It resembles the course of the

* Pleistocene History of Northeastern Iowa, 11th Ann. Rept., U. S. Geol. Surv., p. 218 *et seq.*, Washington, 1891.

Wapsipincon† a few miles to the northeast, in Buchanan county, and that of the Iowa river‡ about the same distance to the southeast, as described by Professor Calvin.

The cause of such behavior on the part of these rivers can only be conjectured. It seems probable, however, that the explanation must in some way be connected with the invasion of the region by the glaciers. It is probable, too, that in Benton county the Pre-Kansan ice sheet was responsible for the development of the present channel of the Cedar river from the vicinity of Vinton to the village of Palo. The evidence for such an assumption lies in the fact that at several points along this portion of the channel, drift of Kansan age forms the bounding hills and continues down to the fluvial deposits of the flood plain. It may be possible that when the Pre-Kansan ice sheet overspread this region, and while it occupied the old channels between Vinton and Palo, mentioned above, a super-glacial stream cut through the ice and became established over the newer portions of the present channel.

In order that the course of this new stream might be made permanent the ice must have maintained the same position relative to the stream during a sufficient length of time for the water to carve the newer portions of the channel to a depth a little below the altitude at which the surface of the abandoned valleys was left when the ice retreated. In this manner the return of the river to either of the preglacial channels along this particular portion of its course would be prevented.

Prairie creek.—Prairie creek drains a larger area in Benton county than any other tributary to the Cedar river. It rises in the marshes of Kane and Homer townships. It flows a little east of south for a dozen miles, in a direction nearly parallel with the channel of Salt creek, which lies ten miles to the westward, and with the valley of Stein creek nearer at hand. However, instead of continuing parallel with those streams and rendering tribute to the Iowa river, its channel bends abruptly towards the east near the northwest corner of section 16 of Leroy township. It swings two miles to the southward as it crosses near the middle of Saint Clair township, and again

† Calvin: Iowa Geol. Surv. Vol. VIII, p. 210, Des Moines, 1897.

‡ Calvin: Iowa Geol. Surv., Vol. VII, pp. 47-48, Des Moines, 1826.

bends as far to the north as it passes across the township of Florence. From the elbow in Leroy township the channel of Prairie creek maintains a trend that is practically parallel with the valley of the Iowa river up to the point where it leaves the county, near the southeast corner of section 12 of the latter township. Its waters meet those of the Cedar river about a dozen miles further eastward, in Linn county.

Prairie creek has a longer flow in Benton county than any other stream, traversing a distance of over forty miles. It embraces in its basin the larger portion of Kane township, the southern part of Big Grove, the northeast corner of Iowa, practically the whole of Union and Saint Clair, the larger portion of Leroy and Florence and the southern part of Fremont and Eldorado townships. It drains an area of more than one hundred and eighty square miles.

Down to where the stream makes its abrupt bend to the east, in Leroy township, the banks that bound the channel are low, symmetrical hills composed of drift material. From this elbow to the point where the creek leaves the township the broad valley is overlooked on the south by the more abrupt ridges which constitute the Iowan drift border. To the north the slopes rise gently up to the level of the Iowan plain. As the creek passes across Saint Clair and Florence townships the southern boundary of the channel becomes more and more poorly defined, owing to the more southern trend of the ridges of the Iowan drift margin. At the same time the northern limits of the valley become more prominent. Beginning at Watkins the stream is overlooked on the north by the paha ridge above described, and further east by the Norway paha, and still further eastward by the abrupt hills which in the county terminate the discontinuous line of ridges that cuts diagonally across it in a northwest-southeast direction.

Throughout the whole of the eastward flowing portion of its course in Benton county the bed of Prairie creek follows parallel with, and only one to two miles distant from, the divide that separates its basin from that of the Iowa river. Its affluents from the south are short, insignificant branches none of which are of sufficient consequence to merit a name. From the north

it receives tribute from Weasel, Buffalo and Mud creeks, the latter being more than a dozen miles in length.

Prairie creek is a typical representative of a class of streams in Iowa that have developed unsymmetrical basins, the channel of the master stream lying very close to the south side of the area which it drains. In this respect it resembles Wolf creek,* a few miles to the northwest, in Tama county, and also Clear creek and Old Man creek in the county of Johnson†. McGee‡ noticed this peculiarity in the basins of the eastward flowing streams over what he called the loess-drift area in central Iowa. Indeed, so frequently do the east and west coursing streams of Iowa have the longer affluents and the wider tributary area on the north side of their channels that Professor Calvin§ refers to this habit as a law that is generally true of such streams in the state.

Of the other streams that owe allegiance to the Cedar river, and which flow for the greater portion of their course in Benton county, the largest are Blue, Prairie and Bear creeks on the north, and Mud, Bear, Pratt, Hinkle and Rock creeks on the south. These are generally simple, consequent waterways without any complex series of secondary branches. They range in length from ten to fifteen or eighteen miles. They are all prairie streams. Their beginnings can be traced back to the swales and marshy meadows of the Iowan drift plain. Out from those boggy sloughs the water slowly filters, forming perennial springs. These unfailing fountains feed the larger streams with a constant supply of clear, pure water.

For some distance from its source the water follows lazily along shallow, grassy depressions that are bordered by no erosion formed banks. After a few miles each stream becomes established in a wide, partially drift filled valley that was formed prior to the advent of the Kansan glacier, and which neither that ice sheet nor the subsequent Iowan succeeded in completely obliterating. Even here, however, the bed of each of the present streams lies but a few feet below the general

* Iowa Geol. Surv., Vol. XII, p. 205, Des Moines, 1903.

† *Ibid.*, Vol. VII, pp. 49-50, Des Moines, 1897.

‡ Pleistocene History of Northeastern Iowa, p. 411, *et. seq.*, Washington, 1890.

§ Iowa Geol. Surv., Vol. VIII, p. 212, Des Moines, 1898.

NOTE.—For a discussion as to the cause of the development of such one-sided stream basins the reader is referred to volume VII, p. 51, and volume XIII, pp. 205-206, of this series of the Iowa Geological Survey reports.

level of the region through which it flows. Along this portion of their courses there is exposed at rare intervals ledges of indurated rock. Such outcroppings are exceedingly infrequent, however, and are limited to the north half of the county, with the exception of a small area adjacent to the town of Shellsburg.

GEOLOGICAL FORMATIONS.

General Relations of Strata.

That portion of the ancient geological history of Benton county directly accessible to observation is written on the rocks of the Middle Devonian series, while the more recent records are preserved in the deposits of the Pleistocene.

In the Middle Devonian series is included the most of the beds of indurated sediments, the limestones and the shales, which form the foundation upon which the soil and superficial materials of the region are spread. Each successive layer of this foundation was at one time the floor of the ancient sea and makes up a separate page in the history of our land and of its life. Each successive stratum was in part constructed from the ruins of preëxisting lands, and contains the remains of forms of life that peopled the sea as age succeeded age.

Outcrops of these rocks are encountered only in the northern and northeastern portions of the county. Over the southern and southwestern portions they are deeply buried beneath a covering of drift. There is little doubt that the rocks which immediately underlie the till over the most of the southern portion of the area also belong to the Devonian system, while those upon which the drift is spread in the southwestern corner of the county belong to the Kinderhook stage of the Mississippian series.

In the regolith,* or mantle of incoherent, superficial materials is recorded much later chapters in our county's varied and eventful story. The materials of this mantle testify to the long occupation of our area by immense glaciers and to the desolation that followed in their train. They bear witness to the flooded streams and river torrents that accompanied the melting of the ice, and to the long genial period of interglacial conditions that intervened between the successive ages during which arctic winter reigned.

A small part of this rock mantle is composed of the residual products resulting from the degeneration of indurated rocks during the long interval that elapsed between the elevation which closed the deposition of sediments, and the advent of the Pleistocene period. This geest or residuum has, for the most part, been intimately mixed with the many times greater quantity of foreign detritus that was transported by the ice from further north and left as a legacy to the region over which it spread.

The following table shows the stratigraphic position of the geological formations known to be exposed in Benton county:

*Merrill: Rocks, Rock Weathering and Soils, p. 299.

TABLE OF FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic	Pleistocene.	Recent.	Recent.	Swamp } deposits Æolian } Alluvial }
			Glacial.	Iowan.
		Yarmouth.		Buchanan gravels.
		Kansan.		Kansan till.
		Aftonian.		Aftonian gravels
		Pre-Kansan	Pre-Kansan till.	
Paleozoic	Carboniferous.	Lower Carboniferous or Mississippian.	Kinderhook.	Shale.
	Devonian.	Middle Devonian.	Cedar Valley	
			Wapsipinicon.	Fayette. Coggan.

Middle Devonian Series.

WAPSIPINICON STAGE.

From the synoptical table it will be seen that the indurated rocks which are exposed in Benton county belong to the Middle Devonian series, and of this series there are represented the Wapsipinicon and the Cedar Valley stages. Of the deposits of the Wapsipinicon stage the known rocks of the county belong to two sub-stages, the Fayette and the Coggan.

The assemblage of layers that have been grouped under the Coggan sub-stage includes a few feet of buff, magnesian limestone. This bed is usually somewhat massive but not infrequently, especially in the uppermost part, it shows more or less distinct lines of stratification. The name of Coggan was given to this sub-stage by Professor Norton* from the town of that name in the northeastern part of Linn county, at which place the rocks of this horizon are well exposed.

The Fayette sub-stage embraces a group of strata composed of a series of diverse limestones. Some of these are very dense and fine-grained. Others are made up of masses rather coarse in texture. Some contain numerous fragments of brachiopod and molluscan shells, while others are barren of any fossil remains. At some horizons the rocks are of a dark drab color, and at others they are almost white. However, they are all in common more or less completely shattered and brecciated. These beds are well exposed near the town of Fayette where this particular phase of the Devonian strata is typically developed. At this place McGee applied the name Fayette breccia to this series of limestones.

Coggan beds.—The rocks of the Coggan sub-stage are exposed in Benton county along the east side of a narrow ridge for a distance of more than one mile. This ridge is only ten or twelve rods in width. Its top stands about twenty feet higher than the adjacent upland surface, and eighty feet above the bed of Cedar river. Its northeastward facing bluff overlooks the lower portion of the channel of Pratt creek and forms the west bank of the Cedar river for several rods below the point where the waters of the creek and the river meet.

On the west side of the wagon road, near the middle of the east side of section 36, Cedar township, Mr. Wallace has opened a quarry in which is shown the following succession of beds:

*Iowa Geol. Surv., Vol. IV, p. 138.

	FEET.
6. Dark colored soil, fine-grained, without pebbles..	1
5. Bed of light colored, brecciated limestone, the fragments imbedded in a matrix of gray material; without any trace of lamination planes or of fossils.....	12
4. Bed of gray, calcareous shale; without fossils...	2
3. Ledge of massive, yellow colored stone, somewhat arenaceous near the middle, but composed for the most part of impure magnesian limestone; containing no fossils....	6
2. Layer of yellowish-gray, magnesian limestone, fine-grained like No. 1, below; without fossils.	2½
1. Ledge of buff, earthy limestone, very fine-grained, slightly banded in appearance and showing imperfect lines of division into layers eight to ten inches in thickness; without fossils.....	2

The characters of the above layers are illustrated in figure 6. In the section numbers 1 to 3 inclusive represent the Coggan sub-stage as the rocks of this horizon are exposed in Benton county. They are uniformly yellowish-gray in color and very fine-grained, sub-crystalline in texture. In composition they are impure, magnesian limestone. They present the appearance of dolomite, but the process of dolomitization is not so complete but that effervescence is quite prompt upon the application of cold hydrochloric acid. In the rocks of this horizon, in the counties of Linn and Cedar, Professor Norton found a few fossils in the form of casts or moulds, but no traces of fossils in any form were seen in Benton county. Number 4 is a band of gray, non-fossiliferous shale which gradually blends above into the lower portion of the overlying bed of brecciated limestone. In Buchanan county, the Independence shale occupies a position immediately below the deposits of the Fayette breccia. There also occurs in Linn county a bed of shale, designated by Norton as the Kenwood, which occupies a corresponding horizon. It is possible that this narrow shale band, number 4 of the section, represents the attenuated margin of the Independence shale deposit. The thinness of the band, the absence of fossils, and the fact that this is the only known exposure in the county of such a shale horizon render impossible the satisfactory correlation of this member with the Independence shale. It is thought best to consider number 4 at this place as a local de-

velopment of argillaceous material at the beginning of the deposits of the Fayette sub-stage. Number 5 is a thick bed of light colored, thoroughly brecciated limestone in which no sign of bedding planes has been preserved, and which contains no trace of fossils. The face of this ledge shows numerous, small cavities, the cementing material not completely filling the spaces between the angular rock fragments. These fragments

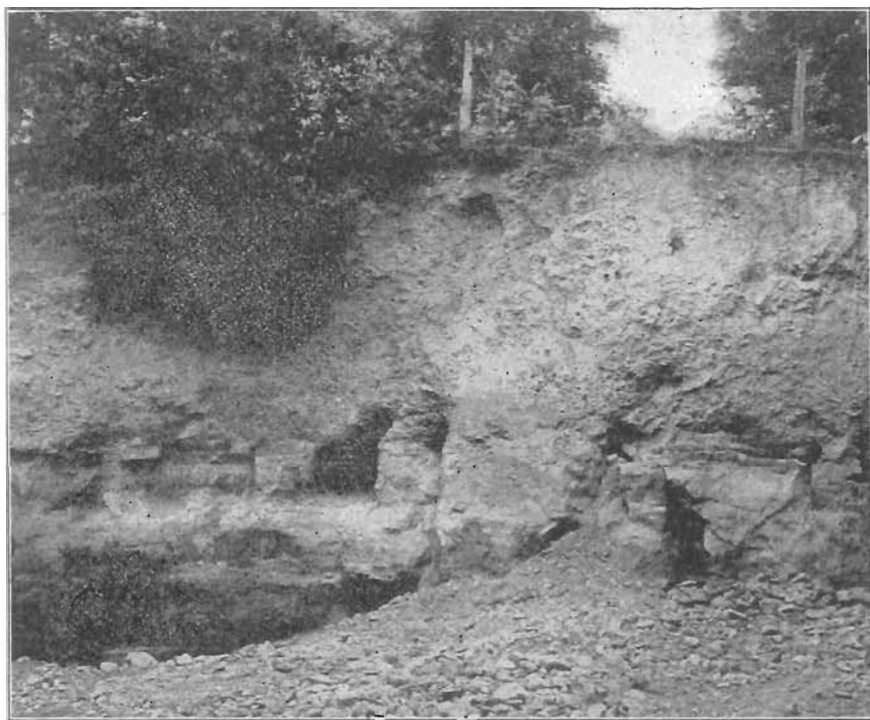


FIG. 6. Exposure in Wallace's quarry, near the southeast corner of section 36, Cedar township. The heavy ledge at the base represents the Coggon beds; the overlying, unstratified materials belong to the Lower Davenport phase of the Fayette breccia.

vary from one or two inches to one foot or more in diameter. They present the appearance of having been coated with quite fluid calcareous mud before the deposit of interstitial material cemented the pieces solidly together. The fragments are composed of very hard, fine-grained, slate colored limestone enclosed in a matrix a little lighter in color.

About three-fourths of a mile southeast of Wallace's quarry, near the southwest corner of section 31 of Harrison township, Aungst Brothers operate a quarry in the west bluff of Cedar river. At this point the following section is shown below the superficial deposits:

	FEET.
2. Brecciated limestone, gray in color, the angular fragments usually small, and very fine-grained in texture; without fossils.....	20
1. Massive ledge of buff, magnesian limestone which is very hard and fine-grained, divided by imperfect lines of bedding into layers one to two feet in thickness; without fossils.....	12

In the above section number 1 is the equivalent of numbers 1 to 3 inclusive of the Wallace quarry section. At this place, however, the stone is more purely dolomitic. It is very dense, almost crystalline in texture, and is of excellent quality for lime burning or general masonry. Mr. Aungst has tunneled beneath the overlying breccia and excavated chambers ten to fifteen feet in depth for a distance of one hundred feet back under the hill. The face of the quarry extends for several rods along the bank of the river. Number 2 of the above section corresponds with number 5 in the section of Wallace's quarry. This member represents the basal portion of the Fayette breccia. In the upper part it probably passes into the Lower Davenport beds of Professor Norton*, which he designates as the second phase of the Fayette breccia. The rocks in the two exposures are quite similar in lithology and in the absence of fossils. The layer of shale, which at Wallace's quarry lies between the magnesian bed at the base and the brecciated limestone above, is wanting in the Aungst quarry exposure.

Fayette breccia.—A low ledge of thoroughly brecciated rock of which the fragments are small and imbedded in a buff colored matrix of coarser texture outcrops in the north bank of Pratt creek, near the southwest corner of section 22 in Cedar township, and at a few other points along the valley of this same

* Norton: Geology of Linn County. Iowa Geol. Surv., Vol. IV, p. 160.

stream. This ledge is also the equivalent of number 2 of the Aungst quarry section, and represents the most northerly extension of the rocks of this horizon in Benton county.

At a point along the Aungst quarry exposure the old Burlington, Cedar Rapids and Northern Railway Company has made a cut through the ridge above mentioned and exposed a vertical height of about thirty-five feet of limestone on either side of the track. The level of the rails in this cut is about the same altitude as the top of the brecciated bed in the Aungst quarry section. The rock exposed in the cut is shattered throughout. This bed together with number 2 of the Aungst quarry section gives a thickness of more than fifty feet of the Fayette breccia at this place. The following section will illustrate the character of the rocks exposed in the cut, although there is no definite line of division between the two members as given below:

	FEET.
2. Brecciated limestone in which the long axes of some of the fragments are four to eight feet in length. The larger masses are a drab color, and lie among smaller, light gray or yellowish fragments, none of which have been cemented together. The following fossils are quite abundant in the larger masses: <i>Spirifer pennatus</i> , the finely-striated, Independence type of <i>Atrypa reticularis</i> , <i>Gypidula comis</i> , <i>Atrypa aspera</i> var. <i>occidentalis</i> , <i>Orthis iowensis</i> , <i>Stropheodonta demissa</i> and a species of <i>Chonetes</i> resembling <i>C. cancellatus</i>	20
1. Brecciated limestone in which the fragments are from a few inches to three or four feet in length, becoming larger and more fossiliferous in the uppermost part. The following fossils were present: <i>Gyroceras</i> sp. <i>Spirifer pennatus</i> , <i>Gypidula comis</i> and the finely-striated form of <i>Atrypa reticularis</i>	13

In the above section number 2 probably represents the *Spirifer pennatus* beds of Calvin which, in the classification of Professor Norton,* constitutes the uppermost phase of the Fayette sub-stage.

Number 1 corresponds with the third phase of the Fayette breccia as defined by Norton in the adjoining county of Linn.†

*Norton: Iowa Geol. Surv., Vol. IV, p. 161. Des Moines.

†Ibid., p. 160.

It includes the Gyroceras beds* as delimited by Professor Calvin in the report on Buchanan county.

The cause and the process by which these brecciated beds were formed are alike somewhat obscure. Professor Geikie† says that true breccias arise from the superficial disintegration of rocks. They may be formed of talus blocks or cliff debris which gradually slide down a slope below an escarpment, or which may be launched forward by a landslide. The materials may accumulate either subaerially, or under water when the cliff descends at once into the sea. In any case the fragments have not been transported any great distance, nor have they been subjected to the action of running water.

The term breccia is also applied to masses of angular rock fragments whose formation is connected in some way with volcanic eruptions, or with the flow of more or less fluid lava subsequent to such eruptions. Breccia has also been formed where strata within the earth's crust have been subjected to strains resulting in movements that produced crushing or dislocation. The angular fragments which originated in any of the above ways may or may not have subsequently been consolidated by the infiltration of some cementing materials.

Professor Norton‡ assumes that the brecciation of the rocks of the Fayette sub-stage in Iowa has probably been accomplished by the crumpling of the strata resulting from lateral pressure. The facts which are revealed in the most of these beds in Benton county are in harmony with such a mode of rock fracture.

There can be traced every gradation of disturbance from that evidenced by the presence of joints without displacement of the rock masses, to that of profound shattering where the beds are made up of fragments of diverse limestones promiscuously intermingled.

In the *Spirifer pennatus* horizon the beds at some exposures are considerably broken, but there is usually small disarrangement of the fragments. Frequent narrow veins of calcite extending in various directions at right angles to the planes of bedding show where small fractures have been healed. At outcrops not far distant the corresponding layers have not been

*Calvin: Iowa Geol. Surv., Vol. VIII, pp. 225-227.

†Geikie: Text-book of Geology, Vol. I, p. 181. 4th Edition.

‡Norton: Iowa Geol. Surv., Vol. IX, pp. 445-446.

disturbed. Lower down there are encountered beds in which the materials are uniformly shattered, as in the lower portion of the Railroad Cut exposure, but it is often possible, even here, to trace the planes of the original layers by the lithological characters of the fragments that occur at the successive levels. Still lower down the rocks are profoundly brecciated and fragments of dissimilar limestones are brought into juxtaposition. Sharply angular pieces of various texture, color and size are cemented together to form the ledges which constitute the Lower Davenport beds of the Fayette breccia. Certain phases of the Lower Davenport breccia seem difficult of explanation by assuming crushing as the mode of formation, and seem to indicate a talus origin. McGee* noticed that the strata which are involved in the beds of the Fayette breccia were confined to those horizons in which the layers show more or less crumpling or distortion. He considers these two phenomena to be related, and suggests that the forces which accomplished the flexing of the strata were the same that caused the brecciation of the beds. The time of such movements he thus fixes at about the close of the period of their own deposition.

The following fossils were collected at the Railroad Cut exposure where the last section was made:

- Fistulipora constricta* Hall.
- Stropheodonta demissa* Conrad.
- Pholidostrophia naerea* Hall.
- Orthothetes chemungensis* Conrad.
- Choneles cf. cancellatus* Calvin.
- Productella subalata* Hall.
- Orthis iowensis* Hall.
- Pentamerella arata* Conrad.
- Gypidula laeviuscula* Hall.
- Gypidula comis* Owen.
- Atrypa reticularis* Linn. Independence type.
- Atrypa aspera* var. *occidentalis* Hall.
- Spirifer pennatus* Owen.
- Spirifer asperus* Hall.
- Paracyclas elliptica* Hall.
- Pelecypods 2 sp's.
- Gyroceras* sp.
- Phacops rana* Green.

* McGee: Pleistocene History of Northeastern Iowa, Eleventh Annual Report, U. S. Geol. Surv., pp. 337-338.

See also Calvin's report on the Geology of Mitchell County, Iowa Geol. Surv., Vol. XIII, p. 316.

In the counties of Cedar and Linn Professor Norton found the Otis limestone and the Independence shales intervening between the Coggan beds at the base of the Iowa Devonian and the Fayette breccia which forms the uppermost member of the rocks of the Wapsipinicon stage. Deposits of the Otis and Independence sub-stages seem to be entirely wanting in Benton county, unless those of the latter are represented by number 4 of the Wallace quarry section.

At the old Bliss quarry, on land owned by the Iowa Paint Company, an exposure in the south bank of Prairie creek, near the northeast corner of section 10, Taylor township, shows the following succession of beds:

	FEET.
5. Shattered limestone, light gray in color, the fragments irregular in shape and size, and containing few fossils.....	8
4. Talus covered ledge.....	12
3. Bed of light gray limestone, in broken layers from three to six or seven inches in thickness; containing <i>Orthis iowensis</i> and <i>Atrypa reticularis</i>	1 $\frac{3}{4}$
2. Ledge of gray limestone made up of imperfect layers two to eight inches in thickness; bearing <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> and two or three species of pelecypods.....	4
1. Rather massive bed of light gray limestone which is cut into rhomboidal blocks by numerous oblique joints, some of which show excellent examples of slickensides. Where exposed the material weathers quite readily into small, irregular fragments. Numerous fossils occur in this member, among which the following are abundant: large, robust forms of <i>Spirifer pennatus</i> , <i>Spirifer bimesialis</i> , <i>Cyrtina hamiltonensis</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>Gypidula comis</i> and, near the base, a species of <i>Gyroceras</i> ..	8

In the above section number 1 represents the *Spirifer pennatus* beds, and it is the probable equivalent of number 2 of the section in the railroad cut above the Aungst quarry exposure. The entire bed is cut by numerous joints and is profoundly shattered, but the position of the fragments has not been greatly displaced nor have the pieces been cemented together. The fractured condition of the bed, the numerous

joints and the presence of slickensides testify to the severe strains and crushing forces to which the strata have been subjected.

Some years ago when the Iowa Paint Company operated at Vinton the material of this lower member of the Bliss quarry was pulverized and used as the basis in the manufacture of paint. The company has since moved its plant to Fort Dodge, and gypsum is now utilized in the place of limestone in their present process of paint manufacture.

Numbers 2 to 5 inclusive in the above section represents the basal portion of the Cedar Valley stage. The fossil content of this zone could not be well made out at this place owing to the large portion of the face of the ledge that was concealed by talus.

CEDAR VALLEY STAGE.

Near the northwest corner of section 27 of Taylor township, a quarry has been opened in the east bank of Mud creek, on land owned by Mr. Quinn. At this place the following succession of layers is exposed:

	FEET.
10. Dark colored soil, fine-grained and without pebbles.....	½
9. Gravel and sand, stained a reddish-brown color.	2
8. Bed of limestone composed almost wholly of fragments of corals among which the following forms are abundant: <i>Acerularia davidsoni</i> , <i>Cladopora iowensis</i> , <i>Favosites</i> sp., <i>Cystiphyllum americanum</i> , <i>Ptychophyllum versiforme</i> and <i>Cyathophyllum</i> sp., together with numerous teeth of <i>Ptyctodus calceolus</i>	5
7. Layer of rather hard, gray limestone which weathers into thin pieces, and contains numerous crinoid remains, besides <i>Favosites</i> sp., <i>Cyathophyllum</i> sp., <i>Orthis iowensis</i> and <i>Spirifer parryanus</i>	3
6. Bed of very hard, light gray limestone which upon weathering shows layers four inches to one foot in thickness, and contains <i>Spirifer fimbriatus</i> , <i>Spirifer pennatus</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>Atrypa aspera</i> var. <i>occidentalis</i> , species of <i>Cladopora</i> and <i>Favosites</i> together with large teeth of <i>Ptyctodus calceolus</i> .	6

	FEET.
5. Layer of very hard, gray colored limestone composed largely of fragments of brachiopod shells among which the following are conspicuous: <i>Orthis iowensis</i> , <i>Spirifer pennatus</i> , <i>Atrypa reticularis</i> and <i>Atrypa aspera</i> var. <i>occidentalis</i> . Species of <i>Cladopora</i> and <i>Favosites</i> were also seen.....	1½
4. Layer similar to number 5 above but with the shells more finely comminuted	1¼
3 Zone of drab colored limestone in the form of a second coral reef which is less compact and not so crowded with coral remains as number 8 above. The member contains <i>Aceroularia profunda</i> , <i>Favosites</i> sp., <i>Cystiphyllum</i> sp., and <i>Cyathophyllum</i> sp., besides <i>Orthis iowensis</i> and <i>Spirifer pennatus</i>	1
2. Bed of fine-grained, white limestone which shows a bluish tinge in a fresh ledge, containing numerous nodules of chert, and weathering into layers from a few inches to two or three feet in thickness. This member is much shattered in places, and contains the following fossils: crinoid fragments, <i>Atrypa aspera</i> var. <i>occidentalis</i> , <i>Spirifer pennatus</i> , small individuals of <i>Stropheodonta demissa</i> , large teeth of <i>Ptyctodus calceolus</i> and a large species of <i>Gomphoceras</i>	13
1. Layer of very hard limestone, bearing chert nodules and containing remains of crinoids, together with <i>Favosites</i> cf. <i>placenta</i> , <i>Favosites</i> sp., <i>Cyathophyllum</i> sp., <i>Atrypa reticularis</i> , <i>Atrypa aspera</i> var. <i>occidentalis</i> , <i>Spirifer bimrisialis</i> , <i>S. pennatus</i> , <i>Cyrtina hamiltonensis</i> , <i>Orthis iowensis</i> and teeth of <i>Ptyctodus calceolus</i>	1½

In the above section numbers 1 and 2 probably belong to the horizon of the *Spirifer pennatus* beds. Together these members correspond with number 2 in the Railroad Cut exposure and with number 1 of the Bliss quarry section. The stone is quite hard and fragments of broken disks and plates of crinoids are not rare throughout the portion of the bed that is exposed. The rocks of this horizon are represented in figure 7. They are quite variable in exposures not widely separated. At some points they are undisturbed and quite hard, but generally they are much shattered. At the Quinn exposure the stone from

this member is the most durable that the quarry produces. It is used extensively in the town of Vinton for foundation work and rough masonry.

Number 3 represents the *Acervularia profunda* zone which occupies a position at the very base of the Cedar Valley stage. It is the probable equivalent of the Phillipsastrea horizon in the adjacent county of Buchanan, although that coral was not seen in the area under consideration. Associated with *Acervularia profunda* at Quinn's quarry are *Cystiphyllum* sp., *Cyathophyllum* sp., *Favosites* sp. and a spherical *Stroma-*

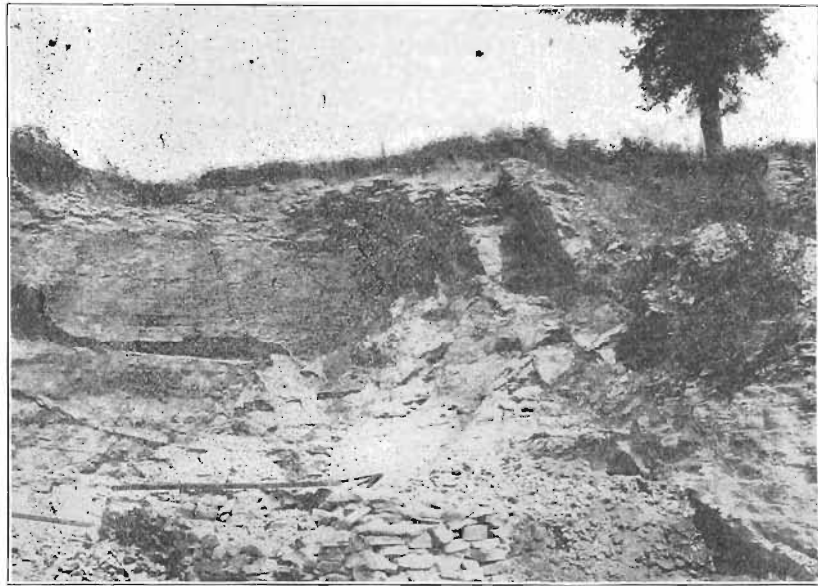


FIG. 7. Exposure of the lower portion of the Cedar Valley limestone in the Quinn quarry, near Vinton. The *Acervularia davidsoni* coral reef appears at the top.

toporoid. This coral-bearing bed marks quite a constant horizon twelve to fifteen feet below the *Acervularia davidsoni* coral reef wherever the deposits of the lower portion of the Cedar Valley stage are exposed in Benton and the neighboring counties.

Numbers 4 to 7 inclusive are composed of layers of firm, gray limestone which are made up largely of fragments of brachiopod shells and coral remains. The adjacent layers are generally

separated by narrow partings of calcareous shale. Of the fossils that are characteristic of these beds *Orthis iowensis*, *Atrypa reticularis* and a species of *Cladopora*, resembling *C. iowensis* Owen, are found throughout all of the members. *Acerularia davidsoni* and *Spirifer parryanus* are not infrequent in number 7, while *Spirifer pennatus* and *Atrypa aspera* var. *occidentalis* are common in the lower members.

Number 8 is the reef of corals composed in large part of coralla of *Acerularia davidsoni* with which are associated *Favosites alpenensis*, *Favosites* sp., *Cladopora iowensis*, *Cystiphyllum americanum*, *Cyathophyllum* sp., *Heliophyllum halli* and *Ptychophyllum versiforme*. At this place the corals are not so closely crowded and the reef is not so compact as it is further north and west in Benton county, the average thickness being about twenty-four inches.

This zone, which will be designated as the *Acerularia davidsoni* coral reef, is one of the best marked and most constantly and uniformly developed layers of the Cedar Valley limestone in the state. It appears at this particular horizon in the counties of Scott and Muscatine, to the southeast, in Buchanan and Howard counties to the northward, and to the east and west as far as the rocks of this stage are typically developed in Iowa. This uniformly present and easily distinguished horizon will be taken as a convenient standard of reference for the layers of the rocks of the Cedar Valley stage in Benton county.

Near the north line of sections 14 and 15 of Taylor township the flood plain of the Cedar river is bounded on the north by an escarpment fifty to sixty feet in height. The ledges in the face of this bluff are mostly concealed by Kansan drift, but there are occasional outcrops where rocks appear at the surface. At the very top of this scarp the weathered edges of the uppermost layers of limestone appear somewhat interruptedly through the till for a distance of more than one mile.

Mr. Pettit has opened a quarry in the northwest quarter of section 14, near the base of the bluff mentioned above. The rocks at this place are yellowish colored limestone, not greatly disturbed. They contain numerous fossils, among which the following forms are not rare: *Spirifer pennatus*, *Atrypa*

reticularis and very large forms of *Orthis iowensis*, besides fragments of several individuals of a loosely coiled species of *Gyroceras*. There is exposed at this place a vertical height of about ten feet. The horizon is that of the *Gyroceras* beds which belong to a zone immediately beneath the beds of *Spirifer pennatus*.

Some rods further west in the same bank there is exposed a ledge about twenty feet in height which occupies a position nearly midway between the base and the top of the bluff. The character of the rocks at this point appears in figure 8. They consist of light gray limestones which are much brecciated

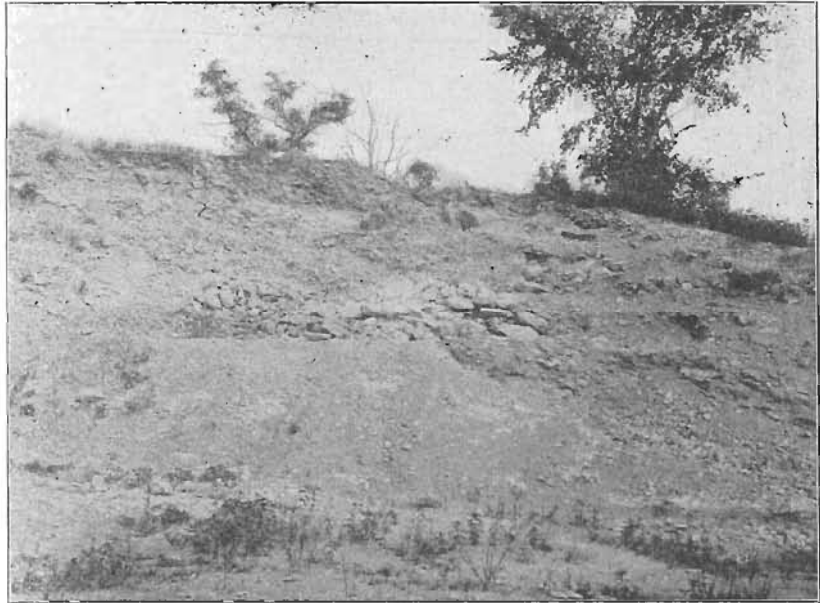


FIG. 8. View of the *Spirifer pennatus* beds at the most westerly exposure in the east bluff of the Cedar river valley, section 15, Taylor township.

throughout the thickness of the outcrop. In the lower portion of this exposure, which lies about ten feet above the top of the Pettit quarry section, there occur in abundance, large and robust forms of *Spirifer pennatus*, and numerous individuals of the finely striated-form of *Atrypa reticularis* with widely extending lamellæ, similar to the type that occurs at Independence.

With these fossils are associated *Spirifer bimesialis*, *Gypidula comis* and large shells of *Orthis iowensis*. In the upper half of this exposure *Spirifer pennatus* becomes less abundant, the form of *Atrypa reticularis* becomes more coarsely ribbed, *Orthis iowensis* continues but the individuals are of smaller size. There appear besides the above species numerous individuals of the variety *occidentalis* of *Atrypa aspera*. The rocks exposed at this point belong to the *Spirifer pennatus* horizon which constitutes the uppermost member of the Fayette sub-stage.

About eight rods east of this place there is exposed, near the top of the bluff, a thickness of about thirteen feet of evenly



FIG. 9. Exposure in an abandoned quarry, section 15 of Taylor township. The *Acerularia davidsoni* coral reef appears at the top. The view shows the character of the layers between this coral reef and the zone of *Acerularia profunda*.

bedded, gray limestone, shown in figure 9. At the very top of this bed there is a layer about two feet in depth composed almost wholly of coral remains. Prominent among these are beautiful colonies of *Acerularia davidsoni*, *Favosites alpenensis*, numerous

individuals of Favosites sp. *Cystiphyllum americanum*, *Heliophyllum halli*, *Ptychophyllum versiforme*, besides an undetermined species of *Cyathophyllum* and of *Stromatopora*. At the top of this layer the coralla are weathered free from the limestone matrix and are much iron-stained, indicating that the reef may originally have been thicker than at present. The upper portion of this bed doubtless suffered degradation through the agencies of weathering before it was covered by the protecting mantle of drift.

Below the coral reef the limestone is in regular layers which vary from a few inches to two or three feet in thickness. The fossils, *Spirifer parryanus* and *Cladopora iowensis* occur immediately below the reef, while *Orthis iowensis*, *Atrypa reticularis* and the varieties of *Atrypa aspera* are abundant in the layers in the lower part of the exposure.

The layers that can be seen at this place correspond with numbers 4 to 8 inclusive of the section of Quinn's quarry. They are all slightly flexed, but they were not involved in the brecciation and disturbance that so profoundly affected the underlying beds which outcrop a few rods west of this place.

From these exposures it is evident that the layers of limestone through which the waters of the Cedar river have cut during the course of development of this portion of its channel are embraced between the *Acervularia davidsoni* coral reef at the top, and the *Gyroceras* beds at the base. These layers include the lower representatives of the rocks of the Cedar Valley stage and the uppermost members of those of the Wapsipinicon. All of the rocks exposed in Taylor township adjacent to the town of Vinton, as well as the most of those which outcrop further eastward, in the vicinity of Shellsburg, find their equivalent in some portion of the beds embraced between the two members mentioned above.

Near the northwest corner of section 22, Taylor township, in the corporate limits of the town of Vinton, Mr. Rosenberger has opened a quarry which is at present operated by the city. At this place the following section was observed below the surface materials:

	FEET.
3. Bed of light colored limestone, in rather regular layers a few inches to one foot in thickness. These layers contain <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>Atrypa aspera</i> vars. <i>hystrix</i> and <i>occidentalis</i>	6
2 Layer of gray limestone in which coralla of <i>Acervularia profunda</i> , an undetermined species of <i>Cystiphyllum</i> and a spherical form of <i>Favosites</i> are not infrequent.....	1
1. Bed of light gray limestone, much shattered and brecciated, in some places showing indistinct planes of bedding; containing the fossils; <i>Spirifer pennatus</i> , <i>Gypidula comis</i> , <i>Gypidula laeviuscula</i> , <i>Atrypa reticularis</i> , <i>Atrypa aspera</i> var., <i>Pentamerella arata</i> , <i>Dielasma iowensis</i> and <i>D. romingeri</i> , besides a gastropod resembling a species of <i>Pleurotomaria</i>	14

In this section number 1 corresponds with the shattered zone described as the *Spirifer pennatus* beds at the most westerly exposure in the Cedar river bluff, in Taylor township. It is the equivalent of number 2 of the Quinn quarry section. The rocks of this horizon are usually more or less shattered or disturbed wherever in the county they are exposed. Number 2 above is the equivalent of number 3 in the Quinn quarry exposure. The presence of *Acervularia profunda* in this member makes it an easily recognized zone immediately overlying the beds of *Spirifer pennatus*. Number 3 of the Rosenberger section is the correlative of number 6 in the section of Quinn's quarry.

In the extreme eastern portion of the county there are exposed rocks which introduce a horizon a little higher than those at the Rosenberger quarry. The following section was made a short distance southeast of Shellsburg, on land owned by Mr. Dwigan. The quarry is in the south bank of Bear creek, near the middle of section 14 of Canton township:

	FEET.
9. Dark gray soil, without pebbles or boulders.....	1½
8. Reddish-brown clay containing numerous pebbles of trap and quartz, and occasional boulders of granite.....	2
7. Ledge made up of layers of much decayed, gray limestone through which numerous water passages have been formed by solution and erosion.....	3

	FEET.
6. Layer crowded with coral remains, among which coralla of <i>Acervularia davidsoni</i> are predominant. <i>Favosites alpenensis</i> , <i>Favosites</i> sp., <i>Cystiphyllum americanum</i> and <i>Ptychophyllum versiforme</i> also are not rare.....	2½
5. Layer of light gray limestone which weathers into thin chips, and contains <i>Spirifer parryanus</i> and <i>Cladopora iowensis</i>	1½
4. Ledge of hard, brachiopod limestone, gray in color, in some places forming a single layer and in others showing an indefinite line of separation into two parts. Fragments of the fossils <i>Orthis iowensis</i> and <i>Atrypa reticularis</i> are very abundant.....	4
3. Bed composed of two layers, each about twenty inches in thickness. This limestone is dark-gray in color and contains numerous remains of <i>Atrypa reticularis</i> , <i>Atrypa aspera</i> var., <i>Orthis iowensis</i> , <i>Spirifer pennatus</i> , <i>Cladopora iowensis</i> and a species of <i>Cyathophyllum</i>	3½
2. Layer of shelly, gray limestone, similar in color and texture to number 3 above, and containing similar fossils.....	1
1. Bed composed of three layers of limestone, respectively 1½ and 2 feet in thickness. These layers carry the following fossils: <i>Spirifer pennatus</i> , <i>Atrypa reticularis</i> , <i>Atrypa aspera</i> var., <i>Orthis iowensis</i> , <i>Stropheodonta demissa</i> and, in the lowermost layer, coralla of <i>Acervularia profunda</i> , and of a species of <i>Cyathophyllum</i> and of <i>Favosites</i>	4½

In the above, which will be referred to as the Dwigan quarry section, numbers 1 to 5 inclusive represent the successive layers of limestone that normally intervene between the *Acervularia davidsoni* coral reef and the zone of *Acervularia profunda*. *Spirifer parryanus* occupies a definite position in the layer immediately below the main coral reef. *Cladopora iowensis* Owen (*Striatopora rugosa* Hall) is generally associated with *Spirifer parryanus*, but it is also abundant throughout the layers for a depth of five or six feet below the zone of that *Spirifer*. Number 6 represents the coral reef of the *Acervularia davidsoni* horizon. Its development here and its coral content are consistent with that of the *Acervularia davidsoni* reef at this particular well marked horizon at other points in the state. It is the equivalent of number 8 of the Quinn quarry section,

and corresponds with the uppermost layer that appears in the north bluff of the Cedar river valley, in sections 14 and 15 of Taylor township.

Number 8 is a bed of Kansan drift so shallow that the atmosphere has more or less completely effected the oxidation of its iron content throughout the entire depth. Number 9 is a dark colored soil that has been formed upon the surface of the till. It is rarely that the drift is exposed at the surface in Benton county except upon hillslopes where the fine-grained overlying material has been removed by erosion. This homogenous deposit is probably a wind blown substance that was laid down above the drift in a manner similar to that of the loess in this portion of the state. The dark color of the soil band is due to the accumulation of carbonaceous matter which has resulted from the decay of countless generations of plants during the centuries through which vegetation has flourished upon the present surface.

About one mile east and seven miles north of Dwigan's quarry, there is exposed a vertical escarpment of limestone forty-two feet in height. In this cliff, which is known locally as Wild Cat bluff, there are presented layers of the Cedar Valley limestone which lie above any of the beds that outcrop around Shellsburg or in the immediate vicinity of Vinton. The ledge is on land owned by Mr. Broaddy, and is located near the middle of section 10 of the congressional township of Benton. It forms the north bank of the Cedar river about twenty rods west of the wagon bridge across that stream. At this place the following section is exposed:

- | | FEET. |
|---|-------|
| 12. Homogeneous, fine-grained material, dark gray in color throughout the greater portion of its depth. This pebbleless soil has slipped down from above, concealing the face of the bed of drift that normally underlies the soil band.... | 4 |
| 11. Bed of impure, yellowish-brown limestone which weathers into layers four to eight inches in thickness. Between the layers are frequently intercalated narrow bands of chert nodules and quartz geodes. This bed contains disks of crinoid stems, besides the shells of <i>Spirifer subvaricosus</i> , a large <i>Spirifer</i> resembling <i>S pen-natus</i> and, in its lower portion, the very large, coarse-ribbed variety of <i>Atrypa reticularis</i> ... | 6 |

	FEET.
10. Bed of yellowish, impure limestone which weathers into thin, fissile fragments and carries the fossils <i>Stropheodonta demissa</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , the large <i>Spirifer</i> somewhat resembling <i>S. pennatus</i> and a species of coral belonging to the genus <i>Cyathophyllum</i>	5
9. Bed of hard, gray limestone which weathers into layers two or three inches to one foot in thickness, and contains fossils similar to those found in number 10 above.....	3½
8. Layer crowded with coralla of <i>Acervularia davidsoni</i> , <i>Favosites alpenensis</i> , and the other corals usually associated with these in the main coral reef.....	2
7. Layer of hard, gray limestone, containing numerous fragments of crinoid stems together with the fossils <i>Spirifer parryanus</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>Cladopora iowensis</i> , <i>Acervularia davidsoni</i> and an undetermined species of <i>Favosites</i>	1½
6. Bed made up of three layers of gray limestone, each about sixteen inches in thickness, containing <i>Cladopora iowensis</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> and a <i>Spirifer</i> much like <i>S. pennatus</i>	4
5. Bed of gray limestone composed of four layers, respectively six, seven, eight and twelve inches in thickness; carrying fossils similar to those found in number 6, together with <i>Atrypa aspera</i> var. <i>occidentalis</i>	2½
4. Bed of white limestone, in three imperfect layers each about four inches in thickness; containing fossils similar to those found in number 5, besides fragments of bryozoans and shells of <i>Orthotheses chemungensis</i>	1
3. Ledge of gray limestone, containing in abundance the fossils <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>A. aspera</i> var. and <i>Spirifer pennatus</i> ...	4½
2. Massive layer of dark gray limestone, composed of coarse fragments of brachiopod shells among which those found in number 3 above are predominant; with these are associated undetermined species of corals belonging to the genera <i>Favosites</i> and <i>Cyathophyllum</i>	5½
1. Bed of light gray limestone, less rich in fossils than the overlying layers; containing <i>Spirifer pennatus</i> , <i>Orthis iowensis</i> , <i>Atrypa aspera</i> var. <i>occidentalis</i> , <i>A. reticularis</i> and a species of <i>Cyathophyllum</i>	6½

In the above section, which may be referred to as that of the Wild Cat bluff, number 1 probably corresponds with the upper portion of the *Spirifer pennatus* beds. Although there is no brecciation or disturbance in the rocks of this member, yet the fossils occurring here are not inconsistent with those found near the top of the Wapsipinicon stage. The relation which this bed sustains to the overlying coral-bearing zone would also indicate its position at the upper part of the *Spirifer pennatus* horizon. This member is the equivalent of number 2 of the Quinn quarry section, and corresponds with the upper part of number 1 of Rosenberger's quarry. At Wild Cat bluff the bank below number 1 is talus covered for a distance of twenty-two feet, down to the water's edge. Number 2 probably represents the zone of *Acervularia profunda*. Although no coralla of *Acervularia profunda* were found at this exposure, corals usually associated with that fossil are abundant in number 2. This member is easily correlated with number 3 of the Quinn quarry section, with number 2 of the Rosenberger quarry, and with number 1 of the section at Dwigan's quarry, near Shellsburg.

The *Acervularia profunda* zone is quite constant in Benton county at a horizon about twelve feet below that of the *A. davidsoni* reef, but in the exposure at Wild Cat bluff there is present a thickness of about nineteen feet of Cedar Valley limestone below the reef of *Acervularia davidsoni*. In Taylor township the position of this coral reef is only about thirteen feet above the base of the Cedar Valley stage. In Buchanan county, farther north, a still less vertical distance separates the *Spirifer pennatus* beds from the coral reef, while to the southward, in Johnson county, a thickness of forty-eight feet of limestone intervenes between the *Acervularia davidsoni* horizon and the base of the Cedar Valley stage. The members 3 to 6 inclusive, at this place, resemble the rocks seen at the corresponding horizon at other points in Benton county. The material is quite hard, and occurs in rather regular layers. It is largely composed of more or less perfectly comminuted fragments of brachiopod shells. The assemblage of fossils which characterize these layers includes very numerous individuals of

Atrypa aspera var. *occidentalis* associated with which are *Atrypa reticularis*, *Orthis iowensis* and *Spirifer pennatus*. While the fossil *Spirifer pennatus* is quite uniformly present in these members it does not occur here in such abundance as it does lower down in the proper *Spirifer pennatus* zone. At this higher horizon, too, the cardino-lateral margins of the shells of this species are usually prolonged into relatively wide extensions. Number 4 contains fragments of the shells of *Orthothes chemungensis*; and in number 6 the coral *Cladopora iowensis* is abundant. The shells of *Orthis iowensis* found in these layers are very much smaller and less flaring than those of the individuals of this species in numbers 1 and 2 of this same section.

Number 7 represents the typical development of the layer which immediately underlies the *Acervularia davidsoni* coral reef. The diagnostic fossil of this layer is *Spirifer parryanus*. Associated with this species there also occur *Cladopora iowensis*, *Orthis iowensis*, *Atrypa reticularis*, occasional coralla of *Acervularia davidsoni* and of a spherical species of *Favosites*, the latter corals being introduced a short distance below the coral reef proper. Number 8 represents the *Acervularia davidsoni* reef with its usual assemblage of corals. Many of the coralla at this place have weathered out of the soft, shaly matrix so that exceptionally perfect and beautiful specimens are exposed.

In the absence of any contrary indications Professor Geikie* assumes that these Paleozoic limestone building corals, like their modern representatives, flourished only in the seas where the minimum temperature never fell below 68° Fahr. If this assumption be true, the constant and uniform development of the coral zones of the Devonian system in Benton county, and in our state, would testify to the prevalence of a much more genial and uniform temperature in our latitude during the ages of the Devonian through which these deposits were being formed. That these ancient corals, like their present relatives, flourished best in seas where the waters were contaminated by no mechanical sediments is indicated by the fact that in the coral zones like the *Acervularia davidsoni* reef the coralla

* Geikie: Text Book of Geology, 4th Ed., 1903, p. 943.

form a compact layer. The interstices only are occupied by calcareous, shaly material which may readily have been derived from the coral masses by the attrition incident upon the action of the waves before the materials became consolidated.

It seems certain that the growth of the Devonian corals was restricted by some special conditions of existence from the abruptness with which the reef species give place to other fossils in the layers immediately above and below the narrow coral horizon.



FIG. 10. Exposure of Cedar Valley limestone in the east bank of the Cedar river, a short distance south of Long's quarry, Harrison township.

Numbers 10 and 11 of the last section are composed of impure, earthy limestone, yellow in color and rather fine-grained in texture. They contain numerous nodules of chert which are often arranged in more or less definite bands. Geodes of quartz are also abundant in these beds. The characteristic fossil of number 11 is the very large, coarse-ribbed variety of *Atrypa reticularis*. The shells of this species are here three inches in length and about as wide as long. The surface is

marked by very coarse striae as compared with the ornamentation of the forms of normal size. The constant occurrence in this zone of such a remarkable form of *Atrypa reticularis* renders the identification and correlation of this member an easy task. It marks a definite horizon about nine feet above that of the *Acervularia davidsoni* reef in the deposits near the middle portion of the Cedar Valley stage. In numbers 10 and 11 there also occur shells of a large *Spirifer* which resembles in some respects *S. pennatus*, *Spirifer subvaricosus*, and large forms of *Stropheodonta demissa* which are considerably wider than long.

Near the northwest corner of section 9, Harrison township, the Cedar river sweeps with a broad curve to the southward. At this place the force of the current has been directed against the bank which bounds the valley on the east. The river here is bordered for several rods by a ledge of limestone fifty feet in height. See figure 10. This exposure below the drift affords an exceedingly instructive section which is given below:

	FEET.
10. Bed of fine-grained, impure limestone, yellowish in color, made up of regular layers from three to twelve inches in thickness, which carry but few fossils, but contain abundant small concretions of chert.....	13
9. Bed of dense, gray, fine-grained limestone which is crowded with detached shells of a large <i>Spirifer</i> and <i>Camarotoechia</i> cf. <i>prolifera</i> . Occasional shells of <i>Atrypa reticularis</i> and <i>Cyrtina hamiltonensis</i> are also present.....	$\frac{1}{2}$
8. Bed of impure, magnesian limestone, in layers from two to twenty inches in thickness, yellowish-brown in color, and carrying but few fossils. Nodules of chert are abundant in this member.....	10
7. Bed of limestone, variable in color, separable into a number of indefinite layers, yielding but slowly to the action of the atmosphere; containing the fossils, <i>Favosites</i> sp., <i>Rynchonella</i> sp., <i>Spirifer</i> sp., and teeth of <i>Ptyctodus calceolus</i> . Near the top occurs the very large, coarse-ribbed form of <i>Atrypa reticularis</i>	7 $\frac{1}{2}$

	FEET.
6. Reef composed largely of coralla of <i>Acervularia davidsoni</i> , containing also the species of <i>Cyathophyllum</i> , <i>Ptychophyllum</i> , <i>Cystiphyllum</i> and <i>Favosites</i> that usually occur in this zone	3½
5. Layer of gray limestone which contains <i>Cladopora iowensis</i> , <i>Favosites</i> sp., <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>Productella subalata</i> , <i>Pentamerella dubia</i> , <i>Spirifer parvyanus</i> and very large tritons of <i>Ptyctodus calceolus</i>	4
4. Bed made up of two layers of hard, shelly limestone, respectively sixteen and twelve inches in thickness. This bed carries the fossils found in number 3 below, together with <i>Cladopora iowensis</i> , <i>Cyathophyllum</i> sp., six-rayed spicules of sponge, four different species of bryozoa, <i>Stropheodonta demissa</i> and a species of <i>Orthothetes</i>	2½
3. Layer of gray limestone, almost a brachiopod coquina, in which there occurs in abundance the remains of <i>Spirifer pennatus</i> , <i>Atrypa aspera</i> var. <i>occidentalis</i> , <i>Atrypa reticularis</i> and <i>Orthis iowensis</i>	3
2. Regular layers of rather hard, gray limestone, not broken or disturbed, and bearing numerous fossils, among which are <i>Acervularia profunda</i> , <i>Favosites</i> sp., <i>Cyathophyllum</i> sp., <i>Cladopora</i> sp., <i>Stromatopora</i> sp., <i>Stropheodonta demissa</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , the var. <i>occidentalis</i> of <i>Atrypa aspera</i> , <i>Productella subalata</i> , <i>Chonetes</i> sp. and a thin shell belonging to the genus <i>Dielasma</i>	2
1. Bed of light gray limestone, somewhat shattered and brecciated, containing the fossils <i>Stropheodonta demissa</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>Atrypa aspera</i> var. <i>occidentalis</i> , <i>Spirifer pennatus</i> and a species of <i>Gomphoceras</i> , exposed to the water's edge	3

In the above, which may be designated as the Cedar River section, number 1 represents the gray, brecciated limestone near the upper part of the *Spirifer pennatus* beds. It is the equivalent of the upper portion of number 1 of the Bliss quarry section, and corresponds with the upper part of number 1 at the Rosenberger quarry. The fossil *Gypidula comis*, which is characteristic of this zone, was not found at the Cedar River exposure.

However, the limited area of the rocks here exposed makes it possible that it may be present at this place, although not detected. The rocks are thoroughly shattered and much displaced in a manner typical of the Fayette breccia horizon.

Number 2 is the *Acervularia profunda* bed which constitutes the basal member of the Cedar Valley stage in Benton county. The elegant coral, *Phillipsastrea billingsi* Calvin, whose large and beautiful colonies are often associated with *Acervularia profunda* at this horizon in Buchanan county, was not seen at any point in the county of Benton. This member is easily correlated with number 3 of the Quinn quarry section, with number 2 of the Rosenberger quarry, and with number 2 of the exposure at Wild Cat bluff.

The members 3 to 5 inclusive, of this section, contain the typical fossils and represent the normal development of the limestones that intervene between the *Acervularia profunda* zone and the *Acervularia davidsoni* coral reef. They find their ready correlative in the beds that lie between those two horizons at all points in the county where these rocks are exposed. Number 6 is the *Acervularia davidsoni* reef which is universally present at this horizon in this county, and in the most of the other counties of eastern Iowa that are crossed by the Cedar river.

Number 7 embraces the bed of variable limestone that, for a few feet in height, normally overlies the coral reef. The presence of the very large, coarsely-striated type of *Atrypa reticularis*, which occupies a position near the top of the bed, makes it possible to assign this member to its proper place in the series of the Cedar Valley limestones, even where the well marked reef which underlies it is not exposed. The upper portion of this member is the equivalent of the lower portion of number 11 in the Wild Cat bluff exposure. The layers that lie between the zone containing the large, coarse form of *Atrypa reticularis* and the coral reef are quite variable in their development. The sediments of which they are formed were probably laid down at no great distance from shore, on a sea bottom where the wave action was vigorous, at times, but more or less inconstant. Shells of a large species of *Spirifer* are frequently

found associated with the large type of *Atrypa reticularis* in the exposures in Benton county.

The layers included in number 8 are evenly bedded, impure limestones which are yellowish in color, fine-grained in texture and contain but few fossils. In the quarries that are opened along the Cedar river in the northern portion of the county, the equivalent of the layers in number 8, and the beds which overlie that member, furnish the best stone that the county affords, with the exception of the limited amount of the Coggan limestone described above.

The thicker layers of this member were originally of a blue color. In some of these the change to yellow has been accomplished only for a thickness of three or four inches adjacent to the planes of bedding, leaving a narrow band of unchanged blue color in the middle portion. The materials of these beds are quite hard and the natural ledges show a good degree of resistance to the disintegrating agencies of the atmosphere where they have been long exposed to the weather.

Number 9 is a narrow layer of very hard, fine-grained limestone. It is gray in color and contains in great abundance a large, undescribed species of *Spirifer*. With this species were associated *Cyrtina hamiltonensis*, *Camarotoechia* cf. *C. prolifica* and a small form of *Atrypa reticularis*. This narrow band is quite constant in its lithology and fossil content over all of the northern portion of Benton county. It furnishes a valuable means of correlation, and marks a definite horizon about ten feet above the zone of the very large, coarse type of *Atrypa reticularis*.

Number 10 is made up of a number of layers of dense, fine-grained limestone of variable thickness. In some of the exposures the layers are composed of yellow, magnesian materials, while at other points not far distant they are light gray, almost pure, limestones without any trace of the magnesian character. Chert nodules are abundant in this bed. Sometimes they are segregated along the planes of stratification so as to form a narrow band, and again they are scattered indiscriminately through the materials of the different layers. At this place the

strata that are exposed in the bluff dip to the south at the rate of about twelve inches in a distance of forty feet.

Just across a ravine a few rods further up the river, Mr. Long has opened a quarry in this ledge, near the southwest corner of section 4 of Harrison township. The beds which he has worked are shown in figure 11. They are embraced between the *Acermlaria davidsoni* coral reef at the base and the layers

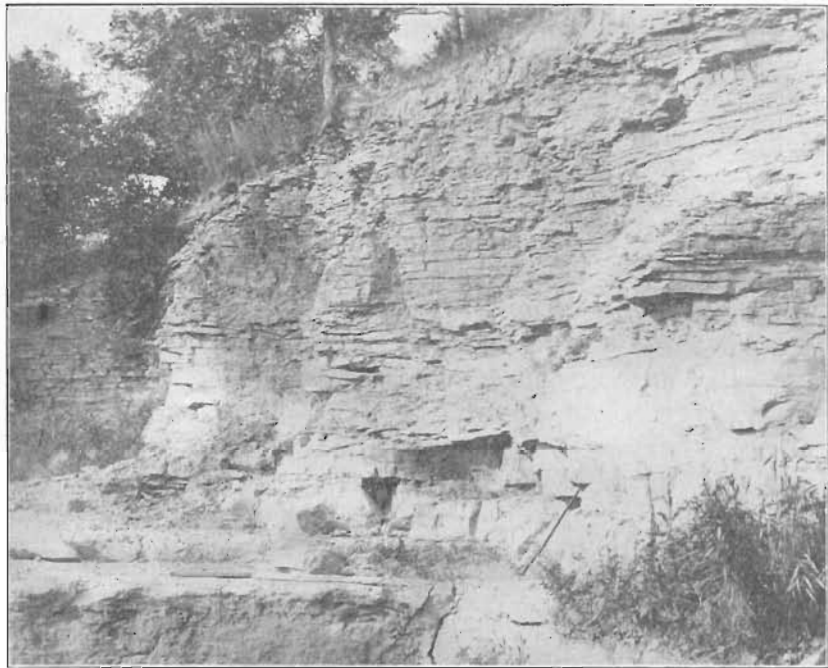


FIG. 11. Long's quarry in the east bank of the Cedar river, section 4 of Harrison township. The thick ledge at the base contains the large, coarse-ribbed *Atrypa reticularis*. The narrow layer near the middle, marked No. 2 on the right, represents the *Camarotoechia* zone.

at the top which constitute the uppermost portion of number 10 in the Cedar River section. About seven feet above the floor of the quarry the large form of *Atrypa reticularis* is encountered. With this fossil also occurs a large form of *Spirifer*, as in the exposure at Wild Cat bluff. About ten feet above the zone of the large *Atrypa* there occurs a narrow layer of gray, fine-grained limestone which is crowded with shells of

an undescribed species of *Spirifer* and a *Camarotoechia* resembling *C. prolifica*. This layer is the equivalent of number 9 of the Cedar River section.

Intervening between the horizon of the coarse *Atrypa* and the narrow zone containing *Camarotoechia* and *Spirifer* sp., there occurs about ten feet of regularly bedded, yellow limestone which is the equivalent of the layers constituting number 8 of the Cedar River exposure. The materials of these layers at Long's quarry are fine-grained, impure limestone, containing numerous chert concretions. In cross section the thinner layers are yellow in color throughout, as are also the thicker ones with the exception of a narrow band of blue in the middle portion. It is probable that all of these layers were originally a blue stone, and that they have been changed to a yellow color through the action of the chemical agencies of the atmosphere and of percolating waters. The stone from this bed is of durable quality. It occurs in layers of such thickness as to be conveniently worked, and it can be quarried in blocks of almost any size desired. Some of the material in the abutments of the bridge that spans the Cedar river near the north line of the county came from the layers of number 8 at Long's quarry. At this place the narrow, *Camarotoechia* zone is succeeded by a bed of limestone about twelve feet in thickness, which is the equivalent of number 10 of the last section presented. The rocks of this uppermost bed resemble those of the corresponding horizon in the Cedar River section in the thickness of the layers, in the color and texture of the materials, in the abundance of chert nodules, and in the scarcity of fossils.

About two miles south of the Cedar River exposure Mr. George Knapp has opened a quarry in the bank which borders Minnie Estima lake on the east. This lake is a lagoon or ox-bow cut-off lying in the flood plain of the Cedar river, in section 16 of Harrison township. At this place the following layers are exposed below the drift:

	FEET
4. Bed of light gray limestone, in layers from three to nine inches in thickness. In some cases partings of soft, gray shale separate adjacent layers. The material is fine-grained, and contains numerous concretions of chert and but few fossils.....	9
3. Layer composed almost wholly of chert nodules which vary from two to three inches to over one foot in long diameter.....	2½
2. Bed of gray limestone which weathers into a number of rather indistinct layers, two to eight inches in thickness; containing <i>Stropheodonta demissa</i> , <i>Spirifer</i> sp., and the very robust, coarsely-striated variety of <i>Atrypa reticularis</i> ..	3
1. Ledge of hard, gray limestone which weathers into thin bits, and contains a large species of <i>Spirifer</i>	2

In the above section the presence of the very large form of *Atrypa reticularis* in the second member determines that horizon as the equivalent of the upper portion of number 7 of the Cedar River section, and of the lower portion of number 11 of the Wild Cat bluff exposure. With respect to number 2 the other members of the section are readily assigned their proper places in the Cedar Valley series. The position of number 1 is about three or four feet above the *Acerularia davidsoni* reef, while numbers 3 and 4 inclusive correspond with number 8 of the Cedar River section.

Some rods to the north of Knapp's quarry, near the north end of the same lake, Mr. McKinley has taken out stone from layers which correspond with number 4 of the Knapp quarry section. In both of these exposures the rocks which belong to the horizon of number 4 above are fine-grained, gray limestones which contain no fossils. Chert nodules are abundant in these beds, as they are in the corresponding layers of the Cedar River and the Long quarry exposures. At McKinley's quarry, too, the layers dip to the south at about the same angle as those described in the Cedar River section.

Directly across the river, and about one-half mile west, from McKinley's quarry the water of the Cedar washes the foot of a ledge of limestone twenty-five feet in height. This bluff is on

land owned by Mr. Kirkland, and is located near the northeast corner of section 17 of Harrison township. The section of indurated rocks shown here is as follows:

	FEET.
9. Bed of light gray limestone, fine-grained, in layers two to eight inches in thickness; containing no fossils.....	4
8. Bed made up of three layers of hard, fine-grained limestone, each about ten inches in thickness. These layers are light gray in color, and are without fossils.....	2½
7. Layer of dense, gray limestone which weathers into bands one and one-half to three inches in thickness; without fossils.....	1½
6. Bed of light gray, fine-grained limestone, in layers two to eight inches in thickness; bearing no fossils.....	4
5. Layer of white limestone, very hard, fine-grained, and containing no fossils.....	1½
4. Bed of impure limestone gray in color, in two layers, one and one-half and two feet in thickness respectively, which weather into thinner laminae. This bed carries no fossils, but contains numerous concretions of chert.....	3½
3. Layer of light yellow, magnesian limestone, fine-grained and quite hard. Nodules of chert are abundant, but fossils are wanting.....	1
2. Bed of gray limestone which is imperfectly separated into three layers. Chert nodules are numerous throughout the bed. Near the top occur in abundance fragments of shells of a large Spirifer and Camarotoechia, cf. <i>C. prolifica</i>	5
1. Bed of yellowish-brown, magnesian limestone, fine-grained and very hard; bearing no fossils but containing masses of chert; to water's edge.....	2½

In the above section the horizon readily recognized is that of the upper portion of number 2, which contains fossils similar to those of number 9 in the Cedar River section. The members 3 to 8 inclusive, of the Kirkland section, correspond with the barren beds embraced in number 10 of the Cedar River exposure. At the Kirkland quarry the material of which these beds are composed is a much purer carbonate of lime than that

of the layers constituting number 10 in the Cedar River section. Number 9 above probably represents a zone higher in the Cedar Valley series than any previously noted in the county. Number 1, together with the major portion of number 2 in the Kirkland section, corresponds with the upper portion of number 8 of the Cedar River section, with the upper portion of the Knapp and McKinley quarry sections, and with the upper part of number 11 of the Wild Cat bluff exposure. The development of the members represented in the Kirkland section is not much different from that in the exposures on the east side of the river. The beds of this horizon become more yellow in color, and carry a much larger proportion of earthy impurities further to the northward, as is seen at Long's quarry and in the Cedar River section given above. This fact is also strikingly shown in an exposure in the west bank of the Cedar river near the north line of Benton county.

This ledge is a short distance below the river bridge, near the northwest corner of section 6 of Harrison township. The quarry is owned by Mr. Keiser, and presents the following succession of layers:

	FEET
12. Dark colored, fine-grained, pebbleless soil.....	1
11. Bed of reddish-brown clay, containing numerous pebbles of quartz and greenstone with occasional granite boulders of larger size.....	2
10. Layer of much decayed fragments of brown limestone, without fossils.....	3
9. Bed composed of two layers of yellow, earthy limestone, each about eight inches in thickness, fine-grained and without fossils.....	1½
8. Bed of gray limestone which weathers into thin layers about one inch in thickness, without fossils.....	3
7. Layer of very hard, earthy limestone, yellow in color and fine-grained in texture; fossils wanting.....	5
6. Bed made up of layers of buff, earthy limestone two to six inches in thickness, which are fine-grained in texture and non-fossiliferous.....	3½
5. Layer of yellow, impure limestone which weathers into indistinct layers three to six inches in thickness; without fossils.....	1½
4. Layer similar to number 5 above.....	2

	FEET.
3. Yellowish-brown layer of fine-grained, impure limestone; carrying occasional concretions of chert which are most numerous adjacent to the planes of bedding.....	2½
2. Layer of variable, impure limestone, fine-grained and very hard. Near the base of this layer chert nodules are abundant, and shells of a large form of <i>Spirifer</i> and <i>Camarotoechia</i> cf. <i>prolifera</i> are very numerous.....	2
1. Bed made up of two layers of buff, earthy limestone in which, at irregular intervals, occur bands and numerous masses of chert, without fossils; to base of the exposure which is about four feet above the level of the water.....	4

The layers in this quarry are cut by numerous, oblique joints which divide the ledge into large rhombic masses. The material of which the beds are composed is mostly a fine-grained, earthy limestone. Many of the layers are strongly magnesian, and some of them are so thoroughly dolomitic that they respond but slightly to the application of cold hydrochloric acid. The entire ledge is regularly bedded, and furnishes quarry stone of convenient dimensions and durable quality.

In the section of Keiser's quarry, number 2, the only member that contains fossils, furnishes the key to the correlation of the beds. From the identity of their fossil contents the lower portion of number 2 is considered the equivalent of the upper portion of number 2 of the Kirkland quarry section, and it corresponds with number 9 in the Cedar River exposure. The numbers 3 to 10 inclusive of the Keiser section are the equivalent of the beds embraced by the numbers 3 to 9 of that at the Kirkland quarry. They are also the relative of number 10 of the Cedar River section. Number 1 of the Keiser quarry section corresponds with number 1 of Kirkland's quarry, and with the upper portion of number 8 of the Cedar River section.

Still further north, in Buchanan county, the materials which compose the rocks of this horizon preserve the yellow color and the earthy, magnesian character that distinguish them in the northern portion of Benton.

The most westerly exposure of indurated rocks in Benton county, as far as is known, is on land owned by Mr. John Tripp,

near the northwest corner of section 17 of Cedar township. This quarry is opened on the south side of the wagon road along the east bank of Rock creek. At this place, too, the beds are cut by very numerous joints, and they are inclined strongly towards the south.

The section exposed below the superficial materials is as follows:

	FEET.
4. Bed of yellow, earthy limestone, fine-grained and without fossils, made up of irregular layers which are not continuous throughout the few rods in length of the exposure	6
3. Bed of buff, fine-grained, magnesian limestone, composed of layers four to eight inches in thickness, without fossils	3
2. Layer of impure, yellow limestone which is fine-grained, and contains fragments of several fossils in a poor state of preservation	1½
1. Bed of buff colored dolomite, made up of two layers, each about eighteen inches in thickness; without fossils.....	3

In this quarry the rock is more or less perfectly dolomitic throughout. It is fine-grained, subcrystalline in texture, and is uniformly of a deep yellow color. The lithology of these layers is unlike that of any beds seen elsewhere in the county. Number 2 of the section contains fragments of the following fossils which furnish the only means of assigning the layers to their proper place in the deposits of the Cedar Valley stage:

Cladopora iowensis Owen.

Favosites sp.

Cyathophyllum sp.

Cystiphyllum sp.

Stropheodonta demissa Conrad. Large, broad forms.

Atrypa reticularis Linn. Coarse forms, but not so robust as the largest type.

Spirifer sp. Large individuals.

Plectodus calceolus Newberry and Worthen. Large tritons three inches in length; also concave teeth, and large fish plates, 6x2 inches.

None of the above fossils are diagnostic of a definite zone. *Cladopora iowensis* occurs most abundantly immediately above, or a short distance below, the *Acerrularia davidsoni* coral reef. This form of *Spirifer* is not infrequently found at the same horizons in Benton county. *Atrypa reticularis* also occurs both above and below the above mentioned reef, but when found below the reef it is almost invariably accompanied by *Orthis iowensis*, which latter fossil did not appear at Tripp's quarry. At this place, too, the *Atrypa reticularis* was larger and more

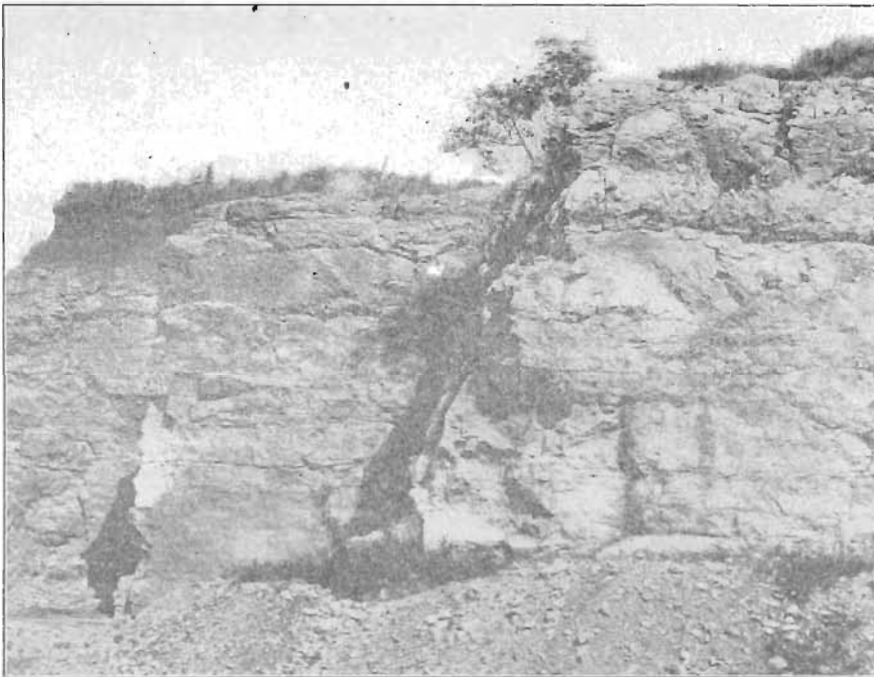


FIG. 12. Exposure in the abandoned quarry on Hinkle creek, near Garrison. The *Stromatopora* reef appears near the top. The rocks here represent the uppermost layers of Cedar Valley limestone found in Benton county.

strongly marked than the form normally occurring below the coral reef, although it was not so robust and coarsely-ribbed as the typical form at the horizon about eight feet above that zone. The large, broad form of *Stropheodonta demissa* normally occurs a short distance above the coral reef, while occasional

coralla of the other corals found in this member might be encountered either above or below the *Acerularia davidsoni* horizon. If the position of these rocks was immediately below the coral reef, they would probably contain the fossil *Spirifer parryanus*. If they represent a zone some distance below the reef they would almost certainly contain *Atrypa aspera* var. *occidentalis* and *Orthis iowensis*.

From the above considerations it seems probable that the rocks exposed at Tripp's quarry represent a dolomitic phase of the Cedar Valley limestones belonging to a horizon not far above the *Acerularia davidsoni* coral reef. Number 2 in the section would then be the equivalent of number 2 of the Knapp quarry section, and would correspond with the upper portion of number 7 of the Cedar River section, and with the lower portion of number 11 of the Wild Cat bluff exposure.

An exceedingly interesting rock exposure occurs about nine miles south and two miles east of John Tripp's quarry. This outcrop is near the southeast corner of section 28 of Jackson township, about one-half mile east of the town of Garrison. See figure 12. At this place stone was formerly quarried in large quantities for the Burlington, Cedar Rapids and Northern railroad. The ledge was worked in the south bank of Hinkle creek, just south of the track and east of the railroad bridge across that stream. A section at this abandoned quarry shows the following succession of layers:

	FEET.
10. Fine-grained, pebbleless material, dark gray in color at the top, grading down to yellow in the middle and lower portions.....	3
9. Bed of reddish-brown clay, containing numerous pebbles and occasional boulders.....	2
8. Ledge of light gray, subcrystalline limestone, very hard and somewhat brecciated, containing numerous spherical Stromatoporoids.....	3
7. Massive ledge of dense, gray limestone, composed largely of various species of Stromatoporoids and masses of <i>Idiostroma</i> -like stems, few of which can be recognized. This bed is also somewhat brecciated in places; and contains fragments of <i>Dielasma iowensis</i> , <i>Gypidula laeviuscula</i> and casts of <i>Straparollus cyclostomus</i>	6

	FEET.
6. Ledge of hard, gray limestone which weathers into two indistinct layers, and contains masses of spherical Stromatoporoids.....	3½
5. Bed of very hard, white, subcrystalline limestone, without fossils.....	1½
4. Ledge of yellowish-gray, non-fossiliferous limestone which is fine-grained and very hard. The upper portion bears numerous small cavities, the largest of which are nearly one inch in diameter.	4
3. Bed of dense, gray limestone, fine-grained and very resistant to weathering; without fossils....	3¼
2. Bed composed of several layers of very hard, fine-grained limestone, white in color and without fossils. The layers are six to fifteen inches in thickness.....	5½
1. Bed made up of two layers of yellowish-brown limestone which are respectively two feet and one and one-half feet in thickness. The material is fine-grained, and contains no fossils.....	3½

The above will be designated as the Garrison section. It seems probable that all of the layers that are encountered in this quarry lie above the zone of the uppermost layers that are exposed in the quarries in the northern portion of the county. Numbers 6 to 8 inclusive are the only members of the Garrison section that contain fossils. In these layers were found numerous masses of spherical Stromatoporoids, and indistinct, branching structures which resemble stems of *Idiostroma*, together with casts of the gastropod, *Straparollus cyclostomus*.

In the upper portion of the deposits of the Cedar Valley stage, in Johnson county, there occur layers whose lithological characters resemble those of the members 6 to 8 inclusive of the above section, and which carry similar fossils in great abundance. It seems probable that the beds embraced in the numbers 6, 7 and 8 of the Garrison section correspond with those of the above mentioned horizon in Johnson county, and that these layers in the Garrison exposure represent the uppermost series of the Cedar Valley limestone, as the deposits of that age are developed in the county of Benton as well as in Johnson.

The materials of which these members are largely composed are light colored, very hard and exceedingly fine-grained. The brecciated or fractured portion consists of sharply angular frag-

ments of this fine-grained material, from one-half inch to two inches in length, which are firmly cemented together by an interstitial deposit of calcite, or by a matrix of very fine-grained, subcrystalline stone. Small, irregularly shaped cavities are not infrequent in this brecciated portion. In some places the fractured material once carried an abundance of fossils, but the disturbance which resulted in the shattering of the beds, and the subsequent action of percolating water from which the interstitial materials were derived, have resulted in the destruction to a very large extent of the fossils which the beds originally contained.

Like the *Acervularia davidsoni* coral reef, at a horizon several feet lower, this Stromatoporoid reef forms a well marked and persistent zone in the upper portion of the Cedar Valley stage over the most of the area in which those rocks are exposed in the state. Besides its occurrence at points in Benton and Johnson counties, already mentioned, this bed of Stromatoporoids overlies the lithographic limestone horizon in Mitchell county. It constitutes the "coral marble" of Charles City and Marble Rock, in Floyd county. Its materials compose number 4 of the general section* of the Cedar Valley limestones in Cerro Gordo county, and it outcrops near Cedar Falls and at other points along the Cedar river in the county of Black Hawk.

The members 3 to 5 inclusive, of the Garrison section, are made up of light colored, very hard and fine-grained limestone which contains no fossils. It seems probable that they are the equivalent of the layers of lithographic limestone which occur a short distance below the Stromatopora horizon, further north, in the county of Mitchell.

General Cedar Valley section.—From the sections described above, a general section of the limestones of the Cedar Valley stage in Benton county might be constructed as follows:

*Iowa Geol. Surv., Vol. VII, p. 160.

	FEET.
9. Bed of light colored limestone, very hard and fine-grained, made up of layers from three to six feet in thickness, brecciated in the upper part and containing numerous Stromatoporoïds together with <i>Gypidula laeviuscula</i> , <i>Dielasma iowensis</i> and casts of <i>Straparollus cyclostomus</i>	12½
8. Bed composed of dense, light gray, fine-grained limestone which is very resistant to the agents of weathering, and contains no fossils, in layers one-half foot to four feet in thickness..	14½
7. Regularly bedded, fine-grained, non-fossiliferous layers which in some places are impure, magnesian limestone, yellowish-brown in color, and in other places are a gray colored carbonate of lime. The layers vary from a few inches to one or two feet in thickness. Concretions of chert are frequent in the lower portion of this bed.....	18
6. Narrow zone of hard, fine-grained limestone, which is usually light gray in color, and contains in abundance disjoined shells of an undescribed species of Spirifer, <i>Cyrtina hamiltonensis</i> , a small form of <i>Atrypa reticularis</i> and numerous individuals of <i>Camarotoechia</i> cf. <i>C. prolifica</i>	½-1
5. Bed of impure, magnesian limestone, yellowish-brown in color and fine-grained in texture, without fossils, made up of rather regular layers which vary from two to twenty inches in thickness, and which contain numerous nodules of chert.....	10
4. Bed of variable limestone, the color of which is not constant, and the texture and lithology of which vary at points not widely separated. The following fossils occur in this bed: Favosites sp., Rhynchonella sp., Spirifer sp. and teeth of <i>Ptyctodus calceolus</i> . At a constant position near the top the very large and coarsely-striated form of <i>Atrypa reticularis</i> is found.....	7½
3. Coral reef composed largely of coralla of <i>Acerularia davidsoni</i>	2

- | | FEET. |
|---|-------|
| 2. Bed of gray limestone, composed of quite regular layers and carrying numerous fossils throughout. The characteristic species are <i>Cladopora iowensis</i> , <i>Stropheodonta demissa</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>A. aspera</i> var. <i>occidentalis</i> , <i>Spirifer pennatus</i> near the base, and <i>Spirifer parryanus</i> near the top..... | 10-15 |
| 1. Bed of hard, gray limestone, which bears numerous fossils, among which <i>Acerularia profunda</i> , <i>Favosites</i> sp., <i>Stropheodonta demissa</i> , <i>Orthis iowensis</i> , <i>Atrypa reticularis</i> , <i>A. aspera</i> var. <i>occidentalis</i> and <i>Productella subalata</i> are conspicuous..... | 2-3 |

From the above general section it will be seen that there is exposed in Benton county a maximum thickness of more than eighty feet of limestones belonging to the Cedar Valley stage. There is a thickness of fifty feet intervening between the Stromatoporoid bed and the *Acerularia davidsoni* coral reef. In Johnson county these two zones are separated by a thickness of only about ten or twelve feet of sediments. The deep bed of yellow colored, magnesian limestone that is so conspicuous a feature of the rocks of this horizon in Benton county does not seem to be represented in the Cedar Valley deposits further southward. To the north in Cerro Gordo county, however, this group of strata attains a development nearly similar to that found in the county under discussion.

The layers which underlie the coral reef are much more uniformly fossiliferous than those which occur above that zone. The following fossils represent a few of the forms of life which peopled this particular portion of the Devonian sea during the age when the above sediments were being laid down:

Astræaspongia hamiltonensis? Meek and Worthen.
Cyathophyllum sp.
Heliophyllum halli Ed. & H.
Ptychophyllum versiforme Hall.
Acerularia davidsoni Ed. & H.
Acerularia profunda Hall.
Cystiphyllum americanum Ed. & H.
Favosites alpenensis Winch.
Favosites sp. spherical.
Favosites sp. ramose.

Cladopora iowensis Owen.
Cladopora magna Hall and Whitf.
Aulopora sp.
Stromatopora sp.
Monticulipora sp.
Fenestella sp.
Stropheodonta demissa Conrad.
Pholidostrophia nacrea Hall.
Orthothetes chemungensis Conrad.
Chonetes scitulus Hall.
Productella subalata Hall.
Orthis iowensis Hall.
Pentamerella dubia Hall.
Pentamerella arata Conrad.
Gypidula læviuscula Hall.
Cyrtina hamiltonensis Hall.
Spirifer fimbriatus Morton.
Spirifer sp.
Spirifer parryanus Hall.
Spirifer pennatus Owen.
Spirifer subvaricosus Hall and Whitf.
Athyris vittata Hall.
Atrypa reticularis Linn.
Atrypa aspera var. *occidentalis* Hall.
Atrypa aspera var. *hystrix* Hall.
Camarotoechia prolifica? Hall.
Bellerophon sp.
Straparollus cyclostomus Hall.
Conularia sp.
Paracyclas elliptica Hall.

Lower Carboniferous or Mississippian Series.

KINDERHOOK STAGE.

During the time of deposition of the later Devonian limestones that portion of the floor of the Paleozoic sea that included what is now Benton county was slowly rising. The upward movement progressed in a general direction from the northeast towards the southwest. The deposits of the Cedar Valley stage in Benton county were brought to a close when the sea retreated such a distance to the westward that the greater portion of our area emerged from beneath the waters and became a portion of the growing continent.

A well put down on land owned by Mr. W. B. Benson, near the middle of section 30 of Kane township, encountered a bed of shale immediately below the drift. Another well located a short distance south of the middle of section 36 of Iowa township, on land owned by Mr. C. B. Greenlee, penetrated a similar body of shale to a depth of several feet. Other wells drilled in Iowa county, a short distance south of the border of Benton, pass through a thickness of one hundred feet of shale intervening between the drift and the white limestone of Cedar Valley age. Further west, in Tama and Marshall counties, this shale bed is exposed at the surface. At these points where the waters were deeper, and where they prevailed for a longer period, the shale is succeeded by beds of sandstone, oölite and magnesian limestone. This entire series of sandstone, shale, oölite and magnesian limestones constitute the deposits of the Kinderhook age of the Lower Carboniferous series, as those deposits are developed in central Iowa.

In the early part of the Kinderhook age a slow upward movement of the land caused the waters to withdraw entirely from the region under discussion. During the remainder of the Kinderhook and the whole of the succeeding ages of the Lower Carboniferous epoch our area remained above the sea and suffered the constant wasting of its surface by the remorseless agents of degradation.

The Upper Carboniferous epoch was ushered in by a downward oscillation of the earth's crust in which all of the central and southern portion of Iowa was involved. With this subsidence there began the deposits of the Des Moines stage consisting of seams of coal and beds of sandstone and shale, which were spread over the surface of the former lands. Such deposits are not known to be exposed in Benton county, but they occur in the adjacent counties lying to the east, south and west, hence there seems little doubt but that they once covered Benton also, perhaps to a depth of many feet.

The source of the sandstone material may have been the degeneration of crystalline rocks which existed as land masses further northward, or more probably it was derived from the disintegration of the old quartzite highland which at that time

stood above the waters in northwestern Iowa and in the eastern portion of South Dakota.

Several years ago a coal prospector by the name of Caldwell put down a shaft in the south bank of the Cedar river at a point known locally as Barr's bluff. This bluff is a prominent escarpment which overlooks the river near the middle of the north side of section 14 of Benton township. According to the statements of Messrs. Carver and La Tourenne, of Shellsburg, some coal was actually taken from this shaft at a depth of thirty feet.

In the Independence shales of Buchanan county there occur occasional seams of black, highly carbonaceous shale and even thin films of real coal.* Wherever the Independence shales are developed they occupy a horizon immediately below the Fayette breccia. It is probable that the shaft thirty feet in depth at the foot of Barr's bluff encountered this deposit of shale, notwithstanding the fact that ten miles further westward, where the contact of the Fayette deposits with those of the Coggan are seen, the Independence shales are not certainly present. Of course there is no possibility of finding seams of workable coal in the strata of Devonian age.

At the time of the writer's visit to Barr's bluff, during the summer of 1903, there was to be seen a depression that indicated the place of the abandoned shaft, but no fragments of shale or coal or sandstone were found either on the dump heap or at the foot of the bluff or along the bed of the stream.

The scarp is over one hundred feet in height and is composed of the normal series of Cedar Valley limestones. The face of the ledge is somewhat talus covered, but in the bank of a small stream that renders tribute to the river a few rods to the west of the abandoned shaft there are well exposed all of the layers which are embraced between the zone of the very robust and coarse-ribbed variety of *Atrypa reticularis* and the horizon of *Acerularia profunda*, at the base of the Cedar Valley series.

While it is possible that isolated outliers of sandstone of the Des Moines stage may be present beneath the drift in Benton county there is small probability that coal will ever be found in such quantity as to be profitably worked. Our county is

*Calvin: Iowa Geol. Surv., Vol. VIII, p. 223.

east of the coal-bearing area of the state at this latitude. During the Des Moines age the water did not cover this region to such a depth or for a sufficient length of time to permit of the accumulation of coal seams such as were formed further to the west and south.

Before the close of the Des Moines age there was an upward oscillation in the level of the land which once more carried our area above the water, and it never again suffered inundation from the encroachments of the sea. From this time to the close of the Paleozoic era, during the whole of the Mesozoic, and until the Pleistocene period of the Cenozoic the region which now embraces Benton county belonged to the domain of the land. Then, as now, the indurated sediments slowly softened beneath the influence of the air and sun and showers, and after a time a mantle of soil covered the once naked ledges. Plants flourished for long ages upon this ancient surface. Strange forms of animals waged here a watchful warfare for existence. As the slow-moving centuries passed away steep hills and deep ravines appeared where once the level coast plain stretched unbroken to the far horizon's rim. As time wore on, the valleys widened, and growing tributaries extended the basins of their major streams on either side. Slowly the contours of the hills became subdued, the slopes gradually faded out and the surface of our land once more approached a plain, the peneplain. With an upward crustal movement the agents of erosion began their task afresh. Again, and yet again, the processes of denudation gradually weakened, only to be quickened and revived as often as a recurring elevation of the land started anew the cycle of erosion.

Of this long interval there remain on our land but meager records. There is left scant history of the successive oscillations, or of the great depth of material that was stripped from the surface. It is certain, however, that some time after an upward movement, while yet the channels of the streams were deep below the level of the uplands, the Glacial epoch of the Pleistocene period was ushered in.

Pleistocene System.

In the Pleistocene system there are two series, the Glacial and the Recent. The latter series includes but a single age, the one in which we live. It embraces all of the time since the permanent withdrawal of the continental glaciers from the north temperate latitudes down to the present. Of the Glacial series there are records in Benton county of the invasions of three successive ice sheets, the pre-Kansan, the Kansan and the Iowan. These long periods of cold were separated by very long intervals of mild climatic conditions, during which streams carved and furrowed the surface, and forms of life much like those of the present peopled the lands.

PRE-KANSAN STAGE.

Pre-Kansan drift—There are no known exposures in Benton county where the drift of pre-Kansan age can be seen at the surface. Its presence is revealed only where the well driller has encountered this deposit beneath a thick mantle of Kansan till. In the northeast quarter of section 29 of Iowa township, a well put down a few years ago on land owned by Mr. Tracy passed through the following succession of beds:

	FEET.
4. Fine-grained, yellow colored material	15
3. Blue clay containing bowlders and gravel	210
2. Layer of gravel and sand	2
1. Bed of blue colored, bowlder-bearing clay	18

In this record number 4 is the loess or loess-alluvium that forms the surface material near the margin of the flood plain along this portion of the Iowa river. Number 3 is a deep bed of till that immediately underlies the loess over the adjacent portions of the county. It represents the Kansan drift, as the Iowan ice did not move over this particular area. Number 2 is a layer of sand and gravel of Aftonian age. It was probably laid down along the channel of the major stream of this region during the earliest interglacial period. This member is the water-bearing stratum which is the source of the supply of water for the artesian wells around Belle Plaine. At some points this porous layer is much thicker than is

indicated in the section given. Many of the wells that pass through numbers 3 and 4 stop in this water-bearing bed after penetrating it to a depth of twenty-five to fifty feet.

Number 1 of the section represents a bed of pre-Kansan drift underlying the layer of Aftonian gravels. The work of this particular drilling was discontinued when the pre-Kansan deposit was penetrated to a depth of eighteen feet. It is not known what the entire thickness of the pre-Kansan till may be at this place. Since a flow of water is usually found in the second member of the section, few of the wells pass into this older bed of boulder clay that underlies it.

The pre-Kansan till is not universally distributed beneath the Kansan drift of Benton county. Numerous wells over the region pass directly into the indurated rocks from the Kansan materials without encountering either the Aftonian gravels or the pre-Kansan till. In all of the natural rock exposures the Kansan drift immediately overlies the ledges of Devonian limestone.

Mr. G. M. Tharp, a veteran well driller of the county, is authority for the statement that in some of the wells of Eden, Taylor and Leroy townships a sheet of sand and gravel containing pebbles of foreign origin was encountered beneath a deep bed of boulder-bearing clay, and overlying the indurated rocks. This gravel bed is doubtless a deposit of Aftonian age, and the presence in it of foreign pebbles bears witness to the proximity, at one time, of an earlier bed of drift from which they were derived. It seems probable that the mantle of pre-Kansan drift was spread quite thinly over the area, and that during the long Aftonian interglacial interval the greater portion of these materials was removed by erosion prior to the deposit of the much thicker bed of Kansan till. Isolated patches of the pre-Kansan drift were preserved only where they were in some way protected from the general denudation that wasted the surface.

From a record of the numerous wells that have been put down in the southwestern portion of Benton county, the southeastern portion of Tama, and the northwestern part of Iowa, Mr. Mosnat* has shown that the Aftonian gravels, and the

*Mosnat: Iowa Geol. Surv., Vol. IX, pp. 521-362.

bed of pre-Kansan drift that here underlies it, occupy a deep preglacial valley which has an average width of nearly six miles. This ancient channel, which extends in a direction from the northwest towards the southeast, has been traced from a few miles above Vining, in Tama county, across the southwest corner of Benton, and as far south as the town of Ladora, in the county of Iowa.

An interesting fragment of geological history is recorded in this buried valley, and has been made accessible to us through the numerous well borings that have been put down over the region. The channel was excavated in the shales of Kinderhook age. For so long a time did the preglacial stream follow this course that its waters chiseled a channel to the depth of more than two hundred feet and expanded its flood plain to a width of five or six miles.

When the pre-Kansan ice sheet spread over the state its mantle of materials this great valley was not completely filled. Upon the withdrawal of the ice it was once more appropriated by a river which was probably the master stream of the region. About this time, too, the level of the land became depressed to such an extent as to prevent the complete removal of the pre-Kansan drift from the bottom of the preglacial gorge. Along the course of this Aftonian river were deposited the beds of sand and gravel which constitute the water reservoir for the artesian wells of this portion of the state. When the Kansan glacier moved down from the north bearing its immense load of drift, this broad valley was completely buried and every trace of its existence was blotted out. Its presence was never suspected until the exigencies of recent years caused the well driller to probe into its secrets in search of water

KANSAN STAGE.

Kansan drift.—Of all the ice sheets that invaded Iowa the Kansan was pre-eminently the carrier of glacial debris. Over the greater portion of Benton county the Kansan drift has a thickness of from seventy-five to three hundred feet. Mr. G. M. Tharp, of Vinton, who has probably drilled more wells over

this region than any other man, has furnished the following data with regard to the depth of the Kansan till in different portions of the area:

LOCATION.	SEC-TION	TOWNSHIP.	DEPTH.
Near west side.....	18	Cedar.....	175 feet.
Near south side.....	6	Eden.....	180 "
Northwest $\frac{1}{4}$	5	Eden.....	126 "
Southeast $\frac{1}{4}$	19	Eden.....	200 "
Northwest $\frac{1}{4}$	36	Taylor.....	175 "
.....	26	Jackson.....	215 "
Northwest $\frac{1}{4}$	31	Big Grove..	250 "
Northwest $\frac{1}{4}$	11	Kane.....	300 "
Southwest $\frac{1}{4}$	11	Eldorado..	228 "
Northeast $\frac{1}{4}$	2	Leroy.....	214 "
Southwest $\frac{1}{4}$	14	Leroy.....	175 "
Southeast $\frac{1}{4}$	19	Iowa.....	172 "

The Kansan drift was spread over the surface an exceedingly long time ago; so long, indeed, that the erosion of the streams has changed entirely the original features of the topography, and the dynamical agencies have changed very profoundly the chemical and physical constituents of its surface materials. In the deeper deposits the till contains an abundance of lime, and is blue or bluish-gray in color. The clay bears a large number of pebbles of trap and quartz, together with abundant small bowlders of granite and greenstone, and occasional masses of quartz and limestone. The surface of some of these foreign rock fragments is beautifully glaciated on one or more sides. At the top where the material has been long exposed to the action of the atmosphere, and to the influence of meteoric waters and decaying organic matter, the calcareous constituent has been leached downward to a varying depth of three to six feet. Where the surface is broken and the slopes are steep an excess of organic matter is not permitted to accumulate in the soil. Over these areas the iron content of this surface drift, which existed originally in the form of ferrous carbonate, has been oxidized to the ferric oxide condition. In this process the color has also undergone a change so that where sections are exposed in ravines or along the roadsides the top of the drift is a deep red or reddish-brown color due to the anhydrous haematite form of the iron which it contains. This ferretto zone

grades downward to a yellow, which color is imparted to the clay by the presence of the hydrated sesquioxide of iron known as limonite, and this, in turn, passes with a gradual transition into the bluish-gray of the unchanged deeper drift material.

Exposures of the thoroughly oxidized, ferretto zone at the surface of the Kansan drift are numerous over the Kansan area in Leroy and Iowa townships, and they are frequently encountered over the rougher portions of the region later covered by the Iowan ice sheet. Wherever the Kansan drift appears in the county its surface is profoundly eroded, and it is usually overlain by a more recent deposit of loess.

Buchanan gravels.—Beds of moderately fine gravel occur at several points in Benton county, overlying the Kansan drift. This terrane is usually concealed beneath a deposit of fine-grained soil. In section 14 of Benton township a gravel deposit three and one-half feet in depth outcrops in the bank of a stream for a distance of several rods. Another bed of this water-laid material is exposed near the middle of section 19 of Canton township, in the south bank of Wild Cat creek. At the latter place the deposit has a maximum thickness of twelve feet and can be seen continuously for more than a dozen rods. A few miles further east, on Bear creek, a bed of gravel appears a short distance west of Mr. Shannon's brick and tile manufacturing plant, at Shellsburg. This latter is probably the continuation of the deposit that is encountered along Wild Cat creek in section 19. Such beds are also exposed in section 33 of Taylor township, and section 35 of Eldorado.

An area of several square miles in the southern portion of Florence township is covered with this coarse material. Near the southwest corner of section 32 a pit three and one-half feet in depth has been opened on the north side of the wagon road. The presence of a gravel train is revealed in the banks of the most of the streams in this portion of the township. West of the station of Walford this deposit has been utilized in the improvement of the public roads. In Saint Clair township, also, a bed of gravel four feet in thickness has been worked near the southwest corner of section 10.

The gravels that appear in all of the known exposures of the county belong to what Professor Calvin has designated as the valley phase of this formation. They consist of coarse sand and small water-worn pebbles, the latter seldom exceeding one and one-half inches in long diameter. Boulders do not occur in these deposits. There is only a small amount of iron present, and a rusty color is not generally imparted to the beds. The materials of these gravel trains were derived from glacier-borne debris, and they came to rest along the courses of swollen streams whose waters were liberated by the rapid melting of the Kansan ice.

Professor Calvin* has shown that this lowland phase of the Buchanan gravels was deposited after the glacier had withdrawn from the valleys, and when the ice margin had retreated some distance to the northward: that they were laid down as broad glacio-fluvial aprons after the streams had emerged from the ice bordered canyons and had spread widely over the lower lands. For this reason their currents had lost much of their original violence, and the waters were now carrying and depositing only the finer portions of the debris with which they were loaded when they started with impetuous haste from their source on the shrinking glacier.

IOWAN STAGE.

Iowan drift—The portion of Benton county that was overflowed by the Iowan ice has been outlined under the discussion of topography. This ice sheet left but a scant covering of the finer detritus over the region that it invaded. The large boulders which it carried are widely distributed, but the proper drift of this age can be seen at but few points over the area. Near the middle of the west side of section 27 of Taylor township the following succession of deposits is exposed in the east bank of Mud creek.

* Calvin: Iowa Geol. Surv., Vol. XIII, p. 68.

	FEET.
3. Fine-grained, yellow colored clay, containing no gravel	3½
2. Bed of yellow drift, containing pebbles and small granite bowlders.....	10
1. Drift deposit which is blue at the bottom, changing to a yellow color higher up, and at the very top it is a deep red. This bed carries numerous pebbles and small bowlders of dark colored trap.....	8

Number 1 of the above section represents Kansan drift, the upper part of which presents the typical ferretto character. The contained greenstone pebbles and bowlders are characteristic of this ancient till. Number 2 is a deposit of Iowan drift. It is of a uniformly yellow color throughout. Its superficial portion is unleached of its calcareous matter, and its iron content is not more oxidized in one portion than another. The bed is here much thicker than is usual for this till. The preglacial channel of Mud creek at this point was not completely filled with the Kansan materials, and an exceptionally deep deposit of the later drift was lodged in the depression. Number 3 is a bed of loess. This material does not usually overlies drift of Iowan age, except over the rougher portions of the Iowan plain. The banks which border Mud creek are crowned with loess to a depth of two to four feet, and at this place the loess appears to have slid down from higher up on the hill.

Over the general surface of the Iowan plain typical drift of Iowan age is seldom encountered. It is concealed beneath a true soil of pebbleless material which is black from its contained carbonaceous matter. Even on the gentle slopes fine-grained, yellow colored clay, without pebbles, covers the superficial drift. Where the slopes are steeper the till that is exposed by erosion is usually the oxidized phase of the Kansan. Along the wagon road, between sections 17 and 20 of Saint Clair township, a yellow, pebble-bearing clay resembling Iowan drift was thrown out where recent holes were dug for telephone poles. Large bowlders of granite, gray or pink in color, are spread more or less frequently over the Iowan surface. In sections 14 and 15 of Benton township they are so numerous over some of the fields as to prove serious obstacles to tillage. Mr

Harger has used these rock masses in the foundation of his house and barn, and has built a thick wall of bowlders as a back to his large stock shed. A large proportion of these are of pink or gray granite. There are a few microcrystalline, dark colored greenstones, and less frequently a bowlder of quartzite.

Notwithstanding the fact that the Iowan drift appears at the surface in but few places in the county, it can be shown that the ice of this age covered almost the entire area. The limits of its distribution can be determined by the bordering moraine;



FIG. 13. Iowan bowlders in a field west of the wagon road in section 15 of Benton township. The view illustrates the Iowan topography over the more broken portions of the Iowan drift area.

by the level or subdued topography; by the choked condition of the stream channels; by the presence of frequent, large bowlders of granite; by the general absence of deep beds of loess, and, especially, by the cumulative evidence of a number of the above features which are usually encountered over the same area.

Iowan loess.—The distribution of the loess in Benton county is consistent with the deposits of this material in the neighbor-

ing counties of Tama and Johnson. The thicker beds overlie Kansan drift and are found adjacent to the border of the Iowan plain. Loess forms the surface materials over all of the Kansan area, and mantles the summits and the slopes over the more hilly portions of the Iowan. The material is easily friable, uniformly fine-grained, and is yellow in color. It contains an appreciable amount of lime carbonate, and possesses such tenacity that the banks of streams, where composed of this substance, stand for a long time with almost vertical walls. The deeper deposits show no well marked evidences of stratification, such as characterize sediments laid down by water. These beds often contain in abundance shells of air-breathing gastropods, which are indiscriminately distributed throughout their entire depth. The loess was laid down upon the very ancient Kansan surface which had suffered practically as much erosion, leaching and oxidation before the mantle of loess was spread over it as it shows today. This deposit does not tend to level up the inequalities of the surface, but forms a veneer alike over the summits, slopes and lowlands. Often the beds are even thicker on the crests of the ridges and the higher portions of the hills.

When the Iowan glacier was at its maximum the ice was thinner over the higher areas. As a consequence these prominences were bared earliest as the ice melted. As soon as the hills were uncovered, and while the ice still lingered over the surrounding lowlands, the higher points would receive a thin deposit of this fine-grained material in a manner similar to that of the hills bordering the Iowan plain. In this way it seems possible to explain the presence of loess over the more broken portions of the Iowan drift surface. Professor Calvin* has shown that the loess materials of eastern Iowa were largely derived from the finer constituents of the Iowan drift. They are probably in the nature of glacio-aeolian deposits with possibly, contiguous to the Iowan margin, some overwash of the finer materials as the ice melted. They were probably laid down during the time of the greatest advance, and immediately succeeding the withdrawal, of the Iowan glacier. It is worthy of note that the loess of Benton county is not stratified. It con-

*Calvin: Iowa Geol. Surv., Vol. VII, p. 89.

forms to prior inequalities, and does not tend to level up the surface. The contained fossils are those of air-breathing, terrestrial forms, and the shells, though exceedingly fragile, are unbroken.

Post-glacial or Recent Deposits.

ALLUVIUM.

Deposits of superficial materials later than those of the Glacial series occur at various points in Benton county. Over the broad flood plains of the Iowa river and the larger of its tributaries there is a mantle of alluvium that was laid down during the Recent age. Along a portion of the channel of the Cedar river and the lower courses of its principal branches rich, fluvial sediments have also been spread over the level bottoms. These deposits are usually dark in color, and rich in carbon-bearing and nitrogenous compounds which have been contributed by the imperfect decay of successive generations of the rank, semi-aquatic vegetation that flourished over the fertile lowlands. During times of overflow the stems and leaves of such plants were effective agents in entrapping the suspended sediments. Each inundation added a thin increment to the surface of the deposit, and each season's growth yielded an increased store of plant food for the crops of succeeding years. In this manner has been developed the extreme fertility of the alluvial deposits.

CUMULOSE DEPOSITS.

When the Iowan ice sheet retreated to the northward it left a somewhat uneven surface, the depressions over which became occupied by lakes. Many of these glacial lake basins are represented at present by swampy or marshy tracts. The transformation from lake to swamp and, in some cases, from swamp to fruitful field has been accomplished since the retreat of the glaciers. As the wind swept the land surface year after year a portion of the fine detritus that it gathered came to rest on the water of the lakes, and slowly sank to the bottom. With

every freshet each streamlet that trickled down from the encircling swells carried a tiny load of silt. These lakes were also shallowed as water lilies and other aquatic forms established themselves in the pools, and pond-loving plants encroached upon the shores. These all, at death, gave up their substance to swell the accumulations which, through the centuries, have filled up, and banished the water from the most of the lake basins. Such deposits of humus or swampy soils, containing a very high percentage of organic matter, are frequently encountered over the surface of the Iowan drift plain.

AEOLIAN DEPOSITS.

The more typical examples of aeolian deposits in Benton county are the beds of sand and mantle of loess that occur over the rougher portions of the area. It is probable that the most of these materials were laid down during the time of maximum extension of the Iowan ice sheet. It seems altogether probable, too, that a large amount of these materials have been shifted and redistributed, and the entire aggregate appreciably augmented during the Recent age. A considerable amount of the inorganic ingredients of the soils has been carried and deposited by the wind since the close of the Glacial epoch, and even now the process of soil formation is going on.

Soils.

Soils are composed of comminuted and more or less decomposed fragments of rock material with which is mingled organic matter from plant and animal decay. The fertility or productive power of soil is dependent upon both its chemical composition and its physical condition. The chemical composition of any soil, aside from its humus, is largely determined by the character of the rocks from which it was derived, and by the amount of washing, leaching and oxidation to which it has since been subjected. The desirable physical condition of any soil can be largely controlled by the continued practice of appropriate tillage. Where nature's methods are not interfered with, each season's growth of vegetation returns to the

soil, with interest, the food compounds that were extracted in its production. When man steps in and harvests the crop he robs the land of nature's annuity and the soil deteriorates, unless intelligent modes of tillage are employed.

The inorganic ingredients of the soils of Benton county have all been transported either by wind, water or ice. None of the soils are residual. There are present in the area five more or less distinct soil types: loess, Iowan drift, swamp, sand, and alluvium. In many places these types grade one into another and not infrequently the soil at a particular point is a mixture of the materials which characterize two or more of the above divisions. These different types of soil are due largely to the difference in the materials which form the subsoil or base upon which each has been developed.

1. *Loess soil*.—Loess soil occurs over all of the Kansan drift portion of the county. This area is so hilly that little humus has been permitted to accumulate in the superficial material of the slopes. As a consequence the loess soil is a yellow clay. The color here, like that of most yellow soils, is due to the presence of the hydrous sesquioxide of iron. The loess is fine-grained in texture yet the particles are sufficiently large to permit the ready passage of water, and to render the soil light, and tillage easy. At the same time the soil particles are so small that moisture is readily brought upward from below by capillary action. This soil is rich in lime which mineral Hilgard* considers more effective than any other in controlling soil fertility and in making it loose and porous, thus permitting good ventilation and favoring the thorough and uniform penetration of the rootlets of plants.

Over level areas the loess soil is durable and very productive. Where the surface is broken the constant rain-wash prevents the development of organic matter in the soil, and rapidly leaches away necessary constituents of plant food. Where such areas are cultivated the disastrous washing of stream erosion, in addition to the strong leaching, speedily wastes what fertility the soil once possessed. See figure 14. Such

*Hilgard: Bulletin, No. 3, U. S. Weather Bureau. 1892.

devastated fields yield scant returns for the labor expended in the effort to produce a crop. When the original soil mantle has never been disturbed the slopes support an excellent growth of native blue grass which, when pastured, improves with the passing years.

2. *Drift soil*.—The typical Iowan drift soils are found over the most of the prairie portions of the Iowan plain. They are a deep, rich loam, containing grains of rock-meal sufficiently large to make the soil light and warm, and to prevent puddling during seasons of excessive rainfall. The color is almost black on account of the wealth of carbonaceous matter that it con-



FIG. 14. Some results of disastrous rain-wash of the land. View looking down the Cedar river in section 10 of Benton township; showing the sand bars and willow-grown mud-flats in, and bordering, the channel of the river.

tains. Iowan drift is typically yellow in color. It is possible that the abundance of vegetable matter in process of slow decay in these black soils has resulted in changing the form of a part of their iron content from the original condition of hydrous ferric oxide to the form of ferrous carbonate. When

in the form of carbonate the wealth of organic matter in the soil would prevent the oxidation of its iron constituent. All of the desirable qualities that are imparted to soils by the presence of lime are possessed by those of the Iowan drift. The surface of these favored areas is level, or gently undulating, so that the slopes are not rapidly leached, nor are they impoverished by the washing effects of rain storms.

The finer material of the drift soils consist of "rock-flour" and "rock-meal," which have been derived from the grinding up of the rocks carried in the ground moraine, and of those at the surface of the ledges over which the glacier moved. By this mode of origin even the finest of the mineral constituents have not suffered complete oxidation and decay, as have those of sedentary soils which have resulted from the degeneration of rocks in situ. Chemical changes are at present taking place in the particles of this recent soil through the agency of air and water and organic matter. In this process soluble compounds suitable for plant food are constantly being liberated. This constant increase in the mineral elements available for plant food, the wealth of organic matter which they possess, and their texture which favors the conservation of moisture, all contribute to render the soils of the Iowan drift exceedingly fertile, and almost inexhaustible.

3. *Swamp soil.*—Isolated areas of swamp soil are quite frequent over the Iowan plain. They represent the partially filled basins of glacial lakes. Many of these marshes are still so poorly drained that water stands over them during long continued rains. The characteristic component of these soils is the black, mucky material with which is mixed a small percentage of mineral matter. These soils are sour and cold. When cultivated the application of lime* would be beneficial in overcoming the acidity and making the soil more porous. Such soils are wanting in ventilation. Almost their only means of aeration is where crayfish have excavated their wells and underground channels. It is estimated † that 40 to 50 per cent of the full water capacity of soils must be drained away before good yields of cultivated plants can be secured. When these

* Roberts: *The Fertility of the Land*, pp. 307-314.

† King: *The Soil*, p. 161.

areas have been thoroughly underdrained, and the soil has been stirred deeply for a sufficient length of time for the air to accomplish the more perfect decay of their organic matter, these soils become loose and light, and rank second to none in productiveness.

4. *Sandy soil*.—A small amount of sand mingled with a large percentage of materials of finer texture forms light, loamy soils of the highest quality. Where the percentage of the ingredients is reversed there results a sandy soil which, unless supplied with an abundance of water, is comparatively unfruitful. Areas of sandy soil are common in the western portion of Harrison township, the southern part of Polk, and over portions of Benton and Taylor. Such soils are light and open. They permit rapid leaching. Even over the more level areas they contain little humus. They are usually poor in organic matter and deficient in soluble mineral compounds essential for the food of plants. They are so porous that their power to retain moisture is small. Their interstitial spaces are so large that water is not readily brought upward by capillary action when evaporation from the surface is rapid. These sandy soils are, when cultivated, the most barren and infertile of any of the soils of the county. It is fortunate that their aggregate area is small.

5. *Alluvial soil*.—The alluvial soils of Benton county are usually a rich loam whose mineral constituents have been derived from the uplands and spread out over the level areas of flood plain. Such soils usually contain a wealth of organic matter which imparts to them a dark, almost black color. They are warm and mellow, never becoming baked or water-clogged after excessive rains. They are usually underdrained by porous beds of water-laid sand. There is generally present a sufficient amount of fine-grained clay to impart to these soils a good capacity to retain water and to furnish efficient capillary action during periods of drought. The successive deposits of the streams have supplied these alluvial soils with all of the fresh mineral compounds with which the drift of the uplands is so richly endowed. All of the necessary elements of plant food are abundant and in such soluble form as can be readily utilized by the growing crops. Where these areas are not subject to

overflow the alluvial soils respond most generously to tillage; they are the most uniformly warm and mellow, the most fertile and highly productive of any of the soils in the county.

Unconformities.

The contact between the Coggan beds and the Fayette breccia is exposed for only a short distance in the county, but where it can be seen the transition is abrupt. From what is known of the relation between the rocks of these two horizons further east, there seems to be no doubt that the deposits of the Fayette sub-stage rest unconformably upon those of the Coggan. Between the rocks of the Wapsipinicon and the Cedar Valley stages there is no distinct line of separation, and no indication of unconformity.

The earliest sheet of drift was spread over the preglacial surface of indurated rocks after an enormous interval of erosion. In no case is there conformity between the deposits of the successive ice invasions, and in every instance there is conspicuous unconformity between the loess and the drift over which it lies.

Deformations.

In the strata of Benton county there are encountered a few slight flexures but no very conspicuous deformations. The most marked example occurs where the Coggan beds are exposed along the bank of the Cedar river with a depth of fifty-five feet of the Fayette breccia overlying them. About two miles south of this place the rocks of the *Spirifer pennatus* beds outcrop on the opposite side of the valley only a few feet above the flood plain of the river. Between these two points there is indicated for the beds of *Spirifer pennatus* a difference in altitude of more than fifty feet. Near the Benton-Linn county line a narrow lobe of limestone, embracing the *Spirifer pennatus* beds, extends into the flood plain of the Cedar river, the

strata here form an arch on either side of which the layers slope downwards at an angle of about 45 degrees. See figure 15.

At the Cedar River exposure the layers of Cedar Valley limestone have a conspicuous dip towards the south. A few rods north of this bluff, just across a ravine, is Long's quarry where the dip is in the opposite direction. The intervening stream occupies the axis of a gentle anticline, on either side of which the strata slope away at the rate of about twelve inches in a distance of forty feet.

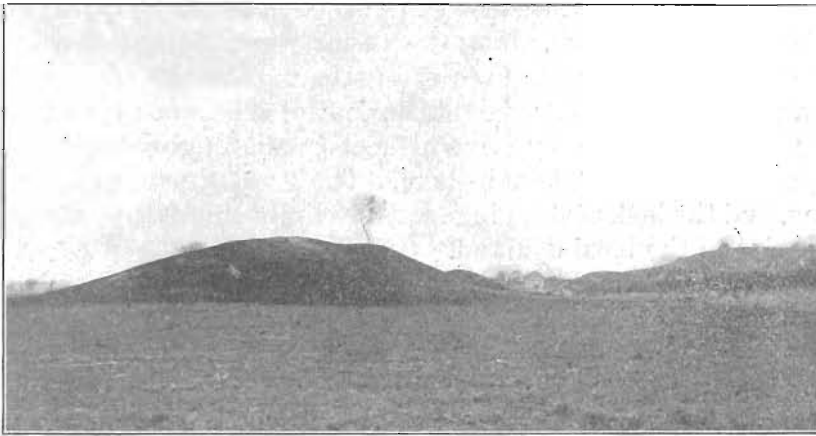


FIG. 15 Hog-back jutting into the valley of the Cedar river near the Benton-Linn county border. The strata belong to the *Spirifer pennatus* horizon, and the inclination of the layers is about 45 degrees.

At John Tripp's quarry the layers are inclined towards the south even more strongly than at either of the above mentioned exposures. At McKinley's quarry also the rocks do not lie in a perfectly horizontal position. The slight inclination of the layers at some of the above points may be due to inequalities of deposition, owing to the unevenness of the sea floor upon which the sediments were spread.

ECONOMIC PRODUCTS.**Building Stones.**

Coggan beds.—The exposures of Coggan limestone, in section 36 of Cedar township and section 6 of Taylor, furnish the best quality of building stone found in the county. The rock is yellow, very hard, fine-grained and strongly magnesian. The ledge outcrops almost continuously at the base of a bluff for a distance of nearly one mile. At the west end of this exposure Mr. Wallace operates a quarry in the Coggan layers. One-half mile further east Mr. Kearns has worked in the same ledge, and still further eastward, along the Cedar river, Aungst Brothers have taken out a large quantity of stone. The one serious disadvantage that attends the getting out of this stone is the fact that it is overlain by several feet of thoroughly brecciated deposits of the Fayette sub-stage. The great expense of stripping, and the lack of shipping facilities limit the output of these quarries to the local demand.

Fayette breccia.—At several points near Vinton quarries have been operated in the layers near the upper part of the Fayette sub-stage. The old Bliss quarry, which formerly furnished the mineral used by the Iowa Paint Company in the manufacture of paint, was worked in the horizon of the *Spirifer pennatus* beds. The lower layers worked at the Quinn quarry lie in the same zone. The Rosenberger quarry stone is also furnished by these fractured beds. At the Pettit quarry, stone is taken from both the *Gyroceras* horizon and that of *Spirifer pennatus*. As a general thing the rocks in the above zones are badly shattered. The stone that they furnish is in rough, irregular blocks, suitable only for rubble and for rough masonry. The deposits of the Fayette breccia furnish a suitable grade of material for making concrete and macadam, and for general road building.

Cedar Valley limestones.—A large percentage of the stone quarried in the county comes from the layers of the Cedar Valley stage. In the vicinity of Shellsburg there are worked beds which lie between the *Acervularia davidsoni* and the *Acervularia profunda* horizons. These layers furnish a grade of

stone that can be used in cellar walls and foundations for common buildings. The local demand of the region, in and adjacent to the town, is supplied from these beds.

In the northern portion of the county the best quarries are operated in the magnesian layers which overlie the zone of the very large, coarsely-striated type of *Atrypa reticularis*. Long's quarry and Keiser's quarry, on the Cedar river, furnish the most of the stone from this horizon. The quality of the output at these quarries is excellent. Blocks with parallel faces are taken out in almost any dimensions desired. The stone is easily shaped and is very serviceable for all kinds of common range work. Where the undisturbed ledges have been exposed to the air for a long period they show a good degree of resistance to weathering. This fact would furnish the very best evidence of the powers of endurance of the stone when laid in a wall. The most of the stone used in the piers of the Mount Auburn-Brandon bridge across the Cedar river came from these layers.

Near the town of Garrison the rocks that have been worked embrace the *Stromatopora* horizon and about twenty feet of the layers which normally underlie those beds. The hard, fine-grained layers of white limestone vary from one to three feet in thickness. They are not so easily worked as are the magnesian layers lower down, but for a nearly pure limerock, they furnish material of a durable quality.

Rock exposures are so widely distributed over the north half of the county that stone for general purposes is readily accessible from every point. At none of the quarries is the equipment expensive. None of them supplies a demand larger than that of the local territory. At no single place is there a very large quantity of stone produced, but the total output from all of the quarries would aggregate an important sum.

Lime.

Lime is at present manufactured at but one point in the county. The stone used for this purpose comes from the Coggan beds in Taylor township. This material is sufficiently dolomitic to make a very excellent quality of lime. For several

years Aungst Brothers have annually burned a kiln, with a capacity of seven or eight thousand bushels, to supply the local market. The more strongly magnesian layers at Long's or Keiser's quarry would furnish suitable stone for lime burning. Some years ago Mr. Long was accustomed to burn an occasional kiln, but of late he has abandoned lime production.

At various places in the state, stone which corresponds with the white limestone layers of the quarry near Garrison has been used in the manufacture of lime. The superior quality of the product made from dolomite has caused the burning of the more pure calcium carbonate to be discontinued. Lime is at present manufactured on a large scale at exceptionally favorable points in eastern Iowa. The excellent transportation facilities, together with the good keeping qualities of dolomite lime, make it possible for the large concerns to supply the markets of the state more cheaply than lime can be burned locally in small kilns.

Road Materials.

Materials suitable for permanent road building are abundant, and fortunately located, over the county. The numerous rock exposures in the townships of Cedar, Harrison, Polk, Benton, Taylor, Jackson and Canton would furnish an unlimited supply of stone which, when crushed, would make an excellent macadam. These outcrops are so readily accessible from all portions of the area that no long hauls would be required to cover all of the main lines of travel with this material. Along the north bank of Pratt creek, in Cedar township, the thoroughly brecciated phase of the Fayette deposits appears at the surface for a distance of half a mile. The fragments here are incoherent, and are so small that, without crushing, they are ready to be taken out and applied to the roads. While no exposures of indurated rocks occur in the townships of Bruce, Monroe, Homer, Big Grove and Eden, yet such deposits are encountered but a short distance beyond their borders.

In the southern portion of the county, where the rocks are buried deeply with the drift, there are occasional beds of gravel

which furnish a cheap and very satisfactory material for road making purposes. Gravel trains outcrop in Saint Clair, Florence, Eldorado, Canton, Taylor and Iowa townships. These deposits lie near the surface and are easily worked. They have been used with excellent results on the wagon road between sections 25 and 36, in Florence township, and also on the road crossing the middle of section 24 of the township of Iowa.

Sand.

Abundance of sand well adapted for use in mortar, cement or plaster occurs at a number of places in the county. Large quantities are annually taken from the flood plain of the Cedar river, and the larger of its tributary streams. At Vinton the supply for building purposes is drawn almost exclusively from the river's bed within its limits. Hills of sand of requisite purity and quality for general purposes occur in Polk, Taylor, Harrison, Iowa and Leroy townships. The sand used at Shellsburg is taken from the channel of Bear creek close at hand. The bed of the Iowa river and of Prairie creek contain a large amount of common, clean sand which supplies the demand of a large area in the southern portion of the county.

Clays.

Clays suitable for the manufacture of common brick and drain tile are widely distributed over the area under discussion. The only deposits utilized are the loess and alluvium. For the production of the cheaper grades of common clay goods these beds furnish a supply of raw material that is excellent in quality, inexhaustible in quantity, and inexpensively worked. Clay goods have been manufactured at the following points:

Vinton.—For some years Mr. V. W. Aikley has produced brick and tile on a small scale at Vinton. The equipment at this place is not expensive. Only a single temporary kiln is burned at one time. The value of the annual output does not exceed \$2,000. Mr. Aikley has given more attention to the

making of brick than of tile. He finds a ready market for his products in his home town. The clay used is a mixture of loess and alluvium which is taken from the valley of Mud creek.

Shellsburg.—A large brick and tile manufacturing plant is operated at Shellsburg by Mr. Samuel Shannon. The cheaper grades of construction brick and all of the common sizes of farm drain tile are produced at this place. This is one of the largest plants in the county. The machinery is of the most approved type, and the wares produced are of superior quality. The clay pit is worked in the bed of Bear creek and the material is a modified drift and loess-alluvium.

Garrison.—Brick and tile are produced on quite a large scale at the town of Garrison, by Messrs. Deutremont and Gross. A good market is furnished for drain tile by farmers over the surrounding, level areas of the fertile Iowan plain. The demand for the clay goods produced at this place is local, but all of the needs of the area in this line are supplied by the home factory. The clay is taken from the flood plain of Hinkle creek. The plant is equipped with up-to-date machinery and the products are of excellent grade.

Norway.—At the town of Norway a brick and tile factory is owned and operated by Charles Trajorsky. The clay pit is located in the loess at the east end of the Norway paha ridge. The equipment includes an Anderson soft mud, and a Nolan and Meaden stiff mud brick machine. The tile machine is of the same make as the stiff mud brick. There are two round, down draft kilns, with brick capacities of 40,000 and 50,000 respectively. All of the wares are air dried. Tile of the usual sizes, from three to eight inches in diameter, are made. The chief market is in the town and the splendid farming district adjacent, within a radius of ten or a dozen miles. Wood is the fuel used. The plant is arranged more especially for the manufacture of tile than of brick. The total value of the combined annual output of brick and tile is between three and four thousand dollars.

Belle Plaine.—Brick is made to supply a portion of the local demand at Belle Plaine, by Mr. Frank Smith. Only the cheaper

grades of construction brick are manufactured. The kilns are temporary and the machinery inexpensive. The clay used is taken from a bank of loess.

Newhall.—Mr. E. H. Morròw, at Newhall, manufactures both brick and tile. The demand is largely for tile and comes from the farmers over the level Iowan drift area whose farms are improved by the underdrainage.

The value of the total output of brick and tile in Benton county would aggregate more than \$24,400. No single plant manufactures a much larger quantity than the demands of the immediate locality warrant. Freight rates are so high that little of the clay products are shipped to other points by rail, and, likewise, but a small amount of the common clay goods used in the county are imported. The several plants are so distributed as to place such wares within easy reach of every point in the county. Since the advance in the price of land of recent years, there has been a large demand for drain tile on the part of farmers over the Iowan area. With proper underdrainage the most level fields are productive, even in seasons of excessive rainfall.

Copper.

Some years ago a nugget of native copper was found by Mr. Conrad Burkhart near the river, in the southern part of Polk township. This fragment was encountered in the drift about six feet below the surface, as parties were digging a well. The mass weighed six pounds and nine ounces, and is almost pure copper. About one year ago a similar mass, weighing twenty-seven pounds, was found near Toledo, in Tama county. The surface of these fragments is covered in places with a thin film of green malachite, or copper carbonate, which has been formed by alteration of the native copper since it left the parent ledge. Such nuggets have been found at several points in Iowa. They always occur in the bowlder clay, never in the native rocks of the state. The original home of these fragments was probably the copper bearing rocks of the Lake Superior region. The masses

were doubtless distributed over the surface of Iowa by the glaciers in the same manner, and at the same time, as the foreign boulders of granite and crystalline rocks which form such conspicuous features of the drift material. The presence of occasional pieces of copper in the drift offer absolutely no indication of deposits of copper ore in the native rocks of our state.

Water Supplies.

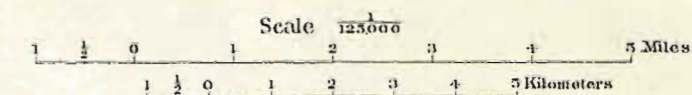
Almost everywhere in the county shallow wells find in the drift a bountiful supply of pure water at a depth ranging from twenty-five to seventy-five feet. The Cedar river and the Iowa furnish an abundant and permanent water supply to the regions through which they flow. The larger tributaries of the major streams have their sources in the boggy springs over the Iowan plain, and their perennial flow supplies stock water of the finest kind to the farms over large areas. The town of Vinton obtains its water from two deep wells which penetrate the Saint Peter and the underlying sandstones. One of these wells has a depth of 1,172 feet, and the other 1,287 feet below the surface.

The southwestern portion of the county is embraced in the Belle Plaine artesian basin. These flowing wells derive their water from the porous gravels that here underlie the Kansan drift, at a varying depth of from ninety to three hundred feet. A number of such wells occur in Iowa township, and a few are found in Kane and Leroy. These artesian wells furnish an ideal supply of water for farm purposes. The water carries such a high percentage of minerals, notably calcium and magnesium sulphate, that it is not suitable for drinking or culinary purposes. It possesses no valuable medicinal properties. It contains such quantities of incrusting and corroding salts that it is unsuitable for use in steam pipes and boilers. Some years ago the Chicago, Milwaukee and Saint Paul railway company put up a round house and other large buildings at the town of Van Horn. On account of the pipe consuming and incrusting minerals in the water at this place the works have been abandoned, and the buildings are now unused.

IOWA GEOLOGICAL SURVEY

MAP OF THE
SUPERFICIAL DEPOSITS
OF
BENTON
COUNTY,
IOWA.

BY
T. E. SAVAGE,
1905.



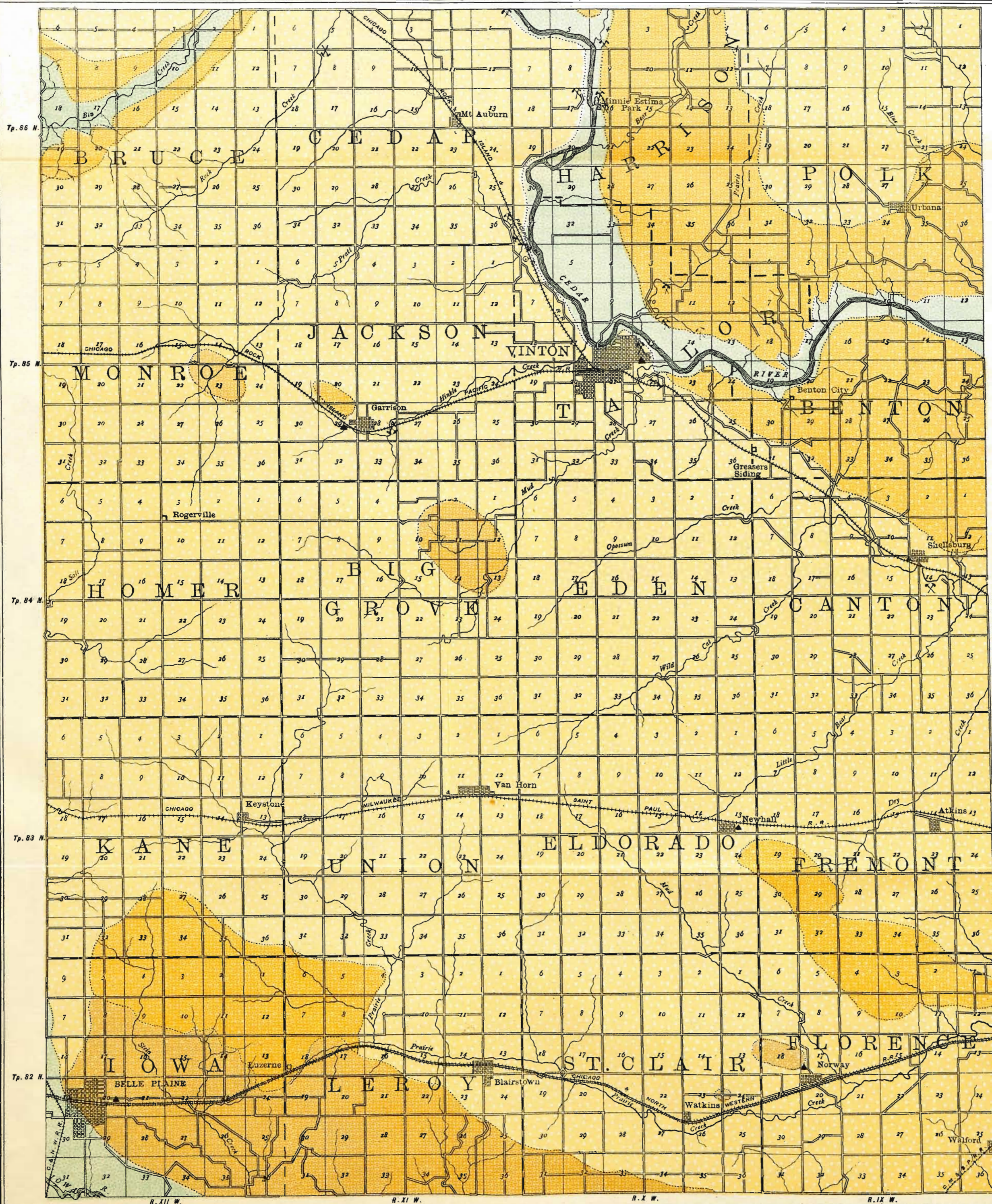
LEGEND

- ALLUVIUM.
- IOWAN DRIFT.
- IOWAN DRIFT.
OVERLAIN BY LOESS OR SAND.
- KANSAN DRIFT
OVERLAIN BY LOESS.

All the indurated rocks that appear at the surface in Benton county belong to the Cedar Valley stage, with the exception of a few outcrops of the Wapsipicon deposits which are exposed near the base of the bluffs of the Cedar river, and along the channels of its tributaries, Pratt and Prairie creeks. Rocks of Kinderhook age probably underlie the drift over a small area in the southwest corner.

INDUSTRIES

- CLAY WORKS
- QUARRIES
- LIME KILNS



R. XII W.

R. XI W.

R. X W.

R. IX W.

DRAWN BY F. C. TATE

ACKNOWLEDGMENTS.

Opportunity is taken at this time to acknowledge the generous assistance received during the prosecution of the field work in Benton county. Thanks are especially due Mr. G. M. Tharp, of Vinton, and Mr. Thomas Carver, of Shellsburg, for important service. Professor Stewart Weller kindly identified some difficult fossils. Professor Calvin has been a helpful adviser in connection with work in the field and during the preparation of the foregoing report. To each of the above, and to all others whose aid was freely offered, the writer extends his hearty thanks.

