GEOLOGY OF BUCHANAN COUNTY.

BY

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INTRODUCTION.

SITUATION AND AREA.

Buchanan is one of the important agricultural counties in the northeastern part of Iowa. Its location is so near the Mississippi river that it attracted early attention from the pioneer homeseekers. Before the advent of the railroad the great watercourse was the main highway of travel, and Dubuque was one of the points from which immigrants began the overland journey into the interior of the state. Buchanan is the third county west of the river, and its relative proximity to what was at the time the nearest market had its influence in determining the choice of many settlers; but the principal attraction was found in the beautiful expanses of undulating prairies, with soils marvelously fertile and easy of cultivation, in the groves that dotted the prairies, and in the wide stretches of woodland skirting drainage streams that ran clear and full through the whole round of seasons.

Buchanan county embraces sixteen congressional townships. The second correction line divides the county into two nearly equal parts. Delaware and Dubuque counties lie between Buchanan and the eastern boundary of the state. Fayette and Winneshiek separate this county from Minnesota. Buchanan is bounded on the west by Black Hawk, and on the south by Benton and Linn.

GEOLOGICAL WORK IN BUCHANAN COUNTY.

Previous to the inauguration of the present Survey, the geology of Buchanan county was the subject of more or less study by a number of observers. As usual, in this part of Iowa, the first geologist to enter the county was Dr. David

Dale Owen, whose parties exploring the mineral lands in the autumn of 1839, examined the townships since named Middlefield, Fremont, Madison and Buffalo. Limestone is reported at one point in Madison township,* but in general no rock was seen except granite bowlders, some of which are described as of gigantic size.

The next geologist to visit Buchanan county was Prof. J. D. Whitney, but no detailed work was undertaken, and the report† subsequently published contained only a very brief reference to the exposures along the Wapsipinicon from Independence to the south line of the county. No rocks were noted except those belonging to the Devonian period. In the same report Prof. James Hall‡ described and figured a number of interesting fossil forms from the quarries near Independence. In Hall and Whitney's report the limestones at Independence are correlated with the Hamilton formation of New York.

In 1872 Hall and Whitfield published a paper‖ on the Devonian of Iowa, referring incidentally to the limestones at Independence, and correlating them, as had been done before, with the New York Hamilton.

Certain coral-bearing beds at Waterloo, now known to lie above the limestones at Independence, were, however, referred by Hall and Whitfield, in the report cited, to the Corniferous or Upper Helderbeg, while the Lime creek shales, which carry a fauna intimately related to the fauna of shales below the Independence limestones, were correlated with the New York Chemung.

The shale beds lying below the Independence limestones were described by Calvin§ in 1878. The position and characteristics of the Independence shales were noted, and attention

*Rept. of a Geol. Expl. of part of Iowa, Wis. and Ill., in the autumn of the year 1839. By David Dale Owen, p. 112. Ordered printed June 11, 1844.

†Rept. on the Geol. Surv. of Iowa. By James Hall and J. D. Whitney. Vol. I, part I, p. 296 1858.

‡Op. cit., vol. I, part. II.

‖Des. of new Sp. of Fos. from the Dev. rocks of Iowa; 23d An. Rep. N. Y. State Cab. Nat. Hist., p. 223, *et seq.* Albany, 1873. Advance sheets of the paper were distributed in 1872.

§Bulletin of U. S. Geol. and Geog. Surv. of the Territories. Vol. IV, No. 3, pp. 725-730. Washington, July 29, 1878.

was directed to the fact that the fauna of these lower shales was very similar to that found in the shales along Lime creek, in Floyd and Cerro Gordo counties. The Independence shales, however, lie near the base of the Devonian system, as it is developed in Iowa, while the Lime creek shales lie near the summit, with at least 150 feet of limestones between the two horizons; and the practical identity of the two faunas could lead but to the conclusion that the whole Devonian of Iowa, as then known, belonged to a single series.

There are some references to the rocks of Buchanan county in the report of the Tenth census.* The statistics on the quarries and building stones of Iowa were compiled by McGee. A brief description of the quality of the stone near Independence and Quasqueton is given, and all the Devonian strata of the state are referred to the Hamilton system.

There are frequent references to the topography, drainage and rock exposures of Buchanan county in McGee's† memoir on the Pleistocene history of northeastern Iowa. The records of a number of wells‡ give the best sections so far available of the Pleistocene deposits of the county.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface of Buchanan county presents little variety in the way of topographic forms. Much the greater part of the surface is covered with drift of Iowan age, and is diversified only by the gentle swells and broad, ill-drained sloughs that everywhere mark the presence of this sheet of till. Examples of erosion are almost entirely absent over the whole area of Iowan drift, the topographic forms being due mainly to the eccentricities of ice molding. Only along the drainage courses are there any signs of erosion since the retreat of the Iowan

*Tenth Census Rept., Building Stones and the Quarry Industry; Iowa, by W J McGee. Vol. X, p. 263. Washington, 1883.

†Pleistocene Hist. of Northeastern Iowa. U. S. Geol. Surv., Eleventh An. Rept. Washington, 1891.

‡Op. cit., p. 519.

ice, and even here the process is in the incipient stage, for it is generally limited to the cutting of the shallow channel and to the carving of short, secondary trenches that extend back only a few rods from the stream. The general surface of the country remains about as it was left by the Iowan ice. The general drift surface is practically unmodified by erosive agents.

In the interval between the going of the Kansan ice and the coming of the Iowan the surface of the older drift was deeply eroded, and in many cases the present surface configuration is controlled to a greater or less extent by the inequalities thus produced. Indications of pre-Iowan topography, only partly disguised by the later drift, are seen—first, in the valley of the Maquoketa, and, second, in the gravel ridges rising forty or fifty feet above the level of the valley, in the northeast corner of Madison township. The broad, shallow depression followed by Buffalo creek, is a partly-filled pre-Iowan valley. It may indeed be preglacial. At all events it was a drainage course at the close of the Kansan, for beds of Buchanan gravels laid down during the melting and retreat of the Kansan ice, and now highly oxidized, are strewn all along its course in Buchanan county. The same is true of Pine creek and its valley in the western part of Byron township. The same is true to a greater or less extent of every stream in the county. Their valleys, if the broad depressions in which they flow deserve to be called valleys, are not products of erosion since the retreat of the Iowan ice. They were determined by the character of the surface before the Iowan drift was deposited. This later drift simply veneered, without completely disguising the old valleys. Nearly all these valleys were waterways when the Kansan ice was melting and were partly choked by trains of gravel which is now recognized as the valley phase of the Buchanan gravels.

That the Iowan drift, in certain localities, is very thin, and simply mantles a topography developed in pre-Iowan time, is illustrated at numerous points. There are ridges of weathered

Buchanan gravels over which the Iowan till is limited to a few inches of dark loam. Even in the valleys the deposit of Iowan age is not infrequently less than a foot in thickness. A rounded, rocky bluff, rising sixty-five feet above the level of the river, in the southwest quarter of section 4, Perry township, has numerous Iowan bowlders strewn over the entire surface, from the level of the water up to the summit, and stands as an example of an old topography practically unaffected by Iowan drift. Over by far the larger portion of the county, however, the Iowan drift completely conceals the characters of the pre-Kansan surface and presents a topography peculiarly its own.

Where typically developed, the Iowan drift plain exhibits a surface that is rather gently undulating. The relief curves are low, broad and sweeping, with the concave portions often longer than the convex. Drainage of the broad, gently concave lowlands is imperfect, or was so before the introduction of artificial conditions. The only evidence of erosion is found in the narrow, shallow channels of the drainage streams cut but little below the level of the otherwise unbroken plain.

Taken as a whole Fremont township has more of the typical characteristics of the Iowan drift plain than any other area of similar size in the county. The relief in general is very low, large areas being flat and imperfectly drained. This is particularly true of the broad plain which is bisected by Prairie creek. From a short distance north of the center of the township, this stream flows in a narrow, shallow, trough-like ditch; but the gradient is so low that the sluggish current is frequently brought apparently to a standstill by beds of spatter dock and other pond weeds that choke the channel. The broad, gravelly plain east of Buffalo creek, in the western part of the township, grades imperceptibly into the relatively high ridge of drift between Buffalo and Prairie creeks, a ridge that forms the watershed between the Wapsipinicon and Maquoketa systems of drainage. This ridge would, however,

be inconspicuous if set in the midst of topography of pronounced erosional type.

All the other townships are cut by drainage streams of more or less importance, and these, as already noted, follow pre-Iowan valleys that give more than the usual amount of diversity to the surface. But over the greater part of every township the features that characterize Fremont are duplicated with only slight modification of details. In some instances, as over most of Newton township, the curves are slightly sharper and the amount of dry land, as compared with the sloughs or damp meadow land, is greater. Newton, on the whole, has more perfect drainage than Fremont. There is a large area of very gently undulating land between Bear creek and the Wapsipinicon river in Homer and Cono townships. Westburg is a distinctively prairie township with some moraine-like knobs and hills in sections 10 and 15, and some dry gravelly and sandy ridges in sections 5 and 6; but in general the surface has the low, monotonous undulations of uneroded drift. Buffalo township is divided, almost diagonally, by a very broad, shallow sag in the general surface, the sag being followed by the west branch of Buffalo creek; but with the exception of some sand hills and rock exposures in sections 13 and 24, the whole township is occupied by typical Iowan drift unmodified since the retreat of the Iowan glaciers. The eastern part of Fairbank township is a very level, dry plateau in which a sheet of Iowan drift varying from two or three to thirty feet in thickness overlies an extensive bed of Buchanan gravels. The plateau is a unique piece of prairie land, without the usual undulations, and without any indications of imperfect drainage. The underlying gravel seems to afford an easy means of escape for the surplus surface waters.

From section 12 of Jefferson township to the south line of the county, Lime creek flows in an old valley, forty to fifty feet in depth, with numerous rock exposures along the sides, and a very meager amount of Iowan drift coming down on the slopes to the level of the stream.

The most anomalous piece of topography in the county is seen in the high hills bordering the Wapsipinicon river, in Liberty township, northwest of Quasqueton. From the west line of this township to Quasqueton the river flows in a gorge 130 to 150 feet in depth. The highlands indeed begin, but are at first not very pronounced, in section 24 of Sumner township, and they attain their greatest height in section 29 of Liberty. The land near the river is conspicuously higher than that farther back on the drift plain. The stream, as in the case of the other anomalous rivers of McGee,* here seems to go out of its way to cleave a channel in the highest land of the whole region. This highland seems not to have been invaded by Iowan ice. Where it merges into the drift plain there are sometimes bare stony hills and channels of pre-Iowan erosion, as in the west half of section 24, Sumner township, and in sections 31, 32 and 33, Liberty township. On the flanks of the hills, a little higher than the level of the drift, there is a deep deposit of sand, but the sand, at still higher levels, gives place to true loess. There is a heavy capping of loess overlying Kansan drift on the hills north of the river gorge, in sections 29 and 30 of Liberty township. From all the data that can be gathered concerning it, this area of hills and highlands seems to have projected as an island above the surface of the Iowan ice. The region embraces an area of a number of square miles, lying on both sides of the river, beginning in the southern part of section 24, Sumner township, and extending southeastward to Quasqueton. It rises above the surface of adjacent Iowan drift to a height of 100 feet or more at the points of greatest elevation. The larger part of the area is north of the river. It was while the Iowan glaciers stood in the surrounding region that the loess was deposited over the higher summits and the beds of sand were laid down at the middle and lower levels.

A curious bit of topography breaking into the general monotony of the Iowan drift plain is seen in the south half of

*Pleistocene History of Northeastern Iowa. Eleventh An. Rept. U. S. Geol. Surv., p. 218, *et seq.* Washington, 1891.

the northeast quarter of section 28, Middlefield township. There is here a series of prominent knobs and rounded hills separated by sharp, narrow valleys, the whole arrangement and aspect recalling a fragment of the terminal moraine of the Wisconsin drift. The summit of the highest point is eighty feet above the road at the east end of the group, a road which follows, on even grade, the valley of Buffalo creek. The height above the creek is about ninety feet. The knobs are grassed over and afford no opportunity to examine their structure, but numerous large granite bowlders sprinkled in the sharp valleys suggest that they are of Iowan age. Elsewhere the broad sag constituting the valley of the Buffalo ascends very gradually in a direction at right angles to the stream and imperceptibly blends with the surface of the upland drift.

There are numerous gravel terraces along the Wapsipinicon river between Littleton and the south line of the county. The gravel is in all cases pre-Iowan, dating from the deposition of the Buchanan gravels. A well marked terrace, separated from the river by a sandy flood plain, passes through the center of section 25, Cono township. Another terrace of the same age and same structure occurs in the western half of section 3 in the same township. There are others of similar type in sections 28 and 29 of Washington township, and in sections 13 and 24 of Perry. All these terraces rise abruptly to a height of ten or twelve feet above the swampy or sandy flood plain between them and the river, the height of the slope being indicative of the amount of erosion that has taken place since the gravels were deposited.

DRAINAGE.

The drainage of Buchanan county is effected chiefly by the Wapsipinicon river and its branches. This stream flows in a general southeast direction from near the northwest corner of Perry township to near the southeast corner of Cono. It follows the southern or southwestern margin of its drainage

basin. Its main branches flow in from the north, there being no affluents of any importance from the south or west. Streams flowing into the Cedar river and draining the southwestern corner of the county have pushed their sources back to within two miles of the Wapsipinicon, restricting the drainage area southwest of the stream to a comparatively narrow zone. On the other, or north side of the stream, the drainage area is much wider. The tributaries are long, and some of them originate within less than a mile of Buffalo creek, which drains a very low and narrow valley northeast of the Wapsipinicon. The law that streams in Iowa seek the south side of the valleys, with longer affluents and the wider portion of their drainage basins on the north side, is very generally, though not universally, true.

The Little Wapsipinicon enters the county at Fairbank, near the northwest corner, and drains the western half of Fairbank township. The eastern half of this township is in general a level plateau without undulations or drainage courses, the surface waters apparently escaping into a bed of Buchanan gravels which here underlies the Iowan drift. The Little Wapsipinicon joins the main stream at Littleton, in Perry township. Otter creek, which, with its branches, drains Hazelton township, is a stream of some importance, supplying valuable water power at two points, and entering the main water course in section 19 of Washington township. The eastern part of Washington township is drained by a number of small streams, among which Harter creek, that flows into the river above Independence, is probably the most important. Pine creek drains the southwestern part of Buffalo township and the greater part of Byron and Liberty. In western Byron it flows in a partly disguised pre-Iowan valley. The banks of the creek are not marshy, as is usually the case in prairie streams, for the reason that heavy beds of Buchanan gravel underlie the surface drift. In Liberty township this stream cuts into the anomalous highlands described under the head of topography. Owing to the thin-

ness or total absence of the later drift along its lower course, Pine creek loses the character of a prairie stream in section 9 of Liberty township, and thence to its mouth runs in an old valley, whose sides present a great number of interesting rock exposures.

Buffalo creek is a typical prairie stream, flowing in a shallow channel cut in drift all the way from the north line of Buffalo township to where it crosses into Delaware county, near the middle of the east line of Newton. Its drainage basin is very narrow and all its affluents, except the east branch in Buffalo township, are short, intermittent streams, usually following mere sags or sloughs, without definite channels. Buffalo creek is in the main parallel to the Wapsipinicon, and is a part of the Wapsipinicon drainage system, the two streams coming together in Jones county, near Anamosa.

The drainage in the northeastern part of the county belongs to the Maquoketa system. The greater part of Madison township is drained by the south fork of the Maquoketa, and nearly all of Fremont township is drained by the sluggish Prairie creek that eventually joins the Maquoketa, near Manchester, in Delaware county.

Spring creek, Lime creek and Bear creek, that drain the part of the county southwest of the Wapsipinicon basin, bear tribute to the Cedar river. They are all of the ordinary type of prairie streams except Lime creek, which, in the southern half of Jefferson township, follows a pre-Iowan valley, forty or fifty feet in depth. This old valley seems not to have been filled with Iowan drift, and its walls are diversified with numerous low, rocky cliffs, or rounded, rocky prominences, covered with a scant layer of residual soil.

GEOLOGICAL FORMATIONS.

General Relations of Strata.

The geological formations of Buchanan county belong to three different systems—namely, the Silurian, Devonian and Pleistocene. The Devonian follows the Silurian in natural

sequence without any considerable break; but between the Devonian and the Pleistocene there is a gap of immeasurable extent. The Silurian and Devonian systems are represented by the limestones and shales that make up the universally spread foundation rocks of the county. These are the so-called indurated rocks. They are the rocks that are worked in all the limestone quarries and are exposed in all the rocky knobs and ledges that project through the loose superficial materials or soils. All the Silurian and Devonian beds are more or less altered marine sediments. On the other hand, the Pleistocene beds are composed of loose, unconsolidated materials laid down by a number of different processes upon the surface of the land. Most of these materials were transported and spread out by glaciers. The pebble-bearing or bowlder-bearing yellow and blue clays, so generally distributed over the county and so universally recognized by well diggers and others who have occasion to make excavations to any considerable depth below the natural surface, are all of glacial origin. Glaciers transported the granite bowlders that, within the limits of this county, are such conspicuous and striking features in every prairie landscape. Torrents of water from melting glaciers transported, sorted and deposited the great beds of rust-colored Buchanan gravels that are found at numerous points in almost every township. The modern streams have built up deposits of clay and sand that are part of the Pleistocene system, and even winds have been instrumental to some extent in shifting and rearranging the loose surface material and making new deposits of Pleistocene age.

The following table shows the taxonomic relations of the strata exposed in Buchanan county.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Post-glacial deposits.
		Glacial.	Loess?
			Iowan.
			Buchanan.
			Kansan.
Paleozoic.	Devonian.	Middle Devonian.	Cedar Valley.
			Wapsipinicon.
	Silurian.	Niagara.	Delaware.

The last column in the table above, giving the names of the several stages represented in the geological formations of the county, is subject to revision. For example, for the term Buchanan, as applied to the interval of time following the age of the Kansan drift, it may be found convenient to adopt the name Yarmouth, proposed by Leverett.* But the only recognized deposits referable to the time immediately following the disappearance of the Kansan glaciers are those to which the name *Buchanan gravels* is applied, and it is for this reason that the term used in speaking of these deposits is retained. It must be borne in mind, however, that the deposition of the gravels seems to have been practically coincident with the withdrawal of the Kansan ice, and from this point of view a strict classification might require us to regard the gravels as only a phase of deposits properly belonging to the Kansan stage. Admitting all this, the fact remains that the marked structural differences between the Kansan drift and the

*JOURNAL OF GEOLOGY, Vol. vi, p. 176, et seq. Chicago, Feb.-March, 1898.

Buchanan gravels renders their separation for purposes of study and treatment a matter of very great convenience, and with this understanding the arrangement, so far as relates to this particular part of the column, may be allowed to stand.

A similar explanation seems necessary with respect to the use of the term *Loess* for the interval following the Iowan drift. The intimate genetic relation between Iowan drift and loess is such as to require us, in a rigid system of classification, to look upon the two deposits as different phases representing the same stage; and it is only as a convenient way of recognizing the differences in physical characteristics which distinguish them that the two are separated. The Buchanan gravels were certainly not laid down until the Kansan ice had retreated from the surface over which they were spread. Loess may have been deposited on the highlands northwest of Quasqueton while the Iowan ice was at its maximum, or even before the maximum was reached. Absolute contemporaneity between Iowan drift and loess is much more possible than between Kansan drift and Buchanan gravels in the same neighborhood.

Silurian System.

NIAGARA LIMESTONE.

The Niagara limestone is found in all the outcrops in the northeastern part of the county. With one or two exceptions presently to be noted, the rocks of this series are coarse, granular, vesicular dolomites, interbedded at certain localities with large quantities of chert. The beds all belong to the Delaware stage and are simply an extension of the strata exposed in the northwestern part of Delaware county.

Along the Maquoketa, near the southwest corner of section 10, Madison township, there are exposures of the coarse Niagara limestone in some low knobs bordering the stream. Excepting some casts or impressions of *Halysites catenulatus*, the beds are unfossiliferous. Niagara limestone is exposed over an area of several acres in extent in the southern part of

section 18 and northern part of 19, in the western edge of Madison township, and there are exposures on the township line between section 18 of Madison township and 13 of Buffalo. The limestone here occurs in stony knobs or prominences and affords a section twelve or fifteen feet in thickness. The beds are quite regular, from two to six inches in thickness, and they have been quarried in a small way at one or two points, and in at least one locality they have been used in the manufacture of lime. The drift is very thin on all the low, rounded hills of the immediate neighborhood, so that the stone could readily be exposed and quarried over a much larger area, if the demand warranted the effort. Silicified colonies of the corals *Halysites catenulatus* and *Favosites favosus* are the principal fossils, and with these are associated a number of Stromatoporoids, silicified, and practically structureless in their present condition. Near the middle of the west line of section 16, in Madison, there is an outcrop of Niagara, covering a small area, and affording silicified corals, mostly *Syringopora tenella.*

In Buffalo township there are exposures of Niagara limestone near the southeast corner of section 13. Where the road between sections 13 and 24 of this township crosses the east branch of Buffalo creek there is a vertical ledge of Niagara which forms the west abutment of the bridge. Other exposures occur at intervals for a mile or more below the bridge. All are of the coarse, granular type, and all indicate a horizon about the middle of the Delaware stage, the equivalent of the Pentamerus and coral-bearing zone described in the report on Delaware county.

Niagara limestone is exposed at numerous points along Otter creek and its branches, in the northern part of Hazelton township. The outcrops are almost continuous along the stream courses in sections 2 and 10, north and northeast of Hazelton. In the southwest quarter of the northwest quarter of section 10 the rock appears in thin, irregular beds which furnish *Lyellia americana* and *Heliolites interstinctus.* In the

southeast fourth of the same quarter section, Mr. J. O. Goff has opened a quarry that shows thin layers in the upper part of the working and thicker beds near the base. There is a large amount of chert interbedded with the limestone. The height of the vertical quarry face is about fourteen feet. The upper two or three feet is made up of soil, reddish-brown residual clays and decayed fragmentary limestone. The length of the quarry face is about 100 feet. In getting out the stone a large amount of rubbish, composed of chert and chipstone of good quality for road making, is produced. Natural exposures of the same beds, much weathered and overgrown with moss, extend along the low bluff east of the quarry for a distance of 500 feet. In the talus along the base of the bluff, and in the wash of the creek, there occur *Lyellia americana*, *Syringopora tenella*, *Favosites hispidus*, *Favosites favosus* and *Favosites alveolaris*, or a species with pores in the angles of the corallites and closely related to *F. alveolaris* and *F. aspera*.

All the exposures in section 10 of this township show the coarse, granular facies of the Niagara dolomite; but in the southwest quarter of section 2 the coarse dolomite passes beneath fine-grained non-dolomitized limestone which may possibly represent the horizon of the evenly-bedded quarry stone in the upper part of the Delaware stage in Delaware and Jones counties. This fine-grained limestone varies in color from light drab to blue. It breaks with conchoidal fracture and has the grain of lithographic limestone; but the texture is not quite uniform and all the pieces observed were still further rendered valueless as lithographic stone by numerous checks and flaws. Some quarries are worked in this horizon in the northeast quarter of the southwest quarter of section 2, the largest being known as the John Conrad quarry. The layers vary in thickness from four to ten inches. The beds are light gray in the upper part of the quarry; bluish in the lower part. Near Coytown, in the southwest quarter of the southeast quarter of section 2, the light gray facies of these upper beds

is exposed in a quarry that has been worked in the manufacture of lime. Near the top of this quarry the layers seem to be brecciated, and thin beds of lithographic limestone are irregularly interbedded with a rather coarse crystalline dolomite. Neither at Coytown nor at the Conrad quarry were any fossils observed in the fine-grained limestone, nor were any found in the overlying residual clays to indicate that beds of the ordinary Niagara type, containing silicified corals and other organic remains, had ever existed above it.

In the banks of Otter creek, at Kiefer Brothers' mill, south of Hazelton, there are ledges of Niagara limestone rising above the level of the water to a height of fifteen feet, and on the hillside sloping to the west there are outcropping ledges, alternating with spaces concealed by clay or sod, up to a height of twenty-five to thirty feet farther. Near the level of the water the layers are quite regular, and free from fossils so far as noted, except for a single cast of a small individual of *Orthis biforata*, such as occurs not infrequently in certain phases of the Delaware stage, in Cedar county. Higher up, on the slope of the hill, *Lyellia americana* and the Favosites with pores in the angles of the corallites, which is referred to the species *Favosites alveolaris*, are not uncommon. These two, indeed, are the most characteristic and persistent species of the Niagara limestone in this part of Buchanan county. There is a small quarry of evenly-bedded Niagara limestone east of the creek, in the northeast quarter of section 18, Hazelton township, but the best outcrop of Niagara in this township is seen in the hill west of the west branch of Otter creek, on the road passing between sections 7 and 18. The locality is known as the Miguet hill. A section showing twenty-five to thirty feet of rock is here exposed. The stone has been quarried on a small scale, and some has been taken out to improve the grade of the road. The lower beds exposed contain *Halysites catenulatus, Syringopora tenella* and *Ptychophyllum expansum.* Higher up there is a larger assemblage of typical Niagara corals, including *Heliolites interstinctus, Lyellia americana*

Halysites catenulatus and *Favosites alveolaris.* At the summit of the hill the beds are largely made up of thin, expanded forms of Stromatopora not silicified. One-fourth mile further west the rock is again exposed, and in the residual surface materials are silicified colonies of Heliolites, Lyellia, Halysites and Favosites. A few layers of soft, earthy Niagara limestone, very much decayed by weathering, are exposed in the railway cut in the south edge of Hazelton, but they show nothing of special importance.

While no outcrops of Niagara were seen in Fairbank township, the formation underlies the drift over an undetermined area, but one of considerable extent, in the northeastern corner. On the Little Wapsipinicon river, one and one-half miles north of the town of Fairbank, the Niagara limestone forms a high bluff on the south side of the stream. The bluff rises forty feet above the level of the water, and the vertical cliffs of brownish-yellow, weathered dolomite measure sixteen feet. On the rounded slopes above the projecting ledges the soil contains masses of residual Niagara chert and silicified Niagara corals, showing that the Niagara limestone is present up to an altitude equaling that of the summit of the bluffs. This fact is of interest only when taken in connection with another fact—namely, that at Fairbank, only a mile and a half south, there are quarries opened in Devonian beds, and the level of the Devonian quarries is forty feet lower than the summit of the bluff of Niagara limestone, twenty-five feet lower than the brow of the vertical cliff of massive Niagara dolomite. The later Devonian was deposited against the side of a steep, anticlinal fold, which lifted the Niagara of northeastern Buchanan much above the position it normally would have occupied had the strata retained, relatively, the position in which they were laid down on the floor of the Silurian sea. To this upward folding of the Niagara is due the strong re-entrant angle which is made in tracing the eastern edge of the Devonian area from the central part of Fayette county to near the southeast corner of Buchanan.*

*See geological map of Iowa, this volume, Plate ii.

Devonian System.

The earlier geologists of Iowa attempted to correlate the Devonian strata of the state with certain recognized Devonian beds belonging to the geological column of New York. Owen referred a part at least of the Devonian formations he encountered west of the Mississippi to the Hamilton series,* and nearly all subsequent geologists have followed his example. The fact is, however, that the Devonian system of Iowa was deposited in an area geologically isolated from that in which the eastern Devonian was developed. The conditions of sedimentation were different in the two areas. The order and succession of faunal conditions were not the same. The eastern Devonian faunas, subjected to certain physical conditions and undergoing certain modifications, probably migrated from the northeast along the eastern border of the continental nucleus, while the western faunas of the same period seem to have come from the northwest along the western border of the Devonian continent. The conditions encountered were different and the modification of the species progressed along wholly different lines. Even in the case of species that are common to the two provinces, there is evidence that the time and order of arrival at the same latitude on opposite sides of the old continent were not the same. The Devonian fauna of Iowa is intimately related, in certain respects, to that at the Ramparts of the Mackenzie river; it bears some resemblance to the Devonian fauna of the Eureka District of Nevada; but, for purposes of minutely correlating strata, it would be misleading to compare it with the faunas of this period in the eastern province. As an illustration of the extent of the error into which even the most eminent and experienced of geologists may be led when attempting to correlate the eastern and western Devonian by means of the geological faunas, it is worth noting that some years ago the quarry stone at Raymond was referred to the Schoharie stage, the coral-bearing

*Owen's Geol. Surv. of Wis., Iowa and Minn. Explanations of figures of Devonian fossils Tables iii and iii A.

beds at Waterloo were called Corniferous, the limestones at Independence were assigned to the Hamilton, and the Lime creek shales were called Chemung. Now the Lime creek fauna is found in shales below the Independence limestones, and so, judging from the fauna, the Independence shales are also Chemung. Furthermore, the coral-bearing beds at Waterloo are younger than the limestones at Independence, for they lie above them, and the quarry stone at Raymond is still younger than the coral beds that were referred to the Corniferous. Beginning with the Independence shales, the actual order of the strata in Iowa, according to the correlation referred to, would be—(1) Chemung, (2) Hamilton, (3) Corniferous, (4) Schoharie—a complete reversal of the order observed in New York. It may be repeated, for the sake of emphasis, that the western Devonian cannot be correlated, except in a broad and very general way, with that of the east.

All the beds of this system observed in Buchanan county are referred provisionally to the "Middle Devonian," and this notwithstanding the fact that no positive evidence of an erosion interval between the Silurian and Devonian is known to exist.

INDEPENDENCE SHALES.

The Independence shales belong to the Wapsipinicon stage of Norton.* The underlying "Otis beds" are not known in Buchanan county, and the shales in question constitute the lowest recognized member of the Devonian in this part of Iowa. In the county there are no natural exposures of the shales that show well their characteristics and entire thickness. The most that is known here concerning them was learned from shafts sunk at the old Kilduff quarry, now owned by Thomas O'Toole, east of Independence. The formation was penetrated to a depth of twenty feet and was found to consist of dark-colored shales, alternating with thin beds of

*Iowa Geol. Surv., vol IV. Report on Linn county, by W. H. Norton. Professor Norton here uses the term "Kenwood beds" for the Linn county equivalent of the Independence shales.

limestone. At certain levels the shale was very dark, carbonaceous, and contained vegetable remains, some parts of which had been transformed into true coal. There are outcrops of the shales in the river bank, at the level of the water, near the center of the north line of section 10, Sumner township. There is a small exposure of the shales in the bank of the creek in the southeast quarter of the southeast quarter of section 35, Washington township; and they are seen again near the bridge at Quasqueton, in Liberty township. Running through this formation at a certain level is a bed of unfossiliferous, laminated, clayey limestone that splits into thin leaves one-fourth to one-half an inch in thickness. This phase is easily recognized, and exposures of it are seen along Harter creek, in the northwest quarter of section 27, Washington township, and along the Wapsipinicon, in the southwest quarter of section 24, Sumner township. In general, however, the natural exposures are few and unsatisfactory, the position of the beds being such that the outcropping edges are either covered with talus or are sodded over. The fauna of the shales embraces the following species.

**Pachyphyllum solitarium* Hall and Whitfield.
Romingeria umbellata Rominger.
**Stropheodonta variabilis* Calvin.
**S. canace* Hall and Whitfield.
**S. arcuata* Hall.
**S. calvini* Miller.
**Strophonella reversa* Hall.
**Productella hallana* Walcott.
**Strophalosia rockfordensis* Hall.
**Orthis impressa* Hall.
O. infera Calvin.
**Rhynchonella (Pugnax) pugnus* var. *alta*.
**Rhynchonella (?) ambigua* Calvin.
Pentamerus (Gypidula) munda Calvin.
**Atrypa reticularis* Linnæus.

**Atrypa aspera* var. *hystrix* Hall var.
Spirifer subumbona Hall?
**Cyrtina hamiltonensis* var. *recta* Hall.

The species marked with an asterisk are common to the Independence shales and Lime Creek shales, at the two extremes almost of the Devonian series. Of some of the species, however, the proportional number of individuals differ very greatly at the two horizons. For example, *Strophеodonta variabilis* is rare along Lime creek, but it is one of the most common and persistent species in the Independence shales, while *Orthis impressa*, which is represented by numerous large and well-developed individuals in the Lime Creek horizon, occurs but rarely in the shales at Independence, and the individuals are small. The *Rhynchonella (Pugnax) pugnus*, found both in Lime Creek and Independence shales, is a small acuminate variety, quite distinct from that occurring in the state quarry beds of Johnson county, Iowa, or in the unique High Point fauna of New York. The form called *Rhynchonella (?) ambigua* is of doubtful generic relationships, and that listed as *Spirifer subumbona* Hall? is probably a new species. Only a very few of the species marked as common to the two shale horizons are found in the intermediate beds.

Fayette breccia.—The widespread assemblage of brecciated beds above the Independence shales constitutes the upper part of Norton's Wapsipinicon stage. Furthermore, the breccia, as defined by Norton, embraces a number of distinct life zones, and even includes beds in which the characteristic brecciation is not very perfectly developed. In some of the exposures there are layers of limestone, unbroken and apparently undisturbed, that lie in the midst of brecciated limestone made up of fragments that, judging from the wide range of color and texture, were derived from a dozen or more different beds.

The breccia, in its lower and more typical phase, is well exposed in the bed of the river, below the bridge at Independence. It is here composed of angular fragments of limestone,

FIG. 1. View in City quarry at Independence, showing effect of crushing in the *Spirifer pennatus* beds, upper part of the brecciated zone.

FIG. 2. Small fold showing the effect of crushing in the upper part of the brecciated zone, near Brandon.

varying in character, evidently the product of many distinct layers, and all cemented together by a calcareous matrix. The fragments range from small pieces with dimensions of a fraction of an inch up to masses a yard or more in length and width and a foot in thickness. There are fine-grained, dark drab fragments which break with conchoidal fracture, and there are finely laminated fragments of the same color. There are pieces of fine-grained, light-colored, lithographic limestone, and coarser, dingy yellowish colored beds were also involved in the general destructive process, whatever it may have been, that reduced a large number of limestone layers to the brecciated condition. The fragments, large and small, of different color and of different texture, are promiscuously tumbled and heaped together, some on edge and others at all possible angles with the original position. Some of the blocks are fossiliferous, but the greater number show no traces of life. The most common fossil in the layers exposed in the bed of the stream at Independence is *Pentamerus* (*Gypidula*) *comis* Owen, the species being represented in some of the constituent blocks of the breccia by occasional perfect shells and multitudes of detached valves. In the south bank of the river, along the north side of section 10, Sumner township, the breccia is exposed, beginning near the level of the water and extending to the summit of the low bluffs. The underlying Independence shale crops out at the water level, and this is followed by the phase of the breccia in the river bed at Independence. Higher up in the bank, above the phase referred to, *Pentamerus comis* is very abundant in the large fragments of limestone that, at this horizon, make up nearly the entire deposit; and a large Gyroceras occurs in considerable numbers. Above the Gyroceras bed is a body of soft, light gray or nearly white limestone, not distinctly bedded, but very much shattered, and cut by joints that, intersecting at every possible angle, divide the bed into a great number of shapeless fragments which still retain their relative positions unchanged. (Plate xiv, Fig. 1).

In this part of Iowa the shattered limestone above the Gyroceras horizon differs very much from the true breccia below. Below the Gyroceras bed the fragments are of many different kinds, evidently displaced and promiscuously mingled; while above this bed the fragments into which the rock has been broken bear evidence of very little displacement. The phenomena of slickensides, very extensively developed on the joint walls, are indicative of tremendous crushing and shearing strains to which the rocks of this horizon have been subjected. At Troy Mills, in Linn county, and farther south, the beds at this same geological level were involved in the process that produced true breccia, and for this reason Norton includes them in the brecciated zone and recognizes them as the fourth phase of the Fayette sub-stage.* While not a true breccia in the neighborhood of Independence, these beds pass into the brecciated condition in the southern part of the county, and must be considered as a part of the Fayette division of the Wapsipinicon stage. At the point under consideration, in section 10, Sumner township, this upper member of the Fayette formation is unfossiliferous at the base, but, without apparent change in lithological characters, it passes up into beds that are exceedingly rich in a great variety of fossil forms. The fossiliferous zone furnishes a very fine ribbed *Atrypa reticularis*, robust forms of *Atrypa aspera* var. *occidentalis*, and large, typical individuals of *Spirifer pennatus*. *Spirifer bimesialis* is the only other spirifer. *Pentamerus comis* occurs, but is rare when these beds are compared with the Gyroceras horizon. Equally rare is *Cyrtina hamiltonensis*, which here assumes the true Hamilton type as seen in the Hamilton shales of western New York and western Ontario. Even more rare are *Heliophyllum halli* and an Astræaspongia related to *A. hamiltonensis* Meek and Worthen. *Orthis macfarlanei* is rare, but more common than the two species last named. Naming this life zone from its typical fossil it has been called the *Spirifer*

*Geol. of Linn County. By W. H. Norton. Iowa Geol. Surv., vol IV, p. 161. Des Moines, 1895.

pennatus beds. To recapitulate, a section of the Fayette breccia includes the following.

	FEET.
4. *Spirifer pennatus* beds, composed of soft, light gray limestone, intersected by numerous joints that cut the formation at every possible angle and divide it into relatively small, shapeless blocks. The most conspicuous fossils are *Spirifer pennatus* Owen, *Spirifer bimesialis* Hall, *Atrypa reticularis* Lin., *Atrypa aspera* var. *occidentalis* Hall var. *Pentamerus comis* Owen, *Orthis macfarlanei* Meek, *Orthis iowensis* Hall, *Productella alata* Hall, *Strophеodonta demissa* Con.....	8 to 12
3. Barren beds, similar in lithological characters and physical condition to the *S. pennatus* beds, but destitute of fossils, or nearly so.....	10 to 15
2. Gyroceras beds, composed of rather large but displaced and tumbled fragments of a coarse grayish or yellowish limestone, though there are occasional small areas in which the beds show no signs of disturbance. Principal fossils, two species of unnamed Gyroceras and *Pentamerus comis* Owen. The last is exceedingly abundant in some blocks, but it is generally represented by separated valves.....	5
1. The true brecciated beds, composed in the main of small, angular fragments, mostly unfossiliferous, many of the fragments fine-grained and dark drab in color.....	15 to 20

The principal exposures of the breccia, besides those already mentioned, are found along the valley of the river between Independence and the south line of the county. In the northwest quarter of section 14, Sumner township, Nos. 1 and 2 are both well exposed. In some ravines in the southwest quarter of 24 and northwest of 25 in the same township, the weathered edges of all the beds from the base of No. 1 to the top of No. 4, are seen at various points in the rather gently sloping and partly sodded hillsides. At Pine creek mill and in the hills west of the mill the *Spirifer pennatus* beds are well developed, the stone being somewhat harder than at Independence; and one of the most extensive exposures, includ-

ing beds 1, 2, and 3, is seen in the river bed below the mill dam at Quasqueton.

The higher phases of the breccia, including beds 3 and 4, are found in all the quarries about Independence. These beds furnish nearly all of the quarry stone of local origin used in Independence and the country surrounding it. The quarries and natural outcrops are too numerous to be mentioned separately, but the constancy of the lithological and other characters of the beds fortunately makes separate description unnecessary.

A quarry worked wholly in the Barren beds, No. 3, is located south of the cemetery, in the eastern part of section 2, Tp. 88 N., R. IX W. The beds exposed in this quarry are, as usual, divided by numerous joints. The stone is soft, light colored where weathered, but bluish in the interior of the larger blocks. Fossils are conspicuously absent, at least there are no organic remains that are obviously of the same age as the beds forming the quarry. Some years ago, however, Mr. J. McMillan took from this quarry some large masses of a silicified Diphyphyllum that all showed evidence of having been worn and rounded before being embedded. The specimens obtained by Mr. McMillan are evidently mere fragments of larger coralla; and yet, while all are large, at least one was nearly four feet in its greater diameter and weighed several hundred pounds. The corals occurred in pockets in the limestone. The species is not definitely determined, but the silicified condition, the character of the matrix in which the corallites are embedded, and the evidence of weathering before being placed in the position in which the masses were found, all suggest that the coral may be Silurian, probably Niagara, in age. It would be interesting to know by what agency these great weathered masses were transported and dropped upon the sea bottom when the material making up the Barren beds of this region was in process of accumulation.

A quarry located in the eastern edge of Independence is

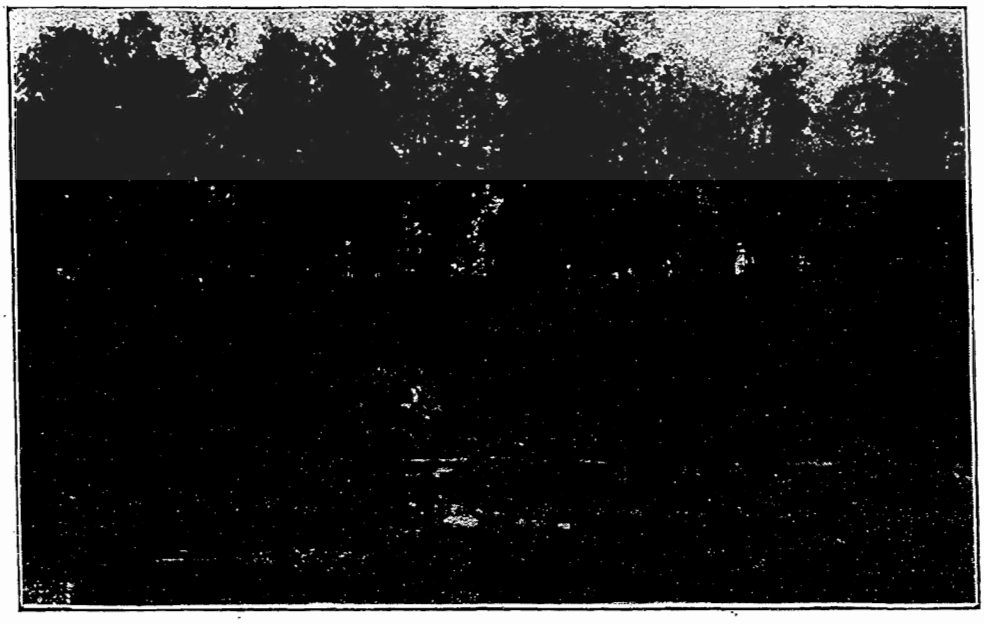

FIG. 1. Regular stratification in Cedar valley limestone, Acervularia horizon, above crushing, near Littleton.

FIG. 2. View of O'Toole quarry, east of Independence. Badly weathered Cedar Valley limestone overlies the *Spirifer pennatus*.

typical of nearly all the natural or artificial exposures of this region. It shows the following section.

		FEET.
3.	Yellowish, rather hard limestone, which rings when struck with the hammer, in rather thin layers, and containing numerous corals, among which *Cystiphyllum americanum* and *Acervularia profunda* are the most characteristic species	4
2.	*Spirifer pennatus* beds showing the usual assemblage of fossil species, not definitely bedded, but intersected by a great number of joints. The phenomenon of "slickensides" developed on the joint faces on an extensive scale	8
1.	Barren beds, lithologically like the *S. pennatus* beds above	10

No. 3 of this section is the lowest member of the Cedar Valley stage of the Iowan Devonian. In this county it is everywhere rich in corals, and in some areas of limited size it becomes a crowded coral reef. From its most characteristic fossil it may be called the *Acervularia profunda* beds. The fauna of the *Spirifer pennatus* beds, No. 2, is about the same at the various outcrops throughout the county. The fine-ribbed *Atrypa reticularis* is the most abundant fossil; but this species, under a number of varietal forms, has a great vertical range, and the *S. pennatus* is therefore the most typical species of this horizon.

The quarry owned by Thomas O'Toole, near the north line of the southwest quarter of section 35, Washington township, is one of the most important of a large number of quarries that have been opened within a distance of one and one-half miles east of Independence (Plate xv, Fig. 2). There occurs here the usual succession of Barren beds at the base of the quarry pit, with very fossiliferous *Spirifer pennatus* beds occupying a middle position and coral-bearing beds of the *Acervularia profunda* zone above. It was in an abandoned pit, a few rods west of the O'Toole quarry, that the first shaft which brought to light the Independence shales of this locality was put down.

Outcrops of the *Spirifer pennatus* beds are seen at a number of points along Pine creek and the Wapsipinicon river in Liberty township. In the southeast quarter of section 32, same township, a mile and a half west of Quasqueton, are some very typical exposures which afford, among a large variety of beautifully preserved fossils, a small celled Favosites resembling in structure, though not in mode of growth, *Favosites placenta* Rominger. In the southeast quarter of section 16, Cono township, a small quarry is worked partly in beds belonging to the horizon of *Acervularia profunda* and partly in beds of the *Spirifer pennatus* zone. Beds bearing *Spirifer pennatus* and its associated species crop out along the creek in sections 31, 32 and 33, Newton township, and the same beds are again seen, a mile or more east, along the south line of section 34. North of Independence the *pennatus* beds crop out in the banks of the stream at Otterville, but the rock exposures seen along the Wapsipinicon for some distance northwest of Otterville belong to higher zones. North of Fairbank in Fayette county, the *pennatus* beds are again seen on the flanks of the Niagara anticline previously noted.

CEDAR VALLEY LIMESTONE.

The line of division between the Wapsipinicon and Cedar Valley stages of the Iowa Devonian may conveniently be drawn at the top of the *Spirifer pennatus* zone. Above this line there is a marked change in the character of the limestone and a still more marked change in the fauna. The rock is harder, at first ranging from yellow to dark grey in color, and the evidences of crushing and disturbance have almost entirely disappeared. The characteristic fauna of the lower beds ceases abruptly, and in the zone immediately following the *S. pennatus* beds corals become the predominating type. The most common species is *Acervularia profunda*, and in the beds characterized by this fine coral there occur *Favosites alpenensis* and several other species of Favosites, *Alveolites goldfussi*, *Clado-*

pora magna, *Cladopora palmata*, two or more species of Zaphrentis, *Aulocophyllum* (sp.?), more than one species of Cyathophyllum, *Ptychophyllum versiforme* and *Cystiphyllum americanum*. Besides the corals there are a number of peculiar stromatoporoids that have as yet received no attention from paleontologists. Near the base of this zone, but in a narrow band containing but few other corals, the large and beautiful *Phillipsastrea billingsi* occurs locally in considerable numbers.

Beds of the *Acervularia profunda* zone occur at the top of nearly all the quarries around Independence. The coral from which the zone is named is not infrequently found in masses a foot in thickness and two feet in diameter. At an old quarry south of the correction line road, about a mile east of Independence there were observed a number of large coralla which, when broken with the hammer, showed a tendency to separate into individual prismatic corallites as in the case of many coralla of *Cyathophyllum rugosum* from near the Falls of the Ohio. *Acervularia profunda* and nearly all the species noted above as being usually associated with it, are found in a soft, granular, easily-weathered matrix at the top of a small quarry on land belonging to Mr. Burke, in the northeastern part of Independence. All the beds worked at present in the Burke quarry belong to the *Acervularia profunda* zone.

The larger coral, *Phillipsastrea billingsi*, seems to occur in isolated patches, and while it has a wider range than *Acervularia profunda*, it is not so uniformly distributed over the area in which it is known to be present. Its place when present, is only a few feet above the base of the Cedar Valley limestone. In this position a number of coralla are seen at the top of the hill on the Winthrop road, one-half mile east of Independence. Fine specimens of this species have been taken from the upper beds of quite a number of quarries in the same vicinity. The coral is present at this same horizon in the river banks above Quasqueton. At the McPike and Elliott springs in the northeast quarter of section 33, Newton township, speci-

mens, weathered out of the limestone, were formerly very abundant, but they have nearly all been carried away by collectors and only those firmly embedded in their original position remain. On the sides of the low, rounded hills in the southeast quarter of the southwest quarter, and southwest quarter of southeast quarter, of section 34, Newton township, specimens of Phillipsastrea in place, or freed by weathering, are still quite numerous. Phillipsastrea is also relatively abundant at Troy Mills, south of the Buchanan county line in Linn county, as well as along the river southeast of Troy Mills for a number of miles. Its position here, as well as elsewhere, is near the base of the undisturbed beds above the Fayette breccia.

At Troy Mills *Spirifer pennatus* is found ranging into beds above the Phillipsastrea horizon, a range consistent with what is known concerning this species of spirifer at a number of other localities, but which has not been observed at any of the exposures around Independence. There are specimens of *Spirifer pennatus* in the lower part of the Cedar Valley limestone at Littleton, Jesup and Gemmel's quarry, near Quasqueton; but wherever this species is found above the true *S. pennatus* beds of the disturbed and brecciated zone, the individuals are rare and are characterized by having the cardinal line longer, the cardinal area wider and flatter, and the whole aspect of the shell coarser than among the typical individuals of the lower horizon.

On the west side of the river, below the mill dam, at Littleton, there are natural exposures of Devonian limestone showing the following section (Plate xv, Fig. 1).

FEET.

8. Yellow, fossiliferous shaly limestone, breaking down, on exposure to the weather, into small flakes of limestone mingled with a large amount of calcareous clay. Fossils include a small-stemmed Cladopora related to *C. iowensis* Owen, *Megistocrinus farnsworthi* White, a large, robust form of *Stropheodonta demissa* Conrad, that is usually much wider than long, *Orthis iowensis* Hall, an extremely coarse-ribbed

		FEET.
	Atrypa reticularis Lin., a Spirifer ralated to *S. parryanus*, but differing in having a narrower cardinal area and having the mesial fold divided by a furrow, a small form of *Cyrtina hamiltonensis* Hall, and a small, thin Dielasma.....	10
7.	Heavy-bedded, yellowish limestone, unfossiliferous...	5
6.	A crowded coral reef made up chiefly of coralla of *Acervularia davidsoni* Ed. and H., with which, however, are associated *Ptychophyllum versiforme* Hall, Cyathophyllum, two or three species, *Favosites alpenensis* Win., a Favosites growing in lenticular or hemispherical masses, like *F. emmonsi*, and Cladopores of different species	1
5.	Hard, regularly-bedded, dark drab or bluish limestone in ledges six to eight inches in thickness. This number contains *Pentamerella dubia*, associated with large numbers of *Spirifer parryanus* and a coarse-ribbed *Atrypa reticularis*. There is also a large, flat form of *Stropheodonta demissa* which differs markedly from the small, very arcuate individuals of this species found with *Spirifer pennatus* at Independence.....	2
4.	Soft limestone in two or three layers, carrying occasional coralla of *Acervularia profunda*.....	1
3.	Soft, yellowish limestone, with Favosites and some other corals, but best distinguished by the presence of *Newberria johannis* in moderately large numbers, with which occur *Pentamerella arata* and *Dielasma* (*Crancena*) *romingeri*.....	2
2.	Bed of dark grayish limestone, containing numerous small specimens of Cystiphyllum, a large Zaphrentis, large masses of Stromatopora and some coralla of *Acervularia profunda*	1
1.	Dark brown or grayish limestone, with many large specimens of *Cystiphyllum americanum* and some stromatoporoids, exposed at level of water, near the mill dam	2

Along the river bluff, a short distance above Littleton, in the southwest quarter of section 4, Perry township, there are, at the level of the water, exposures of the yellow, shaly limestone, No. 8, of the section described above. The bluff above the level of the shaly limestone is partly sodded over, but the details, as far as they can now be made out, would give.

		FEET.
2.	Yellow, earthy limestone, evenly-bedded, in layers varying from two to eight inches in thickness, as indicated in a quarry breast eighteen feet in height at the top of the bluff and occasional outcrops on the hillside. Rock contains broken shells of one or more species of Spirifer, and more perfect specimens of a coarse-ribbed *Atrypa reticularis*.....	60
1.	Yellow, shaly limestone, corresponding to No. 8 of the Littleton section	5

No. 2 of this section lies above the beds described in the section below the mill at Littleton. The quarry at the top of the bluff at the point described belongs to Mr. G. Jesse. It yields flagging and building stone of very fair quality. Another quarry at the same geological level, and showing the same characteristics, is located on land belonging to Mr. Lewis Schreier, in the south half of the southeast quarter of section 33, Fairbank township. It may be said in passing that this is the level of the quarry stone at Raymond, in Black Hawk county.

The beds in the upper portion of the Burke quarry, at Independence, correspond in part to Nos. 1 and 2 of the Littleton section, while all the beds at Littleton, from 1 to 4 inclusive, belong to the *Acervularia profunda* zone. About a mile east of Littleton the fauna of this zone occurs in great profusion and in a beautiful state of preservation in the wash of a small, intermittent creek. The corals are weathered out of a soft, light gray, granular matrix, resembling that at top of the Burke quarry, at Independence; and specimens of Favosites, Alveolites, Cladopora, Zaphrentis, Cyathophyllum, Ptychophyllum, Acervularia, Cystiphyllum, and other genera, including a number of stromatoporoids, all thoroughly cleaned, yet in perfect condition and ready for the museum, may be collected in large numbers.

At Fairbank there is a quarry on the west side of the river showing rather evenly-bedded, yellowish limestone, somewhat argillaceous, and the thicker beds have many cavities lined with calcite. This quarry gives the following section.

		FEET.
5.	Very dark brown, residual clay or geest, containing some complete shells of *Newberria johannis* and some very much weathered fragments of *Acervularia davidsoni*.....A few inches to	1
4.	Limestone, in thin layers, containing *Newberria johannis* and *Pentamerella arata*.....	4
3.	Bed crowded with *Newberria johannis*, mostly broken and detached valves.....	1
2.	Yellowish, soft, evenly-bedded limestone, in layers ranging up to six or eight inches in thickness, containing many small individuals of Cystiphyllum.....	5
1.	Heavy beds, not fossiliferous, exposed at base of quarry.....	2 to 3

The section at Fairbank shows some decided variations in character and thickness of the several members when compared with corresponding beds farther south. No. 2 is the same as No. 2 at Littleton, but it is more argillaceous and does not contain *Acervularia profunda*. Nos. 3 and 4, at Fairbank, are equivalent to No. 3 at Littleton, but together they are much thicker, and the peculiar fossil, *Newberria johannis*, is much more numerous, crowding certain layers to the total exclusion of everything else. The beds here all lie below the horizon of *Acervularia davidsoni*. This species was not seen in place at this locality, but the weathered and iron-stained specimens in the residual clays above the quarry indicate that it was once present in its normal position. About one-half mile northwest of Fairbank, in Fayette county, there are two quarries opened in beds that, at the base of the exposure, carry the fauna of the *Spirifer pennatus* beds at Independence. These beds here, however, are not crushed or brecciated, but lie in regular layers eight to ten inches in thickness. At the top of the quarries are yellowish beds, containing cavities lined with calcite, equivalent to the beds in the lower part of the section at Fairbank, and containing some small, depauperate colonies of *Acervularia profunda*. One and one-half miles north of Fairbank the Niagara dolomite, as already

noted, rises in the hill overlooking the river to an altitude of forty feet above the level of the Devonian limestone in the quarries just described.

There are two quarries, one on each side of the correction line road, one-half mile southeast of Jesup. The north quarry belongs to T. F. Kenyon. The limestone beds, at this point, are somewhat contorted, and dip at an angle of 5° toward the east. The aggregate thickness of the beds exposed is about eighteen feet. The section shows:

		FEET
6.	Black loam	1 to 2
5.	Broken and decayed yellow limestone, more or less disturbed	2 to 3
4.	Yellowish limestone, not very fossiliferous, affords some good quarry stone	5
3.	Beds of soft limestone, easily affected by weather. Fossils are a coarse *Spirifer pennatus* and numerous small Pentamerids of undetermined species	2
2.	Limestone containing numerous stromatoporoids and true corals. The corals embrace the genera Acervularia, Cyathophyllum, Ptychophyllum, Cystiphyllum and Favosites. Some fair building stone	6
1.	Fissile limestone with few fossils	3

The Acervularia in the Kenyon quarry is the species *A. profunda* Hall. All the beds lie below the horizon of *A. davidsoni*. Among the stromatoporoids associated with *A. profunda* is *Stromatopora erratica* H. and W., one of the few species still retained in the genus Stromatopora as emended by Nicholson. The quarry on the south side of the road belongs to Edward Lown. The strata dip slightly toward the south. The beds worked are equivalent to Nos. 4 and 5 of the Kenyon quarry. The beds corresponding to No. 5 are, however, not broken and disturbed as they are on the north side of the road.

East of Quasqueton, on land belonging to G. E. Gemmel, an exposure of Devonian limestone has been quarried at intervals for a number of years. The limestone is quite regularly bedded, and the horizon is very clearly indicated by the fact

that in the upper part of the quarry the strata carry *Acervularia davidsoni* and *Spirifer parryanus*, while lower down are *Acervularia profunda* and the usual association of corals, and still lower are *Atrypa aspera* and *Spirifer pennatus*. *Orthis iowensis* is very common in some of the beds. There is also a large form of *Stropheodonta demissa* characteristic of the Cedar valley beds which carry either of the two species of Acervularia found in this county. The top of the Gemmel quarry is about 80 feet higher than the brecciated beds exposed in the channel of the river below the bridge at Quasqueton.

A number of interesting outcrops of beds equivalent to those seen along the valley of the Wapsipinicon between Fairbank and Troy Mills, occur in the valley of Lime creek in Jefferson township. The *Spirifer pennatus* beds are exposed near the foot of the hill on the west side of the creek not far from the southeast corner of section 14. Farther up the hill the overlying beds of the Cedar valley stage occur. Along the creek in section 23 the beds lying above the *S. pennatus* horizon outcrop continuously for some distance. A reef of *Acervularia davidsoni* is conspicuous a short distance south of the center of the section last named. Five or six feet below the level of the reef there are beds crowded with small individuals of *Atrypa reticularis*, while above the reef the beds are softer and yellowish in color, and correspond in lithological and faunal characteristics, as well as in position, to Nos. 7 and 8 of the section at Littleton. A very good exposure of the yellow shaly limestone is seen in a road cutting along the north side of the northwest quarter of section 26. This member has here a thickness of fifteen feet, and contains the coarse-ribbed form of *Atrypa reticularis* which characterizes bed No. 8 at Littleton. Above the yellow limestone there lies a bed, fifteen feet in thickness, of whitish, compact fine-grained limestone corresponding to the white unfossiliferous beds in the upper part of the exposures in Johnson county. This white limestone is either absent at Littleton or is represented by No. 2

at the G. Jesse quarry a short distance northwest of the town mentioned.

Along Lime creek, south of Brandon, in the northwest quarter of section 34, the beds are well exposed and show the following section.

		FEET.
4.	Soft limestone grading up into yellow shale, which carries silicified individuals of the coarse-ribbed *Atrypa reticularis* and a Spirifer resembling *S. parryanus*	8
3.	Coral reef consisting of Acervularia, Favosites, Ptychophyllum and other corals	1
2.	Evenly-bedded limestone with few fossils or none	4
1.	Limestone, regularly bedded and capable of being quarried, in layers from two to six inches in thickness, the thinner beds serving well as flagging. Beds contain *Sp. pennatus*, *Atrypa aspera*, Favosites growing in hemispherical form, related in structure, though not in mode of growth, to *F. alpenensis* Winchell, and stem segments of Megistocrinus. In these beds occurs a large *Stropheodonta demissa* like the form associated with *Spirifer parryanus* at Littleton	4

In the low bluff bounding the flood plain on the south side of the creek, at Brandon, there are exposures of Devonian strata showing some unusual peculiarities. The beds are folded, buckled and displaced on a scale sufficient to produce a complex series of alternations of lithological and paleontological characters at the same level along the hillside. At one point, for example, there are beds carrying *Spirifer pennatus*. At the same level a few yards away there is a portion of the coral reef with Acervularia, Ptychophyllum, Favosites and other characteristic corals. Farther on are yellow shales corresponding to No. 8 of the Littleton section, and carrying the coarse-ribbed Atrypa and other fossils that everywhere distinguish this horizon. Some of the displacement may be due to faulting on a small scale; but the residual material resulting from extensive weathering conceals the beds over

most of the hillside, and allows only occasional glimpses of the strata. The sharp fold shown in Plate xiv, Fig. 2, is seen at one of the exposures.

The yellow limestone corresponding to Nos. 7 and 8 of the Littleton section is all hard enough for building stone a short distance southwest of Brandon, and a quarry is worked at this horizon in the bluff of Cedar river, south of the county line.

There are a few unimportant exposures of the Devonian strata on Bear creek, in section 36 of Jefferson township, and another outcrop, which furnishes *Phillipsastrea billingsi*, occurs one-fourth of a mile north of the center of section 20, in Homer township.

Pleistocene.

The surface of Buchanan county is very generally covered with beds of drift or other deposits belonging to the Pleistocene system. The sub-Aftonian or pre-Kansan drift has not been recognized at the surface, but its presence is demonstrated in numerous borings and excavations by a soil and forest bed horizon underneath the blue clay of Kansan age. At Oelwein, north of Buchanan county, the forest bed and underlying drift were well exposed in the deep cut on the line of the Chicago Great Western railway, and the details of the section were described in papers read before the Iowa Academy of Sciences in December, 1896.*

KANSAN.

Kansan drift is spread almost universally over Buchanan county. In some cases it comes almost or quite to the surface; in other cases it is reached only after penetrating ten or twenty feet, or even more, of the later Iowan till, and in still other cases it is buried beneath Iowan till and Buchanan gravels. A very common relation of Pleistocene deposits is illustrated by the well section on land of J. W. Welch, in the southwest quarter of section 28, Buffalo township. The record shows,

*Proc. Iowa Acad. Sci., vol. IV, pp. 54-68.

		FEET.
3.	Dark soil and yellow till	4
2.	Reddish ferruginous sand and gravel	23
1.	Blue clay, penetrated	1

No. 3 of this section is Kansan drift, No. 2 is Buchanan gravel, and No. 1 is Iowan till. In the same quarter section another well shows.

		FEET.
3.	Soil and yellow till	22
2.	Reddish gravel	11
1.	Blue clay, with pockets of sand	19

Although the thickness varies considerably, the members of this last section are severally the same as the corresponding numbers in the one above. In a railway cut in the south half of section 3, Buffalo township, the section shows.

		FEET.
4.	Black loam or soil	1
3.	Yellow Iowan till	5
2.	Reddish yellow, oxidized Kansan till	2
1.	Unaltered blue Kansan till	4

The Kansan till is normally a blue clay intersected by numerous joints and carrying large numbers of pebbles and bowlders of dark colored, fine grained greenstone. Fragments of limestone are not uncommon, and there are also some bowlders of light colored, porphyritic granite. The bowlders and bowlderets of various kinds are quite generally facetted and striated on one or two sides. Where the Kansan drift was not disturbed by the later Iowan ice invasion there is a zone of oxidation, varying in thickness, and recording the changes that took place in the superficial portion of the drift as a result of exposure to weather during the long interval between the retreat of the Kansan ice and the advent of the Iowan. The oxidized zone is only partly preserved in No. 2 of the section last above described. Fragments of wood, many of which are referable to the American larch, *Larix americanus*, are distributed through the entire thickness of the blue Kansan till. Wood is, however, more abundant in the lower

part of the formation; and it reaches its maximum in the forest and soil bed that marks the Aftonian horizon and separates the Kansan from the sub-Aftonian drift.

BUCHANAN GRAVEL.

In the latitude of Buchanan county the disappearance of the Kansan ice was attended by strong currents of water flowing away from the ice margin. These currents were loaded with glacial debris including fragments ranging from fine silt to bowlders a foot or more in diameter. The course of the currents was marked by deposits of sand and gravel more or less sorted and stratified, and not infrequently cross-bedded on an extensive scale. It is to these particular deposits that the name Buchanan gravel has been applied. Beds of the gravel are strewn continuously for miles along the valley of Buffalo creek in Byron and Middlefield townships. They are common along Pine creek in the western part of Byron. They are conspicuous along the valley of the Wapsipinicon between Littleton and Independence. All the streams, in fact, are bordered more or less generally by trains of gravel. But the gravels are by no means confined to the stream valleys. They are found quite as frequently on the high lands, and some of the highest points in the county are marked by the presence of coarse, ferruginous stratified deposits of this age. Streams may have flowed in glacial canyons along the hilltops while the adjacent lowlands were still occupied by heavy bodies of ice.

The Buchanan gravel presents two phases, an upland phase in which the materials are relatively coarse, and a valley phase composed largely of sand and fine gravel. Bowlders, ranging to more than a foot in diameter, are not uncommon in the upland deposits; pebbles more than an inch in diameter would rank among the unusually large constituent fragments in the lowland phase.

The type exposure of Buchanan gravel occurs at the gravel pit of the Illinois Central railroad, in the northwest quarter

of section 32, Byron township. Here the deposit is about twenty feet in thickness. It consists of stratified, often cross-bedded, sands and gravels, with many bowlders, six, eight, ten or twelve inches in diameter. A very large proportion of the bowlders show unabraded, glacial-planed surfaces which would indicate that if they had been transported by current action for any considerable distance, they were not rolled but probably had been carried by floating ice. In some parts of the pit the gravels are very ferruginous and weather-stained. Many of the granite bowlders are completely decayed and crumble to sand on the application of very slight force. The gravel rests on typical Kansan blue clay and is overlain by yellow Iowan till which varies from less than a foot in thickness at the western end of the exposure to more than six feet at the extreme eastern end. Two facts are at once apparent; first, the gravel is interglacial in position; second, it is very old as compared with the overlying Iowan till. The characteristics and relations of the gravels at this type locality are illustrated in Plates xvi and xvii.

A very fine exposure of Buchanan gravel is seen in a large pit worked for road material near the northeast corner of section 4, Liberty township. In some respects it is better than the type exposure east of Independence. The oblique bedding, the complete oxidation, the ferruginous characteristics, the deep red color, the decay of the granites, in short, all the distinctive features of this deposit, are exhibited in remarkable perfection. The line of division between the gravel and the overlying Iowan drift is also well shown, and at the south side of the pit there are yet remnants of the interglacial soil bed. The lower ten feet of the exposure is made up of coarse, cross-bedded sand which is sharply defined from the still coarser gravel which constitutes the upper part of the deposit. The decayed granites are most conspicuous in the gravelly portion of the bed, and associated with them are numerous planed bowlders and bowlderets. It is a general rule, illustrated at practically all the exposures of the

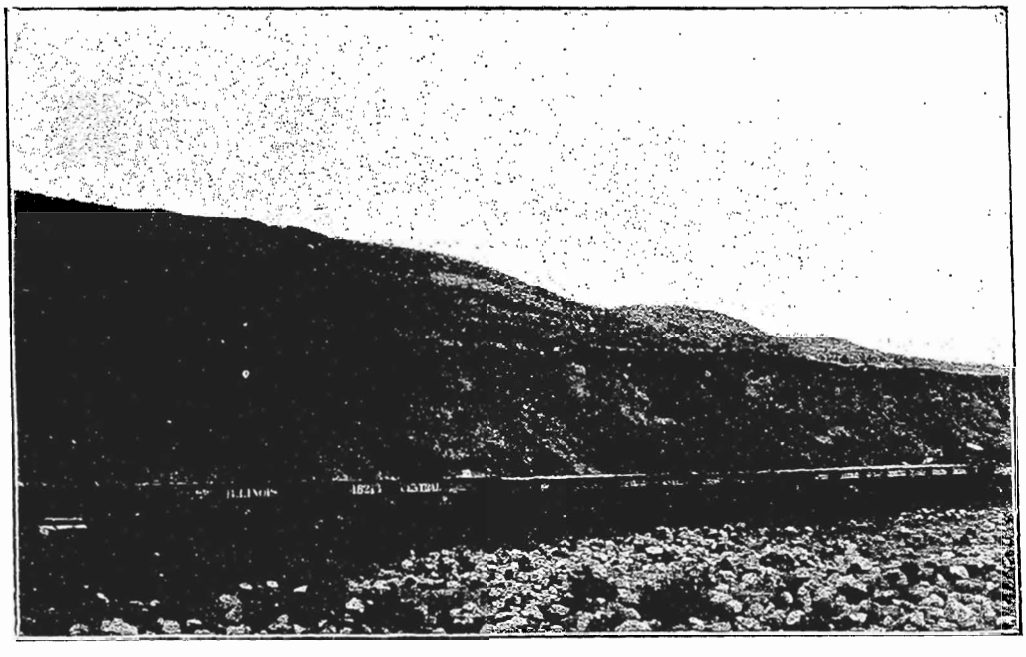

FIG. 1. General view of the typical exposure of Buchanan gravels. Illinois Central gravel pit.

FIG. 2. Nearer view of the typical exposure, showing Iowan drift above the gravel.

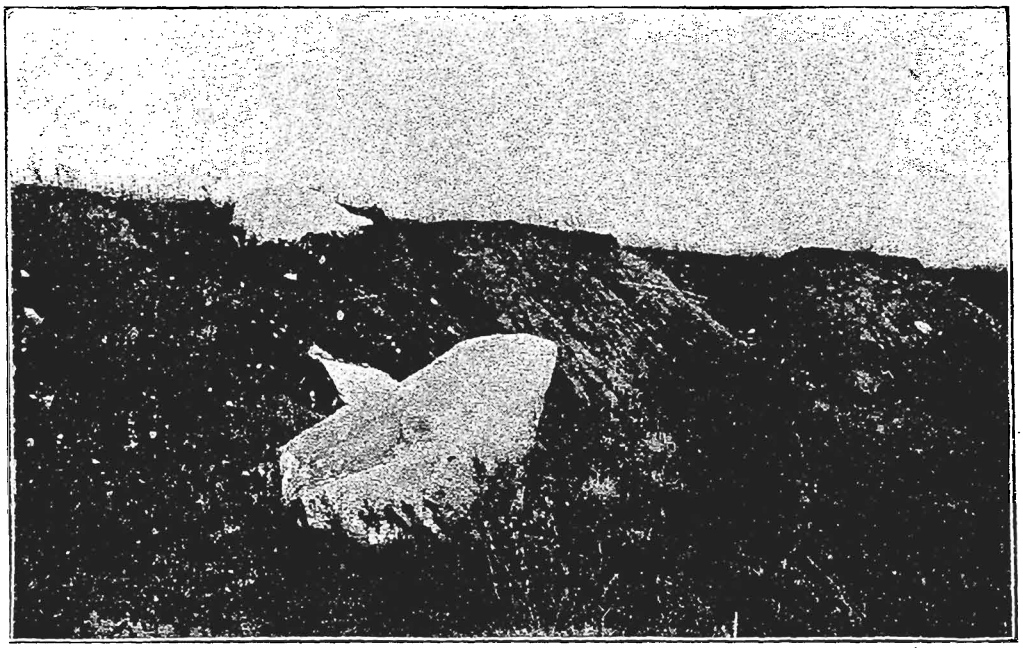

FIG 1. An abandoned part of Illinois Central gravel pit. Stratification is obscured by rain wash. A bowlder belonging to the Iowan stage is perched on the margin of the pit, and others, having been undermined, have fallen to the bottom of the excavation.

FIG. 2. Field immediately north of the Illinois Central gravel pit, showing large numbers of Iowan bowlders.

FIG. 1. Buchanan gravel overlain by Iowan drift, two miles west of Winthrop.

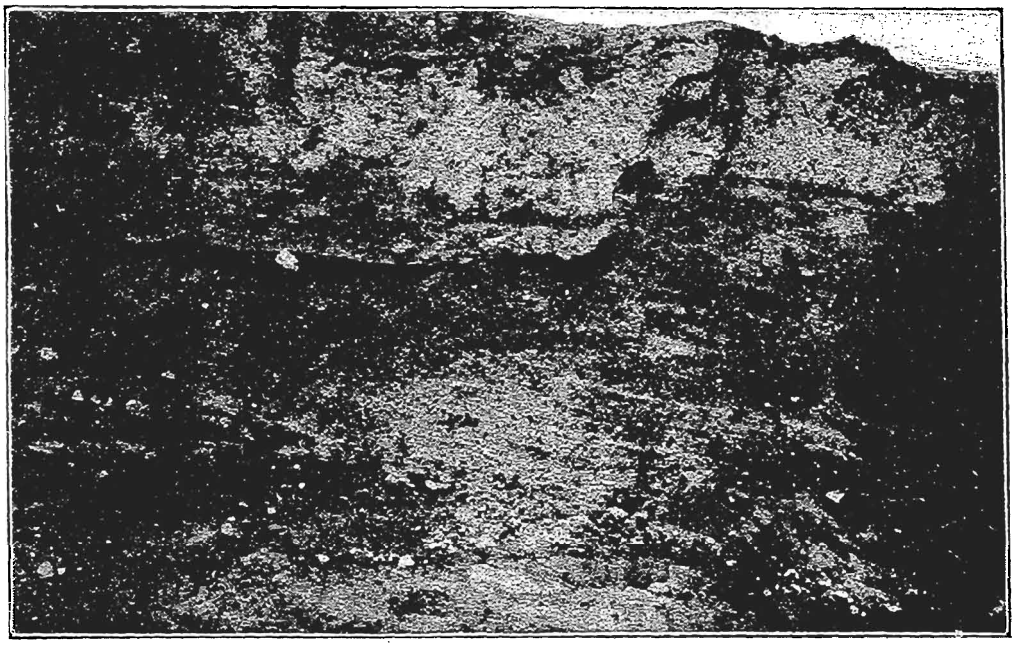

FIG. 2. A nearer view of part of the Winthrop gravel pit, showing coarse material above stratified sand. This is a typical exposure of the upland phase of the gravels.

beds under consideration, that the coarser material occurs in the upper part of the deposit. This exposure is illustrated in Plate xviii, Figs. 1 and 2.

Another excellent exposure of Buchanan gravel occurs west of the center of section 33, Perry township. A large pit is worked for material which is used in improving the streets of Jesup. A thickness of eighteen feet is exposed. The gravel is overlain by a very small amount of Iowan drift. The exposure shows all the usual characteristics of stratification, oblique bedding, ferrugination, oxidation and granitic decay.

About a mile east of Independence there is a heavy bed of Buchanan gravel presenting all the usual characteristics. It is overlain at one point by two and a half feet of Iowan drift. This deposit is remarkable for the fact that it occurs on the highest ground between the Wapsipinicon and the Buffalo. At one point the bed has been worked extensively for road material, but the gravel covers the whole hilltop over quite a large area. The overlying drift in general is thin, and even the Kansan drift beneath the gravel is very scant. The beds at this point illustrate well the upland phase of this formation. It is the upland gravel that occurs in the pit east of Jesup, and the same phase of the gravel forms a sharp ridge in the northeast quarter of section 11, Madison township.

The region about Rowley is well supplied with gravels belonging to the Buchanan stage, as will be seen by consulting the geological map of the county, and there is an extensive area underlain by these gravels in the eastern half of Fairbank township.

The valley phase of the Buchanan gravel is seen in terrace-like deposits that follow Buffalo creek in Byron and Madison townships, as well as the valley of Pine creek in the western part of Byron. The best illustrations of this phase, however, are found along the Wapsipinicon river between Littleton and Independence.

Gravel is found over an area from half a mile to a mile and a half in width east and southeast of Littleton, and it is con-

tinued in a belt of varying width all the way to Independence. It extends up the valley of Harter creek for at least two miles. There are a number of pits, showing well the character of the deposit, in the southwest quarter of section 27, Washington township, and there are natural exposures on Harter creek, in the northeast and northwest quarters of the same section. The deposit here, as is general in the valleys, is made up of sand and fine gravel. These valley gravels are not as ferruginous, nor are they as highly colored, as those on the highlands; but the Iowan bowlders sprinkled over the surface, and the thin layer of Iowan drift overlying the deposit, leave no doubt as to the practical contemporaneity of the upland and lowland phases. Absolute contemporaneity is not assured, for when the upland gravels were depositing, the valleys were probably filled with ice. The lowland gravels of this locality were not laid down until after the Kansan ice had left the valleys, and the general ice margin had retreated some distance to the north or northwest. The upland phase was produced by transportation and deposition in vigorous currents in close proximity to the margin of the melting ice; the valley phase shows the effect of currents that have lost much of their original impetuosity and disposed of the coarser materials with which they were at first loaded. Deposition in connection with the valley phase took place at points more remote than in the case of the upland gravels, from the edge of the retreating ice.

IOWAN DRIFT.

The Iowan drift is the superficial deposit over the greater part of Buchanan county. Since this drift was laid down the surface has been modified to only a very slight extent. The general aspect of a region covered with drift of Iowan age is typically displayed in Cono, Homer and Westburg townships, southwest of the Wapsipinicon river, and in Middlefield, Fremont and Byron, northeast of this stream. The surface is

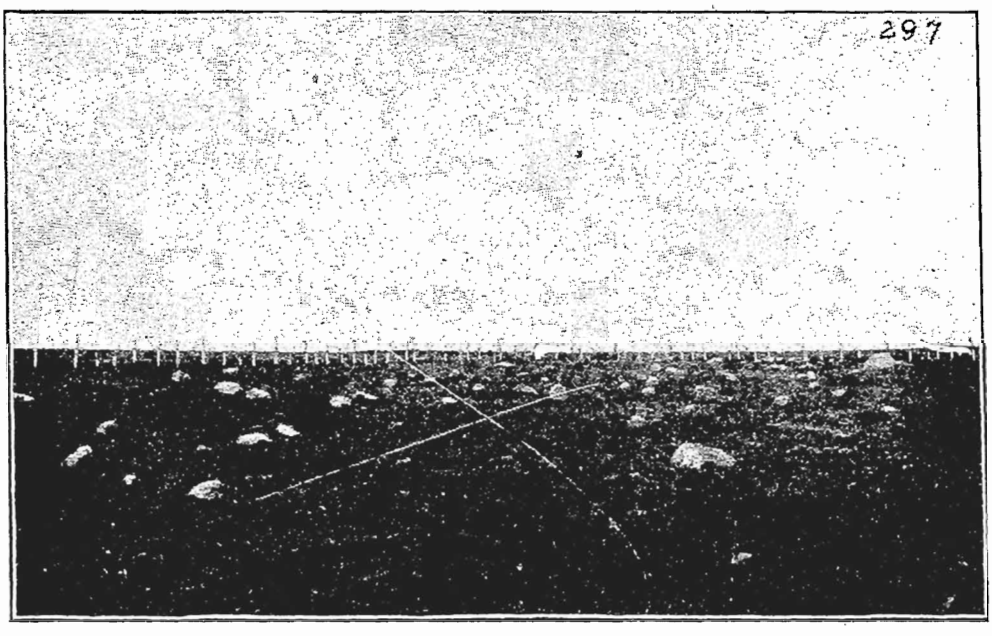

FIG. 1. A characteristic field strewn with Iowan bowlders, in the northern part of Newton township.

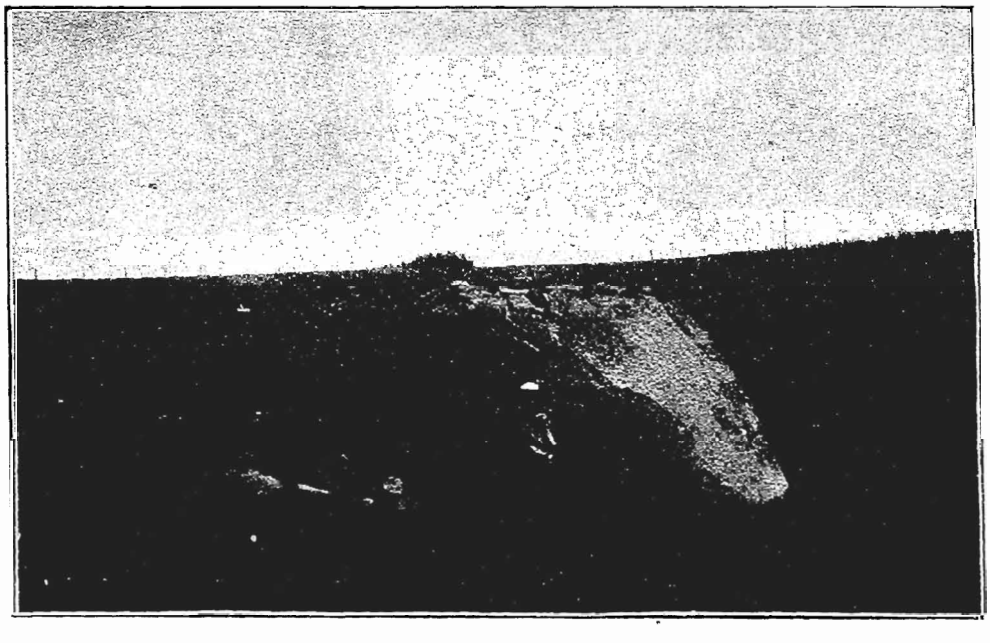

FIG. 2. An Iowan bowlder of medium size, showing effects of weathering.

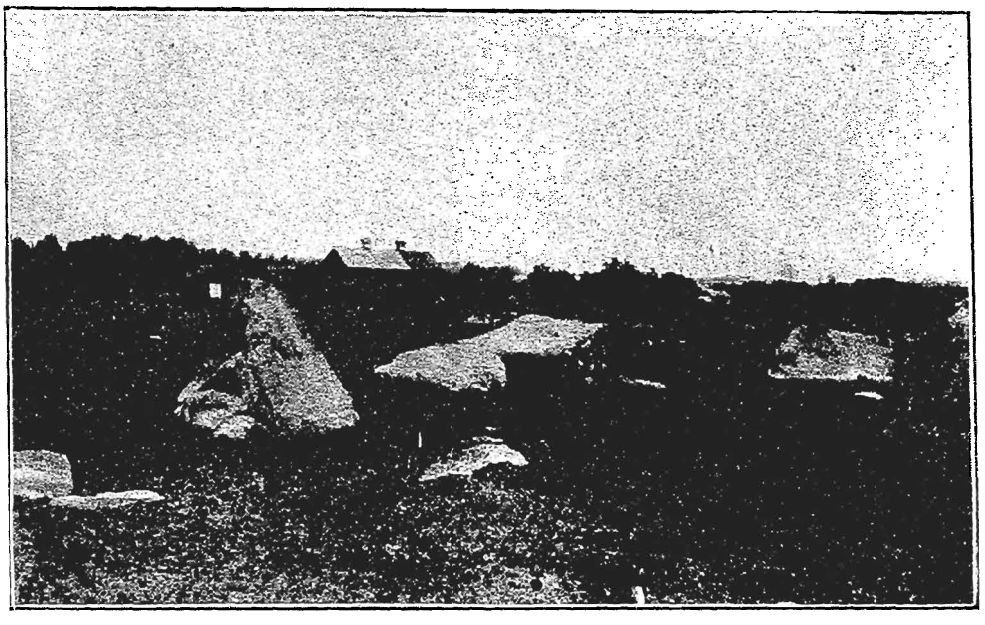

FIG. 1. Group of large Iowan bowlders, southeast of Winthrop.

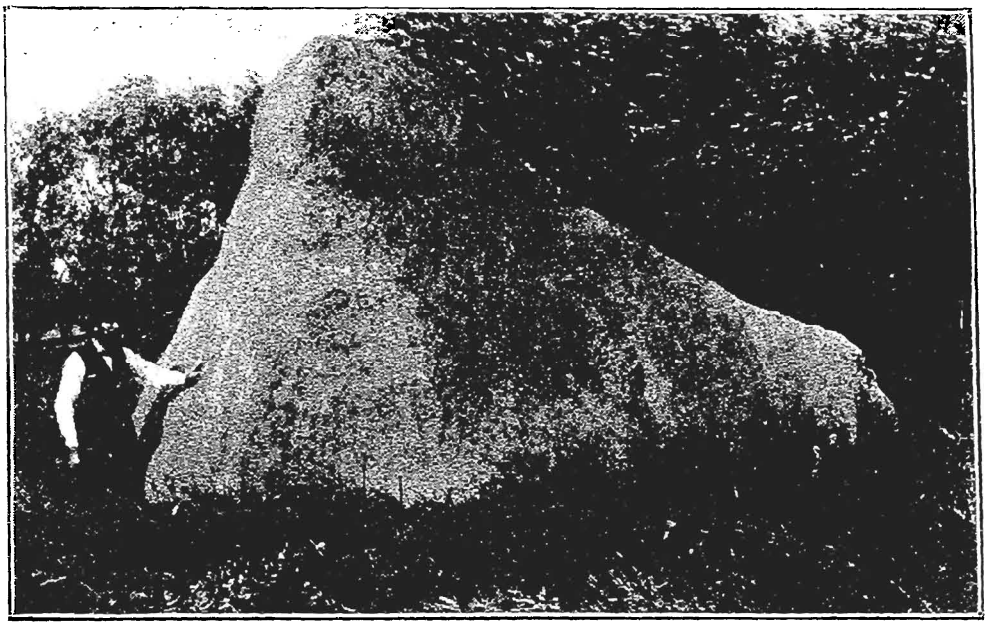

FIG. 2. Large Iowan bowlder near the center of Newton township.

very gently undulating and is liberally sprinkled with enormous granite bowlders. Bowlders ten, fifteen or twenty feet in diameter, and standing conspicuously above the general surface, are common features of the prairie landscapes, and great granite masses, thirty feet in diameter, are known at several points. Multitudes of smaller bowlders, ranging from one to two or three feet in diameter, are a serious encumbrance in many fields and pastures (Plate xix, Figs. 1 and 2).

The main body of the Iowan drift is a yellow, highly calcareous clay. It shows no such differences between the superficial and deeper portions as does the Kansan. It has remained, even at the grass roots, practically unchanged by weathering since its deposition. The great stretches of undulating prairie without marked drainage courses remain unaffected by the agents of erosion. As compared with the Kansan drift or the Buchanan gravels, the Iowan is very young, the time since its deposition being evidently only a very small fraction of the length of the interval between the disappearance of the Kansan ice and the appearance of the Iowan.

The maximum thickness of this drift sheet is unknown. It was evidently deposited on a deeply eroded surface, and it is, therefore, very thin over the pre-Iowan hilltops and deeper in the pre-Iowan valleys. Railway cuts, which of necessity are limited to the higher ridges, usually, in Buchanan and adjacent counties, show only a thin veneer of Iowan drift resting on weathered Kansan. In the big railway cut east of Oelwein in Fayette county, the Iowan stage is represented by a layer of loamy soil less than a foot in thickness, while in the eastern part of Fairbank township, Buchanan county, the farm wells show at least thirty feet of Iowan till overlying highly oxidized beds of Buchanan gravel.

LOESS.

Loess is rather rare in Buchanan county, the deposits of this material being of small importance when compared with the widely spread beds of the same material in Dubuque, Delaware

and Jones counties. In Buchanan, true loess seems to be limited to some high points north of the Wapsipinicon river in sections 28, 29 and 30 of Liberty township. While the loess here is typical in character, its thickness is not very great. It mantles an irregularly eroded surface that rises from sixty to eighty feet above the level of the Iowan drift plain. Rain erosion in the fields and roads has, in places, cut through the entire thickness of the deposit and revealed the underlying Kansan drift with its peculiar bowlders and characteristically weathered surface. There is no Iowan drift on these loess-covered highlands.

A light colored sandy clay, resembling some phases of the loess, is seen in sections 27 and 34, Fairbank township, and a similar deposit occurs at a number of points in sections 26 and 27 of Liberty township. The thickness of the material at the points last named does not exceed two, or two and a half feet. The arenaceous clay appears in some localities to grade into beds of sand of varying thickness. The stretch of sandy road, on the main line of travel between Quasqueton and Independence, passing through section 20 of Liberty township, is an illustration in point. At a certain altitude there are beds of sand; a little higher the sand gives place to an arenaceous loess; and on the highest points of the region the deposit, as already described, becomes a true loess, a fact well illustrated in section 29 of Liberty township.

POST-GLACIAL DEPOSITS.

But little change has taken place in the surface of the county since the retreat of the Iowan ice, the date from which the postglacial history of the county should be reckoned. Some alluvium has doubtless been deposited along the stream valleys during times of high water, but in most cases it is too thin to be differentiated from the loam which has been developed on the surface of the Iowan drift by the numerous agents concerned in soil-making. In the deep preglacial valleys that have been mentioned as occurring at a few points along Lime

creek and the Wapsipinicon river, there are some beds of alluvium, but they are thin, small and unimportant.

In the county there are a few rather anomalous peat bogs which present the unusual phenomenon of being higher than the dry ground in the immediate neighborhood. One on land of Mr. B. Stoner, in the northwest quarter of section 13, Perry township, is typical of all the beds of the kind observed. The peat is coarse and fibrous, with a total thickness of eight or ten feet. The bed occurs on a long, gently sloping hillside and in the center is several feet higher than the dry ground at the right and left. The area covered is small. The surface supports a luxuriant growth of coarse sedge or slough grass. A similar peat bog on relatively high ground was seen in the southwestern part of section 19, Newton township, and there is another in the southwest quarter of section 8, Hazelton township. The location of the peat beds has been determined by the presence of springs or "seeps" issuing from the drift on the hill slope.

Soils.

Soils, in the narrower sense which limits the term to the fine dark colored loam developed on the surface of the loose, superficial materials, are generally, throughout the county, of postglacial origin. Soils vary with the nature of the deposit from which they are derived. Drift soils are most common in the county under consideration, and practically all of the drift soils are developed on the Iowan till. This class of soils is from six inches to two or three feet in depth, dark in color on account of its wealth of organic matter, more or less sandy, warm and easily cultivated. Such soils contain a considerable amount of lime carbonate that, added to the vegetable matter with which they are so richly endowed, renders them capable of producing crops of cereals for many successive years without showing signs of exhaustion. The small area of loess soils in sections 28, 29 and 30, of Liberty township, has recently been stripped of its timber and brought under

cultivation. The results are more satisfactory than in many other areas of similar soils where the slopes are steeper* and the effects of rain erosion are more pronounced. There are small areas of gravelly and sandy soils along the stream valleys, the largest being found north and northwest of Independence.

Deformations.

The anticlinal fold to which reference was made in discussing the Niagara limestone, is the principal disturbance of which there is clear record in Buchanan county. There are some slight folds, probably, however, due to inequalities of deposition, in the Devonian strata. At Brandon there is an example of a short buckling of some of the beds as shown in Plate, xiv Fig. 2.

Unconformities.

The Devonian beds are evidently unconformable on the sloping side of the Niagara anticline in the vicinity of Fairbank, and the relations of the several Pleistocene deposits to each other, and to the indurated rocks on which the lowest drift sheet lies, afford other illustrations of unconformity.

ECONOMIC PRODUCTS.

Building Stone.

Building stone is quarried in a small way at the exposures of Niagara limestone in sections 18 and 19 of Madison township and section 13 of Buffalo. The Devonian limestone is worked for building material more extensively than the Niagara, but there are no quarries in the county that attempt more than to supply local demands. The great number of small quarries around Independence has been referred to in connection with the description of the Fayette formation. The stone is rather soft, not well bedded, and a large part of

*See description of loess soils in reports on Delaware, Jones and Johnson counties.

it yields in the course of a short time to the effects of the weather. A harder, and generally better, quality of stone is found in equivalent beds along Pine creek, in section 21, Liberty township, and in sections 33 and 34, Newton township.

The Gemmel quarry near Quasqueton is operated in beds that include the horizon of *Acervularia davidsoni*, in the Cedar valley limestone. The stratification is more regular, and the stone is harder and more resistant to weather than in the quarries in the Fayette stage near Independence. It is the same horizon and essentially the same quality of stone that is represented in the Kenyon and Lown quarries southeast of Jesup. With only one or two exceptions, the many small quarries along Lime creek, near Brandon, are worked in the Cedar valley limestone, and the product is similar to that from the quarries near Quasqueton and Jesup. In the northern part of the county, at the Fairbank quarry, this horizon furnishes stone in thicker and more regular beds, and the quality on the whole is better.

The quarry stone horizon above the beds containing *Acervularia davidsoni* is represented in the Schreier quarry in the southeast quarter of section 33, Fairbank township, and in the Jesse quarry in the southwest quarter of section 4, Perry township. The formation at this horizon consists of an earthy, soft, yellowish limestone in rather regular layers which range from two to eight inches in thickness. The layers are cut by nearly vertical joints at intervals of from two to eight feet. The stone hardens on exposure, and is not easily affected by the weather. The quarries named are capable of furnishing an indefinite amount of good building stone.

Another source of building stone is found in the great number of granite bowlders sprinkled over the surface. These all belong to the Iowan drift and were transported and deposited by the Iowan ice sheet. Many of the larger bowlders have been reduced to blocks of convenient size by the methods employed in granite quarries, and many of smaller size have, one by one, been dressed into proper shape with the hammer.

All the important bridge piers of the county are constructed of heavy blocks of granite. Foundations for the great mill and other important buildings at Independence are of cut granite obtained from Pleistocene bowlders in the immediate neighborhood. Granite derived from local bowlders was used in the foundations of the hospital for the insane; small granite bowlders just as they are gathered from the fields have been used extensively on the farms as foundations for barns and dwelling houses. Granite quarried from Pleistocene bowlders was at one time exported from Independence on quite a large scale, some of the great blocks being used in the foundation of the state capitol at Des Moines. The supply of granite for building purposes is practically inexhaustible, and the quality of the material is unimpeachable. The appearance and relative size of some of the large bowlders are illustrated in Figs. 1 and 2, Plate xx.

Lime.

At present there is scarcely any lime produced in Buchanan county. Kilns have been operated at Independence, Quasqueton and other points within the area of Devonian outcrops, and in section 19 of Madison township, lime was made from the Niagara limestone. Imported lime has of late years supplanted the local product.

Brick Clays.

Clays suitable for the manufacture of brick occur at a number of points in the county; those most generally distributed belonging to the Iowan drift. The fine yellow clay of Iowan age, with proper treatment, will make brick of superior quality; the difficulty experienced in working it is due to the pebbles and small bowlders with which it is charged. There are portions of the drift, however, from which bowlders and pebbles are absent. The favorable conditions, it is true, are not always present in convenient localities, and it is to this fact that the practical abandonment of brick making in the county, of late years, is probably due.

The pebbleless, loess clay on the highlands west of the mouth of Pine creek in Liberty township, might be used advantageously, and it would make brick of excellent quality, if only enterprise and capital found sufficient encouragement to justify the construction of a plant. A fine quality of pressed brick might be made from the clay in question. So far as known no effort has been made to utilize this important deposit.

Coal.

Several times during the past years there has been more or less interest aroused over the reported discovery of coal. These reports have come from various points in the county and were all based on the fact that borings or excavations had penetrated the Independence shale. In certain localities this shale is black and carbonaceous; it even contains small particles of coal associated with pyritized stems of terrestrial plants; but nowhere does the deposit contain anything of commercial value. The people should bear in mind that the rocks of the county are all older than any productive coal measures. Furthermore, the deeper lying rocks are older than those at the surface, and so, contrary to a popular notion very generally held and expressed, the deeper the boring or excavation the more hopeless becomes the search for coal.

The Independence shale was penetrated by Mr. Kilduff in a pit near the present O'Toole quarry, east of Independence, in a well near Jesup, and again in an excavation near the mouth of Pine creek, in Liberty township.

Road Materials.

In solving the problem of good roads for Buchanan county the Buchanan gravel, with which the region is so generally and so bountifully supplied, will be recognized as a factor of the first importance. Gravel beds occur within convenient hauling distance of almost every neighborhood, and the supply is sufficient to put every foot of clayey and boggy road in the county in excellent condition. The gravels have been already

used to good purpose in making street and road improvements in and around Independence, Winthrop and Jesup, and many stretches of country roads that were formerly, at times, impassable have been greatly benefited by the application of this material. But as yet the work is scarcely begun, and the splendid resources of the county in respect to materials for road improvement have scarcely been touched.

The sandy roads will require different treatment. Some of the longest and worst stretches of sand are conveniently located with reference to the loess-covered area in Liberty township, and loess clay over sand produces excellent results. There are sandy roads near Independence in proximity to a number of quarries from which crushed stone might readily be obtained. This material alone, however, would probably not last well, for the stone from the Independence quarries is rather soft and would soon be ground into fine, calcareous dust under the wheels of ordinary travel and traffic. But the region is well supplied with gravel as well as with limestone, and a foundation of stone, dressed on top with Buchanan gravel, will make a very serviceable and durable roadbed.

Water Supplies.

When the county was settled, near the middle of the present century, the streams, even of the smaller size, seldom failed throughout the year, and well water was found everywhere in the drift at depths ranging from five to forty feet. Within recent years the minor streams are dried up during midsummer, and permanent wells, as a rule, are only found after boring through the drift and from twenty to more than 200 feet into the underlying rocks. In some localities, as in the eastern half of Fairbank township, water supplies are still found at comparatively shallow depths in beds of Buchanan gravel. The city of Independence is supplied with water drawn from a bed of gravel by means of drive wells. The gravel is reached at a depth of from thirty to fifty feet. About seventy of these wells were used in 1896, and about 400,000

gallons were pumped daily to supply the demand. The pumps had a capacity of 500,000 gallons a day.

At the residence of Adelbert Smith, near the northwest corner of section 22, Buffalo township, there is a flowing well which furnishes a constant stream an inch in diameter. The well is 152 feet in depth; it ends at the rock, in a bed of gravel which lies beneath blue clay of Kansan age. Another well on the place, not flowing, however, is twenty-five feet deep and penetrates a bed of Buchanan gravel.

The well records show that the surface of the rock upon which the unconsolidated drift and other superficial materials lie, is very uneven. The preglacial surface had its hills and valleys, and the relief was much greater than that exhibited by the present surface. The known thickness of the Pleistocene deposits varies from zero, where the indurated rocks appear at the surface, to 215 feet in section 4 of Buffalo township.

Water Powers.

There are water powers developed along the Wapsipinicon river at Fairbank, Littleton, Independence and Quasqueton. The most important is that at Independence. There is here a large, expensively equipped flouring mill, which utilizes about 200 horse power. The Kiefer Brothers' mill near Hazelton is on Otter creek. It has a head of twelve feet and uses at times more than 100 horse power. Another mill on Otter creek is located at Otterville.

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IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF BUCHANAN COUNTY, IOWA.

BY

SAMUEL CALVIN
1898.

R. X W. R. IX W. R. VIII W. R. VII W.

T. 90 N.

T. 89 N.

T. 88 N.

T. 87 N.

FAIRBANK HAZELTON BUFFALO MADISON

WASHINGTON BYRON FREMONT

PERRY

WESTBURG SUMNER LIBERTY MIDDLEFIELD

JEFFERSON HOMER CONO NEWTON

Fairbank
Stanley
Hazelton
Aurora
Lamont
Kier
Buchanan
Bryantburg
Castleville
Littleton
Otterville
Jesup
INDEPENDENCE
SOUTH INDEPENDENCE
Winthrop
Middlefield
Quasqueton
Monti
Rowley
Newtonville
Brandon

Scale 1/125000
1 ½ 0 1 2 3 4 5 Miles.
1 ½ 0 1 2 3 4 5 Kilometers.

LEGEND

GEOLOGICAL FORMATIONS

- CEDAR VALLEY
- FAYETTE
- INDEPENDENCE (AREA EXAGGERATED)
- NIAGARA

INDUSTRIES

- QUARRIES
- CLAY PITS
- LIME KILNS
- GRAVEL

NOTE—The margins of the Fayette and Cedar Valley formations are only approximately located, for the reason that, except at a few points, they are concealed by heavy bodies of drift

IOWA LITHO. CO. DES MOINES.

DRAWN BY F. C. TATE