GEOLOGY OF LINN COUNTY.

BY

WILLIAM HARMON NORTON.

GEOLOGY OF LINN COUNTY.

BY WILLIAM H. NORTON.

CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Linn county is situated in the east central part of the state and lies athwart the valleys of the Buffalo, Wapsipinicon and Cedar rivers, extending from the Buffalo-Maquoketa divide on the northeast to and beyond the Cedar-Iowa divide on the southwest. It is rectangular in shape and contains seven hundred and twenty square miles.

PHYSIOGRAPHY.

DRAINAGE.

The three large streams just mentioned trench the county from northwest to southeast to a depth of from two to three hundred feet below the summits of their interplains. The gradient thus afforded to their affluents has been sufficient to enable them to push their subordinate waterways so completely into the inter-stream areas that marshes are not found of any extent. No lakes exist except here and there a moat on the flood plains of the rivers, and a few ponds in depressions in the drift. The drainage system is therefore well advanced beyond the earliest stages in its development.

By far the larger part of the county lies in the catchment basin of the Cedar river. To the south the Cedar valley is narrow, the divide being reached in from two to eight miles from the stream, the only considerable affluent being Prairie creek, whose general direction is eastward. To the north the Cedar valley extends to within from one to three miles of the Wapsipinicon river, and is drained by several large creeks flowing nearly due south in parallel courses. The largest, Indian creek, is about twenty miles in length.

TOPOGRAPHY.

Linn county is included in the area covered by the hypsometric atlas sheets of the United States Geological Survey, so that the relief is known with reasonable accuracy. The relief of the county may be described as consisting of two paha belts of hilly country, parallel and adjacent to the largest rivers, with an intervening drift plain. The general elevation of the central plain is between 800 and 900 feet above tide. Below this level the rivers have cut to as low as 685 feet above tide, while above it the paha ridges, which are described in detail in subsequent pages, rise to a maximum measured height of 1,240 feet above tide. The presence of these ridges near the rivers, in combination with the more active erosion at these points, gives a much more rugged topography along the streams and sharply contrasts the stream and plain areas.

The following table shows the elevation above sea level of the principal towns and villages in the county.

Table of Elevations.

LOCALITY.	AUTHORITY.	ELEVATION.
Bertram.	C. & N.-W. Ry.	720
Cedar Rapids.	City datum.	708
Center Point	U. S. G. S.	820
Coggan.	U. S. G. S.	860
Ely.	B., C. R. & N. Ry.	741
Fairfax.	C. & N.-W. Ry.	773
Linn Junction.	U. S. G. S.	756
Lisbon.	C. & N.-W. Ry.	877
Marion.	U. S. G. S.	840
Mount Vernon.	C. & N.-W. Ry.	847
Otis.	U. S. G. S.	740
Palo.	U. S. G. S.	751
Paralta.	U. S. G. S.	840
Springville.	U. S. G. S.	840
Toddville.	B., C. R. & N. Ry.	780
Viola.	U. S. G. S.	900
Waubeek.	U. S. G. S.	840

STRATIGRAPHY.

General Relations of Strata.

The indurated rocks of Linn county belong to three great systems: Silurian, Devonian and Carboniferous. It is possible that Cretaceous strata may hereafter be found to occur in the form of small remnants.

The Silurian rocks found within the county belong to the upper portion, and occur in six minor divisions. They are succeeded by the Devonian, which has not yet been completely classified for Iowa. In Linn county there are a number of well marked stages which, for the present, are given local names.

The Carboniferous occurs only as outliers. Over the indurated rocks is spread a mantle of drift, or unconsolidated deposits of Pleistocene age, which in this county present particularly interesting features.

The following table shows the formations exposed in the county.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.			Alluvium. Loess. Pre-Loess Sands. Second Till. First Till. Residuary Clays.
Mesozoic.	Cretaceous.			
Paleozoic.	Carboniferous.	Upper.	Des Moines.	
	Devonian.		Cedar Valley.	
			Wapsipinicon.	Upper Davenport. Lower Davenport. Kenwood. Otis.
	Silurian.	Upper.		Coggan. Bertram.
			Anamosa.*	
				Le Claire.
			Delaware.	Coralline. (?) Pentamerus.

The general dip of the rocks of Linn county, like that of the geological formations of the state, is toward the southwest.

* Substituted for Mount Vernon as used in the text at the suggestion of Dr. Calvin.

The lowest strata, therefore, in the geological column of the county are found in the northeast townships.

Geological Formations.

SILURIAN.

PENTAMERUS OBLONGUS BEDS.

These beds of the Upper Silurian enter Boulder and Jackson townships from Jones and Delaware counties, extending as the country rock as far west as Nugent's quarry, one mile east of Coggan. From this point a more rapid dip carries them at Coggan below the bed of Buffalo creek. The descent of the creek displays them again five miles southeast of Coggan at Hill's mills (Tp. 86 N., R. V W., sec. 29, Se. qr., Nw. ¼). Here a section of twenty-four feet of strata is given above water in the Buffalo, presenting the characteristic features of the terrain. The rock is throughout a buff, cherty dolomite, rough bedded, with courses ranging in thickness from two feet four inches at the base to six inches above, parallel, constant and to the eye horizontal. *Pentamerus oblongus* Sowerby, abounds throughout in casts of limestone and chert.

Nugent's quarry has some nine feet of the same rock, but in thinner layers, also abounding in casts of the same fossil. The upper foot or so is of finer grain and the Pentamerus casts are in calcite instead of chert and limestone as beneath. This merges into a foot of thin buff calcareous plates which may be transition beds of another terrain.

CORALLINE BEDS.

Beds of the Upper Silurian higher than the life zone of *Pentamerus oblongus* appear one and one-quarter miles east of Central City (Tp. 85 N., R. VI W., sec. 1, Sw. qr., Nw. ¼). The limestone here exposed at the foot of a hill is four feet thick with an interesting contact, to be described hereafter, with the Coggan beds above. It is a hard, bluish gray dolomite, containing numerous limestone casts of corals, but destitute of *P. oblongus*. A fragment was noticed of a pygidium of Bronteus, probably *B. laphami*, though apparently somewhat shorter. In

Central City, at water level just above the dam, a massive dolomite is exposed from which also *P. oblongus* is absent. This sub-stage will probably be recognized in the detailed study of the Upper Silurian of other counties and may then receive a more appropriate designation.

LE CLAIRE BEDS.

This terrain occupies a narrow strip along the eastern boundary of the county from Viola to the Cedar river, reaching here its ultimate northwestern exposure in the state. At the lime quarries at Viola, belonging to S. H. Gulick, the hard, vesicular, sub-crystalline dolomite repeats not only the physical characters of the dolomite at Le Claire, but is also affected by the same anomalous dip which obtains at that typical locality. At the south quarry, the heavily bedded layers at the south end dip 19° north. The dip lessens toward the north end of the quarry, where it is 8°, east 23° north.

At the north quarry, one-half mile distant, the lower layers dip 3°, west 16° south. They are heavily bedded, from four to six feet thick, and are succeeded by thinner layers, which are one foot thick at the top of the quarry. At the south end of the quarry the courses are all parallel and dip about the same. In the center, however, the lower and middle layers merge into an obscurely stratified mass, above the nearly level surface of which the upper layers, eight feet in thickness, bend down with a northeasterly dip of about 10°.

The Le Claire beds reappear at Mount Vernon and Lisbon, and on the Cedar they outcrop at intervals from the south county line to Ivanhoe bridge. Above this point they front the river in vertical cliffs, locally called the Palisades, nearly to Cedar Springs hotel southeast of Bertram. The outcrops gradually increase in height from the county line until about a quarter of a mile below the hotel where the maximum height of eighty-nine feet above water is reached. From this point (Tp. 82 N., R. VI W., sec. 14, Nw. qr., Nw. ¼) the Le Claire rapidly sinks and, in less than half a mile, disappears beneath the flood plain of the river. From the summit to the base these cliffs are, for the most part, formed of one massive layer undivided by bedding planes and unbroken by lithological alternations. While the rock is broadly homogeneous, there are slight variations in hardness and texture, producing cavernous recesses in its walls and the irregular relief characteristic of long-weathered surfaces of this dolomite. Near water level rude and inconstant courses, approximately horizontal, appear in places. Below Ivanhoe bridge bedding becomes more distinct and extensive in the rock, the dip being gentle and somewhat various.

Where quarried for lime the quarry face presents a conglomeratic aspect, due, perhaps, in part to variation in the resistance to weathering in different portions of the rock. Thus large masses are blasted out, the centers of which are hard and bluish gray, but having surfaces that are buff and somewhat carious. Much of the rock is minutely vesicular from the removal of small fragments of fossils and has therefore a trachytic harshness to the touch. When these vesicles are of some size they are stained with ferric oxide. Silica in any form is absent. In places fossils are so numerous as to affect distinctly the texture of the rock. Bands are seen several feet in thickness, made up wholly of the interstitial filling between moulds of Rhynchonellas, or of a small spire-bearing shell, or of casts of large crinoid stems.

At the lower lime quarry, now abandoned, there are numerous nests of the saucer-like cephalic and tail shields of *Illænus ioxus.*

Though the fauna of this limestone in Linn county differs from that of the typical Le Claire in Scott county, the difference is probably due to geographical rather than secular causes.

MOUNT VERNON BEDS.

The Le Claire limestone, as defined by Hall, included only the hard, brittle, sub-crystalline "limerock" at Le Claire and Port Byron, whose appearance, except in bedding, is substantially the same as that of the dolomite just described.

At Le Claire this is succeeded by a soft, even bedded, granular, but not crystalline, buff or drab limestone, stated by Hall to rest in synclinal axes of the Le Claire, and referred by him to the Onondaga Salt group. This upper limestone has a wide distribution over the Upper Silurian area in Iowa. The question of its relation to the Le Claire is an interesting one, complete data for the solution of which are perhaps not yet at hand. In the later geological literature of the state the relation has been supposed to be sufficiently close to warrant the extension of the term Le Claire to cover these beds also. Though the limestones in question may be practically contemporaneous, still their lithological differences, and to some extent their biotic differences, are marked and constant. Even if these are due only to varying conditions of deposition, accuracy and convenience in description will be subserved by the use of a local term, waiving for the present the question of the relationship of these beds to the geological series in other states. For this reason the upper limestones are here referred to as the Mount Vernon beds, since at that place they present their distinguishing lithological features and contain also a rich fauna, the beds elsewhere, with perhaps a few exceptions, being unfossiliferous. This limestone is sufficiently soft to work with ease, but hardens on exposure. Bedding planes are constant, even, parallel, and usually horizontal or with gentle synclinal or anticlinal dips. The courses are often heavily bedded, but are finely laminated, disintegrating in quarry strippings into thin, soft spalls. The stone is distantly jointed. It is granular, varying from an almost lithographic fineness to a coarser rock, sometimes called "sandstone" by workmen, although silicious sand is quite absent. The fracture is even, following the impact of the hammer in any direction. On fresh surfaces the luster is dull, relieved by scattered minute, sparkling crystalline facets. Sometimes the rock is minutely vesicular, or contains larger cavities filled or lined with quartz or calcite or with both. In color it varys from a warm gray or light cream tint to pale or darker buff, sometimes reddened by ferric oxide. chert nodules are common and thin layers of black flint rarely occur.

The most southern exposures noted in Linn county lie about three-quarters of a mile apart on either side of an amphitheater of hills which opens broadly upon the right bank of Cedar river at Ivanhoe bridge. On each side of this ancient flood plain the

Le Claire rises in cliffs about fifty feet high, the Mount Vernon beds abutting upon it or graduating into it laterally, the actual contacts not being visible.

The southeast outcrop (Tp. 82 N., R. V W., sec. 32, Nw. qr., Nw. ¼) is as follows:

		FEET.
3.	Loess and humus, forming summit of ancient terrace	4
2.	Geest, with drift pebbles	½
1.	Limestone, soft; upper layers thin and rotten spalls, layers quarried four to nine inches thick, rock compact, but some layers highly vesicular with dusty cavities up to 3 inches in diameter (Mt. Vernon beds)	8

In the northwestern quarry, Anton Novak's, the rock is distinctly of the Mount Vernon type, though vesicular. It dips about two degrees to the northwest. The quarry face is about twenty-four feet high and its base is below high water in the river.

The rock of these two quarries once formed a continuous stratum occupying a depression in the Le Claire at least fifty feet deep, and the present topography seems due in part to the difference in obduracy of the two beds.

The relation of the Mount Vernon beds to the LeClaire may be studied also at the Upper Palisades. Not one-half a mile to the northwest of the highest cliffs of the Le Claire (89 feet high), the Mount Vernon is found in a slight excavation at Cedar Springs hotel on a level with the flood-plain of the river. In places along the descending cliffs of the Upper Palisades, the Le Claire shows obscure stratification lines dipping to the northwest as much as thirty degrees. Along the summit of the rapidly sinking ledge the massive, vesicular limerock is seen to graduate laterally and vertically by intercalation, into even layers of crystalline dolomite from three to eight inches thick and finely laminated, the laminæ being defined by lines of discontinuous cavities about 1 mm. in diameter. These layers differ from the Mount Vernon beds in their crystalline texture. On the flat face of one layer a common fossil of the Mount Vernon and Stone City quarries was noted, the upper surface being covered with convex, rod-like bodies, from 1 mm. to 2 mm. thick and from 10 mm. to nearly 20 mm. long, without joints, slightly flexuous or vermicular, the same individual varying slightly in thickness and often tapering at the ends. The attitude of these thin upper layers, apparently transition layers to the Mount Vernon, is significant. They dip strongly to the northwest—one dip of forty-one degrees was measured—but curve to nearly horizontal within a few yards, forming a quadrant whose convexity is southeastward. Where especially noted they are fifteen feet thick, including three feet of interbedded "limerock."

The heavy northwest dip of the Le Claire at this point and its passage into the softer Mount Vernon beds, together explain in part the topography of the region, the sudden change from the gorge of the Palisades to the wide alluvial plain extending on the left bank to Bertram.

At Mount Vernon a similar juxtaposition of the Mount Vernon and the Le Claire beds may be observed. The quarries of the former, belonging to Messrs. Platner, Gregg and Kirby lie some fifty feet higher than the summit of the Le Claire at the Palisades. At about forty rods distant the Le Claire emerges at Robinson's lime quarry in a knob of conglomeratic limerock of which about twelve feet is exposed. On the east side it merges into regularly bedded sub-crystalline limerock, the layers being from four inches to one foot thick and nearly horizontal. On the opposite side it is flanked by the Mount Vernon limestone, which has at first considerable outward dip, but in a few feet becomes horizontal. This part of the quarry has not been worked for years and the actual contact cannot be seen. Borings made in the Platner quarry show that the Mount Vernon stone extends at least sixty feet below the top of Le Claire at Robinson's quarry so few rods away.

A slight deformation causes the Mount Vernon beds to reappear six and three-quarter miles northwest of Mount Vernon in a section described on succeeding pages.

On the Wapsipinicon river these beds extend from Stone City to Waubeek, affording some of the largest and best quarries of building stone in the State.

The following theories have been proposed to account for the deposition of the Mount Vernon beds in these deep hollows of the Le Claire:

(1) The theory of unconformity with a long time interval, during which the troughs in the Le Claire were eroded. This is negatived by the close paleontological relation of the two beds, by the lithological gradation between them and by the occurrence of crystalline "limerock," in places in several counties, upon the granular limestone of the Mount Vernon beds.

(2) By unconformity, the troughs in the Le Claire being synclinal folds. This requires no considerable time-interval, though Hall, who proposed it, allotted the two beds in question to different geological epochs. Some of the objections to the first hypothesis apply here also. Hall has since suggested that the dip of the strata at the Le Claire with which he defined the apparent synclines may be due to false bedding.* Certainly any measurements of the thickness of the strata at Le Claire based on the assumption of true dip give results grossly in excess of what can be conceded. For a distance of about 3,300 feet below the village there is a continuous northern dip which must average at least ten degrees. This would give a thickness to the Le Claire of 570 feet. Yet at Davenport, twelve miles distant, the total Upper Silurian, as measured in the artesian wells of the city, cannot be over 320 feet thick.

(3) By simultaneous deposition of the two limestones under different conditions, the "limerock" representing the irregular aggregations of coral reefs, and the granular limestone, off-shore deposits of calcareous sediments derived largely from the reefs. This theory has been skillfully worked out in detail by Chamberlin in the Wisconsin field, where a like association of similar limestones occurs,† and seems best to explain all the phenomena of the Le Claire observed in Linn county. No conclusive proof has, however, yet been found that the Mount Vernon beds were formed simultaneously with the reef rock. Their great thickness, reaching over fifty feet at Stone City and seventy feet at Mount Vernon, their wide distribution over the central counties

* Twentieth Annual Report Regents N. Y., p. 307.

† Geology of Wisconsin, vol. II. pp. 350-371. 1877.

of eastern Iowa, the appearance in them of post-Niagara species, absent in the Le Claire, indicate that they represent a somewhat later stage of Silurian sedimentation. The gradations observed in this county between the two beds are not more close than obtain between beds whose succession in time is unquestioned.

The Mount Vernon beds were evidently laid down in shallow water. At Waubeek beautiful ripple marks attest the nearness of the soft calcareous silt to the surface of the sea. In the Mount Vernon quarries calcareous "mud-cracks" indicate a still higher position.

BERTRAM BEDS.

In the southeastern and central part of the county the limestones just described are succeeded by a well defined series of beds exposed along Big creek and its tributaries from Springville and Paralta to Bertram. Along this line, nearly ten miles long, abounding in natural sections, the rock is practically the same. It is a magnesian limestone, slow to effervesce in dilute hydrochloric acid, though ultimately dissolving completely, and yielding considerable magnesian precipitate. It is hard and brittle, breaking with an uneven or sub-conchoidal fracture. In color it varies from a light to a medium drab on fresh surfaces but weathers to light gray or white. In structure it is compact, non-crystalline, non-granular. It exhibits occasional brecciation or heterogeneity of structure, owing apparently chiefly to conditions of deposition, since the regularity of the courses is seldom interrupted. Where this brecciation occurs the fragments are always small, usually minute, and like the matrix.

Weathered surfaces are sometimes smooth, sometimes pitted and rough with fantastic projections similar to those on weathered surfaces of the Niagara, but the relief is on a much smaller scale. The upper surfaces of detached blocks are usually crackled with a network of incised lines, the meshes being often rhombic and varying from a fraction of an inch to a few inches in width. Connected with this is the tendency of the rock to weather into small rhombic chipstone. At the Chicago, Milwaukee & Saint Paul railway bridge over Big creek southwest of Paralta, the upper five feet of this rock, though remaining in place, is divided into such prismatic blocks by two sets of fracture planes. A freshly fractured horizontal surface often shows thin veins of calcite, and where the structure is more heterogeneous, calcite is interstitial. In the Bertram beds are found the first evidences of those stresses whose maxima are registered in the Fayette breccia.

Notwithstanding the facts we have mentioned, the rock is commonly heavily bedded. Numerous sections along Big creek record layers two, three and even five feet thick. In one section (Tp. 83 N., R. VI W., sec. 26, Nw. qr.) two layers at the top, each five feet thick, and a basal layer eight feet thick, inclose twenty-four feet of the same drab limestone standing in a nearly vertical ledge, though more thinly bedded and tending to weather into chipstone. An adjacent hillside about fifty feet high is strewn from the summit three-fourths the way to the base with immense blocks of this stone, some being fifteen feet long.

On the whole, courses are quite constant and usually to the eye nearly horizontal, though roughly surfaced. The rock is often finely laminated, the harder laminæ standing in relief on weathered surfaces. These lines are not even and parallel as in the Mount Vernon stone, but slightly flexous. Sometimes a harder lamina is seen to be a true horizontal vein. Close, thin, discontinuous, nearly parallel cracks, undulating, but approximately horizontal, are seen filled with calcite. Near the surface the calcite is dissolved, leaving the rock apparently laminated, the divisions being marked by reddish stained cavities. No fossils have been found except one or two imperfect moulds of an exceedingly minute brachiopod. The position of the Bertram beds relative to the Mount Vernon beds is clearly seen in a low anticlinal, cut across by the valley of Big creek. This fold is the continuation of the deformation to which the presence of the Upper Silurian in the east central and southern parts of the county is due. The crest extends northwestward from Mount Vernon. The following section is taken at the summit of the arch (Tp. 83 N., R. V W., sec. 7, Sw. qr., Ne. ¼).

	FEET.
5. Slope, covered with imbedded fragments and blocks of Bertram limestone; near the base a block or ledge six feet thick, actual contact with No. 4 not observed, though but a foot or so apart	28
4. Dolomite or magnesian limestone; hard, compact, saccharoidal; light gray in color, weathering yellow; in vertical cliffs, with courses more or less obscure, dividing and again reuniting, resembling rough masonry; layers beneath becoming thinner and more distinct	19½
3. Dolomite or magnesian limestone; dark grey, crystalline, similar to No. 4, but evenly and distinctly stratified in layers one-half inch to three inches thick; weathering into chipstone with quadrangular faces	3
2. Not exposed	1½
1. Limestone; fine granular, buff; in a vertical ledge, splitting readily into thin layers with abundant casts of Leperditia (Mt. Vernon beds), to water in creek	12

Three-fourths of a mile to the southwest, at the ford of Big creek (Tp. 83 N., R. VI W., sec. 13, Ne. qr., Ne. ¼), No. 4 of the above section has declined to twenty feet above the water in the creek and is overlain by thirty-four feet of the Bertram limestone, but two feet separating the distinct outcrop of the two beds. Nearly two miles further to the south, the same dolomite reappears at water's edge at the bridge over Big creek on the Marion road (Tp. 83 N., R. VI W., sec. 23, Nw. qr., Se. ¼). To the north of the summit of the arch in the section given, the dolomite dips more rapidly, passing out of sight within three-quarters of a mile.

The Bertram beds are found as far east as school house No. 7 (Tp. 83 N., R. VI W., sec. 25, Se. qr.), on Carraway creek, and on the Chicago and Northwestern railway one mile east of Bertram. They have been traced as far north as one mile northeast of Springville (Tp. 84 N., R. V W., sec. 22, Sw. qr., Sw. ¼). There is at this point a typical outcrop some eleven feet above the track of the Chicago, Milwaukee and Saint Paul railway at a road crossing. A gully discloses above the Bertram beds four feet of a soft, earthy, buff, magnesian limestone, with many cavities and numerous moulds and casts of a small smooth surfaced Spirifer which does not seem to agree entirely with any Upper Silurian species.

The same magnesian limestone, with similar cavities or casts, is found overlying the Bertram beds on Carraway creek, on the Chicago and Northwestern railway one mile east of Bertram, and on Big creek (Tp. 83 N., R. V W., sec. 6, Nw. qr., Sw. ¼), but at none of these places is it exposed as a continuous layer as at Springville.

COGGAN BEDS.

The Bertram beds dip toward the west, since at the first outcrops west of Big creek, four and one-half miles west of Bertram, they have passed out of sight, and the soft, buff, magnesian fossiliferous limestone just mentioned forms the base of the sections. This limestone, which may be called the Coggan beds, as it is typically developed at that place, is succeeded by non-magnesian limestones, the Otis beds. Above these lie the Kenwood shales, which in turn are subjacent to the lower limestones involved in the brecciated zone which has been called by McGee the Fayette breccia.

SECTIONS OF THE COGGAN, OTIS AND KENWOOD BEDS.

The following detailed sections show representative facies of all these beds. Three-fourths of a mile east of Otis, quarries on the Chicago and Northwestern railway disclose the following succession of layers:

	FEET.	INCHES.
18. Limestone, yellowish or grey, highly argillaceous, rough in texture, in part crystalline, containing much silica, partly as masses or nodules of whitish translucent quartz and partly as angular fragments of the same	2	
17. Limestone, yellowish, argillaceous, thin bedded, slightly undulating and weathering rapidly into marly clay	8	
16. Limestone, hard, compact, yellowish grey, argillaceous; in layers four inches or less in thickness, lying in gentle undulations not more than a foot in height and about 22 feet from trough to crest	2	

		FEET.	INCHES.
15.	Limestone, non-magnesian, varying in color from light drab to dark drab and to brown; compact, hard and exceedingly fine grained as if made of finest calcareous silt; layers from nine to seventeen inches in thickness, somewhat irregular in structure and bedding; lying in broad low swells like No. 16; a few rare thin seams display a brecciated structure with calcareous fragments, like matrix, less than an inch in diameter. In all these layers *Spirifer subumbonus* Hall is gregarious	4	4
14.	Limestone, massive, yellowish, crystalline, weathering to reddish yellow	2	
13.	Limestone, ferruginous; weathering into thin calcareous plates yellowish brown in color, and traversed by thin vertical seams filled with calcite; layers from one-fourth to four inchs thick	2	6
12.	Similar to above but in two layers	1	4
11.	Limestone, brownish, weathering lighter and into thin plates	1	
10.	Limestone, hard, brown and crystalline; massive, but with distinct horizontal lines of lamination	1	4
9.	Limestone, hard, compact, brown; weathering to light greenish grey; briskly effervescent in cold dilute HCl; in places macrocrystalline, a fractured surface displaying little except the large rhombohedral faces of an impure brown calcite	1	3
8.	Limestone, magnesian: hard, crystalline, compact, grey; weathering into chipstone of irregular polygonal blocks a few inches in diameter	5	
7.	Limestone, hard, compact, light buff	1	
6.	Limestone, light brown, hard, briskly effervescent, irregularly bedded; layers about six inches thick	3	
5.	Limestone, hard, fine grained, compact, light grey; weathering to irregular layers one-half inch to four inches thick and passing into beds below	1	9
4.	Limestone, magnesian, soft, light yellow, granular, in layers one to four inches thick, not porous or vesicular: with some irregularly distributed cores of darker and harder limestone and also lenticular masses of chert with centers of dark grey flint arranged in thin horizontal layers	1	3

		FEET.	INCHES.
3.	Limestone as above, massive	1	9
2.	Limestone as above in thin layers		6
1.	Limestone, magnesian, massive; soft, light buff; somewhat argillaceous; containing small irregular nodules of chert with horizonta linear arrangement with abundant moulds and rare casts resembling *Spirifer subumbonus* above but generally smaller	4	

The Kenwood beds are represented in the upper three numbers of this section. Numbers five to fifteen constitute the Otis beds, while the lower four members may represent the Coggan beds. A little to the east of where this section was taken the *Spirifer subumbonus* layers become considerably thicker and also carry small irregular masses of black flint.

CEDAR RAPIDS SECTION.

About two miles west of the Otis quarry, above the mouth of Prairie creek, the Burlington, Cedar Rapids & Northern railway has scarped the upper part of a bluff on the west bank of the Cedar river and a quarry below the track continues the section nearly to the water's edge.

		FEET.	INCHES.
11.	Limestone, buff, argillaceous, weathering rapidly into a slope of marly clay and chipstone; some four harder layers each about six inches thick are interbedded and stand out from the slope in low relief	20	
10.	Limestone, non-magnesian	12	
9.	Limestone, light yellow, weathering to buff and reddish; breaking up into quadrangular blocks a few inches thick; layers one to six inches thick; contains many irregularly shaped dusty cavities often arranged in horizontal lines	5	
8.	Limestone, brown, with close thin lamination lines and bands of lighter color; briskly effervescent; in two layers	3	4
7.	Limestone, light buff, hard, compact, brittle, on mural surface displaying a network of perpendicular and diagonal cracks irregularly intersecting similar uneven horizontal cracks at intervals of a foot or less; in places weathering into thin layers from one-quarter to one inch thick	2	6

	FEET.	INCHES.
6. Limestone, brown, crystalline, briskly effervescent, irregularly bedded, with large, solid white calcite nests; much of the rock itself also crystallized in large brown rhomboids	1	2
5. Limestone, similar to No. 7	2	6
4. Limestone, brown, crystalline, similar to No. 6, lenticular below; upper foot thinly laminated	3	6
3. Limestone, light yellowish drab, magnesian; transition beds	1	
2. Limestone, moderately hard, light buff, magnesian; with some thin lenticular seams of black flint layers 6 to 8 inches; transition beds	1	2
1. Limestone, moderately soft, buff, magnesian with moulds and casts of fossils as at Otis, and some large concretions of black flint, eighteen inches in diameter, extending to within eleven feet of the water	6	

Of the above section, No. 11 represents the Kenwood beds, Nos. 3 to 10 inclusive the Otis, and Nos. 1 and 2 the Coggan. No. 10 is a variable member and a generalized description of several exposures along the track will afford a truer representation than a section at any one point. There are two lithological types embraced in it. The first, "A," is a hard, compact, non-magnesian limestone of finest grain and sub-conchoidal or splintery fracture, dark drab or brownish on first fracture, but weathering to light gray or white; often homogeneous and thinly laminated; often somewhat irregular in structure, occasionally containing in a limited area angular fragments of the same rock, which never exceed one-half inch in thickness. This type usually carries *Spirifer subumbonus* Hall. The second, "B" is a coarse, granular, crystalline, non-magnesian limestone usually massive, but sometimes becoming finer of grain and passing into thin layers. When massive it is especially characterized by a rudely concretionary or lenticular structure, the lenticular masses being twelve feet and more in horizontal extent. This rock is brown in color, but often on fresh surfaces displays a fantastic mottling with greenish yellow earthy spots. It also carries *Spirifer subumbonus*, the shells standing in relief on weathered surfaces. It sometimes blends vertically within the compass of a hand specimen with the limestone of the first type. "A" is usually superior, occupying the hollows of the type "B". In one case type "A" thickens from zero on summit of lenticle to one foot on the side in a horizontal distance of four feet two inches. The lenticular masses, which sometimes are seven feet thick, are not arches or folds caused by lateral thrust, but are evidently due to causes affecting deposition. Sometimes type "A" is also inferior to type "B."

On the opposite side of the river, quarries along the Chicago & Northwestern railway have a fine, fissile, greenish clay one foot thick, at the base of the buff shale of number 11, underlaid by eight feet of thin layered drab limestone of the Otis beds. The Coggan beds do not appear further to the north on the Cedar river. From the mouth of Prairie creek to Cedar Rapids they dip gently up stream and pass beneath the river below the rapids to which the city owes its name and which are due to the change which there takes place from the soft and easily eroded strata of the Coggan beds to the harder strata of the Otis beds.

KENWOOD SECTION.

At Kenwood, on the right bank of Indian creek, is a fine cliff whose base is formed of the Otis beds, which lie here at nearly the same level as in the quarries just described.

	FEET.
6. Breccia of small drab fragments with sparse matrix, including the Gyroceras beds of Calvin	11
5. Limestone, massive, brownish, argillaceous and ferruginous; graduating in places into thin reddish plates and into shale; containing many angular siliceous fragments varying in size from sand to a few inches in diameter, and elliptical nodules, sometimes slightly laminated, the major axis reaching one foot in length; these consist of whitish translucent crystalline quartz. A microsection of a nodule from Fayette, identical in appearance, consists of interlocking crystals of quartz and calcite, the former being greatly in excess and containing many and large inclusions. The base of this bed simulates strong unconformity, sweeping downward into the shales below in broad curves and again rising until it nearly meets the breccia; where measured	15

CLIFF AT KENWOOD.

		FEET.
4.	Shales, buff, calcareous; weathering into slope of marly clay; toward the top containing siliceous nodules and fragments, as in the beds above, and toward the base forming small argillaceous, laminated and fragile concretions	13
3.	Limestone, argillaceous, buff; thicker and harder layers, with bluish cores; also showing imperfect concretionary structure	2⅛
2.	Shales, thin, fissile, greenish	½
1.	Limestone, magnesian, thin layers, drab, dense; carrying *Spirifer subumbonus*. The layers are mostly from one-half to four or five inches thick. These are moderately smooth bedded, approximately parallel and lie in long and very gentle undulations. The thicker layers and sometimes the partings are slightly fragmental, the fragments being small, less than one inch in diameter, and a little darker than matrix	8¼

The upper member of this section is the Fayette breccia. The shales and argillaceous limestones of numbers 2 to 5 inclusive are designated as the Kenwood beds, which form a distinct and well defined terrain throughout the county. The lower member represents the Otis beds.

YOUNG'S QUARRY.

To the northeast, up Indian creek, the strata rise, and at Young's quarry (Tp. 83 N., R. VII W., sec. 12, Nw. qr., Nw. ¼), the Otis beds extend to twenty feet above the creek, consisting of three fossiliferous layers, respectively one foot six inches, three feet and one foot thick, overlying five feet of thin bedded limestone without fossils.

MARION.

At the old Twogood quarry at Marion we have the following section:

		FEET.
4.	Breccia (exposed)	10
3.	Kenwood beds, thin bedded, shaly (exposed)	13
2.	Slope, rock unexposed	14
1.	Otis beds, with *Spirifer subumbonus*	6

The Otis beds extend unchanged nearly ten miles east of Marion, to within less than three miles of the Jones county line. A mile southeast of Springville (Tp. 84 N., R. V W., sec.

34, Nw. qr.) they outcrop at an elevation of over 100 feet higher than at Marion. Two feet of characteristic drab rock, traversed by vertical fissures and containing *Spirifer subumbonus*, overlie three or four feet of brown, ferruginous, crystalline, granular limestone, with drab flint nodules; of the latter phase the upper fifteen inches is massive and the remainder is in thin layers.

CEDAR RAPIDS.

Returning to the Cedar river sections, it is seen that the various beds described retain a nearly horizontal position from Cedar Rapids to a lime quarry, now disused, about two miles northwest of the city by the Burlington, Cedar Rapids & Northern railway track. The section here is:

	FEET.
4. Kenwood shales, with quartz nodules, the lower foot being blue; above this buff	15
3. Otis beds, massive with *Spirifer subumbonus* at base	6
2. Same in thin layers, one-half to three inches thick	4
1. Unexposed to level of track	7

Further to the south the characteristic irregularities of the Otis beds appear. The massive layer becomes lenticular and graduates horizontally into thin layers. Thin layers are flexed over it, thinning over the crowns, thickening in the hollows. Beneath number 2 of the above section appears a brown, thick, but irregularly bedded limestone.

From the lime quarry the strata dip to the northwest, and in a little over ten rods the Otis beds sink beneath the railway track, which descends in the same direction. The following section taken here at the southeast end of the railway cut repeats the familar succession:

	FEET.
5. Breccia with abundant buff matrix; fragments few, of drab, finely laminated limestone, often rectangular in shape and sometimes nearly parallel but separated by matrix (Fayette breccia)	5
4. Limestone, moderately hard, granular, semi-crystalline, buff, briskly effervescent and somewhat argillaceous; evenly bedded, gently flexed above, in layers from four inches to one foot thick; quarried for building stone (Kenwood beds)	16

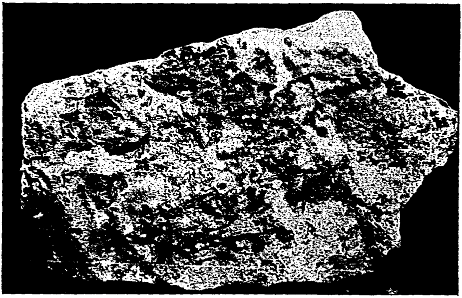
	FEET.
3. Limestone, brown, earthy, semi-crystalline; with a blue, hard limestone and a soft, coarse, granular and earthy limestone, dark drab or dark buff in color, often earthy when weathered. These are each extremely irregular and vary in thickness, but form one layer distinguished by the abundance of lenticular quartz nodules it contains (Kenwood beds)	6
2. Limestone, light yellowish buff, thin, laminated, shaly (Kenwood beds)	14
1. Limestone, light brownish drab, hard, splintery; even-layered, in layers two to four inches; flexed as seen further to the southeast over the irregular upper surface of a brown, massive limestone (Otis beds)	4

There are one or two other exposures of these beds along the Cedar river which may be mentioned. A little over two miles southwest of the railway bridge at Bertram, and the same distance west of the last outpost of the Le Claire at the Upper Palisades, the Otis beds form a ledge in a hill overlooking the flood plain of the river (Tp. 83 N., R. VI W., sec. 4, Sw. qr). The rock here is in places crowded with the common and only fossil of these beds. At the foot of the hill a buff magnesian limestone was once quarried.

A small quarry of the Otis beds on a hillside overlooking the old flood plain of the Cedar, about one half mile west of Otis, has its special interest in the curious intermingling of black flint with portions of the massive *Spirifer subumbonus* layer. Instead of being disseminated in nodules, it is aggregated in irregular columns and vertical leaves in a layer about a foot thick. The same layer was found in Cedar Rapids, in a sewer on Fifth avenue west, extending 120 feet west of Second street.

A hand specimen shows it to be quaintly mottled with impure black flint and grey limestone resembling in outlines the mottlings common in the more massive crystalline, earthy layers of the Otis beds (figure 14). Above this flinty layer were pockets up to two feet thick of dark fissile, non-calcareous shale and eight feet of thin bedded limestone. This has not been seen in place and the workmen could not say whether the shale reached the rock surface or not. Its position at once suggests the greenish shale which forms th extreme base of the Kenwood beds. Its quality refers it rather to the coal measures, and similar clays belonging to a Carboniferous otlie areur found north of the city at Kenwood.

The most northern exposure of the Kenwood beds noted in the Cedar Valley is at the north end of the railway cut of the Chicago, Milwaukee & Saint Paul railway west of Linn, where a few feet of this shaly limestone are obscurely exposed at water level in river. They underlie, however, the Fayette



Finure 14. Dark flint and limestone from Fifth avenue sewer, Cedar Rapids.

breccia over the high prairie to the north, as is proven by wells, and emerge unchanged in the valleys of the Wapsipinicon and Buffalo. The sections along these rivers repeat in every detail the Cedar river section except that the Bertram beds are absent. The Coggan beds repose, therefore, directly upon the earlier formations.

At Coggan, the Coggan beds probably are in contact with the Pentamerus beds of the Upper Silurian, which have been noted as outcropping at higher level a short distance east of the town. The following section taken at Ashby's quarry at the railway station will illustrate the character of the beds:

	FEET.
3. Limestone, grey, hard, compact, sub-crystalline, magnesian; layers from one to four inches thick, weathering into block-chipstone	2
2. Limestone, massive, pale buff, magnesian; moderately hard, granular, sub-crystalline; porous or vesicular, with a few irregular cavities about an inch in diameter; in layers from eighteen to twenty-four inches thick. These contain in abundance imperfect moulds, rarely casts, of a small spirifer-like shell indistinguishable from those at Otis, Cedar Rapids and Springville in beds attributed to this horizon. The lower two feet is variable. In places the rock weathers into chipstone, and is a brownish buff, semi-earthy, semi-crystalline limestone; thickness to quarry floor	8
1. Slope to water in river, elsewhere seen to be occupied by massive limestone as above	6

A few feet above the level of the upper layers in Ashby's quarry the Otis beds are found adjoining the railway track north of the station. The layers here vary, become thicker and thinner, and mass in lenticles thirty feet long, but in a manner highly characteristic of this horizon. In general, the upper member is a hard, light yellowish drab, compact limestone, about two feet thick, with conchoidal fracture and in thin layers. Beneath this are five or six feet of varying brownish limestone. In places it is hard and compact, in places mottled, and earthy crystalline, composed of little angular fragments of hard limestone the size of coarse sand, with buff interstitial filling. Especially above, it tends to develop a black, flinty layer like that at Fifth avenue west, Cedar Rapids, in places passing into a vesicular, siliceous mass, resembling pumice. The total thickness of the section is about eight feet.

Less than half a mile north of Coggan the Mains quarry (Tp. 86 N., R. VI W., sec. 3, Sw. qr., Ne. ¼) exhibits some seven or eight feet of the Otis beds overlain by eighteen inches of interstratified greenish shale and thin, layered limestone with imbedded limestone fragments. The Otis beds here are not so variable as at the railway station. The shales are found well developed in the adjacent cut of the Illinois Central railway. They are here five feet thick, highly argillaceous, somewhat calcareous, thinly laminated, and blue in color. Nowhere in the county is the green or blue shale at the base of the Kenwood beds in such force as here, and as it was believed to be the horizon of the Independence shales a most careful but fruitless search was made for fossils in the abundant debris along the sides of the cut. The shale is overlain by rough buff or purplish limestone, sandy with angular chert and quartz sand, and containing nodules of quartz and calcite. This is four feet thick, and its layers are from one to eight inches in thickness. It is succeeded by two or three feet of thin, calcareous plates and rough, dark-reddish limestone, covered by drift.

One and one-half miles east of Central City is an interesting section, where the base is clearly Niagara in contact with the Coggan beds above:

	FEET.
5. Otis beds, with large masses of black, flinty limestone	6
4. Slope, no rocks in place	10
3. Coggan beds, abundantly fossiliferous, with the same fossils as at Coggan; lithologically similar, but much more cavernous; resting directly and apparently conformably on beds below	16½
2. Limestone, magnesian or dolomite, compact, grey, crystalline, granular; friable, breaking into calcareous sand; made up of two upper layers in even courses four and five inches thick and a lower irregular layer about one foot thick resting directly upon beds below	1¾
1. Dolomite, fossiliferous as described previously (Niagara)	4

At Central City, as has been noticed, a dolomite unquestionably Upper Silurian, lies at the level of the water in the mill pond. At Finson's quarry, a quarter of a mile above the dam, there occurs, six feet higher, a vesicular, white, earthy limestone, and another which is more compact, weathering into polygonal fragments several inches in diameter. These are magnesian, but are not dolomitic, and in some respects resemble the Bertram beds whose place they seem to occupy. They are some three feet thick, and are succeeded by the lower layer of the Coggan beds, a soft, earthy, magnesian limestone with the usual fossil moulds. A few rods further up the river a large quarry displays nearly the full thickness of the Coggan beds. The section taken here is as follows:

	FEET.	INCHES.
5. Limestone, even-bedded, non-magnesian above, becoming more and more magnesian below, and so graduating by thin layers into the beds below that the line between them is somewhat arbitrarily drawn (Otis beds)	12	3
4. Limestone, magnesium, light buff, compact, granular		10
3. Limestone as above, darker, also non-fossiliferous excepting some minute vermicular cavities; in three layers	1	
2. Limestone, massive, buff, magnesian; with moulds and casts of fossils, as at Coggan; porous and vesicular; upper layer cherty, with dark nodules forming in places a continuous band. The layers from above downward are respectively one foot, five feet and ten inches, eleven inches, and four feet ten inches in thickness	12	7
1. Unexposed to river	10	2

Numbers 2, 3 and 4 of the above belong to the Coggan beds. These beds maintain their level to a fine exposure on the left bank of the river, two miles northwest of Central City, at Granger's old quarry (Tp. 86 N., R. VI W., sec. 28, Se. qr., Sw. ¼). The section shows their passage upwards into the Otis beds:

	FEET.	INCHES.
18. Limestone, brecciated, unfossiliferous, composed of drab fragments, with abundant buff matrix in places	4	
17. Limestone, buff, inclosing a few brown, angular fragments	2	
16. Limestone, buff, earthy	1	
15. Slope, with buff limestone fragments protruding in places	34	10
14. Limestone, massive, buff and brownish mottled, with much calcite irregularly disseminated	1	9

		FEET.	INCHES.
13.	Limestone, hard, grey, compact, crystalline; slow in effervescence		10
12.	Unexposed	3	
11.	Limestone, hard, compact, rather dark drab, weathering lighter and breaking up under atmospheric agencies into hard rhombic chipstone; layers two to four inches in thickness; briskly effervescent.	2	
10.	Limestone, hard, compact, light grey, saccharoidal, in layers five, seven and twelve inches	2	
9.	Limestone, hard, dense, non-crystalline, light yellowish drab in color, weathering into small chipstone with conchoidal fracture	2	
8.	Limestone, grey, highly crystalline, the rock as a whole having interrupted crystalline cleavages		6
7.	Limestone, drab, hard, dense, crypto-crystalline, weathering lighter, and into polygonal chipstone; fracture conchoidal, layers two to four inches thick	1	6
6.	Limestone, hard, brown, granular, crystalline, rough to the touch and briskly effervescent		11
5.	Limestone, dense, non-crystalline, of impalpable grain and conchoidal fracture, in thin laminæ	1	
4.	Limestone, hard, grey or light buff, minutely vesicular, especially the upper layer	1	1
3.	Limestone, hard, dense, crypto-crystalline, and non-crystalline; light and darker drab in color; in four layers, which weather into polygonal masses; resting directly and without apparent unconformity on the beds below	1	9
2.	Limestone, magnesian, soft, pale buff, of earthy lustre; in layers of six inches, one foot three inches, one foot two inches, and three feet three inches. The upper layer is more dense than those below, and contains minute vermicular cavities. None of the layers are laminated. They are highly vesicular, with cavities of the small, smooth-surfaced spirifer characteristic of these beds, and contain many irregular, dusty cavities up to an inch or more in		

		FEET.	INCHES.
	diameter. In these layers was found also the cast of a pygidium identified by Dr. Calvin as belonging to a small individual of *Dalmanites verrucosus* (Hall)	8	1
1.	Unexposed to water in river	21	1

Of the above section numbers 1 and 2 belong to the Coggan beds, numbers 3 to 14 inclusive represent the Otis beds and numbers 15 to 17 the Kenwood.

The exposure was first visited by the writer, and a section published, a number of years since, when stone was being taken out for bridge piers at Paris. It was then found that the layers of buff, magnesian limestone, now covered, extended to within ten feet of the water. The thickness of these from below upwards was noted as 31, 19, 27, 9, 9, and 5 inches. It was then supposed to be the only section in the state showing Silurian and Devonian strata in contact. The section has recently been republished by McGee,* together with a similar section at Fayette, Iowa. In the latter the massive, buff, magnesian limestones which underlie the Devonian strata are stated to contain fossil casts, and upon these must rest the question of the identity or diversity of these limestones with the Coggan beds.

In the above section all the courses are even and approximately horizontal, except where otherwise stated, and as in similar sections at Otis, Cedar Rapids and Central City no evidence of unconformity at any points was observed.

SAWYER'S QUARRY.

(Tp. 86 N., R. VI W., sec. 33, Ne. qr., Se. ¼.)

Here Otis beds were once quarried for lime. The succession is the same as so often noted:

		FEET.	INCHES.
3.	Kenwood beds	2	
2.	Otis beds in seven courses, upper layers of ten inches, with black flint as at Cedar Rapids, Fifth avenue west	16	8
1.	Unexposed to river	6	3

On a small creek to the west of the river (Tp. 86 N., R. VI W., sec. 33, Se. qr., Sw. ¼) are found some outcrops that supplement the section at Granger's quarry. The heavily layered

*Eleventh Annual Report U. S. Geological Survey, p. 315. Washington, 1893.

Coggan beds form a ledge near the river. Half a mile up the creek five feet of the upper layers of the Otis beds appear, rough, mottled and lithologically heterogeneous. They are overlain by a blue, calcareous shale four feet in thickness, which has been used experimentally for brick and found to burn white. This graduates into seventeen feet of typical buff Kenwood shales, with quartz nodules some nine inches in diameter. The buff shales merge into four feet of harder argillaceous limestone. They were tested by A. S. Hatch of Central City and found worthless for every economic purpose.

CEDAR BLUFF.

A little over three miles northwest of Granger's quarry, in a direct line, the bluffs on the right bank of the Wapsipinicon afford a number of fine sections. The one known as Cedar Bluff (Tp. 86 N., R. VII W., sec. 24, Ne. qr., S. ½) shows that the Otis and Coggan beds have both dipped beneath the river at this point.

		FEET.
5.	Limestone, fossiliferous, shaly; outcropping along a slope, apparently disturbed or brecciated (Devonian)	10
4.	Breccia, composed mainly of large fragments of hard, drab limestone, with some fossiliferous fragments	23
3.	Limestone, soft, earthy, dark buff, reddish; with angular cavities and with angular limestone fragments; the matrix constituting the main mass of the rock, passing downward into thin, calcareous plates a fraction of an inch thick containing botryoidal aggregations of spherical clayey concretions	17
2.	Limestone, soft, buff, with blue cores in lower layers, finely and evenly laminated	9
1.	Talus to water's edge, where a blue clay or shale occurs. Here, as at Granger's, quartz nodules occur in talus, but were not seen in place	4½

Number 4 is the Fayette breccia and numbers 1, 2 and 3 the Kenwood beds.

WOLF'S DEN.

At the Wolf's Den, about a mile up stream from Cedar Bluff, the Fayette breccia rests directly on thin, soft, and evenly laminated shales. The line of contact is uneven and strongly suggests unconformity, but shale and breccia are so weathered that the alternative of slips along the scarp is possible. The base of the breccia is here seventeen feet above the water. Four miles further to the northwest, at Troy Mills, the Kenwood beds have sunk out of sight and the breccia occupies the channel of the river.

At a few points between the immediate valley of the Cedar and that of the Wapsipinicon, in the central part of the county, the Fayette breccia is cut through, revealing the Kenwood beds. They were noted on East Otter creek (Tp. 85 N., R. VII W., sec. 15, Nw. qr., Sw. ¼), Otter Creek township, and on Dry creek (Tp. 84 N., R. VII W., sec. 28, Se. qr., Nw. ¼).

RELATION OF COGGAN AND BERTRAM BEDS.

The lithological affinities of the Coggan beds are with the Silurian, and the three or four fossils hitherto found seem to be of Silurian types. The rock greatly resembles that of the Mount Vernon beds, differing in greater vesicularity and absence of lamination. It is further distinguished by the interposition of the Bertram beds between it and the Mount Vernon beds, in the central and southern portions of its outcrop.

It must be admitted, however, that the place assigned to the Bertram beds is somewhat anomalous. When the survey of the county was begun, it seemed at first probable that the Coggan beds were the westward extension of the Mount Vernon beds, while the Bertram beds were the eastward extension of the Otis beds. This hypothesis has the merit of simplicity and is supported by several considerations, chief of which is the absence of the Bertram beds in the Wapsipinicon sections, the other members of the Cedar river series being present and unchanged.

Nevertheless, the separation of the Otis and the Mount Vernon beds by the Coggan and Bertram beds is believed to be in accord with the facts for the following reasons:

1. The presence above the Bertram at Springville and on Big creek of a soft, buff, earthy, magnesian limestone (apparently as magnesian as the Coggan beds) with imperfect casts of fossils apparently identical in species and distribution with those

of the Coggan beds. Assuming the identity of this limestone with the Coggan, the subjacent position of the Bertram to the Coggan is proven. The Bertram beds have already been shown to be superior to the Mount Vernon beds. The only possibility of error in this argument lies in the fact that possibly the soft, buff, magnesian limestone lying above the Bertram at Springville and on Big creek may be decayed magnesian layers of the Otis, and that the imperfect moulds and casts found here have not been distinguished from those of a really distinct species in the Coggan beds,* or that the same species ranged from Coggan to Otis time and its presence in the two beds is not proof of their identity.

2. The absence in the Coggan of the fossils of the Mount Vernon and vice versa.

3. The difference between the Otis and the Bertram beds, which, when closely studied, becomes more and more apparent. In the former *Spirifer subumbonus* is found gregarious in every outcrop from southeast of Springville to the Cedar river. In the latter no fossils are found. The upper layers of Otis, whose entire thickness is less than the Bertram, are non-magnesian; the Bertram is magnesian throughout. The granular, crystalline layers of the Otis, often mottled and in part earthy, and containing black flint irregularly disposed, often lying in lenticular masses and alternating with thin layers of compact rock—these characteristic layers of the outcrop of the Otis in all parts of the county are entirely absent from the Bertram. In the absence in it of silica in any form the Bertram resembles the Le Claire rather than the lower Devonian limestones of Iowa. On the whole, also, the Bertram beds are more heavily and more evenly bedded than the Otis.

The force of these considerations compelled the relinquishment of the first hypothesis of the identity of the Coggan with the Mount Vernon beds and of the Bertram with the Otis, and the placing of them as distinct beds in the succession already stated.

* The species in question is a spirifer akin to *Spirifer modestus* Hall. It belongs thus to a type ranging from Silurian to Carboniferous, in which specific differences are inconspicuous in imperfect specimens.

DEVONIAN.

WAPSIPINICON STAGE.

The term Wapsipinicon has been suggested as an appropriate designation for the various lower beds of the Devonian series in Iowa, including as the superior member of the stage the Upper Davenport or Gyroceras beds.* The name indicates the exposure of the entire terrain in the gorge of the Wapsipinicon river from Troy Mills to Central City. The typical exposures, however, of the several beds of the terrain to which they owe their individual names are found elsewhere, along the Cedar and Mississippi rivers. The beds constituting the rocks of the Wapsipinicon stage are the Upper Davenport, the Lower Davenport, the Kenwood including the Independence shale, and the Otis. To these future investigation may add the Coggan. As the Upper and Lower Davenport beds are found in the county only in a brecciated condition they are here described under the name given to this brecciated zone, the Fayette breccia.

OTIS BEDS.

The lithological affinities of these beds are wholly with the Devonian, as has been seen in the detailed description of their many sections given in the preceding pages. They graduate downward by thinly bedded magnesian transition layers into the buff, heavily bedded magnesian limestone of the Coggan.

Spirifer subumbonus Hall, the characteristic fossil of the Cedar river sections (absent on the Wapsipinicon and Buffalo), is a well known Devonian species ranging through the Hamilton and Tully and into the Upper Chemung. The species in its typical form has not hitherto been found in Iowa. The specimens from the Independence shale, so named provisionally by Calvin, are stated in his description to differ from the type materially in size and in the width of the hinge area.* The specimens from the Otis beds are smaller than those from the Independence shales, their hinge area is narrower, the umbonal region of the ventral valve is more prominent and its beak higher and more recurved.

*Proc. Ia. Acad. Sci, 1893, Vol. I, pt. iv, pp. 23-24. Des Moines, 1894.

*Bull. U.S. Geog. and Geol. Surv., vol. IV, p. 729. Washington, 1878.

It is a very interesting fact that these beds which add a new and inferior member to the Devonian series in Iowa do not introduce any species of lower range than those which already constitute the Devonian fauna of the state. So far as the fossils of the Otis beds go—a fauna composed of one species in not a wide basis for induction—they ally them with the Devonian beds above rather than with any beds elsewhere representing epochs preceding the Hamilton. The line of separation between the Otis beds and the Independence shales is in most sections rather sharply drawn. The upper layers of the Otis represent disturbed sedimentation, but the transition is usually quite abrupt between the drab, non-magnesian limestones of the *Spirifer subumbonus* layers and the blue fissile shales at the base of the Kenwood beds.

KENWOOD BEDS.

The position and the nature of these beds define them, or at least their lower member, as the equivalent of the Independence shales. It will be remembered that the Independence shales were first discovered in a shaft sunk near Independence, and consisted of sixteen feet of fissile shale, dark and carbonaceous above, grey below, and carrying a rich and highly interesting fauna, which was fully described by Calvin. They were shown to immediately underlie the Gyroceras beds, and traces of a shale at this horizon have since been noted by the same authority at several points in Buchanan county. From rumors of coal found at various places along the eastern outcrop of the Devonian in Iowa, the generalization was made that these shales were not a merely local deposit, but constituted a widely distributed member of the Devonian series in the state. Subsequently the evidence supporting this conclusion was somewhat weakened by the discovery of Carboniferous outliers at some of the localities referred to from which rumors of coal had gone forth, and by the fact that no natural section of these shales had hitherto been found. Therefore, though the Independence shales have remained an accepted member of the Devonian series, any evidence of their extension beyond the place and county of their discovery is welcome. It is true that the evidence in favor of the identity of the Kenwood beds with the shales of the shaft at Independence might be stronger. The former are destitute of fossils and carry no trace of carbonaceous matter. But the position of both, beneath the Gyroceras beds, and their argillaceous nature we must accept as proof that they occupy the same geological horizon.

The term Kenwood is therefore used in this paper only as a local synonym of the term which has the rights of wide acceptance and long priority.

Such a local synonym has seemed useful and necessary because of the differences which obtain between the shales in Linn county and those of the typical locality, because of their fuller development here, and especially since the exact parallelism of the Independence shales seems to be with the blue shale at the base of the Kenwood limestone and shales rather than with them as a whole. The Independence shales in their typical fossiliferous or carbonaceous phases have been found at two places in the county. Mr. E. N. Beach of Troy Mills states that a well dug west of Walker (Tp. 86 N., R. VII W., sec. 8, Se. qr., Ne. ¼) pierced a blue shale at a depth of one hundred feet. A fossil, *Strophodonta arcuata* Hall, was brought up by the sand pump and is now in Mr. Beach's possession. Crystals of pyrite are attached to the shell and it is filled with soft blue clay.

In 1877, as was reported at the time, a well sunk on the farm of Mr. C. Hemphill, near Lafayette, reached a thin seam of coal at a depth of ninety feet. This also belongs without doubt to the Independence shales, as the well mouth is upon or above the Fayette breccia.

FAYETTE BRECCIA.

The breccia which succeeds the Kenwood beds in Linn county is undoubtedly part of the brecciated zone which extends along the eastern outcrop of the Devonion from Davenport at least to Fayette, at practically the same horizon. In Linn county it is believed that the clastic forces were at a maximum; the breccia is thickest here and best displays its characteristic phases. In this county several distinct lithological and faunal stages are involved, which it may be well to state before giving in detail any farther sections of it. The brown or buff, earthy, ferruginous and quartziferous limestones of the upper Kenwood not infrequently contain sparse, angular, limestone fragments, and pass upward into a breccia in which the buff matrix is abundant and often contains angular, siliceous sand. The included fragments are small and few. This constitutes the first and lowest stage.

Figure 15. Fayette breccia of first stage from Granger's quarry, Central City.

A second stage is that in which drab fragments, usually small, constitute the bulk of the breccia, the softer buff or grey matrix being for the most part interstitial. The fragments are composed of a hard, dense limestone, light or dark drab in color, ringing under the hammer, compacted of impalpable and pure calcareous silt, and breaking with smooth conchoidal or subconchoidal fracture. The rock in its original state was to a large extent thin layered, as may be seen from the irregular rectangular shape of many fragments. They also often show finest and close lamination lines picked out by weathering, but the laminæ remain firmly cemented together. These lines are apt to be undulating, contorted or sharply flexed, or even concentric. This limestone resembles some of the layers of the Otis beds that bear *Spirifer subumbonus*. A theory of the formation of the breccia might possibly be framed which would admit the presence of fragments of the Otis limestone as clastic sediments in the breccia, despite the intervening Kenwood shales. But it is more probable that a lowering of the sea floor

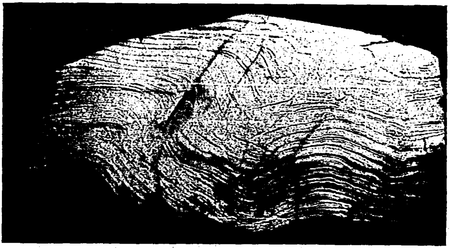


Figure 16. Contorted laminæ in breccia fragment of second stage; from below Robins.

at the close of Kenwood times allowed again the deposition of pure calcareous silt. If the fragments in question were derived from the Otis, in which *Spirifer subumbonus* is so abundant in the Cedar valley, it seems hardly possible that among the many thousands of fragments of this type scanned, none should have been found fossiliferous. The brown crystalline limestone of the Otis is also absent from the breccia. The thin layered, drab, non-magnesian, non-fossiliferous limestone which we believe was deposited upon the Kenwood, and whose fragments constitute the bulk of the breccia is not found undisturbed in Linn county. It is identical with the thin layered, partially brecciated, unfossiliferous limestone occupying this horizon, exposed along the Mississippi from Davenport to Gilbertsville. To avoid repetition of descriptive terms, the limestone which forms the fragments of the second stage may be called the

Lower Davenport type. Although the Lower Davenport beds have been wholly broken up so far as seen in Linn county, large masses are occasionally found which themselves contain rectangular fragments of laminæ of the Lower Davenport type, which still remain approximately parallel and horizontal though separated by a grey matrix. Such a mass from west of Linn Junction is figured below.

Figure 17. Fayette breccia illustrating complex brecciation and parallelism of fragments; from west of Linn.

In this stage brown fragments of the upper Kenwood are also sometimes present.

A third well defined stage is that in which large fragments, often several feet long, of heavily bedded, tough, grey, semi-crystalline limestone predominate. These carry a distinct fauna in which *Pentamerus comis*, Owen, and *Orthis macfarlanei*, Meek, are the most common, and a large Gyroceras and *Rhynchonella intermedia*, Barris, the most characteristic fossils. Other forms are *Strophodonta nacrea*, Hall, *Proetus haldemani*, Hall, and teeth of *Ptychtodus calceolus*, N. and W. This is the Gyroceras bed as defined by Calvin in Buchanan county, and is believed to be the equivalent of the fossiliferous beds at Davenport attributed by Barris to the Corniferous. The matrix resembles usually the matrix and fragments of stage four, and fragments of this upper stage are often found interstratified or in juxtaposition.

A fourth stage is defined by the absence or comparative rarity of fragments of the preceding stages. Matrix and fragments are composed of fossiliferous shaly limestone of the type of the ordinary fossiliferous shaly Cedar Valley limestone at Independence, Vinton, Davenport and many other localities along the eastern outcrop of this formation. This stage embraces the *Spirifer pennatus* beds and often the higher coralline beds as defined by Calvin in Buchanan county. Frequently it constitutes a true breccia, the fragments being of moderate size and tilted at all angles. It is often, however, disturbed but not brecciated, much of it occupying its original horizontal position, with here and there fractures and tilted blocks of large size. On natural sections where it has weathered to a slope covered with fragments, it is extremely difficult to determine the extent to which the beds have been disturbed. This stage includes several biotic zones which will be considered elsewhere.

The stages just defined are not parted by any fixed and constant horizontal boundaries. The forces producing the brecciation of these beds were sufficiently powerful to commingle the strata to a certain extent, and it is only in a broad way that the divisions suggested may be made. They have been found useful in the field and can often be recognized at a glance.

On account of its passage upward into slightly brecciated or disturbed fossiliferous limestone of the ordinary Devonian types, and on account of the fact that in the fourth stage brecciation is not constant, it is difficult to map the area of the Fayette breccia. It may be said to extend from the northern to the southern limits of the county. Its eastern outcrops are between Central City and Paris, at Flemingville and Marion. Its western outcrops as the country rock are near Troy Mills, Lafayette and at Linn. West of these points, at Alice Post Office, Ward's quarry (Tp. 85 N., R. VIII W., sec. 24, Se. qr., Nw.

¼) and Toddville, we have the unbrecciated beds of the Cedar Valley limestone which will be discriminated elsewhere by their fossils.

The following are a few representative sections out of many which may be taken within the area mentioned:

Section on north road from Paris to Troy Mills (Tp. 86 N., R. VII W., sec. 16.)

		FEET.
4.	Breccia of drab fragments (second stage) slightly fossiliferous at top	14
3.	Limestone, rough, brown; with angular cavities resulting probably from dissolution of non-magnesian fragments; sandy near base	12
2.	Shale, Kenwood	13
1.	Limestone, hard grey, Otis	2

Section at Eidemiller quarry (Tp. 85 N., R. VII W., sec. 15, Nw. qr., Sw. ¼).

		FEET.
4.	Limestone, disturbed fossiliferous beds (fourth stage)	4
3.	Breccia of tilted blocks, some being six feet long, of hard grey limestone, with abundant *Pentamerus comis* and with large Gyroceras (third stage) passing into breccia of abundant drab fragments (second stage)	14
2.	Breccia with abundant buff matrix	2
1.	Slope to flood plain of east branch of Otter creek	18

The Kenwood beds are exposed near water level a short distance from this point on the opposite side of the creek.

Hemphill's section on West Otter Creek (Tp. 85 N., R. VII W., sec. 18, Ne. qr.).

		FEET.
3.	Breccia, fossiliferous (fourth stage) some layers horizontal, some tilted at all angles, no small fragments of Lower Davenport type present	6
2.	Breccia, (second stage, Fayette type), composed mostly of fragments of Lower Davenport limestone, usually small, mostly an inch or so in diameter, rarely over six inches, many finely laminated and laminæ sometimes flexed; matrix buff, small in amount, at the base some large fragments of soft bluish grey limestone, one to three feet long, and apparently little disturbed	23
1.	Unexposed to water level	3

In the cuts of the Chicago, Milwaukee & Saint Paul railway between Cedar Rapids and Marion, the structure of the lower breccia may be studied to advantage, though the sections are in no place over eight feet thick. The rough, reddish brown limestone of the Kenwood emerges occasionally in a low broad arch. From the breccia above, hand specimens can be obtained containing siliceous angular sand, fragments of the Lower Davenport type, and of the *Pentamerus comis* or Upper Davenport rock in the same buff matrix. Above this, large blocks of the third stage are seen. A few boulders of sandstone are found, probably belonging to the Marion Carboniferous outlier.

MARION.

At a quarry within the city, north of the cemetery, the basal member of the breccia is exposed for fourteen feet. The fragments here of the Davenport type are rather small, any over six inches being conspicuous and rare. No fossils are found in either fragments or matrix. The matrix is too abundant to be interstitial. It is grey or buff in color, and soft, weathering rapidly so that the imbedded fragments can be easily disengaged with the fingers. At the top, for an area of six feet in horizontal dimensions and four feet vertical, fragments are quite absent, leaving a rough, brown, vesicular, limestone irregularly bedded and with undulating laminæ.

At the south end of the quarry for over twenty feet at the base there is exposed a buff limestone four feet thick, massive on the whole, but showing irregular laminæ in places. This contains very few fragments and is practically undisturbed. Yet it passes into breccia at the same level. In this quarry some of the fragments were evidently derived from the upper layers of the Kenwood.

TROY MILLS.

An interesting horizontal section of the breccia of the second stage is found at the river's edge below the bridge. The matrix here is slight in amount. In certain areas—the largest area noticed was seven feet long—a buff non-fossiliferous limestone was deposited apparently in hollows caused by the unequal aggregation of the larger fragments. This contains a few angular fragments constituting not over twenty-five per cent of its bulk. The fragments in the breccia as a whole are unusually large. Fragments a foot in diameter are common and many are several times as large. One ten feet long was noticed, composed of the laminated limestone of the Lower Davenport type. The size of the constituent fragments renders especially distinct a characteristic feature of this stage, many of the fragments being themselves brecciated, consisting of drab fragments in a grey unfossiliferous matrix.

LINN.

In some respects the best exposure in the state of the Fayette breccia is along the cut of the Chicago, Milwaukee & Saint Paul railway on the Cedar river west of Linn. The line along which, with some interruption from ravines, the breccia stands exposed to the heighth of ten to twenty-five feet above the rails, is some three-quarters of a mile long. The total vertical exposure is about sixty feet, the grade of the railway rising from twenty feet above the river at the south end to fifty-nine feet above it at the north.

The breccia exposed at the south end is some twenty-one feet thick, its base being twelve feet above low water level in the river. The matrix here is scanty, soft, and yellow or grey in color, occasionally arenaceous with angular fragments of quartz perhaps derived from the Kenwood beneath. The fragments are mostly small and of the Lower Davenport type, though some are seen several feet in diameter. Occasionally toward the base a fragment occurs of thin, laminated, brownish crystalline limestone like some of the upper layers of the Kenwood. In two or three places near the summit fragments of the *Pentamerus comis* limestone occur, and here also was found a small quartz nodule with vesicular surface, similar to those plentiful in the Upper Kenwood. A portion of the base is but partially brecciated and consists of a rather soft, whitish grey crystalline limestone, saccharoidal in texture varying to semi-crystalline and yellowish grey, with a few inclusions of angular fragments of the Lower Davenport type. There are traces in the limestone of low arches thirty or forty feet long and three feet high.

A transverse valley about one quarter of a mile wide separates this cut from the next exposure of the breccia at a higher level in a ledge twenty-one feet high. The lower part of the ledge is made of contiguous fragments of the Lower Davenport type and some larger blocks of Upper Davenport limestone containing *Pentamerus comis*, with fewer fragments of shaly, buff limestone of the fourth type, all commingled in the most heterogeneous manner conceivable. Above, the fourth type predominates and in places along the top of the ledge is apparently little disturbed. Even here, a few small angular fragments of the Lower Davenport type are imbedded in buff shales. This horizontal distribution is not constant. Masses of breccia of the second stage rise in places to the summit, alternating with other masses in which a soft, yellow, arenaceous, non-fossiliferous matrix is especially abundant, and the breccia weathers back several yards from the face of the cliff adjacent and forms a talus of two-thirds its height.

Further to the north, as the track ascends, the zone of the third or Upper Davenport stage is well marked by huge blocks in which *Pentamerus comis* is abundant. The larger ones are tilted somewhat, but seem to retain something of their original attitude. One measures eleven feet in length and two feet six inches in thickness. The vertical surfaces of these blocks commonly show slickensides of shallow grooves, usually at about right angles to the bedding planes, trenching rock, thick Pentamerus shells and sections of fossils alike. One block was observed in which this massive grey crystalline limestone graduated at the base into a thin layer of the typical Lower Davenport limestone.

Towards the north end of the cut the breccia of the fourth stage becomes predominant, though fragments of the other types are still present. In places towards the summit, however, they are quite absent and well defined fossil zones may be traced, *Spirifer bimesialis*, Hall, yielding percedence to *Spirifer pennatus*, Owen, and continuous coralline layres in a harder limestone appearing, with *Phillipsastrea billingsi*, Calvin, and *Acervularia davidsoni*, E. & H.

These coralline layers form the summit of the section at the extreme north end of the cut.

At Linn Station, breccia of the third stage is exposed and excellent examples of this and of the fourth stage may be seen in a cut on the Burlington, Cedar Rapids and Northern railway one-half a mile south.

CEDAR VALLEY LIMESTONES.

In this limestone several life zones may be drawn, distinguished more by the general assemblage of their fossils than by the presence of any species elsewhere absent. Immediately succeeding the Gyroceras or Upper Davenport beds lies a zone often involved in the Fayette breccia, marked by the abundance of three species: *Orthis impressa*, Hall, in forms intermediate between *O. macfarlanei*, Meek, and *O. iowensis*, Hall; *Stropheodonta demissa* in small rugosely striated shells of protean forms, approaching, if not including, *S. plicata*, Hall; and *Spirifer bimesialis*, Hall, in its typical form and in a new variety with wider area. Less abundant but still more characteristic is an *Orthothetes*, sp., nov. Associated with these are the following species so far as now determined:

Atrypa reticularis, Linn.
Atrypa aspera var. *occidentalis*, Hall.
Cyrtina hamiltonensis, Hall.
Crania crenistriata, Hall.
Orthis iowensis, Hall.
Orthothetes chemungensis, Conrad var., nov.
Pentamerus comis, Owen.
Pholidostrophia nacrea, Hall.
Productus subalatus, Hall.
Stropheodonta demissa, Conrad, typical form.
Stropheodonta inequistriata, Conrad.
Spirifer fimbriatus, Conrad.
Proetus haldemani, Hall.
Phillipsastrea billingsi, Calvin.
Goniophora, Sp. undet.

To this succeeds a stage in which the more distiactive spirifers are *S. pennatus*, Owen, *S. asperus*, Hall, and *S. undiferus*, Roemer. With these are associated most of the species named above. *Orthis macfarlanei* gives place to *O. iowensis* in large transverse, flaring shells. *Stropheodonta demissa* assumes its typical form. Orthothetes disappears. *Phacops rana*, Green, occurs. The two Atrypas are found in greater proportional numbers. To this or to the zone below belongs *Pentamerella micula*, Hall, and a large Chonetes of the species for which Calvin has announced the name cancellata. In the upper part of this zone occurs a reef of *Acervularia davidsoni*, E. and H., with many favositoid and cyathophylloid corals. At Robins it overlies the Orthothetes zone and at Ward's quarry, Center Point, and at Alice P. O. it overlies beds barren of fossils. At Troy Mills it is succeeded by the hemera of *Spirifer parryanus*, Hall, the highest life zone discriminated in the county.

CARBONIFEROUS.

The Marion outlier belonging to the Carboniferous is described by the writer*. Coal and sandstone are reported to have been found also on the farm of Mr. Wm. Reynolds on west Otter creek, and are reported to lie on fossiliferous Devonian limestone. As the black carbonaceous shale was reached at a depth of six feet from the surface, it probably belongs to the coal measures and not to the Independence shales. To the same horizon probably belongs a greenish shale, with crystals of selenite, disclosed in a transverse ravine lying uncomformably upon the breccia in the Chicago, Milwaukee & Saint Paul railway cut west of Linn. A pocket of light greenish and bluish, unctuous, plastic clay in Conklin's quarry at Mount Vernon is probably Carboniferous, or possibly Cretaceous. It occupies irregular nests or cavities in the Mount Vernon beds, burrowing between layers and being intercalated between the laminæ adjacent, and connecting with a chimney reaching from top to bottom of the quarry. The narrowing base of this chimney is filled with a saccharoidal sandstone. The clay contains aggregations of pisolitic concretions of carbonate of lime. In its position and nature it is quite similar to the pockets of fire clay at Clinton, Iowa, described by Farnsworth†, now considered by

*Iowa Geol. Surv., vol. III, pages 127-128. 1895.
†Am. Geol., II, 331-334. Minneapolis, 1888.

him as Carboniferous. Neither at Mount Vernon nor at Clinton is there any trace of Pleistocene deposits in the clay.

CRETACEOUS.

Limestone boulders with Cretaceous fossils have been found in the drift at Mount Vernon and west of Walker. The distance which these had travelled cannot be told, but a perfect belemnite found in clay at a depth of forty feet (Tp. 87 N., R. VII W., sec. 21, Ne. qr., Se. ¼) and now in the possession of Mr. E. N. Beach of Troy Mills, must have been near its original home. So slender a fossil could not long have resisted attrition in the southward moving ice and drift. Its presence three miles north of the county line suggests the possible presence of Cretaceous outliers in Linn county also.

EXPLANATION OF PLATE.

In plate iii are represented three geological sections across Linn county as follows:

Figure 1. *a-b* Section from Cedar river near Bertram to Stone City.
Figure 2. *c-d* Section from Toddville to Mount Vernon.
Figure 3. *e-f* Section from mouth of Big creek to Cedar river west of Linn.

The numbers used refer to the different beds as follows: 1, Le Claire; 2, Mount Vernon; 3, Bertram; 4, Coggan; 5, Otis· 6, Kenwood; 7, Fayette breccia; 8, Cedar Valley; 9, Drift; 10, Loess. The horizon of the Independence shale is between the Otis and Kenwood beds.

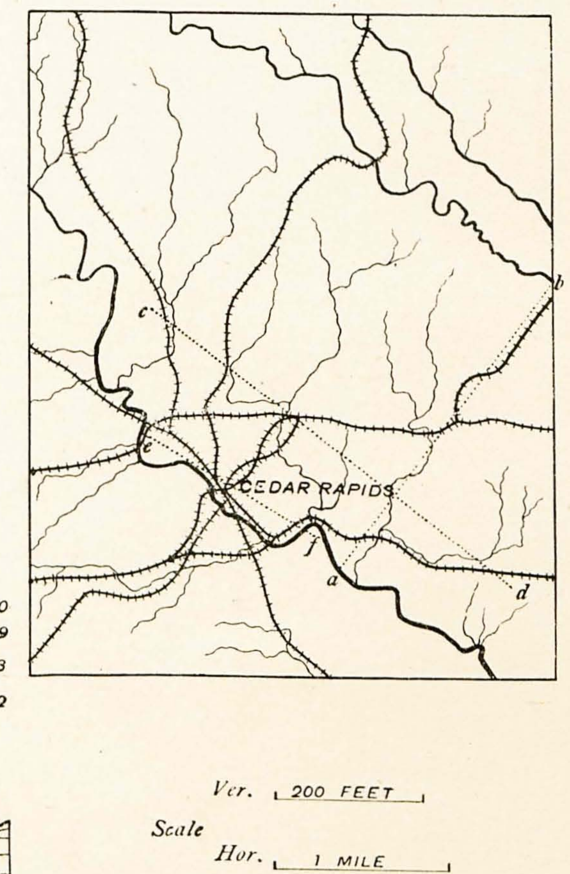
PLEISTOCENE.

DEPOSITS.

The history recorded in the deposits of this period is in this area particularly complex and interesting. It has recently been so thoroughly interpreted by McGee* that only supplementary notes need be given here. The deposits which will be considered include, from the surface downward, the following beds:

1. Alluvial sands and silts.
2. Loess.
3. Pre-loess sand and valley drift.
4. Second or Upper till.
5. First or Lower till.

*Eleventh Annual Rept. U. S. Geological Survey, 190-577. Washington, 1893.



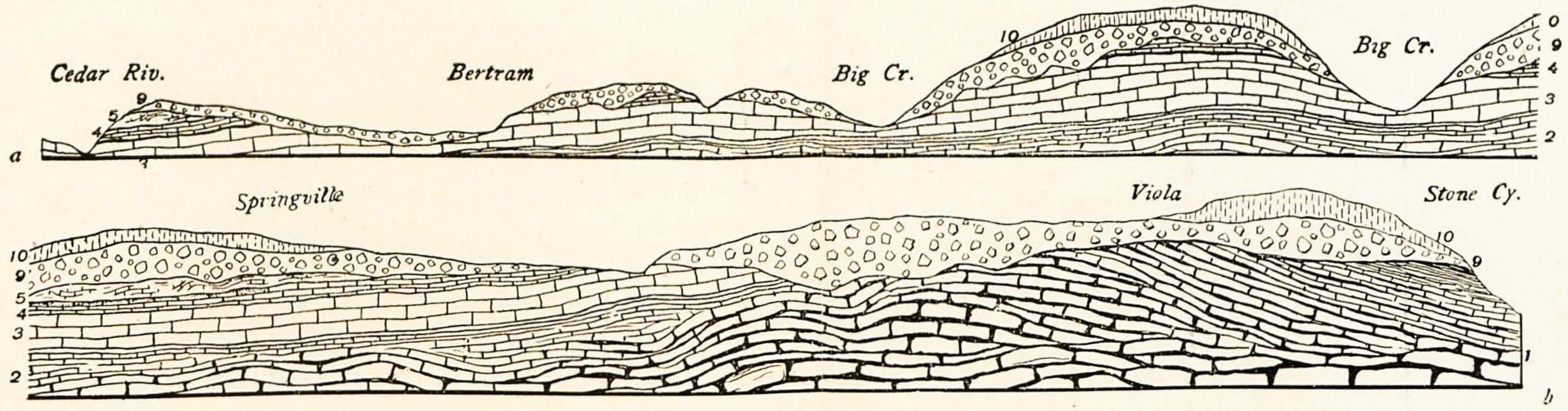


Figure 1.

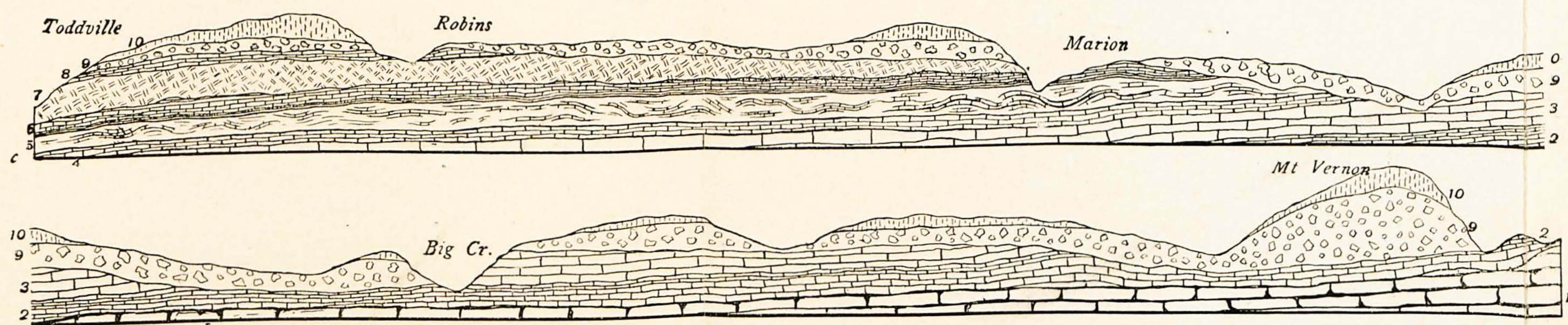


Figure 2.

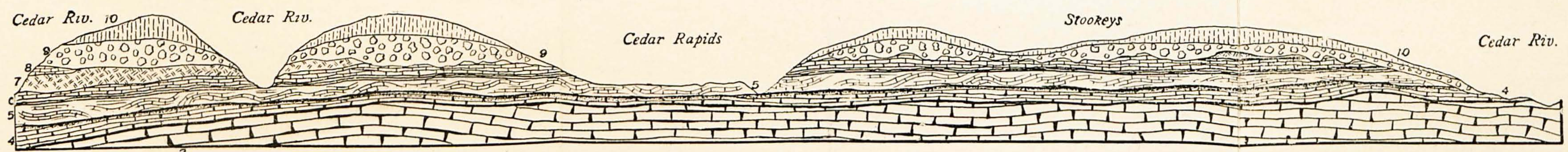


Figure 3.

GEOLOGICAL CROSS-SECTIONS IN LINN COUNTY.

6. Residuary clays.

These will be considered in the inverse order.

RESIDUARY CLAYS.

In all parts of the county the rock is more or less deeply decayed beneath the lowest layers of the drift. Irregular depressions, pockets, pipes and chimneys, mark the rock surface, descending sometimes to a depth of twenty feet or more and lined with an exceedingly fine, unctuous, black or brown residuary clay. This geest is seldom more than a few inches thick, and when the cavities in the rock are of any considerable width their centers are filled with drift. The anomaly of the presence of these preglacial clays and rotten rock in the very track of the ice sheet, is but little lessened by the fact that when the ice plow passed over them they must have been firmly cemented by frost.

THE KANSAN DRIFT SHEET.

First or Lower Till.—This is an unstratified, calcareous, stiff blue clay containing sand, pebbles, and boulderets of the northern igneous rocks with some of limestone and many of residuary flints and cherts. The pebbles are occasionally glaciated and larger stones are often found faceted and striated. Its base is often sandy and gravelly; when in this condition it is one of the chief water-bearing horizons in the county, and is then reddish or brownish in color. In the loess-capped drumloid aggregations of till in this region which McGee has called paha, the first till is sometimes roughly horizontally or concentrically laminated, though from other causes than the sorting power of water. In the railway cut across the north end of the Mount Vernon paha hill, these laminæ are from one to three inches thick.

The thickness of this till varies from zero to nearly two hundred feet. It is exposed in but few places in the county, but it may be seen in the railway cut of the Illinois Central railway between Coggan and Central City; at Peacock's tile factory at Coggan, south of Viola where it is superficial over quite an area; at Conklin's quarry, Mount Vernon, and at Kirkpatrick's mill three miles south of that village. It often contains fragments of wood, especially towards the base.

THE EAST IOWAN DRIFT SHEET.

The Second Till.—This boulder clay resembles the first till in the following particulars:

1. In lithological and structural diversity.
2. In the presence of calcareous meal.
3. In the predominance of clay over coarser ingredients.
4. In the abundance of glaciated pebbles, proving it subglacial and not englacial till.
5. In the abundance of decayed pebbles, distinguishing it from the till of the northern moraines, the East Wisconsin drift sheet, absent in the county.

It may be distinguished from the first till:

1. By its yellow color. When taken fresh from wells, it is distinctly brighter than loess, more yellowish and less buff; and it retains this color even to a depth of eighty-five feet from the surface, and beneath blue or greenish clays. It must therefore be regarded as a deposit distinct from the first till and not derived from it by superficial postglacial weathering.
2. By the presence of larger stones and of boulders*.
3. By the comparative rarity of limestone and chert pebbles.
4. By the beds of sand and gravel at its base, which form one of the main water horizons of the county.

The upper portion of the second till is often more loose in texture and may be englacial. Sand occurs in discontinuous and tortuous veins, as if laid down upon a pitted, irregular and water-washed surface before the deposition of glacial till had entirely ceased. The attitude of the upper sands simulates sometimes, as in the Mount Vernon quarries, a crumpling by superincumbent ice. The upper limit of the till is often marked by a line of more abundant pebbles, some of which are faceted and striated. Above this line nothing is found coarser than the sand of the succeeding member of the series, the pre-loess sands. The second till accentuates the relief of the

*The largest boulder entirely imbedded in till was found in Conklin's quarry, Mount Vernon. It is composed of granite, is over eight feet in length and 512 cubic feet in bulk. It rested on a basal planed and striated surface, inclined at an angle of about seven degrees toward the southeast. The lower edge is separated from the rock by from four to six inches of yellow till. The northwestern end was separated from the adjacent till by a cavity two or three inches wide, evidently caused by the slipping downward and forward of the stone after deposition. Some streaks of sand surrounded the stone as if laid down by water eddying about it.

surface left by the first ice invasion as is seen in the sections of the Mount Vernon paha given below. That it is the product of a later ice invasion and not derivative from the first till by weathering is seen in the fact that its accretion upon the hills of the first till is not regular and uniform; the summits of the hills of the one not corresponding exactly with the summits of the hills of the other. No traces of a forest bed have yet been found in the county in this till or beneath it at its juncture with the first till. The thickness and bulk of the second till are probably less than that of the first and if any conclusion may be drawn from the scanty evidence at hand, it is more attenuated in the Wapsipinicon than in the Cedar valley.

Many of the large boulders of the county probably represent, in part, the englacial drift of the second ice invasion. A large proportion of those now exposed to view may have once been imbedded in the till of the ground moraine. When erosion has been most active and where the loess mantel is absent in the swales and intervales of the drift plains, boulders are therefore most common. No boulder belts or trains have been observed.

THE PRE-LOESS SANDS.

Along the periphery of the paha hills the deposits made by ice are succeeded by waterlaid sands and gravel. While these probably need not be considered as a distinct formation, they no doubt mark a special state in local Quaternary history. The term which is used seems preferable to "sub-loess sands," inasmuch as the loess was not everywhere deposited above them, but it is perhaps objectionable in that it distinguishes them too sharply from the loess into which they often grade. In origin they seem intimately connected with the wash of the till by the water of the melting ice sheet and with the fluvio-lacustrine conditions and slack drainage of the loess epoch which followed. The accumulation of these sands on the outer slopes of the hills of boulder clay which form the centers of paha, and their absence in the interiors and on the summits of these hills, together with their thickening toward the water courses where they merge into valley drift, prove that they were not laid down by glacial streams confined within canyons of ice, but are more akin to the overwash sands of morainic areas. Coarse and gravelly beneath, especially in the neighborhood of waterways, they become finer above and are interstratified with bands of darker clayey sand or sandy clay which become closer, wider and more loamy until they pass into the loess.

VALLEY DRIFT.

Heavy accumulations of silt, sand and gravel occur in the immediate vicinity of the streams of the county, and may be taken as a measure of the volume and swiftness of the floods which occupied these channels at the close of the second ice invasion. The following section at Bertram near the mouth of Big Creek is typical of much of the valley drift of the county.

		FEET.
5.	Loess-like loam	3
4.	Sand, interstratified with sandy clay	4
3.	Sand, finely and horizontally stratified, fine above, growing coarser below	30
2.	Sand and gravel with cobble stones	3
1.	Slope of fine, whitish clay, to water in creek (probably marginal)	6

In the gravel pit of the Chicago & Northwestern railway across the creek from the above section, number two is seen to rest on rock, and between it and number three intervenes a layer two to three feet thick, of fine, whitish clay, with many well preserved twigs and branches of coniferous wood. In stream ways of the smaller creeks and their branches the following deposits are often seen:

4. Black humus, up to four or five feet thick, often reddened at the base by ferruginous accumulations.
3 Fine, bluish-grey, non-calcareous clay of equal thickness with the above.
2. Gravel and cobblestones from the drift, often faceted.
1. Till.

Numbers two and three are evidently valley-wash, accumulated before the soil above them. They are not the product of the present streams which, in many instances, were not in existence a few years since. The digging of a ditch a few inches in depth breaking through the protecting mattress of roots in the swale, or invasion by a subsequent branch from the primary creek by head-water erosion has led, in a score of years, to the trenching of gullies several rods in width and as much as eight or ten feet deep. Often near the head of the narrowing gully a tiny waterfall is seen trickling over the edge of number three, thus visibly continuing the process of retrocessive erosion. In heavy rains the gully is well nigh filled with running water, producing extensive washouts in its sides and bottom, and sometimes bringing to light teeth of the mastodon or mammoth or bones of the buffalo. These washouts cause a serious loss to the pasture lands of the county and should be stopped by the planting of willows.

THE LOESS.

The loess of Linn county may be described under three phases. The first and lowest phase is a fine silt, ashen or drab in color, though sometimes stained with hydro-ferric oxide. "Bull's eyes," ferruginous and calcareous tubelets, and "loess-kindchen" are common, and it is to this phase that the experienced observer looks first for fossils. It graduates beneath into the pre-loess sands when these are present, and it is often interstratified with thin veins of white sand. In the interior of paha hills it graduates upward into loess of the second phase, but on the margin the two phases are sometimes sharply separated by inter-laminated yellow sands and sandy clay, as at the railway cut at Mount Vernon, and the Wolf brick yard at Cedar Rapids. It usually is more strongly calcareous than the phases above. The second phase is typical yellow or bright buff loess, pulverulent and vertically cleft. Neither fossils nor loess-kindchen are common. It graduates downward either into loess of the first phase or by interlamination into the pre-loess sands. It constitutes the bulk of all thick exposures of loess in the county.

Above, it passes without any well defined lines of demarkation into the third phase—a browner, finer, non-indurated loess loam, drying into small blocks a fraction of an inch in diameter which are not readily friable between the fingers. It is usually marked by narrow, parallel, uudulating bands, somewhat darker and harder than the remainder because of ferruginous accumulations. These are most plainly seen after rains, on account of the hygroscopic differences in the clay, and always dip with the slope of the hills. This phase is derived from the second by weathering, and it may also represent differences in deposition, the final stage in a progressively finer sedimentation. It is superficially modified in the humus layer and forms a soil of admirable agricultural qualities.

At the following localities the loess was found to be fossiliferous: "Point of Rocks," southeast of Ivanhoe bridge, Cedar River; railway cut at Mount Vernon; Cedar Rapids, on creek south of Peedycoats' brickyard; Big Creek, in Tp. 83 N., R. VI W., sec. 26, Sw. qr., Nw. ¼.

PREGLACIAL EROSION.

The relief of the county at the close of preglacial times was due to many factors, chief among which were, (1) the inclination of strata; (2) the varying resistance to detrition of the different geological formations, giving a higher relief to the most obdurate like the Le Claire, and a lower tothe softer like the Independence shales; (3) deformations of strata affecting or reversing normal dips, and (4) continental movements of the earth's crust. Little is now known of the relief of the county at the beginning of the glacial epoch. There is a considerable amount of evidence showing that the channels of preglacial drainage were to a large extent the same as those at present.

In the valleys of small creeks and of rivers alike, numerous sections show the drift sheets and loess mantle lying undisturbed on the sloping sides of rock cut valleys, descending perhaps to the water's edge and to the lowest base levels of erosion. That such valleys must have been excavated before the tills were laid down upon them is evident. When the first till is present, the erosion cannot belong to the interglacial epoch, preceding the second ice invasion.

When the rock surface is deeply decayed and overlaid with geest, the erosion must be preglacial. In some instances the rivers have been turned slightly aside from previous channels, but are still well within their ancient valleys. In Cedar Rapids, on the west side of the river, a buried channel sixty feet deep has been found by Mr. H. G. Hays, separated from the present rocky bed of the stream, by rock rising nearly to the level of the low broad flood plain on which this portion of the city is built.

At Central City, an old channel of the Wapsipinicon is disclosed by wells on the east side of the village. It is separated from the present channel by a rocky elevation that comes within a very few feet of the surface of the low plain on which the village stands. The following is a section of a well sunk in this ancient channel on the premises of Mr. Cutler.

	FEET.
2. Black soil	4
1. Sand, fine yellow, to rock	96

From the maps of the U. S. Geological Survey and from a general knowledge of the locality, it is estimated that the depth of this ancient channel is at least sixty feet below water in the river. The following section of a well on the farm of Mr. P. G. Henderson (Tp. 86 N., R. VI W., sec. 17, Nw. qr.) apparently reveals an ancient channel of the same river, about three-quarters of a mile north of the present streamway:

	FEET.
7. Black soil	4
6. Clay, yellow, pebbly, second till	15
5. Sand, yellow	4
4. Clay, blue, changeable from hard to soft every few feet	190
3. Sand, fine white	13
2. Sand, coarser with wood	12
1. Coarse gravel	3

No continuous preglacial waterways, apart from the present paths of the streams, have been traced. Though such exist, they are deeply buried by drift and no surface indications of them appear.

The drill disclosed such a buried channel on the farm of Mr. Joseph Smyth, three miles west of Mount Vernon, were rock was reached at 211 feet; 110 feet below low water in Cedar river. (Tp. 82 N., R. 6 W., sec. 12, Se. qr., Se. ¼). The following is the well section:

		FEET.
7.	Loess	14
6.	Clay, hard blue, pebbly; first till	48
5.	Wood and dark soil	6
4.	First till	66
3.	Sand and gravel	8
2.	First till	63
1.	"River sand"	6

TERRACES.

The following section made from special survey of the immediate valley of the Cedar at Ivanhoe bridge is a typical representation of the ancient flood plains of the Cedar.

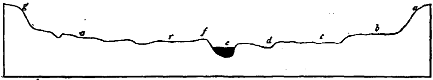


Figure 18. Flood plains of the Cedar river at Ivanhoe bridge.

In the above, *a* and *g* are loess-mantled hills, whose full height is not here represented; *b* is a level terrace with steep sides, as well marked as a railway fill; it is twenty feet in height and its summit is thirty-five feet above low water stage in the river. It is covered to its outer edge with typical pulverulent loess. As it is hardly possible that a terrace of this width could be so uniformly covered with loess derived by creep or wash from the adjacent hills, the formation of the terrace must be as assigned at least as early a date as the closing stages of the second ice invasion. A quarry, in a continuation of this terrace to the south, shows rock, covered with about six feet of soil with loess, covering pebbles of the northern drift imbedded in geest. The quarry is near the river edge of the terrace and is separated from the hill by a shallow ravine. *C* is a flood plain not now reached by river floods and with a long and very distinct scarp some nine feet in height separating it from the present flood plain of the river at *d*. *E* is the river, and from *f* to *g* a flood plain which seems to be degraded by erosion from the level of *b*. The terrace at *f* is composed of stratified sand, showing in places beautiful oblique lamination and sandy brownish clay, passing downward into coarser sand and gravel at its base.

DISTRIBUTION OF PLEISTOCENE DEPOSITS.

Linn county lies in what McGee has aptly termed the "land of the paha"—the aboriginal term for the lenticular hills and elongated ridges whose gentle loess-mantled slopes and inflexible northwest-southeast trend make the landscapes of this region as distinctive as they are unique. The position of these long swells was no doubt determined by the preglacial surface, but of this too little is known to warrant any more definite conclusions. Their trend marks the direction of the flow of the ice beneath which their nuclei were moulded, as clearly as the longer axis of the sand bar marks the direction of the current of the river.

In describing their distribution in the county, it will be convenient to speak of the paha hill, the paha ridge and the paha belt.

CENTRAL DRIFT PLAIN.

From Paralta to Viola and from Marion and Toddville to the divide within one or two miles of the Wapsipinicon river, stretches without interruption a gently southwestward sloping plain formed of drift. A typical well section near Paralta shows that the drift forms only a thin veneer over the rock surface.

	FEET.
3. Black loam	3
2. Second till	7
1. First till to rock	14

The first till seems to constitute the bulk of the drift and occasionally becomes superficial. The surface is scarcely diversified except by the drainage channels which are sunk to sixty or eighty feet below the broad and level inter-stream areas.

THE PAHA.

Bordering the drift plain just mentioned lie two paha belts of hilly country crossing the county parallel and adjacent to its largest rivers. The southern or Cedar paha belt is complex and embraces several paha ridges. Of these the most southern passes through Ely. Its maximum elevation above sea level is 880 feet and above adjacent streamways 140 feet. Its greatest breadth is a little over one mile. Another ridge enters the county at Fairfax from Benton, in which county it has its maximum development. A heavier paha ridge, which may be named from Cedar Rapids, occupies the immediate valley of the Cedar. To it belong the almost continuous hills on the right bank of that river from the southeastern corner of the county to Covington, and on the left bank the hills at the Palisades and those from Bertram to Linn Junction. Thus defined its greatest width is about four miles and its greatest height 940 feet above sea level.

The Lisbon paha ridge has its greatest extension in Cedar county. It extends through Mount Vernon to the high hills south of Marion where it joins the Cedar Rapids paha. Its greatest width in the county is about one and one-half miles. At Mount Vernon it is 932 feet above sea level and about 250 feet above Cedar river.

The Marion paha ridge begins a little northwest of Marion and extends through Robins and Toddville to the Benton county line. An adjacent and parallel ridge on the left bank of the Cedar south of Centre Point may be considered as a part of this. Its greatest elevation is at the western end, 940 feet above sea level.

The Stanwood paha ridge is separated from the Lisbon paha by a well defined plain three miles in width, sloping gently westward and drained by Abby creek. To the east, rock lies within from twenty to thirty feet of the surface of this plain, but to the west the drift upon it is a hundred feet thick, or more. Though nearly level to the eye when viewed from the paha, it consists of billowy till, some of whose crests are covered with loess. At its highest points the Stanwood paha ridge is 960 feet above sea level and measures one hundred feet from base to summit. At its northern extremity at Big Creek it connects by intervening paha hills with the Paralta paha ridge, which extends southeastward from this point into Jones county.

The hills of the Paralta ridge are less directly connected than those of the ridge before mentioned. The highest stands

960 feet above sea level and 140 feet above the streamways adjacent to their bases.

The Wapsipinicon paha belt may be considered one ridge whose axis is cleft by the Wapsipinicon river, so narrow is the valley that at Central City and at Waubeek, separates the paha hills on either side of the stream. It is highest southwest of Waubeek, where it reaches the height of 1,040 feet above sea level, or 200 feet above the flood plain of the river and nearly half as much above the drift plain to the south.

At Waubeek the portion of the ridge situated on the left bank is specially massive, forming a plateau stretching three miles northeastward to the Buffalo. Beyond the Buffalo a drift plain extends to the county limits. A typical section of this plain is given by McGee* from Prairieburg, where the drift is reported to be composed of fourteen feet of first till carrying vegetal matter, overlain by sixteen feet of second till.

Structure of the Paha.—So little has been published of the structure of these unique relief forms, so recently defined and described, that the following sections of paha in Linn county, though few in number, are of special interest.

The first well section, on the farm of Mr. W. Jordan, (Tp. 85 N., R. VI W., sec. 24, Sw. qr., Sw. ¼) is taken on the crest of the highest hills south of the Wapsipinicon about 1,000 feet above sea level, and 180 feet above the flood plain of the Wapsipinicon, two miles north.

		FEET.
7.	Black soil	6
6.	Clay, yellow, almost clear of grit	20
5.	Blue clay, pebbly	38
4.	Clay, yellow, mixed with sand	5
3.	Clay, blue, with a few feet of muck	152
2.	Whitish clay	2
1.	Lime rock	1
	Total	224

About twenty rods west, on still higher ground, the well of Mr. L. D. Jordan gives the following section:

*Eleventh Ann. Rept. U. S. Geol. Sur., p. 532. Washington, 1893.

		Feet.
7.	Black soil	4
6.	Yellow clay	15
5.	Blue clay, pebbly	14
4.	Sand and gravel with some water	6
3.	Blue clay "of all kinds"	75
2.	Quicksand	15
1.	Gravel	4
	Total	133

A section from the top of a lower paha hill of the same ridge is afforded by a well at Mr. G. W. Wiggins (Tp. 85 N., R. V. W., sec. 20, Se. qr., Nw. ¼).

		Feet.
3.	Soil and loess	12
2.	Pebbly blue clay with wood	23
1.	Gravel	4
	Total	49

Two wells at Coggan on the summit of the high hill at whose foot is Peacock's tile kiln show the hill to be composed mostly of the first till. In the F. P. Rice well, 128 feet deep, the blue boulder clay is 100 feet thick; and in the Shaw well, 100 feet deep, it is eighty feet thick. The following section is of a well on the crest of the Paralta paha about 920 feet above sea level on the farm of Mr. Wm. Paul (Tp. 83 N., R. V W., sec. 9, Sw. qr., Sw. ¼).

		Feet.
5.	Loess	27
4.	Sand and a little gravel with water	3
3.	Blue pebbly clay	45
2.	Sand and gravel	12
1.	Rock	2
	Total	89

The following is near the crest of the high paha south of Lisbon, on the farm of Mr. P. J. Fisher.

		Feet.
6.	Soil and loess	28
5.	Hard, yellow, pebbly clay	36
4.	Dark, pebbly clay, about as hard as rock	53
3.	Clay, hard, blue, pebbly	10
2.	Sand and gravel	1
1.	Rock at	128

A well on the farm of Mr. J. Hoffman (Tp. 82 N., R. V W., sec. 23, Nw. qr., Se. ¼) gives a section on the southern margin of the same paha.

	FEET.
6. Yellow loam	14
5. Blue silt	4
4. Hard, blue, pebbly clay	28
3. Dark soil and wood	4
2. Sand and gravel	1
1. Rock	1
Total	50

The hill upon which Mount Vernon is situated is a typical paha, in shape, in form, in orientation, and it is believed in structure also. The latter is so diverse that it can be represented by no one well section. Numerous records of recent drillings are fortunately at hand which allow the presentation of the longitudinal and transverse sections represented in plate iv. which will be found more intelligible than any description. Though not here distinguished, the three phases of the loess are present, the lowest being fossiliferous in several wells and excavations, and in one well found to contain twigs of coniferous wood. The absence of the pre-loess sands except on the margins will be noticed.

The second till is clayey throughout, containing few, if any veins of sand or gravel except at or near its base. The gravel of these basal layers, when gravel is present, is fine.

The greenish, pebbly clay at Dr. Boyd's well in the section is as hard as the second till and differs from it only in color so far as appears in the drillings. In several wells it occurs in thin streaks or lenses, in the midst of second till, of normal bright yellow color. The first till contains wood as seen at the base at the College Library well.

The figure 4, plate iv, is a section across the northern flank of the paha. The angle of the slope is exaggerated with the exaggeration of the vertical scale.

The lower six inches of the brownish buff upper loess, 5, are perceptibly sandy. The sandy layers, 4, are slightly undulating, yellow in color, from a fraction of an inch to a foot or more in thickness, thickening outward and downward and growing slightly coarser beneath. The interlaminated sandy clay or clayey sand is darker in color, varying from buff to brown. The drab silt, 3, is finely interlaminated above with thin veins of white sand, but the layers of silt grow heavier beneath and are found as much as two feet thick. They carry fossils of the loess.

EXPLANATION OF PLATE.

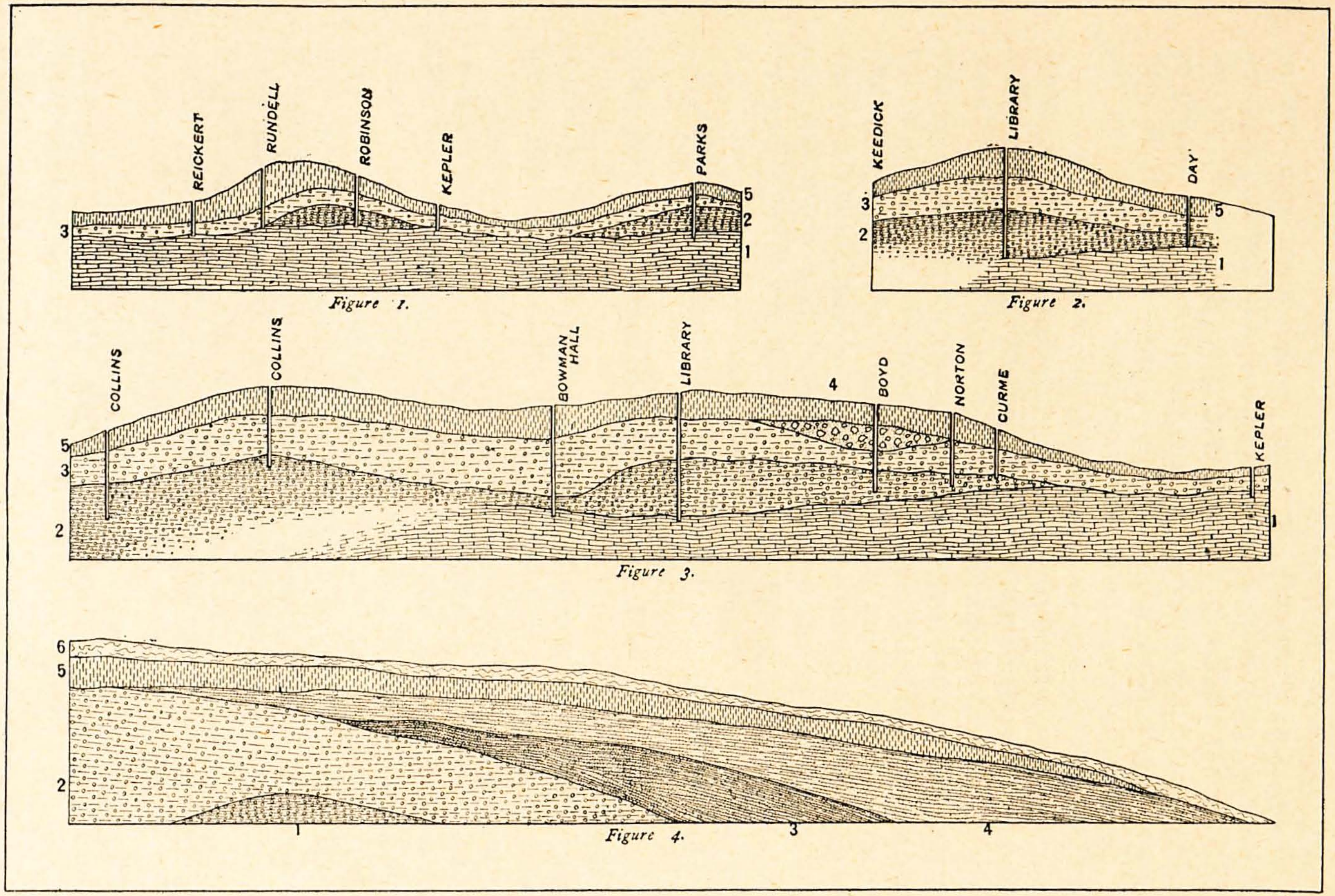
In plate iv are represented several sections through the Mount Vernon Paha. They are as follows, the letters representing the location upon the accompanying contour map, plate v.

Figure 1. Transverse section along the line a-b.
Figure 2. Transverse section along the line c-d.
Figure 3. Longitudinal section along the line e-f.
Figure 4. Section at railway cut, west end of Main street.

In figures one, two and three the numbers refer to the formations as follows: 1, Limestone; 2, Lower till; 3, Upper till; 4, Greenish pebbly clay; 5, Loess. In figure four the numbers refer to the beds as follows: 1, Lower till; 2, Upper till; 3, Fossiliferous drab silt; 4, Interstratified sand and sandy clay; 5 and 6, Loess passing upward into humus.

ORIGIN OF PAHA.

Taking it for granted that the sections given above are typical, it is seen that paha are essentially hills of subglacial till accreted in the direction of the ice flow. They are therefore genetically akin to drumlins, though their elongation in ridges is far more marked. The loess increases their height, but it is regarded as secondary in importance. Hills of characteristic paha form exist in the county, upon which there is no reason to believe that loess was ever deposited. The Wapsipinicon paha ridge on the right bank is destitute of loess from Troy Mills as far south as Paris, but it maintains its bold elevation above drift plain and river and its singular northwest-southeast trend. It is as marked a topographical feature as any paha ridge in the county, although its slopes are less gentle. It is composed entirely of drift, the total thickness of which must be about one hundred feet. A well section (Tp. 86



SECTIONS THROUGH THE MOUNT VERNON PAHA.

N., R. VII W., sec. 16, Se. qr., Sw. ¼), considerably beneath the summit of the ridge gives seventy feet of second till with some sand and gravel overlying the rock.

The drift of these anomalous ridges and hills cannot have been deposited in ice-bound canyons by subglacial and superglacial streams. The absence in the drift of water-washed material, of sands and gravels, to any greater extent than obtains in the drift sheet of the same region precludes their classification with asar or eskers. Their distribution must also be considered. Isolated paha hills are numerous, connecting the different ridges. If these were formed by glacial waters, it must have been by moulins rather than by rivers. Yet their parallelism with the system is conspicuous. The linear courses of the paha ridges are devoid of the sinuosities characteristic of asar. This will be best seen by comparing a map of any large asar region, like Maine, with the topographical map of northeastern Iowa.

Neither can the paha be correctly spoken of as "eskers of loess"*.

The distribution of loess in the county is indeed peculiar. It is the thickest on the highest summits. It thins toward the valleys where it is often absent. But in either paha belt the loess-mantle is practically continuous, except in the immediate vicinity of the streams. The ridges are connected not only by terminal merging and by isolated intervening paha hills, but also by a thin layer of loess on the crests of many of the low swells of drift intervening between the paha within the area of the belt. If the loess of the Cedar paha belt, for example, were deposited between walls of ice, the walls must have been eight or ten miles apart, so remote as to have been without influence in moulding the loess of individual ridges or hills.

If an ice-walled canyon be invoked for the moulding of the loess of each ridge and detached hill a further difficulty is met. It can hardly be conceived that the ice sheet was so devoid of englacial and superficial drift that sand and gravel, to say nothing of larger stones, would not have been mingled with the river silts within the canyon. Yet in the many hundreds of

*Upham. Bul. Geol. Soc. America, Vol. V., p. 95. 1894.

exposures of loess observed in the county, no pebbles or boulders have been seen and the loess is free of sand except at its base.

On the other hand, by the hypothesis of the deposit of the loess of any paha belt in a broad, slowly moving current, the ridges of till beneath the water surface, by locally retarding the current, would accumulate silt bars about them. If the final retreat of the waters was somewhat rapid, either owing to the breaking of an ice dam, or accelerated by a comparatively rapid resilience of the area, much of the valley loess may be conceived as being swept downward with the retreating waters. The detrition of the soft silt remaining must have gone on with special energy until it was finally protected by the return of grasses and forests. These considerations, and the vast lapse of time since the loess epoch, lead to an account for the thickening of the upland loess by differential erosion and deposition as stated.

This theory does not account for the absence of the loess mantle over the wide central drift plain overlooked by the paha on either side. Had such a mantle ever been laid down, some remnants should be left along the north-south axes of the creek divides. Its absence here must prove that it was never deposited over the area, and the ingenious theory of McGee that such drift plains were covered in loess times by ice seems to be the best explanation to the phenomena.*

ECONOMIC PRODUCTS.

BUILDING STONES.

MOUNT VERNON BEDS.

The chief quarries of building stone in the county are in the Upper Silurian limestones of Stone City, Waubeek and Mount Vernon. This stone is so uniform that the general description

*Special acknowledgements for data supplied for this portion of the report are due to the Department of Civil Engineering of Cornell College, whose levels of the region about Mount Vernon were freely placed at disposal of the Survey and by whose students the contour map of Mount Vernon and several of the profiles were specially prepared without charge. Indebtedness is also heartily acknowledged to the intelligent co-operation of several well drillers in the county—Messrs. E. Kemp, West and Woodring, and C. Martz, of Mount Vernon; Messrs. Stewart and Dunlap, of Springville, and Mr. A. H. Gillilan, of Central City.

REDRAWN BY F. C. TATE.

given in the preceding pages applies with little modification to each quarry in the county, if not in the state. It is necessary only to emphasize here a few points relating to its economic qualities.

The color of the stone is pleasing. Its warm grey or cream tint is accordant with nature's scheme of landscape colors. It is not so glaring or so sombre that it is out of key with the color of wood, lawn and street. Its cheerful warmth, the absence of dull leaden, or pale dark grey tints, harmonize with the rich colors which prevail under Iowa skies. The softness of the stone when just taken from the quarry, before the quarry water is evaporated and the lime and magnesia in solution have set, renders it easily worked. The saw encounters no obdurate materials; the chisel finds the fracture even and regular. Bedding planes are so constant, parallel and smooth as to be at once ready for mortar with little or no dressing. Much of the stone can be split horizontally to desired dimensions. Many layers are sufficiently tough and homogeneous in texture that they can be wrought into fine carvings. It is distantly jointed and blocks beyond the facilities of transportation or possible uses can be quarried.

In durabilility the Mount Vernon limestone is believed to be excelled by none of the calcareous building stones in Iowa and by but few in the United States. The fineness and uniformity of its grain allow no inequalities in ratios of expansion under changes of temperature. Injurious minerals which by their ready decomposition stain and weaken many otherwise excellent building stones are absent.

As a dolomite it resists the attack of atmospheric agencies more successfully than pure limestones and marbles. In the Mount Vernon cemetery, tombstones of this material, whose dates run back as early as 1845, are so little affected by superficial decay, that the tool marks are almost as fresh and sharp as when the chisel left them, and there is no sign of checkage, cracks, exfoliation and other evidences of internal disintegration. On the other hand, many marbles of less than half their age show weathering in loss of polish, ready detachment of superficial grains, and obliteration of fine edges, and deeper decay in checks and fissures which predict a ruin not remotely distant. In the case of some of the earlier and poorer marbles, and of the oölitic limestones of the Lower Carboniferous this ruin has already been accomplished. Thus the humble dolomitic memorials of the first settlers bid fair to outlast every monument now in the cemetery except the granites.

The strength of the stone varies somewhat, that of finest grain and laminæ being probably weaker than the layers of coarser grain. The latter are sufficient for any strains and stresses, and the former have ample strength for any building of a height which would probably be erected in the state. Layers in which the lamination is specially distinct and which would be durable when laid in an ordinary wall on their "natural beds," should not be used for curbstones, where exfoliation would be likely to occur. Layers occasionally are found in which hard laminæ alternate with softer porous and vesicular ones. These cannot be recommended as durable. The form of dressing known as "quarry-faced ashlar," either "coursed" or "random range" is specially suited to this stone.

STONE CITY QUARRIES.

CRESCENT QUARRY OF BROWN & COMPANY.

The following detailed section of this quarry, the best developed in the county, will illustrate the stratification of the Mount Vernon beds:

		FEET.	INCHES.
17.	Loess, drift and geest	4	
16.	Rubble	18	
15.	Bridge stone, can be capped at almost any place	3	8
14.	Dimension stone in two layers	2	4
13.	Bridge stone; can be capped in middle; vesicular	2	9
12.	Limestone; hard, compact, with slightly salty effervescence; breaking readily into rhombic chipstone a few inches in diameter; called flint by workmen, although destitute of silica		6
11.	Dimension stone		4
10.	Dimension stone	1	
9.	Dimension stone	8	4
8.	Bridge rock, will not cap except at 24 inches from top	2	9

		FEET.	INCHES.
7.	Dimension stone	6	4
6.	"Flint rock" as No. 12	1	6
5.	Dimension stone	4	5
4.	Bridge stone	3	6
3.	Bridge stone	2	
2.	Dimension stone	3	4
1.	Unexposed to water in river	27	

The bridge stone contains in some layers a few small cavities filled or lined with quartz or calcite, or with both, the former being then exterior. These do not affect the value of the stone and are of interest only to the geologist. The eighteen feet of rubble of No. 16, includes eight or ten feet that in smaller quarries would probably be sold for local building stone. The quarry is but recently opened, and as it is driven back this thickness will probably be added to the amount of dimension stone. The natural facility for handling the stone here is unusually good. Stripping is comparatively little and is readily dumped into the river. The stone is lowered and loaded on the railway cars by gravity. The dip of the rocks here is 2°, E. 17° N.

WAUBEEK QUARRY.

The stone quarried here is indistinguishable in color and texture from that at Stone City. The most important quarry is that of Mr. C. A. Huston. The quarry face is about forty feet high, and the quarry floor is about twelve feet above low water in the river. The upper four or five feet are weathered into thin spalls below which the even courses are from a few inches to four feet in thickness. As no railroad is near, the output is restricted to local uses, though the stone is practically unlimited in quantity and its quality is of the best.

MOUNT VERNON QUARRIES.

The same limestone at Mount Vernon differs from the stone described at Waubeek and Stone City only in a somewhat warmer color, slightly coarser grain and perhaps a somewhat greater toughness. Lack of facilities for shipping has hindered the development of the quarries here, as the stone has to be carted about one mile to the railway station. Since these are the only quarries of the Mount Vernon beds along the main line of the Chicago & Northwestern railway, it is probable that the abundance of excellent stone they contain may in time secure a switch*. The property has recently passed into the hands of Messrs. Platner, Gregg & Kirby. They have, within a year, put in the most complete and expensive quarry plant in the county, embracing a steam channeling engine, steel derrick, two steam planing engines and a steam crusher.

The stripping in the main quarry consists of a few feet of loess and clayey upper till, a little residuary clay in pockets and depressions, and about eight feet of spalls. Beneath these thin layers are several layers six to eight inches thick, and the following succession of layers to the quarry floor: 1 foot, 10 inches, 2 feet, 10 inches, 6 inches, 1 foot, 6 inches, 1 foot, 2 feet 11 inches, 2 feet 4 inches. No chipstone layers are found and no cherty nodules or silica in any form occur.

To test the thickness of this building stone, borings were made with diamond drill to a depth of fifty feet beneath the present quarry floor. The cores show that to that depth the above stone continues unchanged, mostly in heavily bedded courses. A few layers, however, show thin alternating hard and soft laminæ. The last few inches of the cores indicate a near approach to the lime rock of the Le Claire. The local dip is 3°, S. 37° W. The market is local and along the Chicago & Northwestern railway. The adaptability of this stone to large and fine structures is illustrated in the chapel of Cornell College, constructed in 1878 of stone from this quarry at a cost of $70,000.

Mr. William Conklin owns a quarry of similar stone which shares the local market with the quarry just described. At the quarry of Anton Novak, west of the Ivanhoe bridge across the Cedar, the stone, while in several layers similar to that at Mount Vernon, is in other layers highly vesicular, less evenly bedded, and destitute of lamination. In some layers flat, lenticular concretions of chert form almost continuous bands. Interbedded layers of a compact, darker rock occur which weathers into rhombic chipstone. This quarry furnished the stone for the piers of the adjacent bridge.

*Since the above was written, tracks have been built from the Mount Vernon station and the quarries greatly enlarged.

COGGAN BEDS.

These beds, like those which have been described above, are dolomitic. They are heavily bedded, destitute of lamination, and often porous and highly vesicular. Where cavities are few and of small size this stone is well adapted for heavy masonry, and has been used for bridge piers at Coggan, Central City and Paris. The quarries of these beds have been already described.

BERTRAM BEDS.

Except on a few farms the Bertram stone is not quarried. Its brittleness and habits of weathering, as well as locally heterogeneous structure, render it unfit for masonry.

OTIS BEDS.

Some lower and even layers of these beds are quarried at Otis, Central City and other points, for cellars, well curbing and other similar purposes. In general the stone is fit only for macadam, for which purpose it is quarried at Cedar Rapids.

KENWOOD BEDS AND FAYETTE BRECCIA.

Some harder layers near the top of the Kenwood and the Gyrocèras beds of the breccia have been quarried to a slight extent at Marion, near Cedar Rapids and near Flemingville. If the latter, or Upper Davenport limestone, existed undisturbed in any thickness in the county it would prove one of our valuable building stones.

CEDAR VALLEY LIMESTONE.

This stone is often too shaly to be of much use as a building stone. As a rule, it soon breaks up under the alternations of wet and dry and of heat and frost. The bedding is not smooth or even, and it is covered by oblique fracture-planes which make it impossible to quarry blocks of any considerable size. Certain barren beds beneath the *Acervularia davidsoni* life-zone furnish a better stone, which is suitable for foundations for small buildings. The best quarries are George Ward's, four miles southeast of Centre Point, from which that town obtains much of its stone, Todd's quarry at Toddville, Pèter Mack's at Alice postoffice, and Fay's quarry at Troy Mills.

DRIFT.

The boulders of northern drift, though seldom so plentiful as to interfere with agriculture, are sufficient to furnish foundation stone for many barns and farm houses. In some instances granite boulders of large size have been broken up for dressed stone.

CLAYS.

CHARACTER AND DISTRIBUTION.

Valuable clays are everywhere present in the county and are of several kinds, which will be briefly mentioned.

Loess.—The loam of this ancient fluvio-lacustrine deposit makes, when properly handled, an excellent building brick of sufficient hardness and density, and of a fine cherry red color. The best brick clay is found in the upper stratum of the loess. This stratum thickens at the base of loess hills and here brick yards are usually placed. The clay here is finer, tougher, browner, usually finely jointed on drying, and banded with ferruginous stains.

Sand is obtained in the same pits from the sandy loess beneath. In mixing the sandy layers with the upper stratum, the experience and judgment of the burner is followed. The mistake of using too much sand for the sake of ready handling is more common than the opposite one of using too little, especially in yards where the brick are hand made and sun dried. A soft, porous brick results, which must be handled with the delicate attentions appropriate to bric-a-brac, and which goes to pieces if left out over the winter unprotected, and when in the wall develops in a few years a seriously seamy side on the weather face.

In machine brick the quantity of sand can be lessened. The upper stratum of the loess can be used quite pure, although it is said to work better when mixed with the pulverulent loess beneath, or with a little sand or coal ash. An excellent smooth faced brick, though somewhat brittle, is made from this layer by machinery now in use in the county. Some pressed brick made by a Boyd brick press in Chicago from clay in the upper loess taken from the Wolf yard at Cedar Rapids leaves little to be desired in their hard, smooth faces, and even and sharp edges. On low ground adjacent to loess hills, a stiffer, partially decolorized clay derived from the loess is found, which makes excellent tile.

Drift Clays.—Where drift is of the clayey type in which boulders and pebbles are comparatively few, it makes a harder and denser brick than the average loess-loam. The presence of pebbles of any considerable size or to any extent in such brick produces a heterogeneous texture and introduces an element of weakness. The upper or yellow till is better adapted than the lower or blue till when equally clayey, since, though it contains larger boulders, limestone pebbles are not so common. These burn into quick lime, and unless previously crushed, rupture or weaken the brick on slacking. In this class may be included slough clays, or gumbo washed from the drift. These are stiff, often gritty, sometimes pebbly in their passage into the drift, and make excellent brick and tile.

PLANTS IN OPERATION.

Cedar Rapids.—The plant of S. Peacock and Son is the largest in the county, consisting of an engine of twenty-five horse power, a stiff-mud brick machine, the Auger mill No. 5, of Nolan and Maddan's make, with a capacity of 15,000 brick per day, drying sheds holding 150,000 brick, and two circular, down-draft kilns. The clay used is the loess, mostly from the upper layer, and makes a smooth-surface brick of superior appearance.

Mr. P. A. Wolf uses also the loess-loam, making a brick the excellence of which is well attested by experience. A "Chief" soft-mud machine with a capacity of 30,000 per day is used, employing horse power. Drying sheds built on the Pullet system are employed and have a capacity of 100,000. The brick are burned in two clamp kilns, with coal and soft wood.

Mr. J. S. McKee also manufactures largely for home market. He uses the loess-loam to a depth of about three and one-half feet, mixing with it sandy soil and hard coal screenings in definite proportions. The machine used is the Old Reliable hand press, with a capacity of 10,000 per day. The capacity of the drying sheds is 50,000.

Mr. J. L. Peddycord uses a reddish drift clay so strong that it is tempered with the sand which overlies it, and burns into a hard, firm brick. No lime pebbles were noticed, though others of the ordinary drift type are not uncommon. A Quaker horse power machine is used, capacity 18,000 per day. The brick are sun dried and burned in a clamp kiln with soft wood and coal.

Mr. D. W. Stookey operates a tile plant consisting of steam engine, crusher, a Brewer and Tiffany machine, capacity 10,000 three-inch tile per day, three drying sheds and two circular, down-draft kilns, each of 150,000 capacity. The clay used is slough clay or gumbo, passing into drift. A switch of the Burlington, Cedar Rapids & Northern enters the yard. Coal is used for burning. The market is local, and along the line of the above railway.

Marion. The brick and tile yard of Mr. J. Beck is situated one and one-half miles south of town. The loess is used ten feet below the surface. The brick are hand made and sun dried and have been largely used in the business blocks of Marion. Tile is also made, with the Bennett machine, and a drying shed holding 20,000 tile is included in the plant.

Lisbon and Mount Vernon. Mr. J. B. Robinson, of Mount Vernon, and Mr. Henry Goodman, of Lisbon, both use the loess, mixing the upper and lower layers. The ware, which is dried in the sun, and burned in clamp kilns, finds a market in the two towns. Mr. Robinson's brick are hand made, and Mr. Goodman uses a Quaker machine.

The tile works of Deibert and Brenneman are conveniently situated at the Mount Vernon station. A tough, pebbleless clay of loess derivation is used. The plant consists of steam engine, brick and tile machine, with a capacity of 10,000 tile per day, drying sheds and one circular down-draft kiln of the usual capacity.

Center Point. Messrs. Miller and Hart operate a tile plant at this place consisting of Chandler and Taylor machine, capacity 5,000 per day, now run by horse power, soon to be supplanted by steam, with the usual drying sheds and kiln. The tile finds market in the adjoining townships. The clay used is gray jointed gumbo or slough clay, apparently free from pebbles of any considerable size. At the same locality Mr. Charles Johnson manufactures a hand made, sun dried brick from clay on low ground, probably derived from the looss.

Central City. Mr. A. L. Hatch makes a clean, hard brick from the upper jointed loess. The plant comprises a thirty-five horse power steam engine, a soft-mud machine, four drying sheds and a clamp kiln holding 120,000. The market is at home and in adjacent towns on the Illinois Central railroad.

Coggan. A brick and tile manufactory was recently established at this place by J. Peacock & Son, of Cedar Rapids. The plant consists of a Brewer steam crusher, an Ohio Special Frieze machine, steam engine, drying sheds, and a circular, down draft kiln, with a capacity of 40,000 three-inch tile every two weeks. The clay bank is run entire and consists of blue and yellow till. It is perhaps the stiffest clay used in the county.

LIME.

The Le Claire limestone supplies all the lime burned in the county. This formation ranks among the first lime producing rocks of the United States, furnishing a slowly slacking, slowly setting, cool lime, which displaces, wherever it is introduced, hotter limes burned from other formations. Architects and builders give it preference on account of the hardness and durability of its mortar; dolomitic lime having much the same advantages over calcareous limes, as dolomitic building stones possess over pure non-magnesian limestones. Masons and plasterers prefer it because the slowness with which it sets gives them longer time in which they may more thoroughly do their work, and also enables them to work to better advantage and therefore, on the whole, the more rapidly.

Certain physical characteristics are of advantage to the Le Claire as a lime-producing rock. It is quite free from chert, silica and argillaceous matter, containing less that one per cent of these impurities. Its porous and vesicular texture gives ready access to heat in the kiln and to water in slacking. Other counties in Iowa in which the Le Claire is found have, so far, equal advantages with Linn, but in one respect Linn county has a special advantage which ought to stimulate the industry to greater expansion. The market for Iowa lime is largely to the west. To the east it encounters the equally good limes of Illinois and Wisconsin, made from the same or similar formations. To the west, however, it has few, if any, important local rivals. The Le Claire reaches its furthest western extension in central Iowa, in Linn county. The limes of Linn county are nearer the western market than any other Upper Silurian limes in the state. The lime rock in the county also has decayed less than is common in the Upper Silurian. Its lime is therefore heavier and gives the purchaser by the barrel an advantage which the wholesalers who buy lighter limes by weight and sell by measure understand.

VIOLA.

Mr. S. H. Gulick of Marion is the owner of two draw-kilns recently built at this place. Their capacity is 375 barrels per day. One is situated at the quarries at the edge of the village, the other at the quarry one-half mile north. Both are by the side of the Chicago, Milwaukee & Saint Paul railway tracks and lime is loaded directly from the lime houses to the cars. The fuel used is wood. The rock is of a superior quality and has already been described. The amount of stripping necessary in the Pleistocene deposits is rather large and increases as the quarries are driven back into the hill.

MOUNT VERNON.

A patent draw-kiln owned by Mr. E. M. Smith is situated above Ivanhoe bridge on the Cedar, the rock being obtained from the Palisades along the left bank of the river below Bale's branch. The long haul to the cars at Mount Vernon no doubt decreases the profit but it does not increase the price, nor does it lower the excellent reputation of the lime in the Cedar Rapids markets. This is at present the only kiln at the Palisades, but steps are being taken to open up an extensive industry at the Upper Palisades where stripping is readily disposed of in the river, and kilns can be so placed that stone can be hauled with the minimum of labor. The haul to Bertram, three miles away, is an easy one and a track could be laid from that station without any steep grades. The rock in quantity and quality is unexcelled in the west and as the Palisades kilns will be the only ones using the Le Claire rock on the main line of the Chicago & Northwestern they would enjoy special advantages of shipment along its extensive lines. The region is forested at present, but owing to the nearness to Cedar Rapids and Mount Vernon, wood as fuel for calcination would cost more than in some other districts. The question of fuel is a vital one to lime burners, and they will suffer perhaps more directly and immediately than most other industries, by the unnecessary and rapid destruction of our forests now in progress*.

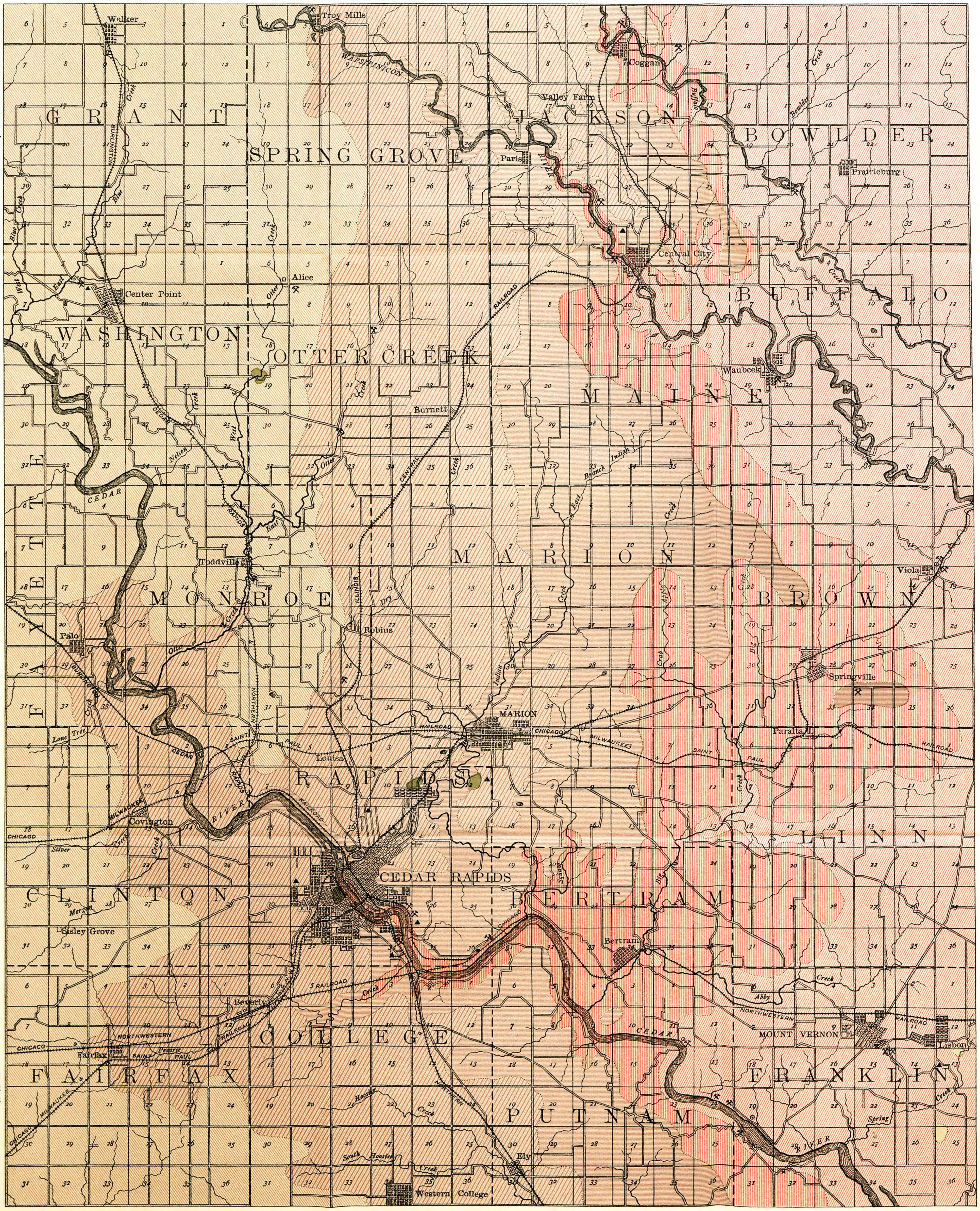
Lime has been burned in considerable quantities from other formations than the Le Claire, but, so far as known, these pot-kilns have all been abandoned and the Le Claire lime now has the entire field. The Otis beds once supplied several kilns near Cedar Rapids and one at Central City, making a "hot" non-magnesian lime. If an intermediate lime should ever be desired, the Bertram beds would furnish it of excellent quality.

SAND.

This necessary building material is readily obtained in most parts of the county from rivers or from the outcropping of the basal sands of the loess, with but little expense besides the cost of hauling.

---

*Since the above was written a spur of the Chicago & North-western Railway has been built from Bertram to the Upper Palisades and the erection of one of the largest lime plants in the State has been begun.



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF LINN COUNTY, IOWA.

BY

WILLIAM HARMON NORTON.

1895.

LEGEND

GEOLOGICAL FORMATIONS.

- DES MOINES (Coal Measures)
- CEDAR VALLEY
- FAYETTE
- OTIS AND KENWOOD
- UNDIFFERENTIATED DEVONIAN
- BERTRAM AND COGGAN
- PENTAMERAS TO MOUNT VERNON (Beds Inclusive)

INDUSTRIES.

- QUARRIES
- CLAY WORKS
- LIME KILNS

DRAWN BY F. C. TATE.

Photo-Lith. by A. HOEN & CO., Balto., Md.