GEOLOGY OF LEE COUNTY.

BY

CHARLES ROLLIN KEYES.

ECONOMIC GEOLOGY OF LEE COUNTY.

BY CHARLES ROLLIN KEYES.

CONTENTS.

INTRODUCTION.

AREA AND LOCATION.

Lee county occupies the extreme southeastern corner of Iowa. In shape it is very irregularly trapezoidal, with an acute angle extending in a southeasterly direction and forming the southernmost point of the state. Three-fourths of its boundary is made up of large streams, which separate it from the two states of Illinois and Missouri on the east and south. It thus holds a somewhat isolated position geographically, as compared with the other counties of the state. The entire eastern border is washed by the great "Father of Waters." Northeastward the Skunk river forms the boundary between it and Des Moines county. On the west flows the Des Moines river. Van Buren and Henry counties bound the northwest quarter of the district. The greater portion of Lee thus lies in the apical portion of the broad triangular area lying between the Des Moines and Mississippi rivers. The total area is a little more than 500 square miles.

PREVIOUS WORK.

Although considerable geological investigation has been carried on in Lee county during the past forty years, it has been carried on chiefly in the interest of pure science. The results have been incorporated mainly in short papers which are now widely scattered through perodicals and official reports of other states. No systematic examination of the county's mineral possessions has heretofore been made.

Among the early workers who visited this region was Dr. D. D. Owen, who under the auspices of the Federal land office, undertook to study the mineral lands of the northwest during the years 1847–1850. To him must be

credited the honor of giving to the scientific world the first accurate accounts of the geology of the region. In 1858 A. H. Worthen, afterwards State Geologist of Illinois, made a hurried reconoissance of the county and his brief description is given in Professor James Hall's report. Twelve years later appeared Dr. C. A. White's geological account of the state. The references made in this report to the geology of this part of Iowa are brief and very general in character.

During the past few years several important papers on the geology of the region about Keokuk have appeared, but they are strictly scientific in their bearing and discuss problems of wide geological interest.

The formations exposed within the limits of the county are geologically among the most interesting occuring in the Continental Interior. The sections along the Mississippi river between Keokuk and Burlington have become classic in the annals of geological science. They were the starting point for the classification of the great series of Lower Carboniferous limestones throughout the entire Mississippi basin. It was in southeastern Iowa that these rocks were first defined and described according to modern geological methods. From this locality the strata have been traced with scarcely a break into the northcentral part of the state. They stretch out in an irregular zone southward to the mouth of the Missouri river, where a branching takes place, one arm passing westward around the Ozark uplift and continuing to the southwest far into New Mexico; the other arm extending eastward and southeastward through Illinois, Indiana, Kentucky and Tennessee into central Alabama. Thus even from a historical standpoint the rocks of Lee possess much more than ordinary interest.

PHYSIOGRAPHY.

SURFACE RELIEF.

Lee county occupies an elevated plateau whose surface, for the most part, is gently undulating or rolling. This broad general plain continues without serious interruption nearly to the margin of the area. There it suddenly drops a couple of hundred feet or more to the water-level of the bounding streams. This marginal declination is so abrupt, that there are formed on all sides steep declivities, often running into bold mural escarpments with prominent salients. Everywhere in the immediate vicinity of the plateau border, steep-sided ravines and deep gorges have been cut. In these the torrential water-courses dash along in their narrow beds, breaking here and there into foaming rapids or miniature falls and cascades. A short distance back all these rivulets flow gently along in broad valleys, their respective drainage basins forming shallow swales in the general upland surface. Broadly speaking, the district then, may be said to be characterized by the plain level and the forms impressed upon it by post-glacial erosion. This is not strictly true, however, as a careful consideration of the phenomena presented show that the present drainage is in large part dependent upon conditions ante-dating the glacial period. Viewed in a broad way the area comprises two wide, shallow troughs trending and sloping southeast. To the northwest these depressions merge into the general level of the plain itself. The axis of the more northerly of these troughs is occupied by East Sugar creek and its branches; the other by the West Sugar. The narrow divide separating the two basins terminates at the high salient overlooking the Mississippi, known as "Keokuk Point." The line of the Keokuk and Northwestern railroad closely follows this ridge.

The area between the East Sugar and Skunk river is trenched for a part of the way by Lost creek; while a similar irregularly elevated district constitutes the divide between West Sugar creek and the Des Moines river. These plateaus represent the portions remaining of the original gently southward sloping plain upon which the present more or less incised topography has been impressed.

Along the Des Moines river the narrow valley is bordered for the most part by steep bluffs, intersected by small ravines, with abrupt, widely branching, dentritic systems and short, steep, V-shaped trenches. A similar topography prevails between Montrose and Keokuk along the Mississippi. Above Montrose the bluffs are destitute of rock exposures and, while generally high and steep, are characterized by the rounded contours so common to drift regions. So also the absence of rock between Sand Prairie and the mouth of the Des Moines is marked by similarly rounded bluff outlines.

The profile (plate xxvii, figure 1) along the line of the Keokuk and Northwestern railroad expresses the general southeastward slope of the plateau. In approaching Keokuk the railroad leaves the divide and follows the valley of Soap creek. The continuation of the plateau is indicated by a dotted line. A second profile transverse to the last shows the manner in which the plateau has been intersected by the drainage systems (plate xxviii, figure 1).

The highest place in the county is West Point, which has an elevation of 758 feet above tide; the next highest is Big Mound with an elevation of 748 feet. Lacrew which stands on the main divide almost directly between these points has an elevation of only 709 feet. It is evident, therefore, that there is a very considerable depression between the two points.

The accompanying table of elevations gives the most reliable estimates derived from all records available. Discrepancies at numerous places have been found in the data at hand, but care has been taken to eliminate all the errors possible:

Table of Altitudes in Lee County, Iowa.

LOCALITY.	ABOVE LOW WATER LEVEL AT KEOKUK.	ABOVE SEA LEVEL.	AUTHORITY.
Argyle	191	668	C., S.F. & C. RR.
Belfast	68	545	Des Moines Valley RR.
Big Mound	271	748	Barometer.
Charleston	217	694	K. & NW. RR.
Cottonwood	236	713	C., Ft.M. & DM. RR.
Croton	73	550	Des Moines Valley RR.
Donnellson	219	696	K. & NW. RR.
Fort Madison:			
Low water level	25	502	Mississippi River Com.
C., S.F. & C. RR	40	522	C., S.F. & C. RR.
Franklin	219	699	C., B. & KC. RR.
Galland (Nashville)	30	507	U. S. P. B. M.
Keokuk:			
Low water level	0	417	Mississippi River Com.
Union Depot	28	505	St.L., K. & NW. RR.
Hubinger well	160	637	City Water Works.
Fourteenth & Grand Ave	178	655	City Water Works.
Lacrew	232	709	K. & NW. RR.
Mount Clare	202	679	K. & NW. RR.
Mertensville	231	708	C., Ft.M. & DM. RR.
Montrose:			
Depot	46	513	St.L., K. & NW. RR.
Low water	23	500	Mississippi River Com.
New Boston	212	689	K. & NW. RR.
Pitman	237	714	C., Ft.M. & DM. RR.
Pilot Grove	168	615	C., Ft.M. & DM. RR.
RR. Crossing (near Mertensville),			
C., Ft.M. & D.M. track	209	686	C., Ft.M. & DM. RR.
K. & NW. track	223	700	K. & NW. RR.
Sawyer	234	711	C., Ft.M. & DM. RR.
Saint Paul	166	643	C., Ft.M. & DM. RR.
Sand Prairie	76	553	Des Moines Valley RR.
Sandusky	29	506	St.L., K. & NW. RR.
Sugar Creek:			
East, on RR. bridge	56	526	C., B. & KC. RR.
West, on RR. bridge	146	623	C., B. & KC. RR.
Summitville	193	670	K. & NW. RR.
Viele	56	533	C., B. & KC. RR.
West Point	281	758	C., Ft.M. & DM RR.
Warren	226	703	C., B. & KC. RR.
Wever	65	542	St.L., K. & NW. RR.

In the lower portion of their courses alluvial plains always border the smaller streams. On the Mississippi, however, the river bottoms have an important development at two points only, one being in the triangular area between the mouth of the Skunk river and Fort Madison, and the other in the crescent-shaped tract between Montrose and the great lobe of drift which, a short distance above Fort Madison, meets the river in almost vertical bluffs one hundred and fifty to one hundred and eighty feet in height. The more northerly of these alluvial districts comprises nearly the whole of Green Bay township; while the other includes a large part of Jefferson township and a small part of Montrose. Near the river the plains are low and wet, intersected by numerous sloughs and subject to overflow during the stages of high water. Farther away the surface rises in a series of sand terraces to a height of about fifty feet, where it meets the bluffs on the west. In both areas three or four well marked terraces occur, each varying from five to fifteen feet in height. In the upper plains these embankments converge toward the south; while in the lower they are approximately parallel and correspond in direction to the crescent shaped outlines. These terraces represent the flood water stages of the river in times somewhat remote, yet subsequent to the deposition of the drift which once covered the area and which was removed by the river in the process of widening its valley.

Another plain exactly similar in character to those already described and evidently having the same origin, occurs at Sand Prairie on the Des Moines. Above this point on that river and below Montrose on the Mississippi, the streams flow in comparatively narrow channels, bounded by more or less abrupt rock escarpments which rise directly from the water's edge.

DRAINAGE.

The drainage of the county passes through three important rivers, one of which finally receives the waters of the other two. They are the Mississippi, the Skunk and the Des Moines. Together they form more than three-fourths

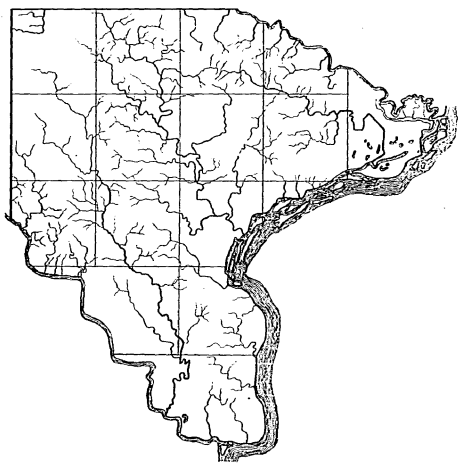


Figure 14. Sketch Map of Lee County, showing Drainage.

of the boundary line of the district. The immediate drainage areas of the bounding streams is relatively very small, and is accomplished by means of numberless short rivulets which cut the margin of elevated upland or plateau. Almost the entire drainage of the area is effected

by three creeks, all of which rise near the extreme northwestern corner of the county.

Mississippi River. This stream passes along the entire eastern edge of Lee, in a southwesterly direction or nearly at right angles to the direction of the general drainage slope. Except at two points, below Fort Madison and east of Wever, it flows in a rock-bound gorge, having almost perpendicular walls. The fall of the river between Fort Madison and Keokuk is twenty-five feet, or an average of about one and two-thirds feet per mile. From Fort Madison to Montrose, however, there is a fall of but two feet, so that the greater part of the descent takes place in the nine miles from Montrose to Keokuk where the stream passes over the chert beds at the top of the Burlington limestone. This gives an average of a little more than two and one-half feet per mile, between the two points last mentioned.

Des Moines River. For more than one-half its distance in Lee county the Des Moines river like the Mississippi flows in a narrow gorge-like valley, with little or no flood plain. Towards its mouth, however, the stream meanders through the broad bottoms of the Mississippi which abruptly begin to appear a few miles below Keokuk. The river flows in a southeasterly direction, its course coinciding closely with that of the general drainage of the entire area. The small rivulets emptying directly into it seldom reach very far back into the interior, rarely more than three or four miles. The Des Moines river between Farmington and its confluence with the Mississippi, has a fall of about forty-eight feet, or an average of about one and three-fifths feet per mile.

Skunk River. The third most important water-course is the Skunk river which has a general southeastward

course parallel to the Des Moines, and like that stream drains a very narrow belt of territory.

Interior Streams. As already stated the county is drained chiefly by three large creeks. The principal one is Sugar creek in the western part. It flows into the Des Moines a few miles above the mouth of the latter.

West Sugar creek is marked throughout its course by rounded, drift-covered slopes. Its channel is confined entirely to the drift, in which it has cut a rather wide trench usually with steep banks. In the upper part of its course the stream flows southeastward, approximately parallel to the Des Moines river, but when it meets the small branch rising near Mount Clara it turns abruptly southward into the Des Moines. The fact is significant, for the small branch is developing its channel in the clays filling an old trench of the Mississippi, while the main stream is making a comparatively feeble like effort to revive an old channel of the Des Moines.

East Sugar creek takes its rise in the southeastern part of Henry county, flows southeastward and discharges its waters into the Mississippi about midway between Fort Madison and Montrose. In the upper part of its course it flows over glacial deposits, but penetrates these in the southeastern part of Marion township, exposing the underlying Coal Measures and Saint Louis limestone, the latter as far down the stream as the southern part of West Point township. The irregularities in different beds of the formation have caused more or less abrupt deflections in the course of the main stream and its tributaries in this part of its course. This feature is easily recognized on the map and thus becomes an index to the uneven character of the rocky floor.

Lost creek is smaller than either of the two just mentioned. Its course is near the Skunk river and parallel to it. The other minor creeks flowing eastward into the Mississippi are Jack, Lamelee, Price and Soap; those emptying into the Des Moines are Lick, Mumm and Monk; all of which are quite small. The parallelism and southeasterly trend is a very marked feature in the streams of Lee county and evidently is but an expression of the general drainage slope of southeastern Iowa.

STRATIGRAPHY.

Geological Relations of Formations.

The rocks of Lee county consist of (1) a series of more or less evenly and regularly bedded deposits comprised chiefly of limestone, sandstones and shales, and (2) a mantle of incoherent clays and sands which covers the harder beds.

The stratified, or indurated, rocks are almost entirely Lower Carboniferous limestones. These form the great basement upon which the Coal Measures of the region were laid down. Although lying on the extreme eastern margin of the western interior coal field and having the basal limestones exposed over a large part of its surface, there are in Lee county several areas, in the aggregate of considerable size, which are occupied by Coal Measure strata.

All the bedded rocks have been subjected to profound erosion which has carved out deep channels and numberless minor depressions. Over this uneven surface the glacial materials have been spread, obscuring in great part

the harder rocks. Subsequent action of running waters has cut through the drift mantle and laid bare the underlying strata at many places.

The general scheme of classification of the geological formations exposed within the limits of the county is shown in the accompanying table:

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic	Pleistocene.		Drift.	Terrace. Loess. Till.
Paleozoic.	Carboniferous	Coal Measures.	Des Moines.	Basal sandstone and shales.
			St. Louis.	Concretionary and brecciated limestones.
		Lower Carboniferous. (Mississippian)	Augusta.	Warsaw shales. Geode shales. Keokuk limestone. U. Burlington limestone. L. Burlington limestone.
			Kinderhook.	Shales.

General Section.—The total thickness of the rocks exposed above low-water level in Lee county is not far from 400 feet, though the actual vertical measurement of an outcrop at any one place is probably nowhere more than

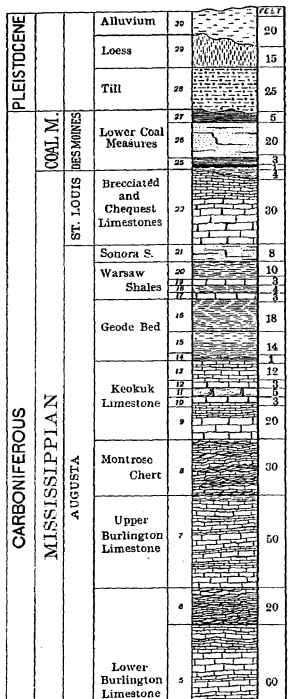


Figure 15. General Geological Section.

one-half of this maximum. Numbers 1 to 5 are best exposed just across the Skunk river, near Patterson station in Des Moines county (section IV); 5 to 9 are well shown at several points on the same stream between its mouth and Augusta (section XVII); 9 to 16 are well exhibited at the mouth of Soap creek (section II); 12 to 27 outcrop in the bluff at the old McGavic mill site (section I); 28 to 30 are found in numerous places capping the bluffs around Keokuk. These several outcrops serve as standards to which all sections in the county may be readily referred; and they may therefore be described more in detail.

Typical Exposures.

STANDARD SECTIONS.

About two miles below the Union depot at Keokuk, in the vicinity of the old McGavic mill, the bluffs are high and almost perpendicular. Here is exposed a nearly complete section of the rocks of the county (see plate XXIX).

I. Bluff Section at Old McGavic Mill.

		FEET.
17.	Drift	30
16.	Shale, gray, clayey	2
15.	Sandstone, ferruginous	1
14.	Shale, black, fissile, filled with small nodular concretions	3
13.	Coal	1½
12.	Fire clay and light colored shale, passing into a coarse, quartzose sandstone, the latter becoming massive and well developed locally; 2 to 6 inches	⅓
11.	Limestone, brecciated, fragments small and large, with interstices filled with green clay; varies in thickness from 10 to 30 feet	20
10.	Sandstone, massive, blue, calcareous, weathers brown; quartz grains more or less angular, and sometimes large, approaching the size of small pebbles; quarried at several places	8
9.	Shale, blue, argillaceous	10
8.	Limestone, coarse, encrinital, gray, quite fossiliferous, not persistent	3
7.	Shale, blue, argillaceous; becomes somewhat friable on weathering	4
6.	Limestone, blue and brown, magnesian, irregular in development, 2 to	3
5.	Shale, argillo-calcareous, breaking down readily to a yellowish clay. No geodes at this point, but abundant farther north	18
4.	Shale, calcareous, with bands of chert, and irregular layers of thin-bedded, gray limestone, which are increasingly prevalent towards the base	14
3.	Shale, blue	½
2.	Limestone, blue, encrinital, coarse grained, composition and stratification somewha variable, nodular chert in considerable quantity	12
1.	Limestone, blue, encrinital, black impressions of *Orthis keokuk* abundant; "White Ledge" of quarrymen, 3 to	4

The members of this section may be grouped geologically as follows:

	FEET.
Pleistocence (No. 17)	30
Lower Coal Measures (12 to 16 inclusive; 23 to 27 general section)	10
Saint Louis (10 and 11; 21 and 22 general section)	28
Augusta: Warsaw formation (6 to 9; 19 to 20 general section)	20
Geode Shales (3 to 5; 14 to 16 general section)	30
Keokuk limestone, proper (1 and 2; 12 and 13 general section)	66

The base of the section is the track of the Chicago, Rock Island & Pacific railroad which is here about thirty-five feet above the level of the Mississippi river at low water. One mile above this place near the mouth of Soap creek there is shown the following section in which three of the beds lying below the base of the previous section are given.

II. Section at Mouth of Soap Creek.

		FEET.
7.	Shale and chert	6
6.	Shale, calcareous, with intercalated beds of limestone; some geodes	8
5.	Limestone, drab, impure, heavily bedded, shaly below	12
4.	Limestone, light colored, with nodular masses of chert; the "White Ledge"	3
3.	Limestone, argillaceous and massive, or massive, calcareous shales; with subspherical massess of calcite, sometimes carrying millerite.....5 to	6
2.	Limestone, coarse, gray, encrinital; with much chert	3
1.	Limestone, with chert in irregular beds (exposed)	5

The section given discloses the strata which are exposed above the water level of the stream. In regard to the character of the rocks below the level of the river it

is of interest to note the results of sinking several deep wells which have recently been put down at Keokuk to depths of nearly 2000 feet beneath the base of the exposures mentioned and over 1150 feet below sea level.

The record of the Hubinger well especially, was very carefully kept by Mr. C. H. Gordon. The list of beds passed through and their probable position in the general geological section of the state are given below.

III. Record of Hubinger Well, Keokuk.

		THICKNESS.	DEPTH.
19.	Clay and sand, boulder clay below Pleistocene	28	28
18.	Limestone, (Saint Louis)	5	33
17.	Sandstone	5	38
16.	Limestone, (Augusta, 12 to 16)	12	50
15.	Shale	58	108
14.	Limestone	62	170
13.	Shale	10	180
12.	Limestone	110	290
11.	Shale, (Kinderhook, 10 and 11)	65	355
10.	Limestone	10	365
9.	Shale, (Devonian, 7 to 9)	195	560
8.	Limestone, shaly	65	625
7.	Sandstone, (water)	20	645
6.	Limestone, sandy in part (Upper Silurian, 5 and 6)	55	700
5.	Sandstone, (water)	37	737
4.	Shale, (Lower Silurian, 1 to 4)	63	800
3.	Limestone, arenaceous in lower part	140	940
2.	Sandstone, fine, white	110	1050
1.	Limestone, alternating with sandstone, chips carried away by water	755	1805

The correlation of certain of the above formations is evident. Number 2 doubtless is the Saint Peter sandstone. Four may represent the Maquoketa shales. Ten appears to be the northward attenuated extension of the Louisiana limestone of Missouri. Eleven seems to be the shales of the Kinderhook, so well exposed at Burlington;

in Missouri the median member or Hannibal shale. The lower part of 14, together with 12 and 13 probably corresponds to the Burlington; while 15 and 16, and the upper part of 14 represent the Keokuk. Eighteen forms the lower part of the Saint Louis.

MISSISSIPPI RIVER SECTIONS.

Along the Mississippi river (see plate xxvii, figure 2) natural exposures are almost continuous from Keokuk to beyond Augusta, so that the entire eastern border of the county from the mouth of the Des Moines, at the extreme southern point of the district to the north county line on Skunk river, may be regarded as open to view above the water level. The two leading Keokuk outcrops, the one at the old McGavic mill and the one at the mouth of Soap creek, have already been noticed. In the latter section there often exists between numbers 2 and 3 lenticular layers which bear numerous forms of fossils, chiefly crinoids. In some cases the decomposition of beds 3 and 4 exposes large numbers of the fragmentary remains of brachiopods, particularly *Spirifera keokuk* Hall. Two constitutes the base of the Geode shale. In the two sections mentioned there is shown nearly the full thickness of what has been widely known as the Keokuk group. The limestone formation fully shown in the second (11) of the two sections has a total thickness of about twenty-five feet. The upper part is well exposed along the bluff between this point and the Union depot as well as between Soap creek and the mouth of the Des Moines river. The base of the Keokuk limestone is here somewhat below the level of the railroad track. A gradual descent of the beds to the north brings the Geode bed nearly to the level of the railroad track above the lower lock of the canal,

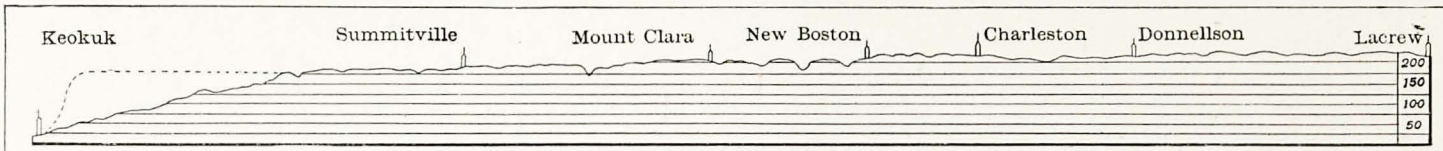


FIGURE 1. PROFILE FROM KEOKUK TO LACREW.

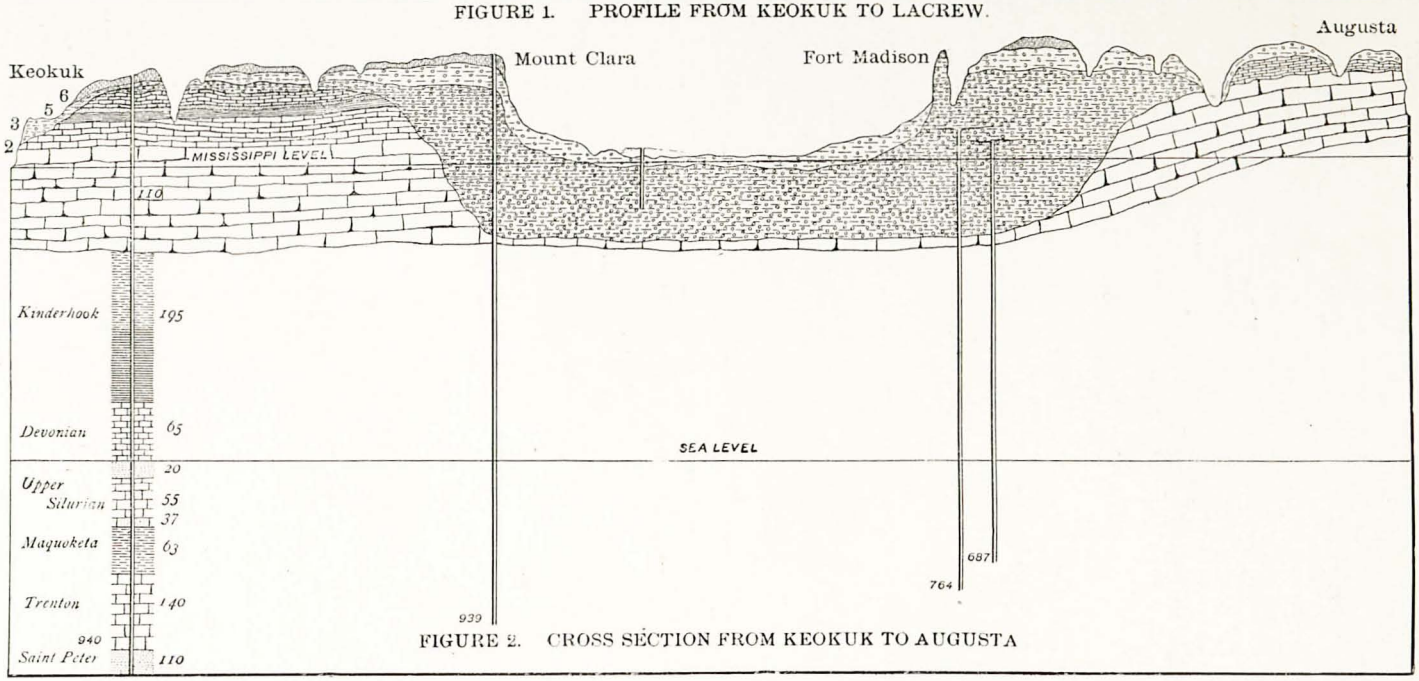


FIGURE 2. CROSS SECTION FROM KEOKUK TO AUGUSTA

GEOLOGICAL CROSS SECTIONS IN LEE COUNTY.

but this does not seem to continue very far, as the top of the Montrose cherts is five to fifteen feet above water level all the way to Montrose.

The rocks exhibited in section 11 are exposed on Soap creek for some distance above its mouth, as are also the overlying rocks in ascending order. About one-half mile above, near Twelfth street, there is presented:

VII. Soap Creek, near Twelfth Street, Keokuk.

		FEET.
6.	Unexposed	10
5.	Shale, blue, clayey	3 to 5
4.	Limestone, magnesian, blue; weathering to brown; thin band of chert at middle	5
3.	Shale, calcareous, but readily breaking down upon exposure; geodes numerous, generally small and thin shelled	20
2.	Shale, calcareous, massive; breaks down less readily; cherty above, geodes larger	20
1.	Limestone, gray (exposed)	1

Numbers 4 and 5 constitute the basal part of the Warsaw formation, while 2 and 3 represent a maximum development of the Geode shales. About one-half mile above this locality number 4 is quarried; and a little distance beyond, near a cooper shop, the upper shales of the Warsaw, which are exposed by stripping, are used for the manufacture of brick at the Hubinger Brick Works. On the south of the creek, below the cooper shop, the following arrangement was determined:

VIII. Soap Creek, west of Cemetery, Keokuk.

		FEET.
7.	Concealed	5
6.	Limestone, brecciated (exposed)	5 to 10
5.	Shale, bluish, partly concealed	15
4.	Limestone, coarse, sub-crystalline; largely composed of fragments of Fenestellids, crinoid plates and brachiopods	3
3.	Shale, argillaceous	5 to 6
2.	Limestone, blue, magnesian	3
1.	Shale, calcareous, with geodes	10

Numbers 2, 3 and 4 constitute the base of the Warsaw, the upper part of which is here concealed. The following fossils were obtained from 4:

Spirifera lateralis, Hall.
Spirifera subcardiformis, Hall.
Spirifera pseudolineata, Hall.
Archimedes wortheni, Hall.
Polypora spinninodata, Ulrich.
Polypora varsovensis, Ulrich.
Lioclema punctatum, Hall.

The Hubinger well section which is important in the present connection is given in another place (section III).

A short distance above Rand park there is an exposure showing in an excellent way the juncture of the Saint Louis limestone with the basal sandstone of the Coal Measures. The sandstone is about fifteen feet thick and rests upon the unevenly eroded surface of the brecciated limestone (see plate XXX; also figure 18). A ravine intersects the bluff at this point showing, towards the west, a replacement of the sandstone, in part at least, by shales, fire clay and coal. At the same time the brecciated limestone becomes thicker apparently causing the sandstone to thin out somewhat in that direction. Beyond this point, so far as Montrose, exposures are frequent in all the ravines and along the creeks which intersect the bluffs. The Coal Measure rocks do not appear to extend continuously over the area but are represented by small isolated basins similar to that seen near Galland. They are likewise exposed at the Sonora quarries on the opposite side of the Mississippi river where they rest unconformably upon beds of brecciated limestone and the sandstone member beneath.

From Montrose to a point above Fort Madison the exposures occurring along the west side of the river are chiefly of drift. At the latter place the following is given:

IX. Bluff Section at Fort Madison.

		FEET.
4.	Soil	4
3.	Loess	30
2.	Clay, yellowish-brown, with pebbles and small boulders; "yellow boulder clay"	50
1.	Clay, as above, but dark colored; "blue boulder clay" (exposed)	100

East of the town about four miles (Tp. 68 N., R. III W., Sec. 32, SE. qr.) a limited exposure of Burlington limestone is said to occur near the river. Directly north of Wever station at the low salient jutting out at the confluence of the Mississippi and Skunk valleys the Lower Burlington limestone is well exposed and a quarry opened there. Immediately west of the same station (Tp. 68 N., R. IV W., Sec. 12, NW. qr., SE¼) a similar sequence is shown at the Lange quarry. It is evidently the Burlington limestone.

X. Section in Lange Quarry, west of Wever.

		FEET.	INCHES.
5.	Drift	4	
4.	Limestone, encrinital, brownish, thinly bedded, with some chert	1	6
3.	Limestone, white, rather soft, somewhat cherty in places		6
2.	Limestone, yellowish	2	4
1.	Limestone, hard, brown, encrinital, heavily bedded (exposed)	2	

An outcropping showing the beds below the base of the exposure just given appears on the north side of the

Skunk river in the bed of Spring creek. The details are shown in section VI.

SKUNK RIVER SECTIONS.

From the last Lee county outcrop on the Mississippi the natural exposures continue at short intervals for a long distance up the Skunk river.

Begining with the Patterson section (VI) in which is exhibited the lowest rocks exposed along the stream, the strata dip rather rapidly to the west until at the first good outcrop on the south side of the river, in the section north of Wever, the Lower Burlington limestone appears at the base of the bluff. Farther up the stream, at Augusta, the Upper Burlington is well exposed in the bed of the river below the mill dam. In the north bluff of the stream at the same place the Upper Burlington, the Keokuk and the Montrose cherts, which separate the other two formations, are displayed in a quarry face.

In the south bluff the same beds are exhibited, but the dividing lines are not so distinct, owing to the heavy talus which covers the hill-sides.

Four miles farther up the river, and two and one-half miles north of Denmark (Tp. 69 N., R. IV W., Sec. 17, NW. qr.) the following section is shown:

XVII. Denmark Section.

		FEET.
5.	Concealed	3
4.	Limestone, coarse, dark blue, sub-crystalline with *Orthis Keokuk*, *Spirifera pseudolineata* and Fenestella	10 to 12
3.	Limestone, like 4, interbedded with chert	6 to 8
2.	Shale, blue, calcareous, with much chert	10
1.	Chert and calcareous shales, with included beds of limestone and clay	20

The Montrose cherts exposed at the bottom of the outcrops are found grading upward into the Keokuk limestone, with no clearly defined line of separation.

A couple of miles northwest of Denmark, well up in the bluff (Tp. 69 N., R. V W., Sec. 13, NE. qr.) is a section showing the upper portion of the Warsaw beds (2) in its normal phase; while a mingling of arenaceous and magnesian characters is exhibited in the beds above (3 and 4).

XVIII. Bluff Section Northwest of Denmark.

		FEET.
5.	Concealed	10
4.	Limestone, brown, magnesian, thin-bedded, varying to a more or less arenaceous rock; undulating below; seems to graduate downward into next.	10
3.	Shale, arenaceous, and calcareous sandstone, irregularly stratified	6 to 8
2.	Shale, blue, somewhat arenaceous at top	10 to 12
1.	Limestone, magnesian, (exposed)	2

A short distance west of the last mentioned section, instructive exposures of the Saint Louis limestones are shown in the old Klopfenstein quarry (Tp. 69 N., R. V W., Sec. 13, NW. qr.)

XIX. Section in Klopfenstein Quarry.

		FEET.
4.	Concealed	10
3.	Limestone, white, granular, oolitic, with a thin bed of chert	12
2.	Limestone, fine-grained, white, not oolitic, showing cross-bedding	2
1.	Limestone, brecciated	20

DES MOINES RIVER SECTIONS.

From the standard section so well exhibited at the McGavic mill (section 1), below the Union railway station at Keokuk, the outcrop along the Mississippi southward, gradually becomes less exposed to view until at the mouth of the Des Moines river the bluff recedes quite gently (see plate xxviii, figure 3). About a mile above the place where the latter stream empties into the larger water-course there is a low hill which lies between the Des Moines Valley railroad and the river, the greater part being composed of limestone, as is well shown in a cutting on the north side. At this point six or seven feet of the geode shales are exposed on a level with the track. No exposures of rock occur between this place and Sand Prairie. At the last mentioned point the Saint Louis brecciated limestone is seen in limited exposures in the ravines above the station. On the opposite side of the river, near St. Francisville, there are good exposures of the limestone. One-half mile beyond the Chicago, Santa Fé & California railroad bridge over the Des Moines, a quarry is operated by the railway company. The following is the section:

XII. Section at Deamude Quarry.

		FEET.
6.	Clay, yellow above, red below	6
5.	Limestone, brecciated, with pockets of green clay; sometimes rudely and coarsely stratified	20 to 30
4.	Limestone, blue, encrinital	1 to 3
3.	Shale, blue, calcareous	1 to 3
2.	Sandstone, blue, calcareous, with discontinuous beds of blue shale, the principal quarryrock	6 to 8
1.	Shale, blue	15

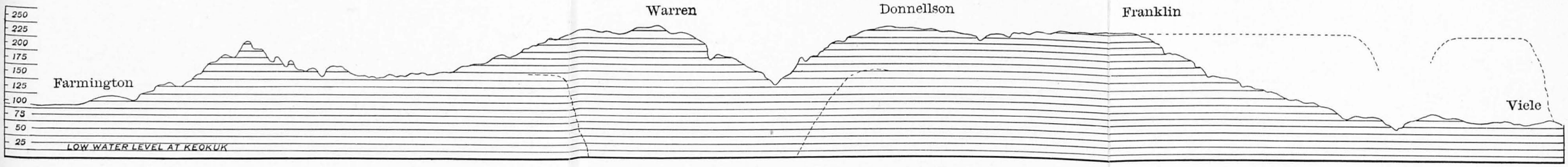


FIGURE 1. PROFILE FROM VIELE TO FARMINGTON.

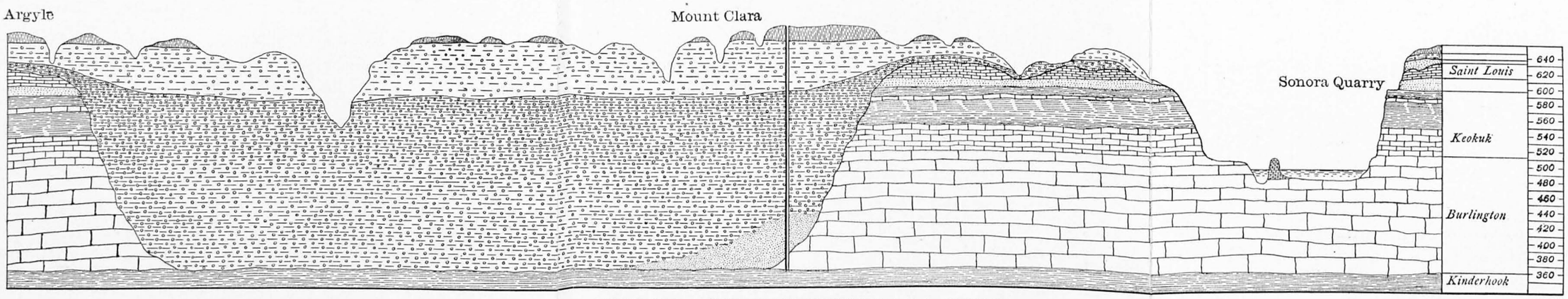


FIGURE 2. SECTION FROM SONORA TO ARGYLE.

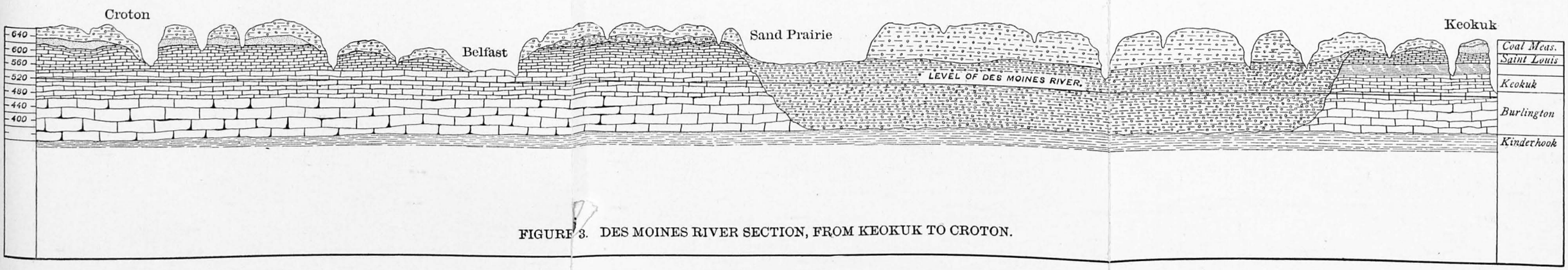


FIGURE 3. DES MOINES RIVER SECTION, FROM KEOKUK TO CROTON.

GEOLOGICAL CROSS SECTIONS IN LEE COUNTY.

Shale 1 is referred to the superior division of the Keokuk (Warsaw); while the remainder of the section is classed as Saint Louis. On the other side of the hill, facing the river, numbers 2 and 3 have a much greater thickness and present considerable variation in bedding, there being rapid alterations from sandstone to shale. In some places these shales are twenty to twenty-five feet thick, nearly all of which may be replaced by sandstones. The bedding is too irregular, however, to make it available for quarrying except at a very few points. At one of these a quarry is being worked by the Chicago, Rock Island & Pacific railroad.

In the south bank of a small stream, discharging into the Des Moines river below Belfast, ten feet of brecciated limestone are seen to be underlain by about ten feet of the massive brown sandstone, the latter resting upon twelve feet of blue shale without geodes and evidently representing number 6 of the Deamude section. About two and one-half miles west of Belfast, some instructive exposures occur on Mumm creek, a short distance above its mouth, (Tp. 67 N., R. VII W., Sec. 33, SE. qr.) The section is readily correlated with the preceding one.

XIV. Mumm Creek Section.

		FEET.
3.	Concealed	5
2.	Sandstone, bluish, weathering brown, somewhat micaceous, thinly bedded in places	15
1.	Shale, blue, argillaceous, readily breaking down into clay; no geodes	5

One-fourth of a mile above on the same stream is a second exposure at which the arrangement disclosed is:

XIV. Bluff on Mumm Creek, above its Mouth.

		FEET.
8.	Concealed	10
7.	Limestone, brecciated, with little if any clay; light colored	8
6.	Limestone, brown, magnesian; lower ledge lighter colored	8
5.	Limestone, magnesian, dovecolored, breaks down quite readily on exposure	2
4.	Limestone, brown, magnesian, quite regular on upper surface but irregular below, conforming to surface of succeeding ledge; not brecciated	2
3.	Limestone, more or less brecciated; sandstone and shale; latter predominates at the middle and separates the bed roughly into two parts	6
2.	Shale, blue, sandy	1
1.	Shale, blue, no geodes (exposed)	1

The shale number 2 is exposed along the edge of the creek and is to be correlated with number 1 of the section just given, while the sandstone of that section is replaced here by limestones 3 to 6 inclusive. Still farther up the stream other rocks appear. One-fourth mile beyond the last is:

XV. Mumm Creek; one-half mile above its Mouth.

		FEET.
4.	Concealed	5
3.	Limestone, hard, white, granular or sandy textured; in thin flag-like beds, with included quartz grains at base	12
2.	Limestone, hard, blue, breaks with conchoidal fracture and is cut by thin veins of calcite	10
1.	Limestone, magnesian, thickly and regularly bedded, slightly brecciated in places	10

Number 1 of this section corresponds to the magnesian beds below number 7 in the preceding section. Following up the stream a short distance number 3 is about 20 feet

thick, with about ten feet of brecciated limestone between it and the magnesian limestone below.

In a railroad cut one and one-half miles south of Croton station the sequence shown is:

XVI. Croton Section.

		FEET.
8.	Drift	30
7.	Sandstone, light brown; stratification irregular..15 to	20
6.	Limestone, brecciated, fragments fine-grained, bluish and white; breaks with conchoidal fracture; nodular chert abundant	10
5.	Limestone, brecciated fragments coarser than above, large pieces of magnesian limestone included	20
4.	Limestone; thin but very persistent layer of pure, lightcolored, fine-grained stone; breaks with conchoidal fracture, weathers white; 2 to 4 inches	½
3.	Limestone, brecciated; coarse, incoherent, breccia; magesian limestone and sandstone predominating like No. 5	15
2.	Concealed; blue clay and fragmentary limestone exposed at top	20
1.	Shale, with geodes in bed of branch one-fourth mile north of point where above was taken	3

The base of the section is about fifteen feet above the Des Moines river. The portion concealed represents the horizon of the Warsaw formation. The beds from 3 to 6 inclusive belong to the Saint Louis, while the sandstone above is the basal member of the Coal Measures. In the bluffs near Croton it is well developed and sufficiently indurated to admit of quarrying. It has been taken out to some extent on the right bank of the branch below the station. Twenty-five feet of the brecciated rock underlie the sandstone. Following up the branch for one-half mile or more, the upper portion of the brecciated limestone is seen to be replaced by hard, white, granular or oolitic limestone, cross-bedded and ripple-marked. The ripple marks at

some points are very broad and deep, measuring five inches from crest to crest and from one to one and one-half inches in depth.

OTHER SECTIONS.

Besides the sections which have been described as occurring along the three principal streams and which are representative of almost continuous exposures along the water-courses, there are several others in the interior of the county which are readily correlated with those along the margins and which deserve mention. On West Sugar creek outcrops of the indurated rocks are infrequent. The most important one perhaps is on a small branch two miles south of Donnellson (Tp. 69 N., R. VI W., Sec. 5, SW. ¼).

XX. Donnellson Section.

		FEET.
4.	Concealed	75
3.	Limestone, white, granular, ripple-marked (exposed)	10
2.	Limestone, brecciated	10
1.	Limestone, brown, magnesian, somewhat sandy, cherty; locally called "sandstone"	5

In passing up East Sugar creek the first exposure of rock occurs near the railroad bridge about two miles northwest of Viele at which place about five feet of the brown magnesian limestone belonging to the lower part of the Saint Louis formation crops out. One mile above this point is another exposure of the same bed at the level of the water in the creek near an old mill. The exposure shows about six or eight feet of brown calcareous sandstone; it has been quarried to some extent. The strata have an apparent southward dip considerably greater than the slope of the creek bed. Two miles northwest of this locality the white limestone of the Saint Louis is quarried on the Graner land. The magnesian beds lie

below, with some brecciated limestone between; while a drill-hole showed blue shale below the whole.

XXI. Section at the Graner Quarry.

		FEET.
10.	Concealed	10
9.	Limestone, white, granular or sandy in texture, cross-bedded	5
8.	Limestone, in heavier ledges; surface of beds beautifully ripple-marked	3
7.	Limestone, more impure than preceding; otherwise similar	2
6.	Limestone, very fine-grained and pure; burns excellently for lime	1
5.	Limestone, granular, white like 8 and 9; separated from 6 by clay parting five inches in thickness.	6
4.	Limestone, brecciated	8 to 10
3.	Limestone, brown, magnesian	8
2.	Shale, blue, argillaceous; no geodes (Warsaw)	10 to 12
1.	Shale, with geodes (exposed)	20

On Little Sugar creek, south of the Graner house, the same beds are evidently exposed for a distance of a mile or more, but show considerable variation in character. They are more or less disturbed and are available for quarrying at only a few points. Moreover, the sandy character is much less marked while the bedding is quite uneven.

On the East branch, about two miles northeast of the Graner quarry, rock escarpments extend along the creek for a distance of a mile or more (Tp. 68 N., R. V W., Sec. 20, NE. qr.).

XXII. Sugar Creek Section; East Branch.

		FEET.
6.	Concealed	5
5.	Limestone, hard, bluish-white; breaking with conchoidal fracture	3
4.	Sandstone, light brown, soft, saccharoidal	10
3.	Limestone, fine, white, chert-like	1
2.	Limestone, soft, or calcareous sandstone grading downward into next	10
1.	Limestone, brecciated, roughly stratified	10

All of this section from 2 to 5 inclusive, evidently represents the white limestone division of the Saint Louis, though the incoherent character of 2 is a phase not observed elsewhere. The brecciated rock which is here quite compact and firmly cemented has the appearance, at one point, of having been channelled and the excavation filled with a breccia of similar but loose and incoherent materials, with a considerable proportion of clay.

About a quarter of a mile down the stream lower beds appear (Tp. 68 N., R. V W., Sec. 20, NE. qr.).

XVIII. Sugar Creek Section, East Branch.

		FEET.
6.	Concealed	6
5.	Limestone, quite regularly bedded	3
4.	Limestone, brecciated ..... 12 to	15
3.	Limestone, brown, magnesian, in massive undulating beds ..... 8 to	10
2.	Shale, arenaceous and marly, containing fragments of chert ..... 3 to	6
1.	Shale, blue, arenaceous above (exposed)	2

The brown, magnesian limestone (3) sometimes incloses lenticular layers of light colored limestone breccia between the beds. Along the line of juncture between 3 and 4 fragments of the light colored limestone are sometimes inclosed in the latter, while fragments of brown, magnesian limestone mingle with the white in the breccia. The layers of 3 show quite regular bands due to staining from iron oxide. On the main creek directly west of this locality is a similarly stained rock evidently belonging to the same formation.

North of Franklin about two and one-half miles there is a bold escarpment of brecciated limestone about fifty feet high presenting much the same character as the formation seen at Croton.

A mile and a half northwest of this, on Big creek, the beds are more regularly stratified; while a seam of coal appears above (Tp. 68 N., R. VI W., Sec. 15, NW. qr., NE. ¼).

XXIV. East Sugar Creek Section; Big Creek.

		FEET.
7.	Concealed	8
6.	Coal; has been worked here, drift now abandoned; about	2
5.	Fire clay	2
4.	Sandstone, soft, quartzose	5
3.	Limestone, white, rather hard and coarse in texture; contains *Bellerophon gibsoni* White, *Productus semireticulatus*, *Zaphrentis pellaensis*, Worthen, Allorisma	2
2.	Shale, somewhat calcareous, lamminated	1
1.	Limestone, granular cross-bedded, irregularly stratified and somewhat brecciated in places; includes a bed of rough silicious rock, also one of clay and chert; the base of the limestone is light colored and contains much nodular chert	26

Numbers 4 to 6 inclusive belong to the Coal Measures; the remainder of the section represents the white concretionary limestone of the Saint Louis.

On Lost creek there are a number of exposures of small extent. In the southeast quarter of section four, Washington township (Tp. 68 N., R. IV W.), the Keokuk limestone appears at short intervals along the creek, sometimes having an exposure of eight to ten feet. In the southwest quarter of section three, ten inches of dark blue, sub-crystalline limestone, bearing *Spirifera logani*, *Spirifera keokuk*, a Productus and a zaphrentis, overlie six feet of cherty shale and earthy limestone. This is evidently very near the line of division between the Burlington and Keokuk limestones. It probably represents the top of the Montrose cherts. For a distance of about two

miles below this point no exposures occur. Near the church in the northeast quarter of section eleven, five feet of Burlington limestone overlain by eight feet of white chert interbedded with brown limestone appear at the side of the creek. Below this point, for a distance of over a mile, the Burlington limestone may be seen in the ravines.

GEOLOGICAL FORMATIONS.

The general sequence and arrangement of the strata exposed in Lee county have been given in the table of formations. The lithological characters of the different members may be inferred from the descriptions of the typical vertical sections which have been selected for special mention as furnishing indices to an accurate correlation of beds in all parts of the district. Considered in its entirety each of the geological formations represented exhibits a somewhat different aspect than when shown in the details in the more or less disconnected sections. The range of formations is not very great since all the indurated rocks belong to one system — the Carboniferous.

Mississippian, or Lower Carboniferous, Series.

The oldest rocks exposed at the surface of Lee county are known as the Lower Carboniferous, or Mississippian, limestones. They have been termed also the Mountain limestones, and the Subcarboniferous, both of which names are now regarded as inapplicable. Lower Carboniferous has been used widely of late to designate the rocks in question, but there are serious objections to the use of this term. More recently the title Mississippian series has come into use in designating the great sequence of limestones lying at the base of the Coal Measures. The word is a revival, with a slight terminal modification, of an old

term employed years ago. It is very appropriate for the group of strata to which it applies as it is typically developed along the great stream for which it was christened.

In the Mississippi valley there are recognized four well marked subdivisions of the Lower Carboniferous, or Mississippian. One of these, the uppermost, is not present in Iowa. This absent member is the Kaskaskia limestone which is well exposed below the mouth of the Missouri river. It is a three-fold division made up of the Aux Vases sandstone, the Kaskaskia limestone proper and the Chester shales.

KINDERHOOK SHALE.

Although this member of the Lower Carboniferous is such an important formation in Des Moines county, immediately to the north, and in northeastern Missouri to the south, it lies almost entirely below the river level in Lee. It has only been recognized in a single place on the Skunk river near the Chicago, Burlington and Kansas City railroad bridge over that stream. In the bed of Spring creek a mile north of the Lee county line and one-half mile west of Patterson station the uppermost beds of the Kinderhook are well exposed.

IV. Section on Spring Creek, west of Patterson Station.

		FEET.
5.	Limestone, heavily bedded, encrinital (Lower Burlington; exposed)	10
4.	Sandstone, yellow, fine-grained	4
3.	Oolite, gray, massive; highly fossiliferous	3
2.	Shale, blue, argillaceous	1
1.	Shale, sandy (exposed to creek level)	1

From this point the Kinderhook is carried down in a shallow syncline which reaches its greatest depth near

Keokuk where it is about 130 feet below the low water mark; then rising rapidly it appears again above the river at Hannibal, Missouri.

AUGUSTA LIMESTONE.

The Augusta limestone comprises a very considerable portion of the surface rocks of Lee county. It forms the greater part of the vertical extent of the bluffs on all the streams bordering the district; but in the interior it is largely overlain by the Saint Louis limestone and Coal Measure shales. The term Augusta has been recently proposed for all those formations which in southeastern Iowa and the adjoining portions of Illinois and Missouri were formerly referred to under five distinct names. The term, therefore, is intended to be applied to the formations which have been known as the Lower and Upper Burlington limestones, the Keokuk limestone, the Geode bed and the typical Warsaw shale. The original localities of all of these formations are in Lee and Des Moines counties.

Lower Burlington Limestone.—In Lee county this rock has a surface exposure over only a small area, on the banks of the Skunk river in the northeastern part of the county, north of Weber and a few miles east of the town of Augusta. The beds comprise chiefly coarse-grained, encrinital limestones, usually firmly cemented, intensely white in certain layers but elsewhere brown or reddish on exposed surfaces. Many of the beds are made up almost entirely of disconnected skeletal plates of crinoids and other animals related to the starfishes and sea urchins. These organic hard parts are firmly cemented together by means of calcareous material. In the upper portion of the Lower Burlington there are sillicious shales and cherty

limestones which have been regarded as the layers separating the lower from the upper division. The distinguishing characters between the Upper and Lower Burlington limestones are chiefly faunal rather than lithological or physical differences, so that ordinarily the two divisions are not readily separated except by an examination of the fossils contained. Occurring only as a narrow strip for a short distance at the base of the Skunk bluffs the formation is not so important in Lee county as a few miles farther north. The economic value of this limerock will not therefore ever be very great on account of the occurrence of equally good beds of similar character immediately over it.

Upper Burlington Limestone.—Though usually very similar in general aspect to the lower member, the Upper Burlington may be often distinguished from it by its thinner bedding and greater abundance of chert in irregular nodules and thin bands. The more massive character of the lower beds is perhaps the only casual mark of distinction which is of value in discriminating between the two. The Upper Burlington is perhaps best exposed in the bed of the Skunk river at Augusta. Here for several hundred yards below the old mill dam the water breaks into ripples forming in places rapids of considerable size. The same rocks are also well exposed in the river banks for some distance both above and below the dam. A good section is found at the south end of the wagon bridge near by.

The flinty beds of the Upper Burlington are now called the Montrose cherts. They have recently been found to have less than one-third the thickness which has been commonly attributed to them, or only about thirty feet. The beds are well exposed along the Mississippi river

from Montrose to Keokuk. Between these points they constitute the bed of the river causing the obstruction to navigation known as the Des Moines rapids. The slope of the strata is very nearly the same as that of the river and hence the upper surface of the formation lies from five to fifteen feet above the water level for the entire distance. A short distance directly north of the Augusta bridge, in Des Moines county, there is an old quarry face showing the entire thickness of the cherts, with the Burlington limestone below and the Keokuk above. Thin layers of limestone are intercalated in the chert beds, the whole being rather thinly bedded as compared with the layers associated. Opposite the town on the south side of the river the same chert beds are found near the middle of the bluffs extending for a considerable distance, both up and down the stream. Other outcrops appear on Lost creek below Denmark.

Keokuk Limestone. Though this formation has its typical development in Lee county the area of its surface exposure is relatively small. It occupies the larger part of Denmark township together with a portion of Washington. In addition it is exposed by erosion in the Mississippi gorge and its tributaries between Montrose and Keokuk and forms the base of the abrupt escarpment which constitutes such a marked feature in the topography of the region. At the city of Keokuk it is well shown in numerous places, the best exposures being along Soap creek and in the west bluff from the foot of the canal to the mouth of the Des Moines river (see plate XXIX).

Along the Des Moines river the rocks lie somewhat above the water level all the way from Sand Prairie to Farmington, but as a rule are not very well exposed.

QUARRY AT McGAVIC MILL; KEOKUK.

For the most part the formation consists of twenty-five to forty feet of coarse-grained, bluish, often crinoidal limestone. Nodular chert is quite prevalent throughout. Some beds are somewhat argillaceous, and this with the presence of chert renders many of the layers unfit for use as a quarry rock. Some ledges, however, are well adapted for building purposes. The best of these layers is known as the "white ledge," which is rather extensively quarried especially at and around the city of Keokuk. The beds are much more massive towards the base and the partings are very thin, usually reduced to mere films; but towards the top the bedding becomes thinner, the separating clays more prominent and the layers assume a somewhat shaly character.

Geode Bed.—The shales immediately overlying the blue Keokuk limestone have a maximum thickness of perhaps forty feet. The lower half is made up largely of indurated calcareous shales with some chert and a few thin bands of limestone. The shales graduate rapidly into the massive limestone below. The upper half is much freer from calcareous material, is somewhat gritty and breaks down under the influence of the weather much more readily than the lower portion. The name of the formation was originally given to it on account of the existence of numerous globular, silicious and calcareous concretions known as "geodes." These are commonly hollow shells lined within by beautiful crystals of quartz or calcite which are studded often with single crystals of various metallic sulphides, among which are sphalerite chalcopyrite, millerite, galena and pyrite. Often the interior is composed of mammillary and botryoidal chalcedony. Sometimes the geodes are filled with liquid bitumen and occasionally with water. The geodes are

characteristic of the formation only in the southeastern part of Iowa and the adjoining portions of Missouri and Illinois.

Warsaw Beds.—Above the geode bed comes the Warsaw formation, as originally defined by Hall. As developed in the vicinity of Keokuk, which is on the opposite side of the Mississippi river from the typical locality, it consists of (1), a bluff magnesian limestone at the base in a massive layer often ten to twelve feet in thickness; (2) a median member made up largely of blue, arenaceous shales, with intercalated limestones in thin bands; and (3), at the top, a buff sandy limestone locally called "sandstone." By Hall the Warsaw was put in with the Keokuk; by White it was placed with the Saint Louis. Since the appearance of the publications of these writers the "Warsaw" has been claimed to be recognized in many localities and much confusion has arisen as to its proper limits and position. In southeastern Iowa this difficulty has been thought to be due to the assumption that the three members already mentioned belong to the same formation; and Gordon is inclined to the opinion, as will be shown farther on, that the "sandstone" is more closely related to the Saint Louis and should be regarded as the basal member of that formation. On the other hand the limestone and shales are manifestly very closely related to the Keokuk both lithologically and faunally. If, however, the title Warsaw is to be retained for any member, or formation, of the Lower Carboniferous series it can at best be applied only as a matter of convenience in local stratigraphy, since beyond the immediate vicinity of Keokuk where it was first recognized the typical Warsaw is not known. It appears to thin out quite rapidly to the north and evidently does not extend a very great

distance in that direction beyond the limits of Lee county.

At the town of Warsaw, five miles below Keokuk, and across the river in Illinois, the formation consists of ten feet of magnesian limestone overlain by thirty feet of blue argillaceous shale, above which is the sandy limestone. At Keokuk the formation is essentially the same though reduced in thickness fully one-third, the lower division being only five or six and the median about twenty feet thick.

Saint Louis Limestone.— There is comprised under this term some of the most important rock formations found in Lee county. The area over which they constitute the surface beneath the drift exceeds that of any other one of the members of the Lower Carboniferous. Numerous exposures of the Saint Louis beds occur on the small tributaries in West Point and Franklin townships. They also appear in the bluffs below Montrose and on the Des Moines above Sand Prairie. They are known on West Sugar creek at a single locality only, near Donnellson. Rocks of Saint Louis age occupy probably one-third of the areal mileage of the county.

In its normal development, in this region, the formation consists, according to Gordon, of ten to twenty feet of magnesian, often somewhat sandy limestone and blue calcareous sandstone below — the upper part of the typical Warsaw of Hall — and a somewhat greater thickness of white, fine, or granular limestone above. This succession, however, appears only at rare intervals as brecciation has taken place to a greater or less extent along the horizon separating the two divisions, and in some cases the process has gone so far as to involve both sections. So universal and prominent is the brecciated character of these beds

in southeastern Iowa that it has to a large degree obscured the true relations of these deposits and has been the occasion of much misapprehension as to the real characters of the Saint Louis in Iowa. While the brecciated character is one that has been impressed, in part at least, upon rocks already formed and hence cannot be considered as a distinct formation, it is equally evident that it may have had its origin in the conditions which existed during the deposition of these beds. In its minor development it uniformly occurs at the horizon between the magnesian and the white limestone. In consideration of these facts it is here treated as a distinct subdivision though its probable secondary character is not overlooked. The lower member consists of bluish-gray and dove-colored magnesian limestone, generally in thick concretionary beds, which on weathering usually assume a characteristic brown color. The limestone becomes arenaceous in places and sometimes passes almost completely into sandstone. This is the case at the Sonora quarries opposite Nashville, and below Belfast. At Nassau bluff, below Keokuk, the formation is represented by eight feet of calcareous sandstone in which the quartz appears in large white, more or less angular grains. This pebbly character is also marked at a number of other places. On weathering, the sandstone becomes brown like the limestone. The formation is well exhibited on the Des Moines river above its mouth where at various points, it shows alternations of the arenaceous and limestone phases.

On Mumm creek, west of Belfast, both phases are shown within the distance of less than one-fourth of a mile. A limited outcrop of the same beds also appears on West Sugar creek, near Donnellson, and there are good exposures at numerous places on East Sugar creek.

Heretofore the arenaceous beds have been considered as underlying the magnesian limestone and as constituting the upper member of the Warsaw division. Gordon is of the opinion that the recognition of the continuity of the arenaceous beds and the magnesian limestone removes the difficulty usually attending the classification of the Warsaw and explains satisfactorily the conflicting statements regarding it. The sandstone occurring on the Des Moines river, opposite Keosauqua in Van Buren county, where it overlies the brecciated limestone and evidently belongs to that division, was identified by White with the upper member of the original Warsaw; while the magnesian division was correlated with the Warsaw limestone and shales. Two distinct formations were thus confounded. In both Lee and Van Buren counties the two phases are readily traced almost directly into each other; while in many and separate localities, each is found to overlie blue, argillaceous shales which bear no geodes and which are of variable thickness, very evidently representing the middle Warsaw. In a thin zone at the top of the shales and below the sandstone or magnesian limestone as the case may be, there are found large quartz grains sometimes almost pebbly in character, while from one to three feet of the succeeding deposit is composed of clay and broken fragments of chert indiscriminately mingled and grading upward into magnesian limestone, where this is the overlying bed, in which irregular silicious masses are abundant at the base. The slight disturbances shown at this horizon have been observed at various places and would seem to indicate a slight degree of unconformity. White has asserted the existence elsewhere of unconformable relations between the Saint Louis and Keokuk divisions, and it may be that the slight discordance here noted is a phase of an erosion interval

exhibited in a more marked degree in other districts. An instructive outcrop of the formation occurs at the Sonora quarries on the Illinois side of the Mississippi river opposite Nashville. The beds are exposed for several hundred feet along the bluff and have been quarried extensively. At the south end of the quarry, ten to fifteen feet of the sandstone in massive beds underlies the brecciated limestone, as at Keokuk. Towards the north the brecciated limestone thins out, allowing the shales and sandstone of the Coal Measures to rest directly upon the Sonora sandstone which becomes more magnesian and in some places shaley as shown by the following section:

V. Sonora Quarry Section.

		FEET.
7.	Loess	10
6.	Clay and sand	4 to 8
5.	Shale, and sandstone, with a few inches of coal in disconnected basins	10 to 15
4.	Sandstone, blue	4
3.	Limestone, bluish, magnesian and arenaceous; banded with yellow, the whole weathering brown; arenaceous layers cross-bedded	15
2.	Shale, arenaceous, graduating horizontally into sandstone	4
1.	Limestone, magnesian, resembling 3, but less arenaceous and more vesicular and cavernous	4

All below 5 belong to the lower member of the Saint Louis and show an increase in thickness of nearly twenty feet within a distance of less than one-fourth of a mile. In some cases this formation becomes involved in the disturbance characterizing the brecciated limestone and thus loses its local individuality. This is well shown in the bluff below Croton.

The brecciated character is a very pronounced feature of the Saint Louis everywhere in southeastern Iowa. It

exhibits considerable lithological variation. The changes are from a mixture of limestone and sometimes sandstone fragments loosely imbedded in clay or firmly cemented by calcareous material, to a more or less quartzose sandstone. The latter phase has been observed in Van Buren county opposite Keosauqua. In Lee county it was seen at only one locality, on East Sugar creek. In general the division consists of ten to twenty feet of a fine white limestone breccia mostly in small fragments and firmly cemented together by calcareous matter similar in appearance to the limestone fragments themselves. Locally it assumes an increased thickness up to seventy-five feet, but loses its consolidated character and contains much clay in which fragments of the lower blue limestone and sandstone predominate below, while above the fragments are prevailingly white in color. In some cases the clay constitutes a large proportion of the mass but more often the limestone predominates and shows a somewhat rude and coarse stratification of the component fragments interstratified with thin undulating layers of limestone which adapt themselves to the irregularities and inequalities of the mass upon which they rest.

Occupying a position normally above the lower member of the Saint Louis, but usually separated from it by the brecciated division is a fine-grained, hard, white or gray limestone which breaks with a conchoidal fracture and bears a close resemblance to lithographic stone. In some cases it becomes granular or sandy in texture and then shows the cross-bedding and ripple marks of a littoral deposit. This character is especially pronounced in Lee county and is seen to good advantage at the Graner quarry and elsewhere on East Sugar creek; also near Donnellson and in the vicinity of Belfast, Croton and

Keokuk (figure 16). It lies immediately upon the brecciated limestone, in some places filling the irregularities in that stratum and is in its origin quite similar to that formation. However, it is evident from the manner in which the upper part of the brecciated and the fine-grained and granular varieties graduate into one another and also from their occurrence in the same stratigraphical horizon, that they are closely related in their mode of origin and constitute essentially the same formation.

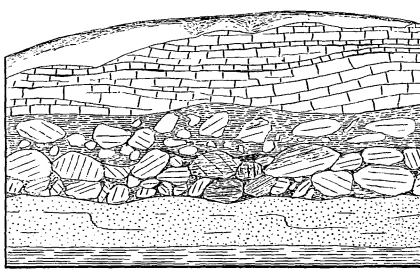


Figure 16. Base of the Saint Louis Limestone, Keokuk.

In the figure 16 number 1 represents the Warsaw shales; 2 is the Sonora "sandstone" a sandy magnesian limestone; 3 is a very compact brecciated bed; while 4 is similar but with a softer clay matrix. The breccia is made up of a very fine-grained, compact, blue limestone, which breaks with a conchoidal fracture. The fragments are angular and vary in size from a few inches to several feet. The interstices are filled with a clayey, calcareous material which is usually much softer than the

limestone, and in weathering allows the limestone boulders to project far beyond the matrix. Above the brecciated portion of this limestone the strata are laid down very irregularly, but upward rapidly pass into evenly bedded layers.

The thickness of the white limestone rarely exceeds twenty feet and more commonly not more than ten or twelve feet.

The most generally distributed fossil of the Saint Louis group is the coral *Lithostrotion canadense*, Castlenau. The remains of this organism are frequently found in the beds of the streams of Lee county, having been dislodged through the disintegration of the limestone. The fossil being completely silicified easily resists the agencies which have disintegrated the beds in which it occurs. In southeastern Iowa this form appears to be confined to the magnesian limestone and the brecciated beds. In the latter case they may have been derived originally from the magnesian limestone. Besides Lithostrotion the magnesian layers often contain abundant impressions of a Fenestella, *Spirifera keokuk* and *Productus semireticulatus*. They seem to be confined principally to the basal portion and are arranged in bands along which the rock is decidedly more magnesian than in other portions. The presence of the fossils may have exerted some influence in the segregation of the magnesia along these planes; or, on the other hand, the presence of magnesia may have preserved the fossils better here than in adjacent portions where this element is much less pronounced. The latter explanation seems to be favored (1) by the gradual transition from the fossiliferous to the non-fossiliferous portions and (2) by the finely vesicular character of the beds where no other evidence of the fossils can be detected and which

evidently is due to the remains of polyozoans (Fenestella) whose organic character has been almost entirely obliterated.

The clays of the brecciated limestone sometimes carry fossil forms, while the upper white limestone is usually marked by an abundance of well preserved organic remains.

The fine-grained limestones which have a conchoidal fracture, usually yield an abundance of *Spirifera keokuk*, Hall, *Rhynchonella ottumwa*, White, and *Productus semireticulatus*, Sowerby. At one locality, on Sugar creek, a bed somewhat intermediate in texture between the granular and fine-grained limestones yielded numerous specimens of *Bellerophon gibsoni*, White, associated with Allorisma, *Zaphrentis pellaensis*, Worthen, and *Productus semireticulatus*, Sowerby.

Upper Carboniferous.

Lower Coal Measures.—These deposits occur principally in three disconnected areas, two of which seem to belong to the main eastward extension of the rocks of this horizon on the west and northwest; while the third is an isolated basin dissected by East Sugar creek and occurs in the interior of the county. There are besides several small areas in the southern part of the district. As elsewhere along the eastern border of the formation in Iowa the Coal Measures occur in basin-like depressions in the Saint Louis limestone, to which circumstance some of the smaller outliers doubtless owe their preservation. Along the Des Moines river the exact limits of the area covered by this formation have not been definitely made out, as the only exposures occur in the immediate vicinity of the

stream. At Croton about fifteen feet of the basal sandstone caps the bluffs, while farther north and west, near Farmington, coal has been mined just outside the county limits.

In lithological characters the Coal Measures differ very much from the other formations with which they are associated. Instead of being made up chiefly of limestone or calcareous shales, as is the case of nearly all of the other strata of the region, the coal-bearing strata are composed almost entirely of soft clay-shales and friable sandstones. In contradistinction to the shales occurring with the limestones the former deposits are as a rule much darker in color, even black, though often light-colored clays are present, especially immediately beneath the coal beds where the white fire-clays are found. In other parts of the Iowa coal field the shales vary greatly in color from pure white to black, yellow, drab, blue and red. Often all of these are intermingled forming what are termed variegated shales. Most of these shales carry more or less fine grit which frequently becomes so abundant as to form sandy shales or even shaly sandstones. In Lee county the Coal Measure shales are largely blue or drab in color; and these beds form by far the greater part of the formation. They occur in considerable thickness and are of wide geographical extent. Difficulty, however, is encountered in attempting to trace the different layers for any considerable distance on account of their tendency to break down readily into plastic clays in which all traces of stratification are lost at once.

The sandstones of the Coal Measures are commonly fine-grained, rather friable, and yellow or brown in color. Occasionally very fine white sandrock occurs; but these beds are usually quite limited in extent and are only a few

feet in thickness. The sandstones as a rule show marked cross bedding which is made more pronounced in weathering (figure 17 represents the base of the sandstone shown in plate xxx).

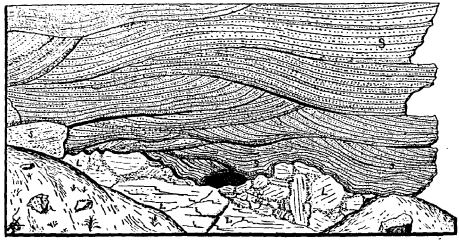


Figure 17. Cross-bedding in Coal Measure Sandstone above the Line of Unconformity.

More specifically the Coal Measures as exhibited in Lee consist of a basal member of coarse, brown, quartzose sandstone somewhat micaceous in places, which is replaced locally, in whole or in part, by brown sandy and dark argillaceous shales, the latter underlain by a bed of coal. The transition from sandstone to shale is often abrupt as is seen in the bluffs above Rand park at Keokuk, where the sandstone is reduced to a few feet in thickness, the shale with a thin bed of coal replacing the upper portion of the bed as shown by the accompanying diagram. Number 1 is the white

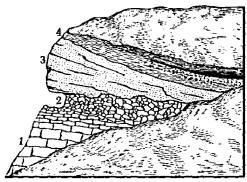
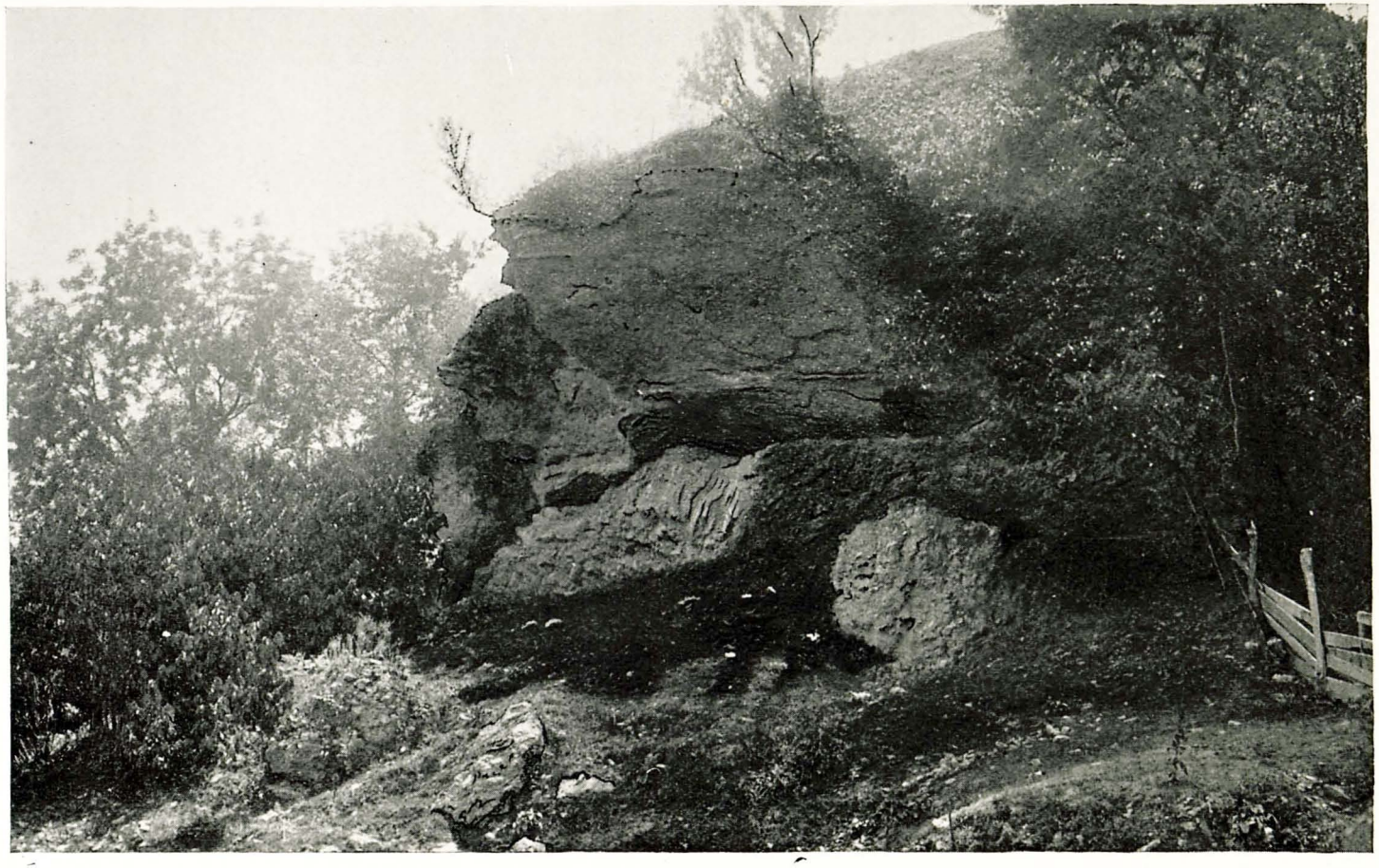


Figure 18. Shale Replacing Sandstone. Keokuk.



COAL MEASURES RESTING UNCONFORMABLY ON SAINT LOUIS LIMESTONE; KEOKUK.

Saint Louis limestone; 2 the brecciated bed; 3 the Coal Measure sandstones; and 4 the shale with a thin bed of coal. A photograph of the line of unconformity between numbers 2 and 3, the Lower Carboniferous and Coal Measures is represented in plate xxx.

The irregular character of the upper surface of the Lower Carboniferous (numbers 1 and 2) is also seen at the Sonora quarry. (Figure 19.)

Usually no other Coal Measure rocks have been found overlying the thicker deposits of sandstone; but in the basins the coal is usually overlain by black fissile layers or

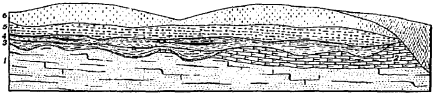


Figure 19. Unconformity of Coal Measures and Saint Louis Limestone. Sonora Quarry.

arenaceous shales. The sandstone frequently extends under the coal and the light-colored shales though diminished in thickness are usually more or less sandy.

Few fossils have been observed in the coal-bearing strata of the county. The following species were obtained from the shale overlying the coal at Keokuk:

Athyris argentea, Shepard.
Productus longispinus, Sowerby.
Streptorhynchus crassus, Meek & Hayden.
Lophophyllum proliferum, McChesney.

The coal beds of Lee county are somewhat limited as compared with the districts lying to the west. Deposits of considerable value have been worked to some extent and others of equal or greater importance doubtless still

await development. In thickness the coal seams vary from one and one-half to three feet. A detailed description of the coal and its workings will be found in another place.

Pleistocene Deposits.

Within Lee county there are no deposits which represent the long period of time intervening between the deposition of the Lower Coal Measures and the beginning of the ice age. If later Coal Measure, Mesozoic or Tertiary strata were laid down over the region they were entirely removed by erosive agencies before glacial times. It is quite evident that the rocks of the Coal Measures at least were deposited in considerable thickness over this part of the state and were connected with the now separated Carboniferous fields of Iowa and Illinois. Something of a measure of the enormous erosion to which the rocks of the region have been subjected is seen in the extensive buried river channels which are described farther on. Upon the rock surface thus gashed and trenched, rest the clays and silts of the Pleistocene period, filling up the depressions and raising the whole surface to a nearly uniform level. The even plain thus formed has a general southward slope, with a secondary inclination toward the Mississippi river. Upon this even plain subsequent drainage has effected various changes but it has not yet destroyed the general relief of the original slightly tilted surface.

The superficial deposits of southeastern Iowa may be classed as (1) Lower Till, (2) Loess and (3) Terrace deposits.

LOWER TILL.

The Lower Till of the region comprises an inferior division of blue boulder clay, varying from a few feet to

two hundred feet in thickness; and a superior portion comprising thirty to seventy-five feet of yellow clay.

Blue Boulder Clay.—This deposit consists of blue clay filled with boulders of various kinds, those of crystalline rocks predominating, though limestone masses also occur. The boulders are generally rounded or subangular and often striated; those with sharp edges showing little if any abrasion are not rare. On the higher levels where the indurated rocks lie near the surface, this deposit is thin or absent. It constitutes the larger part of the filling of the preglacial depressions, however, and exhibits a thickness of fully two hundred feet in the old channel of the Mississippi. In this channel a bed of sand was found in the Mount Clara well, below the blue clay which may represent an old terrace deposit. Beds of sand occur at intervals in the clay in irregular deposits which often constitute the source of water supply of wells on the upper levels.

At Fort Madison bluffs composed entirely of drift capped by loess rise directly from the water's edge. The blue clay constitutes about sixty feet of the nearly vertical embankment, and imbedded in it are numerous fragments of wood. Deep wells also sometimes show considerable quantities of vegetal matter, chiefly wood, enclosed in this deposit. Pieces of the wood taken from the clay were submitted by Mr. C. H. Gordon to Prof. D. P. Penhallow, of McGill University, for identification. He replied that "the material included two genera and probably three species. The best preserved specimens proved to be of the genus Larix (Larches) and from the close specific agreement with *L. americanus*, as well as the recent age of the deposits in which it was found I have no hesitancy in referring them to that species. The second is an

undoubted Taxus though it differs from any modern Taxus with which I am acquainted, in having a number of very small resin passages, and fusiform rays. Otherwise it agrees almost exactly with our modern *Taxus canadensis*, to which I would provisionally refer it in the hope that better material at some future time may serve to clear up the points in doubt. The third is, I think, also a Taxus, but of this I cannot be certain. It clearly differs specifically from the former and the best we can do is to refer it provisionally to that genus."

At Keokuk along the bluff between Main street and the mouth of Soap creek a bed of boulders with some sand and clay rests upon the shales of the Geode bed. The deposit is about fifteen feet thick and the top is sixty-five to seventy feet above the river. Resting upon it is a loess-like deposit. The boulders comprising the bed are of all sizes up to two feet in diameter and are cemented together in places forming a somewhat incoherent conglomerate. The relations of this deposit are as yet imperfectly understood but it is thought to represent a much later stage in Pleistocene history than that of the blue clay. A similar accumulation has been found at one or two other points within the county.

Yellow Boulder Clay.—Above the blue clay is a yellow deposit of somewhat similar character lithologically which also contains rounded and striated boulders. In neighboring places this clay shows faint traces of stratification though no indications of this character were observed within the limits of Lee county. Its differentiation from the lower division is marked chiefly by its color and the character of its boulders which are prevailingly limestones and chert though crystalline rocks are also common. The limestones are often smoothed and striated, all the marks

DRIFT DEPOSITS AT KEOKUK.

appearing fresh and distinct. At the "Yellow Banks" on the Des Moines river, twenty-five feet of sand are seen resting upon the blue clay and over this fifteen feet of silty clay, dark above and overlain by eight feet of yellow clay which in turn is capped by a thin veneer of loess. The sand varies in places to a fine gravel and along the east bank of West Sugar creek near the mouth of the stream it passes into a coarse incoherent sandstone. There is a sharp line of demarkation between the blue clay and the "sandstone" and along the juncture iron charged waters ooze out and fall into the creek below. Whether the relations of this sand bed are with the yellow clay or whether the arenaceous layer represents an independent stage intermediate between the two clay deposits is not clear though some considerations seem to favor the latter view. Generally the yellow clay contains much sand as is well shown along the Chicago, Santa Fe and California railroad where it cuts through the main divide. The surface of the clay is usually highly oxidized and often a line of pebbles marks its line of separation from the overlying loess. The clays are usually cut vertically by sheets of lime from one-fourth to three-fourths of an inch in thicknes. Hollow concretionary nodules of lime are abundant in some places but rare in others. They vary in size from one-half to one inch in diameter and when broken show cracks and crevices on the inside, apparently due to shrinkage. These nodules are typical "loess kindchen" which have long been held to be distinctive of the loess. In southeastern Iowa and northeastern Missouri, however, they are abundant in places in the upper part of the yellow clay and are but sparingly distributed in the loess itself. This may therefore indicate a genetic relationship between the two formations.

LOESS.

This deposit consists principally of a fine, ash-colored silt. It is distributed quite uniformly over the entire area under consideration, varying in thickness from a foot or two up to fifteen feet. Over the greater portion of the district the material does not average more than four to six feet. Along the line of the Chicago, Santa Fe and California railway in the vicinity of New Boston it has a development of fifteen feet. The lower portion is more friable than the upper, and in some cases appears to be somewhat marly at the base. At Keokuk the boulder accumulation already referred to is overlain by stratified white and ferruginous sand grading upward into typical loess. (See plate XXXI.) The thickness of the silt and stratified sand is about thirty feet.

On Soap creek there is an interesting exposure, showing the following:

Section on Soap Creek at Seventh Street, Keokuk.

		FEET.
6.	Loess, fine, ash-colored, retaining a vertical face in excavations for a long time.....	14
5.	Sand, coarse, red, mixed with clay; bands of chert fragments near the middle quite continuous along the face of the exposure.....	6
4.	Sand, fine white, banded with thin layers of red sand quite firmly cemented by iron oxide.....	4
3.	Sand, fine, yellow, more compact.....	3½
2.	Clay, yellow and blue, containing boulders.....	2
1.	Boulders, sand and gravel, resting upon the geode bed below.....	5

The deposits represented by the above section have generally been referred to the loess formation though some doubt has been entertained as to the correctness of this reference. In the study of similar depositions along the Missouri river Todd has considered that much of

what has heretofore been regarded loess is actually a high terrace formation; and facts gathered in Lee county seem to confirm this conclusion, though additional study is needed to settle the question definitely. This statement, however, applies only to those deposits adjacent to the Mississippi and its tributaries; as no doubt exists as to the blanket of loess which is found in the interior of the county. The iron stained sands exhibited in the section (4 and 5) are sometimes developed in such force as to give the bluffs a characteristic redness.

TERRACE FORMATIONS.

Well marked terraces are found in the alluvial plains flanking the Mississippi river above Montrose and the Des Moines below Sand Prairie. Above the first named place these structures rise successively from the river level to a height of about fifty feet. They consist of ridges of water-worn sand, sometimes marked by the whitened, decomposing shells of mussels, like those living in the neighboring streams.

At Fort Madison, the bluff already mentioned as composed entirely of superficial deposits has a bed of sand apparently resting, as shown by excavation, on the blue clay at an elevation of fifty feet above low water-level. This evidently corresponds to the highest terrace observed in the alluvial plain below and is correlated with it. Cut terraces are well shown along the same river bank between Montrose and Keokuk.

GEOLOGICAL STRUCTURE.

GENERAL RELATIONS OF STRATA.

Although the geological structure of Lee county is comparatively simple as regards deformation there are

some very decided stratigraphical complications arising from irregularities of deposition. With two exceptions all of the various beds lie conformably upon one another, in regular sequence. For the most part the inclination of the strata is slight, usually so little as not to be perceptible. The general dip is southward; on an average about ten feet to the mile. The total declination across the county is therefore something over two hundred feet. But notwithstanding the fact that the geological structure on the whole is not very complex there are considerations to be taken into account which are of the greatest importance economically and at the same time of extreme interest scientifically.

GEOLOGICAL CROSS-SECTIONS.

Mississippi River Section.—The description of the lithological characters of the different vertical sections along the Mississippi river has already been given. While the strata have a general dip to the southward the inclination is not uniform. Toward the northern end of the section the slope is much greater than anywhere else and the constant lowering of the successive beds in passing down the stream is quite noticeable. The Keokuk limestone which occupies the very summit of the bluffs near the Skunk river comes down to the water-level at Fort Madison; that is, it falls nearly one hundred and fifty feet in a distance of seven or eight miles. From Fort Madison to Keokuk the dip closely appproaches horizontal, the general slope being very nearly the same as that of the river. This arrangement is shown in the rather detailed section along the Mississippi river represented in figure 2, plate XXVII. The inclination of the beds to the south in Lee and Des Moines counties is met, in north-

eastern Missouri, by a similar slope in the opposite direction. A broad shallow syncline is the result. The maximum depression is in the neighborhood of the city of Keokuk, for which reason it is known as the Keokuk syncline (figure 20). The economic importance of the recognition of the synclinal depression will be at once apparent when it is remembered that the particular structure represented by it is one of the leading factors in the securing of successful flows of artesian water.

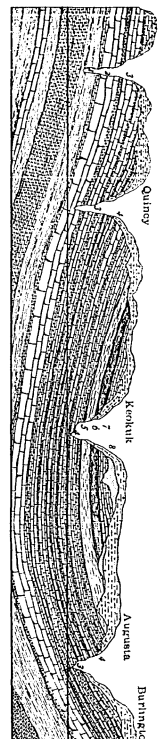


Figure 20. The Keokuk Syncline.

Skunk River Section.— Measurements along this stream, where the outcrop of the various strata may be readily traced, show that there is a considerable inclination of the beds to the west. The Upper Burlington layers which cap the hills at the east in Des Moines county are brought to the water-level at Augusta, the distance being not over four or five miles. This would seem to indicate a dip to the west of about ten or twelve feet for this short distance. But in taking into consideration the average inclination for the entire distance from the mouth of the river to where it

enters Henry county the actual slope is not more than eight feet to the mile. This, however, is made more pronounced by the fall of the stream of about four feet per mile, in the opposite direction; making in all an apparent dip of about twelve feet in the same distance.

Des Moines River Section. — As in the Skunk river section the direction of the Des Moines gorge is nearly at right angles to that of the Mississippi. The general dip is very slight indeed and directly opposite to the course of the stream. The gradual rise in the river bed in passing westward brings the different layers successively to water-level sooner than would otherwise be the case.

DEFORMATION OF STRATA.

Deformation or the warping of the rock layers on account of the working of dynamic agencies analogous to those which act in raising mountains are nowhere very marked within the limits of the district. The larger folds, the principal expression of which is represented by the Keokuk syncline (figure 20), are very broad with comparatively small amplitudes. By reference to the geological cross-sections the details are readily made out. The greatest inclination observable is in the Mississippi section which runs northeast and southwest. Dips in the other two principal cross-sections are relatively slight so that the inference may be drawn that the trend of the trough is nearly northwest and southeast with a veering to the south.

The minor undulations cannot be traced very far from the points of first observation. For the most part they are unimportant.

UNCONFORMITIES.

The most marked irregularties in the relationships of the different strata are several well marked unconformities. Nearly all the stratified rocks exposed in Lee county represent an uninterrupted sequence of deposition. A notable exception is in the case of the Saint Louis limestone and Coal Measures.

Coal Measures and Saint Louis Limestone. — The pronounced discordance in sedimentation between these two formations in southeastern Iowa is shown at various localities. In the bluff at Keokuk, above Rand park, the unconformable relations are especially well exhibited. The basal sandstone of the Coal Measures is a coarse, brownish sandrock resting immediately upon a very uneven surface of the brecciated limestone of the Saint Louis. At the bottom the sandstone presents marked irregularities in bedding as is shown in figure 17. Towards the top the stratification becomes more even and regular.

A still better exposure showing the phenomena is seen at the Sonora quarries, opposite Nashville. It is represented in figure 19.

The Saint Louis limestone in southeastern Iowa has been shown to have great irregularities in its surface. In some cases this is evidenced by the appearance of Coal Measure rocks below the level of the limestone in adjacent exposures. This irregularity is manifestly due to erosion, coupled with the structural peculiarities of the brecciated limestone. This fact has sometimes given rise to a popular misapprehension as to the relations of the two formations, and has caused a fruitless search for coal deposits in positions where they could not possibly occur.

Drift and Indurated Rocks.—It is well known that the mantle of glacial débris which spreads over all Iowa,

hiding the hard stratified rocks from view, has everywhere unconformable relations with the underlying strata. Illustrations of the phenomenon are so common that they attract but little attention. In Lee county there are some features which are especially interesting in this connection and they therefore demand more than passing mention. In the long interval succeeding the close of the Carboniferous, the area, of which Lee is only a small part, was elevated above sea-level for a considerable period of time, as is evidenced by the extensive denudation and channeling which has taken place in the rock surface. It has already been intimated that the Coal Measure rocks and possibly other later formations originally extended over the whole of this region. As to the thickness of the beds removed, and hence the extent of the general denudation there can be only a rough surmise; but that it was considerable is quite manifest.

Among the most noteworthy features to call attention to is the existence of drainage valleys and the general character of the ancient land surface. Though the data with reference to the channels beneath the drift is still far from complete, sufficient evidence has been gathered to indicate the existence of at least two profound gorges representing the former locations of the Mississippi and Des Moines rivers, with traces of other lesser channels which were in all likelihood tributary to these. The great development of glacial material along the west bank of the Mississippi above and below Fort Madison was long ago noticed. The location here of an old channel of the Mississippi was first made known some years ago by Major G. K. Warren, and more recently the position of the same buried channel was discovered and determined independently by Mr. C. H. Gordon, whose results agreed in all essential

respects with the earlier work. From data gathered by him the previous observations were not only confirmed but the extent and depth of the valley was calculated closely. The location of the former course is indicated upon the accompanying sketch (figure 21).

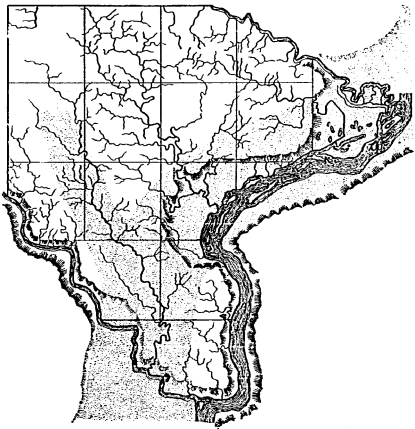


Figure 21. Preglacial Channel of the Mississippi River.

Between the mouth of the Skunk river and Montrose the old channel coincides with the present valley of the river which has been partly re-excavated along the eastern margin of the older valley. From Montrose it sweeps with a broad westward bend to the Des Moines river which crosses it below Sand Prairie. The comparatively narrow

rocky gorge within which the river now flows from Montrose to Keokuk is itself suggestive of its more recent origin than the broad valleys above and below bordered for the most part by drift-covered slopes. Along the western bank, above Montrose, rock exposures are only seen on Lost creek, about one and a half miles west of Wever; on East Sugar creek, west of Viele, at the crossing of the Burlington and Kansas City railroad, and in the northwestern part of Charleston township well back from the bluff on Painter creek. These points are taken to indicate the limits of the channel here. Westward from Keokuk the indurated rocks disappear just above the railroad bridge over the Des Moines and do not again appear in the bluffs until Sand Prairie is reached. A further surface indication of the existence of the channel between Montrose and Sand Prairie is seen in the crescentic alluvial plains found at these points, the former of which is a result of the efforts of the Mississippi river to recover its old channel; and the latter apparently due to the agency of the Des Moines.

Several deep wells put down recently at Fort Madison all agree in indicating a great thickness of clay and sand below the present river level. The thickness of this deposit varies from 175 to 190 feet according to the location of the well, and when reduced to sea-level shows the rock bed to lie at an elevation above tide of 365 to 380 feet. A few miles southwest of Fort Madison, at Mount Clara, where the elevation of the surface is 679 feet, a boring put down showed the rock bottom to be 364 feet above tide level. As the extent of the channel indicates an advance stage in base leveling, the slope of the river bed from Fort Madison to Mount Clara should be slight, and this seems to be borne out by the figures except in the

case of the well at the paper mill which shows an elevation of 379 feet for the rock bottom. At Montrose, which is only two miles northeast of Mount Clara, the low water mark of the river is 500 feet above tide. The bottom of the old course, therefore, is 136 feet below present low water level, or about 130 feet below the bottom of the new channel.

The width of the ancient channel is about six miles, which is about the size of the present rock-gorge which the stream now follows in the revived course above Fort Madison. The river in preglacial times probably did not exceed its present dimensions at least very greatly, and after cutting down its channel in its early history, its subsequent efforts were directed to widening the valley in which it alternated from side to side until it reached the limits indicated upon the map. The accompanying cross-section from Sonora to Argyle (plate XXVIII, figure 2) illustrates the relative sizes and positions of the two channels.

COAL.

Lying on the extreme eastern margin of the western interior coal field, Lee can never be expected to rank among the important coal producing counties of Iowa. At the same time the coal deposits, though necessarily limited, are sufficiently large to be of considerable commercial value; and supplies for local demands and even shipment may be furnished. For many years mining has been carried on in a rather desultory manner; and the veins still continue to be worked from time to time. The principal places where coal is now known to exist in workable thickness are in the northern part of the county near the

center of Pleasant Ridge township and in the northeastern portion of Franklin township; also in the extreme southern part of the district a short distance both north and west of the city of Keokuk.

Pleasant Ridge Township.— Coal Measure rocks cover the greater part of the northern two-thirds of this township. They form a portion of the area which extends northward through southern Henry county. The chief openings in this district are those which have been made on Sutton creek, about five miles northwest of Denmark and a couple of miles from the Skunk river (Tp. 69 N., R. V W., sec. 16, NE. qr., NE. ¼). The coal is obtained both by drifting and stripping. Formerly considerable quantities were mined, the output going chiefly to West Point and the surrounding country. Among the old openings the Norris mine was perhaps the best known. At the present time none of the places are worked systematically, the local supplies being obtained chiefly by desultory stripping along the creek bottoms where the coal is two and one-half feet or more in thickness.

Two miles to the eastward (sec. 14, NE. qr., NW. ¼) coal has been obtained for years to supply local demands, but none of the openings are now operated. An outcrop near the road shows the following section:

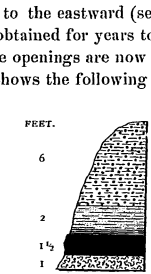


Figure 22. Outcrop northwest of Denmark.

Along the creek near by, sandstone, shales and the Saint Louis limestone are exposed at a somewhat lower level. The coal bed has a very appreciable dip to the west and probably thickens in that direction. The probability of a basin of considerable extent is also shown by the fact that coal has been taken out just west of the township line and a short distance east of the village of Saint Paul.

Marion Township.—There are in this township two areas of Coal Measure deposits which are separated from each other by a broad belt of older rocks. The principal opening is the Stevenson mine a short distance east of Saint Paul (Tp. 69 N., R. VI W., sec. 14, SE. qr., SE. ¼). Like many of the other mines of the county it is only operated at irregular intervals, usually during the winter. About a mile directly south a thin seam crops out in the bed of a small ravine. Overlying it are several feet of black shale and light-colored clay. Three miles southwest of Saint Paul (sec. 33, SW. qr., SW. ¼) is a small shaft which has supplied considerable coal for local use.

Franklin Township.—About four-fifths of Franklin township is occupied by the Coal Measures; and coal has been mined at a number of places. The most extensive mining in the county has been done here and the thickest seam so far found in this region has been opened.

Two miles from West Point coal has been obtained in small quantities for many years. Above the road leading directly west from the town recent washouts have exposed a vein of coal varying from one to two feet or more in thickness, and underlain by a good fire-clay (Tp. 68 N., R. VI W., sec. 1, NE. qr., NW. ¼). One and one-half miles south, in the valley of a small branch, are the abandoned workings of a mine which formerly was operated to satisfy local demands.

Three miles to the west, on Sugar creek, or about five miles from West Point and one mile northeast of Denver postoffice there are several openings. The most important mine is the old Hardwick (Tp. 68 N., R. VI W., sec. 4, NE. qr., NE. $\frac{1}{4}$). It was formerly worked by means of a shaft, which is now abandoned; and the coal is now reached by a drift in a ravine. Coal was at one time taken out of this mine in sufficient quantities to afford abundant local supplies. The vein dips to the south and west and is said to be from three to three and one-half feet in thickness. The relation of the shaft to the drift is indicated in the accompanying cut (figure 23).

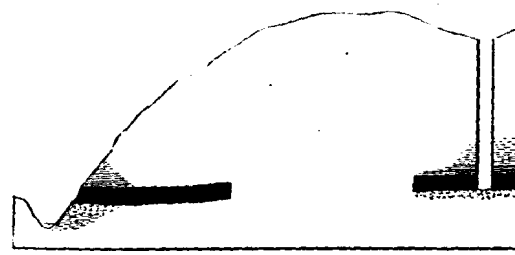


Figure 23. Relations of Drift and Shaft Openings at Old Hardwick Mine.

The details of the section at the mouth of the opening of the drift are:

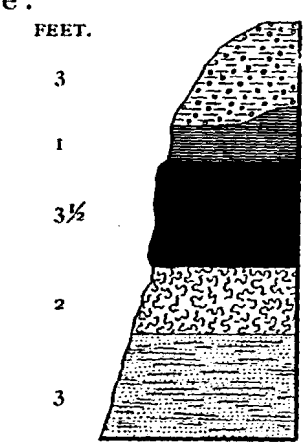


Figure 24. Coal Bed at Old Hardwick Mine. Near West Point.

A mile directly south of the Hardwick mine several openings have been made at various times on a tributary of Sugar creek (sec. 10, NW. qr., NW. ¼), where the following section was measured, the lower half being the the Saint Louis limestone.

Section, Northeast of Donnelson.

		FEET.
8.	Drift	10
7.	Coal	2
6.	Fire clay	2
5.	Sandstone, soft, quartzose	5
4.	Limestone, coarse, irregular, fossiliferous	2
3.	Shale, calcareous	1
2.	Limestone, fine and shaly	3
1.	Limestone, sandy, thinly bedded (exposed)	8

Coal is said to occur also to the north in section 3, (northwest quarter) and directly southward in section 15 (southwest quarter).

Van Buren Township. — Although the Coal Measures are known to occupy fully one-half of the surface of the district no mining has been carried on. On the opposite side of the Des Moines river, in Missouri, several mines were formerly in active operation. In Van Buren county, within half a mile of the Lee boundary, coal is also being taken out in considerable quantities and the same seam doubtless extends eastward into Lee county.

Jackson Township.—In the vicinity of Keokuk the principal places yielding coal are below the city, above Nassau slough.

A section near one of the openings is as follows:

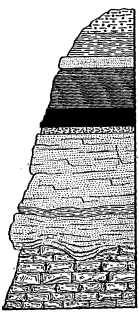


Figure 25. Section at Top of Bluff on Mississippi River at Nassau Slough. Below Keokuk.

		FEET.
8.	Drift	2
7.	Shale, blue, argillaceous (exposed)	2
6.	Sandstone, ferruginous, irregularly bedded.	1
5.	Shale, dark, fissile, many small concretions.	3½
4.	Coal, thickening slightly northward	1½
3.	Fire clay	½
2.	Sandstone, variable in thickness, with irregular bands of clay shale, resting unconformably upon the next	10
1.	Limestone, gray, compact, brecciated (Saint Louis formation)	5

Below number 1 of the above section the full thicknesses of the Saint Louis limestone, the "Warsaw," the "Geode" bed, and part of the Keokuk limestone are exposed. The coal mined here is of very good quality. It has been worked at different times during the last thirty or forty years. No coal, however, appears to have been taken out during the past three or four years.

North of the city, in the bluffs near Rand park, coal was formerly mined by means of drifts. Very little coal was taken out at this point, and the entry is at present blocked or filled by débris from the fallen roof. The position of the coal bed at Rand park is shown in figure 18.

A short distance away, at the place where the coal was mined at one time, the section is:

		FEET.
6.	Drift	20
5.	Shale, dark colored	6
4.	Coal	1½
3.	Fire clay	½
2.	Sandstone, brown, coarse grained	10
1.	Limestone, brecciated (Saint Louis), exposed	8

Six miles to the north, near Nashville in Montrose township, there is a small isolated basin of Coal Measure sandstone, on the crest of the bluff; but no coal is known to be associated.

BUILDING STONES.

Lee county is well supplied with stone suitable for all ordinary constructional purposes. Nearly the entire county is underlain by the Lower Carboniferous limestones, every member of which affords a good grade of stone. Although the limestones vary greatly in quality and texture in the different parts of the county, those supplied by each geological formation may be readily distinguished from that yielded by every other.

The Burlington beds are made up largely of an encrinital limerock, that is, it is a coarse-grained, somewhat crystalline limestone formed almost entirely from the skeletal remains of crinoids, cemented by fine lime material. In color it varies from a brown to a pure white. It is very durable and may be used for all constructions, including those which are especially exposed to weathering influences. The rock is easily quarried and readily dressed. The thick ledges may be used for dimension work of all kinds.

The Keokuk limestone is, as a rule, a compact, rather hard, often sub-crystalline rock, of an ashen or bluish color. Its fracture is even, sometimes however, approaching conchoidal; although often encrinital it is rarely so markedly sub-crystalline as the Burlington. The more pronounced encrinital parts are usually confined to particular layers and do not make up the bulk of the formation, as in the case of beds immediately beneath. The quarry rock of the upper part of the Keokuk, often called the Warsaw, is chiefly a magnesian limestone, containing some sand and fine pebbles. It is generally called "sandstone." The principal quarries in it are at Sonora, on the east side of the Mississippi, and it consequently goes under the name of Sonora sandstone. It is a massive layer six to twelve feet in thickness, bluish or yellowish when first taken out, but after exposure to the weather for a time turns to a buff or brown. It is very durable. Buildings in Keokuk erected of it nearly half a century ago have still the tool marks preserved nearly as fresh as the day when made. For dimension work it is largely used; and wherever dressed stone is required. The Westminister Presbyterian church, several large residences and other buildings have been constructed of this stone; besides the sills and caps of a large number of other structures. It has also been used for bridge piers, dam locks and other works of a similar character, where great durability is required.

The Saint Louis white limestone differs from all the other quarry rocks of the county in being a fine-grained compact limestone breaking with a very marked conchoidal fracture. Usually the color is bluish or gray. Some layers are very similar to lithographic stone and have been used for this purpose to some extent.

The sandstones are more or less ferruginous, coarse-grained and massive. They are rather soft, but usually sufficiently indurated to be a fairly good grade of stone when carefully selected. The sandstones are all Coal Measure deposits. The so-called Sonora "sandstone," as already remarked, is in reality a buff limestone with siliceous grains scattered through it.

Jackson Township.—By far the greatest amount of quarrying in the county is carried on in and about the city of Keokuk. The principal places where quarries have been opened are along the Mississippi river at the base of the bluff, along Soap creek in the western part of the city, and in the northern part of the city above Rand park.

The blue limestone of the Keokuk affords the greater part of the quarry work, but the Warsaw beds of Hall and the Saint Louis also furnish considerable material. The Coal Measures supply a small amount of soft sandstone. A considerable quantity of stone is shipped away both by river and by rail. The transportation facilities are exceptionally good; for in addition to the waterway, several lines of railroad enable the output to be distributed in all directions. The Chicago, Rock Island and Pacific, the St. Louis, Keokuk and Northwestern, the Keokuk and Western, the Keokuk and Northwestern (a part of the Burlington system), and the Toledo, Peoria and Western (a branch of the Wabash system), all afford means of reaching good markets.

In the eastern part of the city of Keokuk small openings have been made for a distance of two or three miles along the river bluff. The principal quarries are, however, below the Union railroad station.

Near the Chicago, Rock Island and Pacific freight depot, on the corner of Timea and Water streets, is the

McManus and Cameron quarry, which has been opened in the Keokuk limestone. The rock is used chiefly to supply local demands, though some stone is shipped west into Iowa and Missouri for a distance of fifty to seventy miles. The local supplies are about equally divided between macadam and building material; some broken stone for riprap along the river is also furnished.

A short distance below is the quarry of Kelley Brothers, near the St. Louis, Keokuk and Northwestern freight depot. The stone is used chiefly for building purposes and macadam, though during the past two or three years the quarry has not been worked much.

Still farther west, beyond the mouth of Soap creek, and between H and G streets, is the new city quarry, which has been opened scarcely a year. The stone is used principally for macadam, for foundation walls and the construction of street gutters. During the first ten months of the present year about 5,000 yards of macadam were taken out. Ten quarrymen and five teamsters are employed.

Near by is the Coyle quarry. Much of the rock taken out is for macadam, though most of what is known as the "white ledge" is used for building purposes.

In the vicinity of the planing mill, and a short distance beyond the Coyle place, is the newly opened Harris quarry, employing for eight months in the year from two to twenty-five men. The rock is loaded directly on the cars and shipped chiefly to points west along the Chicago, Burlington and Quincy system.

Still farther westward, in Nassau addition, and a short distance west of the Rand lumber yard, is the Tigue quarry, which is one of the oldest openings in the vicinity. It has been in operation for more than thirty years. The section shows:

		FEET.
4.	Drift	8
3.	Limestone, thinly bedded, with considerable calcareous shale	6
2.	Limestone, more massive than 3	9
1.	Limestone, rather sandy, with shale partings (exposed to railroad track)	14

This is near the location of the old McGavic mill. A complete section of the bluff at this point is given as one of the standard sections for Lee county.

A short distance to the west, within half a mile of the railroad bridge crossing the Des Moines river, is the "sandstone" quarry of Tigue & Son. The stone is the massive Warsaw magnesian limestone, which contains some grit in the form of fine grains and small rounded pebbles of white quartz. The output is almost entirely for bridgework and sills.

In the western part of the city of Keokuk, along Soap creek for a distance of fully one mile, quarries have been opened at a number of points, the principal openings being near the Seventh street bridge. The section of the rock exposure near the mouth of Soap creek has already been given.

Below Seventh street is the Conroy quarry, situated on the east side of the creek. The output is chiefly macadam and material for foundations. A short distance above, near the corner of Eighth and Cedar streets, is the McManus and Tucker quarry. The stone is used chiefly for foundations. From fifteen to twenty car loads are shipped annually over the Chicago, Rock Island and Pacific railroad. The section at this point is as follows, number 1 being used chiefly for dimension work:

		FEET.
5.	Shale, disintegrating	2
4.	Shale, calcareous, bluish, with thin limestone bands.	6
3.	Limestone, heavily bedded, rather coarse-grained, dark, somewhat encrinital, with some chert	4
2.	Shale, drab, with thin bands of limestone	3
1.	Limestone, heavily bedded, generally sub-crystalline (exposed)	8

On the opposite side of the creek is the Coyle quarry, which works in practically the same layers as shown in the McManus and Tucker section. Only about three or four feet of lower limestone is taken out, the chief supply being from the central encrinital limerock.

There are other small quarries along Soap creek which are worked in a desultory manner for local supplies of foundation stone.

In the northern part of the city of Keokuk, near Rand park, several small openings have been made in the Saint Louis limestone, which at this point supplies a rude flagging that is used largely for sidewalks and street crossings. The stone splits readily in layers two to five or six inches in thickness and slabs several feet square may be readily obtained. The vertical extent of the bed is about fifteen feet. The principal place from which stone is taken out is at the Fowler quarries, which are located on both sides of a small, deep ravine near the crest of the bluff, about three-fourths of a mile directly northwest of the park. The section shows:

		FEET.
5.	Limestone, gray, flag-like, in layers 2 to 5 inches thick, irregularly bedded	10
4.	Limestone, compact, fine-grained, brecciated, with much green clay between the fragments	6
3.	Limestone, very hard and compact, brecciated, but finely cemented	2
2.	Limestone, buff, massive, sandy and somewhat magnesian	6
1.	Shale, blue (exposed)	2

Three miles above the city, near the mouth of Price creek, is the McManus and Cameron "sandstone" quarry. The rock is the seven-foot ledge of the sandy, magnesian limestone which occurs at the top of Hall's Warsaw. The opening has only recently been made; and the rock is used

chiefly for caps and sills and the foundations of the better class of buildings. Near the quarry the section is:

		FEET.
5.	Drift	10
4.	Shale, calcareous	3
3.	Limestone, gray, somewhat arenaceous at the top	15
2.	Limestone, dark blue, with some chert	4
1.	Limestone, gray (exposed)	2

Des Moines Township.—In the eastern part of the township there are no exposures of rock suitable for building stone. Along the Des Moines river the first outcrop met with is in the vicinity of Sand Prairie. A mile west of the station the Saint Louis limestone crops out in several of the ravines opening into the Des Moines valley, and from these stone is sometimes taken out for local use. One-half mile above Hillsdale is the Deamude quarry, which is worked chiefly for the Chicago, Santa Fé and California railroad. The section shown is:

		FEET.
6.	Clay, yellow above, gray below	6
5.	Limestone, brecciated in pockets of green clay, sometimes rudely and coarsely stratified	30
4.	Limestone, blue, encrinital	3
3.	Shale, blue, calcareous	3
2.	Sandstone, blue, calcareous, with discontinuous beds of blue shale, the principal quarry rock	8
1.	Shale, blue	15

The stone is used largely for bridge work; the rubble and small sizes are made into material for concrete. From fifteen to twenty men are employed; and the Chapman steam drill is used.

In the same vicinity is another quarry which has been opened by the Chicago, Rock Island and Pacific railroad. In the northwestern part of the township, a short distance below Belfast, is the McEwer quarry (Tp. 66 N., R. VII

W., sec. 1, SW. qr.). The stone is the same as the Deamude quarry farther south and is used largely for bridge building by the railroad.

Montrose Township.—Six miles north of Keokuk, near Ballinger station, a quarry has been recently opened by McManus and Tucker in the Warsaw magnesian limestone. The stone dresses readily and is used for dimension work of all kinds. It has been taken for the penitentary at Fort Madison, the building of the Canning Company and the high school. A dozen men are employed part of the time.

In the southern part of the town of Montrose a small quarry has been recently opened by Wardlow and Moor. The rock is used chiefly for foundation walls and well linings. The section of the quarry face shows:

		FEET.
4.	Drift	4
3.	Limestone, gray, coarse-grained, fossiliferous, thinly bedded at the top	4
2.	Chert, in thin layers	1
1.	Limestone, dark-colored, with hard shale parting (exposed)	2.

Many of the creeks in the vicinity have ledges of good stone exposed in their beds, and these outcrops are quarried in a desultory manner to supply local demands. Indeed nearly all the smaller streams entering the Mississippi river show rock ledges from which stone has been taken out in small quantities at various times for foundation and retaining walls and for the construction of the Des Moines canal.

Jefferson Township.—A large part of Jefferson township is occupied by an old channel of the Mississippi river so that only the extreme western and northern borders

may be expected to furnish supplies of building stone. At the present time only two quarries are in operation. These are on Sugar creek, two miles above Viele station, in the northwestern part of the district. They are situated on opposite sides of the stream a short distance above the railroad bridge. On the west side of the creek is the Wemmer quarry (Tp. 69 W., R. V W., sec. 5, NE. qr., SW. ¼), which has been in operation in a small way more or less continuously for sixteen years. The exposed ledge is about twelve feet in height, rather thinly bedded above, but heavily bedded below, the layers being from two to three feet in thickness. The stone hardens greatly on exposure to the weather. The output is used chiefly in the surrounding country for foundation and retaining walls. The Applegate opening is in the same beds a few hundred yards to the westward on the west side of the creek; the stone is used in the same way as that from the other quarry.

Charleston Township.—The surface of this district being largely prairie upland, with no large water courses passing through it, and deeply covered by drift materials, there are few exposures of bed-rock. The principal place from which stone is obtained is from the Donnell quarry, which is situated about a mile southwest of Donnellson, on a small branch opening into Sugar creek (Tp. 67 W., R. VI W., sec. 5, SW. qr., SE. ¼.) The output is entirely local. The upper layers are used for walls and the lower ones for other building purposes. The section shows:

		FEET.
3.	Drift	3
2.	Limestone, broken	3
1.	Limestone, yellowish, arenaceous, massive (exposed)	5

Elsewhere along the creek a white oolitic limestone is exposed. It is rather thinly bedded and may be taken out in large flag-like plates. It probably represents the Saint Louis limestone so well exposed in other parts of the county. In the eastern part of the township are a number of places from which stone is removed from time to time as needed n the immediate neighborhoods. On Panther creek (Tp. 67 W., R. VI W., sec. 13, NW. qr., NE. ¼) the Saint Louis beds form outcrops of considerable local importance.

Van Buren Township.— Little quarrying is now being done in the district. Thirty years ago in the days of slack water navigation there was an opening made half a mile northeast of Croton, where a massive yellow sandstone belonging to the Lower Coal Measures was taken out and used largely for the dams and locks in the Des Moines river. This stone is used scarcely at all now. There are also outcrops on Lick and Mumm creeks which often afford supplies for local use, but at none of these localities is quarrying carried on regularly. On the latter stream is the Harlan quarry. Near the mouth of Monk creek is also an opening furnishing stone to Belfast and the vicinity.

Franklin Township.— A considerable portion of the township being covered by Coal Measures, sandstones are exposed at various points. Over the rest of the district, however, limestones prevail. In the southwest the quarry rock is supplied from south of Donnellson; and in the southeast from the Graner place, in West Point township.

In the vicinity of Franklin there are a number of small quarries which afford all the stone needed for local use. The principal points are north of the town with two to the south. All are in the white, granular ledge of the Saint Louis limestone. One mile east of the town is the Edwin

Graner quarry (Tp. 68 W., R. VI W., sec. 25, NE. qr., NE. ¼) which has recently been opened. Flagging is the chief output. The church at Franklin has the area around it paved with this stone. One mile directly north of the Graner place is the Pardel quarry. Most of the stone taken out is dressed, and some of it has been sent to Fort Madison. The church at Saint Paul has also been constructed of it. Two and one-half miles directly north of Franklin on a branch of Sugar creek is a bluff 40 to 50 feet high which is made up chiefly of white limestone. One and one-half miles farther to the northwest (sec. 10, NW. qr., NE. ¼) near an old coal drift the following sequence of strata is shown:

		FEET.
16.	Drift	10
15.	Shale, black	2
14.	Coal (about)	2
13.	Fire clay (about)	1
12.	Sandstone, yellow	5
11.	Limestone	2
10.	Shale, laminated, calcareous	1
9	Limestone, yellow, magnesian and somewhat argillaceous	3
8.	Limestone, oolitic, in flag-like layers	8
7.	Limestone, white, concretionary	2
6.	Limestone, oolitic, more massive than number eight	6
5.	Limestone, somewhat irregularly bedded	5
4.	Shale	1
3.	Limestone, oolitic, irregular and flag-like	2
2.	Limestone, argillaceous	2
1.	Limestone, nodular and brecciated (exposed)	3

Some of the layers are utilized for foundation and retaining walls. At several other points on the same stream quarrying has been carried on in a small way.

West Point Township.—The available stone for building purposes in the West Point district is almost entirely from the Saint Louis limestone. The principal openings now in operation are in the western part of the township.

Two miles northeast of Franklin is the Kiener quarry (Tp. 68 N., R. V W., sec. 18, NE. qr., NE. ¼) where a white limestone of fair quality is taken out to supply local demands. One and one-half miles south of the last mentioned location and about the same distance directly east of Franklin the Graner quarry has been opened in the bluffs of Sugar creek (Tp. 68 N., R. V W., sec. 30, NW. qr., NW. ¼). The face of the quarry displays the following layers:

		FEET.
10.	Drift	10
9.	Limestone, white, granular, oolitic, evenly textured, more or less distinctly cross-bedded	8
8.	Limestone, sub-crystalline	2
7.	Limestone, blue, concretionary	1
6.	Shale, blue	½
5.	Limestone, granular, oolitic	6
4.	Limestone, brecciated	10
3.	Limestone, brown, arenaceous	8
2.	Shale, blue	10
1.	Shale, blue, with geodes	20

Beds 5, 7, and 8 dress well and are used in making tombstones. Number 3 is used for all kinds of rough masonry and for bases for monuments. All the layers are used for manufacturing lime, but number 7 is the best for this purpose.

Three-fourths of a mile to the south on Little Sugar creek (sec. 30, SW. qr., SW. ¼) a fine white sandstone is exposed near the top of the bluff and quarries have been opened in it. The stone hardens on exposure and forms a moderately good constructional material. Below the sandstone a good limestone crops out which is similar to the best layers of the Graner opening. The Judy quarry, from which stone has been quarried for more than thirty years, is about midway between Viele and Franklin in the northeast quarter of the southwest quarter of section thirty-two. The rock is a brown arenaceous limestone

which has been used for all kinds of foundations and bridge work. Lime was formerly burned at this point, the stone used coming from layers above the present quarry ledges. There are numerous other places where extensive quarries might be opened, all of which would have good transportation facilities.

Washington Township.—The chief outcrops of building stone occur in the northeastern part. On Lost creek, a short distance west of Wever station, considerable rock has been removed for constructional purposes. The Lange quarry is the principal opening; and it is located near the Lost Creek church Tp. 68 W., R. IV W., sec. 12, NW. qr., SE. ¼). The output is entirely local and is chiefly utilized in foundation walls. One-half mile west is the Hayes quarry and three miles farther upstream (sec. 4, NE. qr., NW. ¼) is the Eoff place, which has been opened for nearly twenty years. Other small openings have also been worked from time to time along Lost creek.

Green Bay Township.—The greater portion of the district being occupied by alluvial flood plains little building stone is to be expected. Only one opening is now being worked. This is the O'Neil quarry, which is located one mile north of Wever and a short distance west of the St. Louis, Keokuk & Northwestern railroad bridge over Skunk river (Tp. 69 N., R. III W., sec. 32, SE. qr., NE. ¼). The quarry is in the Lower Burlington limestone. The section presents:

		FEET.
7.	Drift	3
6.	Limestone, light buff, encrinital	3
5.	Limestone, sandy, soft	1½
4.	Limestone, brown	1
3.	Limestone, light brown with band of chert	1
2.	Limestone, brown	3
1.	Hidden to water level	30

Denmark Township.— Along the Skunk river, which forms the entire northern boundary of the township, an abundance of good building stone is easily accessible. The Burlington, Keokuk and Saint Louis limestones are all present in force. In South Augusta considerable stone is removed from the bed of the river, which at this place passes over rapids. Also in the ravines of the neighborhood numerous small openings have been made. On the north side of the river are several quarries. Directly north of the town of Denmark stone has been obtained for foundation walls in the crest of the bluff (Tp. 69 W., R. IV W., sec. 17, NW. qr., NE. $\frac{1}{4}$) and elsewhere along a small ravine some distance from the river.

Pleasant Ridge Township.—Several quarries are in operation, the principal ones being the Klopfenstein and the Bascomb, the former being situated two miles northwest of Denmark (Tp. 69 N., R. V W., sec. 13, NW. qr., SW. $\frac{1}{4}$). The rock quarried is chiefly the oolitic bed of the Saint Louis limestone. It has a workable thickness of about twelve feet. There are over twenty feet of ordinary limestone also worked. The second quarry, the Bascomb, is in the northern part of the township (section 3, southwest quarter). It is also in the white Saint Louis limestone, and supplies local demands. Other small openings in the northwestern part of the district are the Kennedy (section 16) and the Balm (section 14).

Marion Township.— In the southeastern corner of the district is the old Jarret quarry (Tp. 69 N., R. VI W., sec. 36, NW. qr., NW $\frac{1}{4}$). The rock is a nodular somewhat cherty limestone, rather regular in bedding but not very uniform in texture. Farther up Sugar creek is the Pilot Grove quarry from which bridging, flagging and foundation stone are taken out. The section is:

		FEET.
6.	Drift	6
5.	Limestone, thinly bedded, with some chert and clay partings	5
4.	Limestone, gray, compact	2
3.	Shale, bluish, calcareous	½
2.	Limestone, bluish gray, brecciated	5½
1.	Limestone, brown, fine-grained, arenaceous (exposed)	2

CLAY DEPOSITS.

CHARACTER AND DISTRIBUTION.

For a district in which the bedrock is so prevailingly calcareous, Lee county is well supplied with clays suitable for all of the ordinary uses to which that material may be put. Aside from the superficial deposits which mantle the entire district several of the geological formations furnish a good grade of clay. Principal among these are the Coal Measures; though the Warsaw beds have recently been brought into use successfully, and it is expected that the Kinderhook shales, which are utilized so extenively farther north at Burlington, will soon be drawn upon.

Kinderhook Shales.—The lowest geological formation which may be profitably used for the manufacture of clay products is probably the Kinderhook. The shales of this division are so well adapted to the making of a high grade of paving brick that they will doubtless come into extensive use for this purpose. These beds, which are some seventy-five feet above the water level of the Mississippi river at Burlington a few miles beyond the northern boundary of the county, and at Hannibal, forty miles to the south, have their nearest surface exposure in the vicinity of the mouth of the Skunk river. There they may be encountered near the water level, but from this point southward they get to be lower and lower until, in the southern

part of the country, they are fully 150 feet beneath the river level, and on the bluffs, 250 to 325 feet beneath the surface. The Hubinger Brick Company at Keokuk are, at the present time, sinking a shaft for the purpose of utilizing these shales at their plant in the western part of the city, and it is expected that they will obtain suitable material in the neighborhood of 300 feet. So far as is known this is the first attempt to work the Kinderhook shales in Lee county.

Warsaw Shale.—Although well exposed in many places in the county, the only point where these shales are utilized for clay products is in Keokuk, at the Hubinger Brick Works. As a rule these shales are too calcareous for the manufacture of good brick and the presence of numerous thin bands and nodules of limerock interferes with their usage for this purpose without special treatment. At the Hubinger place these difficulties are readily overcome. The last mentioned interference is removed by running the material through a disintegrator, and the first by the proper mixture of the ground clay with other varieties. In different places the Warshaw shales vary very considerably in lithological characters, in some localities the clayey portions predominating, in others the calcareous parts. With proper care in selection of sites a large part of the Warsaw shales might be readily utilized for brickmaking purposes.

Coal Measures.—The shales of the Coal Measures occupy considerable areas in Lee county. They are well distributed, and, although chiefly belonging to Carboniferous outliers, extensive pockets of clay shale occur in one-half of the townships. In many places coal sufficient to burn the materials might be taken out with the clay. In other localities but thin seams of coal are present, yet

an abundance of good clays often exists even where there are no coal veins. The drab and yellow shales are well adapted for the manufacture of brick. The clays underlying the coal are suitable for making refractory products and, when properly mixed with other clays, for paving brick. Some of these light colored clays, when sufficiently free from grit, are excellent for pottery ware, and are widely used in other parts of the state. On the whole the Coal Measure shales are the most valuable beds in the county for supplying raw materials for the making of all kinds of ordinary clay products. The northern and western borders of the county and the northcentral portion are well supplied with these deposits. Several areas sufficiently large to supply the surrounding region for centuries exist in the vicinity of Keokuk, one north of Rand park and the other above Nassau slough.

Till.—The drift or superficial deposits of the county belong to what has been commonly called the lower till. It is composed of two rather distinct subdivisions; the basal part, known as the blue boulder clay, and the upper portion, which is known as the yellow boulder clay. The lower member, though much thicker, is as a rule seldom well exposed at the surface, and is rarely utilized for making clay goods. It will never be an important formation from which to obtain clay for commercial purposes, for the reason that the yellow boulder clay everywhere overlies it and is much more accessible. The "yellow" boulder clay is yellowish or light brownish to gray in color, with bands or lenticular masses of coarse sand and occasionally pebbles and boulders of crystalline rocks. Frequently calcareous concretions are present. Owing to these characters, most of the clay cannot be used to good advantage in making even the ordinary clay products.

Loess.—This is the fine siliceous material which is found capping the bluffs everywhere in southeastern Iowa. Though differing somewhat from similar deposits in other parts of the state in some of its physical characters it preserves on the whole its characteristic brownish to ashen color, homogeneous texture and fine silty structure. The material just as it comes from the excavation is not very well adapted to making brick and must be mixed with other clays or receive special treatment to destroy a distinct jointed structure which it possesses.

Alluvium.—For ordinary brick the alluvium has been utilized to some extent in various localities. Its distribution is chiefly along the Des Moines, Mississippi and Skunk rivers, though narrow bands are also present on some of the larger creeks.

For the manufacture of ordinary building brick the loess, till and alluvial clays are used. These are found everywhere in the county but usually only a rough sand-rolled brick is made. Certain of the loess deposits would doubtless afford a good material for a high grade of pressed facing brick.

The paving bricks at present are made from the Warsaw shale and at but a single point. The Kinderhook shale will probably soon afford an unsurpassed quality of material for pavers although reached at only one point, at Keokuk. It will doubtless be a long time before other shafts are put down for this purpose. The Coal Measure shales which are so abundant in many parts of the county will yield unlimited quantities of the best clays for paving brick and in the future these deposits will also be drawn upon for road material.

Pressed and ornamental brick are now made only from the Warsaw shales. The Coal Measure clays and portions

of the loess are manifestly superior for general purposes though a very excellent product is made from this Warsaw shale at Keokuk. Fire brick, furnace linings and all ordinary refractory articles may be readily manufactured from the Coal Measure clays which lie immediately beneath the coal seams or highly bituminous shales. Pottery clays are yet only known in Lee county in the Coal Measures. At Donnellson they have been used for some years.

CLAY INDUSTRIES.

Keokuk.—The Hubinger Brick Company has the largest and most complete plant in the county. It is situated in the valley of Soap creek near the cemetery in the western part of the city of Keokuk. It has been in operation three years, and was erected especially for the purpose of manufacturing pavers and high grade building brick. The Keokuk and Northwestern railroad, a branch of the Burlington system, affords good shipping facilities, the output being loaded directly upon the cars as it is taken from the kilns. Several varieties of clay are used, the chief one being from the Warsaw beds. Surface clay is also utilized. As already mentioned an effort is being made to mine the Kinderhook shales and for this purpose a large shaft is now being put down in order to reach them. It is thought that it will be necessary to sink about 300 feet in order to secure the proper material. Two-thirds of this distance has already been passed through. In addition to the Warsaw shales now used, a loess-like material is obtained on the slopes near the plant; this is used chiefly in combinations. The raw material is very thoroughly treated. It first goes through a Potts disintegrator, from which it passes into a dry-pan and then through a twelve-mesh revolving screen of the

Williams pattern. The finely sifted material is then elevated to an Andrus dry press or a Frey-Sheckler double dye, automatic, end-cut, stiff mud machine. The compact mud blocks are loaded on small cars and run into a four tunnel Chicago Ironclad dryer where they are left twelve hours. Two Raymond Columbian steam power represses are also in use. There are now five Endally downdraft kilns in operation. They have a combined capacity of 800 000 brick. For the dry pressed brick seven days are consumed in water-smoking and seven days for properly burning. For the stiff mud bricks twelve days are necessary. A large variety of light colored and red building brick are made and a good line of pavers.

In the northern part of Keokuk is the Spaan brick yard. The output consists entirely of sand-rolled brick. These are made from an ashen silt or bleached loess. Only the upper fourteen inches is used.

The Worley yard is on Concert avenue, between Eighteenth and Nineteenth streets. Rarely more than a couple of kilns are burned each season. The clay used is the humus bearing silt, similar to that used at the Spaan place. The burnt product is used chiefly in the building of sidewalks.

Fort Madison.—There are several brick yards in this neighborhood, all using drift materials. One of the oldest yards is the Reichelt in the southwest quarter of section thirty-four of Washington township. It has been in operation for about thirty-four years. The clay used is the upland loess of the region and is taken out to a depth of three feet. Below this depth it assumes a jointed character and cannot be used to advantage. A Penfield plunger was formerly used, but this has been replaced by

a stiff mud machine patented by the present operator of the yard. A Carnell & Co. hand repress is sometimes called into service. The kiln is a down draft rectangular pattern of the Reichelt patent, and has a capacity of 60 000 brick.

The Stillern yard is about one and one-half miles north of the town on the prairie upland. Previous to 1893 sand-rolled brick were made. Since that time a home made stiff mud machine has been in operation and a Miller hand press. The clay is the upland silt, or loess, and is taken to a depth of two feet. A short distance to the north is the Meyerthalen yard where brick have been made by hand for upwards of two score years. The material used is similar to that at the Stillern place. It is prepared by continually spading—an old style foreign method.

On the margin of the flood plain of the Mississippi is located the Hausmann yard. For several seasons hand made brick were turned out. Subsequently a Frey-Scheckler machine was used. At the present time an "Ohio No. 2" of the Freese & Co. pattern is in operation. Two grades of clay are used. One is the upland loess and the other the alluvial clay at the foot of the bluff. The former is dug to a depth of five feet; the latter may be used to a greater depth. Two and one-half miles northwest of the business part of the town is the Wigginjost yard. Upland silt to a depth of twenty inches is used. The soaked clay is spaded and respaded before being moulded. Near the northwest limits of the town, on the West Point road, is the Bartell yard. Sand-rolled brick are made from the upland bleached loess.

Donnellson.—At the west edge of town a small yard was opened in 1891. The brick were hand made from prairie soil and were used in building the school house.

At the junction of the two lines of railway was the new Pottery where all the common varieties of stone and earthenware were manufactured. The raw material was taken from the Coal Measures about three miles north of the place. The ware was a little grity but otherwise very good. The pottery has recently been moved to Farmington, a few miles to the west, in Van Buren county.

SANDS.

Sands suitable for building purposes are derived chiefly from the stream beds. The Skunk, Mississippi or Des Moines supplies at almost any point an abundance of good sharp river sand capable of uniting mortar in strong bond. On the smaller streams the sand is obtained from the bars which appear at low water. Along the Mississippi the sand which is dredged from the channel appears to be more satisfactory and is used in preference to that which may be obtained on the bars.

In the drift there are frequently lenticular beds of sand which might be readily utilized for building purposes. They are scattered widely over the entire region. Another source of sand is the soft sandstone of the Coal Measures which occupy a considerable portion of the county. These sandstones in places are quite incoherent or readily disintegrate on exposure to the weather, and often furnish a clean, sharp-grained material equal to the best river sand. Certain beds of the Coal Measure sands are pure white and are practically devoid of iron and other impurities and could probably be used for manufacturing the ordinary grades of glassware. Sands for moulding purposes in iron foundries are generally obtained from the drift beds the material found there being finer and more homogeneous than the river sands.

ROAD MATERIALS.

The subject of good highways has been agitated as much perhaps in Lee county as any other place in Iowa. There are probably few counties in the state which are possessed of superior materials for the betterment of the principal roads. As the matter of cost enters largely into the consideration of improvement, the use of materials is necessarily limited to a few kinds. In the cities and large towns macadam has been used almost exclusively heretofore, but its extension to country roads has been very limited. Vitrified brick, however, are now being successfully used for paving streets, and in the larger places elsewhere they are replacing everything else.

For the country highways there are in Lee county at least three kinds of material of wide distribution which may be made readily available. These are stone for macadam, gravel and burnt clay. The first of these may be found in nearly every part of the district. All of the limestone formations afford good ledges. The cost of preparation, of breaking the large blocks into sizes small enough for placing on the roads, is considerable, and hence this material could be used only on the leading and much traveled routes. Roads thus improved and properly cared for from time to time last indefinitely, and the cost of repairs is very slight if done in the right way. The location of suitable ledges is such that the transportation of material is reduced to a minimum.

The gravel beds are widely scattered. The rivers and larger creeks afford abundant material, as does also the drift. The distances over which it would be necessary to move the material would be greater than in the case of the stone for macadam; but for two or three miles in each direction considerable stretches of roadway might be covered.

Burnt clay is a material which has not come into use very extensively for roadways. Railways are using it largely in some places in preference to gravel and stone for ballast. Driveways to residences are frequently covered with it as it beats down, hardens and does not cut up or become muddy. This use might be widely extended. In the areas having coal the highly bituminous and other shales, mixed with poor grades of coal, could be readily used in road improvement. At the larger mines the "dumps" afford large quantities of clay shale already thoroughly burnt and the roads for several miles in either direction could be soon covered with the best of materials at merely the cost of hauling.

The materials for good roads are, therefore, abundant in Lee county and readily accessible on every hand. It remains for local enterprise to use them.

CEMENTS.

From time to time hydraulic rock has been reported from the southeastern part of the state. It has usually been associated with the coal bearing strata. Probably the dark gray calcareous band frequently found over coal seams is commonly referred to; but even if this were a high grade material for the manufacture of cement, the layers are seldom more than a foot or so in thickness and hence the cost of quarrying would be too great to render it profitable. An abundance of good clays is present in close proximity to the pure white Saint Louis limestones, and with coal also profusely at hand, paying plants might be erected at several points.

LIME.

Material suitable for the manufacture of quick lime is abundant in the greater part of the county. The Bur-

lington limestone affords a fairly good grade of limerock and has been burned at a number of places a short distance north of the Skunk river. On the south side of that stream the same stone has also been burned at several points. The Keokuk limestone furnishes good ledges for lime and has been utilized at a number of points for many years. Keokuk and Montrose are the principal places. Most of the lime which has been burned in the county has been derived from the white Saint Louis limestone. At Keokuk and the vicinity, east of Franklin and northwest of Denmark, kilns have been erected and considerable lime manufactured during the many years they have been in operation. By the judicious selection and use of the magnesian limerocks a very superior article might be readily made, as dolomitic stones, those containing both magnesia and lime, are commonly regarded as making a better bond in mortars than when pure lime is used.

MINERALS.

Besides the deposits which are now being utilized there are a number of other minerals which are not mined at the present time. Some of these are found only sparingly or in quantities too small to be of value as commercial products, yet possess considerable worth as mineralogical specimens, and as such frequently command good prices on account of their beauty, rarity or scientific interest. Many minerals, particularly the metallic substances attract much popular attention, but occur in too limited amounts to pay for working them, yet they annually cause a great waste of time, energy and money in luring persons with the hope of hidden wealth. Some minerals not now attracting attention may in the near

future develop into sufficiently important deposits to call forth both brawn and gold.

Copper.—Small masses of native copper have been picked up at various points, but it is not to be expected that this is any proof of the presence of copper in paying quantities; as the masses are derived from the drift and hence have been transported by ice from the copper regions of the north.

Gold.—Native gold being one of the most universally distributed of minerals occurs in the drift in small quantities where it has been concentrated through a natural process very similar to panning. The small deposits, though frequently arousing considerable local excitement, need not be taken anywhere in Lee county as an indication of quantities of commercial importance.

Silver.—Although this metal probably does not exist in commercial quantities in this part of the country, it is reported that certain layers of the limestone below the city of Keokuk have yielded so much as four or five ounces to the ton upon careful assaying.

Sphalerite.—Zinc blende or the sulphide of zinc, one of the commonest of zinc ores, is rather widely distributed in small quantities, sometimes occupying small cracks and crevices in the rocks, sometimes lining small cavities left by the remains of fossils or often occurring in geodes. In the latter place it is found in thin well crystallized masses associated with calcite and quartz. Some of the crystals found measure an inch along the edges which are quite sharp and well defined.

Pyrite.—Aside from the regular masses of iron pyrites the common sulphide of iron occurs abundantly in certain layers. Small pyrite crystals are abundantly scattered through many of the limestones and shales. In the bitumi-

MILLERITE ON CALCITE; KEOKUK.

nous shales of the coal deposits large quantities of this mineral are disseminated in fine particles, and also in irregular concretionary masses. Frequently pyrite is found replacing the calcite shells of fossils. Many of the geodes contain abundant crystals, usually small but with bright glistening faces and sharp edges. They often stud the interior of calcite and quartz lined grottos, sometimes sparingly, at other times forming almost a complete lining. Occasionally cubes are also found attached to the edges of calcite and quartz crystals.

Millerite.—The sulphide of nickel has been known to occur in very minute quantities in geodes. Recently it has been discovered in larger quantities in small cavities in the upper part of the Keokuk limestone at Keokuk and Fort Madison. As mineralogical specimens some of these are perhaps the finest ever discovered. The mineral occurs in fine yellowish filaments, penetrating crystals of clear calcite after the manner of the *fleches d'amour* or rutile needles in quartz; also in tufts of closely appressed needles. The cavities in which the mineral occurs vary from one upwards to twenty or more inches. These hollows have large thickly set rhombohedrons of calcite projecting in towards the center. The faces are brightly reflecting and the edges sharpely cut. In some of the calcites are found beautiful clusters of tufts having closely arranged brass colored needles of millerite protruding from the center of attachment in all directions to a distance of one and one-half to two inches. In some of the examples the tufts are made up of hundreds of fine filaments, often so close together that the needles of the different clusters are interwoven so as to form a dense matted mass. Often a perfectly transparent calcite has a tuft of long matted millerite completely enclosed; or a

part of the tuft may be embedded in the lime crystal, the extremities of the needles projecting outside. Masses of the calcite thickly covered with the nickel bearing needles sometimes weigh over fifty pounds. The millerite at Fort Madison occurs in a similar way, the needles sometimes adhering to one another and forming bundles, often several ounces in weight.

Calcopyrite.— This mineral is found sparingly in small but very perfect crystals, in certain geodes occurring at Keokuk. It occurs enclosed in calcite, the crystal forms being the tetrahedron with the corners truncated. The crystallographic planes are brightly reflecting and the edges are clearly cut. Perfectly formed crystals from one-quarter to one-half of an inch in size are found frequently.

Quartz.— Though this mineral is rather widely distributed, the most interesting occurrences in Lee county are in connection with the geodes. The geodes are found scattered through a shale lying immediately above the Keokuk limestone, and the layers containing these are widely known locally as the "geode bed." The geodes are miniature grottos, lined usually with quartz crystals. In size they vary from a few inches up to two feet or more. They are usually more or less spherical bodies composed of shells of calcedonic quartz. Lining the inside of these shells are quartz crystals showing a large development of the prism, terminated by the fundamental pyramid. Often the quartz crystals are doubly terminated. Frequently large crystals of calcite rest on the quartz and the whole is frequently studded with small crystals of various metallic sulphides. Some of the geodes, instead of being lined with quartz crystals, have on the interior chalcedony in the form of botryoidal masses. Though as a rule the

geodes are hollow, many of these are perfectly filled. The quartz geodes are generally confined to the lower part of the bed, while the calcite geodes occur most abundantly in the upper part. Usually the quartz is limpid, though some times milk-white, rose-colored or reddish.

Rutile.—In certain geodes there have recently been found some very minute yet very perfect crystals of a mineral which appears to have all the characteristics of rutile.

Limonite.—This is found sparingly in many localities as a pseudomorph after pyrite. Small quantites of the massive form are also found.

Calcite.—This occurs abundantly in the rocks of Lee county, filling narrow veins and crevices and lining small caverns. Beautiful crystals are abundant. In many of the quartz geodes, usually in those found near the top of the bed containing these bodies, single crystals of the calcite, showing perfect crystallographic faces, occur resting immediately upon the quartz points. Sometimes a single lime crystal will nearly fill the entire cavity. In the Keokuk limestone there are often small cavities which are lined with beautiful crystals of this mineral. The aggregates are arranged around a cavity just as in the geodes, but there is no quartz lining, the calcite being attached directly to the limestone. Among the most interesting crystal forms found is the fundamental rhombohedron which occurs abundantly. A very large series of rhombohedrons and scalenohedrons has been obtained among the Keokuk calcites. Beautiful specimens showing vicinal planes are also of frequent occurrence. The majority of all these crystals lining the limestone cavities are as perfectly transparent as Iceland spar.

Aragonite.—This form of lime, identical in chemical composition with calcite, but differing only in the system of crystallization, is occasionally found in geodes.

Dolomite.—Crystal forms showing the various planes occur in the magnesian limestones. The finest crystals, however, are met with in the geodes.

Kaolin.—A fine, snow white powder frequently found in the bottom of geodes appears to be the hydrous silicate of aluminium.

SOILS.

It is hardly necessary to direct special attention to the soils. For the most part those of Lee county are rich. The uplands are covered everywhere with a black loam-like humus to a depth of two or three feet. Although derived almost entirely from the drift, there are but few places and these quite limited, where the tenacious and untractable "gumbo" occurs.

Along the stream the alluvial bottoms are somewhat more sandy than the soils of the uplands, but seldom so arenaceous as to interfere with cultivation.

WATERS.

The waters may be divided into three classes: the surface, the artesian and the mineral. On the whole the county is well supplied with flowing streams. Over four-fifths of its boundary is made up of the largest streams in the state and into these flow several smaller courses which rarely run dry. Everywhere, it may be said, wells of moderate depth yield an abundant and never failing supply of good wholesome water. This is the case whether on the uplands or in the alluvial valleys. Springs of good

water also occur in nearly every township. Some of these nearly fail during protracted periods when there is small rainfall, but others are never failing.

The artesian waters of the district are of particular interest. In the southeastern half at least and probably in all of the county the conditions are favorable for water supplies of this kind. The Keokuk syncline or trough underlies many square miles and the pressure is sufficiently great to produce flowing wells at most points at least. Depths of from 800 to 1000 feet usually reach the water bearing stratum. At Keokuk several wells have been put down at the top of the bluff and large reservoirs have been built to contain the overflow. The strata passed through by one of the principal wells — the Hubinger — are given in section number III in connection with the general geology.

The so called mineral springs which occur in various parts are similar to those which occur abundantly throughout the coal fields. But usually in Lee county they are too small to supply more than local demands for a water containing various sulphates.

The following is the record of the well put down by the Fort Madison Paper Company. The surface at the well is twenty-one and one-half feet above the water level of the river, which is 502 feet above sea level.

		THICKNESS.	DEPTH.
5.	Black loam, quicksand and blue clay, not separated in the record, doubtless largely the last.....	145	145
4.	Limestone.....	35	180
3.	Shale, blue and white.....	250	430
2.	Limestone.....	180	610
1.	Sandstone (water-bearing).....	77	687

The Atlee well which is about twenty-five feet above this, shows 190 feet of clay and alluvium, while the Hospital well, at nearly the same elevation, shows 185 feet. At the Paper Mill the rock surface is found at 379 feet above sea level, while the Atlee well and the Hospital well agree very nearly in placing it at about 365 feet.

At Mount Clara, which is situated at the summit of the divide, west of Montrose, a well put down on the Beck place shows the following arrangement:

		THICKNESS.	DEPTH.
12.	Clay	250	250
11.	Sand	55	305
10.	Limestone, white	25	330
9.	Shale, white	8	338
8.	Limestone	5	343
7.	Shale	325	668
6.	Limestone	115	783
5.	Limestone	10	793
4.	Limestone, flinty	25	818
3.	Limestone	40	858
2.	Limestone, hard	5	863
1.	Samples carried away by water	76	939

ACKNOWLEDGMENTS.

For much that is of value in the foregoing account, and for detailed mapping in different parts of the district, special acknowledgements are due to Mr. C. H. Gordon, now of Chicago University, who formerly resided at Keokuk. During that period he spent considerable time studying the local geology. In connection with his work on a neighboring county, he recently spent several weeks in Lee connecting his own work with what he had previously done, visiting certain parts of the district which needed further investigation, and settling doubtful points. His notes are

so full and excellent that they have been followed quite closely, in places.

Mr. Arthur J. Jones, of Iowa College, spent some days in connection with the work on building stones, and Mr. E. H. Lonsdale, who has charge of the work on clays, visited all the principal clay deposits while getting together material for his report on the subject. The notes of both have been freely referred to in the preparation of the sections on these subjects.

Mr. L. A. Cox, of Keokuk, has rendered timely assistance, and Mr. J. C. Hubinger, of the same place, has given aid freely. Dr. H. Morgridge, and Mr. Atlee, of Ft. Madison, furnished the records of the deep wells at that place.

GEOLOGICAL MAP OF LEE COUNTY, IOWA

BY

CHARLES R. KEYES

1894.

LEGEND

GEOLOGICAL FORMATIONS		INDUSTRIES	
COAL MEASURES		QUARRIES	⚒
SAINT LOUIS		COAL MINES	■
AUGUSTA (KEOKUK)		CLAY WORKS	▲
AUGUSTA (BURLINGTON)		LIME KILNS	⊙
KINDERHOOK			

DRAWN BY F. C. TATE.

PHOTO LITH BY A. HOENS CO. BALTIMORE MD.