GEOLOGY OF DES MOINES COUNTY.

BY

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ECONOMIC GEOLOGY OF DES MOINES COUNTY.

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CONTENTS.

INTRODUCTION.

SITUATION AND EXTENT.

Des Moines lies on the eastern boundary of the state and is the second county above the south state line. Its areal extent is about 415 square miles. In outline it is roughly quadrangular, the Mississippi and Skunk rivers forming the irregular eastern and southern boundaries. The former stream separates the district from the state of Illinois and the latter from Lee county. Louisa county adjoins Des Moines on the north and Henry on the west.

PREVIOUS WORK.

It is very remarkable that, widely as the region under consideration is celebrated geologically, little or nothing has heretofore been done to set forth its economic resources. The rocks which are typically developed at the city of Burlington, where they were first described, and which are known everywhere under the name of Burlington limestones, stretch out over an area of more than one thousand square miles. The peculiar construction of the Burlington limestones, made up as they are of the skeletal remains of marine organisms closely related to the modern star fishes and sea urchins, makes the formation one of unusual interest. Burlington crinoids are known throughout the world as objects of surpassing beauty. They are sought for and highly prized everywhere. In consequence, a great deal of attention has been directed to the consideration of the fossils in the rocks, rather than the rocks themselves. Everything, therefore, which has been written concerning Des Moines county, with the exception perhaps of Worthen's short account, consists of descriptions of fossils, with only occasional incidental explanations of the local geological features.

PHYSIOGRAPHY.

SURFACE RELIEF.

As in Lee county, the surface of Des Moines forms an upland plateau having a slight inclination to the southeast. Interiorly the elevated plain is gently undulating, but much more rolling than in Lee county, on account of the character of the streams and the nature of the strata traversed by them. The eastern and southern margins of the plateau are abruptly cut off by steep declivities reaching in many places to the water's edge of the bounding streams.

The escarpment along the Mississippi river rises to a height of 150 to 200 feet above the flood plain of that stream. It is very much steeper in Des Moines county than either to the north or to the south. This is probably largely due to the character of the rocks, and the peculiar association and arrangement of the various beds. The massive, heavily bedded limestones forming the top of the bluff are underlain by much softer strata in the form of shales, which often occupy fully one-half of the vertical height of the section. The shales, disintegrating much more rapidly than the harder limestones, leave the latter standing out in bold perpendicular walls or overhanging cliffs. Along the Skunk river, the bluffs are not so rugged, but approach the lowlands in much more gentle slopes. Here the strata are more uniform, the shales in passing southward having dipped beneath the river level.

As is so characteristic of the county farther southward in Iowa, the general plateau border is dissected by small ravines and gorges, in which the minor water courses run. As they approach the escarpment the streams break into cascades. In passing back towards the interior the water courses quickly enter broad, shallow valleys.

INDIAN SPRING; NEAR BURLINGTON.

While the elevated plain which forms the greater part of the county has a surface gently undulatory, there is noticeable, in the center of it, a broad, shallow depression, occupied by the dentritic drainage system of the Flint river. The general plateau is thus subdivided into two smaller plains separated from each other by a shallow basin. Together they represent the original plateau surface.

The profile across the county, running westward from Burlington along the line of the Chicago, Burlington & Quincy railroad, indicates the more salient features in the topography of the district. The general uniformity of level is well expressed in the plateau surface, continuing to the very verge of the Mississippi escarpment. (Figure 26.) Another profile, constructed at right angles to the last, and extending from Burlington to the north county line along the course of the Burlington, Cedar Rapids & Northern railroad, expresses similar relations between the plateau surface and the escarpment, the latter here being represented by the bluffs along Flint river, though this feature is not noticeable in the profile, since the railroad follows down the valley of a stream. (Figure 27.)

The character of the relief of the region in the vicinity of the Mississippi escarpment is well exhibited in the neighborhood of Burlington. The area may be taken as

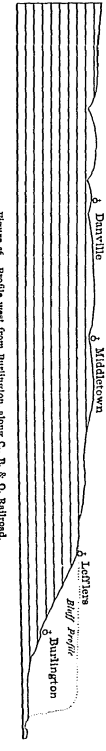


Figure 26. Profile west from Burlington, along C., B. & Q. Railroad.

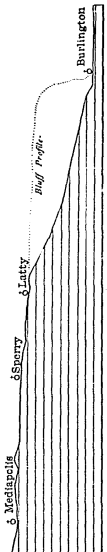


Figure 27. Profile north from Burlington, along B. C. R. & N. Railroad.

typical of the entire district. It is represented in the accompanying map (figure 34), constructed from street and railroad elevations and from lines run with level and rod. The highest portions to the west merge into the general level of the upland plateau; to the east they abruptly terminate in the precipitous bluffs bordering the Mississippi. The minor waterways, as Hawkeye creek and its tributaries, have trenched short, steeply inclined V-shaped courses. Flint river, in the northern part of the area mapped, presents the same features. For a number of miles, however, it has corraded its bed down nearly to the level of the water in the Mississippi, yet its lateral erosion has been slight, as is shown by the high mural bluffs on either side.

The highest place in the county is a few miles from Mediapolis, which has an elevation of 780 feet above sea level. The lowest point is at the mouth of the Skunk river, which is in the neighborhood of 499 feet above tide.

The lowland plains or river bottoms are comparatively unimportant, save in two places. The flood plain of the Mississippi, which is usually from eight to ten miles in width, is almost entirely on the east side of the stream. The river for fully one-half of its extent in Des Moines county hugs the west shore

and leaves for much of the distance no space whatever between the water and the nearly precipitious bluff. The profile of the Mississippi gorge at Burlington is shown in figure 28. In the northern part of the county the flood plain of the Mississippi is for a short distance three or four miles in width, but it rapidly contracts to less than a mile, and finally, a short distance above Burlington, to practically nothing. In the southern portion of the county, at the mouth of the Skunk river, the flood plain of the west side of the great water course abruptly widens out for a short distance.

Figure 28. Gorge of the Mississippi River at Burlington.

The flood plains along the Skunk river are quite narrow, being for most of the distance that the stream traverses Des Moines county, nowhere much more than a quarter of a mile in width.

Along Flint river the alluvial plains are also very narrow. Immediately above its mouth the stream for several miles flows in a narrow gorge; but farther on the valley widens out and narrow flood plains occur for some distance.

In the subjoined table the elevations above the sea level are given for all important places in the county.

Table of Altitudes in Des Moines County,

LOCALITY.	ELEVATION.	AUTHORITY.
Burlington—		
Low water.	511	Miss. Riv. Com.
High water.	527	Miss. Riv. Com.
Union depot.	533	Miss. Riv. Com.
Danville.	549	C., B. & Q. Ry.
Latty.	757	B., C. R. & N. Ry.
Linton.	771	B., C. R. & N. Ry.
Mediapolis.	779	B., C. R. & N. Ry.
Middletown.	727	C., B. & Q. Ry.
Patterson.	549	C., B. & Q. Ry.
Sperry.	757	B., C. R. & N. Ry.
West Burlington.	689	C., B. & Q. Ry.
Yarmouth.	696	B. & NW. Ry.

DRAINAGE.

Des Moines county is well drained. The Mississippi river, though passing along the entire eastern border of the district, drains directly but little of the region; most of the surface water being carried off by means of small streams before reaching the larger water course. The greater part of the rainfall which finds its way ultimately to the Mississippi is carried thither by two streams, the Skunk and the Flint.

Mississippi River.— As already stated, this stream traverses the entire eastern side of the county, flowing south, with a slight western deflection opposite Oquawka. Though meandering through broad alluvial flood plains, it flows along the southern half of its course in the county on the western margin of the gorge. In the northern part of the district numerous bayous and sloughs, which have at all times more or less direct communication with the river, occupy almost the entire flood plain. In times of high water the lowland plain from one side of the gorge to the other is covered by an unbroken expanse of water and the river is then from six to nine miles wide. The

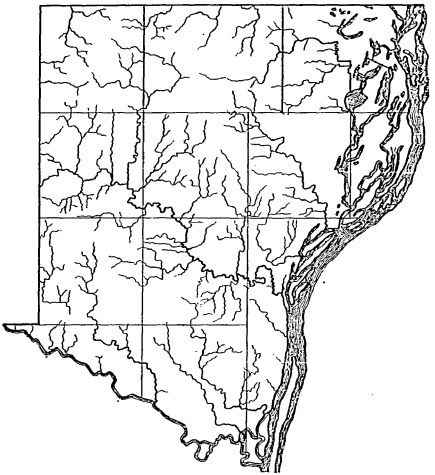


Figure 29. Drainage of Des Moines County.

drainage of the county, which goes directly into the Mississippi, is confined to that from small creeks which dash over the escarpment in foaming cascades. The principal creeks are Swank, Dolbree, Hawkeye, and Spring; Flint river and its tributaries coming in about midway between the north and south lines of the county.

Skunk River.—This stream, forming the southern boundary of the county, receives a number of small creeks. It drains about one-sixth of the total area of the district.

Everywhere except where it begins to meander through the flood plains of the Mississippi it flows in a narrow valley. The principal creeks flowing into it are Long and Bush.

Flint River drains about two-fifths of the county; and the entire central depression formed by its basin is a rather marked feature in the topography of the region. It rises in Henry county and flows southeastward, entering the Mississippi a short distance above the city of Burlington.

STRATIGRAPHY.

General Geological Relations.

Des Moines county lies entirely within the belt of Lower Carboniferous strata, which extends in almost unbroken continuity from the Minnesota line southward into Alabama and New Mexico. For the most part the rocks are massive limestones, though at the base there is a thick shaly member which, however, is not exposed except along the base of the Mississippi escarpment. In the southwestern part of the county several small outliers of Coal Measures exist.

Over all the stratified rocks a mantle of glacial drift is spread, greatly softening the effects of previous erosion. Only in a few places beyond the immediate neighborhood of the Mississippi bluff has the action of post-glacial waters cut through the drift sheet and exposed to view the indurated rocks.

The superposition of the various geological formations which outcrop within the limits of the county is indicated in the subjoined table:

Classification of Geological Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.		Drift.	Terrace. Loess. Till.
Paleozoic.	Carboniferous.	Coal Measures.	Des Moines.	Sandstone and shale.
		Mississippian.	St. Louis.	Brecciated and white limestone.
			Augusta.	Keokuk limestone. Montrose cherts. Upper Burlington limestone. Lower Burlington limestone.
			Kinderhook.	Shale and sandstone.

GENERAL SECTION.

The maximum vertical measurement of all the geological formations in Des Moines county taken together is approximately 560 feet. The greatest thickness shown in any one place is at Burlington, where outcrops sixty to one hundred and twenty-five feet are not infrequent. Of the general section numbers, 1 to 11 are best exposed perhaps in the neighborhood of Burlington (section I); 11 to 13 are well shown in the vicinity of Augusta (section II); numbers 13 to 15 are found outcropping in the extreme southwestern corner of the county (section III), as are also 17 and 18 (section IV). The quaternary deposits are well shown at many places and especially well along the crest of the Mississippi escarpment (North Hill section).

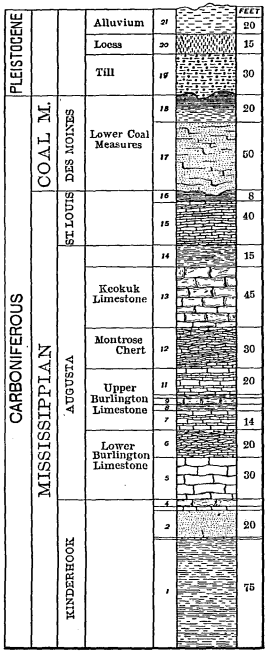


Figure 30. General Section of Geological Formations.

The few sections taken together represent all the strata exposed above the level of the streams in Des Moines county. They may be regarded, therefore, as indices to all the rock beds existing in the district, and all sections wherever found within its limits may be referred directly to them. Their position and close relations with other sections enable all the stratigraphical work of the county to be referred directly to them as starting points and standards for correlation.

STANDARD SECTIONS.

The outcrops showing the lithological details of the lower half of the general section to the best advantage are found in the southern part of the city of Burlington.

On the north end of Prospect hill, west of the railroad bridge across the Mississippi, and in the immediate vicinity the following section is shown:

I. Section at Prospect Hill, Burlington.

		FEET.
11.	Loess	15
10.	Till; yellowish brown clay, with pebbles and small boulders	8
9.	Limestone, white, thinly bedded	10
8.	Chert and silicious shales, with thin, irregular limestone beds, white and red in color	20
7.	Limestone, brown and white, rather heavily bedded, coarse-grained, sub-crystalline; becoming more thinly bedded and cherty above	25
6.	Limestone, buff, soft, sandy locally	5
5.	Limestone, white, oolitic	3
4.	Sandstone, yellowish, soft, fine-grained, highly charged with casts of fossils	6
3.	Limestone, argillaceous, fine-grained, with often an oolitic band or thin bed of purer limerock at base	18
2.	Sandstone, yellowish, soft, friable, clayey	25
1.	Shale, blue, argillaceous, shown by borings to extend 100 feet or more below river level (exposed)	60

The relations of the Upper Burlington and Keokuk limestones with the cherts separating them are shown best perhaps at Augusta (Tp. 69 N., R. IV W., sec. 24).

II. Augusta Section.

		FEET.
4.	Drift	8
3.	Limestone, bluish, encrinital in places, clay partings often highly fossiliferous (Keokuk)	20
2.	Chert, white, thinly bedded, with thin irregular bands of limestone (Montrose)	30
1.	Limestone, white, coarse-grained, encrinital (Upper Burlington), exposed	15

Farther up the Skunk the Saint Louis rocks are found in the top of the bluffs on both sides of the stream. The section on the north bank (Tp. 69 N., R. IV W., sec. 6, SW. qr.) gives the following:

III. Section near Southwestern corner of County.

		FEET.
5.	Drift	10
4.	Limestone, brownish, shaly (exposed)	12
3.	Limestone, buff, somewhat magnesian, rather massive	4
2.	Shale, blue, with thin, discontinuous bands of impure limestone, and containing geodes in the lower part	25
1.	Limestone, blue and gray, with considerable chert, rather heavily bedded (exposed)	30

The Coal Measure deposits of the county are shown to the best advantage a few miles southwest of Danville (Tp. 70 N., R. VI W., sec. 5, NW. qr., NE. $\frac{1}{4}$):

IV. Section Southwest of Danville.

		FEET.	INCHES.
7.	Drift	20	
6.	Shale, light-colored	20	
5.	Shale, bituminous	3	
4.	Coal	1	2
3.	Fire clay	3	6
2.	Shale, brownish gray, gritty	1	6
1.	Shale, light, brownish, sandy in places (exposed)	4	

MISSISSIPPI RIVER SECTIONS.

As has been stated, the Mississippi river has on its west bank a high escarpment, which extends entirely through Des Moines county from the north to the south boundary line. The upper part of the bluff usually forms an almost perpendicular cliff, while the lower portion is commonly covered by a steep talus reaching from one-half to three-fourths the distance to the crest. North of

the city of Burlington the strata lie nearly horizontal, but south of that place they dip to the southward bringing the top of the Kinderhook, which is more than seventy feet above the river level, down to the water's edge (figure 31). In this section, number 1 is the Kinderhook; numbers 2 and 3, the Lower Burlington limestone with the overlying cherts; number 4, the Upper Burlington limestone; 5, the Montrose cherts; 6, the Keokuk limestone; 7, the Saint Louis limestone; 8, the Drift, and 9, the Loess. Among the best outcrops along the escarpment in the extreme northern part of the county is one a short distance south of the Louisa county line, near the angle which the bluff makes in changing from its southeastward to its southerly trend (Tp. 72 N., R. II W., sec. 22, SE. qr., NW. $\frac{1}{4}$), and about two and a half miles north of Huron postoffice:

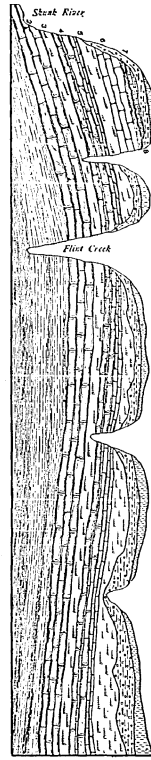


Figure 31. Cross-section along Mississippi River.

V. *Section North of Huron.*

		FEET.
5.	Limestone, white, somewhat irregularly bedded, containing bands of chert...	16
4.	Limestone, yellow, shaly, arenaceous..	15
3.	Limestone, heavily bedded.....	10
2.	Sandstone, friable, argillaceous.....	20
1.	Shale, blue, reported from well near by	4

The sandstone and shale (numbers 1 and 2) are without doubt the upper part of the Kinderhook, while the rest is the lower Burlington, with possibly the lowest part of the upper division.

A short distance southwest of Huron, near the mouth of Dolbee creek (Tp. 72 N., R. II W., sec. 23, SW. qr., SE. ¼), is shown:

VI. Dolbee Creek Section.

		FEET.
5.	Drift	4
4.	Limestone, largely encrinital, white, irregularly bedded	16
3.	Limestone, rather evenly bedded, with a few chert bands	14
2.	Limestone, yellowish, earthy and sandy	8
1.	Limestone, heavily bedded (exposed)	12

Farther south, about five miles from Kingston (Tp. 71 N., R. II W., sec. 35, NW. qr.), on Oak creek, a high salient appears as the stream opens into the valley of the Mississippi river.

VII. Section on Oak Creek.

		FEET.
5.	Loess	8
4.	Drift	6
3.	Limestone, buff and white, heavily bedded below, passing into silicious shales above (Lower Burlington)	35
2.	Shale, buff, sandy, forming incoherent sandstone in places	10
1.	Shale, bluish (exposed)	20

The last two numbers belong to the Kinderhook. The exposure is somewhat obscured by debris and the oolitic bed, which is so well defined at Burlington, is not seen. A short distance to the north, however, this layer is well exhibited with all its characteristic fossils. At the last

named place the Lower Burlington is only eight or ten feet thick at the edge of the escarpment.

In the north part of the city of Burlington, on what is known as North Hill (Tp. 70 N., R. II W., sec 29), similar outcrops are exhibited in the bluff.

From this point to Prospect Hill, two miles directly south, the exposures are well shown and present, practically the same features throughout. (See section I).

From North Hill nearly to the mouth of the Skunk river there is an almost continuous exposure, owing to the fact that the Mississippi sweeps westward cutting its right bank and enabling every little rill to make a clean vertical section of one hundred feet or more. The Kinderhook gradually gets lower and lower until at the Skunk river it passes beneath the water level. On Spring creek, west of Patterson station (Tp. 69 N., R. III W., sec. 25, SE. qr., NE. $\frac{1}{4}$), the upper portion of the Kinderhook is exposed in the bed of the creek.

VIII. 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

SKUNK RIVER SECTIONS.

The cross-section which follows the course of Skunk river is almost at right angles to the Mississippi river section. The direction is nearly transverse to the trend of the slight deformations which exist (figure 32).

The Patterson section (VIII) has already been described. In passing westward the bluffs are comparatively gentle

Figure 32. Cross-section along Skunk River.

for a distance of three miles and the exposures are rather limited. A couple of miles east of the town of Augusta the outcrops show both divisions of the Burlington limestone. In this section the numbers represent the following formations: 1 is the Kinderhook; 2 and 3 the Lower Burlington and overlying cherts; 4 the Upper Burlington limestone; 5 the Montrose cherts; 6 the Keokuk; 7 the Warsaw shales; 8 the Saint Louis limestone; 9 the Saint Louis marls; 10 and 11 the Coal Measures.

To the west the strata dip gradually bringing the Upper Burlington down nearly to the water's level at Augusta. The outcrop showing the Montrose cherts is repesented in section II. West of Augusta the steep bluffs on the north side of the river continue to exhibit good sections at short intervals to the west county line. Section III may be regarded as characteristic of the exposures found in the extreme southwestern corner of the county.

FLINT RIVER SECTIONS.

The Flint river furnishes a series of sections which extend in a line about midway between those of the

Mississippi and Skunk rivers. For a distance of several miles from its mouth Flint river flows through a narrow canyon-like gorge. From the Mississippi escarpment, at the point where the North Hill section is shown (section VIII), the wall of rock is almost unbroken, in many places overhanging. At the place known as the Starr Cave (Tp. 70 N., R. II W., sec. 19, NW. qr., NW. ¼) the formations are shown in detail on account of the perpendicular exposures from the water's edge to the top of the bluffs. (Plate xxxiv.)

About a mile farther up the stream (Tp. 70 N., R. III W., sec. 24, SW. qr., NW. ¼) the Upper Burlington is shown with the following section:

X. Section above Mouth of Knotty Creek.

		FEET.
3.	Drift	10
2.	Limestone, white, encrinital (Upper Burlington)	10
1.	Limestone, buff, cherty and sandy (exposed)	12

Four miles beyond (Tp. 70 N., R. III W., sec. 9, NE. qr., NW. ¼) an old quarry, north of Big Hollow, gives good exposures of Burlington limestone:

XI. Section near Big Hollow.

		FEET.
4.	Loess	6
3.	Drift	4
2.	Limestone, cherty	2
1.	Limestone, white, well bedded and containing characteristic fossils	8

In the southwestern part of Franklin township along Little Flint creek are several good though rather limited sections which appear to belong to the Keokuk limestone. One of these, five miles directly north of Middletown (Tp. 71 N., R. III W., sec. 31, NW. qr., SW. ¼), shows six to eight feet of blue shale overlain by several feet of massive

bluish limestone. On Cedar creek, a branch of the Flint, there are several good quarry faces exhibited about a mile east of Pleasant Grove (Tp. 71 N., R. IV W., sec. 12, SE. qr., NW. $\frac{1}{4}$):

XII. Pleasant Grove Section.

		FEET.
10.	Loess	4
9.	Drift	6
8.	Limestone, yellowish, heavily bedded	6
7.	Limestone, thinly bedded, brittle	2
6.	Limestone, heavily bedded, white	6
5.	Shale, yellow, sandy	2
4.	Limestone, gray, unevenly bedded	4
3.	Chert	1
2.	Shale, yellowish, sandy	2
1.	Limestone, thinly bedded (exposed)	3

GEOLOGICAL FORMATIONS.

The stratified rocks which everywhere underlie the drift mantle in Des Moines county belong entirely to the Carboniferous age. Although both of the two great subdivisions of this age are present, they are very unequally represented. The lower division, or Mississippian series, which over nearly all of the county has no indurated rocks resting on it, is made up, at least above the water level of the streams, almost wholly of limestones. The upper division, or Coal Measures, covers only a small area, in the extreme southwestern corner of the district. The lithological characters of the various formations at the different localities may be readily made out from the descriptive notes which accompany the geological sections already given. The broad relations which the different beds have to one another, and the unity of the individual members which go to make up the general sequence of strata are best understood when the different members are treated separately.

Mississippian Series (Lower Carboniferous),

The oldest rocks exposed at the surface in Des Moines county belong to the Lower Carboniferous or, as it has been more appropriately termed of late years, the Mississippian series. As already intimated, the most prominent members of the formation are heavy limestones. Aside from the great economic value of the rocks, the series as exhibited in Des Moines county is of special interest, historically, to the geologist. The strata along the Mississippi river in the vicinity of Burlington have become classic in American geological literature. Wherever these rocks are known the Burlington limestone is a familiar term. It was at the city of Burlington that they were first studied carefully and described in detail. This place, consequently, becomes the typical locality; and with the section at this point all beds of this age in other regions must be compared.

There are four major divisions of this series, of which three only are present in southeastern Iowa, the uppermost, or Kaskaskia, being absent. This missing member is not found in the Mississippi basin north of the Missouri river. Over this northern area its position is marked by an erosion interval which has left very striking evidences of its duration and extent. The three subdivisions present are the Kinderhook, Augusta, and Saint Louis. The first or lower is a thick shale; the other two are limestones, separated by shale.

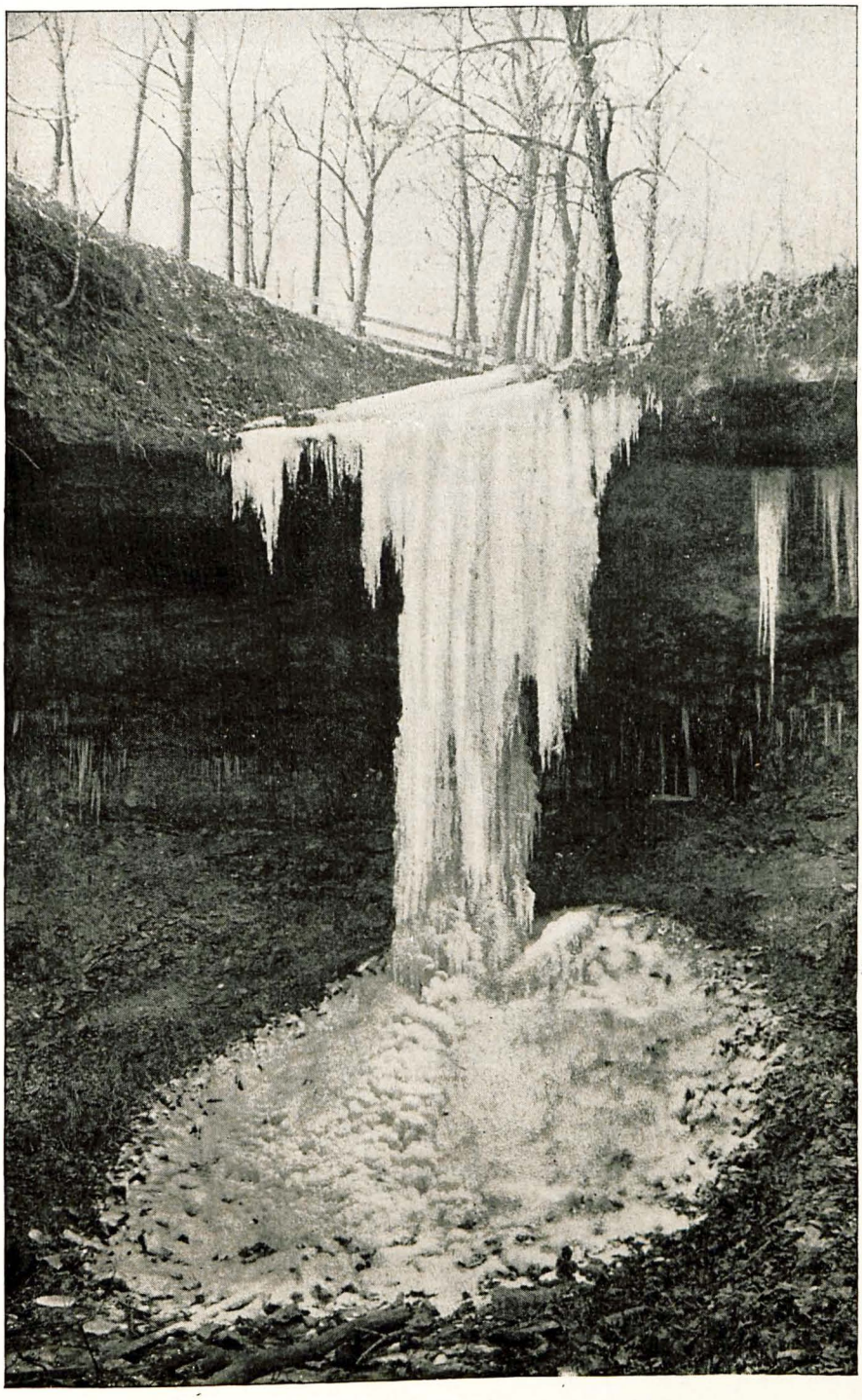
KINDERHOOK SHALES.

The shales of the Kinderhook attain a maximum thickness in Des Moines county of about 150 feet, of which perhaps one-half or seventy to eighty feet are exposed above the level of the water in the Mississippi river. In

this region these beds assume greater importance than anywhere else within the limits of Iowa.

On account of the peculiarities of erosion and the presence of a thick, massive limestone formation above it and very much harder than the basal shales, the Kinderhook beds do not present very extensive outcrops in the southeastern part of the state. Being the lowest of the geological formations appearing above the water level and as slight changes in the dip occur, the shales have no exposures in the uplands. Their natural outcrops are thus confined to a narrow belt at the bottom of the Mississippi escarpment, extending in a few places a short distance up some of the larger creeks which cut deeply through the bluff. This narrow belt is practically continuous along the entire eastern border of the county, the vertical height being from a few to about seventy-five feet.

As just stated the greatest thickness of the Kinderhook in Des Moines county above the water level in the Mississippi river is in the neighborhood of seventy-five feet. Borings, however, indicate that at least fifty, and possibly as much as one hundred feet of similar strata are present beneath this level. This would make the probable thickness of the Kinderhook beds at Burlington about one hundred and fifty feet. This is considerably greater than any observed thickness of these beds farther north. It is over twenty-five feet greater than the vertical measurements of the beds at Louisiana, Missouri, including the Louisiana limestone which has usually been put in the Kinderhook, but about the exact age of which there is now some doubt; and double the thickness of the Hannibal shales which are exposed so well in their full development at both Louisiana and Hannibal and which are thought to be practically the exact equivalent of the blue



KINDERHOOK AND AUGUSTA; "CASCADE," BURLINGTON.

shales as disclosed in the base of the Burlington section. No comparisons of thickness with the Kinderhook sections lying to the north of the district under consideration can be instituted for the reason that the rocks of this age in other parts of the state are largely limestones so far as has been observed and their exact equivalency with the shales at Burlington has not therefore been as yet determined.

The formation consists largely of compact, rather massive clayey shale at the base, with sandy shale at the top. The best exposure, one showing great variation in lithological details, is the Prospect Hill section, at Burlington (section 1). It consists of:

		FEET.
6.	Limestone, buff, soft, sandy locally.....	5
5.	Limestone, white, oolitic.....	3
4.	Sandstone, yellowish, soft, fine-grained, highly charged with casts of fossils.....	6
3.	Limestone, argillaceous, fine-grained, with often an oolitic band or thin bed of impure limerock at base..	18
2.	Sandstone, yellowish, soft, friable, clayey.....	25
1.	Shale, blue, argillaceous, shown by borings to extend 100 feet or more below river level (exposed)...	60

The uppermost member (number 6) is somewhat earthy and apparently contains much magnesia. It doubtless represents a zone of rapid transition between two beds having very diverse lithological features. Its position and textural characters are very similar to the Chouteau limestone of Missouri, which attains a maximum thickness of upwards of one hundred feet. It rapidly becomes thinner northward. The most northerly exposures of it in that state are at Louisiana and Hannibal, Missouri, where it is from ten to fifteen feet thick. In view of these facts it is not unlikely that this layer (number 6) may be eventually regarded as

the extreme northern attenuated extension of the Chouteau limestone of the region farther south. This stratum differs very materially from that immediately overlying it, being practically devoid of crinoid remains which go to make up so large a part of the Burlington limestone. Ordinarily this layer is too soft to be of use as a quarry rock, but in many of the quarries in which the layers immediately over it are worked it greatly facilitates the removal of the harder stone.

The oolitic bed (number 5) has a somewhat variable thickness, the limits being between one and four feet, the average about three feet. In most places this rock is quite massive and compact, forming apparently an excellent dimension stone when first quarried, but its use must be guarded and the selection made with the greatest care. The bed is well exposed at many places in the neighborhood of Burlington. It is shown in the Starr Cave cliff and along the Mississippi escarpment above and below the mouth of Flint creek; and on Spring creek west of Patterson station. The fossils which especially characterize the oolite are *Aviculopecten circulus*, Shumard; *Straparollus obtusus*, Hall, and *Murchisonia prolixa*, White & Whitfield. On the whole the fossils of the oolitic bed are predominantly gasteropods and lamellibranchs.

The fine-grained yellow sandstone (number 4) is remarkable chiefly on account of the prolific fauna it contains. Both in species and individuals the numbers are very great. It was from this bed that nearly all of the Kinderhook fossils which were described from Burlington by Winchell, White, and Whitfield were obtained. The great abundance of small lamellibranchs, gasteropods and peculiar brachiopods is particularly noteworthy. Economically the sandstone is of small value. It is too friable for

a quarry stone, but in breaking down forms a good building sand. Certain parts of it would also doubtless serve admirably as a moulding sand.

The fine-grained, fragmentary, calcareous member (number 3) is usually quite impure, and in most places would more properly perhaps be called a massive calcareous shale. Frequently some fine sand is present and often a rather large percentage of argillaceous material. At the base there is often exposed a thin layer of compact gray, or oolitic limestone or sometimes both. This band is characterized by an abundance of fossils of which a small Chonetes is the commonest. The thickness of this band varies from four to ten inches.

The soft sandstone (number 2) usually contains a considerable amount of clayey material and passes downward into an argillaceous shale. The upper part is considerably coarser than the lower portion. It forms a soft, friable layer which disintegrates rapidly upon exposure; and is one of the principal beds which allows the harder overlying strata to jut out over the lower portions along the escarpment of the Mississippi river.

The most important member, both geologically and economically, of the Kinderhook in Iowa is the basal shale, as shown in Des Moines county. It is a thick, compact massive bed, largely free from grit or layers of coarser material. It is well adapted for making brick and is so utilized extensively. Attention is called to its use in this industry elsewhere. It is capable of furnishing inexhaustible supplies of material for the manufacture of clay goods.

The remarks just made in regard to the Prospect Hill section apply equally as well to most of the Kinderhook wherever exposed in the district. Towards the north,

however, there is a tendency for the sand to become more and more abundant and to occupy an ever increasing proportion of the formation. At the same time the arenaceous beds become harder and firmer, and finally assume the characters of a fairly good quarry rock.

Correlation of the Kinderhook.— The beds of this age in Des Moines county cannot be exactly paralleled with the strata found anywhere else which pass under the same name. Farther south, in Missouri, the Kinderhook is readily separated into three well-marked divisions called the Louisiana limestone, the Hannibal shales and the Chouteau limestone, the latter being at the top. The relations of the Missouri to the Iowa sections cannot be made out by directly tracing the various beds from place to place since a shallow syncline carries the Kinderhook down below the river level between Hannibal and the mouth of the Skunk river.

The section of the Kinderhook at Louisiana shows:

		FEET.
4.	Limestone, buff, fine-grained, somewhat earthy and magnesian	18
3.	Shale, brown, sandy	12
2.	Shale, clayey, bluish or greenish	60
1.	Limestone, buff, compact, thinly bedded	50

This, with the Hannibal section, which is practically the same, is the nearest outcrop on the south with which the Burlington exposure may be compared. The green shales at the Missouri locality are manifestly the equivalents of the basal blue shale at Burlington, in great part at least. The buff, sandy shale above the clay shale at Louisiana perhaps has its representative at Burlington in all the Kinderhook section between the basal blue shale and the oolitic and buff limestone at the top. Although

somewhat thicker and presenting a greater variety of lithological characters than at Louisiana the more northern locality could not be expected to exhibit exactly the same features. That sediments of this description should have a greater development toward the old shore than farther seaward would be expected. Furthermore, the Chouteau limestone which forms a superior member of the Kinderhook in Missouri, and which south of the Missouri river attains a maximum thickness of one hundred feet, thins out rapidly to the north. At Louisiana not more than ten to fifteen feet of the buff, earthy limestone immediately beneath the Burlington beds can be referred to it. On the north side of the Keokuk syncline it appears to be entirely unrepresented unless the few feet of buff, impure limerock and perhaps also the oolitic bed can be placed with it.

The lower member of the Kinderhook, the Louisiana limestone, which is so well developed in northeastern Missouri does not appear above the water level in Des Moines county, if represented at all. It is believed to have thinned out completely before reaching so far northward. In sinking a deep well at Keokuk there was encountered at the base of the Kinderhook shales only ten feet of compact, fragmentary limerock which could in any way be referred to the Louisiana limestone. This being the case, then, it would have been reduced four-fifths of its thickness in a distance of sixty miles.

As regards the correlation of the Kinderhook rocks of southeastern Iowa with those of other parts of the state little can be said at the present time. In the central and north-central parts of the region the strata which have been referred to the Kinderhook are heavily bedded limestones. The yellow sandstones of Muscatine county, fifty miles north of Burlington, which have been usually paralleled

with the strata having similar lithological characters in Des Moines county have been found to have no relationship whatever, but to contain a typical Devonian fauna. The fossils of the Muscatine region formed the chief grounds, probably, for regarding the Burlington sandstones also as Devonian as was argued by Hall and subsequent writers.

Useful Deposits.—The materials of economic importance which occur in the county will be described in detail in another place. It is pertinent here to allude in a general way to the useful deposits which are to be especially looked for in the Kinderhook beds. First in importance are the basal shales. Special emphasis is to be put upon the value of these beds in Des Moines county as a brick material, and particularly in the manufacture of pavers. The extensive plant now in active operation at the "Cascade," two miles below Burlington, has for several years been turning out a superior grade of vitrified brick for paving purposes. This is at a single point only. For a distance of more than twenty miles along the Mississippi escarpment the situation is just as favorable for the erection of plants for similar purposes; and for at least half of the distance shipping facilities by both rail and water are exceptionally good.

The oolite bed may be used for building purposes, but great care must be taken in the selection of the stone. Lime of good quality has been burned from this layer. Building sand may be obtained from the upper arenaceous member of the Kinderhook where this bed has been exposed to atmospheric influences for a long period. Certain of the clayey shales in connection with particular parts of the highly calcareous shales appear to furnish suitable constituents for the manufacture of hydraulic

cement. The chief drawback, however, will be the securing of the proper fuel, cheap enough to warrant the profitable burning of the materials.

AUGUSTA LIMESTONES.

The term Augusta has been recently applied to all the formations which have heretofore been embraced under the Burlington and Keokuk groups. It is taken from the village of Augusta, about seven miles southwest of the city of Burlington in the southern part of Des Moines county, where both of the limestones and the separating cherts are exposed in the bluffs of the Skunk river. The Augusta includes:

6. Warsaw shales (in part).
5. Geode shales.
4. Keokuk limestone.
3. Montrose cherts.
2. Upper Burlington limestone.
1. Lower Burlington limestone.

The typical outcrop of the Augusta is shown in section 11 already given. The reasons for uniting these formations are numerous. Lithologically the rocks are very similar and are especially characterised by being made up in large part of the skeletal hard parts of crinoids or stemmed feather-stars. They have thus long been called crinoidal or encrinital limestones. The fossils contained are very similar throughout the vertical extent of the rocks and show a gradual though notable evolution or development from the bottom to the top. The changes which the organisms of the time underwent as they progressed from the beginning to the end of the period of deposition are best shown in the most characteristic and most abundant form of life — the crinoids. The same phenomena are

shown especially well in other zoological groups, but not quite so conspicuously. These fossils form perhaps the best example known of the evolution of life during past geological ages. In many cases all the different lines of separation may be readily made out and easily followed, with a wealth of material to draw from. Nowhere else in the Mississippi basin is a limited group of strata so strongly linked together by biological ties.

In southeastern Iowa the geological limits of the formation are unusually well defined. A thick shale and an accumulation of shore deposits abruptly terminates it below, while above there is not only a very decided change in lithological characters but also what appears to be a very marked physical break in the continuity of deposition.

Lower Burlington Limestone.—The lower portion of the limestone series as exposed at Burlington was the first part of the Augusta rocks to receive careful attention. It occupies about fifty feet of vertical height if the twenty feet of silicious and calcareous shales at the top are also taken into consideration. The limestone proper is a coarse-grained, encrinital rock, pure white to brown or red in color. It is rather heavily bedded, especially at the base. The so-called crystalline appearance is due to the fractured and separated plates and stem-joints of crinoids which are scattered or disseminated through the beds like pebbles, often so abundantly that it gives at first glance the appearance of gravel. During disintegration, the plates accumulated in beds, the fine material being carried off by running water.

The partings are usually quite thin. Almost the entire section is sufficiently compact and massive to be used as quarry rock. Normally the stone is gray, but portions of

BURLINGTON LIMESTONE OVERHANGING KINDERHOOK SHALES; FLINT RIVER AT STARRS CAVE.

it are intensely white. The characteristic brownish color or reddish hue is imparted to it by percolating waters which enter the crevices and circulate along the bedding planes. By carrying away much of the lime in solution the water forms caverns and cavities which are often of considerable extent. In Iowa the cavernous character of the Burlington is not so pronounced as farther south, in Missouri and especially in the southwestern part of that state. The Lower Burlington beds present some peculiarities in texture which are not met with in such a marked degree in other parts of the Mississippian series.

The conspicuous encrinital character so commonly ascribed to the Augusta limestone is far more pronounced in the Lower Burlington than elsewhere. Crinoidal life at the time of deposition must have been prolific beyond all conception. The organisms made up almost wholly of hard, thick plates composed of carbonate of lime, furnished an abundance of material for the accumulation of extensive beds. An idea of the immense quantity of crinoidal hard parts making up some layers may be obtained when it is remembered that the average crinoid is composed of from thirty to fifty thousand plates of all sizes, and that the remains of half a dozen individuals would occupy the space of about a pint. These plates or ossicles were fastened together by ligaments, which readily decayed when the animal died, allowing the structure to fall to pieces in a confused mass of loose pieces. Only under the most favorable circumstances were the hard parts preserved entire, with the plates in place. The disjointed skeletal remains of the stemmed echinoderms or feather stars form great beds of what has been often called a crinoidal breccia. This agglomeration varies greatly in the degree of consolidation; sometimes it is very hard and compact, sometimes

very open in texture and full of interstices with scarcely any finer cementing material. Broken and shattered calyces, parts of arms and sections of stalks are mingled with the mass of separated plates. Elsewhere thick, compact beds alternate with thin friable layers. Occasionally in the thin, sandy partings there are preserved the remains of the forms, each plate in its original position, and as perfect as when the animals were entombed.

The species which characterize the Lower Burlington are widely distributed geographically. From Iowa to New Mexico they are so near alike that it is impossible to tell from just what part of the country a particular individual comes, so uniform were the conditions of existence. The fossils, particularly the crinoids, are distinguished in a general way from those from other parts of the Augusta by a notable delicacy and lightness of construction and fine, graceful ornamentation. With a few exceptions the crinoids may be told at once by these features.

The upper part of the Lower Burlington is made up of brown and white silicious shales, with much chert in nodules and irregular bands, and some limestone. Ecomomically the shales are of small value.

Upper Burlington Limestone.—The upper division of the Burlington is distinguished from the lower section chiefly by being thinner bedded, containing more chert, and having clay shale layers intercalated. The grain is noticeably coarser and the texture more open. The color is an intense white, which is rendered all the more conspicuous by the alternating bands of brown silicious material.

The most typical section of the Upper Burlington is shown in the Miller quarry, south of Burlington, above the "Cascade."

Section at the Miller Quarry.

		FEET.
8.	Loess	12
7.	Drift	3
6.	Limestone and chert	8
5.	Limestone, brown and white, banded with chert, thinly bedded	6
4.	Limestone, gray and white, heavily bedded	10
3.	Shale, blue argillaceous, fossiliferous	2
2.	Limestone, heavily bedded, white	5
1.	Shale, blue (exposed)	4

The two shale beds form a marked feature in the section. They have not been recognized elsewhere in such thickness. They are fossiliferous, carrying an extensive fauna very different from that of the limestone.

The Upper Burlington limestone forms the surface rock over fully one-fourth of the entire county, occupying a broad belt immediately west of the Mississippi escarpment. On account of its position nearly all of the quarrying done in the district is in the upper division of the Burlington. Throughout the region of its occurrence the water courses cut into it exposing good ledges and making the rock very easy of access. Although the Lower Burlington affords beds more massive and much thicker, the layers of the upper division are usually of sufficient thickness for all ordinary constructional purposes. Moreover, the lower section being so much lower and only exposed in the bluff sides, it is not so accessible; and only at a few points can it be worked to advantage.

The upper member of the Burlington has been regarded as a distinct subdivision chiefly on account of the fossils it contains. Being preeminently a crinoidal limestone the crinoids form the most prominent group of organisms whose remains are preserved. On the whole they represent a stage of development intermediate between those of

the Lower Burlington and the Keokuk. The species have neither the delicacy, frailness and small size of the earlier forms, nor the massive construction, coarseness and exaggerated features of the later organisms of the same group. The most characteristic species are: *Batocrinus rotundus* (Shumard), *Batocrinus christyi* (Shumard), *Eretmocrinus verneuilianus* (Shumard), *Dorycrinus cornigerous* (Hall), *Actinocrinus verrucosus* (Hall), *Strotocrinus regalis* (Hall), *Granatocrinus norwoodi* (Shumard), and *Schizoblastus sayi* (Shumard). Wherever the Upper Burlington is exposed these species are almost always present; and it is rarely that some of them cannot be recognized after a little search. They are the most widely distributed geographically of any species occurring in all of the Augusta rocks. On account of the wide dispersion and great abundance of the fossils named, the Upper Burlington is readily recognized even when it is not possible to make out clearly the associated beds. The horizon thus becomes an important one for purposes of correlation in sections widely separated, and for determining rocks which occur either above or below.

Towards the top, the upper Burlington becomes more and more cherty and finally passes into beds in which flinty nodules and bands predominate, and which have been called the Montrose cherts.

The chief value of the formation is as a quarry rock. As already remarked most of the quarries at present in operation in Des Moines county are opened in the Upper division of the Burlington limestone. The easy access to the stone and the excellent facilities for transportation both by rail and water should cause a very much larger development of the quarry industry in this region. A superior grade of lime is afforded by the burning of the

white layers, but at the present time little is being done in this line. Farther south, in Missouri, the cherts of this formation are used largely for scouring purposes, the nodules being ground to flour-like powder and put in certain grades of soap and polishing preparations.

Montrose Cherts.—The Upper Burlington cherts were formerly thought to have a thickness of from fifty to one hundred feet. Recently well exposed sections show clearly that twenty-five or thirty feet must be regarded as a more accurate measurement. Though a comparatively unimportant bed itself, it has come into considerable prominence on account of forming the extensive obstruction to navigation in the Mississippi river, which has long been known as the Des Moines rapids and which extends from Montrose to Keokuk. In Lee county the cherts extend along nearly the entire eastern border of the district. In Des Moines county they are best exposed along the Skunk river, the most instructive outcrops being in the neighborhood of Augusta. The details are given in section II. With the general rise of the strata towards the north the chert beds are brought more and more to the surface where they have suffered great erosion. At Burlington only the lower part is preserved in isolated places. Few fossils are found in the cherty layers.

Keokuk Limestone.—The third great division of the Augusta is not so important a number as it is farther south in Lee county; yet it probably underlies fully one-fourth of the areal mileage of the district. The rocks occupy a considerable part of the southwestern portion of the county, but are overlain over a large area by the Saint Louis limestone and Coal Measures. The surface distribution would therefore be more accurately a broad strip of territory trending southeast and northwest. Portions of

Pleasant Grove, Danville, Flint River and Union townships would thus be covered by these rocks. The valley of the Skunk river above Augusta also forms a narrow tongue brought out through erosion. In Lee county much larger areas are occupied by the Keokuk limestone and still further southward in northeastern Missouri the greater part of several counties is underlain by this rock. To the west of Des Moines county, however, the Keokuk is only exposed in the beds of the water courses.

In lithological characters the Keokuk limestone may be distinguished from the Burlington beds by its general blue color, its less crystalline texture, and its greater compactness. The great profusion of crinoidal remains which is so marked in the Burlington is largely absent in the Keokuk, or is confined to thin beds of limited extent. Consequently, when the two members appear in the same section the differences are quite marked. Below, the Keokuk is rather heavily bedded. Above, it becomes more thinly bedded and gradually acquires more and more argillaceous material in the partings until these form well defined shale bands. A considerable amount of chert is present in nodules and irregular nodular bands. In many places the flinty material is so abundant that it practically destroys the stone for quarry purposes.

The shales overlying the Keokuk limestone are not so important in Des Moines county as elsewhere in southeastern Iowa. They are exposed to advantage in only a few places. The geodes which are so characteristic of the lower part and which have caused that portion of the section to be called the "geode bed" are not so abundant, and may be absent altogether.

The chief use of the Keokuk must be as a quarry rock, but it will be a long time before the facilities for trans-

portation will be such as to enable it to compete successfully with the other limerocks of the county. The same may be said of it as a lime-burning stone.

SAINT LOUIS LIMESTONE.

The chief exposures of this formation are in the extreme southwestern corner of the county where it underlies an area of perhaps thirty square miles. It covers most of the uplands of Augusta township and probably nearly one-half of Danville township. A small area also occurs in the western part of Union township. The outcrops are principally on Long and Cedar creeks and on the Skunk river. The beds comprise, (1) white clay or marl at the top, (2) gray, flag-like limestone, (3) brown, arenaceous limestone, (4) concretionary and brecciated limestone. A massive magnesian layer like the member forming the top of Hall's Warsaw beds in Lee county has been reported at the base of the beds above mentioned.

The white marly clay is quite plastic and carries an abundance of fossils. It has been observed at only one point, which is about one mile directly north of the town of Augusta on a small stream emptying into Long creek. This clay is in all respects identical with a similar clay or shale which is found at the top of the Saint Louis in many other parts of the state. The fossils so characteristic of this bed as well as the white limestone are: *Rhynchonella ottumwa*, White; *Spirifera keokuk*, var., Hall; *Productus marginocinctus*, Prout; *Zaphrentis pellæensis*, Worthen, and *Athyris subquadrata*, Hall.

The gray, coarse-grained limestone is regularly bedded, and occurs in thin, flag-like layers from two to five inches in thickness. It is quite compact and without fossils. The best outcrops are on Cedar creek, and on Long creek

north of Augusta. A quarry opened three miles northwest of that town in the bank of Long creek (Tp. 69 N., R. IV. W., sec. 10, NE. qr., NE. ¼) discloses a face of eight feet of this stone.

The brown sandy limestone is rather unimportant and is exposed in but few places. On Cedar creek a layer apparently belonging to this member crops out near the base of the bluffs.

The brecciated limestone is in all respects similar to the same rock as it occurs elsewhere in southeastern Iowa. It is composed of a very fine-grained, compact limestone, light blue or ash gray in color and breaking with a well-marked conchoidal fracture. The fragments are all more or less angular, rarely rounded or water worn. In size they vary from the smallest particles to plates and irregular blocks several feet in length. These fragments are closely compacted and the interstices filled with a hard, greenish clayey material somewhat calcareous and weathering much more readily than the limestone.

As a quarry rock and as a material for quicklime the Saint Louis offers good supplies. Some of the layers are capable of furnishing a superior grade of stone for dimension work. The clays associated with the Saint Louis limestones are for the most part too calcareous for brick or pottery.

Upper Carboniferous or Coal Measures.

DES MOINES FORMATION.

The Lower Coal Measures form a comparatively unimportant part of the beds which are exposed in Des Moines county. The entire areal mileage of these rocks in the district probably does not exceed half a dozen square miles. In all, there are only a few isolated areas, confined

entirely to the extreme southwestern corner of the county. Des Moines county forms a portion of a comparatively narrow belt which borders the Mississippi river from the mouth of the Missouri northward and which is underlain by rock older than the coal bearing strata of the Continental Interior. This zone of more ancient rocks separates the Iowa-Missouri coal field from that of Illinois. The present conditions are probably the result of slight deformations which originated during the latter part of Lower Carboniferous times and of subsequent erosion. The Coal Measures have thus been almost entirely removed. The isolated areas remaining consequently partake of the character of outliers.

Recently the extent of the Coal Measure outliers in Des Moines county has been found to be much greater than has been heretofore supposed. Instead of the single small deposit a few feet in thickness which has long been known to exist on Cedar creek in Danville township several other and much more extensive areas have been discovered, the largest being a short distance northwest of Augusta. These outliers are in the upland plain about three miles from the river, and manifestly form a part of a much larger area whose limits have been lately determined on the south side of the Skunk river in Lee county. The Augusta outliers comprise buff or brown more or less ferruginous sandstones, usually rather fine-grained, homogeneous, and massive, but frequently becoming coarse and even pebbly. The beds attain a thickness of from twenty to fifty and even one hundred feet. The base of the sandstone has nowhere been observed and its exact relation to the underlying Saint Louis and Augusta limestones has not been determined. A few miles to the southward beds of coal two to four feet in thickness are

associated with similar deposits; and it is not improbable that workable seams will yet come to light in connection with these sandstones. It is quite likely also that the areal extent is much greater than has yet been determined.

The outlier on Cedar creek in Danville township, shows very little sandstone, only a few feet at the base of the exposure. The greater part of the outcrop (section IV) is composed of clayey shales, the lower part being light colored shale or fire clay and the upper a dark drab bituminous shale. Between the two a thin seam of coal exists. It has a thickness of a foot or more.

Although occupying so small an area in Des Moines county the Coal Measures are more or less important economically. The sandstones furnish a fair grade of building stone. The shales supply, on weathering, a plastic clay which may be used in the manufacture of earthenware. A good quality of brick, both paving and building, may be also made from the clays. While some coal is known to be present it is not to be expected that it occurs in sufficient quantities to create an extensive mining industry; yet it is not improbable that eventually small pockets will be found of sufficient importance and size to supply local demands.

Pleistocene.

GENERAL CHARACTER OF SURFACE DEPOSITS.

The surface deposits which cover the indurated rocks so effectively everywhere except in the immediate vicinity of the water courses belong largely to the first glacial epoch. The accumulations comprise (1) the Lower Till, and (2) the Loess, with some alluvium in the river bottoms. The terrace formations are unimportant and find expression only in a few limited areas.

The drift deposits have been laid down over an old eroded surface even more profoundly gashed and trenched than that existing at the present time. Evidences of this great erosion are now largely obscured by the depositions which have been subsequently made, yet they are being continually brought to light through natural and artificial excavations. Although the old depressions and channels are largely filled with glacial débris the preglacial expression of the country is not entirely obliterated, and the principal features of the modern surface relief are still largely dependent upon the ancient elevations and depressions. In many cases the water courses have endeavored to regain their old channels, often with more or less success. As a result streams are found with thick drift deposits, sometimes fifty to seventy-five feet, on either side, but which are manifestly reclining on the ancient slopes of the indurated rocks. An excellent example is Hawkeye creek at Burlington. A cross-section of this valley is shown in figure 33.

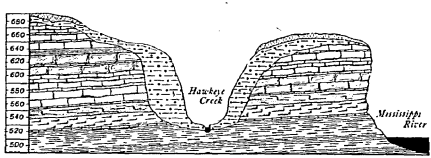


Figure 33. Section across Hawkeye creek at Burlington.

As shown in the section there is an extreme attenuation of the drift deposits over the old elevations and a deep accumulation of débris in the ancient valleys. This is indicated similarly in many other parts of the district.

At Burlington and in the immediate neighborhood numerous excavations and road cuttings disclose the features of the Pleistocene deposits better, perhaps, than anywhere else in the county; and at the same time illustrate just what occurs and what is to be expected in other parts of the district. The area may therefore be taken as typical and as one whose details may be regarded as practically identical with those over most of the county. The topography of the area is represented on the sketch map (figure 34).

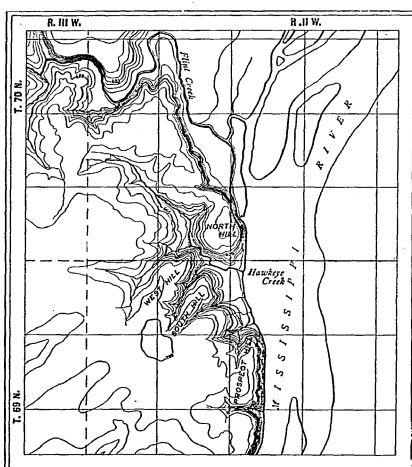


Figure 34. Surface relief of Burlington and vicinity.

The city of Burlington is built upon four "Hills," all of which rise to a height of nearly two hundred feet above low water in the Mississippi river at that place. Perhaps five-sixths of the altitude is formed of Burlington limestone and Kinderhook shales, which along the Mississippi river at Prospect and North Hills, and also in places bordering Flint creek, rise from the water's edge in high, mural escarpments.

North of Hawkeye creek is a nearly insulated plateau, all sides of which are scalloped by steep sided ravines, very deep toward the lower extremities, but interiorly shallowing quickly. The larger ones soon pass into small, shallow drainage basins, which impart to the central portion of the plateau a characteristic, gently undulatory appearance. To the northeastward is a small subsidiary plain of gently undulatory topography, evidently in no way dependent, in its configuration, upon the underlying stratigraphic rocks. It rises thirty or more feet above the broad alluvial flood plain of the Mississippi river and is divided into two parts by Flint creek. Southwestward it passes rather abruptly into the comparatively gentle slopes of the general plateau. It manifestly occupies a preglacial depression, and literally rests upon the irregularly eroded slopes of an ancient water course. A section of this limited auxilliary plain exhibiting all the details of structure forms an exposure continuous for nearly half a mile along Flint creek; and it is practically similar throughout.

Terrace Section Near Mouth of Flint Creek.

		FEET.
7.	Loam, coarse, brown, friable, with occasional small pebbles, graduating imperceptibly into 6.....	3
6.	Clay, yellowish brown, of a characteristic fissured nature; containing a few small boulders or large pebbles, in places indistinctly laminated..	15
5.	Sand and gravel, commingled, irregularly stratified, pebbles up to six inches in diameter, mostly rounded, erratic, but with numerous local angular flint and limestone pieces	10
4.	Clay, drab, homogeneous, unctuous.....	2
3.	Sand, coarse, yellow and white, with a few small erratic pebbles, everywhere quaquaversally stratified	6
2.	Sand, very fine, homogeneous (not present along the entire section).....	1
1.	Sand, coarse, yellow and white, with rounded and striated erratic pebbles up to two feet in diameter, and larger local angular fragments of flint and fossiliferous (Burlington) limestone (exposed).....	12

One mile above, on Flint creek, the coarse yellow sands form a conspicuous feature. A short distance farther north the lower till, with numerous small rounded, erratic boulders up to four feet in diameter, is well exposed in all its characteristic details. It is overlain by six to eight feet of typical loess, containing numerous small loess-kindchen. The deposits here present have an exposed thickness of sixty feet, and are seen to rest against the steep sides of the rather narrow gorge, preglacially eroded by the waters of Flint creek to the depth of more than one hundred and thirty feet. North of Flint creek, and beyond the area represented in the annexed map, the topography in its general aspect is similar to that of the isolated plateau south. On the upper brow of the north slope of

"North Hill" a road cutting discloses the following arrangement:

Bluff Section on North Hill.

		FEET.
3.	Clay, brownish, yellow; free from gravel, and for the most part homogeneous; grading into 2....	5
2.	Loess, typical, ashen, compact, containing numerous loess-kindchen and the following fossils: *Pupa muscorum*, Linn; *Succinea obliqua*, Say; *Patula strialella*, Anth.; *Limnophysa desidiosa*, Say; *Patula perspectiva*, Say; *Helicina occulta*, Say.....	8
1.	Till, with an abundance of gravel, and pebbles up to three feet in diameter (exposed).....	20

Over the entire central portions of the northern plateau the distribution of Pleistocene deposits is essentially the same, except that the lower member suffers a considerable attenuation over the more elevated parts, sometimes being reduced to only a few feet in thickness. Upon the removal of the drift materials glacial scorings and striæ on the subjacent Paleozoic strata have been disclosed in various places.

South of Hawkeye creek rises a broad, elevated plain, so level in many places as to be almost devoid of natural drainage. Northeastward it is scalloped by short, deep ravines, but eastward it abruptly terminates with a perpendicular declivity, washed at its base by the Mississippi river, which has evidently separated the plateau from the highland of Henderson county, Illinois. To the south and west this level, elevated plain gradually becomes gently undulatory and finally more broken by the small tributaries of Spring creek. Northwestward it merges into the general elevated plain occupying the greater portion

of the county. Near the summit of "South Hill" in a recently opened quarry there is exposed:

South Hill Section.

		FEET.
5.	Clay, brownish; free from pebbles; becoming silty below and graduating insensibly into 4.....	5
4.	Loess, compact, ashen, containing loess-kindschen..	9
3.	Clay, red, tenacious, upper portion containing much gravel, the pebbles small, rounded, mainly erratic, a few local flint and limestone fragments disseminated throughout.....	1
2.	Large angular fragments of limestone and flint, the interstices filled with red clay	2
1.	Limestone, Upper Burlington, (exposed)	20

One-quarter of a mile to the southeast, on the corner of South Fourth and Maple streets, a similar arrangement is shown, superimposed on the Lower Burlington limestone. The Quaternary beds of the two places are manifestly continuous, but the elevation of the latter section is somewhat less than the former, and the several beds are all much thicker, No. 5 of the South Hill section having a thickness of six feet, No. 4 of thirteen feet, and Nos. 4 and 3 together of six feet. One-fourth of a mile southwest of this exposure a road cutting exhibits:

		FEET.
3.	Clay, brownish, silty or loess-like below.....	10
2.	Till, typical, lower	25
1.	Limestone, Lower Burlington, (exposed).....	5

LOWER TILL.

The general characteristics of the drift have already been indicated. The deposit is composed of blue or yellow clay, which contains considerable sand either disseminated, or in thin lenticular beds, and boulders which consist largely of rounded masses of crystalline rocks,

together with limestone and some chert fragments. The boulders are rarely angular and are invariably of small size. A few reach a measurement of five or six feet and one, a few miles west of Burlington, is fully fifteen feet across. Good indications of stratification are seldom met with, except when the sand beds are intercalated, and even then the regular bedding lines are not distinct. When the loess overlies the drift a narrow band of small pebbles frequently indicates the line of demarkation between the two. Below, the till gradually mingles with the residuary clays above the limestone; and the zone is marked by a bed, two or three feet in thickness, of dark reddish clay with which is mixed an abundance of chert and some limestone fragments. In many places this appears to be disturbed.

LOESS.

The loess of Des Moines county occurs only over the more elevated areas and always overlies the till. It is usually the characteristic fine ashen or yellowish silt, quite homogeneous and varying in thickness from a few inches to ten or fifteen feet or more. Calcareous nodules, tubules of iron oxide and fossils are more or less abundant. The latter are largely the shells of snails which frequent damp situations. The relations of the loess deposits to the drift is shown in the sections already given (North Hill and South Hill sections).

TERRACES.

Owing to the westward deflection of the Mississippi opposite Oquawka, the river is brought directly against the hard limestone wall which marks its immediate valley. Terraces consequently have an unimportant development. The principal evidences of terrace forma-

tion are at the mouth of Flint creek above Burlington, and north of the mouth of the Skunk river. In the northern part of the county low terraces also exist. The terraces at the mouth of the Flint are about thirty feet above the flood plain of the Mississippi. A vertical section of the different beds comprising it is shown in the section at the mouth of Flint creek.

GLACIAL MARKINGS.

Des Moines county has long been known as one of the few localities in Iowa where ice striations have been observed. In fact, the first glacial markings which were reported in southeastern Iowa were those discovered by White in 1858 near Burlington. There is no exact record of White's original location, but it is thought to be two or three miles north of the city. No account of these striations published at the time, though afterward, on several occasions, mention was made of them. The direction was approximately south 15 degrees east. Until very recently nothing additional has been recorded concerning the glacial striæ of this part of the state.

On the west bank of the Mississippi river for the greater part of the distance between the mouths of the Iowa and Des Moines rivers a high escarpment, capped by a massive limestone, borders the stream. In many places the rocks stand out in bold, cliff-like walls, one hundred to two hundred feet high, with a heavy talus at the base. Along much of this exposed scarp the conditions are exceptionally favorable to the recording of ice scorings.

On North Hill, on the brow of the Mississippi bluff, striated surfaces have been reported from time to time, but rarely have they been carefully examined. On one

occasion the bearing of the striæ was found to be south 63 degrees east, the magnetic deviation being about 7 degrees. Mr. Frank Leverett has stated more recently that he also has measured the direction of some glacial grooves in the same vicinity. He reported the bearings to be south 65 degrees east.

Observations made a few years ago show that the sharp salient at the Cascade two miles south of the city has been manifestly ice-planed. At the present time no ice markings are visible at this place. A few years ago, however, several large limestone slabs, four to five feet long and two or three feet wide, were removed in quarrying from the top of the salient above the present works of the Granite Brick Company. Some of these flat blocks were beautifully glaciated and polished, showing deep flutings and mouldings.

Special attention may also be called to the recent discoveries of similar phenomena by Mr. F. M. Fultz, of Burlington. A number of localities have been examined by him, at all of which ice-planed surfaces are exceptionally well preserved. One of these localities is near Kingston, another is near West Burlington, and more recently, still others have been reported.

GEOLOGICAL STRUCTURE.

GENERAL ARRANGEMENT.

On the whole the strata of the district are remarkably free from all effects of the great secular movements of the earth's crust which are so pronounced in nearly all portions of the globe, and particularly in mountainous regions. The deformations present are so slight that ordinarily they pass almost unnoticed.

Broadly speaking, the strata are in practically the same position as when originally deposited, preserving an almost horizontal position. There is, however, a gentle dip towards the west or rather southwest, in the southern part, and northward in the northeastern part of the county. The latter slope forms the northern side of the Keokuk syncline, which has its maximum depression about at the mouth of the Des Moines river, and by which the strata are carried downward at least one hundred and fifty feet.

For the most part the indurated beds lie one upon another in regular sequence. But in the southwestern portions of the county there is a noticeable exception in that the Coal Measures rest in marked unconformity upon the underlying rocks, though the irregularities of depositions are not so well defined as a few miles farther west and elsewhere in the state. An unconformity even more pronounced is that between the drift and subjacent strata.

GEOLOGICAL CROSS-SECTIONS.

Mississippi River Section.—The structural arrangement of the strata along the Mississippi river may be made out with considerable ease since the gorge of the great stream, which is in this part of its course so well defined, affords unusually favorable opportunities for careful investigation. The escarpment thus formed on the west bank of the Mississippi is very abrupt, and extends practically continuously along the entire eastern margin of the county.

While at no point is the dip perceptibly great there is, in passing both north and south from Burlington, an impression constantly growing that the beds are nearer and nearer the water level. Measurements carefully made of the altitudes of easily recognized and persistent horizons show that this is really the case, and that the city of

Burlington is very close to the crest of a low anticline, or fold. (Figure 31.) Upstream for some distance the strata appear to vary but little from horizontality. Southward from the city the layers have a more noticeable inclination. The top of the Kinderhook, which at Burlington is some eighty feet above the river level, falls to the surface of the stream at the mouth of the Skunk. This is a drop of eighty feet in a distance of about seven miles or a dip of about eleven feet to the mile. South of the mouth of the Skunk river the slope of the beds continues nearly to the southern boundary of the state where a long rise takes place. This forms what is called the Keokuk syncline, from the city which is near the point of greatest depression.

Skunk River Section.—The strata exposed on this water course show only a single direction of dip—the inclination being upstream. At the eastern end of the section the lowermost beds are the Kinderhook which are exposed but a few feet above water level in the Mississippi and are not seen beyond Spring creek, at which point in the bed of the stream only the uppermost layers are exposed. The Lower Burlington soon passes out of sight and the Upper Burlington limestone is brought down to the bed of Skunk river at the town of Augusta. From a point a short distance beyond to the west county line the bed of the stream is occupied by the Keokuk limestone. Making an allowance of a fall in the Skunk river of four feet to the mile, which is rather high, the total difference in the actual level between the eastern and western extremities of the section, which is about eighteen miles in length, would be about one hundred and thirty feet, or an average inclination of eight feet to the mile. While this amount of inclination is too slight to be distinguished by the eye, an increase of four feet, on account of the slope of the river in the opposite direction

makes an apparent dip of about twelve feet which is perceptible in traveling up stream any considerable distance (figure 32).

UNCONFORMITIES.

The lines of unconformity which mark breaks in the deposition of strata are the same in Des Moines county as elsewhere in southeastern Iowa. They are two in number. One is at the top of the Lower Carboniferous and the other is at the base of the Pleistocene, or drift. In all the great sequence of strata, with these two exceptions, deposition has been continuous.

The unconformity between the Lower Carboniferous and the Coal Measures is not so marked a feature as in other parts of the state for the reason that the district lies in the extreme eastern margin of the Western Interior coal field. The only portion of the county where the unconformable relations are to be found is in the extreme southwestern corner. The great thickness of the Coal Measures sandstone—something over one hundred feet in places—seems to indicate clearly that the depressions of erosion which are filled with the sandstone extend not only into the Saint Louis limestone, but also into the Keokuk and perhaps even into the Burlington.

The drift mantle which covers the entire country fills the valleys of an ancient surface as profoundly eroded as the present surface. Its irregular position upon the hard layers is apparent wherever excavations of any extent are made.

BUILDING STONES.

Des Moines county is perhaps as well supplied with good building stone as any similar district in the state. With the excellent railway facilities which it enjoys,

transportation in all directions is at hand. Shipment by water is also open and considerable quantities of rock for the government improvements along the Mississippi are continually sent out by boat.

By far the larger proportion of the available rock for constructional purposes is limestone. There is some sandstone of fair quality, but as yet it has not come into general use — owing chiefly to its position at considerable distances from ready transportion. The limestone is of several varieties, the principal and most important being the common white, or encrinital stone. This is coarse-grained, compact, more or less massive and varies in color from pure white to gray, yellowish or brown. It is made up entirely of crystalline hard parts of various organisms, chief among which are the crinoid plates. The mass of animal remains is firmly cemented by fine calcareous material. Fractured surfaces thus show a coarse, crystalline structure, not unlike many marbles. Through these there are all gradations to ordinary earthy limestone. The sub-crystalline varieties withstand weathering admirably and are readily dressed.

All the principal geological formations of the county yield building stone. The Kinderhook, however, supplies comparatively little, the only bed which is worked being the oolite near the top of the formation. It is compact, gray in color and has a thickness of about three feet. For the most part this bed cannot be depended upon to furnish good material which will withstand weathering influences, especially in exposed places. When kept from moisture it will last much longer than otherwise. If carefully selected in the bed it may form a tolerably durable rock. Its massive, homogeneous character and the readiness with which it is dressed has occasioned a somewhat wide

use of the rock and it affords such excellent dimension stone and material for dressed trimmings that the temptation to use it is great, notwithstanding its liability to rapid destruction through weathering.

The Lower Burlington limestone, while largely subcrystalline through its encrinital character, has a decided yellowish or brownish hue. Certain of the beds are pure white or gray, but unlike those of the Upper Burlington. The rock being very heavily bedded, compact and easily worked, makes it a very desirable stone for dimension work. Although there are inexhaustable supplies of good building rock its distribution is not so extensive as the Upper Burlington, for the reason that almost everywhere thirty to one hundred feet of other strata overlie it. Consequently quarrying in this bed must be restricted to the base of the bluff along the Mississippi. It has been quite extensively quarried in the city of Burlington. The principal opening, which is probably also the largest quarry in the county, is situated a few miles south of Burlington on the Chicago, Burlington and Kansas City railroad.

The Upper Burlington limestone furnishes by far the greatest portion of the quarry rock in the county. As stated in connection with the discussion of the geological formations, the Upper Burlington limestone occupies fully one-fourth of the surface of the county, stretching out in a broad belt parallel to the Mississippi river and reaching north and south entirely across the district. With few exceptions the quarries of the county are opened in this formation. In texture the rock is commonly a coarse-grained, encrinital limestone, often having the crystalline appearance of marble on broken surfaces. It is commonly a pure white rock varying to gray and sometimes to buff.

It is quite massive, firm and compact, and affords a good material for all kinds of common constructions.

Although the Keokuk limestone occupies a considerable portion of the county, few quarries are opened in it, the only one of much importance being near Augusta. While the rock may be termed an encrinital limestone, this character is not so apparent as in the case of the Burlington stone. There is more earthy calcareous matter and the limestone on the whole is more of an ordinary blue or ash-gray rock with the crystalline portions consisting of isolated plates and hard parts of the organisms disseminated through it.

The Saint Louis limestone is a fine-grained, compact limerock, breaking with conchoidal fracture and usually containing few or no fossils. It is rather thinly bedded and is rarely used, except for foundations and retaining walls.

The Coal Measures supply comparatively little building rock. That which does occur is a medium grained sandstone, rather compact, and buff or brown in color. Beds having a thickness of upwards of one hundred feet are found in the southwestern part of the county. Though too far removed from railroad facilities at present to come into general use it is said to be a very durable rock.

The quarry industry in Des Moines county has not near the development that it should have; and with very little effort could be made many fold more important. Although every township in the county supplies quarry rock for local use, the principal quarries are concentrated in and about the city of Burlington. Most of these are in the upper division of the Burlington limestone though a few, and among them the largest in the district, have been opened

in the lower division at the base of the bluff along the Mississippi river.

Burlington Township.—In the west part of the city of Burlington there is a group of quarries near the end of Division street. They have been opened in the valley of the small creek running in a northeasterly direction. One of the principal workings is the Larkin quarry. The face is about twenty feet in height, all of which is in the Upper Burlington. The upper layer shows considerable evidence of erosion, in many places large holes and cavities having been worn out and then filled with drift material. The rock taken out is all used in the city of Burlington, principally for foundations and retaining walls. The following is a section:

Section at Larkin Quarry, Corner of Amelia and Claim Streets.

		FEET.
8.	Loess	3
7.	Drift	6
6.	Limestone, buff, evenly bedded	5
5.	Limestone, yellowish, with considerable chert in the form of nodules and bands	2
4.	Limestone, yellowish, heavily bedded	4
3.	Limestone, white, massive, solid bed	4
2.	Limestone, yellowish, containing much silicious material and many shells of brachiopods	1
1.	Shale, bluish, with flint nodules	4

A block north is the Quell quarry on the north side of Etna street. The section is practically the same as at the Larkin opening, but the bottom of the quarry reaches only to the base of the white limestone. This quarry has been worked along the slope of a small branch for a distance of perhaps thirty rods. Near the west edge the character of the rock changes rapidly and the whole exposure consists of about ten feet of rather brittle, white, thinly bedded limestone.

A short distance farther north on the south side of Division street is the Swan quarry. The white limestone at this point appears to be considerably thicker than in the excavations immediately to the south. On the opposite side of the street is the Muerzenmeyer quarry which is also worked in the same ledges as the others just mentioned. The output of all these quarries is local, being used entirely in the city of Burlington.

Near the center of the city near West Boundary between Division and Angular streets, considerable quarrying has been carried on from time to time. In the ravine directly south of Angular there are a number of deserted quarries. The rock has been removed up to the limits of the ground owned by the quarrymen. On Angular, Maple, Maiden Lane and Division streets considerable quarrying has been carried on by the city in grading, many of the cuts being from twenty-five to thirty feet deep. The rock taken out has been used largely for city improvements.

At the head of Maple street just west of Boundary is located the Hoppmann quarry. This is a small opening in the Upper Burlington giving the following section:

Section at Hoppmann Quarry, Corner of Maple and May Streets.

		FEET.
4.	Loess	6
3.	Drift	2
2.	Limestone, white, thinly bedded, rather brittle	4
1.	Limestone, white, rather heavily bedded (exposed)	6

In another place in what is practically the same quarry the rock has been taken out up to the limits owned. Here the stone appears to be of a somewhat better quality. The quarry is deep and takes in a six-foot ledge of white limestone.

Of the two city quarries which have been opened on Maiden Lane, one is at the intersection of Boundary and the the other at Seventh street. The former is in a white, brittle limestone, rather thinly bedded and of not very good quality. The second cut is about twenty feet deep and passes through a good ledge of white limestone. The section is as follows:

City Quarry, near Maiden Lane and Seventh Streets.

		FEET.
6.	Loess	12
5.	Drift	2
4.	Limestone, white, rather brittle, thinly bedded	3
3.	Limestone, yellowish, heavily bedded	5
2.	Limestone, poorly bedded, with considerable sandy clay and chert	2
1.	Limestone, white, solid bed	6

The rock taken out of number 3 is used largely for curbing and other purposes where dressed stone is required. Number 1, may be taken out in blocks of almost any desired size and is used for heavy masonry and dimension work. Number 4 is used chiefly for macadam. A quarry quite similar to the last was opened some years ago on the corner of Seventh and Division streets but it is now deserted.

On Sixth street south of Division a cut exposes the Upper Burlington resting upon the upper portion of the Lower Burlington.

Road Cutting, Sixth Street, Corner of Division.

		FEET.
8.	Loess	6
7.	Drift	1
6.	Limestone, white, thinly bedded	6
5.	Limestone, white, heavily bedded	3
4.	Limestone, impure, containing considerable clay and chert, with a flint band below	3
3.	Limestone, brownish, with more clay and chert	4
2.	Chert	2
1.	Limestone, yellowish, with numerous bands of chert.	12

Directly east, on the north side of Fifth street, considerable quarrying has also been done. Good sections are still to be seen, but the work of getting out the rock has been abandoned on account of lack of territory.

On Maple street, between Third and Fifth streets, the city has quarried rock in opening the street. On the corner of Third and Maple is the Loftus quarry which is now deserted. It is chiefly in the Lower Burlington and presents at the bottom a heavily bedded limestone eighteen feet in thickness.

Section at Loftus Quarry, Corner Seventh and Maple Streets.

		FEET.
5.	Loess	12
4.	Drift	8
3.	Limestone, somewhat impure, with bands of chert	8
2.	Chert	2
1.	Limestone, buff, heavily bedded	18

Five blocks directly south of the corner of Third and Locust streets is a deserted quarry in the Lower Burlington; and three blocks beyond on South street is a road cutting from which considerable rock has been taken out. A short distance still further south on both sides of a small ravine opening to the eastward, considerable quarrying has been done from time to time, but at present no work is being carried on. One-half a mile southwest of the last named locality is the Miller quarry, which is located in the Upper Burlington limestone. The principal excavation is at the corner of Lynn and Seventh streets.

About two miles south of the Union station on the borders of a small stream called "Cascade," several large quarries are in operation. On the south side of the main

creek are two large openings known as the Miller quarries (Tp. 69 N., R. II W., sec. 16, NW. qr., NW. $\frac{1}{4}$). The quarry face is over fifty feet high and presents an almost complete section of the Upper Burlington.

Section at the Miller Quarry, at Cascade.

		FEET.
8.	Loess	12
7.	Drift	3
6.	Chert and fragmentary limestone, irregularly bedded.	8
5.	Limestone, white, with bands of chert	6
4.	Limestone, white, heavily bedded	10
3.	Shale, argillaceous, blue	2
2.	Limestone, white, solid bed	5
1.	Shale, blue (exposed)	4

On the opposite side of the ravine, to the north, are two other extensive quarries known as the Ervin. (Tp. 69 N., R. II W., sec. 9, SW. qr., SW. $\frac{1}{4}$). Several small openings also exist a short distance to the west. A third of a mile to the east at the pit of the Granite Brick Company there is from forty to sixty feet of Burlington limestone which must be removed in order to reach the underlying shale. The complete section at this point is something over one hundred feet.

Two miles south of Cascade is the "Picnic Point" quarry. Most of the output is used by the government for improvements along the river. The rock as it is taken out is loaded on barges. The opening is in the Lower Burlington and reaches down to the oolitic bed of Kinderhook.

One of the largest quarries in the county is a mile south of the last named locality (Tp. 69 N., R. II W., sec. 29, NW. qr., SW. $\frac{1}{4}$). It is known as the Kemper opening. About thirty feet of rock is exposed, entirely of the Lower Burlington. The lower half of the exposure is

heavily bedded and furnishes a good grade of material for dimension work. It is shipped to Burlington, Fort Madison, Keokuk and other places. The upper fifteen feet is not of so good quality as the lower and is used chiefly for riprap along the Mississippi river where it is distributed by government boats. A mile to the west, near Patterson station, is a small quarry of similar rock, and a short distance beyond on Spring creek stone is taken out along the edge of the stream.

The quarries thus far mentioned in Burlington township are all south of Hawkeye creek. North of the stream in the northwestern part of Burlington several small quarries have been opened for local use. A number of openings have been made in the brow of North Hill, but most of these are now abandoned. Rock is also taken out for building purposes along Flint river in the neighborhood of Starr cave, but these quarries are of small importance at present. Two miles northeast of the last mentioned localities, on the Burlington, Cedar Rapids and Northern railway small quarries have been opened in the bed of the small stream up whose valley the railroad runs.

Union Township.—The quarrying in Union township is carried on chiefly in the western part on Long creek. For several miles along the stream the outcrops are practically continuous. The principal opening is the Stenstrom quarry (Tp. 69 N., R. III W., sec. 18, NE. qr., NW. ¼). Along the face of the north bluff there is a continuous exposure for fully one quarter of a mile, all of which has been worked more or less in getting out rock. The stone is rather thinly bedded above, the various layers being separated by thin, fragmentary shales, one stratum, however, being two feet in thickness. The stone is a hard, gray variety, with comparatively few organic remains. Lower

down the beds are encrinital and assume a sub-crystalline texture. A good grade of building stone is present here, but owing to the lack of proper transportation facilities it cannot have the wide usage it deserves. Most of the section appears to belong to the Keokuk limestone.

One-half mile further down the creek, the Upper Burlington appears in the bed of the stream. A short distance upstream west of the Stenstrom quarry, is a thick sandstone ledge which rises rather abruptly from the creek bed to a height of perhaps one hundred and fifty feet. The sandstone crops out nearly to the summit. A small quarry has been opened a short distance from the west township line. The sandstone here quarried forms a fairly good building rock. It is dark yellow, rather coarse-grained and quite durable. It may be taken out in large angular blocks of almost any required size. There seems to be but little doubt that the rock belongs to the Coal Measures.

In the south part of Union township at various points at the foot of the bluff quarrying in a small way is carried on to supply the respective neighborhoods with material for foundations.

Augusta Township.—The chief quarries are in the immediate vicinity of the town of Augusta, in a small ravine at the west edge of town and directly north of the wagon bridge across Skunk river. A considerable section is exposed showing the Montrose cherts, the underlying Upper Burlington and overlying Keokuk beds (section 11). A good deal of rock has also been quarried in the lower beds at this place and in the bluffs on the south side of the stream. Small quantities of rock have also been removed along the bluff between Augusta and the west county line, all of it being from the Keokuk limestone.

Three miles northwest of Augusta on Long creek (Tp. 69 N., R. IV W., sec. 10, NE. qr., NE. ¼), a small quarry has been opened in the Saint Louis limestone. The face of the quarry is not more than eight or ten feet. The rock is a fine-grained, compact, white limestone, rather thinly bedded. It is removed in large flags from two to five inches thick. Half a mile to the eastward the Saint Louis is also exposed for a considerable distance in the creek beds. Farther down the stream it is overlain by a few feet of white marly clay. At the extreme eastern edge of the township, in the valley of the creek, the sandstone which has already been mentioned in Union township is also quarried to some extent.

Danville Township.—In the southwestern corner of the township, three miles from the station of Danville, on Cedar creek, quarrying has been carried on to some extent. The principal opening is the Renner quarry (Tp. 70 N., R. IV W., sec. 30, NW. qr., SE. ¼). The rock is a sandstone and is quarried to a depth of fifteen feet at which level it rests on a bluish limestone. North of this point for a distance of nearly two miles the rock exposures are almost continuous. About one-half mile north of the quarry just mentioned a white massive sandstone crops out along the low bluff twenty to twenty-five feet above the bed of the creek. The rock appears to be somewhat more friable than the yellow sandstone already mentioned. A short distance beyond (section 30, NW. qr., NE. ¼) a small quarry has been opened for local use. The following is the section:

		FEET.
3.	Sandstone, yellow to white, rather heavily bedded	10
2.	Limestone, compact, fine-grained, bluish	9
1.	Shale, bluish	7

In the extreme northeastern corner of the township a little rock has been taken out for local use. The quarry is in the Keokuk limestone.

Flint River Township.—A number of exposures of good quarry rock are found in the Flint river valley. Quarries have, however, been opened in but few places. The principal one is the Loftus (Tp. 70 N., R. III W., sec. 25, NW. qr., SE. ¼). The stone is well adapted for building purposes and some of the layers furnish large blocks suitable for heavy masonry and bridge piers. The opening is entirely in the Upper Burlington.

Section at Loftus Quarry.

		FEET.
6.	Loess	4
5.	Drift	10
4.	Limestone, thinly bedded, with considerable chert	8
3.	Limestone, sub-crystalline, irregular, heavily bedded	10
2.	Limestone, white, solid bed	6
1.	Limestone, dark gray, somewhat irregularly bedded (exposed)	4

The surface of the rock after stripping, is found everywhere to be covered with glacial striations, in a good state of preservation. Lateral polishing is also shown. The drift overlying the quarry rock contains many striated pebbles and boulders.

Pleasant Grove Township.—The principal quarrying done is on Cedar creek, one mile directly east of Pleasant Grove postoffice. The exposures are entirely in the Upper Burlington limestone. Quarrying has been carried on for a distance of a mile and a half or two miles along the stream. Near the south end of the opening (Tp. 71 N., R. IV W., sec. 12, SE. qr., NW. ¼) a more detailed section shows:

		FEET.
9.	Loess and drift	10
8.	Limestone, heavily bedded	6
7.	Limestone, rather brittle and poorly bedded	2
6.	Limestone, white, heavily bedded	6
5.	Shale, yellow, or calcareous sandstone	2
4.	Limestone, gray, irregularly bedded	4
3.	Chert	1
2.	Shale, or yellow sandstone, calcareous	2
1.	Limestone, thinly bedded	3

This exposure furnishes stone for Pleasant Grove, Washington and a large part of Yellow Springs and Franklin townships. Work is not carried on very systematically. The exposures are so numerous, that as soon as a considerable amount of stripping is required the place is abandoned and another opening is made where the drift covering is not so thick.

Franklin Township.—Although most of the quarry rock from this township is obtained along Cedar creek near Pleasant Grove, some desultory quarrying is done at several points. The principal opening, however, is on Flint creek in the southwestern part of the district (Tp. 71 N., R. III W., sec. 32, SW. qr., NW. $\frac{1}{4}$), where the Upper Burlington yields a good stone for ordinary constructional purposes.

Yellow Springs Township.—A considerable portion of the quarry rock of this township is obtained from Pleasant Grove. One mile and a half southeast of Mediapolis a small quarry for local use has been opened in the Upper Burlington limestone (Tp. 72 N., R. III W., sec. 36, SE. qr., NW. $\frac{1}{4}$), in the valley of a small creek. The exposure is about eight feet in height. In the northcentral portion of the township the Upper Burlington is also quarried for local use. The principal opening being between Linton and Northfield (Tp. 72 N., R. III W., sec 2, SW. qr., SW. $\frac{1}{4}$). In the vicinity of Northfield there are also

numerous good exposures of rock along the creek west of town. A mile to the north (Tp. 72 N., R. II W., sec. 6, NW. qr., NE. ¼) a quarry has been opened in the Upper Burlington affording a face of about ten feet of gray, rather heavily bedded limestone. The Lower Burlington is also exposed near by.

Huron Township.—A short distance west of the Huron postoffice is the Mississippi escarpment which presents a bold exposure of Upper and Lower Burlington. A quarry has been opened here in the extreme southeastern corner of section 14, in the Lower Burlington. About twelve feet of heavy bedded limestone is used. At various points along the bluff small quarries have been opened, but none are worked systematically.

Benton Township.—No regular quarrying is carried on in this district. The ledges, which are numerous, are quarried at various points for local use.

CLAYS.

DISTRIBUTION.

Although clays suitable for the production of ordinary brick and draintile are fairly well scattered over the county, those grades which will be used the most are not so widely distributed. There are deposits of two geological formations upon which special dependence may be put for supplying good clays. These are the Kinderhook shales and the Lower Coal Measures. A small amount of clay might be taken from the Upper Burlington, but this can rarely be obtained without quarrying from 10 to 30 feet of limerock. The shales of the upper part of the Augusta which are exposed in the southwestern corner of the county may also, in time, be brought into use.

Kinderhook Shales.—These shales are confined in their surface exposure to an extremely narrow belt. Yet the

quantity present is sufficient to supply the entire country for centuries. They form the base of the Mississippi escarpment along the entire eastern border of the county, a distance of thirty miles. While they may not be fully exposed everywhere along the line, the removal of the talus at the foot of the bluff will reveal the shales at probably every point. In many of the smaller streams which enter the Mississippi the Kinderhook is often exposed for a short distance above the point where the water courses cut into the escarpment.

There is a thickness of over 200 feet of the shales at Burlington, three-fourths of which is below the river level. The only place however where they are used for making clay products is at the "Cascade" two miles below the city of Burlington. Beneath the upper thirty feet, which is too sandy for use, the best argillaceous portion has a thickness of about thirty-five feet. This is a gray or bluish ashen, rather massive bed, exhibiting few indications of lamination. Immediately below is what is called fire clay, which may prove refractory enough to permit the construction of crucibles and fire brick.

Augusta Beds.— Since the Augusta formation is made up largely of limestone there are slight chances for the occurrence of extensive clay deposits which would be suitable for manufacturing it into a high grade of clay products. The clay beds which occur between the limestone layers are usually very thin; though one is known to be at least four feet in thickness. It could probably be readily mined if it should prove to be of good quality. One of the best outcrops of the bed is at the Miller quarry above the Cascade, south of Burlington. In the southwestern part of the county the shales of the extreme upper part of the formation might be utilized, yet the existence of practically

inexhaustable supplies of a much better grade of clay near the known exposures precludes the idea that they will ever be used very extensively.

Coal Measures.—The Upper Carboniferous formation have an areal extent in Des Moines of only a few square miles. There is but a single locality now known, and this in the extreme southwestern corner of the district. The deposit is a small oval outlier which lies partly in Des Moines and partly in Henry county. Over thirty feet of argillaceous shales are disclosed at one point in a single section. A thin coal seam has been worked in the same vicinity (Tp. 70 N., R. IV W., sec. 5, NW. qr., NW. ¼). Fuel was taken out as early as 1834. Besides supplying unlimited quantities of raw material for draintile and building brick a three and one-half foot bed of fire clay is present, capable of being transformed into fire brick or after washing into the higher grades of refractory products and pottery.

Till.—The superficial deposits consist largely of the boulder clay in which are frequently sand and gravel beds. Two rather well marked phases are shown in some places. One is the widely prevalent yellow variety and the other is red to brown in color. The latter is well exhibited in the neighborhood of Burlington where it has been exposed in many street gradings. It lies immediately beneath a red gravelly clay upon which rests the loess. As it is rather plastic and contains a large percentage of iron oxide it would serve excellently for making brick and tile when freed from the concretions of lime which it bears.

Loess.—This fine silicious clay is found capping the bluffs in many parts of the county. In the vicinity of the Mississippi river the loess resembles more closely than

elsewhere the typical deposits of this formation; over the inland it appears somewhat altered.

Alluvium.—Wherever shown along the streams the material is well adapted to the manufacture of common brick. With the other good clays at hand the alluvium is not destined to come into extensive use for making building material.

CLAY INDUSTRIES.

Burlington.—The sources of raw materials found in the neighborhood of the city of Burlington have already been referred to at length. The most extensive operations are carried on by the Granite Brick Company, whose plant is located at the Cascade immediately south of Burlington on the river bank, a distance of two miles below the Union railway station, and on the line of the St. Louis, Keokuk and Northwestern railroad, a part of the Burlington system. An extensive vertical exposure is presented at the pit from which the material is obtained. The details, according to Mr. E. H. Lonsdale are:

Section at Clay Pit of Granite Brick Company.

		FEET.	INCHES.
15.	Loess, reddish	10	
14.	Chert, white	2	6
13.	Limestone, white and brownish	10	
12.	Shale parting		3
11.	Shale, arenaceous "sandstone"	3	
10.	Limestone, hard, fine-textured	12	
9.	Shale, arenaceous, compact, "sandstone"	2	4
8.	Shale parting		2
7.	Shale, arenaceous, "sandstone"	10	6
6.	Shale parting		4
5.	Shale, compact, "sandstone"	12	2
4.	Shale; very compact and massive	12	
3.	Sandstone	1	1
2.	Shale, massive, silicious	7	8
1.	Shale, massive, argillaceous	10	6

Except when number 1 is used, in which case a siliceous loess-like clay is mixed, all the material taken out is from the Kinderhook beds. Beneath the lowermost stratum given in the section the shale is too refractory to serve for pavers. The treatment of the clay that comes from the pit is essentially as follows. The shale, as it is quarried is loaded on small cars which are drawn up a steep incline and dumped into a dry pan having an eighth-inch screen. The pulverized material is then elevated to a Frey-Sheckler pug mill and from thence into an Improved Acme of the same make. As the cylinders of clay issue from a double dye they encounter a rotary cut off. The green brick are transferred to a large furnace-heated floor where they are allowed to dry a day or sometimes a day and a half before firing. There are five Eudaly kilns having a combined capacity of 105 000 brick.

In the southern part of the city, on the corner of Moltke and Wilhelm streets, is the Kupper brickyard. "The Ohio" machine of Fate and Freese make is used. The material worked is the upland loess of the district and is removed for a distance of three or four feet. The moulded brick are dried on shelved racks.

In the north part of Burlington, at "Sunnyside," is the Ritter yard. Sand-rolled brick are made and the output is quite large. The material used in making the brick appears to be a modified loess and is used to a depth of from three to five feet. The green brick are spread in the yard or in roofed sheds to dry and afterward burned in ordinary temporary kilns. In addition to the regularly shaped brick there is moulded a form with one corner rounded.

The Schott yard has recently been opened on Osborn and Bernard streets. Ashen or white loess is used to a

GORGE OF THE MISSISSIPPI RIVER; GRANITE BRICK PIT, BURLINGTON.

depth of about four feet. The moulded brick are dried on the ground.

Mediapolis.—The Johnson Brick and Tile Works are situated a short distance north of the railway station. Operations have been carried on successfully for a period of more than ten years. The clay which is obtained near the factory, is an ash-colored loess, having a thickness of about eight feet. Beneath it nine feet of till is used; then comes gray drift and finally the blue boulder clay. Bed rock is encountered at a depth of thirty feet. From the pit the material is conveyed to a Penfield smooth roller and from thence to a No. 6 Brewer machine. The moulded product is raised to the second floor of the shed and dried. Three kilns are in use; one a Swift, and the others round, down draft. Four days are required to burn the tile and over a week for the brick.

One and one-half miles north of Mediapolis the Burlington, Cedar Rapids and Northern Railway Company established a station for burning clay for ballast. The material used was the ashen loess similar to the clay at the surface at the Johnson plant. Operations were only carried on for a period of four months, though during this time enough clay was treated to ballast over ten miles of track. It appears that the methods of burning the clay were not fully understood and consequently all of the material was not thoroughly prepared. With proper treatment the clay would doubtless be well suited for the purpose.

Kossuth.—Brick making has gone on in this vicinity for some years. The Pratt yard makes a sand-rolled brick from an altered till. The clay is dug only to a depth of about one foot, below which the deposit becomes jointy. The product is burned in cased kilns.

A mile south of the town is the Lundeen Brick and Tile Factory. The raw material used is similar to that taken out at the Pratt yard. The output is chiefly three-inch tile. It is burned in an updraft kiln.

Parrish.— One of the oldest clay concerns in all southeastern Iowa is the Melcher Pottery, which is situated in the southwestern corner of the county (Tp. 70 N., R. IV W., sec. 31, west half). Manufacturing of clay goods has been carried on here almost uninterruptedly for nearly half a century. The material used is from the Coal Measures, and is obtained from two localities, one about a mile north of the factory and the other a short distance south. At the former place the shale is gray or white becoming darker below. The thickness of this stratum varies from three to five feet. The usual combination is one part from the first pit and two parts from the second; and very satisfactory results are thus obtained.

Before moulding, the clay is cleaned; a process which consists in agitating the wet clay in a tub in which is suspended a rotating harrow. After being thoroughly stirred, the clay held in suspension is passed through fine screens into vats and dried, and afterwards pugged in an ordinary mill. Four turning wheels and one jolly are in operation. In the summer the green products are dried in the sun; in winter on furnace-heated floors. Albany slip is used in glazing. There are two kilns; a Howard patent, with a capacity of 3 800 gallons, and an ordinary potter kiln holding 2 000 gallons. All the common articles issuing from potteries are made. The largest sized ware is the fifteen-gallon jar. Some experimenting in glazing with a Coal Measure clay from a five-foot bed near the Skunk river, a short distance to the south, has been carried on with partial success. The results make it appear not

improbable that with certain admixtures the material may yet be used advantageously, and a glaze produced not inferior to that at present obtained.

COAL.

The coal-bearing strata of Iowa reach Des Moines county only in isolated basins. The district is too far to the eastward to expect very extensive deposits of carbonaceous material as a part of the Iowa field, and not quite far enough east to come within the Illinois area. The district is thus situated between two large coal producing regions which touch its borders but which do not as yet allow fuel to be taken out in commercial quantities within its boundaries. With the exception of a few square miles the entire area is covered beneath the drift mantle by strata which are older than the Coal Measures and which therefore lie beneath the productive beds.

The coal measures consist chiefly of dark and light colored shales, and brown ferruginous sandstones. Occasional nodular bands of dark calcareous rock occur immediately over the coal seams. The only shales which are likely to be mistaken for coal shales are the Kinderhook beds. In the vicinity of Burlington several shafts have been sunk at different times into these layers with the hopes of obtaining coal. Some of these excavations have reached depths of forty to fifty feet before the enterprises were given up as fruitless. In all of these cases a considerable expenditure of time and money was wasted in places which were entirely below the coal-bearing beds. At other places in the county similar searches after mineral fuel have been undertaken with like results.

As stated in another place, the limited areas of Coal Measure rocks which occur in the county are found in

depressions in the limestone floor; depressions which were once ancient valleys or ravines excavated in the hard bed rock by old water courses that existed previous to the laying down of the coal strata.

The various basins now isolated may have been at one time connected and subsequently the strata eroded until now only occasional remnants are left. The only areas of Coal Measures at present known in Des Moines county are in the southwestern part. Others may occur in the western half of the district, in the central and northern portions and in all probability do exist, though as yet they have not been located. It would not be at all surprising to find at no distant day several such pockets containing coal seams of sufficient thickness to be profitably worked and to afford supplies for local use.

The most extensive deposits of Coal Measures now known in the district are two miles northeast of Augusta. The exposure is largely a buff to brown sandstone, massive, firm, and homogeneous in its texture. It rises in bold almost perpendicular cliffs and is thought to have a thickness of more than one hundred feet. Its base has not been observed so that it is not known whether shales and coal are associated. It probably represents the basal sandstone of the Coal Measures in this region, in which case the carbonaceous layers, if any exist, are to be looked for toward the top rather than at the bottom. The position of the outcrops is such that with very little trouble tests could be made to find out whether or not coal exists at the base of the sandstone.

The most important outcrops and the most hopeful from an economic standpoint are on Cedar creek, about three miles southwest of Danville station on the Chicago, Burlington and Quincy railroad. The area covered by

Coal Measure shales and sandstone comprises a number of square miles, part lying in Des Moines and part in Henry county. The best section now exposed is on the Jester place (Tp. 70 N., R. IV W., sec. 5, NW. qr.), where fourteen inches of coal may be seen.

MINERALS.

In addition to the mineral deposits which are now operated on a commercial scale, and which have been already described, there are a number which are known to occur within the limits of the county but which are not yet worked to any extent. Most of these probably are not sufficiently abundant to be profitably mined, but some of them doubtless will prove eventually to be commercially valuable. With others there is small hope of their ever occurring in sufficient quantities to pay for the time and money expended. Yet, periodically more or less excitement bursts forth over some reputed discovery of gold, lead or other mineral.

Copper in the native state is found in Des Moines only as erratic fragments in the drift, having been transported from the far north by the glaciers.

Gold likewise occurs only in small quantities. It is often concentrated by running water from the drift and accumulates in the stream beds in sufficient quantities to be perceptible after panning. Starr cave is the principal place where the yellow metal is reported and from time to time such reports lead to a working of the gravels for several days at a time. There are similar sands and gravels in different parts of the district which yield small amounts of gold. But it is hopeless to expect that paying deposits of this mineral will be found.

Zinc.—Sphalerite, or zinc sulphide, is occasionally found in small crystals in cavities in the limestones. The samples are of interest chiefly as mineralogical specimens.

Pyrite.—The sulphide of iron, while abundantly and widely distributed in minute crystals through certain rocks, is never found in large enough deposits to make it commercially valuable. In the Kinderhook shales it is found usually in small balls from the size of shot up to three or four inches in diameter. Many of these masses consist of aggregates of small crystals with bright faces. Frequently also the crystals occur singly. The crystallographic habit is commonly the octohedron modified slightly by the cubic faces. Small amounts are also found in the bituminous shales of the southwestern part of the county.

Marcasite, which is another form of iron sulphide, also occurs in some of the shales but it is not nearly so widely distributed as the pyrite.

Galena.—The common ore of lead is found in the same way as the zinc, small masses scattered through cavities in the limestone. It rarely is of interest from a mineralogical standpoint and is of no value economically. The reports of the finding of this mineral in paying quantities in Des Moines have been frequent, but all have thus far proven false.

Quartz, though usually widely distributed, is of rare occurrence in the district under consideration and is found as small crystals and masses in limestone cavities. None of the quartzose sands are sufficiently free from impurities to permit their use for making glass.

Limonite exists in small amounts as a pseudomorph after pyrite.

Hematite is not found in quantities of commercial value, though frequently occurring in some of the Coal Measure sandstones in apparently considerable quantities.

Calcite is one of the most abundant of minerals found in the region. Aside from its occurring in seams and masses through the limestones, it is found in beautiful crystals lining cavities in the rock.

Gypsum occurs only as small crystals in the Coal Measure shales of the southwest.

Epsomite, the sulphate of magnesium, or native epsom salts, is found at Starr cave, northwest of Burlington, where it accumulates under the overhanging cliffs of limestone along Flint creek. It forms efflorescent encrustations on the rocks when sheltered from rains. Its origin as given by White is as follows:

The rock upon which the epsomite accumulates is an impure limestone containing also some carbonate of magnesia, together with a small proportion of iron pyrites in a finely divided condition. It is doubtless by the double decomposition of these that the epsomite results. By experiments with this native salt in the office of the survey, a fine article of epsom salts was produced, but the quantity that might be annually obtained there would amount to only a few pounds, and of course is of no practical value whatever, on account of its cheapness in the market.

POLISHING MATERIALS.

An abundance of a white amorphous silicious material in the form of chert exists in nearly every ledge of rock exposed in the county. At the limestone quarries large amounts of it are thrown out as worthless. As yet no use is made of the Des Moines cherts. In other states these cherts are ground into a flour-like powder which is

sold for scouring and polishing purposes. Large quantities are also mixed with certain soaps to make them more effective. The pure white varieties which are obtained in almost every quarry in the county appear to be admirably adapted for this purpose.

LIME.

Des Moines county is so well supplied with good limestone that it is somewhat surprising that the manufacture of lime is not carried on much more extensively than it is. Although there are a number of lime kilns in the county none of them have more than a local output and most of them are idle a good part of the time. In former years considerable quantities of lime were burned at several points, principally at Burlington. In the vicinity of that city are several old kilns which are now rarely used. Certain of the beds in the Burlington limestone are surely well adapted to the manufacture of a good grade of lime. At Hannibal, and especially Louisiana, on the Mississippi river one hundred miles to the south, large quarries have been opened in identically the same layers that occur at Burlington and large kilns are kept in active operation the year around, making and shipping away great quantities of a very excellent lime.

That a good grade of lime can be produced is shown by what has been done in previous years in the vicinity of Burlington, at one or two points on Flint creek, and at Augusta. Besides the ordinary limestones of the Augusta formation, particularly the Upper and Lower Burlington limestones, there is the buff limerock lying near the top of the series which occurs in the southwestern part of the county and which in certain parts should supply a very superior grade of material for lime. It contains sufficient

magnesia to make it especially sought after since the limes composed of a mixture of calcareous and magnesian elements are usually regarded as very much better than one made from the former alone. The white Saint Louis limestone, also exposed in the southwestern corner of the district, furnishes a good rock, and in other parts of the state the same stone is used extensively for burning lime.

ROAD MATERIALS.

Good highways form a prominent factor in the material prosperity of a community, and the constantly increasing interest which is being taken in the subject everywhere makes it important to know just what materials in each locality are available for the betterment of the roadways. Suitable gravels for improving the roadways occur not only along the larger streams but in the drift in various parts of the district. The location of several of these beds is well known and the quantity found is sufficient to supply very considerable areas. Other similar deposits will doubtless be found when the material begins to be used extensively.

The limestones which are exposed in nearly every township afford an abundance of good material for macadam and may be widely used. The cost of breaking into suitable sizes may deter somewhat the extensive use of this material, but with proper appliances and the right kind of supervision this could be readily overcome. In this connection it may be well to state that the chert which is so abundant in all the limestones of the region might form an excellent material for road purposes. At all the quarries it is thrown out as useless and it accumulates in large piles. It breaks readily under the hammer into sizes of the right dimensions, is much harder than the limestone, more durable, cleaner, and on account of the

angularities on the fragments it packs better in the roadway, forming a very smooth, clean bed. The ease with which it yields to hammer blows, its worthlessness as a quarry rock, its hardness, and the cheapness with which it may be obtained, recommend it for highway purposes.

Another material which is certainly destined to become widely used for making good roads, is burnt clay. It forms a non-plastic, hard, smooth surface, almost noiseless, and in all respects equal to macadam. In other parts of the state it has been used successfully for private driveways. Some of the railroads are utilizing it extensively for ballasting the roadbeds, it forming a good elastic surface, allowing the cars to run with less jar and noise than with stone ballast, and on the whole causes much less wear in the rolling stock. Much of the drift and alluvial clay is well adapted for this use. Aside from its cheapness and ease in preparing and handling, it has the great advantage of usually occurring in localities where few or no rock exposures exist.

SANDS.

Sand for building and other purposes may be obtained from several geological formations. Commonly it is taken from the bars in the streams. At Burlington, where the channel of the Mississippi comes up to the very foot of the escarpment on the west side of the river, the sand used is dredged up from the bottom of the stream and carried over to the city in barges. As a rule the river sand is quite clean, sharp and well adapted for mortars of all kinds. In the drift deposits numerous lenticular beds of fine to coarse sand occur and these are available in every township of the county. Often considerable coarse material and gravel are mixed or interstratified with fine sand

but this rarely prevents the latter from being utilized. Certain of the arenaceous strata of the Coal Measures in the southwestern part of the county are suitable for utilization in building; and the softer sandstones, especially the weathered portions from the same formations, are also available. The upper layers of the Kinderhook are composed of soft sandstone, fine-grained and homogeneous. They readily disintegrate upon exposure into loose sand which often forms a bed a dozen or more feet in thickness. Such deposits exist near Starr cave, four miles northwest of Burlington.

WATERS AND WATER POWERS.

With waters for domestic uses the district is well supplied. The principal streams are never failing sources of water which may be readily utilized for all purposes. Abundant springs occur everywhere in the eastern and southern portions of the county along the escarpments of the Mississippi and Skunk rivers, and also along Flint creek. These send forth gushing streams of cold crystal waters. For the most part they are small in size but others are larger and form the headwaters of creeks, which do not run dry even in periods of protracted drought. None of the spring waters contain sufficient quantities of dissolved salts to allow them to be called mineral waters. Many of the springs burst forth from immediately beneath the Burlington limestone; where these occur along the bluffs of the two largest rivers the little streams dash along in miniature torrents to the foot of the escarpment. The creeks rising some distance back from the eastern and southern borders flow gently along until they reach the brow of the cliffs formed by the hard limestone overlying the softer shale of the Kinderhook

when they break into cascades or waterfalls often of considerable height.

In all parts of the county good, clear and a medium soft water is readily reached by sinking wells to moderate depths. As yet no deep wells have been sunk for artesian purposes, but it is quite probable that practically the same conditions prevail that exist to the southward in Lee county, at Keokuk, Mount Clara and Fort Madison. Moreover, the depths to which it would be necessary to go in order to reach the water bearing strata could not be so great as in the neighboring district.

The water powers have not been utilized very much. On Skunk river, at Augusta, a dam has been constructed from which power was secured for running a mill for many years. On Flint river also, a small dam has been built. On both of these streams a much greater amount of water power could be readily brought under control than is at present.

ACKNOWLEDGEMENTS.

In the preparation of the account of the geology of Des Moines county, Mr. F. M. Fultz of Burlington assisted in the field mapping of certain portions of the district, and took detailed notes of these areas. The photographs reproduced were also taken by him. To Mr. Charles Wachmuth, also of Burlington, acknowledgment is due for information regarding numerous localities which were visited several years ago during a two years residence in that place. Mr. E. H. Lonsdale visited all the clay works and from him chiefly were obtained the notes on the clay industry.

R. IV W. R. III W. R. II W. R. I W.

T. 72 N. T. 71 N. T. 70 N. R. V W. T. 69 N. T. 68 N.

WASHINGTON YELLOW SPRINGS HURON

FRANKLIN JACKSON

PLEASANT GROVE BENTON

FLINT RIVER

DANVILLE

BURLINGTON

AUGUSTA UNION

Linton Northfield Yarmouth Roscoe Huron Kossuth MEDIAPOLIS Kingston Sperry Pleasant Grove Dodgeville Lafty Danville W. Burlington MIDDLETOWN Parrish AUGUSTA Cascade

Crooked cr. Honey Creek Burlington Western Railroad Cedar Rapids Northern Railroad Quincy Railroad Chicago Burlington Mississippi River Skunk River

GEOLOGICAL MAP OF DES MOINES COUNTY, IOWA

BY

CHARLES R. KEYES

1894.

LEGEND

GEOLOGICAL FORMATIONS.

- COAL MEASURES
- SAINT LOUIS
- AUGUSTA (KEOKUK, UPPER BURLINGTON, LOWER BURLINGTON)
- KINDERHOOK

INDUSTRIES.

- QUARRIES
- LIME KILNS
- CLAY WORKS
- COAL

DRAWN BY F. C. TATE.

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