GEOLOGY OF MARSHALL COUNTY.

BY

SAMUEL WALKER BEYER.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Marshall is one of the middle tier of counties and lies between Tama and Story counties on the east and west respectively. The Iowa river makes a bold bend southward nearly to the center of the county, where it turns abruptly eastward, cleverly detaching the northeast quarter. As in the case of most of the inland counties of Iowa, Marshall comprises a rectangular area of approximately five hundred and seventy-six (576) square miles and considerably more than a third of a million acres.

PREVIOUS GEOLOGICAL WORK.

Considering the great value of the natural resources of Marshall county and the varied and abundant fauna entombed in the rocks, the literature concerning the geology of the region is extremely meager.

David Dale Owen* in his "Reconnaissance of the Carboniferous Rocks of Southern and Western Iowa," was the first geologist to visit the county in an official capacity. He traversed the county in the vicinity of the Iowa river, and incidentally called attention to the more salient geological features. J. D. Whitney† in treating of the geology of Marshall and adjoining counties records the occurrence of coal in Bangor township, and briefly describes a section exposed on Timber creek near the old road leading from Marietta to Indiantown, in which he remarks the close resemblance of the rocks to the lower Burlington limestone as exposed at its typical locality.

More than a score of years later White‡ described the exposures near Le Grand and definitely refers the formation to the Kinderhook stage of the Carboniferous system. Certain quarry products are also described, and in the same

*Geological Surv. Wisconsin, Iowa and Minnesota, p. 101-102. 1852.

†Geology of Iowa, vol. I, pp. 267-9. Albany, 1858.

‡Geology of Iowa, vol. I, pp. 197-198. Vol. II, pp. 260, 312-314 and 316. Des Moines, 1870.

report Prof. Rush Emery* reports an analysis of "Iowa marble," from the Le Grand quarries.

The crinoidal remains so abundant in certain layers at Quarry and Le Grand have received the attention of the late Charles Wachsmuth† and his co-laborer, Frank Springer, of Burlington, and others.

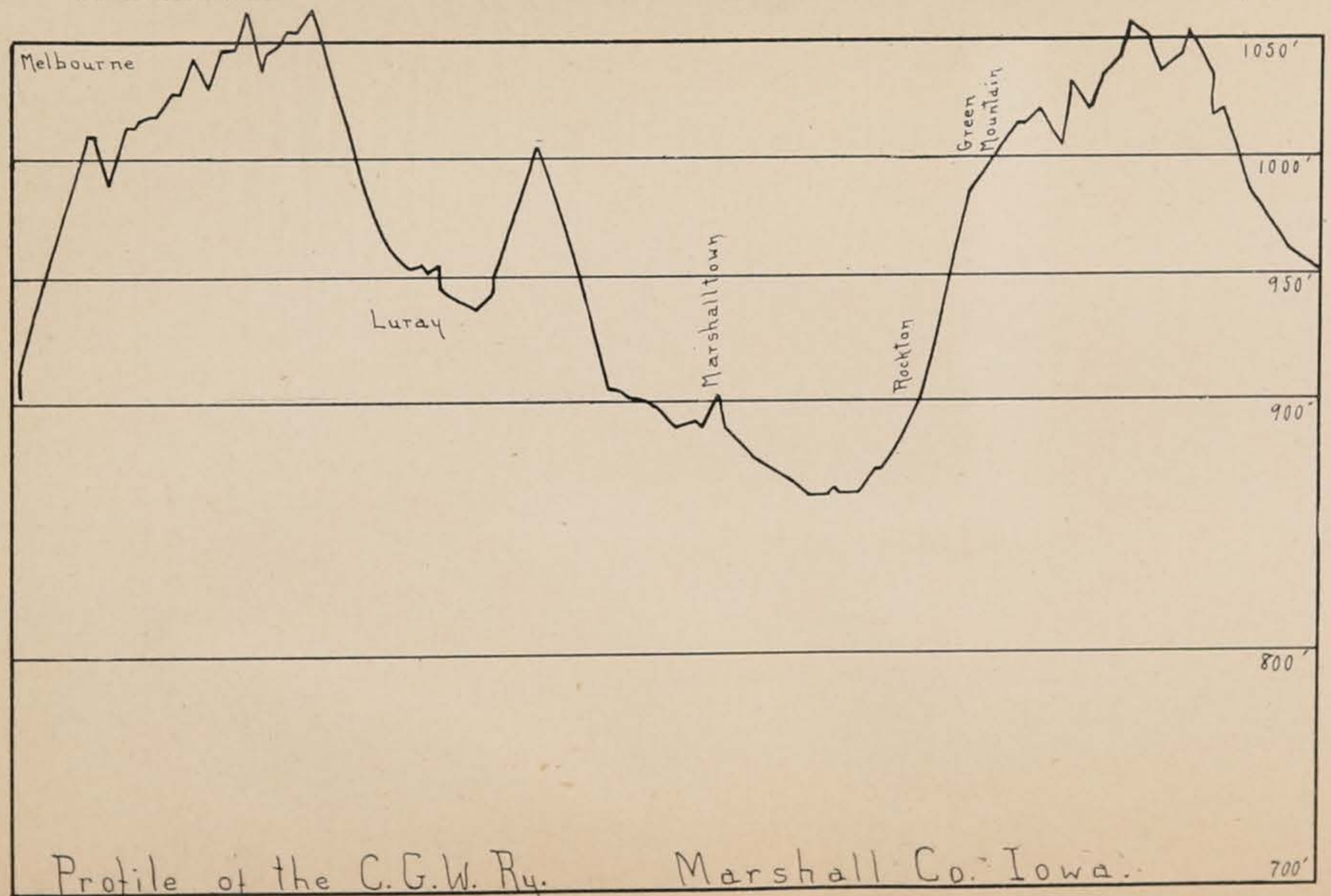
PHYSIOGRAPHY.

TOPOGRAPHY.

The topographic features of the county are varied. In order better to understand the more general configuration, conceive a more or less regular surface very gently inclined to the southeast. Let there be a slight depression in the position of the Iowa river, flanked on either side with parallel ridges, the crest on one side bisecting Vienna township diagonally, while a line passing through State Center, Van Cleve and Laurel marks approximately the position of the other. Spread over the surface a material which responds readily to water action, but holds with equal fidelity the vigorous carving of the spring freshet and the most delicate tracery of the summer shower; given these conditions, time and the erosive agents are the only requisites to account for the general physiography of the region.

The principal water courses have wrought out well-marked flood plains bordered by the usually gently rising uplands, all of which attest topographic maturity. The vertical interval between the lowlands and the adjoining uplands varies from 50 to 100 feet, but the altitude gradually increases towards the divides which attain an elevation of more than 200 feet above the water level in the Iowa river. Plate v shows the cross-section of the general plain. The most vigorous land forms occur in the marginal areas which intervene between the upland plain and the flood plains of the greater streams. These areas, with the flood plain, originally supported a luxuriant forest growth, but have in large part been dismantled.

* Ibid vol. II, p. 347.
† Geological Surv. Illinois, vol. VIII, pp. 157-205, and pls. xv-xvii, 1890.



Profile of the C.G.W. Ry. Marshall Co. Iowa.

While the whole county is heavily drift-laden, yet the territory readily resolves itself into three distinctive topographic areas which are coincident in a general way with the areas occupied by the Wisconsin, Iowan and Kansan drift sheets, and will be designated by the terms, drift, drift-plain and drift-loess types respectively. The first type is represented by a wedge-shaped area on the western margin of the county, whose apex is approximately at the southwest corner while its base spans little more than three miles on the north line. The characteristic features of the region are the prevalence of depressions, sloughs and "kettle holes" and eminences with kame and drumloid affinities. Drainage is imperfect and this, when taken in conjunction with the unique surface features, is indicative of topographic youth.

The second comprises an area of scarcely more than fifty square miles in the northeast corner of the county. Although the Iowan till sheet probably extended over a greater area in the county it was not competent to control the configuration of the region to the extreme limits of its attenuated margin. Away from the larger streams this territory is characterized by a monotonous, plane surface interrupted by occasional gentle swells, and as a rule it is moderately well drained, while oftentimes prairie sloughs are much in evidence. This triangular area is a fragment of the great drift-plain which extends northward far into Minnesota and comprises an area of more than seven thousand square miles in Iowa.

The drift-loess type constitutes more than four-fifths of the surface of the county. The topographic features are purely erosional and the contours are strengthened by the loess top-dressing. The upland is dissected by a plexus of small streams which gives the surface a graceful, billowy aspect, very pleasing to the eye. Sharp V-shaped valleys and convex hills are the rule in the broken areas and bear silent testimony to the instability of the surface configuration. The larger streams meander through broad valleys which are almost destitute of salient topographic features. The divides are better defined

than is usual in this type of topography. The head branches of opposing drainage systems often interlock, so sharply is the territory contested.

TABLE OF ELEVATIONS.

The following table of altitudes is compiled from the profiles of the different railroads which traverse the county.

STATION.	Altitude.	AUTHORITY.
Albion	937	I. C. Ry.
Dillon	975	I. C. Ry.
Divide, Iowa and Cedar rivers	1054	C. G. W. Ry.
Divide, Iowa river and Linn creek	952	I. C. Ry.
Divide, Iowa and Skunk rivers	1116	C. & N.-W. Ry.
Dunbar	878	C., M. & St. P. Ry.
Ferguson	909	C., M. & St. P. Ry.
Gilman	1090	I C. Ry.
Gladbrook	954	C. G W. Ry.
Green Mountain	1000	C. G. W. Ry.
Haverhill	1023	C., M. & St. P. Ry.
Iowa river, Chicago Great Western crossing	865	C. G. W. Ry.
Iowa river, county line	926	I. C. Ry.
Iowa river, Iowa Central crossing, south of Albion	895	I. C. Ry.
Lamoille	940	C. & N.-W. Ry.
Le Grande	940	C. & N.-W. Ry.
Linn creek, Great Western crossing southwest of of Marshalltown	905	C. G. W. Ry.
Linn creek, Great Western crossing east of Marshalltown	875	C. G. W. Ry.
Laurel	1040	I. C. Ry.
Liscomb	950	C. G. W. Ry.
Duray	885	C. & N.-W. Ry.
Marshalltown	890	I. C. Ry.
Marshalltown	900	C G. W. Ry.
Malta	1062	I. C. Ry.
Melbourne	1045	C. G. W. Ry.
Melbourne crossing, Chicago, Milwaukee & St. Paul railway	1060	C. G. W. Ry.
	1033	C., M. & St. P. Ry.
Nicholson creek	896	C. G. W. Ry.
Pickering	987	C., M. & St. P. Ry.
	1025	I. C. Ry.
Quarry	885	C. & N.-W. Ry.
Rhodes	1015	C., M. & St P. Ry.
Rockton	880	C. G. W. Ry.
State Center	1073	C. & N.-W. Ry.
State Center Junction	1051	C., M. & St. P. Ry.
Timber creek, Iowa Central crossing	874	I. C. Ry.
Timber creek, Chicago & North-Western crossing	855	C & N.-W. Ry.
Van Cleve	1054	I. C. Ry.

DRAINAGE.

Marshall county is well watered and for the most part is also well drained. The annual rainfall averages about thirty inches per annum, of which less than one-third is gathered up into the streams and carried to the gulf. Five-sixths of the annual "run-off" finds a convenient outlet through the Iowa and its tributaries, while small triangular areas in the southwest and northeast corners contribute their surplus waters to representatives of the Skunk and Cedar river systems respectively.

Iowa river system.—The Iowa river is the master stream in the system and in large measure establishes the grade for its numerous tributaries. It meanders through a broad alluvial

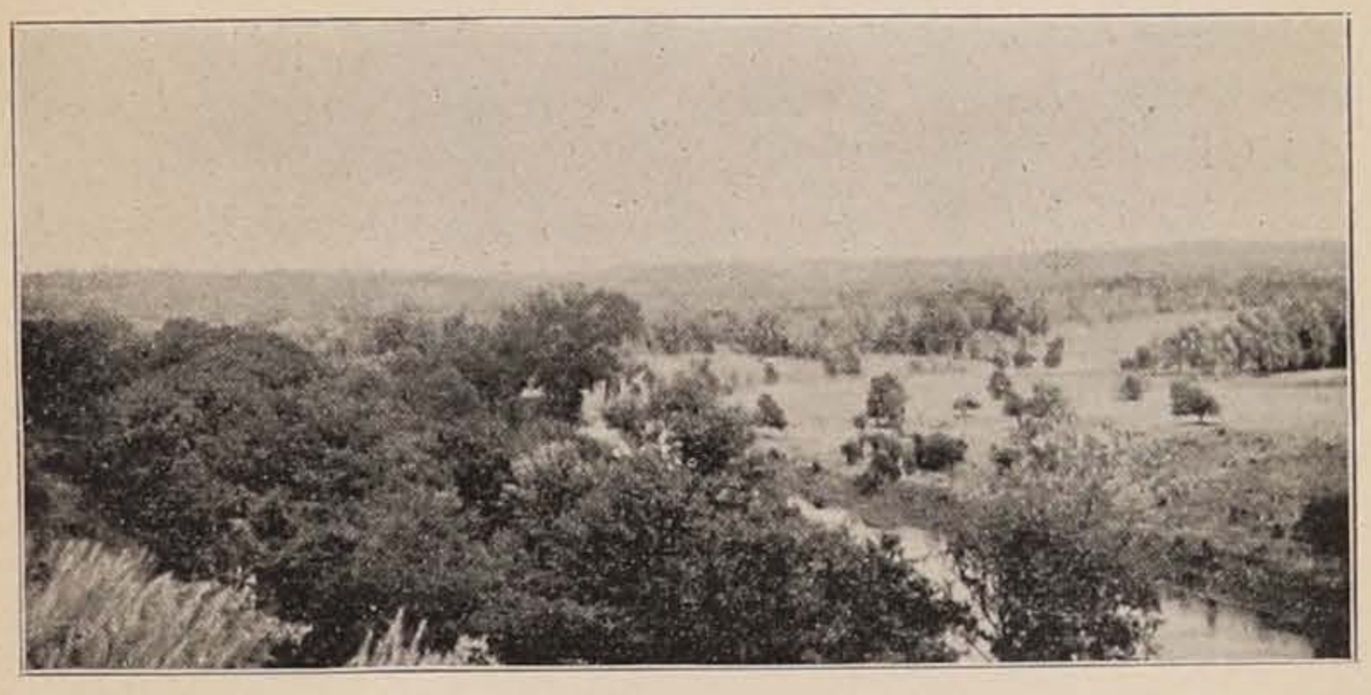


FIG 25. Le Grand gorge.

valley which averages from one to two miles in width. The river crosses the Kinderhook escarpment at two points; near its entrance into and exit from the county. At the latter place the river flows through a gorge scarcely a quarter of a mile in width. The present stream occupies a channel but little below the general level of the bottom land and extensive reaches of territory are subject to periodic inundation. Deserted channels are everywhere in evidence, and northwest of Marshalltown sand flats are common features of the

flood plain. The Iowa river has long since passed its adolescent stage, has reached maturity and is now approaching old age. The stream is not corrading its channel at any place. Excavations for bridge piers and abutments show that the country rock lies ten to fifteen feet below the present stream bed. At the Marshalltown waterworks there is an apparent exception to this. The river impinges strongly upon the south bank, and the country rock is close to the surface in the bed of the stream. Excavations for the water galleries on the north flank of the flood plain reveal the fact that the old rock bottom slopes away from the present position of the channel.

The Iowa drainage system is of the asymmetric type with the greater tributaries coming from south and west as are the Skunk and Des Moines rivers in central Iowa. Rock, Burnett and Asher creeks are the principal tributaries received from the north; while Timber, Linn, Minerva and Honey creeks are the more important branches received from the south and west. All of these have much the same general characters as does the greater stream. All are long in proportion to their volume, and all are characterized by drainage basins which are relatively narrow in proportion to their length.

The tributaries from the north are relatively of much less importance than those from the south. They have narrow flood plains or none at all, and have deposited but little alluvium save in their lower courses. Asher creek is the largest and drains an area of about fifty-four square miles. Each has cut through the drift at certain points exposing the upper member of the Kinderhook beds.

Timber creek, which enters the Iowa from the south near Quarry, collects the water from an area of 130 square miles. It comprises three principal branches which are named according to their geographic positions—North, Middle and South Timber creeks. North Timber flows almost due east, and is much the longest member, while the south branch

flows north and comprises the greatest drainage basin. All have narrow, but well marked flood plains, which follow well up far towards their sources.

The drainage basin of Linn creek is the narrowest in proportion to length of any in the county. The proportion of length to breadth is about six to one, and the valley comprises an area of about seventy square miles. Its course is almost exactly parallel to the North Timber creek, but it has not progressed as far in valley forming as the latter. The most rugged topography in the county is found in the territory traversed by Linn and the Timber creeks.

Minerva creek has its source in Hardin and Story counties. It pursues a tortuous course in a southeasterly to easterly direction, and enters the Iowa a little north of west of the town of Albion. The head waters of this stream arise in the area of the Wisconsin drift, and drain more than two-thirds of the region covered by this till sheet in the county. The lower course of the Minerva has a flood plain which, considering the volume of the stream, is quite broad. It has numerous small branches; but where its tributaries leave the Wisconsin, the valleys are sharply constricted. In the upper reaches little or no alluvium has been deposited, and there is a dearth of minor streamlets.

Honey creek has done an immense amount of work in the way of valley cutting, which as in the case of the Minerva, is out of all proportion to the size of the present stream. It has cut through the drift and exposes the coal measure shales and Lower Carboniferous limestone near Bangor. Mud creek, a prairie stream through the greater part of its course, and without the usual accompaniment of alluvial bottom land, is the principal tributary of Honey creek—the two streams joining just as they enter the flood plain of the Iowa.

Age of the Iowa system.—The Iowa system bears the impress of age; of advanced maturity. The original topography of the county did not depart far, perhaps, from that of a plain and the present configuration is due almost wholly to erosive

forces. The limiting divides average about two hundred feet higher than the Iowa flood plain. The down cutting alone would require thousands of years, while the true enormity of the task and the vast lapse of time can only be realized when it is considered that the river valley averages from one to two miles in width. Sufficient data are not at hand definitely to determine the age of the system; but, considering the broad valleys of the Iowa and its principal tributaries, and the fact that the Kansan drift, apparently undisturbed, follows down the hillsides at least to the level of the flood plain, much lower than the outcroppings of the country rock as in the vicinity of Quarry, Le Grand and Timber creeks, it may tentatively be stated that the system, in part at least, is pre-glacial. The profoundly glaciated surface exposures at Le Grand, Timber creek and Linn creek, all located on the south flank of the present stream valleys, may also be admitted as evidence of preglacial depressions in the direction from which the ice came. It seems probable that the Iowa river, from Le Grand to the mouth of Honey creek at least, the lower courses of Timber, Minerva, Honey and perhaps Linn creeks have sought out and partially reopened their old channels. The minor streams and the upper courses of the larger tributaries are doubtless usually superimposed upon the glacial deposits and are independent of preglacial configuration. In terms of stream development the Iowa has passed its zenith and old age is slowly but surely coming on unless stream action be reinvigorated by deformation and uplift of the region. The surface inequalities have long since reached their maximum and the hills are slowly melting away to fill the valleys. The melting snows and summer showers humble the one that they may contribute to the upbuilding of the other. Man himself is a potent factor in this leveling process. The old settler can well remember the time when the waters of our streams were untarnished at the spring freshets or summer floods save by the crystal amber from our virgin prairies. At the present time after

such periods the streams flow liquid mud. The prairie grasses and forest trees were conservators of moisture and firmly held the soil in place. The processes of agriculture in subduing the prairies and denuding the forest areas have increased the "run-off" and rendered the soil easily eroded. Culture has stimulated the small streamlets to a new cycle of cutting, as is evidenced by gullied fields and roadsides. Some of these cuttings are more than ten feet in depth.

Skunk river system.—A triangular area in the southwestern part of the county drains through tributaries of the Skunk river. The hypotenuse of the triangle is approximately followed by the State Center branch of the Iowa Central railway and its area is about ninety square miles. The principal representatives of the system are Clear creek, North Skunk river and Snipe creek. All flow approximately at right angles to the general slope of the county. Clear creek and the Skunk river are wooded streams, while the Snipe is timberless. Clear creek has more deeply incised the region through which it flows than its co-workers, but none of them have done much in the way of valley formation. The valley of Snipe creek is boggy in character and suggests the fitness of its name.

The Cedar river system is feebly represented in the northeast corner of the county. The drainage from about two square miles takes this route to the "father of waters."

TERRACES.

Stream terraces are doubtfully represented in Marshall county. Timber creek, on sections 8 and 17 in Le Grand township, is accompanied by a low shelf fifteen to twenty feet above the flood plain in the streams. This bench can be identified at several other points in the various branches of this stream and is the nearest approach to a terrace found in the region.

Minerva creek, in Liberty township, sections 22 and 27, is apparently terraced. The bench is eight to ten feet above

the flood plain and is composed of Wisconsin drift. Here is the semblance of an old valley partially filled by the Wisconsin ice, and the present narrow flood plain represents the cutting since the retreat of the last ice sheet.

STRATIGRAPHY.

General Relations of Strata.

The geologic history of Marshall county is recorded in strata which belong to two distinct series separated by an enormous time break. A feeble realization of the immensity of the interval which elapsed after the completion of the first chapter and before the commencement of the last, can only be gained when we catch occasional glimpses of profoundly eroded areas and base-leveled plains.

The underlying stratified rocks belong to the Carboniferous system. Lying unconformably upon these is a thick mantle of Pleistocene deposits which effectually conceal the older rocks, save along some of the larger streams. The formations present are tabulated below.

CLASSIFICATION OF FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvial.
		Glacial.	Wisconsin.	Fourth till.
			Iowan.	Loess. Third till.
			Buchanan.	
			Kansan.	Second till.
			Aftonian.	Albion gravels.
			Sub-Aftonian?	First till.

CLESSIFICATION OF FORMATIONS—*Continued.*

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Paleozoic.	Carboniferous.	Upper, or Pennsylvanian.	Des Moines.	
		Lower, or Mississippian.	St. Louis.	
			Augusta.	
			Kinderhook.	Marshallt'wn shales. Le Grand beds. Hannibal shales?

The Lower Carboniferous forms an unbroken platform upon which all of the later deposits rest. The coal measures partially overlap this formation and comprise about one-half the area of the county. While the present surface slopes gently to the southeast, the underlying stratified rocks are inclined to the southwest or at right-angles to the general surface inclination. The average dip of the strata is about fifteen feet per mile in the eastern portion of the county, but the beds become almost perfectly flat to the westward.

The deeper strata have only been explored at one point,—Marshalltown. The following is the sequence of strata passed through in sinking the deep well near the city water works. The record* is based on sample drillings saved by Dr. W. S. McBride of Marshalltown.

		THICKNESS.	DEPTH.
13.	Limestone, light gray in fine sand, with many angular fragments of limpid quartz at 68 feet		70
12.	Limestone, light yellow, compact, earthy luster, three samples	45	115
11.	Limestone, brown, crystalline, cherty, at 115	30	145

*Prof. W. H. Norton kindly loaned to the writer his manuscript on the Marshalltown well, and from it the recorded descriptions and interpretations are taken almost verbatim.

		THICKNESS.	DEPTH.
10.	Shale, soft, light green, calcareous	175	320
9.	Limestone (?) no samples	145	465
8.	Limestone, hard, brown; gray and brown crystalline, rapid effervescence, samples at 465 and 560	155	620
7.	Dolomite, yellow, gypseous and cherty	55	675
6.	Limestone, magnesian, brown, samples at 675, 690 and 700, cherty at 675	95	770
5.	Dolomite, cherty and gypseous; drillings consist mostly of white and translucent chert	30	800
4.	Chert, white and translucent; samples at 800	75 (?)	875
3.	Limestone, rapid effervescence; drillings consist almost wholly of chert with some gypsum, samples at 875 and 900	15	915
2.	Dolomite, white in powder, with some chert and gypsum	10	925
1.	Shale, blue and green-gray, non-calcareous in samples, 925 to bottom of boring at	95	1,020

SUMMARY.

NO.	FORMATION.	THICKNESS —FEET.	DEPTH —FEET.
11, 12, 13.	Mississippian (Kinderhook limestone)	145	145
10.	Kinderhook (Shales)	175	320
8, 9.	Devonian	300	620
2–7.	Silurian	305	925
1.	Maquoketa penetrated	95	1,020

The sub-crystalline gray limestone and the buff magnesian limestone which attain such prominence in the exposures near Le Grand can be recognized as Nos. 13 and 10 respectively in the above section; but no trace of the equally prominent oolite and blue sandstone is to be found in the drillings. The whole assemblage of limestones above the green shale undoubtedly belong to the Kinderhook, while the taxonomic relations of the shale itself are not so clear. For the present, perhaps, it is best to follow Professor Norton and provisionally treat the formation as belonging to the Kinderhook, although latter developments may show it to be in part Devonian. Mr. C. N. Hutson, well driller, reports 260 feet of shale penetrated in sinking a well at the glucose works in the

south part of town. This heavy bed of shale does not outcrop any place in the county, nor, so far as known, any place in central Iowa, but its stratigraphic position seems to be the same as the thick shales encountered in the deep wells at Ottumwa and Sigourney* and the blue shale which outcrops at the base of the bluffs along the Mississippi river at Burington.†

The section ends in the Maquoketa shales which forms a well defined terrain throughout central Iowa, which may be taken as a standard of reference to determine the general dip of the deeper strata for this region. At Ackley and Cedar Rapids‡ this formation is reached at about 400 and 300 feet respectively above sea level. At Marshalltown the top of the shale is fifty feet below tide, while at Ames the shale rises more than 100 feet above sea level.

Standard Sections.

The best exposures are found in the vicinity of Quarry and Le Grand along the Iowa river. The Le Grand Quarry Co. in the development of their property have laid open to inspection sections which aggregate nearly two miles in length and nearly one hundred feet in vertical thickness. Other sections of less importance may be observed where the smaller streams cross the Kinderhook escarpment, as, for example, on Timber, Linn and Honey creeks, and near the towns of Albion and Bangor.

The following sequence of beds may be observed at the East quarries near Le Grand.

SECTION 1.

		FEET.	INCHES.
18.	Loess, interstratified sands and silts below	16	
17.	Bowlder clay oxidized a deep brown and containing bowlders much decayed	5–10	
16.	Limestone, sub-crystalline, pebbly	3	
15.	Oölite, fine-grained, with many brecciated grains	4	

* Geology of Iowa, vol. III, pp. 203-205, pl. xviii, 1893.
† Geology of Iowa, vol. I, pp. 192-193, 1870.
‡ Geology of Iowa, Vol. III, pp. 189-192 and 195-197. 1893.

		FEET.	INCHES.
14.	Limestone, gray, slightly oölitic	2	6
13.	Limestone, gray above, and yellow below	2	
12.	Limestone, buff, magnesian, rather heavily bedded, bisected by chert band about four feet from the base	9	
11.	Limestone, mixed gray, blue and buff, breaks very irregularly ("Brindle" of the quarrymen)	3	6
10.	Chert		4
9.	Limestone, soft, yellow, in thin layers and arenaceous; earthy in places	2	6
8.	Chert		4
7.	Limestone, blue, variegated to yellow-brown	6	
6.	Chert		3
5.	Fossil-breccia with lenses of crystal calcite	1	
4.	Limestone, buff, magnesian, fine even texture and massive; cherty, concretions scattered promiscuously throughout. One quitepersistent band of chert about four feet from the base	12	
3.	Limestone, blue, variegated to brown, hard, conchoidal fracture, and in heavy layers	3	6
2.	Oölite, in layers, 14, 12, 8, 9, 6, 36, 26, 24 and 42 inches in thickness	15	
1.	Sandstone, fine-grained, blue, calciferous, in part shaly (exposed)	10	

No. 1 in the above section is exposed in the quarry north of the river and appears at no other point in the county. The dip is about four degrees to the southwest, and this, with the slope of the stream, soon carries the beds below the surface. Near Indiantown, in Tama county, the base of the oolite lies more than twenty feet above the water level, while at the west quarry both oölite and sandstone have passed below the bed of the river, and No. 16 has a thickness of about twelve feet. The upper layers at Le Grand probably form the base of the section at Marshalltown. At the latter place the following series, which consist principally of shales, may be seen near the Woodbury flouring mills.

SECTION II.

		FEET.
7.	Loess, sandy	2
6.	Clays, and sands with some bowlders, variegated; highly oxidized in streaks	6
5.	Calcareous, pebbly material containing large chert concretions; the original limestone structure is almost obliterated	4
4.	Shale, ash-blue, graduating downward into arenaceous beds	6
3.	Limestone, arenaceous, impure	2
2.	Shale, dark blue, slightly sandy and concretionary and slacks rapidly on exposure; many of the fragments spotted with white flocculent material	4
1.	Limestone, brown, sub-crystalline, base	

All of the beds are more or less irregular and are cut out eastward. A continuation of the above exposure, in the form of a low ridge, runs southwestward from the mill, departing somewhat from the river, and perhaps outlining the position of an old escarpment. The ridge continues for nearly a mile, gradually wanes and passes under the drift bluff at the Soldiers' home.

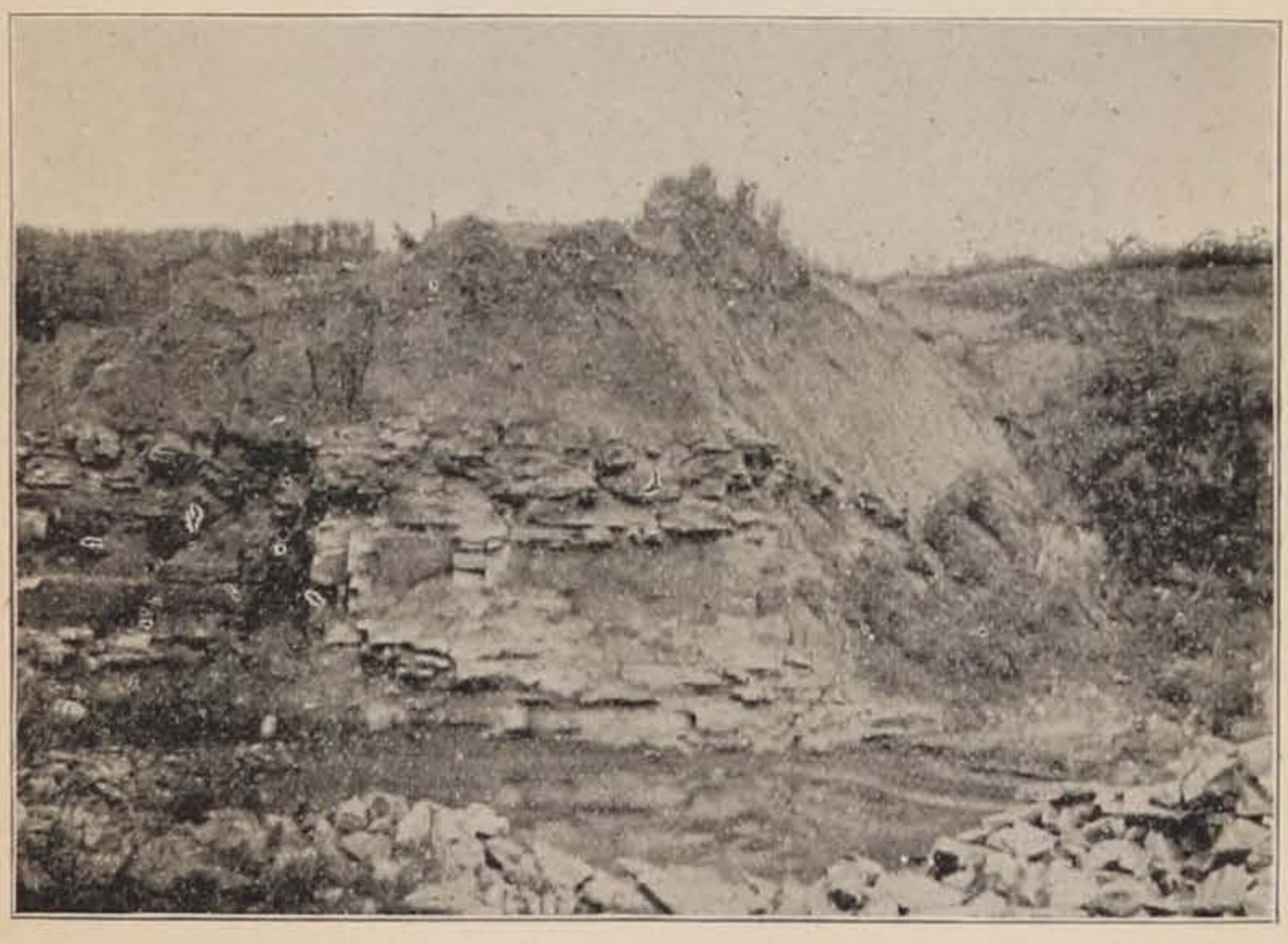


FIG. 26. The upper Le Grand beds as exposed at Rockton.

At Rockton the upper portion of section 1 is duplicated almost perfectly.

SECTION III. ROCKTON.

		FEET.
6.	Loess and soil	1–3
5.	Till, yellow (Iowan)	2–4
4.	Till, reddish-brown, sometimes blue below (Kansan)	0–3
3.	Limestone, brown, sub-crystalline, rubbly	3–5
2.	Limestone, oölitic, heavy bedded	5
1.	Limestone, gray-brown, beds thinner and slightly argillaceous	2

Two drift sheets are represented here. Numerous granitic

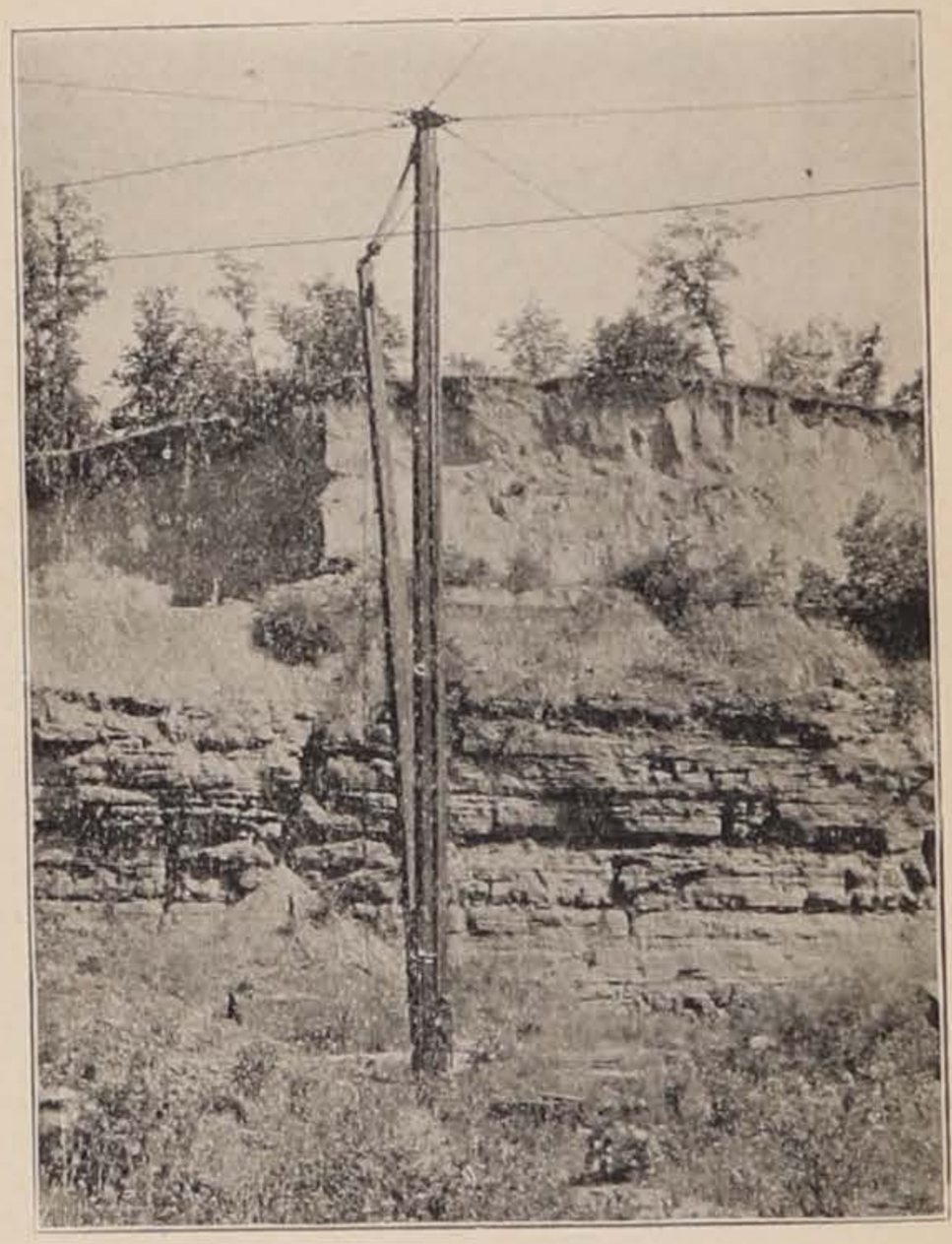


FIG. 27. The Le Grand beds as exposed on Timber creek at the I. C. Ry. crossing. The loess maintains a vertical scarp, while the Kansan till slopes.

bowlders are present in the base of the Iowan in places. Numbers 1, 2 and 3 in the above section may be referred to Nos. 14, 15 and 16 respectively in section 1.

At the point where the Iowa Central railway crosses Timber creek a slightly different facies of the Kinderhook beds may be observed.

SECTION IV. TIMBER CREEK.

		FEET.
8.	Loess, sandy, below	10
7.	Bowlder clay (Kansan)	6
6.	Limestone, brown, sub-crystalline, thinly bedded, and rubbly above, heavier below	8
5.	Limestone, yellow, brittle, with occasional small caverns decorated with concretionary calcite	1½
4.	Limestone, blue, hard, brittle	2
3.	Oolite in three layers, 8, 22 and 6 inches respectively	3
2.	Limestone, gray-brown, with layers of blue, sub-crystalline limestone interbedded	6
1.	Limestone, gray-blue, close textured, soft when first exposed, weathered portion, yellow; layers vary from 6 to 18 inches, very evenly bedded, magnesian	12

The oölite in the Timber creek section is undoubtedly the equivalent of the oölite exposed at Rockton and the "upper oölite" of section 1, numbers 1–6, in the above section find their counterparts in 12–16 in the Le Grand section, with the possible exception of number 5, which was not recognized farther north. The differences in physical properties and coloration are largely, if not wholly, due to the differences in weathering. The Timber creek beds are better protected than those at Le Grand. The prevailing colors of the unweathered product are shades of blue and gray, while tones of yellow and buff are brought about through the action of weathering agencies. The hardness of the Timber creek stone increases on exposure.

SECTION V.

(Tp. 83 N., R. XVIII W., Sec. 8, Sw. qr., Se. ¼.)

		FEET.
3.	Loess	1–3
2.	Till, oxidized throughout a deep brown	2–5
1.	Sandstone, reddish-brown in heavy beds, certain layers show oblique bedding, exposed	12

The sandstone exhibits a conglomeratic facies in part. Well polished grains of sand and gravel are held in a matrix

of ferric oxide. Some of the iron oxide is often in the form of small nodules which frequently are hollow and possess the concentric structure peculiar to concretions. Throughout the beds are the impressions of the trunks and branches of trees which have retained their woody structure in a remarkable degree, although their original organic substance has been entirely replaced by mineral matter. In some instances a pulverulent ash surrounded by a highly ferruginated shield are the only remains. In one case, a central core of very

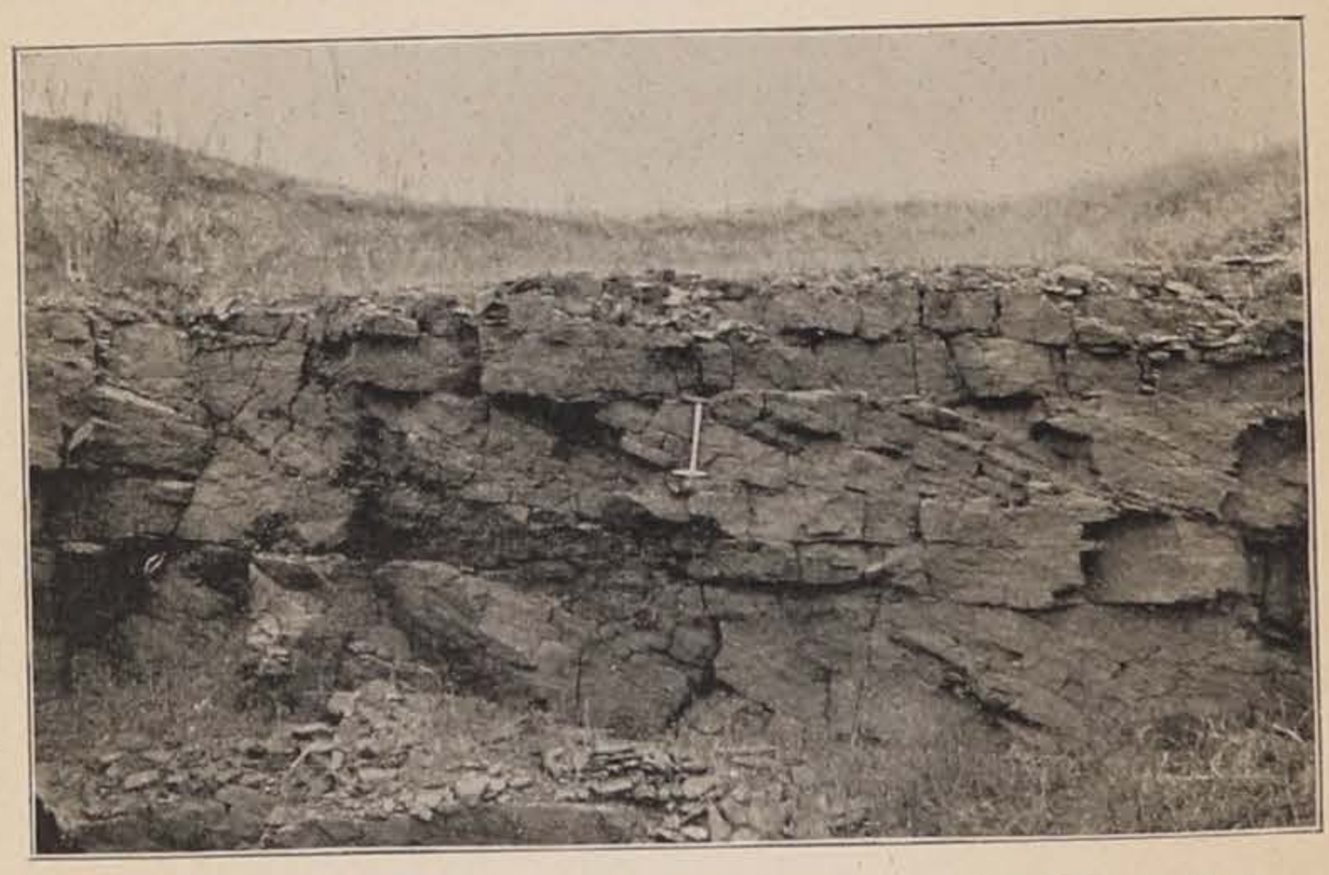


FIG. 28. Carboniferous sandstone in Timber Creek township, Sec. 8, Sw. qr., Se. ¼.

hard material, almost quartzitic, was noted; around this a zone of wood fiber, and surrounding all the concentric ferruginous shield. All of the stems were in a recumbent position. No faunal remains could be found.

Geological Formations.

CARBONIFEROUS SYSTEM.

With a few unimportant exceptions, the stratified rocks in the western half of the county are entirely concealed by the Pleistocene deposits. Rocks of the Lower Carboniferous age

have been exposed northwest of Liscomb near the Iowa river, and also east of Bangor on Honey creek. Coal measure outcroppings appear on Honey creek and along the Iowa river between Bangor and Albion.

MISSISSIPPIAN SERIES.

Owen, in his description of the Carboniferous rocks of the Iowa river definitely referred the rocks exposed near Le Grand to the Subcarboniferous. He says in part: "It was not, however, until reaching the northwest corner of Tama county that rocks of the Subcarboniferous era were seen unequivocally in place. Here, on the left bank of the Iowa, * * * both oölitic and encrinital beds of Carboniferous limestone protrude; and where the river crosses the corner of Marshall county the characteristic fossil, *Pentremites pyriformis* was found, along with *Terebratula plano-sulcata*, *Spirifer striatus* and *Productus semireticulatus*." He also calls attention to the change in the surface configuration, the beginning of a more vigorous topography, and the increased growth of timber, both of which, perhaps, are more or less independent of the country rock, but mark the transition of the drift plain into the loess-drift topography.

J. D. Whitney describes a section on Timber creek and disposes of the exposures near Indiantown and Le Grand as follows: "About one-half mile northwest of the town [Indiantown] a thin bedded, brittle limestone with a pinkish tinge is seen cropping out along the summits of the low ridges, * * * succeeded, in a descending order, by thin layers of white crystalline limestone filled with fragments of crinoidal columns. These layers contain intercalated masses of chert, and some of the beds are oölitic in structure, the whole assemblage closely resembling the outcrop of the Burlington member of the Carboniferous limestone as seen at that place. * * * In some loose masses of oölitic limestones * * * there were found specimens of Spirifer (?) ————, and an Avicula resembling *A. marionensis* Shumard."

* Geology of Iowa, Pt. 1, pp. 267-8, 1858.

White, in his discussion of the "Carboniferous System,"* describes the section at Indiantown, which is practically the same as the exposures at Le Grand, as consisting of.

		FEET.
3.	Soft irregularly bedded magnesian limestone passing up into purer and more regularly bedded limestone	40
2.	Light gray, oölitic limestone in heavy layers	15
1.	Yellowish, shaly, fine-grained sandstone	20

Continuing he says: "The characteristic fossils of the Kinderhook formation prevail throughout the whole series of beds found at Indiantown, even including the whole forty feet of No. 3. Although the upper part of No. 3 presents the lithological appearance of some parts of the Burlington limestone, yet its distinctive paleontological characters are wanting or feebly shown. The whole is therefore referred to the epoch of the Kinderhook beds, especially since the line of demarkation between the rocks of this epoch and those of the Burlington limestone is nowhere definite."

Wachsmuth and Springer,† in their chapter on the crinoids and blastoids from Le Grand, Iowa, accept White's reference of Nos. 1 and 2 in the above section, but observe that the upper part of No. 3, of the Le Grand and Indiantown sections is, in their opinion, very probably the representative in part of the Lower Burlington limestone. A specimen of *Actinocrinus proboscidialis* which is one of the most characteristic species of the Lower Burlington, is mentioned as having been found in the upper layers; and these authors suggest that the upward limit of the Kinderhook is coincident with upper limits of the magnesian limestone.

To summarize briefly, Owen and Whitney considered the Le Grand beds to be the equivalents of the encrinital formations,—the Lower Burlington limestone at Burlington, the correlation being based almost wholly on lithological resemblances. White definitely assigns the assemblage to the Kinderhook as defined by Meek and Worthen, basing his opin-

* Geology Iowa, vol. I, pp. 195-7, 1870.
† Geol. Sur. Illinois, vol. VIII, pp. 155-208, 1890.

ion on paleontologic evidence; while Wachsmuth and Springer, in their study of the echinodermatous remains in the beds, confirm White's reference, in the main, but suggest the probability of certain of the upper layers belonging to the Lower Burlington.

The present investigation affords no reason to dissent from Professor White's reference. Professor Calvin has kindly identified a series of fossils collected at Le Grand, Timber creek and Rockton, some of which were taken from the extreme uppermost strata, and he finds them to possess distinctively Kinderhook characters.

KINDERHOOK.

The Kinderhook beds in Marshall county attain a maximum thickness of nearly 150 feet.* The entire sequence may be

FIG. 29. Kinderhook outlier. Marshall-Tama line on the Iowa river.

observed by visiting two sections. The greater portion of the section is exposed at Le Grand, while the uppermost beds may be seen at Marshalltown.

THE LE GRAND BEDS.

The Le Grand beds comprise a total thickness of about 135 feet, as evidenced by the deep wells in Marshalltown which penetrate these deposits. Scarcely 100 feet of strata are

* The above estimate does not include the 175 feet of shale exhibited in the Marshalltown deep well, which is doubtfully referred to the Kinderhook

exposed at the Le Grand when all of the outcrops are combined. Although the Le Grand beds constitute a strati-

FIG. 30. Le Grand beds as exposed at southwest quarry, Le Grand. (1) Oölite, (2) Chert beds, (3) Orinoid zone, (4) Ice-planed surface of the brown and gray subcrystalline limestone.

graphic unit, for convenience of discussion they may be subdivided lithologically into four fairly well worked terrains, as follows:

		FEET.
4.	Brown and gray subcrystalline limestone	30
3.	Buff magnesian limestone, cherty below	35
2.	Gray-white oölite	15
1.	Argillaceous, blue sandstone	20

The lowest member consists of a very soft, fine-grained bluish white sandstone, slightly argillaceous above and heavy bedded below. The sandstone is exposed only at the north-

east quarry within the limits of the county. At Indiantown, about two miles east of Le Grand, the sandstone is very friable and takes on a yellowish tone due to weathering. Casts of fossils were observed.

The oölitic member is in very heavy layers and is evenly bedded. It is of a gray-white color and is only exposed in the two east quarries at Le Grand. This terrain is fossiliferous throughout. The principal forms recognized were:

Entolium circulus Shumard.

Straparollus latus Hall.

Productus sp. (?) and fish spines and plates.

The third member comprises about thirty-five feet of homogeneous, fine-grained, buff, magnesian limestone, which, lithologically and faunally, may be subdivided into three zones.

		FEET.
3.	Heavy bedded magnesian limestone; barren zone	12
2.	Arenaceous marly layers; Encrinital zone	4
1.	Chert beds { Barren zone, 12 feet / Chonetes zone, 8 feet }	20

The chert beds consist of irregularly bedded magnesian limestone, much divided by quite persistent chert bands and cherty concretions scattered promiscuously throughout the deposit. This division is almost devoid of organic remains, save in the chert bands and associated layers near the base, which are closely set with Chonetes. *Productus arcuatus* Hall, was found along with the Chonetes. The chert beds are separated from the oölite by a variegated, heavily bedded, subcrystalline brown and blue limestone, whose most characteristic organic remains are fish spines. A large spine of Ctenacanthus, similar to *C. furcicarinatus* of Newberry, was found in this layer.

The middle layers are thinly bedded and of a marly arenaceous character, forming a fit receptacle for the abundant crinoidal fauna which they contain. More than nine-tenths of the Echinodermatous remains found at this locality were confined to these shaly, marly layers, which have an aggregate

thickness of less than four feet, and may fittingly be designated the "Encrinital zone."

Wachsmuth and Springer,* the eminent authorities on the Paleozoic Pelmatozoa, have described the following species of crinoids and blastoids from the Le Grand beds:

Athinocrinus ornatissinus W. & Sp.
Athinocrinus nodobrochiatus W. & Sp.
Athinocrinus arnoldi W. & Sp.
Megistocrinus nobilis W. & Sp.
Megistocrinus parvus W. & Sp.
Batocrinus macbridei W. & Sp.
Dorycrinus immaturus W. & Sp.
Dorycrinus radiatus W. & Sp.
Dorycrinus parvibasis W. & Sp.
Rhodocrinus kirbyi W. & Sp.
Rhodocrinus nanus Meek & Worthen.
Rhodocrinus watersianus W. & Sp.
Platycrinus symmetricus W. & Sp.
Platycrinus planus Owen & Shummard?
Dichocrinus inornatus W. & Sp.
Graphiocrinus longicirrifer W. & Sp.
Scaphiocrinus elegantulus W. & Sp.
Scaphiocrinus globosus W. & Sp.
Taxocrinus fletcheri Worthen.
Taxocrinus intermedius W. & Sp.
Orophocrinus conicus W. & Sp.
Orophocrinus fusiforms W. & Sp.

In describing the mode of occurrence and former habitat and state of preservation of this most interesting assemblage of organisms, the above authors write as follows: "It appears that the Le Grand crinoids were deposited in very quiet waters, and in many cases were imbedded just as they died. They occur in nests and colonies, and genera and species are commingled indiscriminately. It is, therefore, a curious fact that while the specimens of some species are of

* Geological Surv. Illinois, vol. VIII, pp. 157-205. 1890.

pure calcareous composition and of a light color, those of others, under precisely similar conditions, lying side by side with them, sometimes even with stems and arms intertwined, are harder and of a very dark brownish-gray color. * * * The stems are short, * * * and is worthy of note that in all our perfect specimens from Le Grand * * * taper to a fine point, giving off rootlets in all directions, and there is in no instance any indication of an attachment by the column to a solid substance * * *. Taking everything into consideration, it seems to us the numerous small rootlets, spreading in all directions lead to the conclusion that those crinoids, with but few exceptions, either lived upon a soft, oozy bottom, in which they were rooted like plants, or that the rootlets served as an anchor by which the animal attached itself to foreign bodies."

The brachiopodous fauna is represented as follows in this zone:

Spirifer biplicatus Hall.
Orthothetes crenistria Phillips.
Rhynchonella sp (?).
Spirifer sp (?).

The upper layers of the magnesian limestone consist of heavy beds two to four feet in thickness and rather evenly bedded. A chert band bisects the division near its middle, but otherwise it is quite free from siliceous matter. Fossils are rare.

The magnesian limestone is exposed in its entirety in the two east quarries at Le Grand. At the west quarry the upper two divisions only are exposed. At the Timber creek quarry the top of the upper division is but little above water and this division alone has been explored. These are the only localities where this formation appears in the county.

The uppermost Le Grand beds comprise a composite series consisting in the main of gray or brown, subcrystalline limestone, and gray oölite. This oölitic layer is near the base and is composed of four feet of typical oölite resting on two

feet and a half of shell breccia with an oölitic facies. The limestone above the oölite is hard, thinly bedded and rubbly in character. Occasionally chert bands are present, but they are less abundant than in the magnesian layers. The whole assemblage is highly fossiliferous throughout, the chief forms being:

Spirifer subrotundus Hall.
Spirifer extenuatus (?) Hall.
Spirifer biplicatus Hall.
Orthothetes crenistria Phillips.
Rhynchonella, sp (?).
Terebratula, sp (?).

Fish remains and crinoid stems are often present in abundance, but *Actinocrinus proboscidialis* Hall, is the only crinoid calyx described from these beds.

The upper division is present wherever the Le Grand beds have been recognized within the limits of the county. It plays an important role in the Kinderhook escarpment, whose position is approximately marked out by a line passing through the Le Grand, Rockton, Corrick and Liscomb quarries. The valleys of the streams which have cut into the country rock are constricted where they cross this line. This is best seen in the valley of the Iowa itself. (See Pleistocene map.) The most extreme westward outcrops may be noted on the Iowa river north of the Soldiers' Home, on North Timber creek, and on South Timber creek near Ferguson. At the last three places only the thin bedded, brown, subcrystalline limestone may be seen.

MARSHALLTOWN SHALES.

About fifteen feet of argillo-calcareous beds are exposed near the Marshalltown Flouring Mills. They consist of ash-blue to deep blue shales interbedded with argillaceous limestones. Chert nodules are present in the upper calcareous layers. After diligent search no trace of organic remains could be found. In the absence of distinctive characters these

beds may be referred conditionally to the Kinderhook. Concretions similar to those mentioned above are found along the river westward to the great bend, but not in place.

AUGUSTA.

Although Hall considers the Le Grand beds to be the equivalent of the Lower Burlington and Wachsmuth and Springer have suggested the probable equivalency of the brown subcrystalline layers at Le Grand with the same formation, yet the matter now stands pretty much as it did more than a quarter of a century ago, when White failed to find sufficient reason for the differentiation of the Lower Carboniferous in Marshall county. With the data in hand at the present time the Augusta cannot be recognized definitely within the confines of the county.

SAINT LOUIS.

In Bangor township in the Sw. qr., Sw. $\frac{1}{4}$ of Sec. 16, a heavily bedded, close-textured limestone is quarried in the bottom of Honey creek. The rock is of a dark, ash-gray color and contains some small, cherty concretions. Iron pyrites occur in bands and sheets in certain layers. The rock breaks with an uneven or hackley fracture, and some blocks give a metallic chink when struck with a hammer. No fossils could be found. Lithologically, these beds have a very close resemblance to the lithographic facies of the Saint Louis limestone as exhibited at the quarries north of Ames on the Skunk river, and at Webster City on the Boone river. The area is mapped as Kinderhook, but probably should be referred to the Saint Louis. Coal measures overlie these beds at this point.

DES MOINES STAGE.

The coal measures (Des Moines) overlap the Lower Carboniferous formation in an irregular manner and occupy nearly one-half the superficial area of the county. The general trend of the overlapping edge of the formation is east of

south, extending from the northeast corner of Bangor township to the southwest corner of Green Castle township. There are reëntrant angles where the principal streams make their exit from the measures, with the exception of Middle Timber creek; there being an extension at this point. A prolongation of the coal measures extends westward into Iowa and Liscomb townships and may have been at one time continuous with the outlier in Vienna and Taylor townships, which marks the extreme eastward limit of the Des Moines in the county. Outcroppings of the coal measures are few and unimportant, so perfect is their concealment by the glacial debris. At certain points along the Iowa river northwest of Albion on Honey creek, a thin coal seam along with carbonaceous shale may be noted. In Timber Creek township a heavily bedded, red sandstone appears along a tributary of Linn creek, near the Chicago Great Western railway on sections 8 and 9. Outcrops of the same beds may be obscrved near the water level on the Middle Timber in sections 26 and 34. Away from the margin there are no exposures of the Des Moines in the region. The deeper wells in the vicinity of State Center undoubtedly penetrate the coal measures, which consist largely of shales. In sinking a well for Emanuel Hepner, Tp. 85, N., R. XVII W., Sec. 30, Se. qr., Ne. ¼, the following sequence of strata was reported.

	FEET.	INCHES.
Loess and drift	120	
Sandy, shelly rock, greenish yellow	2	
Coal		6–8
Red sandstone, soft	16	
Argillaceous limestone, very hard	1	
Argillaceous shale, light, ash-color	13	
Coal, carbonaceous shale and fire clay	6	
Hard, gray limestone (penetrated)	10	

Other wells in the vicinity are reported to exhibit a similar sequence. The Hepner well seems to be near the center of the outlier and hence the maximum thickness of the measures in this region may be taken as approximately forty feet. The Des Moines is doubtless much thicker in the western portion

of the county, but at present no well authenticated records are at hand.

Here, as elsewhere in Iowa, the Des Moines stage of the Upper Carboniferous consists essentially of shales and sandstones, with occasional layers of argillaceous limestones and seams of coal, all of which are interbedded in an intricate manner. The shales predominate in Marshall county and vary structurally from massive structureless clays through clayey shales to fissile shales; texturally form the purest shales through arenaceous shales to argillaceous sandstones. Colors are equally variable from the gray-white fire clays to the jet-black carbonaceous shales.

The prevailing sandstones are in shades of red, but in other regions, where better exposed, they are found to be equally as variable in physical properties as are the shales.

So far as at present known the argillaceous limestones and coal seams are sparingly developed in this territory.

PLEISTOCENE.

With a few unimportant exceptions where the larger streams have succeeded in cutting through and exposing the older formations, the Pleistocene deposits form a continuous mantle over the entire county. They are composed essentially of bowlder clays, sands, gravels and silts, often interbedded and intermingled in a most complex manner. Bowlders are not uncommon attendants to this most heterogeneous assemblage. The average thickness of the glacial debris on the uplands in this region, is upwards of 100 feet, and the present surface features are sculptured almost wholly in this material. At certain points in the county much greater depths are attained. In Eden Tp. on the northwest quarter of section 8, 190 feet was reported; Jefferson Tp., Sw. qr. of Sec. 22, 220 feet; Marietta Tp., Sw. qr. of Sec. 25, 212 feet; Liscomb Tp., Nw. qr., Sec. 22, 260 feet; Taylor Tp., Se. qr., of Sec. 1, 300 feet, and on the Sw. qr., 400 feet of drift was penetrated. In the latter township there seems to be a rock-

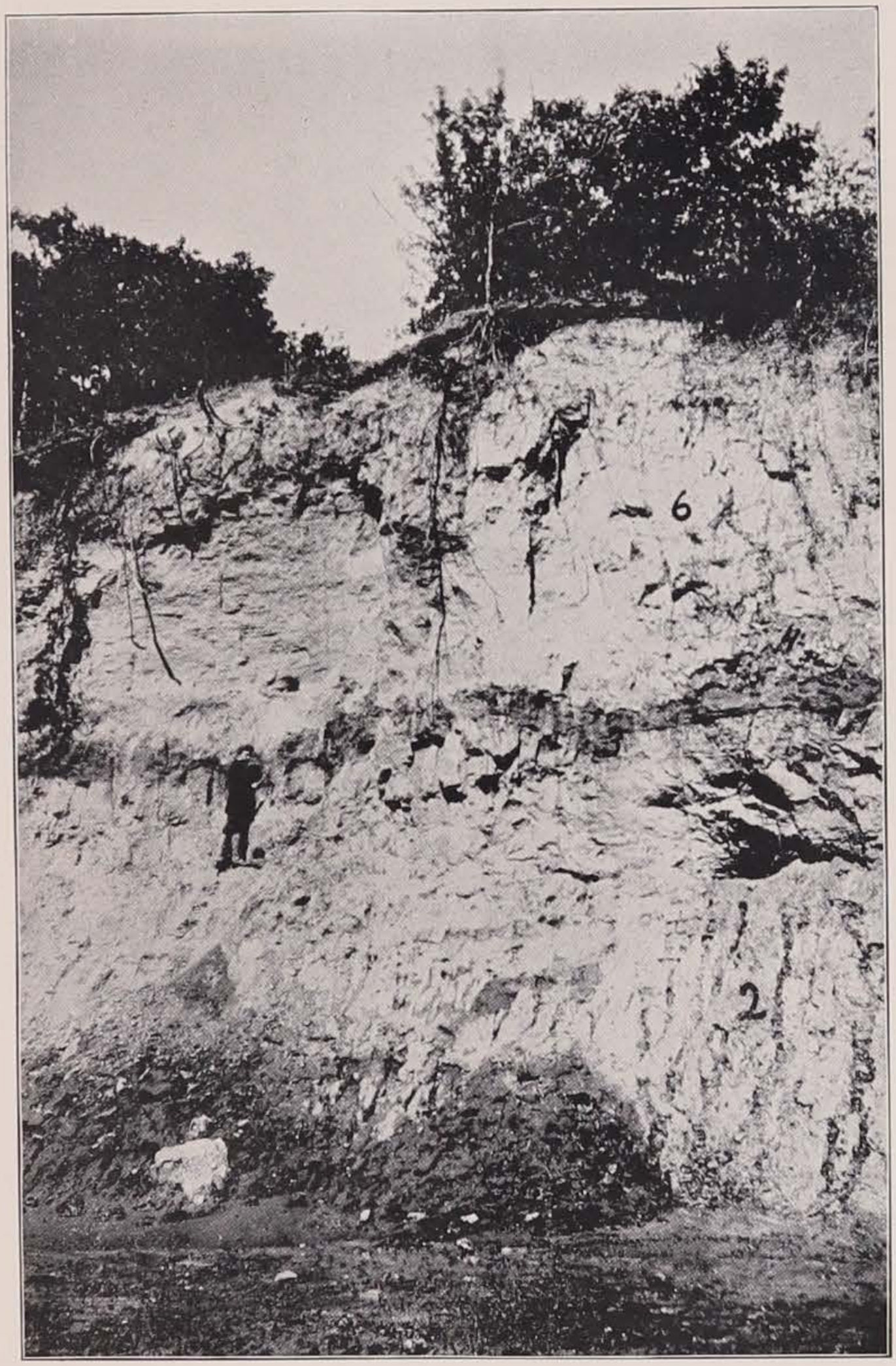
bound gorge trending northeast-southwest, bisecting sections 1 and 11, and more than a half mile in width. The southern wall of the gorge is apparently very abrupt, while the north wall rises gradually. The rock rises to seventy or eighty feet of the surface within half a mile southeast of the line of the gorge. Northward the rock is reached 190 and 180 feet below the surface on the Sw. and Nw. qrs. of section 2, respectively. The inequality of the slopes of this buried channel is analogous to that of the great majority of the Iowa streams of the present day. The south flank is almost universally the more abrupt. *

Although there are occasional hints of preglacial channels and depressions, none can be mapped definitely, and the general testimony of the drift wells is that the preglacial topography was milder than that of the present time. The type of topographic maturity. the pure plain, is suggested.

Marshall county has been subjected to at least three and perhaps four distinct ice invasions, separated by intervals of vigorous erosion and surface corrugation, or surface silting. The first two ice sheets were followed by gravel trains, while the last two were succeeded by intervals of surface silting and alluvium forming, respectively. The sequence of events may be described briefly in chronological order, and the corresponding deposits arranged stratigraphically as follows.

8.	Deglaciation and erosion	Recent (Alluvium in part.)
7.	Glaciation (western margin of county)	Wisconsin till.
6.	Deglaciation and surface silting	Loess.
5.	Glaciation (northeast corner)	Iowan till.
4.	Deglaciation and vigorous erosion	Buchanan gravels.
3.	Glaciation (general)	Kansan till.
2.	Deglaciation and erosion	Aftonian gravels.
1.	Glaciation	Sub-Aftonian till.

* The writer is indebted to Mr. Harry Weatherby for the records in Taylor township. The data is based on drillers' notes or derived from a personal interviews with the respective land-owners. Such evidence must be taken with a grain of allowance. The Kinderhook shales lie scarcely 100 feet below the general rock surface and might easily be mistaken for drift clays.



DRIFT SECTION AT ALBION.

SUB-AFTONIAN.

No till sheet below the Kansan has certainly been identified in this region. At the Albion mill, about ten miles northwest of Marshalltown, the following sequence of deposits may be observed, the basal members of which are pre-Kansan, and may be the equivalent of the sub-Aftonian.

ALBION SECTION.

		FEET.
6.	Loess, stratified sand and silt below	20
5.	Yellow till, apparantly wanting in places and often represented by characteristic bowlders only. (Iowan)	0–1½
4.	Gravel, bowlders four or five inches in diameter present, granitic members often much decayed; limestone pebbles common; bowlders of Kansan adorned with pebbles noted. (Buchanan)	2
3.	Till, upper portion oxidized a deep reddish brown, the lower portion unoxidized and gray-blue in color; jointed structures prominent throughout. (Kansan)	5
2.	Sand and gravel, stratified, coarser below; oxidized in streaks and bands approximately parallel to bedding planes. (Aftonian)	10
1.	Blue till* (Sub-Aftonian)	10

At the well put down in section 7, in Warren township, for Wm. M. Wallace, the drillers' record is as follows:

	FEET.
Yellow clay (loess, Iowan and oxidized portion of Kansan)	30
Blue clay (Kansan)	40
Sand and gravel (Aftonian?)	30
Blue clay (Sub-Aftonian?)	50

The above records at least suggest the presence of the pre-Kansan till sheet, but additional data are necessary before more explicit statements can be made concerning its characteristics and distribution.

AFTONIAN.

At the base of the Albion section ten feet of stratified sand and gravels may be observed. These beds were laid down,

* Not exposed, but R. W. Sheets reports ten feet of bowlder clay penetrated in sinking the abutments for the bridge.

in large part, through the agency of running water. Many of the pebbles and small bowlders bear polished, striated or facetted surfaces, yet the granitic members are oftentimes in an advanced stage of decay. The relation of this deposit to the Kansan is unquestionable, because till of the Kansan age rests immediately upon these beds. Gravels similarly related to the Kansan have been reported from various parts of the county, and the maximum thickness attained is about thirty feet.

The presence of a well marked terrane consisting of sands and of gravels, many of the pebbles and small bowlders of which bear the unmistakable imprints of glaciation, almost necessitate a preëxistant glacier and its universal product, the till sheet. *A priori*, this fact in itself would be sufficient reason for suspecting the presence of pre-Kansan glaciation (sub-Aftonian drift sheet).

KANSAN.

The Kansan ice covered the entire area under consideration and extended far southwestward into Missouri and Kansas, receiving its name from the latter state. As a till producer this great ice sheet is without a rival, and the elements of the present topographic features are boldly outlined in the till of this sheet.

The Kansan drift is composed essentially of bowlder clays containing pockets of sand and gravel and occasional bowlders of moderate size. The coloration is almost wholly due to the state of oxidation, and the formation may be divided arbitrarily into an upper oxidized portion and a lower unoxidized portion. The oxidized zone varies in color from a bright yellow to a deep reddish brown, while the unoxidized portion assumes some shade of blue, and constitutes the blue clay, hard pan, etc., of drillers. The degree of leaching to which these beds have been subjected varies greatly, and approximately keeps pace with the process of oxidation. In the cuts along the Chicago Great Western railway on sections

8 and 17, in Timber Creek township, these facts are beautifully illustrated. The maximum thickness of Kansan till exposed here is about fifteen feet, covered with 3 to 10 feet of loess, the latter being the thickest upon the hill flanks. Near the line of contact the till is a deep red-brown in color and thoroughly leached. Passing downward, the color becomes lighter and the leaching less perfect. The lower five feet of the partially oxidized zone is of a faded yellow color, and lime concretions similar to those found in the loess which mark the incipitent stages of leaching are very abundant.

The pebbles and bowlders consist chiefly of granites, greenstones and gneisses. In the eastern half of the county fragments of limpid quartz and cherty limestones are very common, while quartzites occur infrequently. Many of the bowlders are fractured and striated. The granites and gneisses often crumble on exposure. Fragments of coniferous wood are not uncommon inclusions in the lower portion of the formation.

The Kansan till covers the whole county save where it has been removed by erosive agencies. The thickness of the sheet varies from a few feet, where it caps the outliers of the Kinderhook to more than one hundred feet in the uplands of the south and west, with an average thickness of little less than the latter figure. The oxidized portion is usually rather more than ten feet thick.

BUCHANAN.

The retreat of the Kansan ice was closely followed by a season of vigorous erosion and a working over of the newly deposited drift. This was a time of gravel accumulation. Well rounded bowlders of Kansan till are found in these gravel beds and may be taken as evidence of the still frigid climate, for it is reasonable to presume that fragments of clay would not permit attrition and transportation unless frozen. At Albion these gravels attain a thickness of about two feet and are typically developed. They are very much

coarser at this point than those referred to the Aftonian. The gravels near Gifford are probably of the same age, but are finer textured and distinctly stratified. During the remainder, and by far the greater portion of the inter-glacial interval, the surface was profoundly eroded, oxidized and leached.

IOWAN.

The Iowan ice traversed the northeast part of Marshall county and left evidence of its visit in the form of a thin sheet of till, and a goodly sprinkling of bowlders, some of

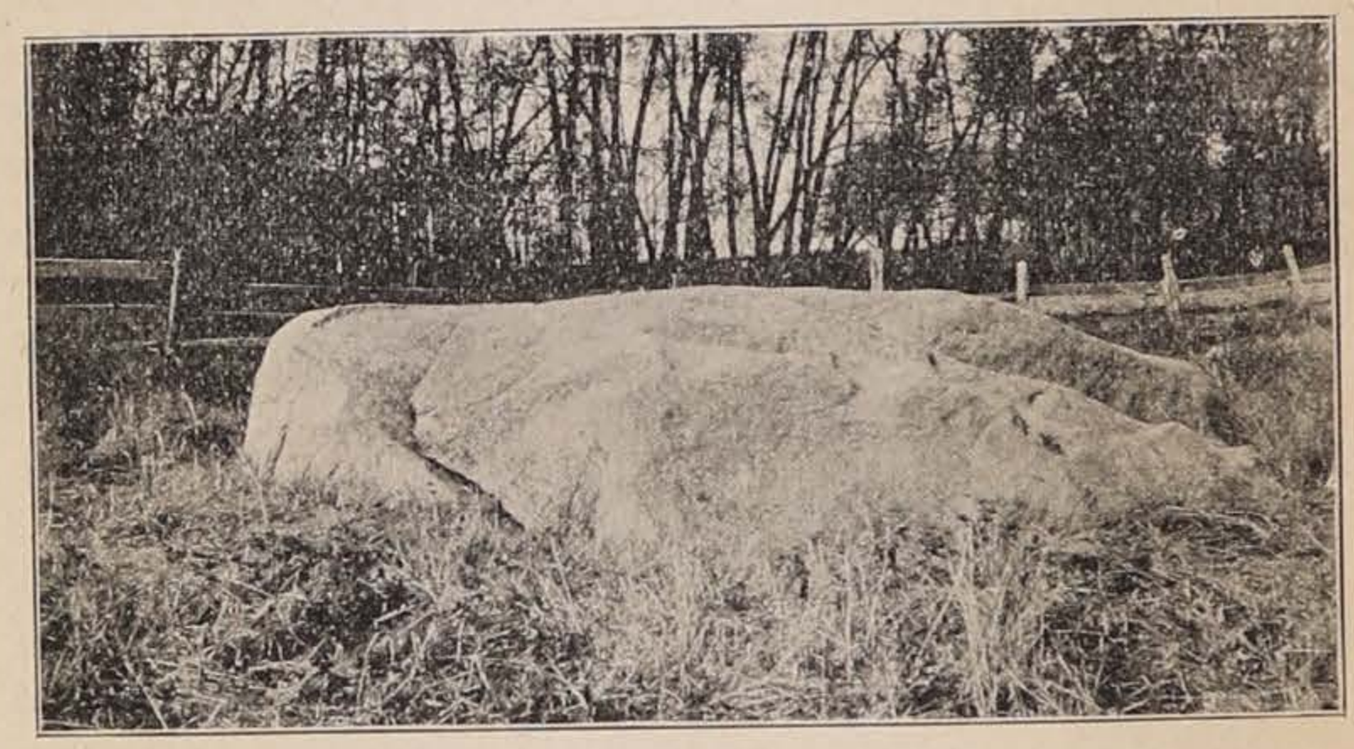


FIG. 31. Iowan bowlder, red granite, situated two and a half miles north of Marshalltown.

which are of enormous size. Unlike the Kansan, the Iowan contributed but little bowlder clay. Exposures of Iowan till may be observed at the Albion mills, Rockton, the cuts along the wagon roads in the northwest corner of section 2, Tp. 89 N., R. XVIII W., and various places between sections 5 and 6, Tp. 84 N., R. XVII W. This drift sheet never attains more than a few feet in thickness, and over perhaps the greater portion of the area, the bowlders, many of which occur well up the hill flanks, are the only witnesses of its presence. The Iowan till is light to bright yellow in color and is imperfectly oxidized and leached. It is sandier and lacks the tough, plastic char-

acter of the Kansan. The bowlders, both great and small, are prevailingly granites, and are much fresher than those common to the older drifts.

The Iowan ice was undoubtedly thin in this region, and the extreme advance of the attenuated edge is probably approximately outlined by the Iowa river, but no bowlders were observed on the flood plain below Albion.

LOESS.

The loess is a homogeneous, siliceous silt varying from light buff to a brownish buff in color. It in some measure resembles the drift after the coarser and finer materials have been removed. The constituent particles vary in size from

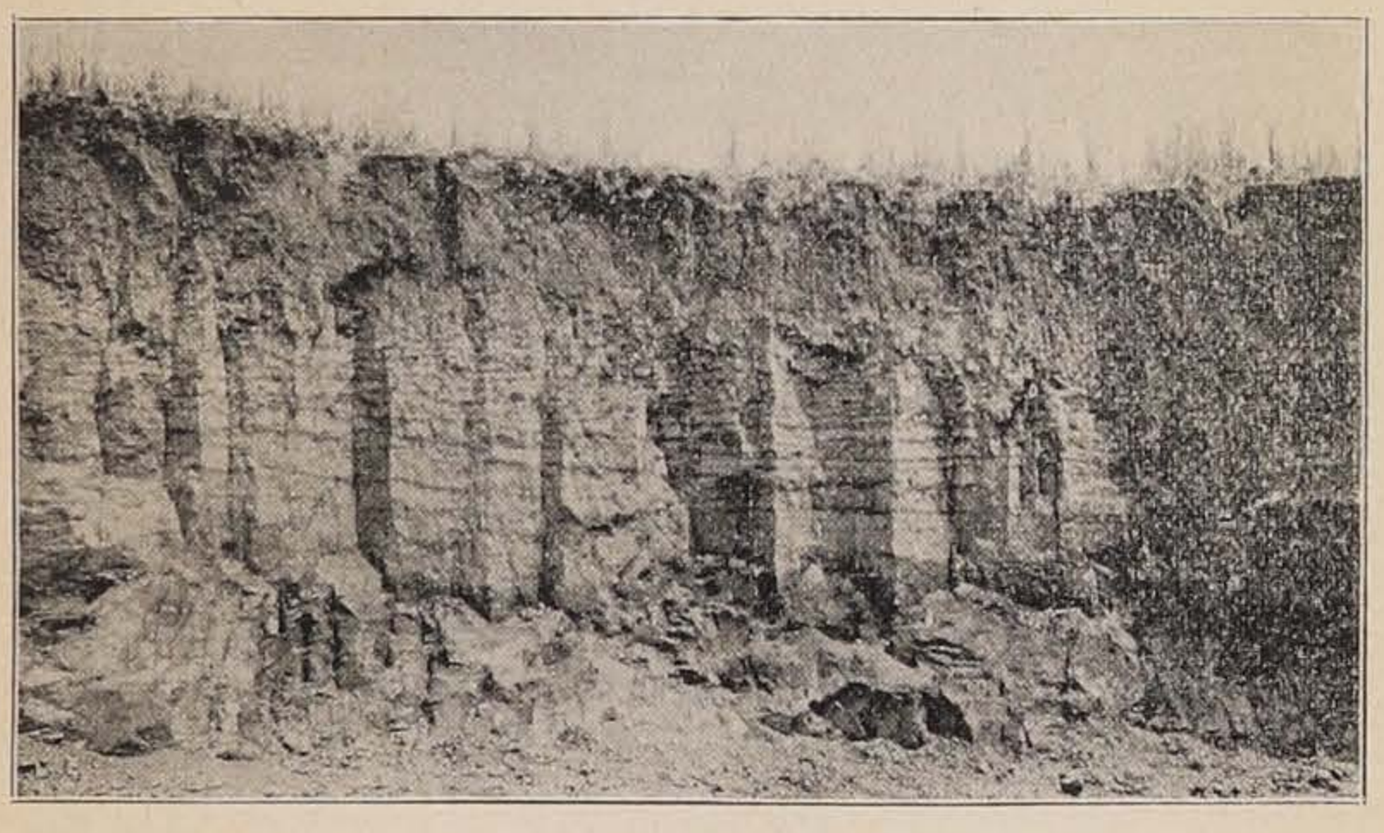


FIG. 32. Stratified loess, in clay pit of Sieg and Size, west of Marshalltown on the Iowa Central railway.

the finest silt to fine sands and usually present sharp angles. Lime concretions, *losspuppen* and *lossmanchen*, are often present in great numbers. Structurally, the deposit is uniformily massive, although in many exposures stratification lines are plainly visible. Typical loess possesses the peculiar physical property by virtue of which it tends to maintain a vertical scarp, regardless of its apparently incoherent character, and it

thereby greatly sharpens the contour lines of the regions thus clothed.

With the exception of the territory covered by the Wisconsin till and a small area near the northeast corner, the loess mantles the entire county, irrespective of altitude, save where removed by the streams. It is thickest in the vicinity of the probable margin of the Iowan ice, that is along the Iowa river, where it attains a maximum vertical measurement of upwards of twenty feet. In this region the deposit always grades downward imperceptibly into stratified sands. The loess is relatively both thicker and sandier near the greater waterways than upon the uplands. On many of the hills near the Iowa and, in a less degree, its greater tributaries, the upper silt has been removed and the sub-loessial sands comprise the present surface. This is notably true of the hills south of Albion and in Marshalltown and vicinity. The Chicago Great Western, crossing the divide between Linn and Timber creeks, lays bare some interesting facts concerning the distribution of the loess. While all of the hills are wholly loess mantled, the deposit gradually thickens from the summit to the slopes and is largely dissected out in the valleys.

The quarries near Le Grand expose from 15 to 20 feet of loess which is slightly sandy above, loess and sand interstratified in the middle, and almost pure sand at the base of the section. Loess concretions and fossils were not noted. At the clay pits west of Marshalltown, the loess is beautifully stratified throughout and becomes more siliceous below. Lime concretions occur sparingly, but no fossils were found. The above section may be considered typical for the immediate vicinity of the Iowa river. Two miles west of Marshalltown a road cut exhibits the following section.

	FEET.
Typical loess, slightly arenaceous below	6 to 8
Interstratified sand and loess, exposed	4

Fossils are abundant in the upper portion and persist in diminished numbers where lines of stratification are apparent. The principal species identified* are listed below.

* Professor Shimek kindly identified the fossils found in the loess.

Succinea avara Say, very abundant.
Succinea obliqua (Say).
Zonites shimekii Pilsbry.
Patula striatella Anthony.
Vallonia pulchella Mueller.
Zonites fulvus Draper.
Pupa muscorum Linnaeus.
Pupa alticola Ingersol.
Pupa pentadon Say.

One-half mile south of Bangor, fifteen feet of loess are exposed. The lower portion is filled with root casts, the largest of which measure an inch and a half in diameter. The matrix consists of interstratified, light colored sand and silt, the result of the removal of the iron constituents and the concretionary casts. Numerous concretions and fossils occur in the upper portion, the most common fossils observed being:

Succinea avara Say, very abundant.
Pupa pentadon Say.
Pupa muscorum Linnaeus.
Helicodiscus liaeatus Say.

About one and one-half miles north of State Center the above section is almost perfectly duplicated in all particulars. Fossils were noted in the clay pits at Rhodes and Melbourne and other points, but whenever observed, *Succinea avara* Say constituted more than one-half the specimens.

Origin of the loess.—Even since the publication of von Richthofen's "China," with the description of the Chinese loess, and the formation of the "Æolian Hypothesis" by that distinguished geologist and writer, the origin of this most anomalous deposit has been a fruitful subject for hypotheses both in this country and in Europe. It is not intended in the present discussion to espouse any particular theory, but rather to record the more salient features of the Marshall county loess and suggest their probable significance.

The stratified sub-loessial sands and interstratified sand and silt render plausible a subaqueous origin. But whether these conditions were brought about by a general depression of the surface and consequent ponding of the streams, or by drainage obstructed through the existence of an ice dam, the facts at hand do not warrant a conclusion. The general distribution of the loess, the absence of structural characters peculiar to waterlaid materials, the presence of land mollusks, some of which are now native even to arid regions, certainly lend credence to an æolian hypothesis. The angularity of the constituent particles has also been considered favorable to wind as the transporting agent. The validity of this inference is not well founded. It is an established fact that while the coarser sand grains are usually rounded through mutual attrition and impingement against obstructions, the cushioning action of the water adequately protects the finer sands and silts so that they maintain their angularity though transported great distances.

WISCONSIN.

The Wisconsin ice was represented in Iowa by a great tongue-shaped lobe, whose apex reached Des Moines, and which by a flank movement invaded the western border of Marshall county. The accompanying till sheet is second only to that of the Kansan. The upper portion of the Wisconsin till is slightly oxidized to a faint, dull yellow color and is succeeded downward by a blue bowlder clay less massive than that of the Kansan. Samples of both the oxidized and unoxidized portion effervesce freely when treated with cold, dilute hydrochloric acid. Lime balls are very abundant in many places. Bowlders are much more numerous in this region than in any of the older drift sheets, but are of smaller size than those of the Iowan age. The predominating types are gray and red granites, with less abundant quartzites and gneisses. Basic rocks are comparatively rare. The bowlders present a strikingly different aspect from those peculiar to

the subjacent Kansan, being as fresh as when they were broken from the parent ledge.

ALTAMONT MORAINE.

The limits of the Wisconsin lobe are marked in many places by a hummocky aspect of the surface with "kettle holes" and ponds liberally interspersed. This is the place where the melting glacier dumped its load of rock debris, which had been gathered during its journey from the far north and is technically known as the terminal moraine. In Marshall county

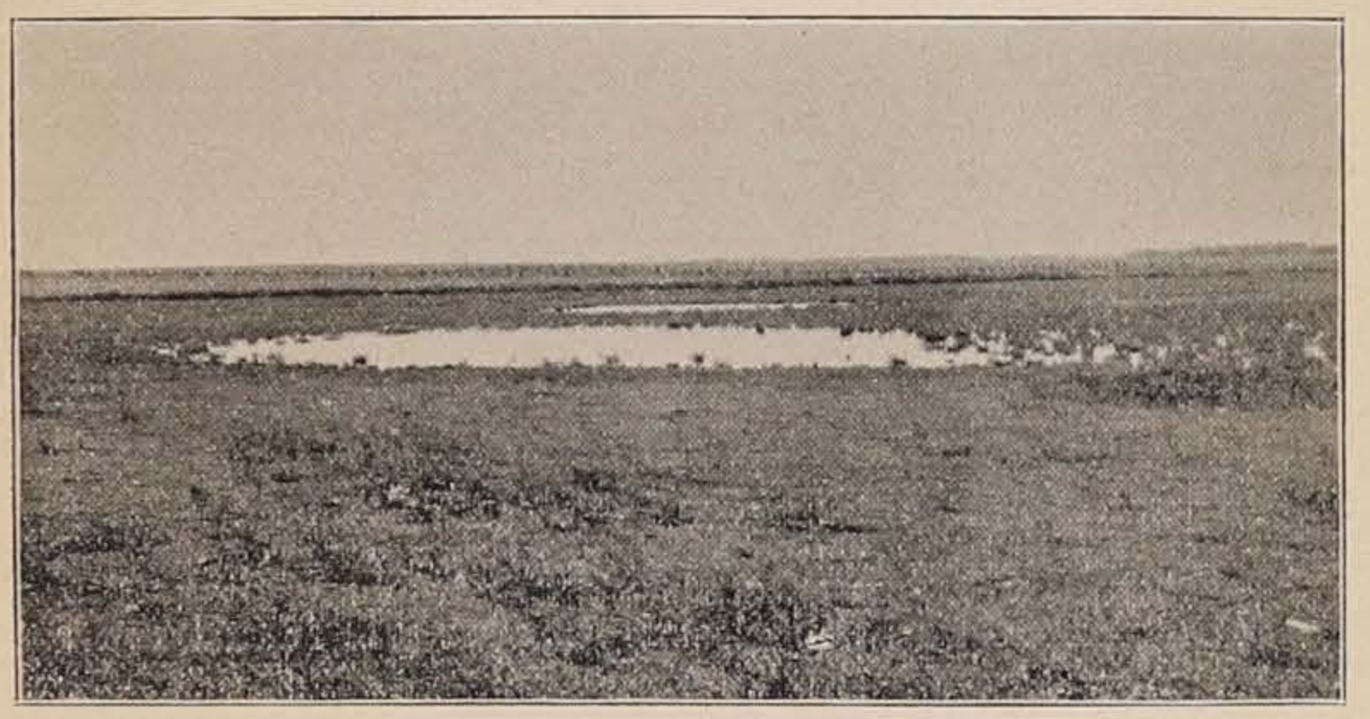


FIG. 33. Typical Wisconsin drift topography showing shallow "kettle-holes." Between State Center and St. Anthony.

the terminal moraine is but feebly developed. West of State Center is the nearest approach to a moraine in the region. Although distinctively morainic characters are but mildly expressed, the decided change in general surface configuration in passing from the older to the newer drift, facilitates the easy establishment of the boundary of the Wisconsin lobe.

GLACIAL SCORINGS.

The salient portions of the Kinderhook at Le Grand and Timber Creek, and the coal measure sandstone on section 8, Tp. 83 N., R. XVIII W., have been deeply planed and striated by the great ice sheets which traversed these regions. The

surface in all cases faces north, and all of the points are situated on the south bank of the Iowa river and the tributaries mentioned. No examples of rock scoring could be found on the opposite side of the flood plain. This may be considered additional evidence as to the preglacial character of the principal waterways. The northern slopes are protected by an accumulation of talus, while the southern flanks have been scraped clean of the rock debris and profoundly planed owing to a change in the gradient. The scorings and finer striæ were hermetically sealed by a layer of impervious blue clay and their state of preservation approaches perfection. At Le Grand the striæ trend south, 24° east; at Timber Creek they trend south, 25° east; at Sec. 8, Tp. 83 N., R. XVIII W., south, 20° east.

ALLUVIUM.

The alluvium is an important deposit in Marshall county. All of the principal streams on the older drift sheets flow through alluvial bottoms, while the Iowa river traverses a belt of this deposit which averages more than a mile in width. Most of the deposits which are mapped as alluvium are not wholly riverlaid material, but rather a mixture of loess and fluviatile deposits. Many of the streams have been alluvium making since the retreat of the Kansan ice. Northeast of Marshalltown on the broad bottomland of the Iowa, the finer debris has been removed in large part and extensive sand flats result.

Geological Structure.

The Kinderhook beds constitute a conformable series but are overlain unconformably by the Des Moines series. After the deposition of the Lower Carboniferous rocks, the general upward movement of the continent brought the whole of Marshall county above the level of the great Mediterranean sea to the southwest. Then followed an extended interval of denudation. The youthful surface was set upon by the erosive agents and dissected by streams until the physiography of the region was as strongly characterized as is the

LIBERTY
BANGOR
LISCOMB
VIENNA
IOWA
TAYLOR
MINERVA
MARIETTA
MARION
LINN
STATE CENTRE
TIMBER CREEK
LE GRAND
WASHINGTON
LOGAN
EDEN
JEFFERSON
GREEN CASTLE

Bangor
LISCOMB
St. Anthony
Clemons
Bromley
Minerva
ALBION
MARIETTA
Rocktons
MARSHALLTOWN
La Moille
STATE CENTRE
Luray
Malta
Dillon
MELBOURNE
Haverhill
Ferguson
Pickering
Vandeleve
RHODES
Laurel

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

R. XX W. R. XIX W. R. XVIII W. R. XVII W.

IOWA GEOLOGICAL SURVEY

MAP OF THE SUPERFICIAL DEPOSITS OF MARSHALL COUNTY, IOWA.

BY

S. W. BEYER.

1897.

Tp. 85 N.

Tp. 84 N.

Tp. 83 N.

Tp. 82 N.

R. VIII W.

R. XVII W.

LEGEND

GEOLOGICAL FORMATIONS.

- ALLUVIUM.
- WISCONSIN DRIFT.
- IOWAN LOESS.
- IOWAN DRIFT. IN PART LOESS COVERED.
- KANSAN DRIFT. LOESS COVERED.

INDUSTRIES.

- QUARRIES.
- COAL SHAFTS. ABANDONED.
- CLAY WORKS.
- MILL.
- ARTESIAN WELL.

present configuration. This was followed by a season of depression until the valleys were submerged, and finally perhaps, the whole surface of the county was near or below sea level and received contributions of sands, silts and clays, with some vegetable debris, which were lain down unconformably upon the older rocks. The deposits were compacted into sandstones, shales and coal seams, and constitute the coal measure series. The irregularity of the outline of the present Carboniferous deposits is due to the irregularities of the preëxisting surface. This period of deposition was closed by reëlevation the surface which was profoundly eroded through an immense interval of time; through, perhaps, the whole Mesozoic and the greater portion of the Cenozoic eras. The Pleistocene deposits lie unconformably upon all of the Paleozoic rocks and each drift sheet rests unconformably upon its predecessor. Although the surface may have oscillated up and down many times, the movement was continental and the strata are consequently approximately parallel.

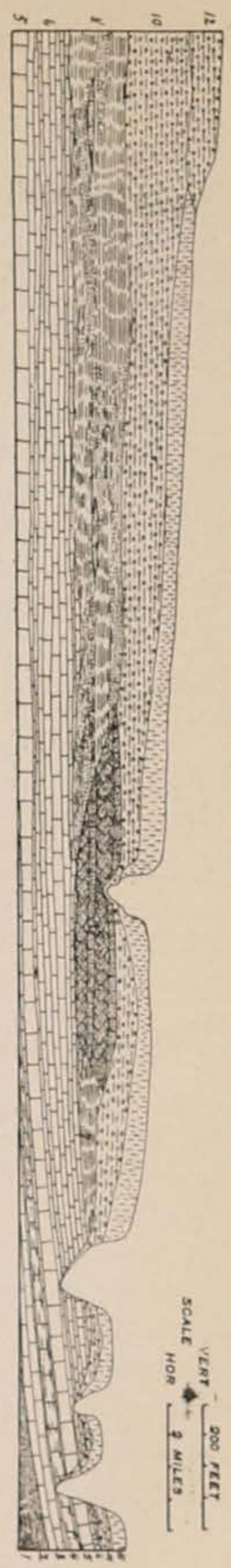


FIG. 34. Le Grand-State Center section. 1, Hannibal shales (?); 2, blue sandstone; 3, oölite; 4, chert beds; 5, magnesian limestone; 6, gray and brown limestone; 7, Marshalltown shales; 8, coal measure shale and sandstone; 9, coal measure sandstone; 10, Kansan till; 11, loess; 12, Wisconsin till. Numbers 2-6 make up the Le Grand beds.

ECONOMIC PRODUCTS.

Building Stone.

As has been said, the stratified rocks belong wholly to the Paleozoic era; and the Mississippian and Pennsylvanian series underlie about equal areas in the

county. The former consists essentially of limestones. The principal outcrops where quarry operations have been carried on are in the vicinity of Quarry and Le Grand, along the Kinderkook escarpment, and and on Timber creek. The Pennsylvanian series consists chiefly of shales, and a dull red sandstone is the only stone worthy of mention in this connection.

KINDERHOOK.

The most valuable quarry products in the county are derived from the basal member of the Mississippian series. In the southeastern portion of the state there are extensive outcrops of rocks of Kinderhook age, which consist chiefly of shales. In central Iowa, and in Marshall county in particular, the Kinderhook beds take on a calcareous facies and afford some of the best building stone to be found in the state. These beds are the more valuable because of their availability. The principal outcrops are located near the main lines of the Chicago & Northwestern and Iowa Central railways. The overlying glacial deposits are comparatively thin and may be removed at a minimum expense. The principal layers sought are the oölite and magnesian limestone, but the entire series is utilized.

LE GRAND QUARRY COMPANY.

The pioneer in the quarry industry, as well as the largest company operating in the county at the present time, is the Le Grand Quarry Co. with their central office in Marshalltown. The company owns and operates quarries at Quarry, Rockton and Timber Creek.

Quarry.—Three quarries are connected with the C. & N.-W. Ry. by branch lines at this point. Active operations were begun as early as 1860, when a limited quantity of building stone and lime was produced. Two years later the railway tracks were extended into the quarries, and the company has maintained a steady growth since. The manufacture of lime was discontinued some years ago.

The quarry plant is provided throughout with the most approved machinery. The equipment consists of steam crusher, gang mills, steam drills, derricks, lathes and planers; and quarrying and stone working is carried on most expeditiously and according to modern methods. The Le Grand beds in their entirety have been exploited to some extent, though the position of the blue sandstone renders it almost unavailable at present. (See Le Grand section.) The oölite and upper magnesian limestone layers afford the most valuable products, although the chert beds and rubbly limestone, along with the debris consequent to quarry operations, are worked up into riprap, concrete, ballast, etc., and constitute an important source of revenue to the company.

The chief building stones put upon the market are known commercially as oölite limestone, Iowa marble, Iowa caen stone and blue limestone.

The basal blue sandstone has not been sufficiently explored and tested to such an extent as to allow its merits as a building stone to be stated definitely. Small quantities of the stone have been removed from the east quarries, and certain blocks are now being tested as pavers in the streets of Marshalltown with some promise of satisfactory results.

There are two grades of oölitic limestones. The lower layer measures three and one-half feet in thickness and is coarse grained. The upper twelve feet is finer textured and consists of layers of the following thicknesses, respectively, from below upwards: 24, 26, 36, 6, 9, 8, 12 and 14 inches. The oölite is quarried only at the two east quarries, the dip of the beds and the slope of the river carrying the layers below the bed of the stream before the west quarry is reached. Formerly, the coarse, heavy basal layer was used for constructional purposes, but of recent years experience has demonstrated that it suffers disintegration when exposed for a season to atmospheric conditions. The fine-grained layers are close, even-textured and stand the test of time well. This is not only shown in artificial structures where the

blocks have maintained their angularity against sunshine and storm for upwards of a quarter of a century, but better still in the natural exposures where these layers stand out in bold relief. The oölite is composed of small, rounded, concretionary calcareous grains imbedded in a semi-crystalline matrix of cementing material of the same composition. Many of the concretions contain small angular siliceous grains. The unaltered rock is of a gray-blue color, while the weathered portion assumes a yellowish hue. Certain of the layers are highly fossiliferous and as the rock takes a high polish the beautiful effects are much enhanced, and this variety is known commercially as fossilite marble. Such slabs need to be collected with some care, for small grains of iron pyrites are often present and produce black stains when subject to moisture.

The upper portion of the magnesian limestone furnishes both the Iowa "marble" and the Iowa "caen stone," the former containing a higher percentage of $MgCO_3$. The Iowa marble occurs in heavy beds from two to three and a half feet in thickness. The slightly weathered portions are plain, light buff in color, while the weathered layers are of a a deeper color and beautifully veined with iron oxide. The stone receives a high polish, but like other limestones does not retain it when exposed to atmospheric agencies. It is very desirable for panelling and all parts of inlaid work when kept dry, aside from its qualifications as a first class building stone.

The caen stone is similar in color to the marble, but is softer, more tenacious and of lower specific gravity. It is especially adapted for carvings and molding.

A ledge of blue limestone lies between the chert beds and the oölite and also immediately above the chert beds. This limestone is very hard, compact and somewhat irregularly bedded, which renders quarrying and working rather difficult. The stone is used to some extent as a coursing stone and is very durable, but its untractable character renders its production expensive and it is mainly used as ballast.

The brown subcrystalline limestone with its interstratified oölitic layers affords some coursing stone and would be considered desirable for foundations in regions where building stone is scarce, but by far the greater quantity is transported to the crusher.

Rockton.—Active quarry operations have not been carried on at this point for several years. The beds worked comprise the brown subcrystalline limestone with the interbedded oölitic layers and the upper layers of the magnesian limestone. The characteristics of the beds exposed here are similar to their equivalents at Quarry. The upper oolite is perhaps heavier bedded and more important than at the last mentioned place.

FIG. 35. The Le Grand beds as exposed on Timber creek at the Iowa Central railway crossing. The section is, in part, along the line of a natural fissure and illustrates the differential weathering of the beds. 1, Blue limestone; 3, upper oölite; 3, brown and gray subcrystalline limestone.

Timber Creek.—The Le Grand Quarry Co. has been developing rapidly their quarry interests at this point during the past few years. A side track is laid in from the Iowa Central railway and the plant is well equipped with modern machinery. The beds operated are the same as those at Quarry from

the magnesian limestone upwards. As has been mentioned, the magnesian limestone differs in color from its homologue at Quarry and Rockton. At the latter places shades of buff prevail, while at the Timber Creek quarries the chief beds are a gray-blue with occasional layers in part light yellow. The fact is emphasized that the predominating color in the unaltered Le Grand beds is a gray-blue, which is changed to tones of buff and yellow through weathering agencies. Here, as in

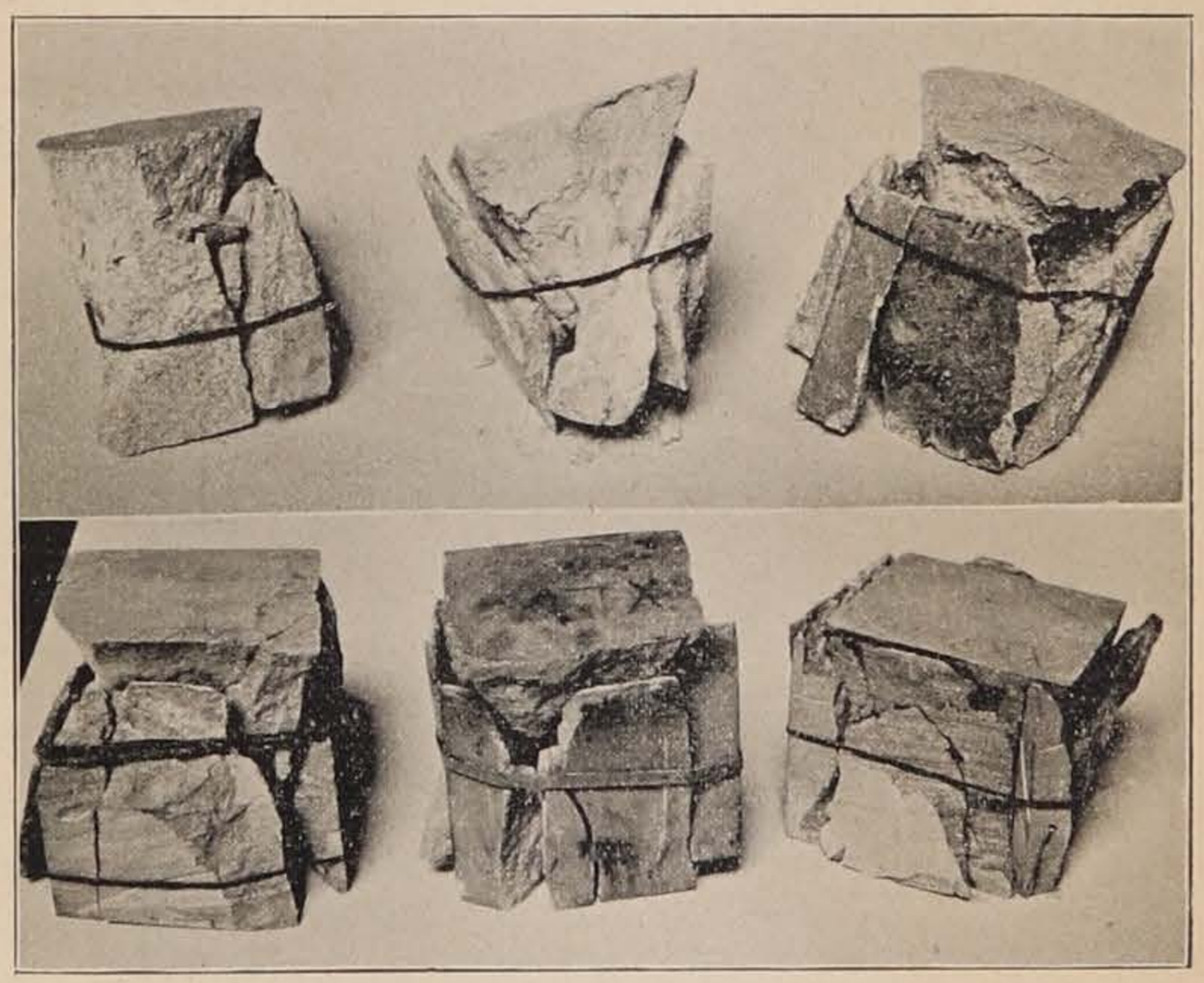


FIG. 36. Characteristic fractures of Le Grand building stone. Upper row, cölite; lower row, magnesian limestone.

other places, the magnesian layers succumb less readily to disintegrating forces than the associated beds.

The upper oölite and brown subcrystalline limestone are of more importance here than at the exposures along the Iowa river.

The Le Grand Quarry Co. employ on an average 200 men during the working season, and the daily output is about a train load.

TESTS OF THE LE GRAND STONE.*

The principal varieties of the Le Grand stone were subjected to three series of tests, viz:

1. Strength and ratio of absorption to determine the compactness of the stone, and hence its ability to withstand the atmospheric agencies.

2. Freezing and thawing alternately, and carefully noting the loss in weight and strength; and hence determining the tendency of the stone to disintegrate or weaken under the action of frost.

3. Chemical analysis to determine the relative amounts of desirable and deleterious constituents present.

In previous investigations on building stones, rectangular blocks of various sizes and shapes have been employed. The consensus of opinion of the highest authorities on the subject at the present time favor the two-inch cube as possessing the most convenient dimensions and giving the most satisfactory results. In the present investigation the two-inch cube was adopted. Great care was exercised in their preparation in order to guard against the production of incipient fractures through the impact of tools, and thereby lessening the strength. The blocks were sawed out approximately with the diamond saw, and then reduced to the proper dimensions by grinding. The results are tabulated in the subjoined tables.

*The mechanical tests were made in large part by Messrs. G. W. Zorn and J. W. Elliott under the personal supervision of Prof. A. Marston, in the Dept. of Civil Engineering of the Iowa Agricultural College. The chemical analyses were made for the survey by Prof. G. E. Patrick.

TABLE I.

MECHANICAL* TESTS.

	KIND OF STONE.	Height of cube.	Surface dimensions.	Area.	BREAKING LOAD IN LBS.		LOAD PER SQUARE INCH.		REMARKS.
					Spalling began.	Failure.	Spalling began.	Failure.	
	†Oölite, fine grained, northeast quarry	2.03	1.98x1.99	3.94	----------	46,680	----------	11,600	Failure accomp'n'd by much shattering.
4	do heavy bedded	2.02	2.00x2.00	4.00	47,500	53,800	11,875	13,450	do
5	do " "	1.97	2.00x1.98	3.96	54,000	59,300	13,636	14,900	do
6	do thinly bedded	1.96	1.96x1.96	3.84	39,400	39,400	10,260	10,260	do
22	Oölite, light, southeast quarry	2.05	2.00x2.04	4.08	42,000	52,000	10,280	12,740	do
23	do	1.97	2.00x2.00	4.00	57,000	57,000	14,250	14,250	do
43	do heavy bedded	2.00	2.00x2.00	4.00	38,000	53,000	9,500	13,250	do
	†Iowa marble, plain, west quarry	1.98	1.98x1.97	3.90	----------	47,120	----------	12,080	All samples of the Iowa marble broke in such a way as to show much elasticity.
16	do	2.00	2.02x2.04	4.12	60,500	63,300	14,685	15,120	
	†Iowa marble, colored	2.00	2.02x2.01	4.06	----------	37,060	----------	9,128	
27	Blue limestone, northeast quarry	2.00	2.02x2.02	4.08	----------	----------	----------	----------	63,000 lbs. applied, no effect.
24	do	1.99	2.00x2.02	4.04	----------	----------	----------	----------	63,000 lbs. applied, no effect.
11	Fossiliferous limestone, northeast qr.	2.00	2.00x2.00	4.00	42,000	----------	10,500	----------	Sustained 65,800 lbs. without further rupture.
12	do	2.00	2.00x2.00	4.00	63,300	----------	1,582	----------	Beyond capacity of machine to crush.
15	do southeast quarry	1.99	2.00x2.00	4.00	43,700	----------	10,925	----------	Sustained 65,800 lbs. without further rupture.
26	do	2.00	2.00x2.02	4.04	58,300	66,400	14,430	16,435	
28	do west quarry	1.97	2.00x1.98	3.96	38,700	38,700	9,773	9,773	
33	Blue limestone, Timber Creek	1.98	1.98x2.00	3.96	28,000	34,500	7,070	8,712	
34	do	2.00	1.98x2.00	3.96	29,000	33,200	7,320	8,383	

*An Olsen testing machine was used in making these tests. The specimens were placed between two steel plates, the upper being fixed, while the lower was free to oscillate in a hemispherical protuberance, which fitted accurately in a well lubricated socket, thus distributing the pressure equally when the parallelism of the cube faces was imperfect. The load was applied at a uniform rate.

†Tests made under the direction of Prof. G. W. Bissell, Dept. of Mechanical Engineering, I. A. C.

TABLE II.

FREEZING TESTS.*

Number.	KIND OF STONE.	Height of cube.	Surface dimensions.	Area.	BREAKING LOAD IN LBS.		LOAD PER SQUARE INCH.		Loss in weight in per cent.	REMARKS.
					Spalling began.	Failure.	Spalling began.	Failure.		
20	Oölite, fine grained, northeast quarry	2.05	2.00x2 08	4 16	55,700	56,400	13,390	13,558	0.0014	Loud report.
21	do	2.08	2.00x2.08	4 16	26,000	-------	6,250	14,280	0.0013	Sustained 59,400 lbs. Very slight spall at 26,000 lbs.
38	Oölite, fine grained, southeast quarry	1.99	1 97x2.00	3 94	50,000	60,000	12,690	15,230	-------	Loud report and cube much shattered.
44	do	2.00	2 00x1.96	3.92	34,000	55,700	8,673	14,210	-------	do
46	do	2 02	1 97x1.97	3.88	50,000	56,500	12,890	14,560	-------	do
19	Iowa marble, west quarry	1.96	2 02x2.02	4 08	50,000	56,500	12,255	13,850	0.0007	Broke with a loud report.
17	do	1.92	2.00x2.00	4 00	42,600	52,700	10,650	13,175	0.0008	do
18	do	2.00	2 04x2 02	4.12	38,000	51,700	9,225	12,550	0 0009	do
14	Blue limestone, northeast quarry	2 00	1.98x1 97	3 90	------	-------	-------	15,360†	-------	59,400 lbs. applied without effect.
3	Fossiliferous limestone, northeast qr.	2.00	2.00x2.02	4.08	------	------	-------	14,560†	-------	59,400 lbs. applied without effect.
2	do	1.98	1.97x2.00	3.94	55,600	-------	14,035	14,900†	-------	59,400 lbs. sustained.
29	Fossiliferous limestone, west quarry	1.98	2.04x2 02	4 12	35,900	40,000	8,715	9,710	-------	Weak report.
30	do	1.97	1.99x1.96	3.91	30,500	35,000	7,800	8,950	-------	do
32	Blue limestone, Timber Creek	2 00	2 04x2.01	4 10	28,000	36,300	6,830	8,850	-------	Slight report.‡
45	do	1.96	1.98x1 96	3 88	32,700	32,700	-------	8,430	-------	

*The cubes were placed in distilled water until completely saturated, after which the specimens were encased in cotton batting saturated with distilled water and placed in wooden trays, eight by eight inches and two inches deep, provided with wire bottoms. The trays after be ng securely packed were placed in the refrigerator and kept at a temperature of from 17° to 19° F. for forty-eight hours. Then they were removed from the refrigerator and subjected to a temperature of 70° F. for twenty-four hours. This process was repeated six times. The specimens were afterwards subjected to refrigeration and thawing ten times; but the conditions were less constant than in the first six. In the latter series the minimum temperatures ranged from 21° to 32° F.

†The above table shows that the blocks suffered no appreciable loss in weight or strength during the investigation. It is highly probable that lower temperatures would have given very different results.

‡In spite of the apparent weakness, low specific gravity and rather high percentage of absorption, the quarry face along natural fissures shows this stone to be one of the most durable quarried in the county. (See figure 36.)

TABLE III.

ABSORPTION AND SPECIFIC GRAVITY TESTS.

Number.	NAME OF STONE	LOSS OF QUARRY WATER THROUGH DRYING—WT. IN GS.			WATER ABSORBED AFTER IMMERSION, EXPRESSED IN PERCENTAGES, OVER DRY WEIGHTS.				Specific gravity.	Weight per cubic foot in lbs.	REMARKS.
		0 hours.	1 hour.	5 hours.	1 hour.	3 hours.	24 hours.	144 hours.			
20	Oölite, fine grained, northeast quarry	350.90	350.70	350.58	0.85	1.59	2.66	2 75	Average, 2.57 lbs.	160.5 lbs.	
21	do	348 91	348.79	348 63	1.56	3 26	3.95	4.05			
38	Oölite, south quarry	335 03	334.99	334.97	1.20	1.50	2 50	2.61			
44	do	333 90	333.79	333.63	0.71	1 85	2.11	2.20			
46	do	326.90	326.30	325.63	1 50	1.96	2.55	2.64			
19	Iowa marble, west quarry	323.10	327.70	322.47	2 33	3.02	3.60	3.87	2.54	153.2	Average.
17	do	309.40	309.00	308.01	1.81	2.43	3.31	3.57	------	------	
18	do	320 90	319.20	318.20	2.31	3.06	3.97	4.37	------	------	
10	Blue limestone, northeast quarry	348.70	348.21	348.19	0.48	0.86	1.86	2.02	2.77	173.0	
3	Fossiliferous limestone, northeast quarry	344.00	343.78	343.52	0.72	1.01	1.72	1.79	2.60	162.5	
2	do	353.86	353 40	353.20	0.22	0 50	0.70	0.77	------	------	
30	Fossiliferous limestone, west quarry	311.00	310.90	310.87	0.06	0.84	1.65	1.79	------	------	
29	do	340.91	340.46	340.38	0 22	0 84	1.64	1.79	------	------	
32	Blue limestone, Timber Creek	320.76	320.36	320.00	2 03	3.01	3 17	3.36	2.30	144.0	
45	do	285 74	285.36	285.15	4.00	4.67	5.41	5.65	------	------	

TABLE IV.

CHEMICAL ANALYSES OF LE GRAND STONE.

CONSTITUENTS.	Fine grained oölite.	Blue limestone.	Iowa caen stone.	Iowa marble, plain.	Iowa marble, colored.	Stratified limestone.
Hygroscopic water (loss at 100° C.)	0.03	0 09	0.06	0.04	0 06	0.04
Combined water (expelled by ignition)	0.13	0.21	0.15	0.19	0.12	0.12
Silica and insoluble	0.77	0.96	1.24	0.80	0.89	1.22
Carbonic acid, CO_2	43.62	43.30	43.79	44.85	44.76	43.85
Alumina, $Al_2 O_3$	0.05	0.07	0.18	0.14	0.15	0.14
Iron, $Fe_2 O_3$	None	None	0.15	0.15	0.31	0.26
Iron, Fe O	0.09	0.27	0.09	0.19	0.10	0.09
Lime, Ca O	55.05	54.85	50.56	45.42	45.39	50.42
Magnesia, Mg O	0 28	0.28	3.70	8.21	8.28	3.96
Manganese oxide (Calc. as Mn O)	-------	0.08	-------	-------	-------	Trace
Phosphoric acid	-------	-------	Trace	Trace	-------	-------
Totals	100.02	100.11	99 92	99.99	100.06	100.10

PROBABLE COMBINATIONS.

Water	0.16	0.30	0.21	0.23	0.18	0.16
Calcium carbonate, Ca Co_3	98.30	97.95	90.28	81.11	81.05	90.04
Magnesium carbonate, Mg Co_3	0.59	0.38	7.77	17.24	17.39	8 08
Silica and silicates, Alumina, iron, oxide, etc.	0.95	1.37	1.74	1 42	1.38	1.72
Totals	100.00	100.00	100.00	100.00	100.00	100.00

CORRICK QUARRY.

(Tp. 84 N., R. XVII W., Sec. 7, Nw. qr. Nw. ¼.)

This quarry is operated intermittently to supply the local demand. The layers worked correspond to the upper oölite at Quarry and are only used for foundation work and rough masonry in the immediate vicinity. Some quarrying has been done on section 36, Nw. qr., Ne. ¼, of the same township and range. About eight feet of rubbly limestone rests upon the upper oölitic layers. The section here exposed bears a very close similarity to the beds exposed at Rockton.

The upper layers of the Le Grand beds have been worked to some extent at different times on South Timber creek near Ferguson, on Little Asher creek, Tp. 85 N., R. XVIII W., Sec. 24, and northwest of Liscomb on the Iowa river. In all

cases the stone was for local consumption, and then only for the roughest grades of masonry.

SAINT LOUIS LIMESTONE.

CHAPIN QUARRY.

James Spear operates a quarry on land owned by O. B. Chapin of Union. The stone produced is a close textured, ash-gray limestone, which exhibits a hackly fracture and contains small siliceous concretions, with little iron pyrites in streaks and patches. The quarry is operated only to supply the local demand, but the product is apparently a durable stone.

DES MOINES.

The coal measures in Marshall consist chiefly of shales. A heavy bedded sandstone appears in Timber Creek township, and has been developed to a limited extent. Quarries have been opened on sections 8 and 9, and a considerable quantity of stone suitable for the roughest grade of masonry has been quarried. The sandstone is dark, reddish brown in color, and apparently durable. At present only the upper layers have been explored. The lower layers are more evenly bedded and give promise of a stone suitable for building and trimming.

Clay Industries.

The Paleozoic strata afford little material which is available for the manufacture of clay products. The Hannibal shales of the Kinderhook are too deeply covered to be utilized in this region, while the argillaceous layers exposed at Marshalltown are of doubtful utility. The latter deposits were tested experimentally a few years ago. A sample of the yellow-gray argillaceous marl was made into brick. The color of the burned article was not very different from that of the raw material, and when subjected to the heat given brick for paving streets, no shrinking nor altering of shape was perceptible, and to all appearance there was an entire absence of fusion. On the other hand the pavers were

completely vitrified on certain of the faces. It was hoped that the experiment would prove the manufacture of paving brick possible, but the burned article was left porous and too soft for such a purpose. The manufacture of superior fire brick is demonstrated as a possibility, but the limited extent of the deposit renders its profitable utilization doubtful. The coal measure shales are almost wholly concealed by the glacial debris, and no deposits of economic importance are known within the confines of the county.

In striking contrast to the limited supply of raw material accessible in the Carboniferous series, the Pleistocene deposits are wholly inexhaustible. As has been said the Pleistocene covers the entire county and at nearly every point in such quantity and character as to enable a brick factory to be founded thereon. The material utilized at the present time belongs wholly to the loessial type.

The loess of Marshall county is ordinarily of the common variety. It has a maximum thickness of not less than twenty or twenty-five feet. Certain areas are exceptionally siliceous, and when dry appear as beds of loose sand. The clays are suitable for the manufacture of drain tile, for making common brick by any method, and for making stock and ornamental brick by the dry-press method. The products always have an excellent color and when properly burned their porosity is not so great as to be objectionable. At present clay manufactories are in operation at not less than six localities.

MARSHALLTOWN.

Anson Company Brick & Tile Works.—This is one of the largest plants of the county. It is situated in the southern part of the city, where operations were begun nearly fifteen years ago. It has grown from a small hand yard to a factory with a large output of both common brick and drain tile. A Penfield, No. 15 D with the corrugated crusher, has been used for several seasons. The crusher is required only for the dry clay. Closed sheds are used for drying the product, and

three large clamp kilns for burning. This latter process takes up nearly two weeks. Common brick and tile from 3's to 8's constitute the output. Some loss is experienced through checking which takes place upon the evaporation of the uncombined water.

Sieg & Size operate two yards, one about two and the other about one mile west of Marshalltown, near the Iowa Central track. The one on the south side began operation about forty years ago. The material at each yard is typical loess in a bank from six to twenty-five feet deep; clayey in upper part but more argillaceous below. Certain sections of the the formation in the vicinity are too sandy for brick making purposes. At the south pit the fine sands and silts are beautifully interstratified. An Eagle soft-mud machine is in use at each plant. The brick are dried on pallets in roofed sheds, and no checking occurs if the proper mixture of materials is secured. Three clamp kilns with a total capacity of 200,000 brick are employed for burning. This process takes up only eight days. In addition to these two plants the firm has also a hand yard which is operated in case of an unusual demand.

The G. H. Kohr brick and tile yard is just east of the city limits on the lowland. The raw material, consisting of rather strong modified loess, is treated by a Brewer machine. The newly moulded ware is placed in a closed dry-shed, and little or no checking occurs. Only a single clamp kiln is in use.

MELBOURNE.

The Wulke Factory is located at the crossing of the railroads. There are seven feet of yellow, overlying one-third as much gray, short loess, while a two inch band of ochre separates the two colors. The total thickness of the formation is twelve feet, and under it is blue drift clay. The raw material is drawn up to and run through the pug-mill, then through an auger of the Decatur Leader manufacture and moulded by a machine of the same make. Closed sheds heated with exhaust steam enable drying of the product to be carried on quite

successfully. Three down-draft kilns serve to hold the tile, and the brick are burned in cased kilns. The character of both kinds of the output is very creditable.

RHODES.

A. Harmon now operates a brick plant for the production of brick and drain tile along the right of way of the Chicago, Milwaukee & St. Paul railway. Loess to a depth of ten feet is taken and treated by a "Plymouth" machine. The lower portion of the section utilized is of a bluish color, followed by ocherous layers and finally grading upward into typical loess. Fossils are abundant throughout, but loess concretions are absent, although limey patches may be observed near the base. The color of the well burned product is a cherry red. Considerable loss is sustained through checking. The burning capacity is limited to two small round kilns.

BROMLEY.

Just south of the station at this point is the plant of the Bromley Brick and Tile works. An H. Brewer machine is in operation. The clay is run through the mill, afterwards placed in sheds tightly closed until the mud becomes "set;" otherwise much loss is occasioned through checking. The kiln capacity is 43,000 three-inch tile. Burning can be accomplished in four days. The loess comes from the top of the gradual slope about a half mile south of the railroad. At the bank the top soil is removed and the clay is used to a depth of six feet, below which it becames too sandy. Lower on the slope the character of the formation is decidedly different and is almost entirely sand.

GILMAN.

The Gilman Brick and Tile Works is a new plant situated in the extreme southeast corner of Marshall county and has a large territory adjacent to furnish a market for the products. The raw material is nothing more than modified prairie loess

taken to a depth of several feet. It is strong and the moisture is freed with some difficulty, necessitating artificial heat. A two story shed has been erected, and before long the equipment of the plant will be quite adequate for a large business.

Small plants have been operated intermittently in the vicinity of State Center and Quarry. Hand made brick is the sole product.

Lime.

About a quarter of a century ago lime-burning was carried on to a limited extent. The oölitic beds were chiefly used for this purpose and the manufactured product was of acceptable quality. As transportation facilities improved, lime produced from the older Paleozoic rocks sharpened the competition to such an extent that the manufacture of lime in Marshall county was abandoned.

Building Sand.

The sand flats along the Iowa river between Marshalltown and Albion, and the sand bars in the principal streams, furnish an inexhaustible supply of good building sand. The sub-loessial sands are widely distributed over the county and often attain a considerable thickness. At Marshalltown there are five to ten feet of siliceous material at the base of the loess. The southwestern half of the county is deeply covered with loess and drift, but it is meagerly supplied with the more arenaceous deposits.

Moulding sands.—The sub-loessial layers afford an abundance of material suitable for moulder's use.

Road Materials.

Outliers of the Kinderhook in the eastern portion of the county furnish an abundance of road materials. The larger stream channels afford large quanties of sand and gravel suitable for road work. In the western half of the county materials for the improvement of the roads are almost entirely wanting.

Coal.

Marshall is one of the marginal counties of the Iowa coal field. The coal measures occupy one-half of the district, underlying the western and southwestern portion especially. The coal pockets also doubtless occur in different parts of the area. The records from a number of wells in southwestern Vienna and northeastern Taylor townships record the presence of coal measure strata in that region which constitute the easternmost outlier of the Des Moines in the county. Four miles southwest of Marshalltown a coal measure sandstone outcrops along the Chicago Great Western railway. In both of these localities coal in economic quantities is not known to be present.

The principal locality where coal has been mined in Marshall county is on the Iowa river at a place called Mormon Ridge, three miles northwest from Albion. (Tp. 88 N., R. XI W., Sec. 34, Sw. qr. Se. ¼.) A shaft fifty feet deep was sunk a few years ago and was known as the Mormon Ridge mine. The coal was three feet in thickness. The sequence of layers is as follows:

		FEET.	INCHES.
6.	Sand	20	
5.	Clay, light colored	3	
4.	Shale, dark colored, fissile	2	
3.	Coal	3	
2.	Fire clay		4
1.	Sandstone, exposed	1	

FIG. 37. **Coal at Mormon Ridge mine near Albion.**

At one time fourteen men were employed. The shaft was operated but a brief period for the reason that only three feet of shale intervened in the roof between the coal and a thick stratum of water-bearing sand. The water gave so much trouble that the mine was abandoned after being operated

about a year. Not more than 100 tons of coal were taken out. A few years later another company leased the property and attempted to work the coal, but owing to the defective pumps made little progress. This mine has been abandoned.

On the north side of Mormon Ridge, on the northwest quarter of the same section, James Hall* states that a limited amount of coal had been removed previous to his visit in 1857, although the shaft was abandoned at that time. Evidence of former prospect holes may still be seen around the base of the hill, but no exact data concerning the coal measures could be obtained.

In a drill hole put down one mile northwest of the Mormon shaft, on the farm of W. C. Ruddick (Tp. 85, N., R. XIX W., Sec. 28, Sw. qr., Sw. ¼), a bed of black shale with some coal was encountered at a depth of 118 feet. The seam was reported to be several feet in thickness and immediately underlain by a thin layer of fire clay.

Some years ago a shaft was sunk on the farm now owned by Americus Dakin on Minerva creek, five miles west of Bangor (Tp. 89, N., R. XX W., Sec. 9, Se. qr., Se. ¼). Coal was found here, but to what extent is not definitely known.

At the present time Marshall is not a coal producing county. Future prospecting will doubtless reveal isolated pockets of coal of economic importance, but with the data at hand, it is hardly reasonable to expect that coal will be produced in commercial quantities within the limits of the county.

Soils.

Marshall is preëminently an agricultural county and the soils greatly outrank in economic importance all of the other geological formations put together. The soils readily fall into four fairly well defined types. The drift, which is composed of glacial debris; the loess, composed of silt and very fine sand; the drift-loess, a combination of the first two, and the alluvium, an admixture of sand and silt in varying proportions. The origin of the soil types has been discussed

*Geology of Iowa, Vol. I, p. 269, 1858.

already under the various divisions of the Pleistocene. The drift soil is coextensive with the Wisconsin drift sheet. This soil contains a high percentage of clay and in many places the processes of agriculture are handicapped by the large number of small to medium sized bowlders. This type is highly productive when well drained, but cold and heavy when not properly ventilated.

The typical loess soil is confined to the immediate proximity of the larger drainage lines. This type prevails in Linn, Timber Creek and western Le Grand townships. It is subject to excessive wash during rainy seasons, and, unless very sandy, it bakes when drying. In productiveness this soil type ranks lowest.

The drift-loess soil comprises by far the greatest area in Marshall county. It is a happy combination of the soils and fine sands of the loess with the glacial debris of the Iowan and Kansan drift sheets. The drift-loess is an open, porous soil allowing the easy penetration of the most delicate rootlets, yet firm enough to support the most vigorous forage plants. It is easily tilled and is a conservator of moisture. It is to this type that Marshall owes her prestige as an agricultural county.

The alluvium flanks the principal streams, and when not too sandy it compares favorably in productiveness with the drift and drift-loess types. When unprotected by levees large tracts of these lands are subject to periodic inundations.

Water Supply.

The larger water courses furnish an ample water supply to the areas through which they flow. The smaller streams are usually dry through a considerable portion of the summer and autumn months. Shallow wells from 40 to 150 feet in depth have proved adequate for domestic purposes until the recent extended dry period, when it was found necessary, in many cases, to go deeper. At present most of the "stock wells" draw their water supply from the glacial sands and gravels

near the base of the drift or from the sandy layers of the Kinderhook. The older water-bearing horizons of the Paleozoic have not been explored in the region, but the Saint Peter and Saint Croix sandstones may be reached at about 1,300 and 1,800 feet, respectively. At Ames and Boone, the Saint Peter sandstone affords about 10,000 gallons per day, while the Saint Croix yields about 200,000 gallons.

West of Rhodes, just out of the corporation, is an artesian well which yields about 2,000 gallons per hour. The water is slightly mineral and is not utilized at present, save as a wayside watering place. The well is about sixty feet in depth and appears to be wholly in the drift.

The Marshalltown water works draw water from the gravel beds of the Iowa river. The water filters through the river sand and is collected into numerous galleries from which it is pumped. The supply is barely adequate for ordinary purposes, while in cases of fire the Iowa river must be drawn on. As several other large cities in the state obtain their water supply in much the same manner as outlined above, it is deemed fitting to append some of the results obtained from a sanitary study of the water. It is a well known fact that the spread of contagious diseases is often contingent on the source of our potable waters and "sewage contamination" is an altogether too common a phrase in our board of health reports treating of epidemics.

BACTERIALOGICAL STUDY OF THE MARSHALLTOWN WATER SUPPLY.

Prof. L. H. Pammel kindly furnished the following abstract of results. The work was done in a large part under his personal supervision.

Mr. G. L. Steelsmith* made an examination of the Marshalltown water supply during the summer and fall of 1896. Dr. Walter H. Haines, of Chicago, had previously made an examination, the results of which are as follows.

		GERMS PER C. C.
No. 1.	Across the river from water works	25
No. 2.	Bunce well	190
No 3.	River water	2,240

* Marshalltown Evening Times-Republican, April 23, 1896.

The statement is here made that the maximum number according to Koch of Berlin, and the Franklands of London, is 100 germs per C. C. The maximum number has, however, sometimes been placed at 1,000, and some authors place the number at 3,000. An absolute fixed standard cannot be made, except that 1,000 germs per C. C. is more nearly the maximum in a large number of our river waters. The quanity of organisms is dependent upon the quantity of organic matter present. The important point in connection with a bacterialogical analysis is the quality rather than the quantity. A single organism of *Bacillus coli-communis* or *B. typhi-abdominalis* is sufficient to indicate sewage contamination.

Mr. Steelsmith's determinations are as follows.

		GERMS PER C. C
No. 1.	June 7th, water from river above mill dam	2,170
No. 2.	June 7th, water from hydrant, Dr Meghill's office	1,800
No. 3.	June 7th, water from pumping station	1,200
No. 4.	June 7th, water from sixteen hydrants, average	1,900
No. 5.	Sept. 9th, water from six hydrants, average	2,040

So far as the number from streams is concerned, the above would not be considered excessive or necessarily injurious, since water taken from the Croton reservoir, New York, contained 5,000 to 15,000 germs per C. C.; water from the Spree, which furnishes Berlin with water, contains, according to Frankel, 6,140 germs per C. C.; but this number increased to over 245,000 below the city. Water from the Mississippi at La Crosse, Wisconsin, during the spring months contained 3,000 germs per C. C. In all streams there are extraordinary fluctuations so far as quantity is concerned. These fluctuations are due to the amount of soil carried from the surrounding country. The great number found in the Iowa river last summer must be associated with the frequent rains. Numerous investigators have shown that during the autumn and winter, germs are far less numerous than during the spring and summer months, and yet the former seasons are the periods of most frequent occurence of typhoid fever.

Of the germs found in the hydrant water of Marshalltown, but one was regarded as suspicious. It agreed quite closely with the morphological and physiological characters given for *Bacillus coli-communis* and proved to be pathogenic for rabbits. The relation of this organism to sewage contamination can no longer be questioned, as this Bacillus is an inhabitant of the human intestines and it is only natural that it should find its way to the river.

The results of this investigation go to show that the water which has filtered through the river sands is safe and wholesome, but that the water drawn from the river direct may be at the peril of the public health.

Water Power.

The Iowa river furnishes an abundance of water power, the average gradient being about three feet per mile and the flow fairly constant. Flouring mills are in active operation at Albion, Marshalltown and Le Grand respectively. A head of six feet is obtained at Albion and six and one-half feet at each of the other two localities. All of the mills can be run on full time and at full capacity save during periods of very high or very low water. From fifty to eighty horse power is available at each point. The flow of water in the smaller streams is too small and inconstant to merit attention in this connection. Mills of small capacity on Timber creek were formerly operated intermittently. None are active at the present time.

ACKNOWLEDGMENTS.

In the preparation of the present report the representative of the survey received much encouragement and friendly assistance from many citizens of the county. Thanks are especially due to Dr. W. S. McBride of Marshalltown, and the officials of the Le Grand Quarry Co., who have been untiring in their efforts to facilitate the investigation. The notes of Mr. E. H. Lonsdale on the clay industry have been used freely, and the writer has been the recipient of many courtesies from the different members of the Survey.

LIBERTY
BANGOR
LISCOMB
VIENNA
IOWA
TAYLOR
MINERVA
MARIETTA
MARION
LINN
TIMBER CREEK
STATE CENTRE
WASHINGTON
LOGAN
EDEN
JEFFERSON
GREEN CASTLE
LE GRAND

Bangor
St. Anthony
Clemons
Bromley
Minerva
LISCOMB
ALBION
Green Mount
MARIETTA
Rockton
MARSHALLTOWN
La Moille
STATE CENTRE
Luray
Malta
MELBOURNE
Haverhill
Ferguson
Pickering
RHODES
Vandeeve
Laurel
Dillon

R. XX W.
R. XIX W.
R. XVIII W.
R. XVII W.

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

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF MARSHALL COUNTY, IOWA.

BY

S. W. BEYER.

1897.

LEGEND

GEOLOGICAL FORMATIONS

DES MOINES.

KINDERHOOK.

INDUSTRIES.

COAL MINES. ABANDONED.

CLAY WORKS.

QUARRIES.

ARTESIAN WELL.

LISCOMB

VIENNA

TAYLOR

MARION

MARIETTA

LINN

TIMBER CREEK

LE GRAND

JEFFERSON

GREEN CASTLE

Albion

Marietta

Rockton

Marshalltown

La Moille

Green Mountain

Quarry

LE GRAND

Dillon

Laverhill

Ferguson

Pickering

Dunbar

Laurel

GILMAN

Tp. 85 N.

Tp. 84 N.

Tp. 83 N.

Tp. 82 N.

R. XIX W.

R. XVIII W.

R. XVII W.

GEOLOGY OF MADISON COUNTY.

BY

J. L. TILTON AND H. F. BAIN.

GEOLOGY OF MADISON COUNTY.

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CONTENTS.

INTRODUCTION.

Madison county lies in the south central part of Iowa in the third tier of counties north of Missouri. North of it is Dallas county, while to the east is Warren; to the south, Clarke and Union, and to the west, Adair. In form it is an approximate square and includes sixteen congressional townships; townships 74–77 north and ranges XXVI–XXIX west. Owing to errors in the original survey the area is only 566.4 square miles instead of the customary 576.

Geologically the county is of especial interest because of the fact that the Bethany limestone, forming the base of the Missourian formation, extends across it. An opportunity is thus afforded for a study of the relations between the productive and the non-productive portions of the coal measures. Winterset, the point at which the Bethany limestone was first studied in detail in Iowa, is the county seat and is located near the center of the county on the border between the Missourian and Des Moines stages of the Carboniferous.

In the course of his work in Iowa White spent some time in Madison county studying particularly the limestone. His

observations were published in part in 1868* and more fully in 1870.† The position and thickness of the limestone were determined, and its most characteristic fossils were noted. It does not seem that previous to this the limestone itself had ever been studied; though the higher beds of the Missourian as exposed along the Missouri river had been referred by Owen to the Sub-carboniferous, and by Geinitz, Marcou and others, in part to the same formation and in part to the Permian. More recently there has been considerable discussion in regard to the proper division of the coal measures and the correlation of the limestone found at Winterset with the Bethany limestone of Missouri and the Erie limestone of Kansas. For these reasons it has seemed desirable to make a detailed study of the outcrops which were taken by White as the type for the formation. It was hoped that data might be collected which would be of service in these broader correlations.

The work was begun some years since and in a preliminary paper‡ a section was given connecting the Winterset limestone with the Ford sandstone, the relations of which to the underlying strata had been determined by Keyes.§ In the report upon the coal deposits of the state‖ a few notes were also given on the coal beds of the county.

In the present work the authors have had the assistance both in the field and the office of Professor Calvin, and to him is due particularly the determination of the fossils. Notes on the building stones of the county collected in 1894 by Mr. Arthur C. Spencer have been freely used. While indebted to many people within the county for numerous acts of kindness, we are especially indebted to Mr. Paul Price, of Winterset, for assistance in collecting fossils. Acknowledgments are also especially due to Mr. J. A. Wilkins, of the

*First and Second Annual Reports of State Geologist, pp. 70-73. Des Moines, 1868.

†Geol. Iowa, vol. I, 241-250, 305-316. Des Moines, 1870.

‡Tilton: Geological Section along Middle River in Central Iowa. Iowa Geol. Surv., vol. III, pp. 135-146. 1897.

§Bul. Geol. Soc., Am., vol. III, pp. 277-292. 1891. Also, Iowa Geol. Surv., vol. I, pp. 94, 107; vol. II.

‖Iowa Geol. Surv., vol. II, pp. 304-306. 1894.

same city, for the excellent blue print from which the accompanying map was drawn. The work as originally planned was not to be completed until the fall of 1897 but it became necessary to finish it much sooner, and in the absence of the senior author the work was completed by his associate. To this change in plan may be charged any minor omissions or lack of detail which may be noted.

PHYSIOGRAPHY.

TOPOGRAPHY.

Madison county lies on the eastern flank of the great divide between the Mississippi and the Missouri. The divide itself runs through Adair, the next county to the west. The area under discussion forms a portion of a much dissected upland plain, sloping to the northeast about ten feet per mile. In the southeast the high divides between the rivers rise from 950 to 975 A. T. Earlham, Winterset and Truro, all located on the upland and approximately in line, are 1,116, 1,127 and 1,078 A. T. respectively. Still further west, Stuart and Lorimer, in a line parallel to that passing through Earlham and Winterset, are respectively 1,216 and 1,230 above tide. Beyond this the surface maintains its slope to between 1,400 and 1,500 feet at Adair. This general plane, which the divides touch, is very much cut by erosion. At Bevington, Middle river has cut down to 833 A. T. At Lida, near the east county line, North river has reached 840 A. T. At Afton Junction, a short distance south of Madison county, Grand river has cut 210 feet below the upland, or to about 1,040 A. T. These three rivers drain the greater portion of the county, and the depth to which they have cut has made it possible for their many tributaries and minor feeders to cut to corresponding levels.

The land forms seen within the county are exclusively erosion forms. The later ice sheets did not extend into this area, and the length of time since the Kansan drift was deposited has been so great as to allow the streams entirely to destroy any peculiar drift topography which the county may once have had.

While the topographic forms have all been developed by erosion acting on a probably even plane, the differences in the character of the underlying rocks have been so great as to produce two distinct topographic areas. These correspond quite closely to the areas shown on the accompanying geologic map as underlain respectively by the Missourian and Des Moines formations. The former terrain, so far as this county is concerned, is made up principally of limestone. As will be seen later there are important shale beds present, but it is the limestone which controls the topography and gives it its distinctive character. The Des Moines terrain is as usual made up mainly of argillaceous and arenaceous shales, soft

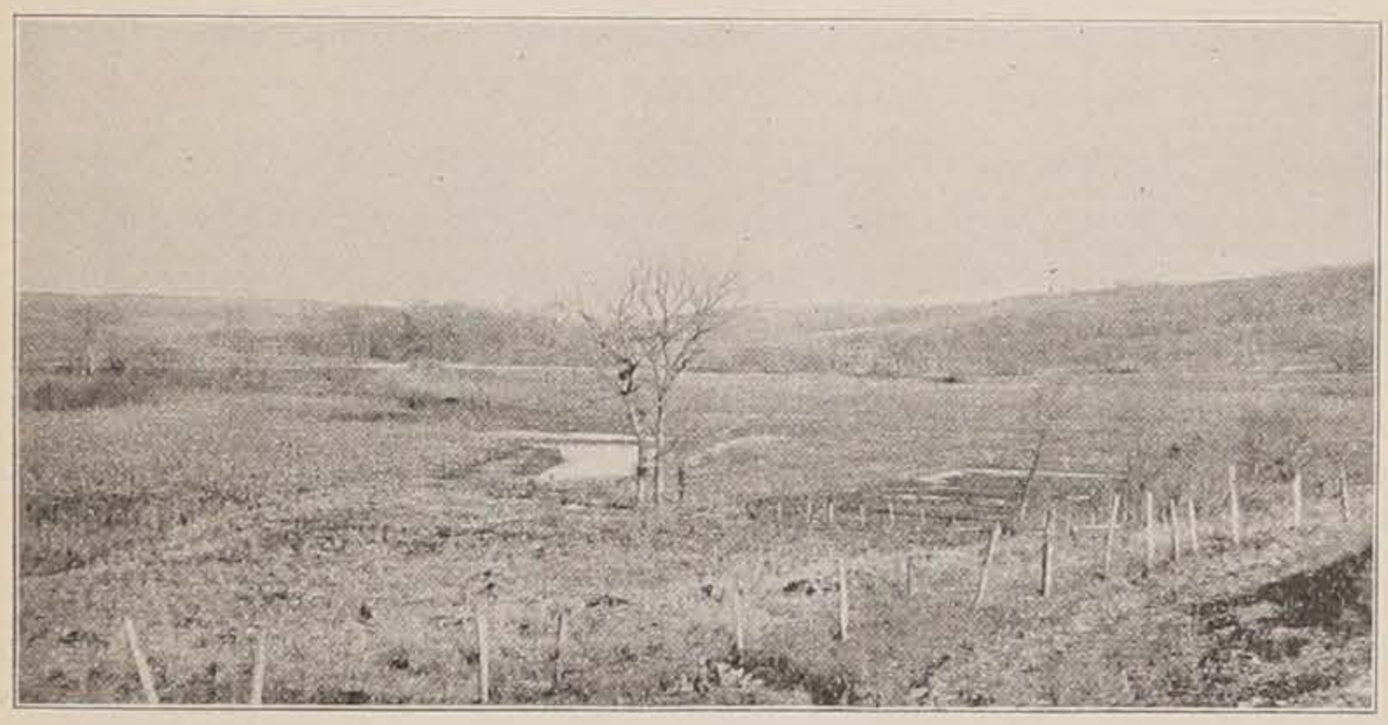


FIG 72. View down Middle river valley from a point about one mile east of Buffalo. The limestone is in the hills on either side.

sandstones, thin coal seams and easily eroded beds. There are only a few limestones, and those present are so thin as not to affect the topography to any marked extent.

As will be seen by the map, North river and Middle river have cut through the Missourian and exposed the Des Moines more than half way across the county. The minor streams, Bulger, Cedar and Jones creeks, produced results of like character, but of less extent. The valley of Clanton creek is essentially like the others in origin and character. These

valleys in the limestone country are as much as 200 feet deep and in places a mile and a half to nearly two miles wide. They have been cut by headwater erosion, and mainly by undermining of the various limestone ledges. If one travels toward the source of one of these streams, or some one of its tributaries, he will pass along a flat bottomed, canyon-like valley, until the point where the river crosses the limestone is reached. The different ledges of the latter are crossed by the stream in a series of abrupt falls or rapids. Above the latter the river becomes a mere prairie stream, with a shallow valley having gently sloping sides. In the case of the major streams the falls have been almost entirely cut away so that the crossing of the limestone is marked only by shallow rapids. The shortness of the lateral tributaries below the prairie portion and before the streams reach the region where they are uninfluenced by the limestone is worthy of notice. Some of the small streams running south from Winterset to Middle river make the whole descent of nearly 200 feet in a mile or less.

The divides between the major streamways are characteristically flat topped. Over much of this central and western portion of the county the drift is usually thin, and the streams over the upland portion have developed only the faintest relief. The limestone has sharply limited the amount of erosion that could take place over the upland, and while the time has been long—so long indeed that the whole country has been invaded and reduced to slope by feeble streams of slight grade—the relief is so little that the predominant effect is one of flatness. As one looks off over the country he sees only a broad even plain, and the semblance of a plain is preserved up almost to the brink of the wide, trough-shaped valleys which tell of the immense time through which the rivers have been at work.

In the eastern portion of the county but little of the old plain is left. The impression which a glance at the topography gives is rather one of hills and valleys. The main streams have a network of tributaries which reach out and

cut into almost every foot of intervening territory. The relief is usually 120 to 160 feet, so that large areas of level land are rare. The region east of Clanton creek forms a table land at about 1,050 to 1,075 A. T., and has been but little invaded by streams. It is held up by the underlying limestone.

Throughout most of the eastern region the action of the streams has been unhindered. The loess, drift and coal measures have approximately the same degree of hardness, and

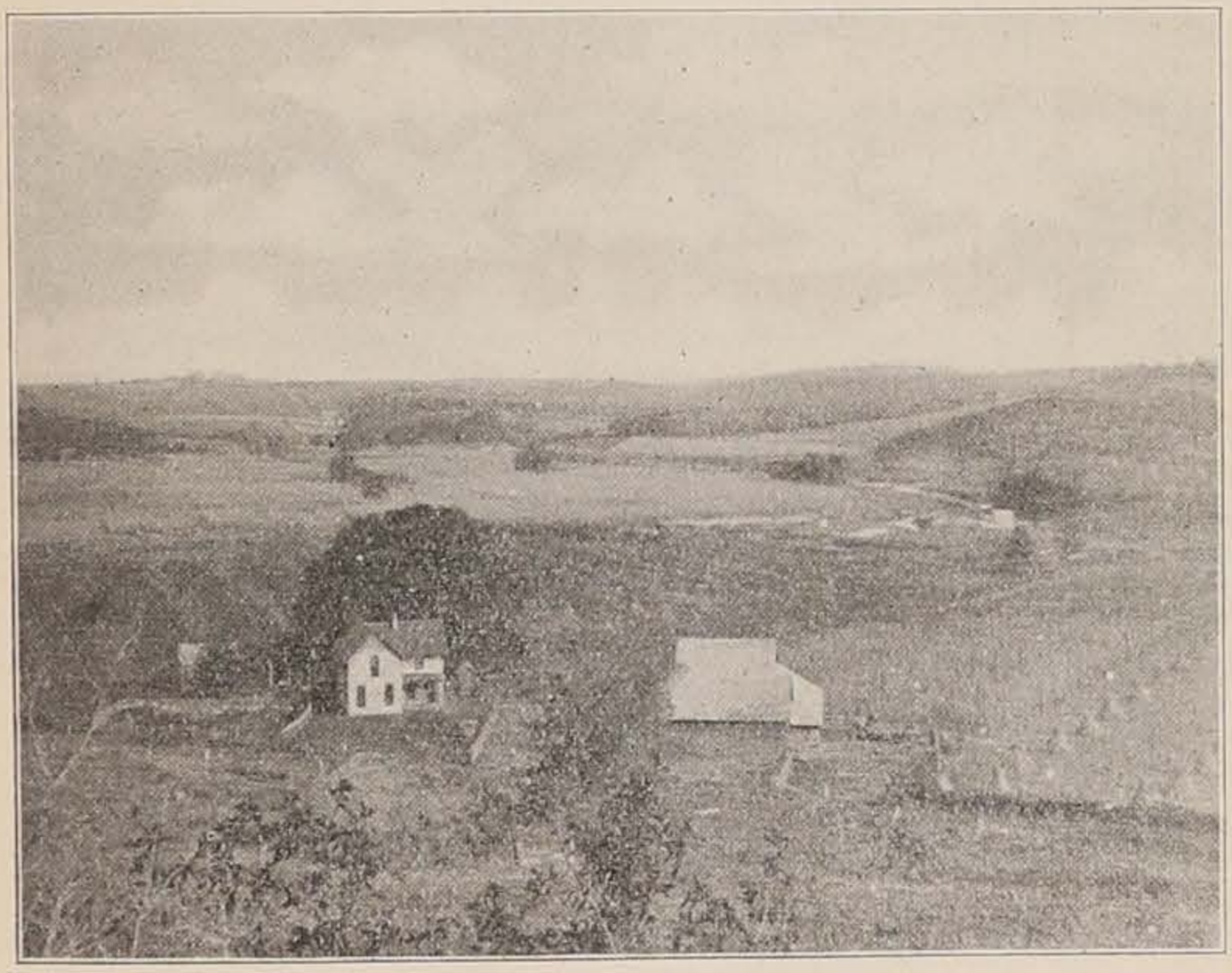


FIG. 73. View down the valley of Cedar creek in Union township (section 22), showing hill slopes of the Des Moines formation.

the profiles form continuous curves. These are usually paraboloid in character with the upper arm relatively long and showing a gentler slope. The lower portion of the curve is in most cases merged into a long gentle concave curve, which in turn passes into the almost straight slope of the river bottom land. In some instances the lower concave portion is absent, and the parabola meets the flat surface of the bottom land quite

abruptly, as if there had been recent filling in of the valley by material not derived from the sides. The valleys are broad and have well developed flood plains. The streams are not deepening their channels, and the major erosion in the county is in the western division. At places along the valleys there are the usual sloughs, marking the half-filled cut-offs left by the meandering river. In general the streams flow along the southern sides of their valleys, which is accordingly steep as compared with the long, gentle slope to the north.

TABLE OF ELEVATIONS.

The following elevations of points within the county or near its borders have been taken in part from Gannett's Dictionary of Altitudes, and in part from the profiles of the various railway lines.

STATION.	Altitude	AUTHORITY.
Barney	1053	C. Gt. W.
Bevington	849	C., R. I. & P.
Clanton creek, north of Hanley	878	C. Gt. W.
Clanton creek, west of Barney	1066	C. Gt. W.
Earlham	1116	C., R. I. & P.
Hanley	858	C Gt. W.
Lorimer	1230	C. Gt W.
Middle river at Patterson	854	C., R I. & P.
Peru (East)	948	C. Gt W.
Stuart	1216	C., R. I. & P.
St. Charles	1066	K. & W.
Truro	1078	K. & W.
Winterset	1127	C., R. I. & P.

DRAINAGE.

The major portion of the drainage of this county finds its way through the Des Moines to the Mississippi river. A smaller portion passes through Grand river south to the Missouri and thence to the Mississippi. The larger streams of the county are North and Middle rivers, and Clanton creek, a tributary of Middle river, which joins the larger stream in Warren county. North of the North river drainage basin is a small area, including about ten square miles, which sends its

waters through Bulger creek to the Raccoon river. Southeast of Clanton creek and beyond the Truro-St. Charles upland, is the basin of South river, including in this county thirteen and five-tenths square miles. The Grand river basin lies in the southwestern portion of the county and includes twenty-eight square miles. Of the remainder of the county North river and its branches drain 246.5 and Middle river and Clanton creek 268.4 square miles.

North river, Middle river and Clanton creek originate as prairie streams above the limestone and flowing down over

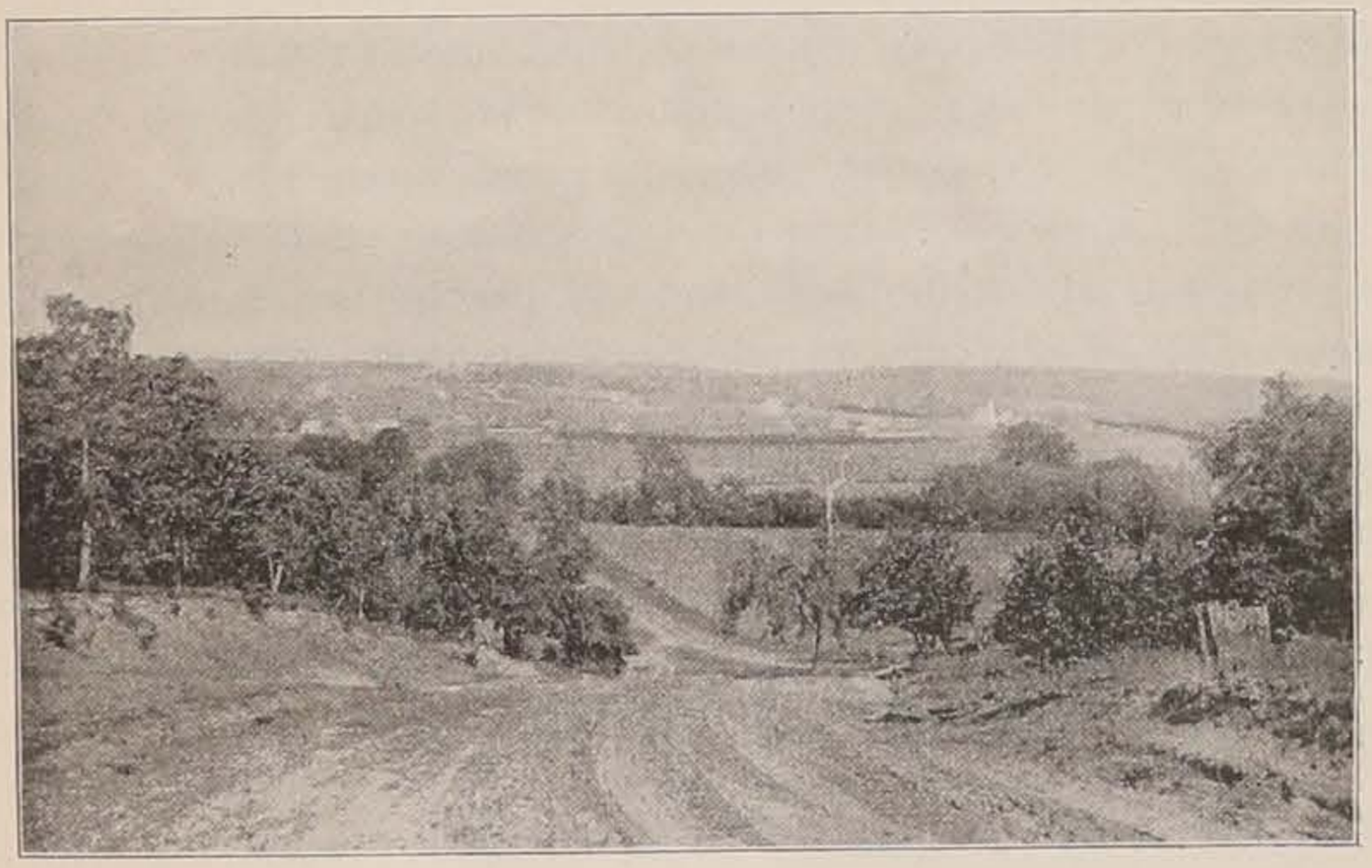


FIG. 74. View across the valley of Clanton creek toward Hanley.

the latter passes over the Des Moines formation in the broad valleys with gently sloping sides, already described. Bulger, Cedar and Jones creeks are essentially similar. Grand river flows parallel to the edge of the limestones and, throughout the county and for many miles after leaving its borders, flows over the drift. With the exception of Grand river the larger streams and many of the minor ones are flowing generally in preglacial valleys. The valley of Middle river below the "Backbone" (sections 16–15, Lincoln township), North river,

Cedar creek, Steeles branch, Jones creek, Clayton creek, Hay branch and South river all have in their valleys undisturbed drift and loess which determine their preglacial age. They do not, however, always exactly follow the older courses. Clanton creek is in a preglacial valley from Hanley to Barney, but it may be doubted whether its upper portion occupies the main part of the old channel. In sections 27 and 35 of Walnut township there is a great thickness of drift which is suggestive of a filled in valley.

Middle river has had an interesting history. The present stream had its source in the southwestern portion of Guthrie county. In its upper course in Guthrie and Adair counties it runs over the drift. In Madison county down to the locality known as the Devil's Backbone it runs generally on the drift, but occasionally cuts into the limestone in such a manner as to indicate a drift-filled valley only partially cleared. From section 21 of Lincoln township a preglacial valley, now filled with Kansan drift, extends in a winding southwesterly direction from the mouth of Fletcher branch across section 31, thence crossing westward through sections 3 and 10 of Grand River township, running south of Macksburg through sections 16, 21 and 28.* This old valley is comparable in size to the present valley of Middle river and seems, in fact, to have been its former extension, or at least the valley of an important tributary. In preglacial times Middle river accordingly drained an area to the southwest which is now served by Grand river.

Upland meanders as defined by Marbut† are excellently exhibited on Middle river. The best example is the Devil's Backbone already mentioned. The river here makes a long bend to the northward and back to within a few hundred feet of the starting point. Both above and below this point the valley is marked as usual by steep bluffs on the south and longer, gentler slopes at the north. At the Backbone this is reversed. The outside of the broad crescentic curve is

*Tilton: Proc. Iowa Acad. Sci., vol. IV, p. 51. 1897.
†Missouri Geol. Surv., vol. X, p. 93. 1896.

marked by abrupt rocky bluffs. The tongue of land around which the river runs slopes gently to the north. It is composed entirely of rock, as is well shown by the numerous exposures, so that the appearance cannot be due to filling in. In all essential particulars it agrees with the meanders described by Marbut and is similar to the Keosauqua bend illustrated by Gordon.*

The meander must have been developed *in situ*, as has been urged for similar meanders in Missouri by Winslow.† It is not to be interpreted as due to inheritance, as proposed by Davis,‡ since the two rocky sides have such markedly inequal slopes; slopes which in this instance are the exact reverse of the normal slopes throughout the region. A slight obstruction or inequality originally throwing the stream to one side set in motion the chain of processes by which the river was thrown farther and farther to the north at the same time that it cut step by step into the limestone. By constant undermining the north wall was kept steep, while by the constant shifting of the stream the south wall was preserved from similar action. It seems to have been this action, continued for a long time, which produced the broad curve and the Backbone. Clanton creek, where it crosses the limestone between Barney and Peru, shows upland meanders quite as perfect as any on Middle river.

The general character of the preglacial surface of the county may be inferred from the present topography. The drift is throughout most of the area relatively thin. At many points it is almost absent. The high, flat-topped divides and the broad, yet canyon-like valleys, were present then as now. The relief was probably somewhat greater, and in part of the county may have been as much as 300 feet. The eastern portion was then marked by less abrupt slopes, as it is now, and the southwestern portion seems to have been cut to a general altitude somewhat lower than that of the eastern edge of the limestone.

*Iowa Geol. Surv., vol. IV, plate VII. 1895.
†Science, vol. XXIII, pp. 31-32. 1893.
‡Science, vol XXII, pp. 276-279. 1893.

The time when the streams of the region originated cannot be sharply fixed. The youngest indurated rocks in the county belong to the Missourian. The Cretaceous may formerly have covered a portion of the area, though there is no direct evidence on the subject. Above the limestones of the Missourian there are only the residual clays and the drift deposits. As has been seen the region shows evidence of a former plain into which the streams have cut. It seems probable, however, that this plain could not have been a base level; at least, that it was not a base level which had required a long time for its development. There is some slight evidence in the thinning of the various limestone members of the Missourian toward the northeast that the original shore line of the Missourian seas passed through the county and that the shore deposits, very little eroded, are still preserved. If this be true, it follows that the country stood relatively low, or was, at least, preserved from great erosion from the time when the limestone rose above the sea to the cutting of the present valleys. This hypothesis is to be received with caution since it controverts supposed changes in altitude adduced from study of the surrounding counties, and is itself improbable in that it postulates a freedom from change for a longer period of time than has been usual in the earth's history.

Whenever the streams originated, they have in the main held their courses ever since. They belong to the resurrected type characteristic of the Kansan drift.* Many minor changes took place in the course of the glacial period and in recent time a considerable amount of cutting has been done. The most striking fact in relation to the drainage is its age and completeness, and while the recovery of a once completely drained area by a series of resurrected streams would be relatively rapid, these facts can only be interpreted as indicative of a very long period of time since the ice left the region.

*Bain: Iowa Geol Surv., VI, 458-460. 1897.

STRATIGRAPHY.

General Relations of Strata.

The strata exposed in Madison county belong to two groups widely separated in character, origin and age. The underlying indurated rocks belong to the Carboniferous; the overlying unconsolidated beds belong to the Pleistocene. Between the two is a great unconformity indicative of a long time interval. Possibly in the drift-covered southwestern portion of the area, outliers of the Cretaceous occur between the Carboniferous and the Pleistocene. No such beds, however, have been seen in the field or reported from drill holes Fragments from the Cretaceous conglomerate seen in Guthrie county occur commonly in the drift of Madison, but at present there is no sufficient evidence for believing that the beds occur *in situ* within the limits of the county. From the close of the Carboniferous, perhaps from the early part of the Upper Carboniferous, to the oncoming of the great glaciers of the Pleistocene, Madison county seems to have been the scene of erosion rather than deposition; and yet, as has been suggested, the amount of erosion accomplished in that interval, while great as compared with that now being carried on, is small as compared with the length of the time.

The beds of the Carboniferous include rocks which make up two series of strata. The lower series is composed of sandstones, shales, coal seams and a few thin limestones. It is the Des Moines formation and includes the beds which White referred to the middle and lower coal measures. The upper series is the Missourian and is represented here by the Bethany limestone with the intercalated shales. It answers to the Upper Coal Measures of White. Both the Des Moines and the Missourian belong to the Upper Carboniferous series defined by Branner as the Pennsylvanian and currently known as the coal measures.

The Pleistocene beds include the modern alluvium, the loess and the Kansan drift sheet. An earlier drift sheet is perhaps present but has not been differentiated.

The taxonomic rank of the various formations is shown in the following table.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.	Iowan.	Loess.
			Kansan.	Drift.
Paleozoic.	Carboniferous.	Upper Carboniferous. (coal measures)	Missourian.	Bethany limestone.
			Des Moines	

Geological Formations.

CARBONIFEROUS.

DES MOINES FORMATION.

The strata referred to the Des Moines are the oldest beds outcropping in the county. They underlie the eastern portion of the county and are cut into by the river valleys. Only the upper portions of the Des Moines formation outcrop within the county; the earlier beds of this stage lie below the level of the valleys of erosion. The lowest beds known in the county are probably 350 feet above the Saint Louis limestone, which lies just beneath the productive coal measures. Sections along Raccoon river by Keyes, and along Middle river by the senior author, indicate the character of the lower beds.

The Des Moines formation is characteristically a complex of shales of many kinds, sandstones, coal seams, and thin limestones. In its lower portion there is a marked lack of persistence of individual beds. The rapid and complete lithologic changes which the strata undergo have so far made it impossible to trace individual beds for any great distance. To a certain extent this is true of the upper portion of the Des

Moines formation as shown in Madison county, but in general the characteristics of individual beds persist over wide areas. In Guthrie and Dallas counties Mr. Leonard and the junior author recognize a well defined series which extends under a portion of Madison county. Farther south, however, the character of the formation changes somewhat so that it is only possible to make the most general correlations between the Des Moines beds of southeastern Madison and those farther north.

The best exposures of the Des Moines so far noted within the county may be found in South township along a stream running down to Clanton creek not far from Hanley (sections 35, 34 and 27). Starting from the Fragmental limestone, which is regarded as the base of the Bethany and exposed not far from the Des Moines & Kansas City railroad, the following section is exposed.

		FEET.	INCHES.
22.	Shales, drab, argillaceous, with abundant *Derbya crassa*, *Chonetes*, probably *Chonetes parvus* Shum., at the top	12	
21.	Shales, red, argillaceous	3	
20.	Limestone, fragmental, earthy, with bits of fossils		2
19.	Shale, blue to green, argillaceous, grading into red below	3	
18.	Shales, blue to green, sandy, with nodular segregations of limestone	12	
17.	Shales, blue, calcareous	12	
16.	Limestone, compact		2
15.	Limestone, fragmental, loose, with young *Conetes mesoloba*		10
14.	Limestone, fragmental, but firmly cemented, reddish color, with *Spirifer cameratus* and *Productus costatus*	1	
13.	Shales, green, argillaceous	29	
12.	Limestone, blue to black, in two ledges, with *Spirifer cameratus*, *Rhynchonella* and *Productus*	1	
11.	Shale, carbonaceous	2	
10.	Shale, clayey, drab	1	
9.	Shale, yellow, sandy, with marked horizontal bedding planes	4	
8.	Shales, black to drab, carbonaceous		6

		FEET.	INCHES.
7.	Limestone, nodular, sandy, with *Productus cora*, *Chonetes mesoloba* and *Athyris subtilita*	1	4
6.	Shale, gray, sandy	3	
5.	Limestone, similar to number 7		10
4.	Shale, clayey, drab to blue		10
3.	Shale, carbonaceous	1	
2.	Limestone, thin bedded, leaf-like in texture, with *Productus muricatus*, *Chonetes mesoloba*, *Derbya crassa* and *Productus costatus*		3
1.	Clay, green	3	

The lower portion of this section, numbers 1 to 7, is seen best on the east side of Clanton creek near Hanley (Tp. 75 N., R. XXVI W., Sec. 22), numbers 1 to 4 being seen only at this place.

Below the limestone ledges quarried north of St. Charles and belonging to the Bethany limestone, beds corresponding to numbers 14–17 of the above section are exposed at the proper horizon. The limestone (numbers 14–16) carries *Productus muricatus* and fragments of fish teeth.

Still farther north on the road leading into St. Charles from the north (South township, section 11) the following beds are exposed in a gully. The section starts 100 feet below the upland.

		FEET.	INCHES.
19.	Shale, gray, clayey below, to micaceous sandy above	30	
18.	Limestone, compact, earthy brown, with *Spirifer plano-convexus* (?) and *Spirifer cameratus*	1	
17.	Shale, gray, argillaceous		8
16.	Shale, black, carbonaceous		6
15.	Coal, impure		5
14.	Shale, gray to buff, argillaceous	4	
13.	Coal, impure	3	
12.	Shales, gray, argillaceous	3	
11.	Clay, yellow, ocherous, with *Productus cora*	4	
10.	Limestone, impure, earthy, with *Productus muricatus*	6	
9.	Shales, argillaceous, green below, red above	3	

		FEET.	INCHES.
8.	Limestone, dense, non-fossiliferous		3
7.	Shales, gray to drab, clayey	1	
6.	Shales, black, carbonaceous, with *Productus muricatus*	1	
5.	Limestone, fragmental		2
4.	Shale, gray, clayey	2	
3.	Limestone, similar to number 5	1	6
2.	Shale, gray, clayey	2	
1.	Limestone, soft, yellow, earthy	8	

This section may be correlated, though not closely, with the Hanley section. Number 18 in the present section probably represents number 12 of that; numbers 15 and 11, numbers 13 and 8; numbers 10 and 7, numbers 8 and 5; numbers 6 and 3 and numbers 5 and 2 may be considered as equivalents. The comparison shows well the persistence and the variation in the beds of this portion of the Des Moines.

South of Patterson the exposure along a ravine (Tp. 76 N., R. XXVI W., Sec. 32. Nw. qr., Se. ¼) yields the following section:

		FEET.	INCHES.
14.	Shale, black	2	
13.	Unexposed	21	
12.	Shale, blue, clayey above, gray, sandy below	16	
11	Limestone, dense, drab, fossiliferous	1	
10.	Shale, blue, clayey	3	
9.	Sandstone, gray		5
8.	Shale, clayey, blue and gray	27	
7.	Sandstone, gray, nodular	1	
6.	Shale, sandy, drab	27	
5.	Limestone, arenaceous, gray, fossiliferous		9
4.	Shale, black	2	
3.	Shale, gray, clayey (only partly exposed)	30	
2.	Coal		6
1.	Shale, red (only partly exposed)	32	

The base of this section is on a level with Middle river. The imperfect exposure of some of the beds makes its correlation difficult, but it seems probable that number 1 represents numbers 14–16 of the Hanley section.

Aside from these sections along Clanton creek and its tributaries there are occasional outcrops of Des Moines strata throughout the eastern portion of the county.

North of Tileville is a section which will be discussed later. In Lee and Jefferson townships the strata are quite generally concealed beneath the drift. They seem to consist largely of clayey and sandy shale with some sandstone. About four miles southwest of Boonville (Tp. 77 N., R. XXVIII W., Sec. 11) a two-foot layer of sandstone appears in the hillside 106 feet below the upland. Sixty feet above it is a stratum of gray sandy limestone, about two feet thick and weathering into thin layers. Similar beds may be seen farther down Badger creek in section 12 of Jefferson and sections 20 and 15 of Lee townships. The limestone is thought to be identical with that seen along the Raccoon river and numbered 13 in the following section obtained by Mr. Leonard in Dallas county (Tp. 78 N., R. XXVII W., Sec. 26, Nw. qr., Sw. ¼):

		FEET.	INCHES.
15.	Drift	6+	
14.	Sandstone, soft, gray, with flakes of yellow mica	8	
13.	Shales, sandy, gray	15	
12.	Limestone, sandy, fossiliferous	1	2
11.	Shales, carbonaceous, coaly below	1	4
10.	Shales, gray	4	
9.	Sandstone, heavily bedded with Lepidodendrons	4	
8.	Shale, sandy above	6	
7.	Coal		6
6.	Shales, clayey, variegated	20	
5.	Shales, bituminous	2	
4.	Limestone, fragmentary	5	
3.	Shales, blue to gray	6	
2.	Shales, carbonaceous	2	
1.	Shales, blue, clayey, exposed	5	

Number 7 of this section is considered by Mr. Leonard to be the Marshall coal, and the various members of the section have been recognized along the Raccoon as far west as Guthrie county. In Madison county the limestone and coal are present in Crawford township, sections 17 and 18, and are probably represented in some of the coal horizons noted along Clanton creek. The exact correlation, however, of the

Dallas county and the Clanton creek exposures cannot be made out, and it is doubtful whether the two sections are to be considered as equivalent in other than a general way.

MISSOURIAN FORMATION.

The beds found in Madison county which are referred to the Missourian belong entirely to the lower member, the Bethany limestone. They afford an almost complete section of that member, certain of the higher beds found on Grand river in Union county alone being lacking. The Bethany, as seen here, includes four bodies of limestone separated by shales. The complete section is well exposed on Middle river in Lincoln township, and along a ravine in section 22 the following section, which may be taken as typical, was made out.

		FEET.	INCHES.
20.	Limestone, yellow, earthy, in thin layers, with Fusulina, Aulopora and *Productus semireticulatus*	4	
19.	Shale, drab to yellowish	1	
18.	Alternating calcareous and shaly bands, yellowish, with *Derbya crassa*, *Productus longispinus* and *Spirifer plano-convexus*	3	
17.	Dark shale	2	
16	Ledge of compact limestone	1	2
15.	Dark blue shale, with many crushed individuals of *Productus longispinus*		6
14.	Black, very carbonaceous shale	1	
13.	Shale, argillaceous above, becoming sandy below	4	6
12.	Limestone, coarse, divided by shaly partings	3	
11.	Shale, dark, in part very carbonaceous, with band crowded with *Chonetes verneuilianus* and with occasional specimens of *Spirifer cameratus* and *Productus cora*. In places the Chonetes are cemented into a thin band of limestone	8	
10.	Blue limestone, very fossiliferous, in three bands separated by shale	3	
9.	Shale, dark above, lighter below	2	
8.	Marly, yellowish shale	3	

		FEET.	INCHES.
7.	Yellowish, soft limestone, which becomes harder below	5	
6.	Thin layers of limestone with shaly partings	12	
5.	Black slate and shale	3	
4.	Yellowish, earthy, calcareous beds showing effect of irregular deposition	4	
3.	Limestone, with thin alternating beds of shale	12	
2.	Black shale	3	
1.	Band of limestone		6

At the mouth of the ravine and below number 1 of the above section is a sandy shale about fifteen feet thick shown in the lower portion of figure 75. A short distance up the

FIG 75. The Earlham limestone and underlying beds as seen in section 20 of Lincoln township.

river, at the locality known as the Devil's Backbone, beds equivalent to those enumerated are exposed. Below the shales just mentioned and forming the ledges over which the water falls is the following:

		FEET.	INCHES.
4.	Limestone, thin bedded, weathering into nodular fragments	5	
3.	Shale, parting		3
2.	Limestone, similar to above	4	
1.	Shale, blue to buff, to river	2	

In number 2 of this section *Athyris subtilita* occurs, being small, rather smooth, and with a feebly developed fold and sinus. In number 4 the specimens of Athyris found are larger. In number 2 *Spirifer cameratus*, *Meekella striatocostata* (small) and *Axophyllum rude* also occur.

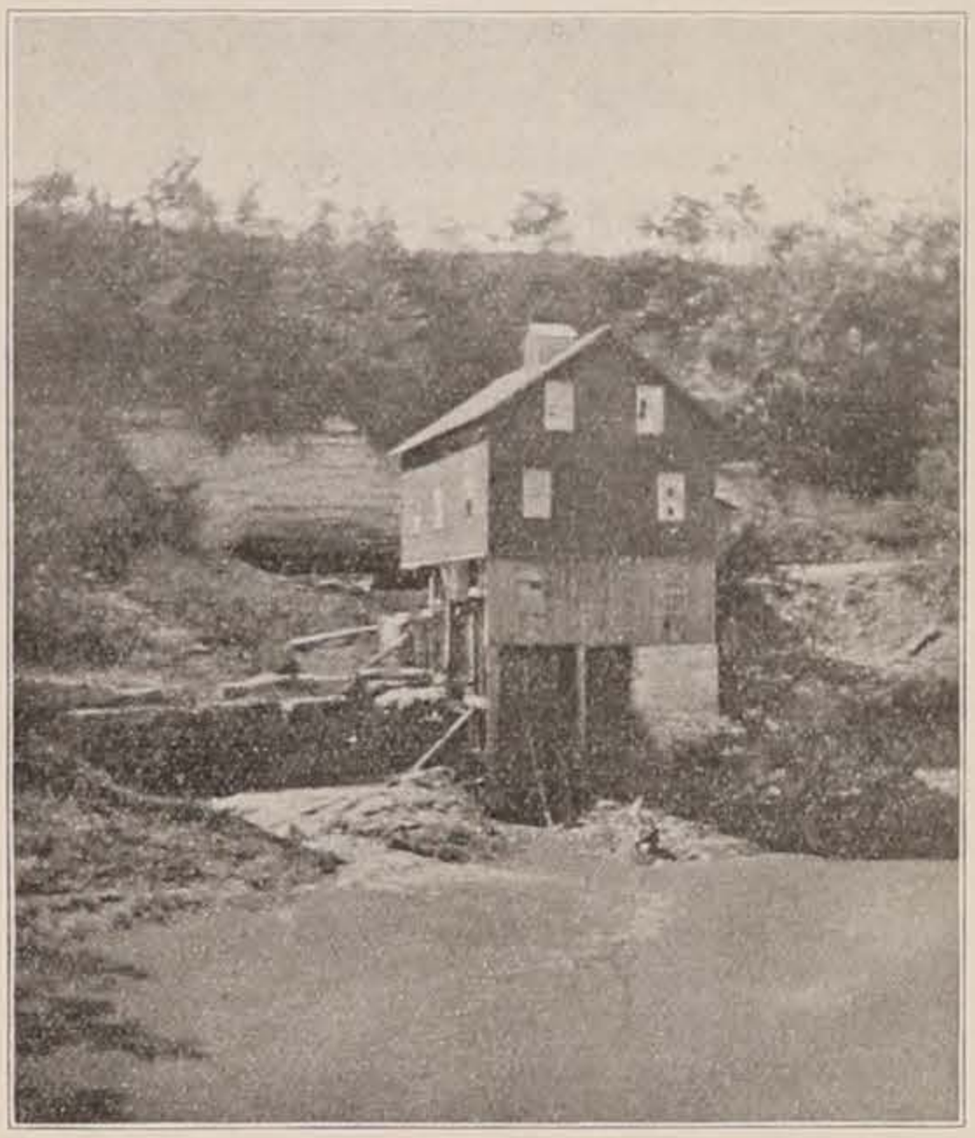


FIG. 76. The Tunnel mill at the Devil's Backbone. The main body of the limestone over the tunnel is the Earlham. That over which the water falls at the mill is the Fragmental.

The limestone forming numbers 2 and 4 of the section just given occurs at many points in Madison and adjoining counties. It forms the lowermost of the heavy limestones which mark the base of the Missourian formation and is considered to be the basal member of the Bethany. From its general character it is called the Fragmental limestone.

The first heavy limestone above the Fragmental, number 3 of the exposure in section 22, Lincoln township, is the equivalent of the beds quarried at Earlham, and hence may be called

the Earlham limestone. Numbers 6 and 7 are well exposed at Winterset, and have been extensively quarried there, so that the term Winterset, heretofore used loosely as the equivalent of Bethany, may be appropriately restricted to this horizon. Number 20 forms the base of a limestone member attaining in the vicinity a thickness of as much as twenty-five feet, and which from the abundance of Fusulina characterizing it may be called, for the present at least, the Fusulina limestone. The characteristics of these individual beds will be brought out in discussing the various exposures.

The Fragmental limestone is not well exposed in the vicinity of the Earlham quarries, though north of that place on Bear creek, Mr. Leonard has found it with the usual assemblage of fossils. In Guthrie county, just north of Stuart, it is well developed. Along a small stream emptying into Deer creek north of Stuart the basal portion of the Bethany is exposed. The lowest rock seen is the Fragmental limestone, which is made up of irregular bits of limestone filled in with calcareous shale. At one point it can be pulled to pieces with the fingers. At another it is hardened into massive (two feet) ledges. A total thickness of ten feet is seen. The fossils found include the following:

Lophophyllum proliferum.
Archæocidaris, sp.?
Productus longespinus.
Orthis pecosi
Athyris subtilita
Hustedia mormoni.
Spirifer lineatus
Spirifer cameratus.
Bellerophon, sp.?
Straparollus, sp.?

The fauna is much like that found near St. Charles.

The Fragmental rock is seen southwest of Winterset along the ravine leading down to Middle river, but the best exposures are along Clanton creek and around the edges of the St. Charles-Truro upland. About a half mile south of Peru, on

the east side of the Chicago Great Western track, the Fragmental rock in its normal facies of loosely cemented bits of limestone is exposed twenty-four feet above Clanton creek. It carries abundant *Spirifer lineatus* and *Athyris subtilita* with frequent *Hustedia mormoni*. It is seen at several points in the vicinity, and a total thickness of ten feet is indicated. It is covered by fifteen to seventeen feet of gray shale, over which is found the Earlham limestone and the normal sequence. The rock is seen again just east of Peru in the banks of the creek and along tributaries of the main stream, and has been opened up at several points east of Hanley. At the point north of Truro (section 35, South township, at which the section of Des Moines beds already given is exposed), the Fragmental rock is found capping the Des Moines. It is here two and one-half feet thick, and is not particularly fragmental in character, but carries the following fauna:

Productus costatus.
Productus longispinus.
Athyris subtilita.
Hustedia mormoni.
Spirifer cameratus.
Spirifer lineatus.
Spiriferina kentuckensis.
Rhynchonella (Pugnax) uta.
Dielasma bovidens
Bellerophon, sp.?
Naticopsis, sp.?

At the quarries north of St. Charles the rock shows the same thickness in ledges of four to six inches. The fossils found there are:

Productus longispinus.
Productus costatus.
Athyris subtilita.
Hustedia mormoni.
Spirifer cameratus
Spirifer lineatus.
Rynchonella (Pugnax) uta.
Bellerophon, sp.?

Naticopsis altonensis.
Straparollus catilloides.
Straparollus, sp.?

The same bed is seen southeast of St. Charles (section 1, Ohio township), and on South river (section 28). At each locality the usual assemblage of fossils, characterized by the great abundance of small, smooth specimens of *Spirifer lineatus* and *Athyris subtilita* and the comparatively rare occurrence of *Spirifer cameratus* and *Productus costatus*, was found. The fauna is one of the most characteristic, both in species, character, and relative abundance of forms found in the region, and makes an excellent guide for tracing the base of the Missourian. Near Truro and St. Charles there are no good exposures of the higher limestone, though their presence is indicated. On South river the exposures show the following section.

		FEET.	INCHES.
6.	Limestone, thin bedded with *Productus cora*, and *Athyris subtilita* (large)	2	6
5.	Unexposed	6	
4.	Limestone, fragmental in part, with *Spirifer lineatus*, *Athyris subtilita* (small) *Rynchonella uta*, *Hustedia mormoni*, etc.	3	
3.	Shale, argillaceous drab to black	3	
2.	Unexposed	10	
1.	Sandstone, yellow, with ripple marks and heavy cross-bedding	6	

Number 6 of this section probably represents the Earlham. More limestone seems to be present in the hills, but is not exposed.

The Earlham limestone is best exposed in the quarries near the town of that name. At the Robertson quarry, two miles east of Earlham, the following section was noted:

		FEET.	INCHES.
11.	Bed of soft, yellowish, magnesian, earthy limestone, decomposing readily when exposed to weather	4	
10	Limestone in three heavy ledges at west end of quarry	4	
9.	Buff shale with *Chonetes verneuilianus*		4
8.	Limestone, like number 4	2	

		FEET.	INCHES.
7.	Ashen shale with very few fragments of brachiopod shells		6
6.	Earthy limestone, decomposing readily, yellowish, carrying large individuals of *Athyris subtilita*		3
5.	Drab shale, with *Productus longispinus*, *P. costatus*, crinoid stems and fragments of other fossils		6
4	Quarry limestone, in thin layers, irregularly bedded	8	
3.	Unexposed	20	
2.	Sandstone, in heavy layers	7	
1	Base of sandstone to creek, unexposed	17	

At one point the quarrymen had worked down in the bottom of the quarry and exposed, below number 4, drab and black shales to the depth of three feet, and below the shales a ledge of limestone six inches in thickness.

Distributed through the limestone beds number 4 are the following:

Lophophyllum proliferum McChesney.
Stem segments and body plates of crinoids.
Various species of Bryozoa.
Meekella striatocostata Cox.
Productus punctatus Martin.
P. costatus Sowerby.
P. longispinus Sowerby.
P. cora D'Orbigny = *P. pattenianus* of authors.
Athyris (*Seminula*) *subtilita* Hall.
Hustedia mormoni Marcou.
Spirifer cameratus Morton.
Spiriferina kentuckensis Shum.
Allorisma subcuneatum M. & H.

Chonetes verneuilianus N. & P. is somewhat common in number 9 but is very rare in the other members of the section. *Spirifer cameratus* and *Productus longispinus* are most abundant near the base of number 4, while *Productus costatus* and *Athyris subtilita* are more common in the upper layers. All the species enumerated, however, with the exception of *Allorisma subcuneatum*, range through all the beds making up number 4.

At the quarries south of Earlham in section 18, Madison township, the beds from 4 to 11 inclusive of the Robertson quarry section are exposed and are overlain by blue, drab and buff shales eight feet in thickness. The beds here carry the same fauna as the corresponding beds at the Robertson quarry.

North of Winterset the beds making up the sections seen in the quarries near Earlham are exposed along Cedar creek in section 25 of Douglass township. The beds rest on the black shale seen beneath number 4 at Robertson's quarry. The entire section is as follows:

		FEET.	INCHES.
8.	Limestone, in heavy ledges	4	
7.	Shale, buff, with very abundant *Chonetes verneulianus*		4
6.	Limestone, heavy bed	2	
5.	Shale, blue, with a thin bed of reddish decomposing limestone carrying large *Athyris subtilita*		8
4.	Limestone, thin bedded quarry rock	8	
3.	Shale, drab to black	2	
2.	Limestone, dense black	1	
1.	Shale, drab	4	

Equivalent beds may be seen at several points between Earlham and Winterset. At the latter place the Earlham rock is exposed near the old lime kiln southeast of town. Along the ravine running down to Middle river the completed section is as follows:

		FEET.	INCHES.
26.	Limestone, blue, Meekella zone		4
25.	Shale, drab to yellow	3	
24.	Limestone, blue, three thin ledges separated by shale, *Chonetes verneulianus* very abundant	1	
23.	Shale, drab	1	3
22.	Limestone, blue		4
21.	Shale, drab, with very many specimens of *Derbya crassa* in and just below the limestone	4	
20.	Limestone, earthy magnesian, easily disintegrating	5	
19.	Shale, drab	4	

		FEET.	INCHES.
18.	Limestone, medium grained, coarse bedded, quarry rock	12	
17.	Shale, clayey, drab	2	
16.	Shale, black, slaty	1	
15.	Shale, drab	4	
14.	Limestone, soft, earthy	6	
13.	Limestone, nodular, irregularly bedded	4	
12.	Shale, yellow		6
11.	Limestone nodular	4	
10.	Limestone, thin bedded with *Productus cora*, *Meekella striatocostata*, *Athyris subtilita*	10	
9.	Shale, blue to drab	1	
8	Shale, black, slaty	1	6
7.	Limestone, black, impure		6
6	Shale, gray, clayey to sandy	15	
5.	Limestone, fragmental	3	
4.	Unexposed	6–	8
3	Shale, gray, clayey	1	
2.	Unexposed	3	
1.	Limestone, fragmental	3	

Of the above section numbers 1 to 5 may be referred to the Fragmental limestone. Number 10 represents the Earlham. Number 18, which has been quarried at the edge of town, the quarries being west of and above the lime kiln quarry, represents the Winterset. There is a slight dip to the west here which is at first deceptive.

The Earlham beds are seen southwest of Winterset below the old Court House quarries (section 12, Lincoln township) and again at the Backbone, where they form the heavy bed of rock above the tunnel. At this point the member attains a thickness of twenty-one feet. The thin band of shale carrying *Chonetes verneulianus* and the underlying black slate and black limestone are excellently developed. The beds are also seen along Clanton creek.

The Winterset limestone has been noted in describing the preceding sections. It is best exposed in and near Winterset and along Middle river southwest of the county seat. The beds above it and below the Fusulina limestone are of particular interest because of the abundance and perfection of the

contained fossils. Along the roadside in section 1 of Lincoln township (Sw. Sw.) large collections were made not far from the old Court House quarries. The beds exposed are the equivalents of numbers 7, 8, 10 and 11 of the typical section. The fossil-bearing horizon is limited to number 10 and the associated bands of shale. The commoner fossils, such as *Athyris subtilita*, etc., occur here in rare perfection, and associated with them are *Myalina subquadrata*, *Myalina kansasensis*, *Myalina swallowi*, *Aviculopecten occidentalis*, *Productus*

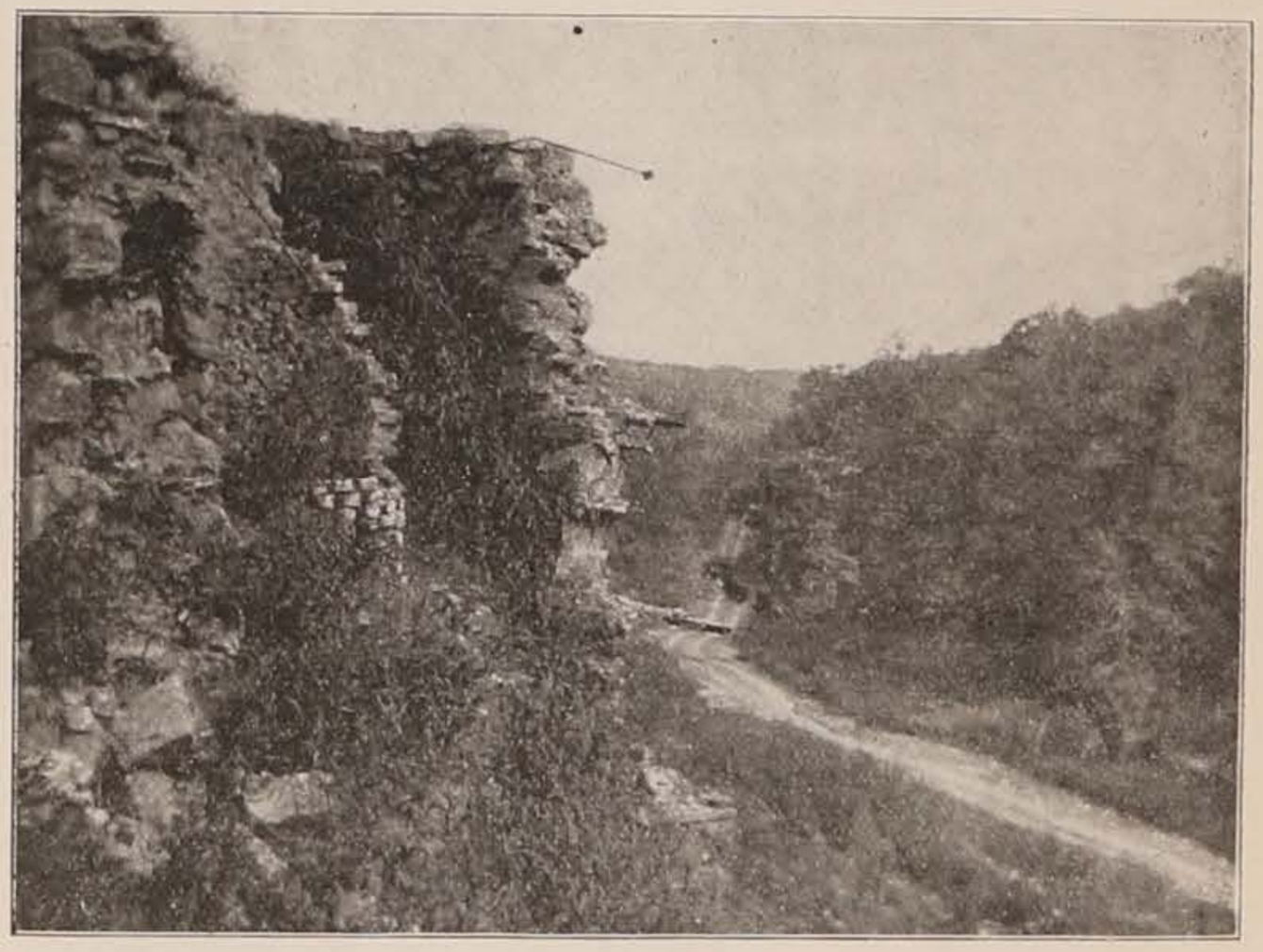


FIG 77. The Earlham limestone, with a portion of an old lime kiln, in the southeastern portion of Winterset.

nebrascensis and some others not heretofore enumerated. Just above number 10 at the point where the fossils were collected, there are weathered slabs showing great numbers of individuals of a very attenuated variety of *Fusulina cylindrica*. This slender form of Fusulina may deserve to rank as a distinct species. The horizon here is below that at which *Fusulina cylindrica* attains its normal development. The

length of the individuals under consideration is about the same as that of average specimens from Montgomery county and other localities where the normal condition prevails, but the diameter is less than half that of average specimens in southwestern Iowa. Farther west, in Nebraska and neighboring states and at a slightly higher horizon, the form described as *Fusulina ventricosa* occurs. The forms at Winterset constitute an interesting term in the series showing that this Carboniferous Foraminifer, after its introduction in the lower part of the Missourian stage, became progressively more and more robust until its disappearance in the so-called Permo-Carboniferous of Nebraska and Kansas. The Fusulina limestone at the Backbone shows the following:

		FEET
3.	Limestone, with many Fusulina	2
2.	Limestone, thin bedded	13
1.	Limestone, massive ledge very full of Fusulina	3

At some points in the vicinity this member attains a thickness of twenty-five feet. The lower ledge especially seems to be very constant in character, and the great abundance of the Fusulina here as compared with their number in the lower members of the Bethany makes the bed easily recognized.

As has already been suggested the upper portions of the Bethany are not exposed over the eastern portion of the county. At Tileville (Tp. 76 N., R. XXVII W., Sec. 27, Ne. qr., Sw. $\frac{1}{4}$), in a ravine running down to Cedar creek, the lower portion of the Bethany is shown as given in the following section.

		FEET.	INCHES.
14.	Limestone, shaly, gray	8	
13.	Unexposed	6	
12.	Limestone, in thin layers	4	
11.	Shale, clayey	5	
10.	Limestone, bluish, dense	1	2
9.	Shale, clayey, in places sandy	1	2
8.	Sandstone, calcareous		4
7.	Shale, clayey, dark blue	2	3
6.	Coal		1
5.	Shale, clayey	3	
4.	Shale, red and yellow	1	6
3.	Shale, sandy, gray, with reddish layer	24	
2.	Sandstone, calcareous	2	3
1.	Not exposed to Cedar creek	57	

The limestones numbers 12 and 10 probably represent the base of the Bethany. They are not particularly fossiliferous and the whole section is slightly out of harmony with the stratigraphy of the neighborhood. The lack of good exposures for the present prevents the tracing of the beds to their equivalents.

PLEISTOCENE DEPOSITS.

Over the limestones of the Missourian and the shales and sandstone of the Des Moines are the bowlder clays, sands and loess deposits which mark the action of the Pleistocene glaciers. The most notable fact with reference to these beds, as compared with the corresponding deposits of the neighboring regions, is their exceptional thinness. There are regions of thick drift, but they are unusual, particularly in the western and northwestern portion of the county, where the thinness of the drift becomes striking. In some portions of the county, as near Winterset, and between that point and Peru, the topography is strikingly like that of a driftless area. The same is true to a less extent of the region between Winterset and Earlham. The level divides, the canyon-like valleys, and the absence of the long, gentle slopes so common in the drift-covered regions, all recall, in their general aspect, the areas from which drift is absent. The frequent and abundant presence of residual clays tends to heighten the delusion. In the quarries at Earlham, and to an almost equal extent at Winterset, such clays are quite common. The red to reddish brown sticky clay which has resulted from the secular decay of the limestone, is found penetrating far down into the joint cracks and resting upon the upper surface of the rock. When shale forms the upper member of the rock series, the residual material is not so noticeable, though disintegrated shale, grading on the one hand into drift, and on the other into the undecomposed and undisturbed material, may be noted in the quarries of the Earlham Land Co. and at other points. The presence of the geest and undisturbed shale attest the feebleness of the glacial action. The ice crept in over the country,

with almost no scouring effect. In contrast with its behavior in some other portions of the country it produced here very little erosion. Its action was rather that of deposition. Nevertheless, in the deeper, sharp-walled valleys which the glaciers crossed, there seems to have been comparatively little drift deposited. Probably the relative narrowness of the valleys, their abrupt walls, and their position approximately at right angles to the major motion of the glaciers, caused them to be filled with comparatively stationary ice, while the main ice stream passed over their tops.

The deposits within the county include representatives of the Kansan drift, the loess and the alluvium. While the older Albertan or Sub-Aftonian ice sheet probably crossed the county, the deposits left by it have not so far been recognized.

KANSAN DRIFT.

The Kansan drift is quite generally distributed throughout the county and is exposed along most of the streams. The lower part consists of a compact blue clay with small water-worn and flattened pebbles scattered through it. Where the ravines have been cut down into this clay these pebbles have often worn pot-holes, giving the otherwise smooth and rounded exposures a pitted appearance. This lower clay is best seen in the southeastern part of the county, especially southeast of Truro.

Above the blue clay is a yellowish brown layer usually two to four feet thick. In places it is much thicker. It seems to have been derived from the blue clay, the change in color resulting from the oxidation of the iron content. The clay contains numerous pebbles and bowlders. The latter consist largely of greenstone, granite and reddish quartzite, and lighter quartz rocks. These are rounded, smoothed and often well striated. Sioux quartzite is one of the most common rocks found in the drift. A block of this material is represented in figure 78. This bowlder is located a mile north of Patterson and measures ten feet long, six feet wide and five feet high,

as exposed. Such large bowlders are uncommon, but are occasionally found in the stream ways. Bowlders ordinarily are not found on the upland. It is only where the streams have cut through the loess that they appear.

Stratified sandy material is occasionally found in the drift. In general it seems to have resulted from the reworking of the drift itself, rather than to have been originally deposited in its present form. Such beds are found near Barney (Walnut township, section 35) thirty-five feet thick. Near Macksburg, on Grand river (Tp. 74 N., R. XXIX W., Sec. 28, Nw. qr., Nw. ¼) there is a thirty foot exposure of the same material.

FIG 78. Surface bowlder one mile south of Patterson (Tp. 76 N., R. XXVI W., sec 20, Se. qr., Sw. ¼) The rock is red quartzite, 10 feet long, 6 feet wide, and 5 feet above ground. It is said to extend 5 feet into the ground.

LOESS.

The loess is the surface deposit throughout the county. It spreads over upland and extends down into the valleys. It is everywhere present except where it has been cut away by recent erosion or buried beneath the alluvium. It is a light yellowish to buff, unstratified, pebbleless clay, which is highly

siliceous. Where it forms the surface the upper few inches are blackened by the admixture of humus. Elsewhere the buff color obtains. It frequently contains the calcareous concretions known as loess-kindchen.

There are two phases of the loess in the county. The upper is the one just described. Below it is frequently a darker portion, more clayey, less porous and, as contrasted with the upper, unfosiliferous. So far as observed this lower loess is characteristically free from lime nodules. In the northwestern portion of the county it forms the subsoil and is in places troublesome because of its impervious character. The two phases may be seen at the Mardis brickyard, a mile east of Winterset (Tp. 76 N., R. XXVII W., Sec. 32), and the line of separation seems to be properly correlated with the old soil seen in the railway cut at Churchville. A similar division of the loess into two phases has been observed in Warren county.* It is to be noted that the lower portion corresponds in character to the white clays of Ohio as described by Leverett, and the two phases may not improbably stand for a real and considerable difference in the age of the deposits.

ALLUVIUM.

Alluvium is present along most of the streams of the region, but is most pronounced along the larger ones. It lies as a wash over the loess and drift which partially fills the old valleys, and in places attains a considerable thickness. West of the Winterset escarpment it is not so clayey as east of that line. Its greatest development is in the broader valleys cut in the Des Moines shales and coal measures. Along Middle river, south and west of Winterset, there is a well defined terrace rising eighteen feet above the flood plain. This seems to be an older flood plain or terrace of aggregation. Traces of similar terraces are found along certain of the other streams in the county.

*Iowa Geol. Surv., vol. V, pp. 318-356. 1896.

ECONOMIC PRODUCTS.

Building Stones.

Madison county is well supplied with stone suitable for various constructional purposes. The Bethany limestone includes nearly eighty feet of stone, most of which is available for one purpose or another. It is exposed in the ravines over much of the county and good quarry sites abound. As a rule but little stripping is required.

As will be seen from the general section already given there are four main bodies of limestone, designated respectively from the base to the top: (a) Fragmental, (b) Earlham, (c) Winterset quarry, (d) Fusulina. The general distribution of these beds has been already noted. Their varying thickness may be learned from the sections given. In general it may be said that they are thicker to the southwest. Some instances of their variation in this particular have been given. Each of the four members is capable of yielding good quarry rock at some point in the county, but not all are equally good at all points.

The Fragmental rock is best seen, and is exposed in its greatest thickness, at the Backbone mill, where it forms the ledge over which the water falls. At this point about nine feet of the rock is shown with only one important shale parting. The rock seems firm and should yield large blocks, but in view of its known character elsewhere in the county it is to be received with suspicion. In general the rock is very loosely cemented and breaks down readily into small nodular fragments.

The Earlham ledges are the most quarried. They yield a good grade of stone suitable for dimension work, rubble and concrete. When quarried, the Earlham is usually unprotected by overlying ledges and hence has been long exposed to weathering. As a result it is frequently badly broken up and creates a less favorable impression than the real merits of the stone warrant.

The Winterset quarry beds include those worked near Winterset and from which the stone used in the court house at that point was obtained. Their high quality is sufficiently attested by the excellent appearance of that building. The rock here used was taken from the Bevington quarry (Tp. 75 N., R. XXVIII W., Sec. 22), and certain of the layers tested at the Rock Island arsenal in 1881 showed a crushing strength of 4,588 pounds per square inch. The specific gravity of the rock was 2.73 and the ratio of absorption .042603. Stone from these beds rarely reaches the market at present, as the quarries have not been opened up except at Winterset and it requires a long haul over hilly roads to reach the railway at this place.

The Fusulina limestone is best exposed at the Backbone and seems capable of yielding excellent stone. At this locality compact ledges two and one-half to three feet in thickness may be obtained. Farther southwest the member attains a thickness of twenty-five to thirty feet. At Peru in the Reed quarry about fifteen feet are found. The stone here is thinner bedded than in the western outcrops.

In the main the quarry industry is concentrated around three points, Earlham, Winterset and Peru. The first has the advantage of location on the main line of the Chicago, Rock Island & Pacific railway, with a down grade haul of about thirty miles to Des Moines. As a result considerable quantities of stone, mainly crushed for concrete work, are marketed in the capital city. Winterset, on a branch line of the same road, is farther from market and suffers the disadvantage of less favorable freight rates. The quarries now open near this city are not so well located for connecting with the railway as at Earlham, but if the projected road southwest from Winterset be built, many excellent quarry sites will become available, and a large amount of stone can be placed on the market. At Peru and Barney the quarries are located near the Chicago Great Western but have no track facilities, so that a short wagon haul is necessary. The stone now quarried at Peru is so high in the

bluffs, seventy-four feet above the station, that a track to the quarries would not be practicable. The lower (Earlham) ledges occur not far above the level of the track, but to open them up it would be necessary to work out the overlying ledges as well. This would require considerable stripping and the handling of all the shales between the various ledges. It is doubtful whether such work would pay, certainly not without ample capital and an extensive plant. For the present only the best ledges can be marketed, as the poorer stone will not warrant the wagon haul and must be thrown on the dumps.

At Barney the Great Western track is more than fifty feet higher than at Peru, and west of there it ascends to the top of the bluff. About two miles east of Barney the Winterset rock has been cut through by the road, and in the bank of Clanton creek the Earlham layers are exposed. Quarries could be opened here with the minimum of track expense and with very little stripping. While the rock exposed is not to any great extent suitable for dimension stone it is excellently adapted for concrete, and a considerable amount of rubble could be obtained. Some dimension rock is exposed, and it seems probable that the Winterset beds, which are mainly talus-covered, would warrant opening.

EARLHAM DISTRICT.

Robertson quarry.—When the state capitol was being built at Des Moines the limestone around Earlham was opened up at a number of points. The principal of these old quarries was located northeast of Earlham on Bear creek. They have long since been abandoned, and ledges nearer the main line of the Chicago, Rock Island & Pacific railway are now worked. The rock as seen in some of the older workings on the north side is shown in plate ix. The main quarrying is now, however, carried on on the south side.

A section near the middle of the quarry shows the following:

		FEET.	INCHES.
9.	Stripping	10	
8.	Limestone, soft, disintegrated, with geest in the crevices	4	

EARLHAM LIMESTONE IN OLD QUARRIES NORTH OF THE RAILWAY.

		FEET.	INCHES.
7.	Limestone, compact, massive, bluish	1	6
6.	Shale, drab, calcareous		4
5.	Limestone, compact, bluish, in thin ledges	3	
4.	Shale, bluish, with very many *Chonetes vernculianus*		4
3.	Limestone, compact, blue	2	
2.	Shale, blue, calcareous	1	
1.	Limestone, ashen, thick to thin layers	10	

But little dimension rock is taken from the quarry. Some of the stone is used for foundation and retaining walls, but

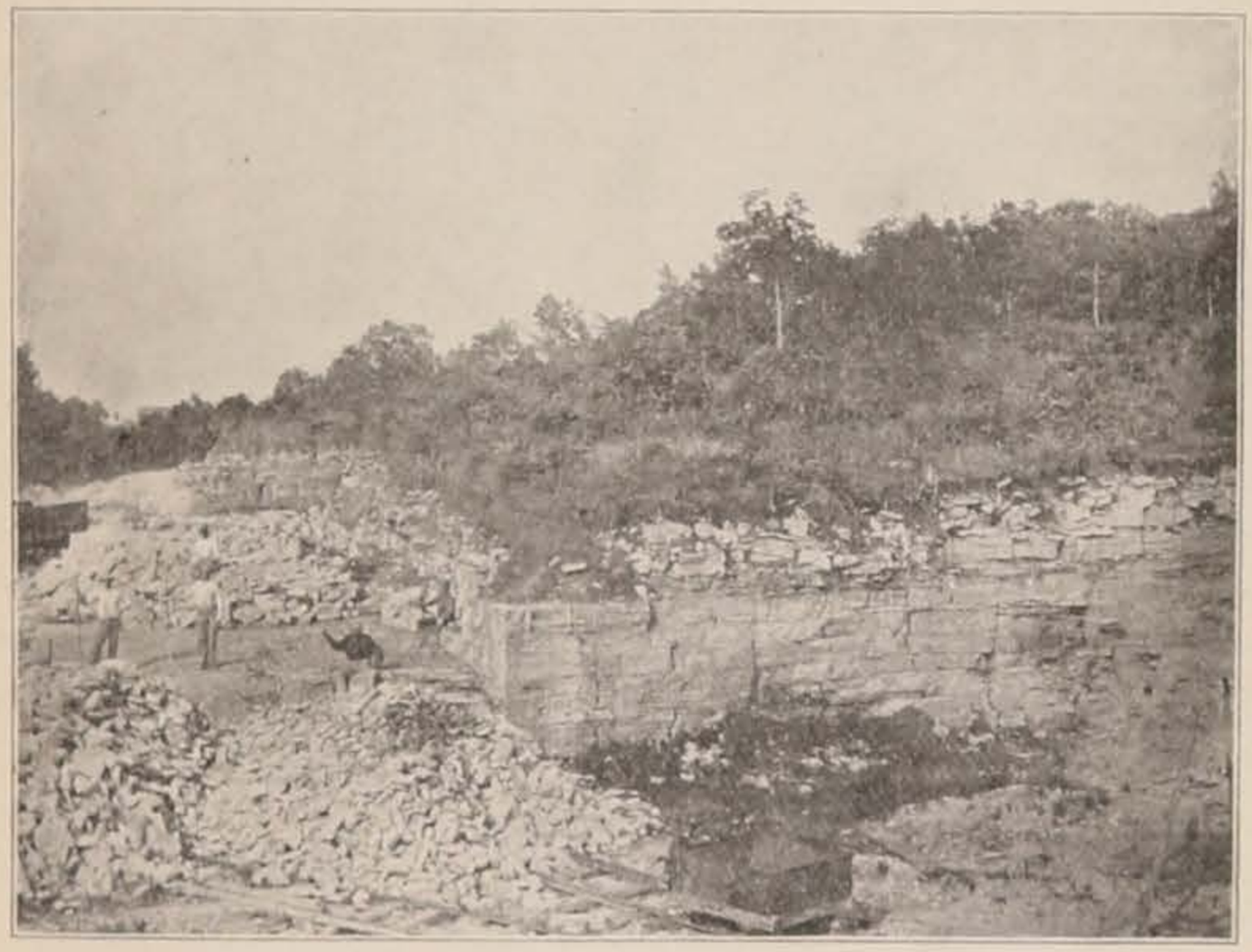


FIG. 79. A portion of the Robertson quarry east of Earlham, showing a typical exposure of Earlham limestone.

most of it is crushed. The stripping is done by hand. Very little blasting is necessary to loosen the rock. The stone is hauled to the crusher in tram cars of about one cubic yard capacity, and hoisted and dumped by tail rope. The plant includes a forty-horse power steam plant, one Gates crusher, elevator and revolving screen. The screen takes out all

material less than three-eighths inches in diameter, the fine material being used by the railway for yard filling at Valley Junction. The coarser rock is used mainly for concrete at Des Moines, and brings $1.30 per yard. The plant has a capacity of about 200 yards per day.

Earlham Land Co.—The quarries of this company are located south of town, in the valley of North river, and are illustrated in plate x. As has already been stated, the beds opened up are the equivalents of those found at the Robertson quarry. There is, however, an overlying shale not found at the latter place.

The rock is cut by a series of joints, some of which have spread till there is an open space of as much as seven inches. These crevices are sometimes filled by stalactitic matter, which usually coats merely the sides, but in places the crevices are completely filled. The presence of the joints and bedding planes makes the quarrying easy, and very little powder is used. As at the Robertson quarry most of the rock is crushed, though some good dimension stone could be obtained. The crushing plant includes a Gates crusher, tail rope, screens and steam plant. The capacity is 150 to 200 cubic yards per day, and the quarry employs about thirty men. The output is shipped on a switch from the Chicago, Rock Island & Pacific railway.

Nevitt quarry.—This is a local quarry opened some years since a mile southeast of Earlham. It supplies an important local trade.

Eureka quarry.—This quarry, formerly known as the McGorrisk, is a mile and a half south of Earlham (Tp. 77 N., R. XXIX W., Sec. 18, Nw. qr., Se. ¼). It is not worked at present.

WINTERSET DISTRICT.

There are numerous quarries in and near Winterset, though none are very extensively worked at present. The Clark quarry north of town (Tp. 76 N., R. XXVIII W., Sec. 25), is opened in the Earlham beds. In the southeastern portion of

QUARRY AND CRUSHER OF THE EARLHAM LAND CO.

the city both the Winterset and the Earlham beds have been opened up. In the city quarries the former ledges show about fifteen feet of rock. The lower courses may be used for dressed stone, though they are not easily quarried nor are they generally worked. Good rubble and crushing stone is abundant. On the Arnold place the Earlham stone has been opened up, and was for some years burned into lime at the Cooley kiln. South of Winterset the Brown quarry (Tp. 75 N., R. XXVIII W., Sec. 1, Sw. qr., Se. ¼) was reopened in 1893, and has since furnished considerable curbing stone. The old Kipp quarry, near by, is not now worked. Extensive quarries were formerly worked in the Winterset beds about a mile farther south (Tp. 75 N., R. XXVIII W., Sec. 12, Nw. qr.). It was from these quarries that a portion of the stone for the court house was taken. The pillars and much of the cut stone came from the Backbone quarries (Tp. 75 N., R. XXVIII W., Sec. 16, Ne. qr., Se. ¼). The section at this point has already been given in connection with the description of the limestone.

At the Backbone the heavy ledge at the base of the Fusulina limestone is well shown. It is known to the quarrymen as the magnesian ledge, though several different ledges in various parts of the county are confused under that term. It yields an excellent grade of stone. Higher portions of the Fusulina limestone are exposed in sections 22 and 23 of Webster township. It seems probable that the Fusulina stone, when properly opened up, will be found to yield some of the best rock in the county.

PERU DISTRICT.

In the tops of the hills at Peru the Fusulina rock crops out and is quarried at several points on the west side of the stream. At the Reed quarry from ten to fifteen feet of stone are found, it being for the most part fine-grained and breaking with a conchoidal fracture. The lower portion, four to five feet thick, is heavily bedded and shows some twelve to four-

teen-inch stone. Above this heavy stone is a six-inch bed of shale over which is a thinner bedded, much jointed rock. It furnishes four, six, eight and some twelve-inch stone. Some of the rock is fine-grained and of almost lithographic texture, but is too much cracked and seamed to be of value for dimension work.

The lower beds, including the Winterset, Earlham and Fragmental, have not been opened up, though they show in the hills. About two miles east of Barney the Winterset rock has been cut into by the railway, though the ledges are now largely covered with talus. The blocks exposed show thicknesses of six and eight inches. Below the limestone (1,020 A. T.) the usual black shale is exposed. Along the creek near by, at the proper level below this shale, the Earlham beds are shown and exhibit the following section:

		FEET.	INCHES.
4.	Limestone, thin, shaly, grading into calcareous shales	4	
3.	Limestone, coarse, made up of shell fragments, rather heavily bedded, ranges up to fourteen-inch rock, good quality	5	
2.	Shale, calcareous, gray, *Chonetes verneulianus* abundant, *Spirifer cameratus* rare		6
1.	Limestone, thin and irregularly bedded, ledges of six inches and less, stone apparently argillaceous, with dull earthy fracture; carries *Chonetes verneulianus*, *Spirifer cameratus*, *Productus nebrascensis*, *Productus costatus*, *Productus cora*, *Athyris subtilita*, *Meekella striatacostata* and corals; ledges capped by a ten-inch layer of coarse gray rock made up of finely comminuted shells	6	

The only quarry in the vicinity is that of Mr. Irains, where about five feet of stone suitable for dimension work is obtained with very little stripping. In Mr. Irains' house, built of the product of this quarry, the good qualities of the stone may be seen.

ST. CHARLES–TRURO DISTRICT.

Near St. Charles the thin ledges of the Fragmental rock already described are quarried locally. The total thickness of stone is about two and one half feet, the ledges running from four to six inches. Thicker ledges probably occur higher in the hill, but have not been opened up. The quarries at St. Charles marketed last year about thirty perch of stone at 75 cents a perch. Equivalent ledges have been opened southwest of St. Charles.

Road Material.

The matter of good roads is deservedly attracting attention within the county. The considerable portion of the area not reached by railway lines makes wagon hauling more than usually important. To reach a market or to go to the county seat, requires in many cases a drive of ten to twenty miles. A portion of this drive is almost certain to be over very rough roads. The distribution of the drainage and the resultant configuration of the topography causes the north and south roads of the eastern and central portion of the county to be necessarily rough. The considerable relief and the flat topography of the uplands make steep grades at the river crossings almost unavoidable. The grades could be much bettered if the roads had been located with reference to the topography rather than the land lines, but here, as was usual in the Mississippi valley, the necessity for wholesale methods in the rapid settling of the country made deliberation impossible, and it must be the work of the future to correct some, at least, of the mistakes of the past.

The east-west roads chancing to follow drainage lines or the interdigitate divides, have in the main avoided steer grades. Some of the principal lines of travel are, so far as this factor is concerned, excellently located. The north-south roads of the extreme western portion of the county have also, in general, relatively few steep grades. It is not, however, altogether a matter of grades that is provoking here, as else-

where, a good roads agitation. The character of the roadway, be the grade ever so good, may be, and often is, so bad as to make the road quite impracticable at certain seasons. During good weather the roads are beaten hard, and in time are worn smooth; but in the spring, when the frost leaves the ground, many of the roads can be traversed only with the lightest loads. This condition obtains on some of the poorer roads almost the year round. The stiff undersoil of the loess on the uplands, the blue clay of the till, the geest, and much of the alluvium, all of which enter largely into the material forming the surface of the roadways, are predominantly impervious. They are usually, also, notably plastic. They prevent free drainage, and yet form a surface of black, sticky mud which adds greatly to the traction.

The improvement of the roads will necessitate, aside from the matter of location, adequate drainage and surfacing with road metal. More care in the building of the roadways so as to provide the necessary drainage is perhaps the first requisite. For road material the main reliance must be the limestone. Gravel beds of any importance have not been found in the county and probably do not occur, since the Wisconsin, the main gravel-forming ice sheet, did not reach so far south as either to enter the county or cross the headwaters of its streams. The earlier gravel-forming period which followed the pre-Kansan drift has left no traces in the county so far as can be discovered. The streams have not, by their own work, accumulated gravel beds to any considerable extent.

Limestone, however, occurs abundantly throughout most of the county. Some of the worst roads are along the foot of limestone cliffs. Rock could be obtained along most of the main roads readily and cheaply. It has already been used to a limited extent with excellent results. It is crushed in large quantities for the Des Moines market, being used for concrete, and is excellently adapted for macadam.

In stone for macadam two qualities are important: First, it must be sufficiently hard to resist too great wear, and Second,

it must be of such a nature that it will cement rapidly. The matter of hardness is relative only. Rock used in pavements exposed to continuous wear under heavy loads, must be able to resist considerable crushing strains; but for country roads, where the wear is relatively slight, this factor is of less importance. The limestone of the county, while it will of course crush under the wheels and will ultimately wear out, is not apt to prove particularly troublesome in that regard.

A macadam pavement derives its good qualities from the fact that the stone, under the roller or the wheels of traffic, breaks up and yields a fine dust, which with water forms a cement, binding the whole together. In effect a macadam pavement is a cheap concrete in which the bond is derived from the finer portions of the crushed rock. Not all stone, not even all limestone, will furnish a dust which has the requisite cementing properties. In some cases it has proven necessary to cover a macadam roadway with a thin surface of crushed iron or other material in order that the whole should be made to set. The limestone found in Madison county needs no such surface material. It is quite pure and dissolves under the action of surface water with relative rapidity. The dissolved material is frequently redeposited, not far from the point of solution, in the form of stalactitic matter. As was noted in the description of the quarry of the Earlham Land Co., this redeposition is locally important. The redeposited stalactitic matter forms a firm cement, holding together any pieces of rock which may be imbedded in it. Upon the roadway an analogous process takes place, and under proper conditions the recemented rock will form a firm and durable pavement.

The amount of stone necessary for covering a roadway will vary somewhat with the conditions as to foundation, grade, traffic, etc. Upon a properly drained and rolled foundation six inches of stone should be ample for most of the roads of the county. Upon this basis about 1,500 yards per mile would be necessary for a roadway fifteen feet wide. Stone is now being

furnished in Des Moines at $1.30 per yard, but this price could be very materially lessened in case the county crushed its own stone. The expense of grading and rolling the foundation, with that of delivering and spreading the stone would vary with the locality. In New Jersey certain roads are costing about $3,000 per mile. It is probable that the main roads of Madison county could be improved at an average amount considerably less than that sum; perhaps $1,000 to $1,500 could be taken as a fair estimate. To obtain the best results the work would need to be carried on according to a systematic plan, so that the work done each year should be a permanent improvement—a part of a single larger piece of work. The road work now carried on is essentially of a makeshift character. If to the amount of the road tax now annually expended were to be added the aggregate cost of breakdowns, undue wear on horses and vehicles, loss of time due from the light loads hauled, and losses due to inability to market produce rapidly when prices are most favorable, the relative cost of present and improved roadways would appear in the reverse of their present order.

Lime.

The limerock found in the county can be burned to a lime, but the quality of the latter is not of the best. Curiously enough it is not the purest limestones which make the best lime, but those which contain a certain percentage of magnesia—the dolomites and magnesian limestones. For the most part the limestones of the county contain little magnesia. The lime formed from it is white, but is quick and heats rapidly. In slacking it must be handled very carefully and an abundance of water kept on hands. Lime was formerly burned at Winterset, Peru, in section 32 of Jefferson township, and section 9 of Madison township. At present there are no kilns in operation, and it is quite unlikely that kilns will ever be established except for local trade.

Clays.

The abundance of stone and the nearness of the large brick works at Van Meter and Des Moines have prevented the development of any important clay industry in the county. The loess, which is everywhere present, and most of the alluvium found along the streams could easily and cheaply be made up into standard building brick. Only the simplest processes, those of the hand yard, would be necessary. Much of the loess could be made to yield better grades, including stock and face brick, if treated either as a stiff-mud or on a dry-press. In the eastern portion of the county where the Des Moines formation crops out, shales suitable for a considerable variety of products occur. So far they have not been utilized, the only brick now manufactured in the county being made from top soil and loess.

At Winterset there are two brickyards, both without machinery. The T. F. Mardis yard is one mile east of town (Tp. 76 N., R. XXVI W., Sec. 32). Two kilns of 100,000 to 150,000 capacity are ordinarily burned each season. In addition to brick of the usual size, brick twelve inches long are turned out. Southwest of town (Tp. 75 N., R. XXVIII W., Sec. 1) is the brickyard of W. D. and Joel Clark. They maintain two up-draft kilns of 25,000 capacity each for burning brick. At Earlham small quantities of hand-made brick have been made from the loess.

The wide distribution of the loess and the ease with which it can be worked up into brick and draintile upon the inexpensive auger machines, would seem to warrant investment in a plant. The stronger under loess which has given trouble in the hand yards will be found excellently adapted to the manufacture of drain tile, though it must not be dried too rapidly.

Water Supply.

The numerous streams throughout the county adapt it excellently to stock farming. When water is needed for household or industrial purposes it is usually obtained from

wells at shallow depths. The base of the loess and the base of the drift are common water horizons. Water may, however, be found in gravel pockets at almost any level in the drift. The different shale horizons in the Missourian usually furnish water and their outcrops are marked often by lines of springs or water seepage. Water, though not usually of the best quality, is readily obtained from the Des Moines beds. In Jefferson township (section 36) Mr. C. D. Fletcher has a well 268 feet deep ending in a sandstone that lies near the base of the Des Moines. The following analysis of the water, by Dr. Floyd Davis, is published by the courtesy of Mr. Fletcher.

Total solids	5,580
Loss on ignition	1,800
Chlorine	497.5
Free ammonia	1.76
Albumenoid ammonia	Trace
Nitrogen in nitrites	None
Nitrogen in nitrates	None

"These results show that this is a highly mineralized water. The salts in it are principally sodium chloride (common salt). There are no poisonous substances in it. The salts present are really beneficial constituents of a mineral water; the commoner salt acting as a mild tonic, and the glauber salts as a strong cathartic. The sanitary analysis shows that this water is almost entirely free of organic matter, such as might come from drainage, and there are no reasons whatever why this is not a good water for domestic use and for stock."

Water Power.

The rapid fall of the large streams of the county where they cross the Bethany limestones affords many excellent water powers, few of which are at present utilized. In former days there were several mills, the most famous, perhaps, being the tunnel mill at the Backbone. At this point, by means of a tunnel a few hundred feet long, water is

drawn from the river above the Backbone and a head of nearly twelve feet obtained.

North river Middle river, Clanton creek, and many minor streams cross the Bethany limestone. In each case there is a total fall of about eighty feet. This is distributed somewhat, but as each of the four benches of limestone is crossed there is usually a fall of ten to twenty or even more feet. Such water power may well become quite valuable, and it is not improbable that the future will see an important milling industry founded on it.

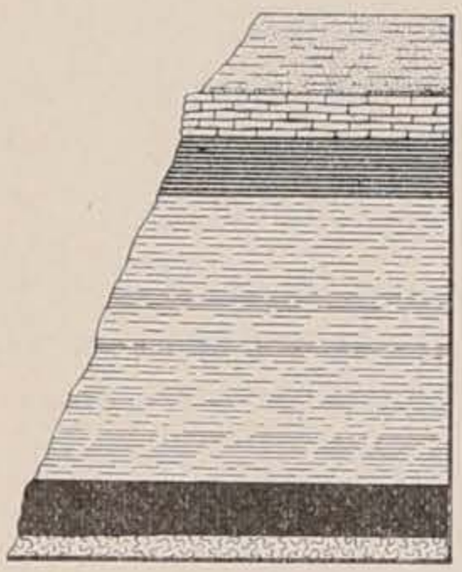
Coal.

While Madison county lies within the limits of the coal measures there are at present no mines of more than local importance. The Missourian formation, which covers so large a portion of the area is practically barren. The only coal beds of importance known to occur in this formation are found in beds that lie above the divisions of the Bethany limestone outcropping here. The black shale horizons noted in the general section of the formation carry some impure coal, but neither in quantity nor quality is it important.

The upper portion of Des Moines formation, as exposed along the Raccoon river, contains three horizons along which coal has been generally found. Two of these coal horizons have been named respectively the Lonsdale and the Marshall, and between these is an intermediate horizon to which no name has been given.

This intremediate coal appears on Bulger creek in Jefferson township, Madison county. Coal was formerly worked in Madison township (section 25) and it is not improbable that it belonged to the Lonsdale horizon. The coal found in Crawford township, on Cedar creek (sections 17 and 18), south of Patterson (section 32) and southwest of Bevington (section 36) can not be definitely correlated. Coal horizons have been noted in the sections near St. Charles, and similar beds occur at approximately the same levels along Clanton Creek and Middle river.

All these coal beds are quite thin. In many cases only a little impure coal is mixed with the black shale. The thickest beds noted include that reported at the old Clarke mine (Tp. 77 N., R. XXVIII W., Sec. 25, Nw. qr.) and that south of Patterson (Tp. 76 N., R. XXVI W., Sec. 32, Ne. qr., Sw. ½). At the Clarke mine the bed is said to have been two feet thick. White gives the following section:

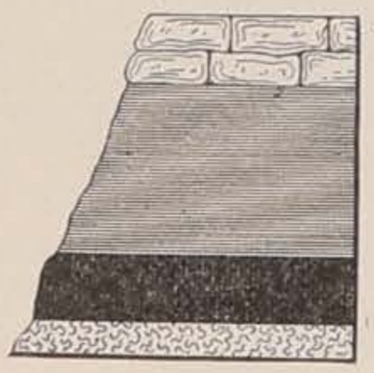


		FEET.
6.	Shale, sandy	32
5.	Limestone, impure, bluish	2
4.	Shales, black, bituminous	3
3.	Shale, argillaceous, bluish	14
2.	Coal	2
1.	Fire clay	1

FIG. 80. Coal at Clarke mine.

The coal would seem from this section to represent the Marshall horizon. It is not now exposed.

The section south of Patterson is as follows:



		FEET.	INCHES.
4.	Limestone, gray, compact, fossiliferous	1	
3.	Shale	2	6
2.	Coal	2	
1.	Fire clay		6

FIG. 81. Coal bed near Patterson.

The mines of Madison county are small, and are worked only in the winter to supply the local trade. Some coal is obtained by stripping and some by drifting. No deep shafts have been sunk, and no extensive prospecting has as yet been undertaken. Thick, workable beds probably occur within the county, but at some depth beneath the surface. At Van

Meter, just outside Madison county, two veins have been worked. One lies 285 feet below the surface, which is 884 A. T., and the other about twenty feet below. Each vein averages about three feet in thickness. In Guthrie thick coal has been found at several points at equivalent levels below the Bethany limestone. In Polk, Marion and Monroe counties coal is taken from horizons which are below the beds of Madison county. How far west along these horizons the coal will prove thick enough for mining is an open question, and can only be solved by drilling. At Peru, in 1887, the Chicago Great Western railway put down a hole to a depth of 303 feet. At 212 feet a thin bed of coal is said to have been encountered. This is about the horizon at which the coal worked at Commerce should occur if present. There are thin coal beds worked in Warren county, the uppermost passing beneath the bed of Middle river close to the east county line. This horizon usually shows sixteen inches of coal. Forty-five feet below is a horizon showing coal of equal thickness, and thirty-five feet still deeper is a horizon with eighteen inches. Probably coal may be found along these horizons over a portion of the county. The beds have a general dip toward the southwest of three to four feet per mile, and seem to have been but little disfurbed.

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