GEOLOGY OF DECATUR COUNTY.

BY

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CONTENTS.

INTRODUCTION.

Decatur county lies in the southern tier of counties, almost midway between the Mississippi and Missouri rivers. Ringgold bounds it on the west, Clarke on the north, Wayne on the east, and Harrison and Mercer counties, of Missouri, on the south. In area it includes 528 square miles, with some fractional pieces of land, the total being 343,910 acres. The townships run from 67 to 70 north, the southern tier being fractional, and the ranges from XXIV to XXVII west. The county is, as usual, divided into sixteen civil townships.

To the geologist Decatur county is of especial interest, because of the fact that running through it is the heavy limestone which forms the base of the Missourian series and which derives its interest to the economist from the fact that it divides the productive from the unproductive coal measures. This limestone, or assemblage of separate limestones, is known as the Bethany or Bethany Falls limestone, a name first used by Broadhead. In Iowa the exposures have been mainly studied are in the vicinity of Winterset, and to the strata at that point White gave the name of Winterset limestone. The beds outcropping at Bethany, Mo., and Winterset, Iowa, have for some time been believed to be identical, and the actual continuity of the two has, in fact, been recently proven. Between the two points mentioned, however, no detailed sections have been published, and it was mainly to supply this lack that the study of Decatur county was taken up at this time.

Previous to the present survey White seems to have been the only geologist who had worked in the county. His notes* include sections at a few points along Grand river and its tributaries, but the short time allowed for the work precluded anything like a detailed study of the area. The adjoining counties of Iowa were also described by him in the report cited. In Missouri, Harrison and Mercer counties, which

*First and Second Ann. Repts. State Geologist, pp. 42-43. 1868. Also Geology of Iowa, vol. I, pp. 318-327. 1870.

adjoin Decatur on the south, have been visited by various members of the Missouri Geological Survey. The earliest notes are those of Swallow, descriptive of certain fossils collected in Harrison county.* The coal beds of both counties are noted by Winslow.† The character of the surface deposits are noted by Todd,‡ and the altitudes and topography discussed by Marbut‖. Broadhead has also published notes on the coal measures of the region, which will be more particularly referred to in the body of this report.

PHYSIOGRAPHY.

TOPOGRAPHY.

Decatur county lies well up on the Mississippi-Missouri divide. The streams belong to the Missouri river system, but the country belongs rather to the high land between the rivers than to the Missouri valley proper. It is a broad, even, but much dissected plain, with little or no slope, and includes the northern continuations of the Warrensburgh platform and the Lathrop plain, defined by Marbut.§ In the country under discussion the two physiographic areas are not very distinct. The influence of the drift seems to have been such as to obscure the divisions which here may perhaps never have been so sharply defined as farther south. In a general way it is true that as one passes west from the Des Moines to the Missouri river the ascent is made by a series of steps. This is shown by the profile of the main line of the Chicago, Burlington & Quincy railway. This road runs across the drainage lines of the region and accordingly crosses a series of intermediate upland stretches. These bits of upland are approximately level but stand successively higher toward the west. The divide between the Des Moines and the Chariton runs from Maxon to Albia at 959 A. T. and is about 300 feet above

*Trans-St. Louis Acad. Sci., vol. II, pp. 81-101. 1863.
†Missouri Geol. Surv., vol. I, p. 99. 1896.
‡Missouri Geol. Surv., vol. X, pp. 143-181. 1896.
‖Missouri Geol. Surv., vol. VII, pp. 225-316. 1895. Ibid, vol. X, pp. 45-49. 1896.
§Missouri Geol. Surv., vol. X, pl. ii. 1896.

Ottumwa. The second upland is almost level from Russell, 1,037, to Chariton, 1,042; being 90 feet above the plain just mentioned. The third upland, from near Brush to Murray, has a slight rise to the west, being at Osceola, 1,132, and at Murray, 1,216. West of Murray the railway dips down into the valley of Grand river, just touching the level of the top of the Bethany limestone (1,051) at Afton Junction. At Creston, 1,312, it is again on an upland which extends with slight slope to Hillsdale, 1,189, not far below the crest of the Missouri river bluffs. Into this latter plain the Nishnabotna and Nodaway rivers have cut 200 to 250 feet, while the Missouri bottom land at Pacific Junction lies at 962 A. T.

From Creston west to the edge of the Missouri valley there is a long gentle slope not broken by marked escarpments. To the east the country first drops down to the Osceola platform, 1,132 A. T., and then by a further drop of about 100 feet to the Chariton platform. The Albia platform lies about 125 feet still lower and from there the slope to the Des Moines is gentle. At Chariton, Osceola and Creston there is a great thickness of drift. At Chariton, as shown by drill holes, the rock is found at 882 to 897 A. T. At Osceola the top of the limestone quarried northwest of town lies 140 feet below the railway station. At Creston there are no exposures and the drift is known to be very thick. The nearest exposures lie 260 feet below the level of the town. The rock then, rises between Chariton and Osceola from 882 to 1,092 feet, while from Osceola west present evidence seems to indicate that it maintains an approximately even surface. This would apparently indicate that in preglacial time the Bethany limestone formed in Iowa, as it does now in Missouri, a marked escarpment. The distribution of the drift, however, is such that this escarpment is almost wholly concealed.

The major portion of Decatur county, being underlain by the Missourian, would belong to Marbut's Lathrop plain. The portions of the Warrensburgh platform penetrating the county are confined to the river valleys, and hence form but an insig-

nificant fraction of the whole. It is the general upland plain which is most obvious as one travels through the county. The valleys are all clearly erosional and the roughness encountered when one descends from the upland is indicative of the completeness with which the streams have dissected the area.

The major streams of the county have a north-south direction. Their tributaries follow the main streams and do not usually travel from far to the east or west. The result is that the original upland plain has been cut by a series of long relatively narrow river valleys with high narrow ridges between. The resulting topography was quite fittingly described by the early settlers who spoke of the region as the "devil's wash board." An east-west traveler must cross a series of alternating ridges and valleys. The north-south traveler may usually find a ridge road. From the latter, looking off over the country, the tops of the successive flat-topped ridges appear rising to an even surface and restoring the old plain in which the valleys have been carved.

By examining the following table of elevations the position of this plain can be understood. Weldon and Van Wert, 1,147, are upon the upland. Leroy, 1,107, and Garden Grove, 1,114, occupy similar positions. Lamoni, 1,126, and Tuskeego, 1,175, in the southwest are on divides which form a portion of the plain. Decatur City near the center of the county, at 1,111, is also on the plain. De Kalb, 947, Grand River, 957, and Davis City, 914, are all on flood plains. Blockley, 1,042, and Leon, 1,025, are on partially dissected land. Pleasanton, 1,173, on the extreme southern line of the county, again marks the upland. The differences in these upland levels are not important and may be to a limited extent due to errors arising from comparing different surveys. On the whole they indicate a very even surface with little, if any, slope.

For convenience of reference these elevations are put in tabular form.

Table of Elevations.

STATION.	AUTHORITY.	FEET.
Blockley	D. M. & K. C. Ry	1,042
Cainsville (Mo)	D. M. & K. C. Ry	936
Davis City	C., B. & Q. Ry	914
Decatur City	D. M. & K. C. Ry	1,111
De Kalb	H. & S. Ry	947
Garden Grove	C., B. & Q. Ry	1,115
Grand River	H. & S. Ry	957
Lamoni	C., B. & Q. Ry	1,126
Leon	D. M. & K. C. Ry	1,025
Le Roy	K. & W. Ry	1,107
Pleasanton	D. M. & K. C. Ry	1,173
Tuskeego	C., B. & Q. Ry	1,175
Van Wert	K. & W. Ry	1,147
Weldon	K. & W. Ry	1,147
Westerville	K. & W. Ry	987

DRAINAGE.

The streams of Decatur county are all tributary to Grand river, which flows into the Missouri in Chariton county, Mo. Grand river itself has two main branches coming together near Chillicothe. The eastern fork alone penetrates Decatur county, though certain of the tributaries of Big creek, which is independent of this eastern fork, tap the southwestern portion. It is the eastern branch of Grand river proper which is known in Iowa as Grand river. In Missouri, when the term is used without qualification, the western or the united stream is usually referred to. Grand river in Iowa is an important stream having its headwaters in Adair county and crossing Madison, Union, a corner of Ringgold, and the western part of Decatur county. As far south as Afton Junction in Union county there is no reason to believe that the stream is preglacial. Throughout its course in Decatur county it is quite certainly older than the Kansan drift, since the latter is found undisturbed in its valley while the rocks rise in the hillsides a considerable distance above the flood plain. It has a broad valley whose width is suggested by the outline of the Des Moines formation where the river has cut through the Bethany. From Terre Haute to Davis City the Des Moines area shown

on the map outlines the bottom land. It will be noted that the river runs close along the south bluff, where it has an east-west trend. On the north the slope is long and gentle and the bottom land is broad. The south bluff is abrupt, rising in section 28 of Burrell township, 140 feet above low water. This is true again north of Westerville, where the south bank of the river is a sharp bluff, while the north side of the valley shows a long, gentle slope. Where the stream runs from north to south it shows no especial predilection towards either bank.

This tendency of east-west streams in Iowa to run along their southern bank has been noted by McGee,* Tilton† and Calvin.‡ The latter has suggested that it is due to the greater activity of weathering agencies upon a southward facing slope. McGee was evidently inclined to consider the phenomena as due to structural agencies. In Decatur county, however, there is no evidence of structural peculiarities adequate to account for the phenomena, and its almost universal presence throughout southern Iowa, regardless of the character of the rocks which the stream may be eroding, seems warrant for the conclusion that the climatic cause suggested by Calvin is a true one. The phenomena cannot be due to individual tilted blocks of strata, as suggested by McGee, and any other structural agency competent to the task could only be a prolonged uplift to the north, which would induce a migragation of the divides toward the uplift, as has been shown by Campbell.§ This would account for the larger number and longer course of the tributaries flowing from the north into an east-west stream, but would hardly account for the marked difference in the slopes of the valley sides proper. It is probable that while uplift to the north has been a potent factor in providing the phenomena, the climate factor is also to be taken into account.

*Eleventh Ann. Rept. U. S. Geol. Surv, Pleistocene Hist. N. E. Iowa, p. 412. 1891.
†Iowa Geol. Surv., vol. V, p. 307. 1896.
‡Iowa Geol. Surv., vol. VII, pp. 49-50. 1897.
§Jour. Geol., vol. IV, p. 567, 657. 1896.

That Grand river in this portion of its course is an old stream will be readily believed by anyone familiar with this valley. The size of the latter, and the fact that much of it is cut in rock, is alone convincing. The distribution and character of its tributary drainage lines afford additional proof. Still further evidence tending to prove its great age may be adduced from the great bend in the river in the northwest portion of Burrell township. (See Fig. 1, Plate xxi). This has originated as an upland meander and has been cut through the Bethany down to the Fragmental limestone. It is characteristically developed, but the tongue of rock running out into the bend has been very largely cut away. Only a low spur protrudes from a high bluff at the base of the bend. Such a spur would, in any case, be short lived, as it is exposed to vigorous erosion on three sides, but the fact that it has here been almost completely cut away, seems to be of more than usual significance. Upon Middle river, in Madison county, and Raccoon river, in Guthrie county, as well as on other rivers which cross the Bethany escarpment, upland meanders are well developed,* but in no case is the rock tongue so much eroded as in the Decatur county example. Here it has been so nearly cut away that at first it was thought to be absent. Upland meanders are developed by a long and slow process,† and where they have not only been developed, but almost destroyed, they indicate a considerable lapse of time. The meander and the stream valley are, of course, of later age than the peneplain, and they indicate that the time of stream cutting anterior to the drift was long, and that the peneplain is, relative to the drift, old. Further than that it seems impossible, at present, to fix its age.

Within the county the most important tributaries of Grand river are Elk creek from the west, and Long branch from the east. Both are important streams, cutting through the drift and into the rock. Exposures of Carboniferous are found

*Geol. Madison county, Iowa Geol. Surv., vol. VII, pp. 500-501. 1897.
†Marbut: Mo. Geol. Surv., vol. X, p. 98. 1896.

FIG. 1. View of Grand river bottom land, across the big bend in Sec 5. Burrell township, Decatur county.

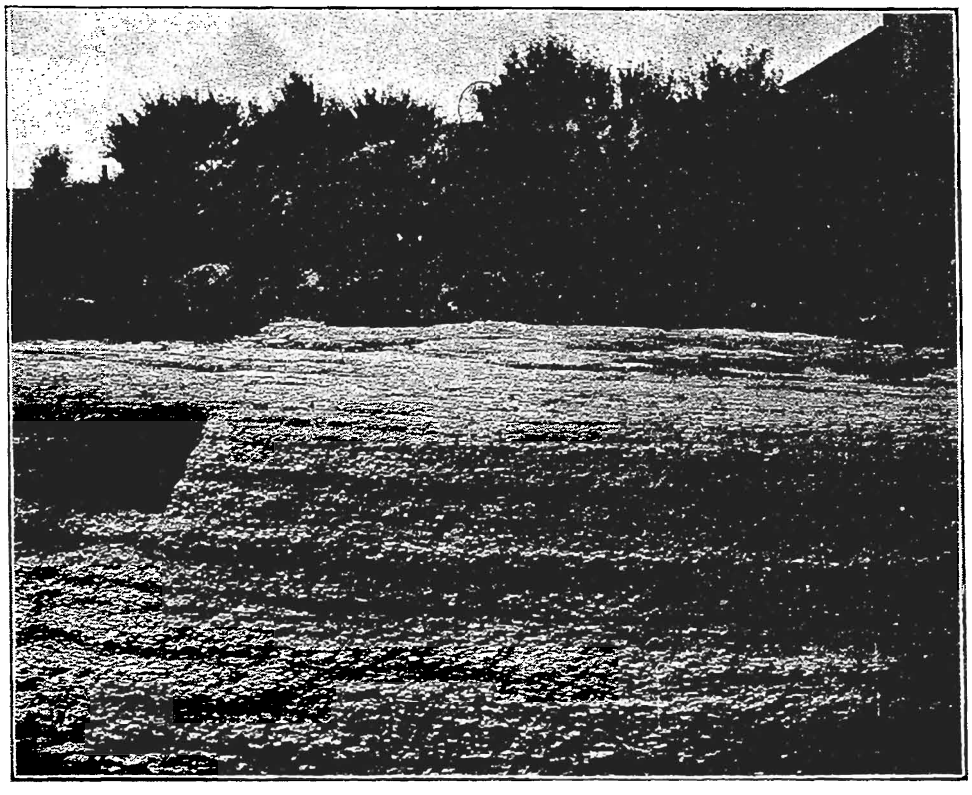


FIG. 2. Near view of Fragmental limestone, below mill, Bethany, Mo.

along the branches of Elk creek from sections 21 and 22 of Grand River township to the mouth, and along Sweet creek, a tributary, from section 23 of Bloomington township to the main stream. The minor tributaries show exposures for corresponding distances. Elk creek with its branches drains most of Bloomington and Grand River townships, but in addition to it Grand river receives from the west Sand creek near Westerville, Bad run near Grand river, Roaring branch and Russells branch between there and the north of Elk creek, Pot Hole creek or Potters branch near Terre Haute, Dickerson creek near Davis City, and some minor streams between that place and the Missouri state line. These streams with their tributaries reach out into all that portion of the county west of Grand river, except portions of Bloomington and New Buda townships and all of Fayette, which are drained by Shane and Seven Mile creeks, streams having courses through Big creek to the main branch of Grand river near Pattonsburg, Mo.

Long creek, with its tributaries, Bee and Wolf creeks, is the most important stream flowing into Grand river from the east. It receives Short creek near De Kalb, and at the latter place has cut 200 feet below the upland at Van Wert. There are rock exposures along the lower portion of its course.

Aside from Grand river there are two important rivers in the county, Weldon and Little rivers. Weldon river has its source in Franklin township and flows east through Garden Grove, and thence almost due south to the state line, receiving Jonathan, Brush and Steel creeks with Turkey run and List branch. Little river has its source near Van Wert and a course from there south past Leon, Blockley and Spring Vallay.

The streams of the county are almost entirely pre-loessial in age. Only the minor tributaries have had a later origin. The major streams, Grand river, Weldon river and probably Little river, are preglacial, or at least pre-Kansan. Some of the tributaries are perhaps as old as the main streams; but most of them are merely pre-loessial.

It seems probable that the preglacial drainage of the county was in outline quite similar to the present. In contrast with most of Iowa the present streams seem to be working on a lower level than that which obtained in preglacial times. They are cutting in the rock and usually show no important drift filling below low water. The bridges over Weldon river and Steel creek in Morgan, Woodland, and even sections 13 and 25 of High Point township, rest on rock or shale foundations. The same is true of the Little river bridges in Hamilton township and of the Grand river bridges as well as those over Long and Elk creeks. Yet in the valleys of Weldon, Little and Grand rivers there are places showing undisturbed drift down to low water level. The entire absence of great drift-filled channels in this region as compared with that farther east* would indicate that in later glacial times, and perhaps in the present, the surface of Iowa has been warped, the west rising more than that to the east. This is in accord with other observed phenomena.

The effect of the varing hardness of the underlying rocks upon present valleys is shown in the alternate widening and closing of their valleys, though the latter is probably also due in part to other agencies, as already suggested. The effect is also shown in the ponding of the streams as each of the members of the Bethany is crossed; phenomena first observed and described by White.†

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

The geological formations occurring in Decatur county fall into two series, differing widely in character, origin and age. The underlying rocks are indurated. They include principally shales and limestones, and record the time when what is now

* Proc. Iowa Acad. Sci., vol. II, pp. 23-26. 1895.
† Geol. Iowa, vol. I, pp. 318-320. 1870.

a portion of a beautiful prairie plain lay beneath the waters of the Carboniferous sea. They are the products of the destruction of an older land and were laid down by the action of marine agencies. Partially at that time and partially since, under the influence of circulating waters and slight pressure, they have been changed from relatively loose, unconsolidated sea deposits to the firm, hard rock now found.

Over these older rocks are the loose and unconsolidated gravels, sands and clays which form so common and conspicuous a feature of the surface. These are of very much later age than the indurated rocks, belonging indeed to the Pleistocene period, and have been in part deposited in present time. They are the product not of the sea, but of ice; an incursion of immense glaciers or a sheet of land ice, which spread over much of the northern hemisphere. In part these deposits were made by the ice itself, and in part by the waters from its melting. Some of the beds present were formed by the present rivers by ordinary processes, such as may even now be seen in operation. Some were laid down by waters of uncertain age and extent, and some perhaps by winds. The relations and ages of these beds are indicated in the subjoined table. Their distribution and character will be described later.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium
		Glacial.		Loess.
				Gumbo.
			Kansan	Drift.
			Pre-Kansan (?).	Drift (?).
Paleozoic.	Carboniferous.	Missourian.	Bethany.	Westerville (?).
				De Kalb.
				Winterset.
				Earlham.
				Fragmental.
		Des Moines.	Pleasanton.	

Carboniferous.

The Carboniferous of the Mississippi valley is divided into two major divisions long known respectively as the upper and lower. The latter does not occur within the county and its only importance in this connection arises from the fact that the St. Louis limestone, one of its members, forms the floor upon which the coal measures rest. In any future deep drilling for coal the St. Louis will indicate the horizon below which it is inadvisable to prospect.

The upper Carboniferous is commonly known as the coal measures, and the term Pennsylvanian series has been proposed to cover the same beds. In this immediate region it consists

of two major members, known as the Des Moines and the Missourian, each divisible into subordinate groups. These correspond respectively to the lower or productive and to the upper or unproductive coal measures. Keyes has proposed* to consider each of these divisions as independent series; dividing the Carboniferous of the interior into the Mississippian, Des Moines, Missourian, and Oklahoman. While it is not certain that these different divisions are of strictly equivalent rank, and probably some include more than others, it is a great convenience in discussion and in mapping to use the terms in the sense proposed, and for these reasons they are adopted here, leaving to future critical paleontologic studies the adjudication of the rank of the divisions.

DES MOINES SERIES.

PLESANTON SHALES.

The Des Moines formation is but sparingly exposed within Decatur county. The best exposures are on Weldon river. Immediately south of the state line (Tp. 67 N., R. XXIV W., Sec. 28), at the wagon bridge over the Weldon, a thin sandy limestone is exposed about four feet above the water. The rock carries *Productus costatus*, but seems to show no specimens of *Chonetes mesoloba* which is usually found in the Des Moines strata. In physical characteristics it very closely resembles a bed found at the corresponding horizon in Madison and adjoining counties and it is confidently referred to the Des Moines formation.

At the bridge in section 15 of Morgan township, there is an exposure showing twelve feet of blue sandy shale of Des Moines character and differing from anything found in the Missourian of the region. The basal portion of the Bethany outcrops high in the hills on the west side of the river, and beds probably representing the Earlham horizon have been opened up in a small quarry. In the first ravine west of Little river

* Am. Geol., vol. XVIII, pp. 22-28. 1896.

(Sec. 16, Se. Se.) a sandy limestone corresponding in character to that found on Weldon river, near the state line, outcrops. It is here fourteen inches thick and, as usual, non-fossiliferous. About six inches above it are traces of a three-inch black shale, an unusual member of the section and perhaps only locally developed. The arenaceous limestone outcrops again about two miles west of Weldon river on Lick branch (Sw. of Se., Sec. 17, Morgan Tp.) at which point it has more of the shaly character.

Along Grand river there are few exposures of the Des Moines, the fragmental limestone of the Bethany, or the Earlham, outcropping usually at the edge of the flood plain. Near Davis City, however, the upper portion of the lower beds may been seen. Along the small ravine leading down past the old lime kilns north of town (Nw. of Se., Sec. 35, Burrell Tp.) below the base of the Bethany is the following exposure.

		FEET.
5.	Shale	3
4.	Shale, black, "slate"	1
3.	Shale, drab, sandy	4

Farther down and near the mouth of the ravine is the following.

2.	Shale, sandy, yellow	6

On the main stream near the mill, and accordingly below the above, the following beds are exposed.

1.	Shale, drab, clayey, with several thin bands of blue-black non-fossiliferous limestone	4

It is stated that before the dam was put in, limestone used to show in the bottom of the river below these beds, and it is known to extend below the bottom land as far across the valley as the trestle opposite town extends. Limestone has also been encountered in wells north of Davis City under the low platform reaching out from the hills to the west and under the bottom land (Nw. of Sw. Sec. 7, and Nw. of Nw. Sec. 12, New Buda Tp.). Since the Fragmental limestone is exposed on

Dickenson creek at a level above this bottom land (Sw. Sec. 3) this lower limestone would correspond to the arenaceous limestone exposed on Weldon river. No. 1 of the section as given would correspond to the same number in White's section* at this point. The other numbers give details of the beds comprised under No. 2 in his section. He mentions finding here specimens of *Beyrichia americana*, which he also collected from corresponding beds in Guthrie county. This would strengthen the reference of the beds to the Des Moines.

The beds here referred to the Des Moines form the top of that formation. With the exception of the arenaceous limestone already mentioned they are predominently shales. They are usually arenaceous to a noticeable degree. They correspond in general facies and in stratigraphical position to the Pleasanton shales of Kansas.† While the actual equivalence has not been proven, it has been suggested‡ and it seems quite likely to prove the correct correlation. In the interests of simplicity of nomenclature the name applied by the Kansan geologists may be used for these beds. They are not extensively exposed in Iowa though they have been described in Guthrie,‖ Dallas§ and Madison** counties, and are known at other points. It is, perhaps, significant that to the east of the Bethany limestone one finds in Wayne, Lucas and Clarke counties a broad, open prairie, such as would readily be formed over the area of outcrop of these shales by step and platform erosion.†† The actual surface is, of course, due to the drift, and the underlying step and platform is correspondingly obscured. The topography, nevertheless, serves to outline the probable outcrop of these beds and would suggest that they are of greater importance than knowledge derived from their outcrops alone would indicate. Their

*Geol. Iowa, vol. I, pp. 321-322. 1870.

†Haworth: Kansas Univ. Quart., vol. II, p. 274, 1895; Univ. Geol. Surv. Kansas, vol. I, pp. 154-155, 1896.

‡Keyes: Proc. Iowa Acad. Sci., vol. IV, pp 22-25. 1897.

‖Bain: Iowa Geol. Surv., vol VII, 443-444. 1897.

§Leonard: Ibid., vol. VIII, pp. 78-82.

**Tilton and Bain: Ibid., vol. VII, 504-509. 1897.

††Marbut: Mo. Geol. Surv., vol. X, p. 29. 1896.

probable thickness and the character of the underlying beds is discussed in connection with the subject of coal.

MISSOURIAN SERIES.

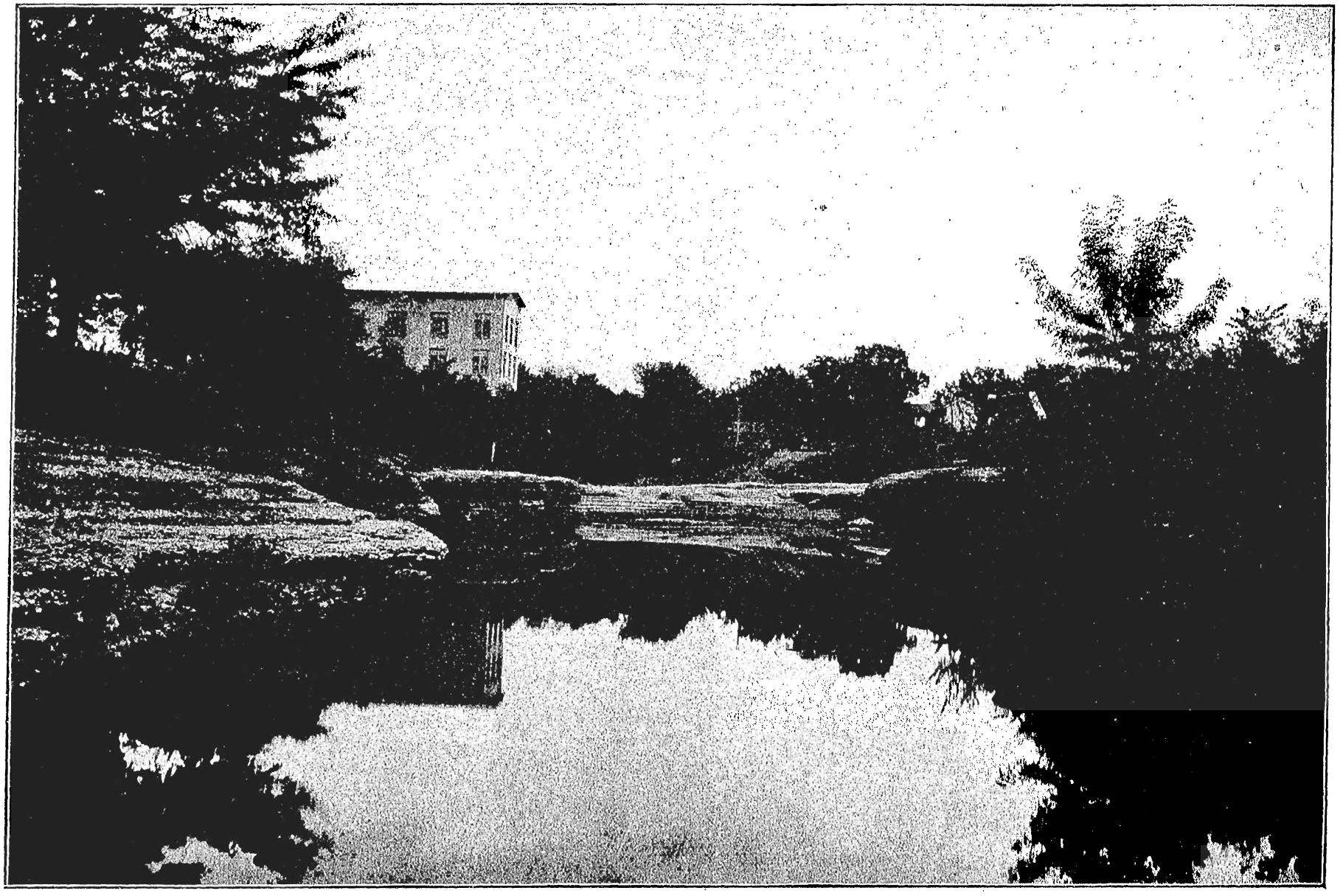
As will be seen by the maps, the major portion of the county is underlain by the Missourian, or upper coal measures. This formation, as here developed, consists of several beds of limestone separated by shales of various types. This assemblage of shales and limestones taken together constitutes the Bethany limestone, the lowermost of the several subdivisions of the Missourian. The Missourian as a whole has not yet been much studied, though the Bethany limestone and its equivalents have received considerable attention in Kansas, Missouri and Iowa.

BETHANY LIMESTONE.

At Bethany, Missouri, where the limestone was first studied by Broadhead,* the beds as now exposed yield the following sequence as shown along a small tributary of Big creek running through the town. The first exposure, which shows the top of the Bethany, is near the railway bridge north of the depot, the top of the limestone being at about 888 A. T.

		FEET.
6.	Limestone, fragmental, loosely cemented, with many specimens of *Meekella striato-costata, Chonetes verneuilanus, Productus costatus, Athyris subtilita, Productus longispinus, Spirifer cameratus* and *Dielasma bovidens*....	6
5	Shale, clayey, green to drab, with thin bands of limestone	2
4.	Shale, clayey, drab to black	2
3.	Limestone, dark blue, two ledges, 9 and 3 inches thick respectively	1
2.	Shale, black	1
1.	Shale, black to drab, with irregular nodular and thin layers of impure black limestone, carrying large, well-formed *Productus cora, Productus*	

*Trans. St. Louis Acad. Sci., vol. II, 311, 1862; Mo. Geol. Surv., Iron Ore and Coal Fields pt. ii, p. 77 *et seq.* 1873.



TYPICAL EXPOSURE OF BETHANY LIMESTONE AT BETHANY, MO.

	FEET.
nebrascensis, *Athyris subtilita*, *Myalina subquadrata*(?), *Schizodus* sp? In the shale itself are *Myalina subquadrata*, *Productus nebrascensis*, *Athyris subtilita*, *Rhombopora lepidendroides* and plates of *Eupachycrinus verrucosus*.....	6

Below this exposure for some distance there are no outcrops, but in the western part of town there are some small quarries which show the following beds.

		FEET.	INCHES.
7.	Shale, clayey, drab.....	6	
6.	Shale, calcareous, transition beds, with *Spirifer cameratus*, *Meekella striato-costata*, *Productus cora*, *Productus costatus*, *Productus nebrascensis*, *Rhombopora lepidodendroides*, *Fistulipora nodulifera*, *Myalina subquadrata*, *Athyris subtilita*, *Derbya crassa*.....	1	6
5.	Limestone, heavy ledge, many *Fusulina cylindrica*.....	2	10
4.	Limestone, thin bedded, with many of the fossils collected above, particularly *Athyris subtilita*, *Productus cora*, *Productus costatus*, *Spirifer cameratus* and *Meekella striato-costata*	10	
2.	Unexposed.....	8	
1.	Limestone, thin bedded, with *Productus costatus*, *Productus cora*, *Productus longispinus*, *Athyris subtilita*, *Spirifer lineatus*, *Spirifer cameratus*, *Spiriferina kentuckensis*, *Chonetes verneuilanus*, *Hustedia mormoni*, *Dielasma bovidens* and *Fusulina cylindrica*.....12–15		

Not far from here is the mouth of the stream which enters just above the falls of Big creek. The rock forming the falls lies probably six to eight feet below the base of the limestone just described. It is about twenty feet thick, the upper eighteen feet being made up of a coarse but finely cemented limestone breccia, such as is shown in Fig. 2, Plate xxi. It is marked by long dark streaks which suggest corals, but which fail to show structure. The only fossil collected from it was *Productus cora*. Below the breccia is about two feet of fine-grained gray limestone, carrying large, well-formed *Spirifer cameratus* with

Productus cora. The brecciated character of the limestone and the absence of marked sedimentation planes has yielded, under water action, rounded forms and knob and pot hole surfaces. (See Plate xxii.)

The general sequence found here with the four bodies of limestone, separated by shales, is the same as has already been found in central Iowa. The exposures in the latter region were first studied by White* and have been more recently reviewed by the present Survey.† In many of the minute details even there is a close correspondence between the Bethany section and that of Madison and adjacent counties. The latter may be summarized as follows.

		FEET.
8.	Limestone, thick and thin bedded, characterized by a particular abundance of *Fusulina cylindrica*, and hence called the Fusulina limestone	15–30
7.	Shales, predominantly dark colored and argillaceous, containing several thin bands of bituminous limestone, which are usually quite fossiliferous. About midway of the shales is a horizon which is particularly fossiliferous. The more usual forms, including Athyris, Productus and Spirifer, occur in great abundance and perfection. With these forms are vast numbers of *Derbya crassa* with *Myalina subquadrata*, *Myalina kansasensis*, *Myalina swallowi*, *Aviculopecten occidentalis*, *Productus nebrascensis*, etc. Not far above this horizon is usually a thin band of limestone literally made up of *Chonetes verneuilanus*. The whole thickness of the shale is	10–20
6.	Limestone, medium grained, thin to thick bedded quarry rock, with *Athyris subtilita*, *Productus cora* and *Meekella striato-cosata*. Best exposed near Winterset, and hence called the Winterset limestone	12–15
5.	Shale, usually dark and including a black bituminous horizon	8–12
4.	Limestone, well shown near Earlham, and hence called the Earlham limestone. Carries an abundant fauna, which will be noted later	20

*First and Second Ann. Repts State Geol., pp. 71-72. Des Moines, 1868. Geol. Iowa, vol. I, pp. 245-250. Des Moines, 1870.

†Proc. Iowa Acad. Sci., vol. I, pl. iii, pp. 26-271, 893; Iowa Geol. Surv., vol. III, p. 137, 1895; Ibid., vol. VII, pp. 446-451, 1897.

		FEET.
3.	Shale, with bituminous horizon, and at many points a thin, black limestone	3–8
2.	Shales, sandy, light colored, very variable thickness	2–16
1.	Limestone, fragmental, made up of irregular bits of lime rock, filled in with calcareous clay. In places the rock can be picked to pieces with the fingers, elsewhere it hardens up into massive, thick-bedded layers. Along a small tributary of Deer creek, in Guthrie county, it is quite fossiliferous, yielding *Spirifer lineatus*, *Spirifer cameratus*, *Athyris subtilita*, *Hustedia mormoni*, *Productus longispinus*, *Naticopsis altonensis*, *Lopophyllumn proliferum*, *Orthis pecosi*, *Bellerophon sp.*, *Straparollus sp.*, *Archæocidaris sp.*	10–15

As the Earlham limestone is particularly well shown in Decatur county and presents there many analogies to the beds at the type locality, the following details regarding the latter may be quoted.* The typical section is given below.

		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 verneuilanus*		4
8.	Limestone, like No. 4	2	
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 No. 4, drab and black shales

* Geol. Madison county, Iowa Geol. Surv., vol. VII, pp 514-515, 1897.

to the depth of three feet, and below the shales a ledge of limestone six inches in thickness.

Distributed through the limestone beds No. 4 are the following.

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

Chonetes verneuilanus N. &. P. is somewhat common in No. 9 but is very rare in the other members of the section. *Spirifer cameratus* and *Productus longispinus* are most abundant near the base of No. 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 No. 4.

The best exposures of the Bethany limestone in southern Iowa are found along Grand river and its tributaries. From the outcrops found here a complete section can be made from the Fragmental limestone at the base up to and above beds which farther north have been called the Fusulina limestone, but which, from their excellent development in that vicinity, may now perhaps be best called the De Kalb limestone.

In Union county there is an important bed of limestone which, from the fact that it is well shown on Sand creek near Westerville, may be called the Westerville limestone. It lies some little distance above the De Kalb horizon. In Jones township of Union county (section 28 and farther south along

FIG. 1. Surface of Winterset limestone, showing position of glacial striæ.

FIG. 2. Glacial striæ near Lamoni. Most of the striæ are S. 1° W., a few S. 4° W., and one or two S. 5° E. Magnetic variation, N. 7° 30° E.

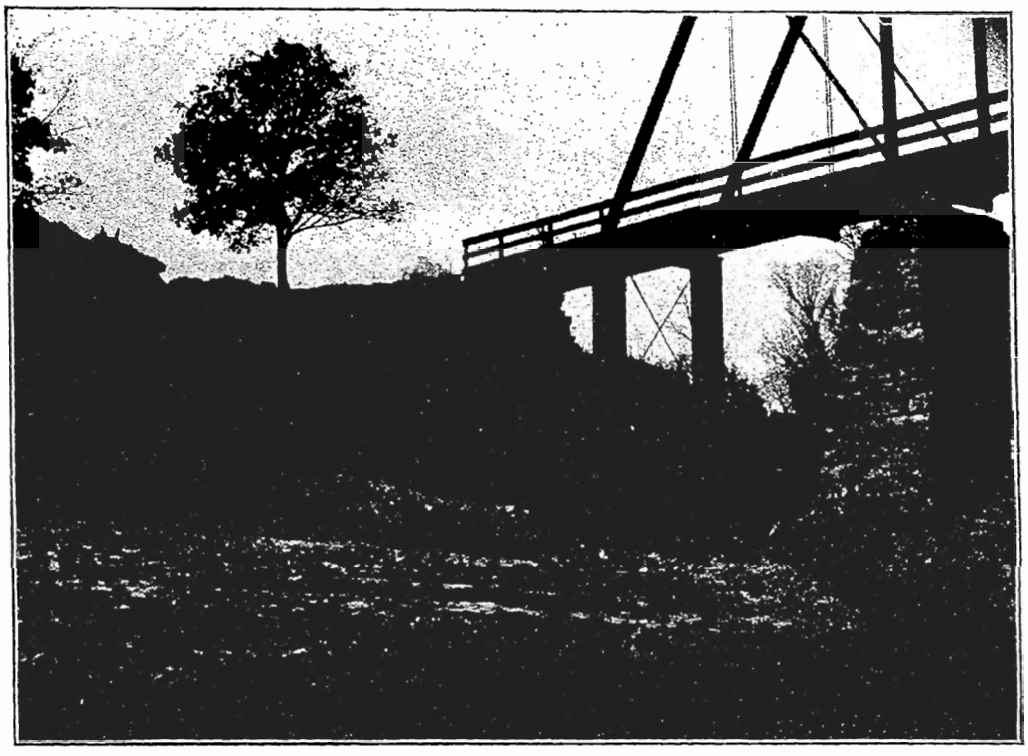


FIG. 1. Winterset limestone, west of Decatur City, with Myalina shales and Blue limestone ledge above.

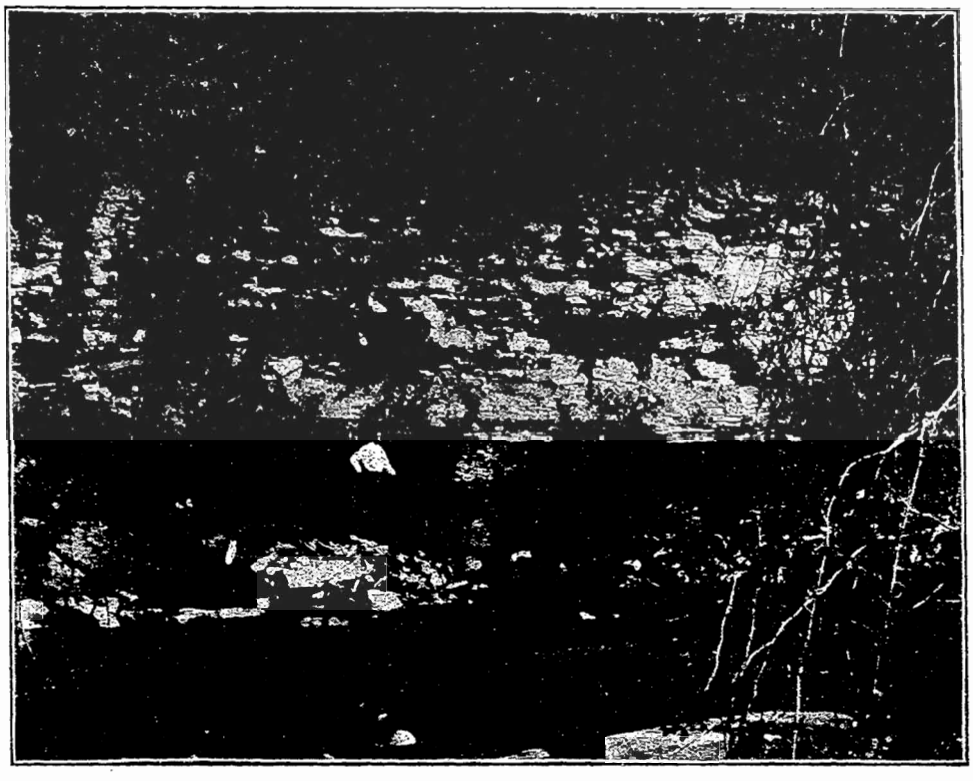


FIG. 2. Winterset limestone on Potter's branch with shales below extending down to the Earlham limestone.

the river) the beds are exposed, showing the following section.

		FEET.
5.	Limestone, ash gray, fine grained, thin bedded, becoming almost shaly at the top, with *Productus cora*, *Productus costatus*, *Spirifer camerata*, *Athyris subtilita*, *Chonetes verneuilanus* cf. *glabra*, *Lophophyllum proliferum*. *Straparollus subquadratus* and Fenestelloid bryozoa	10
4.	Shale, gray, calcareous, with thin nodular bands of limestone	4
3.	Shale, drab to black	10
2.	Limestone, impure, nodular, in two bands	2½
1.	Shale, drab to black, well exposed at Westerville	8

These beds extend into Decatur county, being seen near Westerville, on Sand creek, and on Grand river. It seems probable that the shale (No. 1) extends down to the top of the De Kalb or Fusulina limestone which is exposed near Grand river and was at one time quarried at the old Madarasz quarry. (Sec. 36, Tp. 70 N., R. XXVII W.) The best exposures of the latter limestone, and the ones which may be taken as typical, are found a short distance east of De Kalb station. (Sec. 28, Tp. 70 N., R. XXVI W.) The section at this point is given below.

		INCHES.
5.	Limestone, irregularly water worn	6
4.	Shale, hard, drab	6
3.	Limestone, irregularly bedded	8
2.	Shale, calcareous, becoming in places a poor grade of limerock	2
1.	Limestone, in thick to thin ledges	48

The limestone is quite fossiliferous, the forms collected including *Productus costatus*, *Productus longispinus*, *Athyris subtilita*, *Spirifer camerata*, *Spirifer kentuckensis*, *Dielasma bovidens*, *Derbya crassa*, *Lophophyllum proliferum* and *Fusulina cylindrica*. This fauna is more abundant than is usually found in the same beds farther north, though no exhaustive collec-

tions have been made in Madison and adjoining counties, and many of the species collected at De Kalb are known to be present, sparingly at least, in the former regions. The marked predominence of *Fusulina cylindrica* which is so striking a characteristic of these beds in Madison county, is not so noticeable at De Kalb. This is probably due as much to the greater abundance at the latter point of the other forms mentioned as to any real decrease in the numbers of the Fusulina. It is, nevertheless, true that in the earlier advent, or at least culmination, of Fusulina the Decatur county outcrops show much closer relations to the rocks as developed at Bethany, than to the Winterset section. It is for this reason, in part, that the term, De Kalb limestone, is to be preferred to Fusulina limestone, since neither the presence nor the abundance of the latter form is found to be consonant with a constant stratigraphical horizon.

The beds below the De Kalb limestone are shown near the wagon bridge just north of the railway station. The section exposed is as follows.

		FEET.
5.	Limestone, De Kalb, thin bedded, very fossiliferous.	2
4.	Shale, soft, gray	2
3.	Shale, fine black "slate"	1
2.	Shale, black, soft	2½
1.	Shale, drab	4

These shales are not particularly fossiliferous, as the section does not extend down to the Myalina horizon already noted. The latter is well shown on Grand River at the bridge about three miles west of Decatur (Tp. 69 N., R. XXVI W., Sec. 30, Sw. Sw.) The section at this point is as given below. Fig. 1, Plate xxiv.

		FEET.
5.	Limestone (De Kalb) lower ledges only	3
4.	Shales, drab to black, carrying *Derbya crassa*, *Myalina subquadrata*, *Athyris subtilita*, *Productus nebrascensis*, *Lophophyllum lepidendroides* and plates of *Eupachycrinus verrucosus*, exposed as a slope. Thin ledges of limestone found on the slope made up of *Chonetes verneuilanus*	15

		FEET.
3.	Limestone, blue to black, with *Productus cora*, *Productus nebrascensis* and *Athyris subtilita*.....	3
2.	Shale, drab, clayey.....	12
1.	Limestone (Winterset), coarse bedded, with *Athyris subtilita*, *Productus costatus* and *Meekella striata-costata*.....	10

The Winterset limestone dips north here about five feet per hundred and its maximum thickness is not exposed. The dip seems to be local only. The Winterset is exposed south from the bridge as far as the abrupt turn of the river in the southeast corner of section 36, Grand river township. Within a mile the Earlham rock appears, and at the ford in section 7, of Burrell township, the Fragmental rock is seen in the bed of the river.

The Winterset rock at the Decatur bridge is quite similar to the typical beds at Winterset, both in physical characteristics and the character and relative meagreness of its fauna.

The shales between the Winterset and the De Kalb limestone form one of the most marked stratigraphic horizons in the section, and their close resemblance in all particulars to the corresponding beds at both Winterset and Bethany will be at once seen. The same fossils occur and in the same perfection and abundance.

The shales below the Winterset and extending down to the Earlham limestone are not well shown on Grand river. Elsewhere they are usually about ten feet thick and carry about their middle a one foot black slate horizon. The Earlham limestone is quite well shown near the bridge in Ne. of Nw. of section 5, Burrell township. The exposure, which is on the east side of the river just south of the bridge, shows the following beds.

		FEET.	INCHES.
6.	Limestone, coarse grained, with *Fusulina cylindrica* and *Athyris subtilita*.....	2	
5.	Shale, clayey, carrying *Athyris subtilita* and *Chonetes verneuilanus*.....		6

		FEET.	INCHES.
4.	Limestone, quarry rock, 4 to 12 inch ledges, with *Productus cora*, *Athyris subtilita*, *Hustedia mormoni*, etc	8	
3.	Shale, argillaceous, drab	1	
2.	Shale, black "slate"	1	6
1.	Shale, drab, soft	4	

The very strong resemblance of this section to the typical Earlham section as already given will be noticed at once. The partings in each case are of the same character and carry the same fossils. *Hustedia mormoni*, which is abundant wherever the Earlham is exposed, has not been collected from any of the higher beds along Grand river, although at Bethany it is found frequently at higher horizons.

The Fragmental rock is not shown at the exposure just described though it is exposed a short distance below at water level. On Pot Hole branch, south of Terre Haute (Tp. 68 N., R. XXVI W., Sec. 29, Se. of Nw.), it is present about ten feet below the base of the Earlham, being firmly cemented and non-fossiliferous. A thickness of four feet is shown in the bed of the creek and more may be present. The Fragmental rock is also below the base of the quarries opened up southwest of Davis City (Tp. 67 N., R. XXVI W., Sec. 3, Se. of Sw). Here it is also non-fossiliferous.

The exposures in and near Davis City show the Earlham beds excellently. They are the ones which have been much opened up, though the Winterset and the De Kalb are present high in the hills. From the Earlham limestone on Dickenson creek, southwest of Davis City, the following forms were obtained: *Productus longispinus*, *Productus costatus*, *Athyris subtilita*, *Spirifer cameratus*, *Chonetes verneuilanus*, *Fusulina cylindrica*, *Hustedia mormoni* and plates of Archæocidaris and Zeocrinus.

In the eastern portion of the county, on Weldon and Little rivers, it is apparently the Earlham which is exposed, though the rock has not been opened up enough to make the determination sure. The Fragmental does not show, being concealed

by talus and drift, but has been encountered in bridge excavations. A short distance south of Spring Valley, limestone, apparently the Earlham, is exposed along a small stream running into Little river from the east (Se. of Se. Sec. 13). The stone is fine-grained, ash gray, breaks with irregular fracture and weathers white. One ledge as much as eighteen inches in thickness is indicated by the blocks found on the surface. The rock is said to be underlain by shales. The fossils found included *Athyris subtilita*, *Productus longispinus*, *Productus costatus*, *Chonetes verneuilanus*, and *Spirifer cameratus*.

Beds corresponding to those just described outcrop about a mile north (Nw. of Ne. Sec. 13) along a tributary of Little river, and have been in fact opened up at several points in the vicinity. At the old Cole mill (Nw. of Ne. Sec. 14) the section given below is exposed in the west bank of the river. The limestone is probably the Earlham.

		FEET.
4.	Limestone, thick bedded, with *Athyris subtilita*, very abundant corals, and plates and spines of Archæocidaris	5
3.	Shale, gray to drab	4
2.	Shale, black "slate"	1
1.	Shale, gray, sandy	6

The limestone found on Weldon river (Se. Sec. 15, Morgan Tp.) is probably also the Earlham. The only fossils collected were *Athyris subtilita* and Archæocidaris. The outcrops indicate that higher limestones occur.

In the western portion of the county there are a number of excellent exposures of the various members of the formation. Many of them will be referred to in the notes on the quarries. The exposures in the eastern portion of the county are rare and with the thick drift present it is difficult exactly to locate the eastern limits of the formation. As laid down upon the accompanying map the line is subject to some correction. The limit in the southeastern corner of the county is probably quite correct, though there may be an outlier east of Caleb

creek. Farther north it is fixed by some exposures on Whi te-breast creek in Clarke county. Between these points it may be found to extend a little farther to the east or west than is indicated.

Pleistocene.

In recent years the unconsolidated materials which so generally form the surface formations have attracted considerable attention. This is particularly true of those beds which were laid down by, or in connection with, the great glaciers or ice sheets which, in the period immediately preceding historic times, spread over much of North America as well as certain portions of the old world. The deposits made by the ice sheets are well displayed in Iowa and have been found to be of peculiar interest. Within the last year or two it has been shown that the drift deposits of this state have had a much more complex history than has been heretofore ascribed to them. Near Afton in Union county to the north, and again in Harrison county, Missouri, to the south, certain phenomena of more than local interest have been observed. When the study of Decatur county was taken up it was hoped that in the exposures along its deep cut valleys decisive evidence on certain mooted questions would be obtained. The result of the investigations are neither altogether satisfactory or altogether disappointing. Their value and bearing upon general questions may, however, be better estimated after a review of the evidence.

The drift deposits of Decatur county include the Kansan bowlder clay, with certain possibly older beds, the gumbo, the loess and the alluvium. The latter is the most recent deposit and is found along all the streams, occupying the lowlands. The loess is the surface formation over the upland and runs over the divides and down into the valleys in the form of a mantle. The gumbo is under it and has the same stratigraphic relations as the loess. The drift deposits proper are under the gumbo and often under the alluvium. They cover

the whole of the upland region to a variable depth, averaging probably 150 to 200 feet. The drift also runs down into the preglacial valleys.

KANSAN AND OLDER DRIFT SHEETS.

The drift sheet left by the major advance of the Keewatin ice sheet and extending out from under the later Iowan and Wisconsin tills is known as the Kansan drift. It is believed to have extended on the south to the Missouri river and on the southwest across that stream into Kansas. When named* it was thought to be the oldest drift sheet in North America. Dawson† has since shown that in Canada there is an older drift, named by him the Albertan, and the evidence of two drifts in southern Iowa, long since noted by Chamberlin‡ and McGee, has been interpreted as indicating a pre-Kansan drift§ in that region.

The interpretation accords with the results obtained from a study of the Alps‖ to the extent that it postulates two old drift sheets. In the latter region there is, outside the moraine of the last glacial period, evidence of two older and widely separated invasions of the ice, the younger of the two apparently representing our Kansan. The interpretation here offered is also in harmony with numerous other phenomena. In a word it may be stated that under the Kansan drift there are traces of a still older drift, though the limits of this older drift are not known, nor is the evidence with regard to its existence everywhere as satisfactory as could be desired.

*Chamberlin: Gekie's Great Ice Age, pp. 773-774. 1894. Jour. Geol., vol. III, pp. 270-277. 1895.

†Dawson: Jour. Geology, vol. III, pp. 507-511. 1895.

‡Chamberlin: Loc. Cit. McGee: Pleistocene Hist. N. E. Iowa, Eleventh Ann. Rep. U. S. Geol. Surv., pp. 493-499. 1891.

§Chamberlin: Jour. Geol., vol. IV, pp. 872-876. 1896.

§Calvin: Annals of Iowa (3), vol. III, No. 1, pp. 1-22. 1897. Iowa Geol. Surv., vol. VII, pp. 18, 19. 1897. Amer. Geol., vol. XIX. pp. 270-272. 1897.

§Bain: Trans. Iowa Hort. Soc. 1896. Iowa Geol. Surv, vol. VI, pp. 463-467. 1897. Ibid., vol. VII, pp. 335-338. 1897.

‖See Le Systems Glaciaire des Alpes, guide publie, a de occasion du Congres geologique International, 6 m Session, Zurich, 1894, par M M. Penck, Brückner et du Pasquier. (With references.)

The surface drift throughout Decatur county is old. This is shown not only in the topography, but in the condition of the drift itself. Where the surface of the bowlder clay has not suffered recent erosion it is uniformily highly colored. The iron content has been oxidized until a reddish-brown surface corresponding to the "ferretto" of Italian geologists has been produced. This reddish-brown grades through orange to yellow below, and the yellow in turn gives place to blue, which is the fundamental color of the Kansan bowlder clay. Often the yellow is seen following down into the blue along cracks and fading out from their edges. All the evidences indicate that here, as elsewhere, the blue and yellow clays belong together. The change in color is a matter of oxidation, and is most marked when the oxidation has been most active.

The blue bowlder clay and much of the yellow contains a large amount of calcium carbonate, fine limestone dust. This causes it to give a vigorous reaction when tested with acid. The upper surface of the bowlder clay gives no reaction, and the strength of the reaction, increasing from nothing at the surface to full vigor at a depth of seven to nine feet, is proportional to the amount of leaching which the clay has suffered, which in turn is approximately proportional to the depth below the surface. The bowlder clay contains a considerable variety of pebbles and bowlders, they being in most cases flattened and planed, and often showing striations.

In a cut on the Humeston & Shenandoah railway, near De Kalb, the following kinds of rock were observed in the till: gray and red granite, red porphyry, Sioux quartzite coarse and fine-grained, quartzite with pebbles of clean quartz and red jasper, gabbro, fine-grained greenstones, iron concretions, bits of clear, white quartz, small pieces of limestone, chert, and very small bits of sandstone. The sandstone and limestone doubtless come from the coal measures of the adjacent region. The quartzite, including that with the quartz and jasper pebbles, probably came from the Sioux Falls region. The granites and greenstones came from farther north.

Many of the granite cobbles, both large and small, are so badly weathered that they may be easily picked to pieces with the fingers. This is particularly true of those near the top of the formation and becomes less noticeable toward the bottom. It is not confined to particular kinds of rock which might be supposed to weather easily, such, for example, as coarse-grained granites with large feldspars, but is true of a wide variety of stones.

It is believed that the weathering of the granites, the oxidation of the iron and the decalcification of the bowlder clay, in view of their obvious relationships to the original surface of the latter, are to be interpreted as evidence of a long period of subærial decay after the bowlder clay was deposited. The ferretto surface maintains itself under the loess and outlines the present topography, so that this period of exposure, which the advanced stage of the topography indicates must have been a long one, occurred after the bowlder clay was laid down, and before the overlying gumbo and loess were deposited. It is this drift which forms the bulk of the Pleistocene deposits of the county and which has been called the Kansan. Relative to the question of a possible pre-Kansan there are certain exposures of interest.

In section 36, Pleasant township of Union county, the following exposure is seen in the bank of Grand river near the ford. This is within a mile of the northwest corner of Decatur county.

		FEET.
4.	Loess-like top soil	1
3.	Sand, fine to coarse, with some gravel below	6
2.	Gravel, sandy, much weathered material	10
1.	Bowlder clay, blue-black, in physical character resembling the older bowlder clay at Afton Junction	12

The sand and gravel are evidently waterlaid beds and belong together. They graduate laterally into a reddish clay and these into a drab to blue bowlder clay. This shading off of the gravels into a bowlder clay is true as well of the gravels

at Afton Junction. The gravel found at this exposure is similar in every regard to that found farther up the river. It wants only the bowlder clay over the gravel to make the exposure complete, and as the exposure is some distance below the high land, there can be little doubt of a higher bowlder clay. Between the two exposures there are traces of the same beds, and it is evident that what explains one exposure must serve also to explain the other.

About three miles northwest of Davis City (center of Sec. 28, Burrell Tp.) a bluff at another ford across Grand river shows an interesting drift exposure. The hills here on the south are close to the river. A spur runs out a little from the bluffs as indicated on the sketch map.

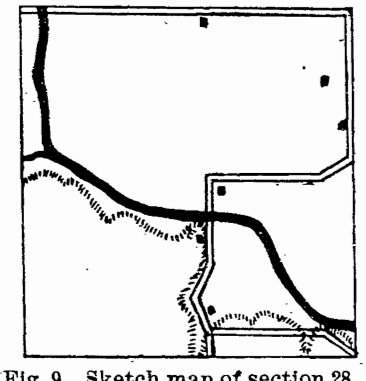


Fig. 9. Sketch map of section 28, Burrell Township.

The nose of this spur has been cut across by the river, making the exposure. At the water's edge stratified sands are exposed. Fifteen feet above the water is a well marked soil horizon buried beneath thirty feet of yellow bowlder clay sloping up to the bluff 150 feet high. The bowlder clay is evidently Kansan. From the fact, however, that it shows a certain amount of rude stratification, as well as the fact that the soil horizon is about on a level with the present flood plain, the exposure may perhaps be thought to represent side filling in over the bottom land. The absence of direct evidence favoring this, and the fact that so large an amount of bowlder clay could hardly slip down without leaving direct evidence of the fact except by a remarkably slow and uniform movement, while the bottom land is evidently young, seems sufficient reason for rejecting this hypothesis.

There is another exposure of interest found in the east bluff of the river near the bridge, about four miles southeast of Davis City (Sw. of Nw. Sec. 18, Hamilton township). Above

the bridge there is a small ravine coming in from the east and cutting in two what was once apparently a continuous exposure. The portion of this exposure south of the ravine shows at the base a blue-black bowlder clay with many pebbles. This clay has the typical characteristics of the pre-Kansan. Its blackness here is quite noticeable and leads one on first view to expect a Carboniferous shale. It does not extend along the entire base of the exposure and seems to be separated from the remainder of the latter by a zone of weathering. Over it where first seen are beds of stratified sand, gravel, and loess with at least one pretty well marked zone of weathering. North of the ravine is a blue bowlder clay, not so dark in color, breaking cubically rather than in flakes, and passing upward into a yellow bowlder clay containing masses of highly weathered gravels of Aftonian aspect. Then yellowing, resultant on oxidation, here follows the cracks well down into the blue clay. In the adjoining region the usual succession of loess, gumbo, yellow and blue bowlder clay is seen. The compact black flaky bowlder clay is unusual. At the exposure itself the facts are not altogether clear, but this much may be stated definitely, that there is here a bowlder clay of a type uncommon for this region but of physical character very like that of the older drift at Afton Junction.

Directly west of Leon, on the main road to Decatur City (Sw. Sw. Sec. 29, Center Tp.), a long westward facing slope shows the exposure sketched below.

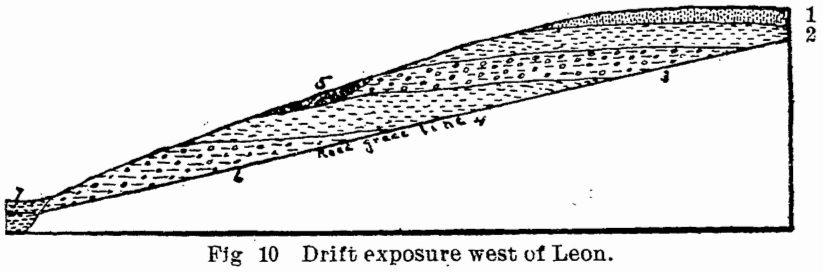


Fig 10 Drift exposure west of Leon.

On the top of the hill is the usual upland loess (1) running down over the edge of the rather steep slope. Below it is the normal gumbo deposit (2) eight to ten feet thick. Under this

is a yellow bowlder clay (3) with all the usual characteristics. So far the section is exactly the same as occurs throughout the county. The bowlder clay is, however, only about fifteen feet thick, and below it is found a second gumbo about twelve feet thick. This is a dark blue-drab clay. At its upper limit it contains humus and a distinct soil three to five inches thick. The soil is quite black and well marked, though thin. It contains some roots which do not seem to come down from the bowlder clay. The latter shows slight evidence of water action for as much as a foot above the gumbo, but above that is the normal unstratified bowlder clay. Under the gumbo is a second yellow bowlder clay (6) not differing in any known particular from that above. It carries cherts, red and gray granites, limestones, greenstones, iron concretions and quartzites. The same sorts of rocks are found in the clay above. Both show evidence of age and carry much weathered material. At the foot of the slope is the alluvium of the bottomland.

The ravines at the side of the road have cut back far enough to show that the beds lie directly under each other as indicated. The upper bowlder clay (3) where it rests upon the lower gumbo (4) is not the hillside wash or the result of creep. The material brought down by these processes is shown at 5 and is quite distinct. It includes smaller pebbles, is sandier, very gravelly, and distinctly waterlaid. It can be distinguished at a glance. No hypothesis of slipping seems able to account for the arrangement of the beds and they seem to indicate true and original superposition. This is the more probable from the fact that exactly similar exposures, except that the relations are even clearer, may be seen about one and a half miles east of Osceola in Clarke county. At several points in the ravines north of Weldon the same phenomena seem to be present though the exposures are not good. Only at the Leon exposure was the soil on top the lower gumbo noted. It has here the appearance of a buried soil with the upper portion removed, leaving only a little of the soil proper over the

subsoil. There is no sufficient evidence of erosion at any point in the section lower than the top of the upper bowlder clay.

In regions where the superimposed drift sheets occur, buried forests are not uncommonly encountered. This is particularly true in regions near the edge of an upper drift, where, probably as a result of the fact that but little ice passed over the forest, it is better preserved. Buried forests are not of equal significance. They may readily occur as a result of temporary retreats and advances of the ice where only one drift sheet is present. It is only when they throw light upon the climate or physical conditions obtaining during the interrum that they have important bearing. It should always be remembered, however, that the simplest explanation is not necessarily the true one, and that where the facts are capable of explanation equally well by the hypothesis of one or of two ice sheets, it is by no means necessarily true that the former hypothesis is to be preferred.

There are evidences of a buried forest in Decatur county, and in the adjoining region. Indeed, such evidence is found at a number of points in southern Iowa, and has been reviewed at another place.* In Decatur county the forest bed is best known in the vicinity of Lamoni, where it has been encountered in several wells. In the elevator well at that place it was struck at a depth of 85 feet, and below it there was a thickness of 100 feet of bowlder clay. It is clear that this forest bed is far below the base of the loess and is in the bowlder clay. There are no specimens of wood at hand, though the material examined by Prof. T. J. Fitzpatrick was found to be coniferous. The climatic bearing of the find is unimportant. The significant facts are that the bed is of some thickness, occurs commonly in the deep wells over quite a wide region, and is in the bowlder clay. It evidently neither represents adventitious wood in the latter, nor any post-Kansan accumulations.

*Proc. Iowa Acad. Sci., vol. V.

In Harrison county, Mo., Dr. C. R. Keyes* reports a nine-foot forest bed struck at a depth of about 120 feet and in the drift. The evidence here would seem to be of the same nature as at Lamoni, but the thickness of the bed makes more impossible any reference of the deposits to adventitions sources, and indicates some little time of accumulation.

These two cases represent the better examples of buried forests in Decatur and its immediate vicinity. Other cases are reported, but do not seem so reliable. In Union county good specimens of peat have been obtained from wells near Afton, but the horizon is not well fixed and may be of later age. Setting aside for the present the buried gumbo near Leon, it will be noted that there are in this county or its immediate vicinity the following evidences of two drifts.

1. Waterlaid deposits between tills.
2. Buried forests and soil horizons.
3. Traces of an underlying till of peculiar and marked physical character.

In considering the first of these it will at once suggest itself that the large amount of ice necessitates considerable water-action (though not necessarily "great floods"), and that accordingly waterlaid beds may be expected to occur at various horizons in and about the drift. It is possible, however, that the deposits should be of such a nature as clearly interdict any reference to ice-derived floods in their formation, or their distribution might be such as to show that they followed a considerable period of erosion. Neither is exactly true in this case, but it is true that the gravels found above Westerville are of the same character and occupy the same position as those found at Afton, and there are some reasons for believing that the latter accumulated during a considerable period of erosion.

Regarding the evidence derived from buried soils and forest beds but little can be added to what has already been said. It is manifestly uncertain and of slight independent value.

*Private communication.

The third point is one hard to estimate. It is true, however, that whatever one may think of correlations based upon the color and physical characteristic of bowlder clays, there is certainly some significance in the fact that at every known exposure in Iowa, of bowlder clays which for various reasons are considered as probably older than the Kansan, the phy sical character of the bowlder clay is the same, and that it is markedly different from that of the Kansan.

This is true not only of such clays in southwestern Iowa but of the exposures at Albion in Marshall county, Oelwein in Fayette, and at Muscatine. It is certainly a fact of some significance. Probably none of these classes of evidence at this point would independently prove the presence of a pre-Kansan drift, but it must be remembered the facts have a cumulative value. If, for example, a single exposure showed a forest bed, a soil and waterlaid deposits between drift sheets of markedly different physical characters, and there were no opposing phenomena in the surrounding region, but one inference could be drawn. In the same way when the three classes of phenomena occur not in the same, but in contiguous exposures, they gather weight from the association. For this reason it is believed that the evidence from Decatur county, meager though it admittedly is, supports the hypothesis that there are traces of a pre-Kansan drift sheet in the region, separated from the Kansan by an unknown but probably important interval.

The exposures near Leon, it is believed, are best interpreted as results of changes in the front of the Kansan ice sheet. The gumbo alone proves only that there was a period when fine sedimentation such as is characteristic of still waters could go on for some time. The soil has been so nearly removed that its original thickness can only be guessed, and it is recognized that soils alone do not necessarily indicate an especially long lapse of time. The thickness of the overlying till and the total lack of distinguishing marks between it and that below the gumbo throws the exposure out of harmony

with those of the Aftonian and pre-Kansan beds. The apparently local nature of the phenomena, confined as they are to a relative narrow belt stretching from Osceola to Leon, suggests a local cause.

In the recent railway cuts of the D. M. & K. C. railway there are, at a few points, gravels suggestive of the Buchanan. The gravel consists of small well rounded pebbles, is highly stained, carries weathered material, and occurs apparently in pockets in the top of the Kansan and under the gumbo. It has the appearance at times of local hillside wash; but its occurrence at such widely scattered points as Leon, New Virginia, and Truro, together with the fact that in eastern Iowa the Buchanan gravels often occur some miles out from the edge of the later Iowan drift, suggests the advisability of keeping in mind the alternative hypothesis.

Glacial striæ.—The limestone on Pot Hole creek at one point shows striæ as indicated in Plate xxiii. As measured by Prof. T. J. Fitzpatrick these have a direction of s. 1° w. magnetic. They are upon the Winterset limestone and below the Kansan drift.

LOESS AND GUMBO.

The only general deposits occurring throughout the county and later than the drift are the loess and the gumbo clay. They are of the general type familiar throughout southern Iowa and northern Missouri. The loess is of the older or white clay phase, and as compared with that found along the Mississippi and Missouri rivers as well as inland farther north, is less porous, more plastic, and non-fossiliferous. It carries lime nodules but is free from pebbles. It graduates upward into the black loam which forms the prairie soil.

The gumbo belongs stratigraphically with the loess. It occurs below the latter, and has a blue to drab color. It is even more plastic and less porous than the loess. When damp but not wet, it has a mealy appearance which is quite deceptive as to its real character. It rarely carries pebbles though a

few have been found in it. It often contains small lime balls but these are neither so large nor so numerous as in the loess. It has the appearance of being finer grained than the latter and suggests a quiet water deposit which has since been compacted or puddled by water. In general the gumbo is about ten feet thick and rests on the ferretto horizon of the Kansan. The loess is from ten to as much as twenty feet thick. Both deposits passed down the flanks of the hills into the larger valleys.

ALLUVIUM.

The alluvial deposits of Decatur county while extensive have little that is peculiar. They cover the broad bottoms of Grand, Weldon and Little rivers, and occur along many of the minor streams. As a rule the alluvium is not of any remarkable thickness. Along Grand river the flood plain is usually about fifteen feet above ordinary water stages. The alluvium is necessarily made up in the main of material derived from the loess and gumbo. South of Davis City, however, along Dickerson creek, it contains large bodies of sand and gravel, derived apparently from beds of the same age as the gravels above Westerville. Inasmuch as the river does not show this material in the region between Westerville and Davis City, it is highly probable that the beds which formed the source of the Dickerson creek deposits are concealed below the drift in the hills west of Davis City.

STRUCTURE.

The rocks of the county have been subjected to very little disturbance. The dip noted west of Decatur (see Plate xxiv) is the most pronounced in the county. It is entirely local and throughout the area the rocks lie very nearly horizontal. Apparently the general dip to the southwest which characterizes the rocks of so much of the state is here almost entirely absent. There are no data which warrant considering it here to be more than one or two feet per mile. The base of the Bethany,

so far as Decatur county is concerned, seems to occupy a practically horizontal plane.

ECONOMIC PRODUCTS.

Coal.

That Decatur county lies within the limits of the coal measures has long been known. The exposures of black shale outcropping along the streams in various portions of the county, and already discussed, have led to considerable exploration in a small way, and have been the basis of various local coal excitements. As has already been stated the shale seen along the ravines belongs almost exclusively to the Upper or barren coal measures. In a few cases it carries with it a little coal. Along Weldon river in early days some coal was taken from the horizon below the Earlham limestone. Near the Cole mill (Sec. 14, Hamilton Twp.), in excavating for the bridge, it is stated that as much as eight inches of coal was found at this horizon. This thickness is quite exceptional. At no place in the county does coal of workable thickness outcrop. Any supplies which may be obtained must come from lower horizons. As has already been stated the Des Moines formation extends under the Missourian. The dip is such as to bring the various coal horizons worked in the counties northeast of Decatur some distance below the base of the limestone here.

The Des Moines formation in southern Iowa is composed of three members. (1) The lowermost beds of shales, sandstones and coal exposed along the Des Moines river, and from there west to the Chariton, and probably the equivalent of the Cherokee shales of Kansas;* (2) the Appanoose formation consisting of a series of limestones and shales, and carrying the Mystic coal outcropping west of the Chariton river in Appanoose county† and extending under the eastern portion

*Haworth and Kirk: Kansas Univ. Quart., vol. II, p. 105. 1894. Haworth: Univ. Geol. Surv., Kansas, vol. I, pp. 150-151. 1896.

†Geol. Appanoose county, Iowa Geol. Surv, vol. V, 378, *et seq.* 1896.

at least, of Wayne county; (3) a shale sequence, as yet but little studied and infrequently exposed, extending over western Wayne county, and outcropping immediately below the base of the Bethany in Decatur and adjoining counties. It is probable, but as yet unproven, that this formation is to be correlated with the Pleasanton shales of Kansas*. The Pleasanton shales in this region, at least, are not coal-bearing. Their thickness is not certainly known, but is probably not less than seventy-five feet.

The Appanoose formation carries a much worked and valuable coal bed, thirty inches thick. This coal thins, however, to the west; being at Harvard in Wayne county but twenty-two inches in thickness. The dip of the bed if persistent is such as to bring the Mystic coal horizon about 100-150 below the base of the Bethany limestone in Decatur county. It is not certain, however, that the Appanoose formation maintains itself so far to the west. Toward the north in Lucas, Warren, Madison, Guthrie and Dallas counties, its equivalents take on a character somewhat different from that of the typical exposures. The general facies, however, of the formation remains the same; *i. e.*, it consists of argillaceous shales, thin limestones and thin but persistent coal beds. Its normal thickness is usually about eighty feet. Its base should be about 160 feet below the Bethany.

The coal output of Iowa, with the exception of that derived from the Mystic bed, comes almost entirely from thick coal beds of the Cherokee shales. The workable coal occurs in this formation along certain fairly persistent horizons marked in general by the presence of bituminous matter in some form, but varying much and rapidly in the thickness of actual coal. The better horizons are uniformly near the base of the formation. The best, perhaps, may be called the Wapello horizon from its considerable development in the county of that name.

The Wapello horizon has been proven through much of Keokuk, Mahaska, Marion, Wapello, Monroe and Lucas coun-

*Haworth: Kansas Univ. Quart., III, 274, 1895; Univ. Geol. Surv., Kansas, I, 152-153. 1896. Keyes: Proc. Iowa Acad. Sci., vol. IV, 24-25. 1897.

ties. The old Whitebreast mines at Cleveland in the last county mentioned, were the farthest west of any mines which have worked this horizon. From its proven extent and general richness it is the horizon most likely to yield returns to prospectors. Near Chariton, it occurs at about 675–700 feet above sea level and approximately 200 feet below the base of the beds corresponding to the Appanoose formation. At Centerville it should be at approximately 525 feet above sea level or 400 feet below the base of the Appanoose. Making the proper allowance for dip, the horizon should occur at a depth of approximately 500 feet below the base of the Bethany in Decatur county.

Whether or not it would carry workable coal so far to the west can not be foretold and can only be determined by careful work with the diamond drill. In the region where the horizon has so far been opened up it has been found to be generally rich but to be often entirely or practically barren. Even where the field is best known and has been most largely developed it requires careful and extensive drilling to locate the coal accurately enough to warrant opening a mine. The coal is not evenly distributed along this horizon but lies in a series of partially or wholly disconnected basins. Within the limits of a single square mile it varies in thickness from nothing to seven feet. In a recent set of twenty diamond drill holes through this horizon only ten showed coal of more than three feet in thickness and seven showed no coal at all.

The attempts so far made to locate coal, in or near Decatur county, have not been entirely successful. At Davis City a boring was put down about twenty years ago. Starting near the base of the Bethany limestone it was carried to a depth of 212 feet and is said to have shown only two seams of coal four inches and six inches thick respectively. Near De Kalb a hole was sometime since put down without success. This started at the base of the De Kalb limestone and ended apparently in the Pleasanton shales. An examination of such of

the drillings as have been preserved shows the usual limestone and shale sequence.

At Bethany, Missouri, a hole was drilled in 1895, starting at the base of the Bethany limestone. It was carried down to 650 feet and should accordingly have reached the Wapello horizon. No coal more than nine inches thick was reported. Winslow* who reports the drillings, casts some doubts on its accuracy.

In 1897 Mr. C. Woodruff of High Point, in drilling for water reported three beds of coal respectively one foot, three feet and four inches in thickness. The hole was located upon the highland and started accordingly approximately 1125 feet above sea level. It was carried to a depth of 412 feet and seems to have stopped in the Cherokee shales.

So far as known all drilling mentioned was done with the churn or jump drill. In the last case at least, coal was not sought, so that no special preparations were made for the accurate determination of its thickness. As is easily understood, results, particularly at such depths, based upon churn drill records have very small value. The method does not permit, except under the most favorable circumstances of fine discrimination. Results of real value are only to be obtained by means of the core drill.

There has been some recent discussion in the county as to the advisability of direct prospecting for coal, and because of this fact, as well as the further facts that the conditions here are very similar to those obtaining over a considerable portion of southwestern Iowa, it may be advisable to say a little as to the cost of such work. From what has been said it will be readily understood that there is no coal to be obtained in the surface formations. Also that below these is a thickness of seventy feet of shales which are practically, if not entirely, barren. Below these in turn is a thickness of 150–200 feet which from all previous experience may be expected to carry thin coal, but no thick seams; probably no coal as much as two feet

* Mo. Geol. Surv., vol. I, p. 99. 1891.

thick. There is accordingly a thickness of at least 200 feet under the lowland or 400 feet under the high table land which for practical purposes may be expected to prove barren. Below this is a thickness of 300–400 feet in which coal may be found; the chances of thick coal increasing toward the bottom. To explore the strata thoroughly a hole running from 500 to 600 feet in depth would have to be drilled even if one could so locate the work as always to drill from the lowland. If the prospecting company owned its own drill and were not unfortunate in the loss of diamonds, the cost would probably average $1 to $1.25 per foot provided 5,000 to 10,000 feet were drilled. To locate 400 to 600 acres of workable coal, provided the strata prove as rich as farther east, a matter unproven, once could hardly count on less than twenty and might need 100 drill holes. The work would accordingly cost $10,000 to $40,000 or more. In the end it might prove that the money would be lost, though on the whole it seems probable that some coal at least would be located, though perhaps not enough to warrant a large mine. In some exploratory work in Iowa where the holes are about half as deep as they would need to be here about $7,000 was spent and work was carried on for nearly two years before a good coal basin was located. If a suitable coal basin were located the cost of working it would probably not be prohibitive. It would depend more upon the amount of railway track necessary than the depth to the coal, and if it should chance that the shaft could be located near a present railway the mine might even cost less than some now operated. The amount of capital invested would depend largely upon whether the mineral rights were leased or purchased, and upon the equipment of the mine. It might perhaps be as low as $60,000 under very favorable circumstances, or as much as $150,000. A large percentage of this would necessarily be invested before any return could be expected.

It will hardly be seriously thought that the present local market, or any probable local market of the immediate future,

would warrant such an investment. It remains to examine the chance for a shipping mine. A mine in Decatur county would have the theoretical advantage in competition of nearness to Missouri river points. Practically this advantage would not be entirely realized. The C., B. & Q. railway would furnish a direct line to St. Joseph and when the D. M. & K. C. railway is extended, a short line to Kansas City would be open. Both of these markets are, however, well supplied, and competition is so keen as to offer few attractions to prospective investors. Coal would not, of course, be sold north or east to advantage. In reaching the Omaha, Sioux City and Nebraska markets, a local railway tariff would always tend to destroy any slight advantage which the location gives.

Under present circumstances it will be seen that the opening of the Decatur county coal field would be too hazardous to be a legitimate business venture. One might put down one hole and strike workable coal, and open up on such slender prospects. Such things have been done occasionally with profit, often with loss; but the undertaking would be a gambler's chance, not a business proposition. For the present it is probably better not even to put down random search holes. If good coal were found in such a hole it probably would not serve to interest capital and if no coal were found it would discourage future work, even though such a result is entirely unwarranted by the conditions of the field. Some time in the years to come when the demand for coal is greater, southwestern Iowa will be prospected and then the Grand river valley will prove the most inviting field, not so much because of any better prospect of coal occurring there rather than under the hills or in other valleys, but because the depth to which the river has cut will make the prospecting cheaper and easier. Until that time Decatur county's wealth must come, as in the present and past from its other resources.

Clays.

The clays so far developed in Decatur county have come entirely from the surface formations. The loess present throughout the county, is of the older type common in southern Iowa. It has become somewhat changed for a depth of twelve to eighteen inches from the surface, losing some of the finer and more soluble constituents and acquiring a considerable proportion of humus. The soil resulting is admirably adapted to the production of hand brick, having all the usual characteristics of alluvium. It is now used at Garden Grove and Leon. The main body of the loess below the soil, and the gumbo clays below the loess have not so far been worked. The gumbo clays are not of any value for manufacturing except in the production of clay ballast. For this purpose they are unexcelled, their plasticity and high tensile strength causing them to shrink considerably in burning and so by cracking, open up the pieces of clay to thorough interior burning. These very properties make them unavailable for use in ordinary clay works. The gumbo clays are widely distributed throughout the county and their ready accessibility makes them a valuable source of burned clay. So far they have been used only by the C., B. & Q. railway, for which several kilns have been burned at Davis City. The material here is obtained from lowland forming a long gentle slope on the west side of Grand river. It may represent, in part at least, redeposited gumbo worked over by the river. The earliest kilns here were burned by hand and required a large force of men. Ballast is now being hauled out which, however, was burned about five years ago with the aid of machines.

The material is light, porous and yet strong. It seems probable that in the future it will become an important source of road metal and be applied to the improvement of the wagon roads. The wide distribution of the clays, the ease with which it can be obtained and the cheapness with which it can be burned, all render it worthy of serious investigation.

The shale clays occurring in the county have never been utilized. From the point of view of accessibility the shales at Davis City and De Kalb are the only ones at present worthy of consideration. In each case the thickness is not great, and the shales carry limestone nodules. At De Kalb an important portion of the section (p. 278) consists of bituminous shale or slate, which would need to be thrown aside. The clays would in all probability yield a good hard brick, and possibly pavers could also be made. They could not, however, be worked by open pits, but would need to be mined. This would impose no especial burdens at De Kalb as there is a good limestone roof and a fair thickness of clay above water level. It would, however, make the work more expensive than at many competing plants.

The brick made at present are the common salmon brick. bringing about $6 per thousand. The Foster Mullinix yard is located in the northeastern portion of Leon. The brick are hand made from the surface loam and burned with wood in a cased kiln. South of Leon (Tp. 68 N., R. XXV W., Sec. 9, Sw. of Se.) W. H. Mills has burned brick of the same character. None were burned here in 1897. W. H. Jenkins runs two kilns having a capacity of 100,000 each, in the northern part of Leon, and Mr. G. C. Dilsaber burns brick of the usual character at Garden Grove. Mr. Dilsaber has recently installed a brick machine and intends to work the loess under the surface loam. The loess here should make a good hard brick of cherry red color if properly handled. It will doubtless, as usual, require extra care in drying, but there is no reason to doubt that here, as at other upland points in the county, a considerable and profitable industry in the manufacture of standard building brick can be built up.

Building Stones.

The great limestone formation which underlies so considerable a portion of the county has been opened up and quarried at a number of widely distributed points. In the main, the

quarries are located in the western half of the county. In the southeastern townships a little stone has been taken out, but none of the openings there are extensive enough to be called quarries in a commercial sense. Indeed nowhere in the county is stone quarried upon an extensive scale. A majority of the openings are for local and temporary purposes. Few enjoy a regular trade and all are worked intermittently. Nevertheless the aggregate amount of stone taken out in any one year is fairly considerable. For the most part it is used rough for foundations and for well rock. A considerable amount is used in the county bridge work. Some is sold as dimension stone and some has been dressed and used for monumental purposes.

The quarry appliances are of the simplest. In general the stripping is removed by hand and wheelbarrow; occasionally scrapers are employed. The rock is pried loose by wedges and crow-bars, or where these means are ineffectual, the jump drill and blasting powder are called into requisition. In most instances perhaps, the quarries are worked on short leases; royalties being paid to the fee holder, and the quarryman deserting the opening so soon as the stripping becomes heavy or the bedding too massive for his tools. For these reasons the stone has not been opened up enough to allow its real value and character to be positively determined. That which has so far been placed upon the market has been almost entirely obtained from the croppings.

So far as shown by the natural outcrops and the quarries now open, the stone is predominantly thin-bedded. Ledges of over 12 inches are rare, though stone of 14 and 18 inches may be found. The majority of courses, however, show 4, 6 and 8 inch stone. In this particular there seems to be but little difference between the various members of the formation, except that in general the Winterset seems to include heavier courses than either the De Kalb or the Earlham, which are the main quarry rocks. In physical characteristics there is considerable uniformity. The rock is fine-grained and usually

ash-grey to buff in color. It breaks with a conchoidal fracture showing smooth surfaces set with inclosures of clear calcite. It is a non-magnesian stone of great purity and contains little or no pyrites. So far as its mineralogical constitution is concerned it is well adapted to withstand weathering agencies. As a matter of fact the stone so far quarried does not usually withstand weathering so well as its general appearance would lead one to expect. It splits and cracks under frost action, the fault apparently being in the physical structure of the rock. It is cut by minute cracks which allow the absorption of water, while the close texture prevents this from freezing out, so that the full force of the expansion, which has been calculated to be as much as 138 tons per square foot, is expended upon the rock. Since this rock has a crushing strength only of about 4,500 lbs. per square inch, a good deal of it gives way before this strain. Some of the ledges naturally withstand frost action better than others, but it is doubtful whether it would be practicable to quarry them separately with a profit. For the purposes to which the stone is now applied it answers well enough, but its use in large and important structures or in bridge work, except after careful selection, can not be recommended.

It is quite probable that the Winterset rock would yield an average stone of better quality than that now marketed; but so far it has been but little quarried.

The Westerville limestone occurring in the hills along Sand creek, has not been quarried to any great extent. In general it is very similar to the De Kalb in character. A thickness of about ten feet is present and the stone is readily accessible. The rock showing near the water at the mill is the same as is exposed at Reynold's ford. It is a thin bed of impure nodular rock and has only a slight value.

In the vicinity of Grand river station there are numerous quarries working the De Kalb limestone. Among them are the quarries of S. C. Jennings, Blair Brenneman and C. Miles. The Miles quarry is east of the town near the railway bridge

over Grand river. The total thickness of the stone is about three feet, the ledge yielding rock six and eight inches thick. It is a hard blue stone somewhat similar to the Reynolds' Ford rock and may represent the same horizon, though apparently at Grand river it is not far above the De Kalb proper. The most pretentious attempt to quarry the De Kalb limestone was at the old Madarasz quarry, now abandoned. This quarry is located on the river about three miles northeast of town, in section 36. It was opened near the Humeston & Shenandoah railway and at one time had a switch from that road. It is said that considerable rock was taken from the quarry for railway construction. Nothing can now be seen of the quarry face, which is said to have shown ten feet of stone with the base five feet above the river.

East of De Kalb station are the typical exposures of the De Kalb rock. A section has already been given but the following details from a neighboring quarry will show the thickness of the individual ledges.

		FEET	INCHES.
6.	Stripping, bowlder clay	6	
5.	Limestone, irregular and waterworn		6
4.	Shale, hard		6
3.	Limestone, irregularly bedded		8
2.	Shale or bastard rock	2	
1.	Limestone in five ledges that are respectively 9, 12, 6, 13 and 8 inches in thickness	4	

The upper courses yield little of value and the main output is of stone from the lower ledges. There are two quarries here, the south one being owned by Mr. B. D. De Kalb and the north one by Martha Fry. A short distance west of De Kalb station the stone has also been opened up on Short creek (Ne. of Nw. Sec. 32, Long Creek Tp.). In the quarries here the following section was observed.

		FEET.	INCHES.
10.	Shale, gray to green	2	6
9.	Limestone, shaly		6
8.	Limestone, solid		9
7.	Shale, drab to yellow	2	

		FEET.	INCHES.
6.	Limestone, thin, shaly		4
5.	Clay parting		2
4	Limestone	1	
3.	Limestone		5
2	Limestone		4
1.	Limestone.		6

The rock is the usual character and carries *Productus nebrascensis, Productus cora, Productus costatus, Meekella striato-costata* and *Chonetes verneuilanus.*

Along Hall run and Elk creek, in Grand River and Bloomington townships, there are numerous exposures of the De Kalb and Winterset, and, near the mouth of Elk creek, the Earlham limestones. The exposure shown in Fig. 2, Plate xxiv, is one of the best and shows the Winterset limestone to a thickness of fifteen feet with the shales below it and extending down to the Earlham. This exposure is almost five miles northeast of Lamoni on Pot Hole or Potters' branch. The section at this point includes the following beds.

		FEET.	INCHES.
6.	Limestone (Winterset) with *Spirifer camerata, Productus punctatus, Productus costatus, Athyris subtilita*, etc	15	
5.	Shale, gray to drab	3	6
4.	Shale bitmuinous	2	6
3.	Coal		1½
2.	Shale, gray	6	
1.	Limestone (Earlham) in bed of creek.		

A few miles north of here at the Millsap quarries (Sec. 34, Grand river Tp.) the base of the De Kalb limestone shows again with some ledges of rock thirty-six inches thick. Below the limestone is a drab to gray shale carrying *Athyris subtilita* and *Productus longispinus.* About five feet below the base of the limestone, and in the shale, is a third band of limestone very full of *Chonetes verneuilanus* and overlying an irregular ledge of nodular blue limestone carrying large well formed *Productus cora.* The exposure does not seem deep enough to expose the Myalina horizon though *Derbya crassa* is present.

In the southeast corner of the same section the blue limestone shows again and a short distance farther down the Winterset is exposed.

In the northwestern portion of Burrell township the Fragmental, Earlham and Winterset limestones and associated shales are exposed on the west side of the river (Sec. 7, W. ½ Ne. ¼). On the east side of the river the Earlham has been quarried on the Anton Rauch land. This quarry has not recently been worked but the stock pile shows some excellent eighteen-inch rock. The stone from the quarry has been dressed and sold for monumental work.

South of Terre Haute on Pot Hole branch, near the exposure of Winterset figured above, there are the S. A. Ferguson, N. N. Hazelton, and Isaac Toney quarries, all in the Earlham rock. The section here is as follows:

		FEET.
3.	Limestone, ash gray to brown, fine-grained, thin-bedded, with courses up to 1 foot in thickness and shale partings	6–10
2.	Shale, drab, imperfectly exposed, but showing 1 foot of black slate	10
1.	Limestone, brecciated or fragmental type, firmly cemented and apparently non-fossiliferous	4

It is the upper rock which is quarried and which carries *Athyris subtilita* (abundant) *Productus cora*, *Productus cameratus*, *Productus costatus*, *Rhynchonella uta*, *Hustedia mormoni* (rare) and the usual stems and spines of crinoids. The rock dips to the west, and the Winterset present in the hills above is exposed farther up the stream.

Near Davis City there are quarries both north and southwest of town. The main quarry north of town is the S. Radnick, which is opened in the Earlham. The quarries southwest of town are along Dickerson branch and include the W. Rickards, Hugh Sutherland, Jos. Boswell, and C. Noble openings. These are all small openings in the Earlham.

As seen at the Boswell quarry the section is as given below.

		FEET.	INCHES.
6.	Stripping, loess-loam	2–4	
5.	Limestone	1	
4.	Rotten stone and shale	2	
3.	Limestone, 14-inch ledge carrying a 3-inch ledge below	1	5
2.	Shale and rotten stone	1	
1.	Limestone, with wavy bedding, ledges running from 3 to 16 inches	6	

The bedding in the lower stone is quite irregular. The courses are persistent but vary rapidly in thickness so that the surface lines are wavy. In the roadway, about ten feet below the stone, are traces of a black slate; and in the stream, about twenty feet below the quarry, the Fragmental rock outcrops. It is unfossiliferous except for the presence of *Productus cora*, is loosely cemented and crumbles so readily that it does not form a ledge. The Winterset limestone is present higher in the hills and possibly also the De Kalb.

The location of the various outcrops in the southeastern portion of the county and the character of the stone has already been sufficiently indicated.

Lime.

In the earlier years of the settlement of the county lime was burned at several points. The rock is not, however, adapted to the manufacture of the best grade of lime, owing to its non-magnesian character, and with the better transportation facilities now enjoyed by the region the trade has passed into the hands of producers in other sections of the country. The non-magnesian rocks burn to a clear white lime of good appearance, but which really affords a weaker bond than that furnished by the magnesian lime. It is also difficult to handle and can only be worked by exercising great care in slacking and by using an abundance of water. For these reasons it would compete upon unequal terms with the lime now on the market, and except in especial instances the old industry is not apt to be revived. The purity of the stone

suggests that it would be an excellent source of lime for cement production whenever it becomes economical to grind limestone for that purpose. For the present the chalks and marls shut it out of that field.

A partial analysis made for the survey by Dr. J. B. Weems gave the following results.

$Ca\ CO_2$	91.96
$Mg\ CO_3$	1.99
H_2O	.07

This sample was from the De Kalb limestone as shown at the type locality. It emphasizes the fact of the purity of the stone which is essentially calcium carbonate and would yield 51.25 per cent of lime (Ca O). While, as has been stated, this would be a non-magnesian lime, it may be remembered that the St. Louis and other Missouri limes, which enjoy a large trade, are of this character. Analyses of several of these are given below.*

	I	II.	III.	IV.
Carbonate of lime	99.815	92.75	97.76	98.80
Magnesia	Tr.	3.26	.12	.02
Oxide of magnesia	Tr.	.....	.....	.....
Alumna	.054	.48	.....	.40
Oxide of Iron	.011	.40	.20	
Silicic and insol	.12	.495	.26	.08
Phosphoric acid	None.	.....	.....	.....
Sulphuric acid	Tr.	.....	.....	.....
Calcium sulphate	.....	Tr	.....	.....
Water	.....	.675	.....	.....
Alkalis and loss	.....	1.94	.....	.....
Total	100.00	100.00	98.34	99.30

I. Ash Grove white lime.
II. Champion white limestone, Ash Grove, Mo.
III. Limestone from St. Louis county.
IV. Limestone from Marion county, Mo.

*Minn. Res. U. S., 1889-90, pp. 406-407.

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF DECATUR COUNTY, IOWA.

BY

H. F. BAIN

1898.

Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

MISSOURIAN

DES MOINES

INDUSTRIES

CLAY PITS ▲

QUARRIES

IOWA LITHO. CO. DES MOINES.

DRAWN BY F. C. TATE.

ACKNOWLEDGMENTS.

In the preparation of this report the author has received information and other courtesies from a large number of persons both within and without the county. It is impossible to mention everyone but especial reference must be made to Prof. T. J. Fitzpatrick of Graceland college who furnished the list of forest trees appended and to Mr. F. M. Smith with him for the photographs from which Plate xxiii and Fig. 2, Plate xxiv, were prepared. To Prof. Calvin is due the determination of the fossils and to Mr. William Haven of Ottumwa, is due certain valuable suggestions used in discussing the coal. To Mr. Morgan G. Thomas, state mine inspector, the author is particularly indebted for reviewing the latter section of the report and checking the cost estimates there made.

FOREST TREES AND SHRUBS OF DECATUR COUNTY.

BY T. J. FITZPATRICK.

Decatur county is essentially an expanse of prairie with narrow sinuous belts of timber stretched along Grand river and its tributaries. Unbroken prairie is being slowly occupied by forests. In such places the hazelnut, ground oak, laurel oak, red oak, bur oak, white oak, and the elms are slowly establishing themselves. Many of these embryo forests exist and are annually drawn upon for fencing material and firewood. While perhaps the larger number of such forests are being reduced in size or destroyed, in order to increase the area of tillable soil or of pasture, yet these forests, if carefully husbanded, would be sufficient for future needs. The older forests are confined to the main water courses and are of limited extent. Here the soft timber predominates. The

white oak, hard maple and other trees of like character are too few in number to be of consequence in the manufacture of lumber. A few saw mills are located in the county and produce annually a small amount chiefly of soft lumber which is used locally.

The nomenclature of the following list of trees and shrubs is that of the sixth edition of Gray's Manual.

TILIACEÆ.

Tilia americana L. Basswood, Linden or Linn. Common in river bottoms and frequent in rich uplands.

RUTACEÆ.

Xanthoxylum americana Mill. Northern Prickly Ash. Frequent in woods.

CELASTRACEÆ.

Celastrus scandens L. Climbing Bitter Sweet. Frequent in upland woods.

Euonymus atropurpureus Jacq. Burning-Bush. Rich woods, infrequent.

RHAMNACEÆ.

Rhamnus lanceolata Pursh. Buckthorn. Common along fence rows bordering woods; frequent in thickets along highways.

Ceanothus americanus L. New Jersey Tea. Prairies and upland woods, rather rare.

C. ovatus Desf. Prairies and roadsides, common.

VITACEÆ.

Vitis riparia Mx. Wild Grape. Rich woods, common.

V. cinerea Englm. Downy Grape. Waste places, rare.

Ampelopsis quinquefolia Mx. Virginian Creeper. Rich woods, frequent.

SAPINDACEÆ.

Æsculus glabra Willd. Ohio or Fetid Buckeye. Rich woods, common but less so than formerly.

Acer saccharinum Wang. Hard or Sugar Maple. Frequent along Grand river but disappearing. Frequent in cultivation.

A. dasycarpum Ehrh. Soft Maple. Common in river bottoms, a frequent grove tree.

Negundo aceroides Moench. Box-Elder. Rich woods, common. Frequent in cultivation.

ANACARDIACEÆ.

Rhus glabra L. Smooth Sumach. Upland open woods, common.

R. toxicodendron L. Poison Ivy. Fence rows, woods; frequent.

LEGUMINOSÆ.

Amorpha canescens Nutt. Lead-Plant. Prairies and open woods, common.

A. fruticosa L. False Indigo. Rich soil in sloughs and low places, common.

Robinia pseudacacia L. Common Locust. A frequent tree along roadsides and in waste places.

Cercis canadensis L. Red-bud. Wooded bluffs. Frequent along Grand river below Woodmansee bridge.

Gymnocladus canadensis Lam. Kentucky Coffee-tree. A few in low woods below Woodmansee bridge.

Gleditschia triacanthos L. Honey-Locust. River bottoms and rich uplands, frequent.

ROSACEÆ.

Prunus americana Marsh. Wild Plum. Upland woods, common.

P. serotina Ehrh. Wild Black Cherry. Upland woods, frequent.

P. virginiana L. Choke-cherry. Rich woods, common.

Physocarpus opulifolius Max. Nine-bark. Rocky banks; infrequent.

Rubus occidentalis L. Raspberry. Fence rows, thickets, not common.

R. villosus Ait. Blackberry. Uplands, not common.

Rosa arkansana Porter. Common Wild Rose. Prairies, common. Determined by Mo. Bot. Gar.

Pyrus coronaria L. Crab-Apple. Thickets, common.

P. malus L. Apple. A frequent escape into fields and waste places.

Cratægus coccinea L. Red Hawthorn. Thickets, common.

C. tomentosa L. Scarlet Thorn. Thickets, frequent.

C. crus-galli L. Cockspur Thorn. Thickets, common.

Amelanchier canadensis T. & G. Service-berry. Wooded bluffs, frequent.

SAXIFRAGACEÆ.

Ribes gracile Mx. Missouri Gooseberry. Open low woods, frequent.

CORNACEÆ.

Cornus sericea L. Silky Cornel. Rich soil, frequent. This and the following were determined by the Mo. Bot. Gar.

C. paniculata L'Her. Panicled Cornel. Waysides, thickets, frequent.

CAPRIFOLIACEÆ.

Sambucus canadensis L. Elder. Rich soil, frequent.

Symphoricarpos vulgaris Mx. Coral-berry. Rich open woods, common.

RUBIACEÆ.

Cephalanthus occidentalis L. Button-bush. Swampy soil, frequent.

OLEACEÆ.

Fraxinus viridis Mx. Green Ash. A frequent tree in low or rich upland woods. Determined by the Mo. Bot. Gar.

F. americana L. This species is undoubtedly present but has not been observed.

BIGNONIACEÆ.

Catalpa speciosa Warder. Catalpa. A frequent tree in cultivation, rarely an escape.

URTICACEÆ.

Ulmus fulva Mx. Red or Slippery Elm. Rich woods, frequent.

U. americana L. White Elm. Rich woods, common.

Celtis occidentalis L. Hackberry. Low woods, frequent.

Maclura aurantiaca Nutt. Osage Orange. Formerly cultivated for hedge fences, frequently spontaneous.

Morus rubra L. Red Mulberry. Wooded bluffs and low woods, frequent.

PLATANACEÆ.

Platanus occidentalis L. Sycamore, Buttonwood. An infrequent tree along Grand river and its tributaries.

JUGLANDACEÆ.

Juylans nigra L. Black Walnut. Rich woods, frequent.

Carya alba Nutt. White Hickory. Upland woods, common.

C. sulcata Nutt. Shell-bark Hickory. Low woods along Grand river, once frequent but disappearing.

C. amara Nutt. Bitter-nut or Pignut Hickory. Rich woods, common.

CUPULIFERÆ.

Corylus americana Walt. Hazelnut. Uplands, common.

Ostrya virginica Willd. Ironwood, Hop-hornbeam. Wooded bluffs, frequent.

Carpinus caroliniana Walt. Ironwood, American Hornbeam. Wooded bluffs, frequent.

Quercus alba L. White Oak. Uplands, frequent.

Q. macrocarpa Mx. Bur Oak. A large tree in rich woods, shrubby on the prairies; common.

Q. bicolor Willd. Swamp White Oak. Bottom woods, common near Woodmansee bridge and elsewhere.

Q. muhlenbergii Englm. Chestnut Oak. Upland woods, infrequent.

Q. prinoides Willd. Ground Oak. Uplands, common.

Q. rubra L. Red Oak. Upland woods, frequent.

Q. coccinea Wang. Scarlet Oak. Upland woods, common.

Q. palustris Du Roi. Pin Oak. Low woods, frequent.

Q. imbricaria Mx. Laurel Oak, Shingle Oak. Upland woods, common.

Q. nigra L. Black Jack or Barren Oak. Uplands, frequent.

SALICACEÆ.

Populus tremuloides Mx. Quaking Asp. Upland woods.

P. monilifera Ait. Cottonwood. Low woods, frequent.

P. alba L. White Poplar. A cultivated variety of this is becoming a frequent escape.

Salix humilis Marsh. Prairie Willow. Prairies, common. Determined by the Mo. Bot. Gar.