Bain, H. F.
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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Guthrie county lies in the west central portion of the state, being in the fourth tier of counties east of the Missouri river, and occupying a similar position with reference to the southern boundary of the state. Carroll and Greene counties bound it on the north, Dallas lies to the east, Adair joins it on the south and Audubon on the west. It includes sixteen congressional townships and is divided into an equal number of civil townships. Owing to the presence of a correction line the townships of the southern tier are irregular in size and position. The county includes 593 square miles, of which a very small percentage only is unavailable for farming.

PREVIOUS GEOLOGICAL WORK.

Although Guthrie county offers exceptional facilities for geological research along certain lines, it has never been studied in great detail. Both Dr. C. A. White and Mr. O. H. St. John, in the course of their work in Iowa, spent some time in the county, and to them our previous knowledge of the region is very largely due.

Dr. White announced the discovery of Cretaceous rocks within the limits of the county in 1868.* Mr. St. John, in the season of 1867, spent some time in the region, his preliminary report being published in 1868.† In the final reports of the survey numerous incidental references were made to the rocks of Guthrie county by Dr. White, and a rather full description of its geology was given by Mr. St. John.‡ At the time this work was carried on the problems of the drift were very imperfectly understood and many wrong conceptions obtained, so that what was then written about the surface materials is in some respects misleading. The first special study of the glacial deposits of this county was that of Mr. Warren Upham

*Proc. Amer. As. Adv. Sci., 1868, XVII, 326-327. 1869.
†First and Second Ann. Rept. State Geologist, pp. 173-201. Des Moines, 1868.
‡Geol. Iowa, II, 95-130. Des Moines, 1870.

who, in 1880, visited Coon Rapids and adjacent portions of Guthrie county* and located the outer limit of the Wisconsin drift in that vicinity. The discovery of natural gas at Herndon led Mr. R. E. Call to visit the county, and a brief note upon the occurrence of the gas was published by him in 1892.† With these exceptions the county remained unvisited by geologists from the time of Dr. White's work up to the organization of the present survey.

In the course of the work of the present survey the region was visited in 1893 by Mr. A. J. Jones, who collected notes upon the coal deposits of the region,‡ and in 1894 by Mr. E. H. Lonsdale, who studied the clays. The notes collected by Messrs. Jones and Lonsdale have been freely used in the preparation of this report and the author is much indebted to them. In the course of the present field work the writer has had the advantage of the company of Prof. T. C. Chamberlin while visiting some of the more important localities. He has also had important field assistance from Mr. A. G. Leonard, and is furthermore indebted to Professor Calvin for many valuable suggestions, both in the field and office, and for the identification of fossils. Messrs. Lonsdale of Dale City, have aided the work in many ways. Their long and intimate acquaintance with the country and intelligent appreciation of the work has made their assistance particularly valuable. To Dr. James Lonsdale the survey is particularly indebted for pertinent suggestions.

PHYSIOGRAPHY.

TOPOGRAPHY.

Topographically Guthrie county is sharply separated into two portions, the dividing line following, in general, the right bank of the Middle Raccoon river. Through Cass and a portion of Victory townships the parallelism between this line

* Geol. Nat. Hist. Surv. Minn., Ninth Ann. Rept., 1880, 298-314, plate. Minneapolis, 1891.

† Mon. Rev. Iowa Weather and Crop Serv., vol. III, No. 11, pp. 6-7. Des Moines, 1892.

‡ Jones: Proc. Iowa Acad. Sci., vol. I, pt. iv., p. 61. Des Moines, 1894. Keyes: Iowa Geol. Surv., II, 242-253. Des Moines, 1894.

and the river is quite exact. Through a portion of Victory, and through Dodge, Highland and Orange townships, the line swings north of the river, touching it only at the mouth of Willow creek, and again just below Coon Rapids. This line is that of the southern limit of the Wisconsin drift as traced upon the accompanying map. The area within and lying northeast of this line has a characteristic drift topography; that outside has an equally characteristic erosion topography.

The drift topography as developed in Guthrie county is predominantly flat. There are no prominent elevations, no marked valleys. In detail, the flat plain breaks up into a series of low, rounded, often circular swells, irregularly disposed and separating a series of interlocking, saucer-shaped basins which are in contour the reverse of the swells. The relief is low, being normally less than thirty-five feet. The low swells do not have sharp contours, and are hardly pronounced enough even to deserve the name of hills. They have little individuality and are not arranged according to any order or system. Between them lie ill-defined basins occupied usually by shallow ponds, swamps or swales; areas of slough and shallow water. There are very many basins without outlets, and the whole is clearly a region of immature drainage. Springs are frequent and give rise to small streams, which wander aimlessly through the basins and are finally lost in some swamp or miniature lake. The few streams within the area, such as Bays branch and Mosquito creek, have indefinite valleys and no systematic series of tributaries. The sluggish water flows in narrow, ditch-like trenches, which are frequently barely cut through the sod.

Near the Raccoon river the country becomes more broken. At a few points it becoms quite morainic. In section 24 of Highland township there is a group of irregular hills rising fifty feet above the loess tableland, which is itself 130 feet above the river to the south. The hills present an irregular and intricate topography of steep slopes and considerable relief. The trend of the range is northwest-southeast. The

morainic topography extends but a short distance, and usually the greater roughness along the edge of the Wisconsin drift is, in this county, due to the nearness to the Raccoon river and the consequent greater erosion. Directly south of Bayard and between Willow creek and the river is a ridge rising fifty feet above the drift plain. It is composed of Cretaceous sandstone, and the prominence is probably due to the persistence of preglacial topography.

The influence of the Wisconsin ice shows itself in the Raccoon valley in two ways. At many points there is a gravel terrace which rises twenty to twenty-five feet above the water. It is usually wider than the widest alluvial plain, and is genetically related to the Wisconsin drift. At Rock Bluffs and along the lower portion of the Raccoon river the ice pushed over into the valley, so that one finds a bluff face which has not been modified and does not show normal erosion. In general, however, the Raccoon valley is but slightly influenced by the Wisconsin ice.

The topography of the area covered by the Wisconsin drift has not been fashioned by streams and it has been only slightly influenced by them. In this regard it stands in sharp contrast with that outside the Wisconsin limits. In this southern portion of the county the land forms are, as has been said, erosion forms. They have been developed upon the drift surface by the action of weathering and running water. In part, this water has been concentrated in gullies and ravines and has taken the form of rivulets, creeks and rivers. In part it has acted as a broad sheet over wide surfaces. By these two methods of erosion the land forms have been developed. The two different modes of action have produced two different forms of surface which in cross-section yield different curves. These curves, as developed in the region under discussion, are so well developed, so characteristic, and reveal this region so clearly that a brief description of them may not be out of place.

The materials in which the erosion has taken place, while somewhat diverse, are in a general way homogeneous. They include drift, soft sandstones and shales. These materials weather and erode differentially, and yet, in a broad way, the action is uniform. The differences induced by differential weathering are slight, are not at first operative, and in the end serve merely to modify the general results. The erosion dates in the main from the retreat of the Kansan ice, and with exceptions to be noted later, the surface may be considered to have been at that time a fairly even drift surface. The region is then one in which there has been long continued erosion upon an even plain of relatively homogeneous material. The erosion has been so long continued that the country is almost wholly reduced to slope. The slopes, however, are not all of the same character. The general surface is trenched by a system of major valleys, which are cut about 150 feet below the general upland level. These larger valleys have a well developed system of secondaries which in turn support tertiaries, all developed regularly, and together covering the country with a network of water courses and ravines. Back from each valley proper there is a long gentle slope to the divide between it and some neighboring valley. The slopes near the streams are quite pronounced, often becoming well marked bluffs. The general upland slope is very gentle, and often is hardly to be noticed. The upland slope and the upper portion of the bluff slopes are convex. The lower portion of the bluff slope where it joins the flood plain is concave. The convex slopes above lose their convexity and approach more nearly to a plain as the distance from the bluff increases. The concave slopes below obey the same law. One is the reverse of the other, the two meeting in the sharp bluff face. The concave slopes are not so conspicuous and are apt to be overlooked. As one passes over the country it is the long, sweeping convex slopes, merging by degrees into the almost plain lines of the upland, which make the greatest impression. It has been customary to consider the convex slope as the

product of weathering* and the concave slope as the curve of erosion.† For the region under discussion, however, this does not seem to hold true. The very gentle upland slope, hardly to be called a curve, though merging into the convex curve of the bluff, is developed in the region which has been moulded by weathering agencies. The sharply convex slope of the bluff is at the point where erosion is most active. The concave curve appears only where there has been deposition coupled with erosion. This seems to hold true for the whole region, and one is forced to reject the concave as the normal curve of erosion if this region represents average conditions. This does not of course apply to the general curve of the whole of a river profile which is well known to be concave; nor does it apply to curves produced by the erosion of alternating hard and soft strata where concave curves are often produced in the manner discussed by Noe and Margerie.‡

McGee§ has noted the prevalence of concave forms on the land, and has interpreted them as expressing the "law of land profiles" as contrasted with the "law of water course profiles," yielding concave curves. Gannett‖ seems to have had much the same idea in speaking of the convex curve as the "curve of the terrain," and the concave as the "curve of the valley." As has been shown elsewhere the normal processes of erosion on homogeneous material tend to develop convex curves.¶ In the streamways the potential excess of transportation over erosion leads to undercutting and the development of concave curves. These are essentially similar to the curves originating through alternating hardness of strata. The concave curves along the valley sides arise, however, as a result of deposition.

The sandstones of the Dakota, the limestones of the Missourian, and the sand and limestones of the Des Moines all tend

*Hicks: Science, Bul. Geol. Soc. Am., vol. IV, p. 135. 1893.
†Gilbert: Geol. Henry Mts., p. 110. 1880.
‡Noe et Margerie, Les Formes du Terrain, p. 24, 28, *et seq*. Paris, 1888,
§Eleventh Ann. Rept: U. S. Geol. Surv., p. 246. 1891.
‖Mon: XXII, U. S. Geol. Surv., p. 143. 1893.
¶Iowa Geol. Surv., vol. VI, pp. 449-458. 1897.

to break up the general curves developed on the drift. Where the indurated rocks occur along the streams, they usually show as shoulders on the valley side, or as steep precipitous bluffs. The presence of the Cretaceous is frequently detected by these shoulders, of which an excellent example may be seen about a mile south of Dale City on Beaver creek. The sandstone is here grassed over but shows a well defined bench which is particularly well shown where minor streams come down the bluff face. The drift itself, however, often shows exceedingly steep slopes, so that the latter can not always be taken as indicative of the presence of rock.

TABLE OF ELEVATIONS.

In the following table is given the elevation of most of the towns in the county or near its borders. The figures are taken from the profiles of the Chicago, Milwaukee & St. Paul and the Chicago, Rock Island & Pacific railways, and revised to agree with Gannet's Dictionary of Altitudes.

Adair	1,415
Bagley	1,166
Bayard	1,237
Casey	1,237
Coon Rapids	1,178
Dexter	1,157
Glendon	1,047
Guthrie Center	1,075
Herndon	1,064
Jamaica	1,041
Menlo	1,271
Montieth	1,045
Stuart	1,216

DRAINAGE.

The streams of Guthrie county belong to two separate systems. In the southwestern portion of the area are a few minor waterways which drain into certain tributaries of the Missouri; the major portion of the county is drained by various branches of the Raccoon river, which itself empties into the Des Moines, through which the waters find their way into

the Mississippi. The watershed between the tributaries of the two great master streams of the continental interior traverses the country. In Bear Grove township it separates the headwaters of Troublesome creek from those of Seeley creek, and in Grant township it forms a barrier between Crooked creek and the upper branches of Middle river. At Adair, near the southwestern corner of the county, the watershed is crossed by the Chicago, Rock Island & Pacific railway at an elevation of about 1,400 feet. From this point the country slopes down toward the east to the Mississippi river at Rock Island 542 A. T., in a distance of about 200 miles measured direct. Toward the west the surface declines to the Missouri, 962 A. T. at Omaha, in about seventy miles. The watershed is not a marked physiographic feature but may be traced by the heading of the streams.

The pronounced differences in topography already noted are reflected in the streams of the county. The area covered by the Wisconsin has immature drainage. Small lakes and surface pools are found. Swales or sloughs are not uncommon, and the few streams which occur represent the youngest type of newly formed rivers. They have no well marked valleys but flow rather through a series of loosely connected, low-lying swales in the drift. They are rarely timber marked. Such a stream is Mosquito creek in Richland township, flowing into the Raccoon river near Redfield in Dallas county. Willow creek in Highland and Bays branch in Cass township are streams essentially similar except in their lower reaches.

In the area lying without the Wisconsin limits the drainage is much more complete. The county as a whole is traversed from northwest to southeast by both South and Middle Raccoon rivers. These two streams nearly parallel each other the entire distance and are from three to seven miles apart. For more than half the distance the narrow strip of land between the two is cut by Brushy Fork, which runs parallel to the two rivers to near Monteith, where it joins the South Raccoon. These three streams are of the type of long, nar-

row, non-branching streams and, with the exception of South Raccoon, they receive comparatively few tributaries. The latter stream receives a number of branches from the southwest, including Seeley, Bear, Beaver and Deer creeks, Long branch and several minor streams. These tributary streams are of the short, branching type. They divide and sub-divide until the whole area is cut up by a complex network of minor stream-ways such as mark a well developed drainage system.

Between the headwaters of the tributaries of South Raccoon and the Missouri-Mississippi watershed is a narrow strip of country traversed by Middle river and its branches and touched by North river. In general appearance this latter region resembles that drained by the Raccoon river. Middle river is here a very minor stream but in a general way parallels, and may be classed with, the Raccoon.

The county is, then, divided into two areas; one is of immature drainage, coextensive with the Wisconsin area, another of very mature and well developed drainage coextensive with the Kansan loess covered area.

The contrast between the topography and the drainage of the two portions of the county is manifestly largely a contrast of age. Both have the same underlying rocks and structure, both are covered by drift, and both have about the same elevation. One is, however, covered by a later drift sheet than the other, and the differences in drainage and topography are but the expression of this fact. The more complete drainage of the southwest is a result of the greater lapse of time since the retreat of the ice.

The streams of the extra-Wisconsin area are in the main of post-Kansan, pre-loess age. Portions of some of the valleys seem to be earlier than the drift, but the system as a whole is later. It is pre-loessial since the loess runs down into and partially fills the valleys. It is not earlier than the drift since the divides, so far as can be ascertained, are not made of drift-veneered rock but are almost wholly drift. The surface of the rock seems to have been a fairly even plain when the ice

invaded it. The valleys present at that time, while to some extent taken advantage of by the present streams, do not seem to have been generally perpetuated.

The most striking anomaly in the drainage is the parallelism of the three streams, Middle and South Raccoon and Brushy Fork. No very satisfactory reason for this parallelism can be offered. The streams bear no definite relations to the underlying rocks since they maintain their courses regardless of both lithological variations and changes of dip and strike. They were not conditioned by the edge of the Wisconsin since the valleys were cut much as they are now before the Wisconsin came into the region, and furthermore because the later ice did not reach Brushy Fork or South Raccoon, and only touched a portion of the valley of Middle Raccoon. Since the general direction seems to have been developed upon the Kansan drift before the streams had cut through it, it is probably due to some factor of the Kansan ice, possibly indicating a series of halts in the retreat of the ice with the development of successive streams parallel to its front.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

The rocks of Guthrie county include representatives of the three great groups, Paleozoic, Mesozoic, and Cenozoic. The first is represented by the shales, coals, limestones and sandstones of the Carboniferous. These beds are exposed along the streams and occur immediately beneath the drift throughout the eastern portion of the county. Over them and beneath the drift of the central and western portions, the Mesozoic is represented by the sandstones, gravels and clays of the Cretaceous. Over the whole county, mantling and concealing the indurated rocks, are the unconsolidated gravels, sands, clays and drift deposits of the Pleistocene. The Carboniferous, Cretaceous and Pleistocene are separated from each other by unconformities indicative of long time intervals and much erosion. The rank of the different beds is indicated in the accompanying table.

GROUP.	SYSTEM	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial.
		Glacial.	Wisconsin Iowan Kansan.
Mesozoic.	Cretaceous	Upper Cretaceous.	Dakota.
Paleozoic.	Carboniferous	Upper Carboniferous.	Missourian. Des Moines.

CARBONIFEROUS.

The Carboniferous of the Mississippi valley is made up of two series of strata. The lower or Mississippian series does not occur in Guthrie county, being buried by later beds. It is known throughout this region from well borings only. No record of any well within the county which reached the Mississippian is available, so that the thickness of the coal measures cannot be positively stated. Two well borings in the southwestern portion of Dallas county passed through the coal measures and into the underlying Saint Louis. These indicated a thickness of about 400 to 540 feet of coal measures between the Winterset and Saint Louis limestones. At Des Moines certain borings* show that a total thickness of about the same amount, though the rocks at that place are considerably below the horizon of the Winterset limestone. The Saint Louis was found at a depth of 498 feet, or at 374 A. T. in the Greenwood Park well.†

While the various borings in Polk and Dallas counties do not give uniform results it seems probable that the base of the coal measures lies probably at about 600 A. T., or at a depth of 550 to 650 feet below the upland of the eastern portion of Guthrie county. Farther west this horizon would be reached at greater depth, because of the rise of the surface in that

*Geol. Polk. Co., Iowa Geol. Surv., vol. VII.
†Norton: Iowa Geol. Surv., vol. VI, p. 299. 1897.

direction. It is also probable that there is a slight dip in the same direction, though this is not great, and west of the Des Moines the lower rocks are essentially horizontal, as has been shown by Norton,* and as is indicated by the fact that the base of the Earlham limestone, 1,000 feet above sea level at Earlham, is found at Stuart at about 915 A. T.

The Carboniferous rocks occuring at the surface represent the upper series which has been called the Pennsylvanian by Branner, but is more generally known as the Coal Measure series. The latter name is hardly ideal for the reason that the term is used in different parts of the United States to refer to strata of widely differing age and position. For this reason also it is thought better to use the term Des Moines and Missourian to refer to the two divisions of the series found in Iowa rather than the older terms Lower and Upper Coal Measures.

DES MOINES FORMATION.

In Guthrie county the beds present were referred by St. John mainly to the Middle Coal Measures,† though the presence of both the Upper and the Lower was recognized.‡ It was principally from the exposures in Dallas and Guthrie counties that the general section of the Middle Coal Measures§ was built up by that author.

In the course of the present work in Polk, Guthrie, Dallas and Madison counties it has been found necessary to make certain changes in this general section. As given by St. John it included forty-four members divided into three general divisions, an Upper, Middle and Lower respectively. If one will take the plate published to illustrate the section‖ and making proper allowance for the variation in character along individual horizons, compare the Upper and Lower divisions he can hardly fail to be struck by the similarity. In each

*Iowa Geol. Survey, vol. VI, 328-334. 1897, pp.
†Geol. Iowa, II, 104. 1870.
‡Op. Cit., 105, 128.
‡Geol. Iowa, I, 272-283. 1870.
‖Opposite p. 272, Op. Cit.

case there are three coal horizons separated by about the same distances. In each case the sequence above and below the coal horizons is closely similar. The limestone bands are found in similar development and order in each division. The heavy sandstone (number 35) which forms such a well characterized horizon in southeastern Guthrie county has its corollary in the lower division. For the purpose of making this clearer, the following table has been prepared, the data being taken from the plate mentioned.

UPPER DIVISION.	LOWER DIVISION.
44. Arenaceous shales and sandstone.	18. Sandstone.
43. Bituminous shales.	17. Shales, blue and yellow.
42. Lonsdale coal	16. Wheeler coal
41. Shales, light and blue.	15. Shales, red and yellow.
40. Limestone (5 feet).	14. Limestone (3 feet).
39. Shales, light, red, blue, arenaceous.	13. Shales, blue and yellow.
	12. Shales, calcareous, local.
	11. Shales, blue, yellow.
38. Limestone (2 feet).	10. Limestone (6 in +).
37. Bituminous shale	9. Bituminous shale.
Coal.	8. Panora coal.
36. Shale, yellow and blue.	7. Shales, variegated.
35. Sandstone (10 feet).	6 Sandstone (10 feet).
34. Shales, arenaceous, yellow and blue.	5. Shales, light and dark blue, local bituminous shales with fossils at base.
33. Marshall coal.	4. Lacona coal
32 Shales, blue and yellow.	3. Shales, light and blue.
31. Limestone, impure, fragmentary.	2. Limestone, compact, gray.
30. Shales, variegated.	1. Shales, variegated.

The similarity of sequence here is certainly striking. There are variations in the thickness of the individual members not shown by the table, but these variations are not greater than can be found in the field by careful tracing of individual layers from point to point. In view of the general character of the Des Moines coal measures it is the persistence rather than the reverse which becomes noticeable. The similarity in the fossils obtained from corresponding beds is no less striking, as may be seen by comparing St. John's published lists and

as will be brought out later. Below number 30, as given above, is a thin shale sequence resting upon a buff fragmentary limestone (number 26), which is one of the easiest horizons to recognize in the field. This in turn rests on a sequence of variegated predominantly arenaceous shales corresponding in character in a general way to the main portion of St. John's middle division.

Numbers 26 to 44 of St. John's section may be readily recognized throughout the southeastern portion of Guthrie county and will be illustrated in the sections to follow.

The lower beds of this section are seen on Middle Raccoon river near the old Tann mill, southwest of Linden (Tp. 79 N., R. XXX W., Sec. 25, Ne. qr., Sw. ¼). As now shown the section is in part talus covered, but at the time St. John visited it was quite well exposed. He gives* a careful section which is reproduced below with a few changes necessitated by present studies. Opposite the numbers of the section are numbers corresponding to the place of the bed indicated in the general section. The beds best exposed now are numbers 10, 12 and 15.

TANN MILL SECTION.

GEN'L SECTION NUMBER.			FEET.	INCHES.
	16.	Drift, Kansan	6	4
40	15	Limestone, thin bedded, buff with *Productus cora*, *Chonetes granulifera* and *Athyris subtilita*	1	6
39	14.	Shales, gray, argillaceous; becoming blue below and carrying *Lopophyllum*, *Productus punctatus*, *P. longispinus*, *Chonetes granulifera*, *Derbya crassa*, *Spirifer kentuckensis*, *S. plano-convexa*, *Athyris subtilita*, *Hustedia mormoni*, *Bellerophon carbonaria*, etc	20	
38	13.	Limestone, nodular, impure		6
37	12.	Shales, bituminous, mixed with impure coal	1	6
36	11.	Shales, light colored	8	
35	10.	Sandstone, coarse, yellow, with flakes of coaly matter and remains of poorly preserved Neuropteris	10	

*Op. Cit., p. 112.

GEN'L SECTION NUMBER.			FEET.	INCHES.
34	9.	Shales, arenaceous, blue and yellow	3	
33	8	Coal, impure		6
32	7.	Shales, dark and light blue	7	
31	6.	Limestone, thin, irregular	1	
	5.	Shales, blue	2	
	4.	Limestone, earthy, irregularly bedded with *Productus muricatus*, *P. cora*, *Derbya crassa*, *Athyris subtilita*, *Spirifer plano-convexa*, *Rhynchonella uta*, etc	1	6
	3.	Shales, blue	1	
	2.	Limestone, impure, many *P. cora*, *P. muricatus* and *Chonetes mesoloba*	1	
	1.	Shales, blue and gray, exposed about twenty-five feet above the river	2	

About three quarters of a mile north of the exposure just described, Mr. St. John found the same beds exposed along Hooks branch at a somewhat higher level. Under a coal seam taken to represent number 8 were three limestone beds corresponding to numbers 2, 4, and 6. Below these the following section extended down to the river.*

HOOKS BRANCH SECTION.

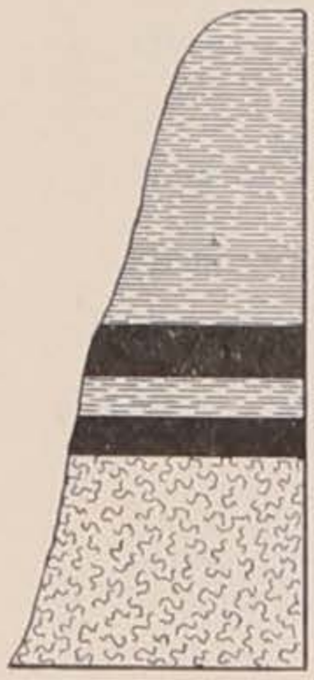
		FEET.
11.	Shales, red, blue and yellow in color, with nodular bands; *Productus muricatus*, *P. cora*, *Athyris subtilita*	6
10.	Limestone, impure, shaly	2
9.	Clays, blue and reddish, with a band of fosiliferous shale near the top, carrying *Spirifer plano-convexa* and Petrodus	8
8.	Shales, in part argillaceous, blue to red; in part arenaceous, yellow, and becoming shaly sandstone at the top	17
7.	Sandstone, compact to shaly, gray, with *Productus cora*, *Derbya crassa* (?) Myalina, sp. und.	1
6	Clays, yellowish and blue, gritty, merging above into soft, gray, arenaceous shale	12– 13
5.	Unexposed	15– 25
4.	Shales, blue	15
3.	Shales, calcareous and bituminous, dark gray to drab; *Productus muricatus* very abundant, *Derbya crassa* (?) *Athyris subtilita* and a minute gasteropod	1½
2.	Coal	½+
1.	Shales, blue to river	1

*Op. Cit., p. 115.

Passing east from the Tann Mill section there are numerous exposures along the river. The strata rise and pass over an anticline, as has been worked out by Mr. A. G. Leonard.* Beyond this anticline the general sequence already noted is found in the hill tops and below the sandy member corresponding to the "Middle" division (19–26) of St. John is a series of beds extending along the river down to and connecting with the section worked out by Keyes.† These lower beds as found by Mr. Leonard do not correspond to beds 1–18 of St. John's section, and can not be correlated with them. The Guthrie county exposures do not show anything corresponding to them, and the revised section leads inevitably to the conclusion that the lower portion of the old section is in error. This conclusion must rest mainly upon the evidence from Dallas county since the exposures between the Tann Mill section and Panora are not sufficient to allow very exact correlation. Such as occur, however, accord nicely with the view that the exposures in and near Panora belong with those of the southern portion of the county rather than below them.

About three miles northwest of the Tann Mill section is a group of small mines, near one of which, the Dygart (Tp. 79 N., R. XXX W., Sec. 16, Se. qr.), the following section is exposed not far above the river.

DYGART MINE SECTION.



		FEET.	INCHES.
5.	Shale, exposed	3	
4.	Coal		5
3.	Clay shale		4
2.	Coal		4
1.	Fire clay, exposed	2	

FIG. 67. Bluff at Dygart drift.

*Report on Dallas county not yet published.

†Bull. Geol. Soc. Am., II, pp. 277-292, 1891. Iowa Geol. Surv., I, 94-105. 1893.

Still nearer Panora, at the mouth of Bays branch, is a second group of small mines, all of which are now abandoned. The coal formerly worked has been called the Panora horizon, but seems to represent number 37 of the general section. It is exposed in the bluffs not far above the river. The following section at this point is given by Keyes.

		FEET.
7.	Drift	4
6.	Limestone, impure	3
5.	Shale, dark drab	8
4.	Limestone, impure, bituminous	½
3.	Shale, black, carbonaceous	1½
2.	Panora coal	1
1.	Shale, light colored and variegated; exposed,	10

There are good exposures along the river in the vicinity of Panora, and the mining development there has made known something of the geology of the underlying beds. At the clay pit of the Panora Brick & Tile Co. is shown an impure coal with bituminous shale, which marks the horizon just noted. The limestones which usually accompany this coal bed are not well shown. The section varies in different parts of the pit, but is in general as follows:

		FEET.
3.	Shale clay, argillaceous, red	12
2.	Coal and bituminious shale	2
1.	Shale, argillaceous-sandy, blue to white with irregular bands of calcareous material; exposed to within six feet of the river	18

Near this section and above the coal is a small quarry in a gray sandstone. The latter is irregularly bedded and broken. It is coarse-grained and quite full of broken bits of plant remains. Similar stone is exposed in the old quarries west of town, where the following beds may be examined.

		FEET.
3.	Drift	6 +
2.	Shale, sandy, light colored	2– 4
1.	Sandstone, coarse-grained to conglomeratic, with bituminous shaly partings	6–10

The position and significance of this sandstone will be discussed later.

On the south side of the river coal has been mined for some time. Three seams are known to be present. In the top of the hills is a very thin seam which here is of no value. It apparently represents the horizon of the Lonsdale coal. About twenty to twenty-five feet above the river is the coal which has been called the Panora, but which, as already mentioned, probably represents number 37 of the general section. It was this seam which was worked at the time St. John visited the region. Thirty feet below the river is the bed now worked. The mouth of the Reese coal shaft, put down in 1896, is about on a level with the Panora coal. The section afforded by the shaft is as follows:

		FEET.
9.	Drift	6
8.	Limestone	1
7.	Clay shale, red	7
6.	Shale clay, soft	2
5.	Sandstone, white to gray, with flakes of mica	30
4.	Shale, bituminous, fossiliferous, becoming a cannel coal below	10
3.	Coal	1⅜
2.	Fire clay	8
1.	Sandstone	10+

As indicated by this section the beds between numbers 33 and 37 of the general section have thickened very considerably and have also changed a little in character. It will be noted that the sandstone, number 33 of the general section, maintains its position. The thin limestone above is exceptional but not wholly anomalous.

A short distance northwest of town is the mine of the White Ash Coal Co. The shaft is sixty feet deep and the mouth is seventy-five feet above the river, so that in position the coal corresponds more nearly with the Panora seam than with that worked in the Reese mine. Still farther up the river (Tp. 80 N., R. XXXI W., Sec. 24, Nw. qr., Se. ¼) is the Clark mine, the mouth of which is twenty feet above the river. Near the mine the coal measure shales are exposed, with the Cretaceous sandstones and conglomerates overlying them.

The section will be described in connection with the Cretaceous. About three miles beyond, in the neighborhood of Fanslers, is a group of mines which have been in operation for some time. The coal worked lies about fifty feet below the river and is the same at all the mines except the Scott mine, where a second seam has been found a few feet below the one generally worked. The section at the latter mine is as follows:

		FEET.	INCHES.
7.	Shale, light colored, argillaceous, sandy in places, exposed	4	
6.	Clay shale, dark, fissile	2	
5.	Sandstone, "caprock"	1	
4.	Coal, containing heart shaped pericas in pyrite, with four inches of shaly material at the bottom	1	10
3.	Fire clay and clay shales	10	
2.	Coal	1	6
1.	Fire clay	1	

FIG. 68. Section of Scott shaft. Fanslers.

This lower coal has not been found at any of the other mines and is evidently a local deposit. The coal measure shales are covered by Cretaceous sandstone. St. John mentions* an upper seam about four or five feet above water level. The bed was thin and is not now worked. The upper seam is about the same distance above the Fansler coal as the one outcropping at Panora is above the coal at the Reese mine. The river runs at only a slight angle with the strike of the beds and there is apparently a dip to the west. The coal

*Opus cit., p 106. There is evidently a misprint at this point, as the locality mentioned, Tp. 81 N., R. XXXII W., Sec. 19, is far from the river and near no known coal outcropt. It should evidently read Tp. 80 N. The location of Clark's mine, not the present Clark mine, has evidently been confused. If instead of section 24, section 4 be read, the facts fit the description.

present at the two points may be considered as representing the same horizons.

Farther up the river the coal measures are cut out at Rocky Bluff by the Cretaceous. Beyond the bluff the Cretaceous has been cut through by the river and the coal measures are again exposed.

The Wales coal bank is located on the south side of the river (Tp. 81 N., R. XXXIII W., Sec. 33, Ne. qr.). The coal, which is sixteen to eighteen inches thick, rests on shales and lies about twelve feet above the river. Over it are black shales from which St. John* collected *Productus muricatus*, *Derbya crassa* (?) and *Lingula carbonaria*. The coal measures have a thickness of twenty-seven feet above the coal as shown in the air shaft. In the hillside near by there are exposures of the sandstone of the Dakota. A mile or more above the river the coal is again reached by the Perkins drift (Tp. 81 N., R. XXXIII W., Sec. 29). Near the mine (Sec. 20, Sw. Sw.) is a high bluff of Cretaceous sandstone and clay, while in sections 29, 20, 19 and 24, coal has been mined at various points. In section 24, apparently, two seams are present. The one now worked is found by shafts thirty-nine to fifty-six feet deep, and seems to lie about twenty-eight feet below the river. Formerly a surface seam was worked† lying about two feet above the water.

It will be seen from an examination of this section that the usual sequence holds in passing up the river. The beds dip a little to the west, and the shales thicken so that the coal horizons are spread farther apart. The character of the beds changes to the west, new strata appear, and the formation takes more and more the inconstant character usual throughout the Des Moines formation.

In the southern portion of the county along South Raccoon, Long branch, Deer creek and Beaver, there are many exposures showing the beds from the Missourian limestone down to the heavy mass of sandy shales which forms the base of

*Op. cit., 105.
†St. John: Op. cit., 105.

known sequence already described. Throughout the region the basal portion of the Missourian, the Bethany limestone, outcrops in the hills. The streams have cut through it and down deep into the underlying beds. One of the best sections, starting however, some distance below the Bethany, is found along a ravine north of Glendon, and leading down to the river near the old Belle Valley mill site (Tp. 79 N., R. XXX W., Secs. 30-31). The section is made up of numerous scattered outcrops along the hollow, but fitted together gives the sequence nicely.

		FEET.	INCHES.
16.	*Limestone, yellow, earthy, corresponding to No. 38 of the general section	1	
15.	Shale, bituminous, with some coal (No. 37)		8
14.	Shale, yellow (No. 36)	5	
13.	Sandstone in hard three inch ledges separated by softer shaly layers (No. 35)	4	
12.	Shale, sandy (partly exposed)	2	6
11.	Coal, Marshall (No. 33)		3
10.	Shale, gray, clayey (No. 32)	1	
9.	Limestone, sandy, with plant remains abundant, Myalina with a narrow accentuated beak frequent, *Nuculana bellastriata* and *Productus cora* (No. 3)	1	6
8.	Shale, blue, clayey	2	
	Unexposed	8	
7.	Shale, sandy, yellow	2	
	Unexposed, probably as above	10–15	
6.	Limestone, fragmentary, with many well rounded pebbles of ash gray limestone of conchoidal fracture bedded in reddish earthy limestone matrix; carrying *Athyris subtilita*, *P. muricatus*, moderately common and a dermal tubercule of Petrodus (No. 26)	3	
5.	Shales, argillaceous, blue	6	
4.	Sandstone, fine-grained, ripple marked		3
3.	Shales, sandy, with a slight dip up the river; imperfectly exposed	50‡	
2.	Clay, yellow to gray		6
1.	Coal in two benches as follows: Coal, 4 inches; clay, 5 inches; coal, 3 inches	1	

Below the coal there are no exposures along the stream down to where it empties into the river. From the presence of the great thickness of sandstones and shales above the coal and below the fragmentary limestone, it is probable that the coal found belongs to the Redfield horizon. The base of this stream is probably thirty or forty feet above the river. Passing up the latter a half mile one comes to the exposure at the site of the old mill, an outcrop which will be later described.

Corresponding beds are seen at many points south and east. Near Dale City the heavy sandstone (number 35) with the black shale and limestone (numbers 37 and 38) above it is found exposed. At this point a boring was put down some time since by John Lonsdale & Sons. The record reproduced below by their courteous permission shows a number of coal seams, the more important being at 264 and 318 feet. The head of the boring is estimated by Mr. Charles Lonsdale to have started some feet below the Marshall coal.

		FEET.	INCHES.
69.	Drift	12	
68.	Shale, red, blue and brown	19	
67.	Sandstone, light gray	3	
66.	Shale, gray	11	7
65.	Shale, gray, dark	10	7
64.	Coal		2
63.	Fire clay		4
62.	Shale, with impure coal in alternate layers	1	10
61.	Yellow stone		1
60.	Fire clay		6
59.	Shale, dense gray with traces of coal	4	9
58.	Sandstone	1	4
57.	Shale, blue	4	
56.	Shale, dark gray	14	4
55.	Sandstone, white	6	6
54.	Shale, blue	2	
53.	Limestone		2
52.	Shale, yellow	1	4
51.	Limestone		9
50.	Shale, gray		3
49.	Limestone		9
48.	Shale, blue		2

		FEET.	INCHES.
47.	Limestone	1	4
46.	Shale, brown	2	
45.	Shale, blue, black at bottom	3	7
44.	Limestone, gray, very hard		10
43.	Slate, black	2	
42.	Coal		4
41.	Shale, light blue	15	
40.	Shale, brown	2	6
39.	Shale, variegated	7	
38.	Shale and limestone in thin layers	3	4
37.	Shale, variegated	8	
36.	Shale, blue	25	3
35.	Shale, yellow	1	9
34.	Limestone, buff		4
33.	Shale, gray, blue black at bottom	6	8
32.	Coal	1	4
31.	Shale, blue fire clay at top	6	10
30.	Limestone, gray	1	8
29.	Sulphur band		2
28.	Sandstone, fine-grained	11	
27.	Limestone, very hard	3	1
26.	Sandstone, white	2	6
25.	Shale, variegated	4	9
24.	Sandstone, gray	7	2
23.	Shale, gray	3	9
22	Sandstone, gray	3	9
21.	Shale, blue gray	10	10
20.	Shale, gray	23	
19.	Coal	2	6
18.	Fire clay		6
17.	Shales, light and gray	17	10
16.	Sandstone		8
15.	Shale	1	3
14.	Limestone, brown	2	
13.	Shale, dark	1	2
12.	Black stone		2
11.	Slate, bluish black	5	8
10.	Sulphur band		1
9.	Shale, blue	1	5
8.	Shale, blue and gray fire clay at top	17	8
7.	Coal	3	4
6.	Shale	1	6
5.	Coal	1	
4.	Shale		8
3.	Coal		10
2.	Shale, light and dark	17	5
1.	Shale, dark blue	2	

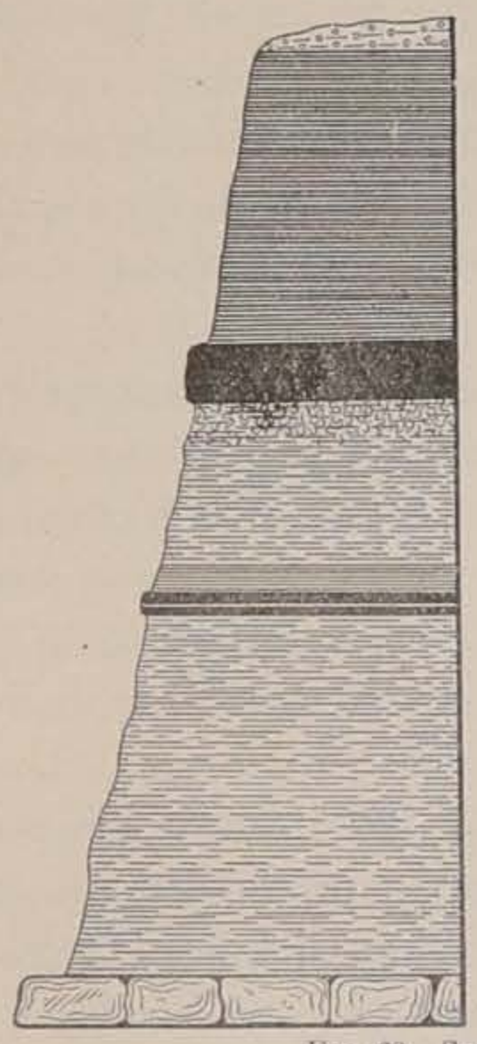
South of Dale City (Sec. 6, Tp. 78 N., R. XXX W.) a roadside gully shows the presence of the limestone and underlying coal and shale forming numbers 38 and 37 of St. John's section. On Hog branch, near the road crossing in section 6, is an exposure showing the Marshall coal in its usual development, with shales above and below. There is, however, an unusual three inch band of limestone in the shales about four feet above the coal. In the bed of the Raccoon river, just below the mouth of the branch (Tp. 78 N., R. XXX W., Sec. 5, Sw. qr., Sw. ¼) is a limestone corresponding to number 31. Near the head of the branch (Sec. 7, Ne. of Se.) the Muldoon mine is opened in a coal probably the Lonsdale, and not far northwest (Tp. 78 N., R. XXXI W., Sec. 12, Sw. of Sw.) the Driscoll mine works the same bed. The Marshall coal and overlying beds is seen again on the south side of the river, about two miles below Dale City (Tp. 78 N., R., XXX W., Sec. 4). On the opposite side of the river the heavy sandstone, number 35, is well shown and in the hillside above deserted dump heaps mark the level of the Lonsdale coal. The latter is best seen along Deer creek.

Near the west line of Penn township (Tp. 78 N., R. XXX W., Sec. 18, Sw. qr., Sw. ¼) is the Lonsdale mine, a shaft sunk near the base of the Winterset limestone. The coal lies thirty feet below the lowest bed of the Missourian limestone, a soft white sandstone intervening. The coal itself averages twenty inches in thickness. It is divided by two clay bands as shown below:

		INCHES.
5.	Coal	12
4.	Clay	2
3.	Coal	4
2.	Clay	½
1.	Coal	4

The same seam has been opened at a number of points along the river. The Lamb mine, directly north of Stuart (Tp. 78 N., R. XXX W., Sec. 20, Ne. qr.), was worked for some time. It was found here that the lower bench dipped to the

east, though this may be a local development. Near this mine the coal is exposed in the creek as shown in the following sketch.



		FEET.	INCHES.
8.	Drift	10	
7.	Shale, bituminous to drab above	4	
6.	Coal		10
5.	Fire clay	2	
4.	Shale, light colored		8
3.	Coal, with shaly partings		3
2.	Shale, light colored	5	
1.	Limestone, fossiliferous	4	

FIG 69. Section of bluff on Deer creek.

The thickness of the partings between the two benches of coal varies somewhat. Above the shale covering the coal is a buff clay shale running up into sandy shale and sandstone. Below the limestone seen in this section (number 40 of general section) is a bed of variable shale of some thickness.

Near Glendon, coal measures are exposed along the streams, the Cretaceous outcropping well up in the hills. In a cut on the Chicago, Rock Island & Pacific railway not far north of the town (Tp. 79 N., R. XXXI, W., Sec. 36, Se. qr., Sw. ¼) there is an exposure showing both formations.

GLENDON SECTION.

		FEET.
6.	Sandstone, soft, yellow to red, irregularly bedded	2
5.	Clay, yellow, free from grit, much like geest	1½
4.	Limestone, brecciated, gray, with common coal measure fossils	2
3.	Shales, yellow, clayey	8
2.	Limestone, soft, sandy	½
1.	Shale, clayey, red to greenish	12

Numbers 1 to 4 may be referred to the coal measures. They have equivalents at other points in the vicinity and on Spring branch (Tp. 78 N., R. XXXI W., Sec. 3, lot 12) a thin coal seam, supposed by St. John to represent the Marshall horizon, was formerly exposed.*

A lower bed, said to have been two feet six inches thick, was at one time worked at a depth of 100 feet, and a thicker bed, four and one-half feet, was reported sixty to seventy feet still lower.

Outcrops of coal measure strata are reported along Beaver creek for a distance of two miles west of this point. At one point (Tp. 78 N., R. XXXI W., Sec. 5, lot 4) a fourteen-inch seam of coal was formerly worked. Coal measures are also reported on South Beaver (Sec. 5, lot 19) and on Spring branch (Tp. 78 N., R. XXXI W., Sec. 16, Ne. qr., Sw. $\frac{1}{4}$) a thin seam was formerly reached by drifting.

Along Middle Raccoon and Brushy Fork there are no good coal measure outcrops, though coal is mined on the former near Guthrie Center (Tp. 79 N., R. XXXI W., Sec. 17, Sw. qr.) and on the latter southwest of Bayard (Tp. 80 N., R. XXXII W., Sec. 5, Sw. qr.). At the Guthrie Center mine the coal is eighteen inches thick, and is found at a depth of eighty-seven feet; the overlying strata being shale and sandstone. This is probably the same vein that was formerly worked at Glendon. In a boring put down some years since on the Tracy, now Stover and Metz land, a mile west and half a mile north of the court house at Guthrie Center, the corresponding vein was struck at 132 feet. As reported by Hon. Charles Ashton, the bed is twenty inches thick and lies below six and one-half feet of black slate. Below this bed of coal, at a depth of 197 feet, a second vein four feet and five inches thick, and covered by a soft white clay, was reported. About five feet below another bed of coal and black clay was reported. The drilling was done just west of the Raccoon, and passed through forty feet of drift, below which was forty-four feet of

*Op. Cit., 126.

a soft sandstone, probably to be referred to the Cretaceous. At the Brushy Fork mine the shaft is not deep, and the horizon probably represents that opened on Middle Raccoon river to the north.

The beds above the Lonsdale coal up to the base of the Missourian consist essentially of sandstone or sandy shale. As penetrated at the Lonsdale mine (Sec. 18, Penn township), there was a thickness of thirty feet of such shales between the coal and the lowest limestone ledge. There is some question, however, whether this limestone should not be included with the Des Moines rather than the Missourian. It is about twelve to fourteen inches in thickness, of granular texture, and carries small, smooth specimens of *Athyris subtilita*. As seen on Deer creek (Sw. of Nw. Sec. 17, Penn township) it is about ten feet below the fragmental limestone which it is proposed to take as the base of the Bethany. Between the two are sandy to argillaceous shales. The limestone is seen near the Driscoll mine, and at several points on Deer creek and South Raccoon, but is apparently not always present. In the boring at Stuart no trace of it seems to have been found. Below what may be taken as the base of the Missourian was about ninety-two feet of sandy shale, with some harder bands. This would seem to indicate the absence of the limestone in question and a thickening of the shale. In Madison county an arenaceous limestone is occasionally found at the indicated horizon. At Tileville it is twenty-five to thirty feet below the base of the Winterset, and rests upon about fifty feet of sandy shale. At other points similar relations obtain. In general they indicate a thickening of this upper shale member toward the south, and a dip of the beds in the same direction.

The strata found in Guthrie and neighboring counties below the base of the Missourian fall naturally into the four following groups.

1. Shales, variegated, but predominantly sandy, characteristically free from coal, with an occasional development of arenaceous limestone somewhat above the middle of the bed.

This formation corresponds in a general way with number 44 of St. John's middle coal measure section and includes numbers 1 to 3 of White's Winterset section.* It varies in thickness from forty to 100 feet, increasing to the south. In a general way it is probably the equivalent of the Pleasanton shales of Missouri and Kansas. The original northern boundary of this formation seems to have been not far from its present limits in Guthrie county, as it thins very rapidly from Stuart north.

2. Shales, sandstones, and limestones with three coal horizons. This formation includes numbers 26 to 43 of St. John's section and its character is sufficiently indicated by the sections already described. It is characterized by the great persistence of its individual members and is recognized through Guthrie and Dallas counties and in part in Madison county. It is probably the equivalent of the Appanoose formation† of southern Iowa and the Henrietta formation of Missouri.

3. Sandstones and sandy shales with Redfield coal at base, including numbers 19 to 25 of St. John's section. Seen in part at the Tann Mill exposure and well exposed in Dallas county. This member is probably not to be separated from number 4, though in the immediate region it is rather distinct.

4. Shales, sandstones and thicker coal seams characteristic of the greater portion of the Des Moines formation. Represented in the deeper borings of Guthrie county and exposed in the counties to the east; corresponding in general character and position with the Cherokee shales of Kansas.‡

These beds form a continuous series and are, so far as can be seen, conformable. In Appanoose county, however, there is a well marked conglomerate over the Appanoose formation.§ In Guthrie county one of the limestones of the second

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* Geol. Iowa, vol. I, plate opp. p. 245, 1870
† Iowa Geol. Surv., V, p. 378.
‡ Haworth: Univ. Geol. Surv., Kansas, I, 150-151. 1896
§ Iowa Geol. Surv., V, 394-398.

member contains many rolled pebbles and other evidences of shore action, while the sandstone just below shows ripple marks. The sandstone found near Panora does not fit in with any portion of the section seen there. It is anomalous in character and is in places quite conglomeratic. There is some evidence of unconformity between it and the underlying beds. Nevertheless it contains plant remains which unmistakably ally it with the Des Moines. These facts all give evidence that throughout the later as well as the earlier portion of Des Moines time there were disturbances, and that local unconformities may be expected throughout the formation. The best exposure of disturbed strata may be seen at the Belle Valley mill exposure. Here about fifty feet of lower beds have been thrown up so that the strike is now Ne–Sw, with a dip of 45° to the southeast. They have been to some extent faulted, and after the upheaval were planed off so as to form an even surface over the top. Evidently the rocks formed then a flat-topped knob, as a later sandstone laid down over the top is also banked in against the side and with bedding planes dipping away from the upturned beds. This later sandstone is similar in character to that found at Panora. It carries the same plant remains and at the base includes fragments of the underlying rock. The disturbance evidently took place during the Des Moines. The beds thrown up belong to the Des Moines strata, though their exact place in the section cannot be given. They evidently do not belong with those seen in the neighborhood (see p. 437), but are lower and probably represent the upper portion of the Cherokee shales. If this be true a considerable amount of erosion took place before the deposition of the overlying sandstone; which accords well with the indications of the exposure itself. The beds thrown up are all as follows:

		FEET.	INCHES.
12.	Limestone, impure, clayey, with *Productus muricatus*, *P. cora* and *P. nebrascensis*	1	
11.	Shale, drab, becoming coaly at top	4	
10.	Limestone, similar to number 12	1	

		FEET.	INCHES.
9.	Shale, drab to green, clayey	5	
8.	Limestone, earthy, unfossiliferous		4
7.	Coal, impure	1	
6.	Shale, drab, clayey	12	
5.	Calcareous sandstone		8
4.	Shale, argillaceous, drab above to red below	10	
3.	Limestone, fine-grained, argillaceous, non-fossiliferous		6
2.	Shale, black, slightly bituminous	6	
1.	Shale, drab, argillaceous	4	6

The movement does not seem to have been sufficiently intense to have developed any secondary structure. The shales have cleavage planes parallel to original bedding and the jointing in the surrounding sandstone seems to have no relation to the upthrust. Numbers 7 and 8 have been faulted at one place, there being a throw of nearly a foot. The beds above and below are not affected. Numbers 11 and 12 appear only at the lower corner of the exposure and might be taken for a repetition by faulting of 9 and 10, if it were not for the well marked coaly character of the upper portion of number 11. In character and fauna number 12 resembles number 38 of the general section; but even after the upthrust it is below the level of that bed and the strata below are entirely out of harmony with anything seen elsewhere along the river.

MISSOURIAN FORMATION.

Above the Des Moines and covering the southeastern portion of the county is the Missourian formation. The only portion of this formation outcropping is the basal or Bethany limestone. This is shown along the lower portion of Beaver creek, Deer creek, Long Branch and South Raccoon river. The stone has not been quarried to any considerable extent, so that there are no extensive exposures. The rock, as usual, lies in ledges varying in thickness from six to twenty-four inches, which are separated by shaly argillaceous partings. A total thickness of fifty-five feet is indicated near the Lonsdale mine. This is near the edge, and probably does not rep-

resent the full thickness of the formation. The Easton well, at an altitude of about 1,200 feet, showed a thickness of 140 feet of drift below which was eighty feet of limestone. Since the base of the Earlham limestone in the Earlham quarries is at about 1,000 feet A. T. this would indicate that the strata here are practically horizontal and would agree with the results obtained by Norton from a general study of the artesian wells of the state. The limestone, where exposed, is quite fosiliferous, the forms present being those common to the limestone in other counties. The following is a list of fossils collected along Deer creek north of Stuart by Professor Calvin.

Lophophyllum proliferum.
Axophyllum rude.
Stems of *crinoidea.*
Archæocidaris, three species.
Fistulipora nodulifera.
Rhombopora lepidodendroides.
Orbiculoidea nitida.
Derbya crassa.
Derbya robusta M. & H.
Meekella striato-costata Cox.
Chonetes granulifera Owen.
Productus longispinus Sowerby.
P. costatus Sowerby.
P. nebrascensis Owen.
P. cora = P. prattenianus.
Spirifer cameratus Morton.
S. plano-convexus.
S. lineatus.
Athyris subtilita = S. argentea (Shepard) Keyes.
Hustedia mormoni Marcou.
Terebratula (Dielasma) *bovidens* Morton.
Cryptacanthia compacta W. & St. J.
Nucula ventricosa Hall.
Nuculana bellastriata Stevens.
Edmondia sp.
Aviculopecten sp.
Bellerophon percarinata.
Bellerophon sp.
Pleurotomaria sp.
Petrodus occidentalis.

Along a small tributary of Deer creek, where most of these fossils were found (Sec. 19, Penn township), the following beds were made out.

		FEET.
5.	Limestone, coarse, gray; with Fusalina similar to that occurring at Winterset	2
4.	Shales, only in part exposed	8
3.	Earlham limestone, ash gray, with conchoidal fracture, in layers two to ten inches thick, separated by shale partings	12
2.	Shale, gray, argillaceous, becoming bituminous and slaty at the top	10
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 (two feet) layers	10

The Fragmental limestone (number 1) rests on sandy shales which form the top of the Des Moines formation. The rock itself is very characteristic, and has been traced through Dallas and Madison counties. Besides its distinctive physical characteristics it carries a well marked fauna, of which the following forms were collected at this point.

Spirifer lineatus, very abundant, and especially characteristic of this horizon.
S. cameratus.
Athyris subtilita, common.
Hustedia mormoni, fairly common.
Productus longispinus.
Naticopsis altonensis.
Lophophyllum proliferum, common.
Orthis pecosi, very rare.
Bellerophon, *sp.*, rare.
Straparrollus, *sp.*, rare.
Archiocidaris, *sp.*, very rare.

In the shale partings of the Earlham limestone the following forms were collected.

Chonetes verneuiliana, common.
Spirifer cameratus.
Athyris subtilita, common.
Productus cora.
P. nebrascensis.

P. costatus.
Rhombopora lepidodendroides, common.
Meekella striata-costata.
Archiocidaris.

The character of the rock and the fossils found leave no doubt as to the correlation of these beds. The Winterset beds, occurring above the Earlham limestone, were not seen at this point, unless the Fusalina-bearing rock be taken as their representative. A rock similar in all respects occurs at Winterset and the bed found here is probably to be referred to that horizon rather than to the Fusalina limestone proper occurring farther west in Madison county. This is the more probable from the fact that the Winterset beds are present in the vicinity. It may be noted that the limestone found here shows each division in its normal thickness and character.

The Bethany limestone, using that term to cover the Fragmental, Earlham, Winterset and Fusalina limestones with intercalated beds, is made up of the four separate limestones just enumerated. Of these, the Fragmental and Earlham are well developed in Guthrie county. The Winterset, restricting that term to the beds quarried southwest of Winterset, is present, but not well shown. The Fusalina limestone seems to have been cut away.

The limestone found here outcrops throughout the southwestern portion of Dallas county to Earlham in Madison county. From this point it has been traced by Tilton to Winterset, where it is quite well exposed. At the latter point this layer of heavy limestone has been recognized as the base of the Missourian formation.* It represents the same horizon as the Bethany limestone of Missouri and the Erie limestone of Kansas, the connection between the Winterset and the Bethany limestone having been traced in the field.†

There has recently been some discussion as to which of the three terms, Winterset, Bethany or Bethany Falls as first used, or Erie has priority. The section at Winterset was

* Tilton: Iowa Geol. Surv., vol. III, p. 135. Des Moines, 1895.
† Iowa Geol. Surv., vol. VII, p. 23. 1897.

described by White in 1868* and again in more detail in 1870.† It was selected by him as typical for the upper coal measures and the fossils characteristic of it were specified. Tilton‡ later used the name carefully noting the position of the limestone at the base of the Missourian formation. The term Bethany Falls was used by Broadhead§ in describing the Missouri exposures. The equivalence of the Bethany Falls and Winterset limestone was recognized by Keyes‖ and has since been traced in the field. In Kansas the equivalent horizon was discussed by Haworth and Kirk¶ under the name of Erie, was later referred to by Haworth** as the Triple limestone and was finally given the name of Erie.†† The equivalence of the three formations was recognized by Keyes in 1895 and it was suggested‡‡ that the term Bethany be extended to cover the whole horizon. Later§§ the same author showed the term Erie to be pre-occupied and urged the priority of Bethany.

Broadhead's prior use of the term Bethany seems to entitle it to recognition, and it is proposed to use that term for the basal limestone of the Missourian formation. As has been suggested, this basal limestone includes four members, and for one of them the term Winterset is reserved. The various members of the Bethany have been recognized along Grand river in Decatur county, and at many intermediate points. In Union county there are higher, as yet unnamed beds.

The Guthrie county outcrops are the most northerly of the exposures of this limestone in the central portion of the state. The strike of the formation in Madison county is northwest, in Dallas the strike changes to west, and in Guthrie this strike is maintained to the point at which the lime-

* First and Second Ann. Rept. State Geologist, 71-72. Des Moines, 1868.
† Geol. Iowa, vol. I, pp. 245-250. Des Moines, 1870.
‡ Iowa Acad. Sci., vol. III, p. 144. 1895. Iowa Geol. Surv., III, 137. 1895.
§ Trans. St. Louis Acad., vol. II, 311, 144. 1862. Mo. Geol. Surv., Iron Ore and Coal Fields, pt. ii, p 77, et seq. 1873
‖ Mo. Geol. Surv., vol. IV, p. 82. Jefferson City, 1894.
¶ Kansas Univ. Quart., vol. II, p. 108. Lawrence, 1894.
** Ibid., vol. III, p. 275. 1895.
†† Univ. Geol. Surv. Kansas, vol. I, p 154. 1896.
‡‡ Amer. Jour. Sci., (3), vol. L., p. 243. 1895.
§§ Ibid, (4), vol. II, pp. 221-225. 1896.

stone passes beneath the Cretaceous. It probably does not change between this point and the Missouri river. In drill holes and shafts along South Raccoon, Brushy Fork and Middle Raccoon there are no traces of the Missourian north of its present line of outcrop. In the western portion of the state the most northerly outcrops known are on the Boyer river in Harrison county,* almost due west of the Guthrie county outcrops, so that a line connecting the two points probably marks the present northern border of the formation.

It is probable that the Missourian originally extended out over the Des Moines. Its present outcrop is an accident of erosion rather than a function of original distribution. Within the area of the Missourian there are, in this county, no outcrops of strata higher than the Bethany limestone, so that only the basal portion is known to be present.

CRETACEOUS.

DAKOTA.

Above the coal measures, and covering the major portion of Guthrie county, is a series of sandstones, shales and conglomerates which belong to the Cretaceous. These beds are exposed along both branches of the Raccoon river, Brushy Fork, Beaver creek, Spring branch and many of the minor streams. They are separated from both the Carboniferous and the Pleistocene beds by unconformities.

Exposures of the Cretaceous are frequent along Middle Raccoon as far down as Clark's mine, about three miles northwest of Panora (Tp. 80 N., R. XXXI W., Sec. 24, Nw. qr., Se. ¼). Above the wagon bridge at this point and on the east side of the river is the following exposure.

		FEET.
4.	Drift	10
3.	Conglomerate, quartzite and cherty pebbles, with sandy matrix, only slightly consolidated	8
2.	Sandstone, soft, yellow, with a few scattered pebbles similar to those occurring in the conglomerate	20
1.	Shale, sandy, drab	4- 8

*White: Geol. Iowa, vol. II, p. 179.

The shale, which evidently belongs to the coal measures outcropping along the river, is separated from the sandstone by an obvious unconformity. The sandstone and the conglomerate belong together since they grade in places into each other, the pebbles becoming more abundant and the sand less, till the material is best called a coglomerate with sandy matrix rather than a sandstone with scattered pebbles. Traces of conglomerate may be seen near the mine, and pebbles from it are very common in the drift south and east of here. The pebbles are all water worn and thoroughly rounded. There are many bits of clear and colored quartz, chert and siliceous fragments of Devonian and Silurian fossils. Farther up the river the sandstone becomes more and more prominent. It is frequently exposed near Fanslers, and in the vicinity of Rocky Bluff (Tp. 81 N., R. XXXII W., Sec. 27, Ne. qr.) forms a constant bench in the hills at a height of seventy feet. It is soft, yellowish red, cross-bedded, and contains occasional pebbles such as mark the conglomerate. Opposite the mill it forms a sharp bluff, exposing seventy feet of thickness above the water's edge. A few miles beyond (Tp. 81 N., R. XXXII W., Sec. 20, Sw. qr., Sw. ¼) the sandstone forms a ridge between the river and a small stream flowing in from the southwest. It rises to the usual height and has two thin beds of very clear plastic blue clay interstratified with it. Still farther up the river (Tp. 81 N., R. XXXII W., Sec. 24, Ne. qr.) the clay is more prominent. St. John gives the following section at this point.*

		FEET.
7.	Very soft, light colored, irregularly laminated sandstone	35- 40
6	Yellow clay, enclosing ferruginous, arenaceous bands	4
5.	Blue clay	5
4.	Soft red and yellow sand rock, with ferruginous nodules and bands, and thin layers of pebbles, with pebbles of silicified corals of Devonian and Silurian origin	20
3.	Ferruginous arenaceous layer containing isolated "pockets" of coal	2

*Op. cit., p. 100.

		FEET.
2.	Blue, arenaceous clays	17
1.	Light colored, incoherent sands, capped with deep red shaly ferruginous sandstone	10– 15

These beds rest unconformably upon the coal measure strata. The coal mentioned is doubtless an impure lignite and has not been observed in the course of the present work. The lower blue clay is not so clean or plastic as at the section observed farther down the river. There are outcrops of the sandstone and conglomerate in the vicinity, but upon the whole it does not seem that individual layers can be widely correlated. The sandstone is usually bright colored. It varies in induration, but is usually soft. At Guthrie Center it is so soft as to be excavated for building sand. In the pit of Mr. Samuel McLune, at three feet above the river, is a five foot bed of clean white sand, so loose as to be easily shoveled. Above this is twelve to fifteen feet of darker material, becoming harder at the top. It contains the quartz pebbles, such as are so characteristic of the formation. Still higher in the hill is the dark red sandstone, closely set with quartz and chert pebbles, such as is commonly shown in outcrops.

Across the river near the fair grounds an unusual amount of clay is shown in connection with the sandstone. The clay is about twenty feet thick, reddish below, but becoming white above, and rests on the sandstone. It contains some bands of sand and thin ferruginous streaks, and has a slight dip to the west.

Near Glendon the sandstone shows numerous outcrops. In a section already given it rests upon the coal measures at a height of twenty-five feet above the railway. In a neighboring cut the sandstone is exposed at much lower level with no evidence of disturbance, so that there is excellent proof of unconformity. At this point the stone contains plant remains, but the specimens are so imperfect as not to permit specific identification. In the judgment of Professors Calvin and Macbride, however, they represent Mesozoic forms.

The conglomerate is best exposed along Spring branch between Glendon and Menlo. It is so unconsolidated that it has been used by the Chicago, Rock Island & Pacific railway for ballast, and has been dug out by shovel and pick as ordinary gravel. It has here the usual constitution, with the marked prominence of quartz and chert pebbles. The material is thoroughly rounded and waterworn. Sand, or loosely cemented sandstone, forms the bottom of the pits and is in places interstratified with the gravel. The general appearance of the gravel is shown in figures 70 and 71.

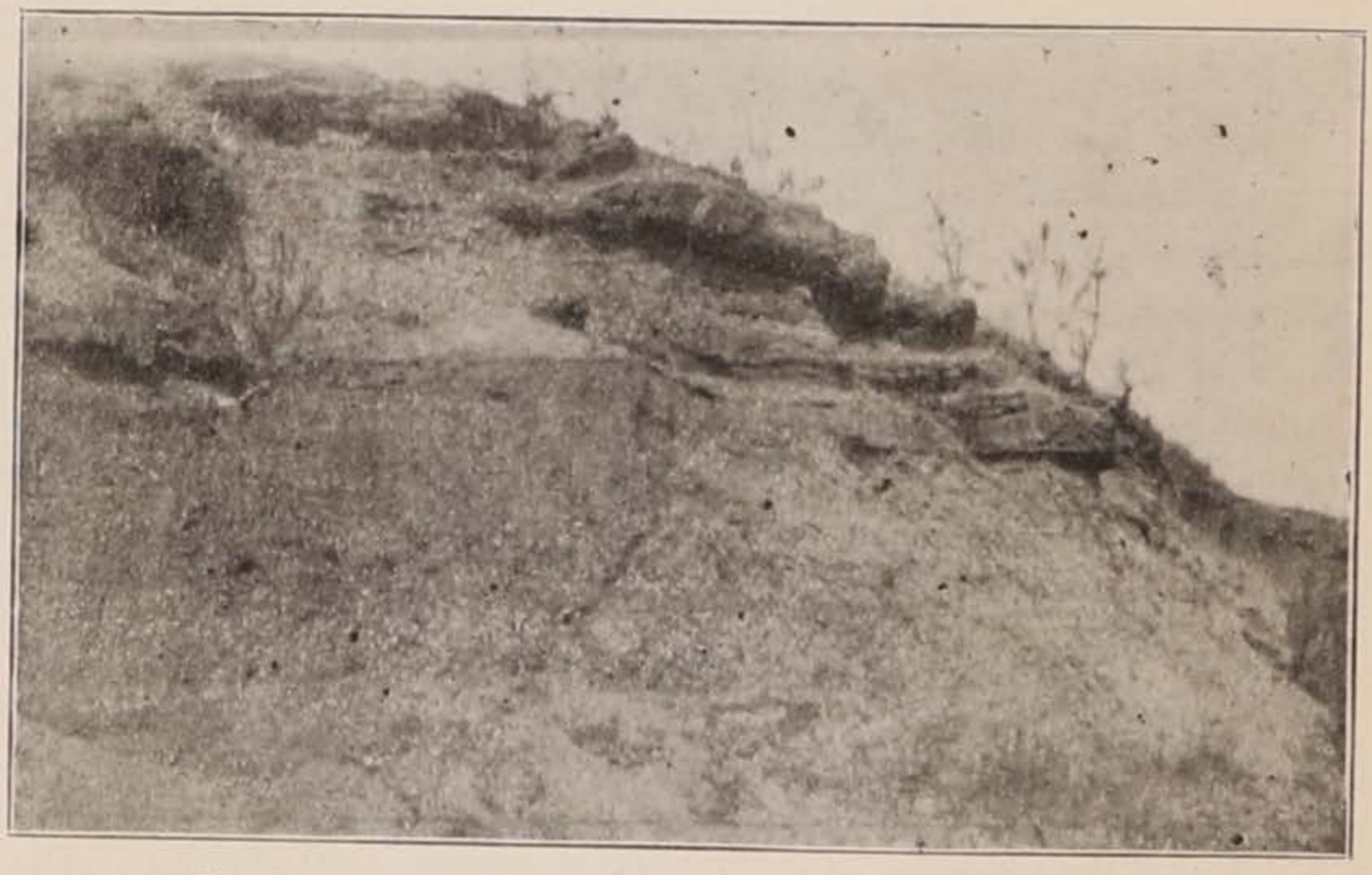

FIG. 70. Dakota conglomerate near Glendon. East end of gravel pit.

The formation which is here referred to the Cretaceous will be seen to include three kinds of beds; sands or sandstones, clays or shales, and gravels or conglomerates. The clay or shale members are least widely spread. In addition to the occurrences already noted the only one of much importance is near the Anderson mine southeast of Guthrie Center where Cretaceous clays are found in connection with the sandstone. There are other occurrences in the southwestern portion of the county, but in general the Cretaceous of this

region carries very little argillaceous material. The sediments of which the formation was formed were mainly the result of mechanical disintegration.

The sandstones are widespread and are found outcropping throughout the area indicated on the map. They are lithologically similar to the sandstones of the coal measures, and perhaps could not be differentiated from the latter if it were not for the presence of the pebbles characteristic of the gravels. The lithological resemblance makes it easy to

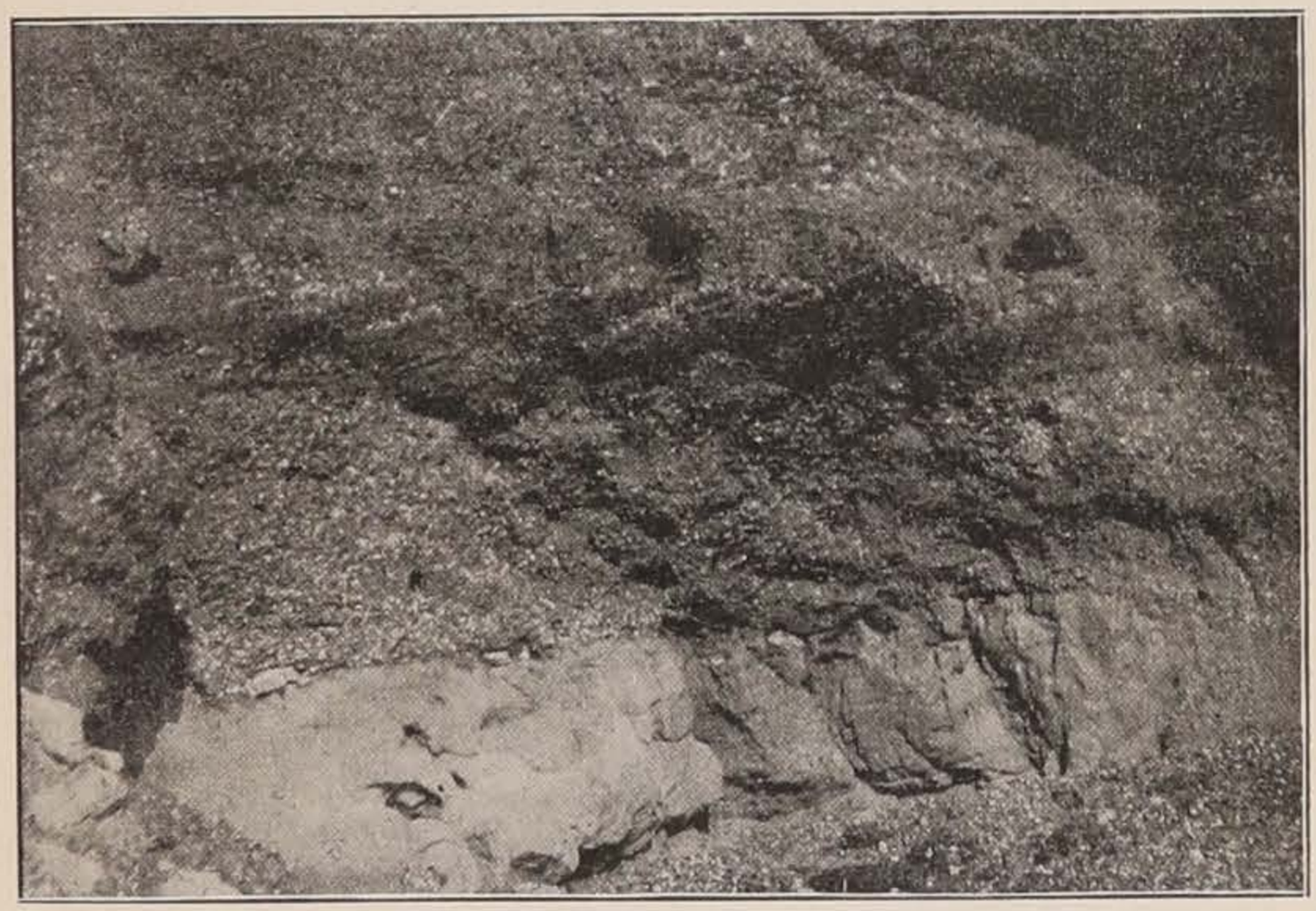

FIG 61. Dakota conglomerate near Glendon. Center of railway gravel pit.

assign the coal measures as the source of the sand of the Cretaceous. This is well in accord with the stratigraphy of the region. The gravel is perhaps the most interesting member of the Cretaceous. It is wholly unlike any other gravel or conglomerate in this portion of the state and cannot be confused with anything in the coal measures. In eastern Iowa, outliers have been noted by Norton* which carry chert and quartz pebbles, with occasional bits of red jasper and pink

*Norton: Iowa Geol. Surv., vol. III, p. 128.

quartz, and which are of Carboniferous age, but no such beds are known in the coal measures of central Iowa. In addition to the cherts and quartzes found in the Guthrie conglomerate or gravel are numerous silicified bits of fossils, the following being determined by Professor Calvin.

Cyathophyllum, sp.
Bryazoa; DEVONIAN?
Spirifer, cf. *S. eudora;* NIAGARA.
Favosites favosus, Goldf.; NIAGARA.
Streptelasma, sp
Favosites hisingeri, Ed. & H. (*F. venustus* (Hall) Rom., *Astrocerium venustum* Hall); NIAGARA.
Ptychophyllum expansum, Owen; NIAGARA
Streptelasma spongaxis, Rom.??; NIAGARA.
Zaphrentis stokesi, Ed. & H.; NIAGARA.
Favosites, cf. *F. hispidus*, Rom., NIAGARA.

The presence of these fossils derived from the older Paleozic of eastern Iowa indicates that before the conglomerate was formed eastern Iowa had been exposed to erosion for a very long time and apparently had been base-leveled. Only the cherts and siliceous fragments which were left practically untouched by solution remained. It should be noted furthermore that the conglomerate, though it is made up of very hard material only, and though it was manifestly formed after a long time interval of erosion, is not strictly a basal conglomerate. In every observed case it rests upon sands and finer material which are of the same age and do not belong to an earlier formation. The Cretaceous sea apparently crept in over a base leveled country. Mechanical agencies became supreme after a long period in which solution had been at work. The friable material of the coal measures was first broken up and redeposited as sand. It did not form a basal conglomerate, since it was too easily disintegrated to take conglomeratic form. When the sea laid under tribute the previously leached plains of the earlier paleozoic it found the surface covered with hard material already separated, and a conglomerate resulted. Conglomerates do not necessarily mean the

breaking up of rock, and great unconformities are by no means always marked by conglomerates. The latter are formed merely when the sea can get hold of suitable material, and that may be when it first invades a region or some little time after, as in this case.

The beds here referred to the Cretaceous are, as has been said, unconformable upon the coal measures and represent a later period of deposition. They are evidently much later than the paleozoics of eastern Iowa from which the chert nodules were derived. They were made by the sea creeping in over an apparently base-leveled surface.

The deposits found in Guthrie county represent shore deposits, but they do not represent the greatest eastern extent of the Cretaceous in Iowa, nor does the present line of outcrops represent exactly the present eastern limit of the formation. It is altogether probable that outliers will be found in this and the counties to the east. Dr. James Lonsdale reports an outlier in Jackson township (Tp. 79 N., R. XXX W., E. ½, Sec. 27). In wells in the northeastern portion of Guthrie it is usual to find sandstone below the drift. In many cases this is probably Cretaceous, especially since it seems frequently to be covered by gravels such as belong to that formation. The sandstone may, however, belong to the coal measures and the gravels may represent the drift, so that it is not possible accurately to discriminate the Cretaceous. Similar beds have been penetrated in certain wells in Dallas county and the peculiar gravel charateristic of the Cretaceous is abundant in the drift of that county. Possibly some of the gravel is *in situ*. Certainly much of it has been very little moved. Cretaceous fossils have frequently been found far to the east of the present outcrops. Keyes has found well preserved fossils in the drift at Des Moines.* White† has reported them from the drift of Howard, Black Hawk and Johnson counties, and Worthen‡ notes similar

*Proc. Iowa Acad. Sci., vol. I. pt. ii, 1890-1891, p. 21. 1892.
†Proc. Am. As. Adv. Sci., vol. XXI, pp. 187-192. 1873.
‡Geol. Surv. Ill., vol. VIII, pp. 3-7. 1890.

occurrences in Iowa, Illinois and Missouri. N. H. Winchell has reported Cretaceous *in situ* as far east as Goodhue* and Dakota† counties in Minnesota. H. V. Winchell has found Cretaceous beds in the northeastern portion of the same state,‡ the beds being also described by Spurr.§

These various occurrences make it evident that the Cretaceous formerly extended much farther east. Lithologically similar deposits occur at points throughout Iowa, Illinois, Minnesota and Wisconsin. Some of these have been shown to be of Carboniferous age.‖ Others, including the Rockville conglomerate described by McGee,¶ have been referred to the Cretaceous. Still others have been considered to be Tertiary.**

It is certain that while some of these outliers may be correctly correlated with the Guthrie county beds others may be of later or earlier age. The sea advancing over the paleozoic rocks of the upper Mississippi valley after a period of base-leveling would be apt to build up the same sort of beds, regardless of the time of the invasion. In this case a correlation upon homogeny†† or community of genesis, would alone lead to unsatisfactory results. Fortunately there is better evidence of the age of the Guthrie county Cretaceous. While fossils are not abundant they have been found. St. John mentions‡‡ "impressions of linear leaves" derived from the sandstone on Beaver creek. The specimens collected in the course of the present work from the railway cut near Glendon have been already mentioned. Cretaceous invertebrate fossils have been from time to time found in the drift, but so far they have not been discovered *in situ*. Specimens of Callista, Cardium and Buccino-fusus, collected near

*Geol. Nat Hist., Surv. Minn., Final Rept., vol. II, pp. 44, 45. 1888.

†Ibid, 84.

‡Sixteenth Ann. Rept., Minnesota Geol. Nat. Hist. Surv., 395-478. 1888. Amer. Geol., XII, 220-223. 1893.

§Geol. Nat. Hist. Surv., Minnesota, Bul. X, pp. 80, 148-199. 1894.

‖Osborn: Proc. Iowa Acad. Sci., vol. I, pt. II, 1893-1891, p. 115. 1892. Norton: Iowa Geol. Surv., vol. III, pp. 129-130. 1893.

¶Eleventh Ann. Rept., U. S. Geol. Surv., pt. I, pp. 304-308. 1891.

**Worthen: Geol. Surv. Ill vol. I, p. 330, 1866; Ibid, vol. IV, p. 91, 1890; vol. VIII, 3-7, 1890. Salisbury: Jour. Geol., vol. III, 655-667. Chicago, 1895.

††McGee: Am. Jour. Sci., (3), vol. XL, pp. 36-41. 1890.

‡‡Op. cit., p. 104.

Stuart by Mr. E. E. Hadley, are quite well preserved, and show portions of the matrix in which they were imbedded. This is a coarse-grained, friable sandstone, identical in character with that which occurs so abundantly in the Cretaceous of the vicinity.

The stratigraphical relations make it evident that the beds may not only be referred to the Cretaceous but more specifically to the Dakota. When first described by White* and St. John† they were referred to the Nishnabotna, which was considered to be the equivalent of a portion of the Dakota as defined by Meek and Hayden.‡ The typical Nishnabotna is exposed in Cass, Adams, and Montgomery counties,§ and is clearly the stratigraphic equivalent of the Guthrie county beds. At Lewis, in Cass county,‖ and at Red Oak, in Montgomery county,¶ plant remains have been found which Meek considered to be the same as species occurring in the "Lower Cretaceous of Nebraska," Dakota, as now known.

North of Guthrie county the Cretaceous crops out in Greene,** Carroll†† and Sac‡‡ counties. Near Auburn, in the latter county, it is found in connection with the chalk deposits,§§ as at Sioux City. The distribution, stratigraphical position, fauna and flora so far as known, and the lithological character of these various outcrops place them together and indicate that they are of Dakota age; that they represent the basal portion of the Cretaceous of the state. The upper beds found near Sioux City are not now present in the region though it is not improbable that they may at one time have been present. The long and vigorous erosion to which the region was subjected between the close of the Cretaceous and the beginning of the Pleistocene has cut away all but a remnant of the formation.

*White: Geol. Iowa, vol. I, p. 299. 1870.
†St. John: Idem, vol. II, p. 99.
‡White: Loc. cit.
§Lonsdale: Iowa Geol. Surv., vol. IV, pp. 412-424. 1894.
‖Lonsdale: Op. cit., 413.
¶White: Am. Jour. Sci., (2), XLIV, 119. 1867.
**St. John: Geol. Iowa, vol. II, p. 133. 1870.
††Idem: pp. 143-145.
‡‡Lonsdale: Proc. Iowa Acad. Sci., II, 1894.
§§Calvin: Iowa Geol. Surv., III, p. 226. 173. 1895.

PLEISTOCENE.

GENERAL RELATIONS.

Guthrie county lies on the southwestern border of the Des Moines lobe and affords an opportunity for studying the relations obtaining between the Wisconsin and the underlying drifts. The two formations present may be studied not only as superimposed but as deployed. The contrasts between the drift within and without the Des Moines lobe are well displayed, and differences which might fail of recognition under one set of conditions are obvious under the other. The region is as a result an exceptionally interesting one to all students of glacial geology. The interesting topographic contrasts have already been suggested. It remains to study more in detail the formations themselves.

KANSAN DRIFT.

The outlying drift sheet is that known as the Kansan drift. The Iowan drift does not appear upon the southern and southwestern borders of the Des Moines lobe. The drift present agrees in character with that which has been called Kansan in other reports of the Survey.* It has the same general constitution, being fundamentally a blue bowlder clay weathered above into a yellow, which in turn is usually a deep reddish brown at the surface. It contains the same sorts of pebbles, an examination near the Driscoll mine showing quartzite probably from the Sioux formation, sandstone from the Cretaceous, shale and limestone from the coal measures, light gray granites, pink quartz, porphyry, greenstone, vein quartz and other varieties of rock from extra-limital sources.

There is the usual large amount of local material, and large numbers of greenstones. The granitic bowlders are badly rotted and easily broken to pieces. The upper surface of the drift shows marked ferrugination and leaching. The drift has all the characteristics of an old drift long exposed to

*Norton: Iowa Geol. Surv., vol. IV, p. 169. 1895. Bain: Ibid, vol. V, p. 153. 1896. Beyer: Ibid, vol. V, p. 203. 1896. Calvin: Ibid, vol. V, p. 63-65. 1896.

weathering agencies *in situ*. As has already been seen, the topography is suggestive of the same history. The Iowan drift of northeastern Iowa is thinner, of different color—a light yellow—carries many large surface bowlders, shows many fresh cobbles, and only a few that are badly decomposed. It has a less percentage of local material and a higher percentage of gray granite, and shows almost no leaching or ferrugination. Upon these differences alone there would be ground for separating the two.

The topography gives further warrant for a separation. The topography of both areas is a river erosion topography, and the drainage is complete. The Kansan topography has, however, much greater relief than the Iowan. The latter is marked by a series of wide shallow river valleys having no marked river trenches. The marked, though not easily expressed contrast between the typical river valley of the Iowan drift area and that of the Kansan, affords yet another reason for distinguishing between the outlying drift of Guthrie county and the Iowan. Aside from these differences is the fact that the Kansan, as developed in Guthrie, may be traced around the southern end of the Des Moines lobe, being characteristically developed in Dallas, Polk and Jasper counties, into Marshall, where it is known to pass beneath the Iowan. It may also be traced more to the southward, as far east as Johnson and Cedar counties, where the same relationship holds true. The outlying drift of Guthrie county is not then the next drift sheet in point of age preceding the Wisconsin; but is still older. There is here an unconformity and overlap as real as any shown by the indurated formations.

That there may be a still older drift sheet present seems probable from the phenomena observed in other counties. At Afton in Union county, at Harvey in Marion, at Hastie in Polk and at many other points, the Kansan drift is known to overlie a still older sheet of till. In Guthrie county there is a certain amount of evidence which points in the same direction. At Stuart there is a bed of fine sand lying ninety feet

below the upland on which the station is built and outcropping in some of the neighboring ravines. This bed is ten to fourteen feet thick and is made up of thoroughly rounded particles 1 to 2 mm. in diameter, consisting mainly of quartz and feldspar with occasional bits of some ferro-magnesian constituent. The bed seems to occupy a constant horizon and is the source of the local water supply. Below it is reported a fine pebbleless blue clay with lime nodules but no pebbles, and said to be fossiliferous. It is not now exposed, but was at one time tested for brick making and at that time the lime content was found to be high. The description fits well a buried loess or at least a lake deposit. Such a deposit might of course have been formed at some stage in the retreat or advance of the Kansan ice, but it might also be formed in inter-glacial time and, particularly if the clay be a loess, falls in nicely with the evidence derived from the surrounding region and pointing to a widespread pre-Kansan drift. In the recent boring at Stuart 158 feet of bowlder clay was found below the buried sand beds. This lower bowlder clay here evidently occupies a buried channel cut almost through the Bethany limestone.

At the Belle Valley mill exposure there is, over the upper sandstone, a bed of coarse cross-bedded sandy conglomerate eight to ten feet thick. It is made up almost wholly of material derived from the Dakota gravel but includes also some greenstones, granite and glacial material. It is covered by three or four feet of coarse sand running up into a sandy loess-like material. The deposit is well down in the valley and may be considered to be post-Kansan. Probably it is also pre-Iowan and hence the equivalent of the Buchanan gravels of eastern Iowa.

The Kansan drift does not outcrop over large surface areas within this county since it is quite generally covered either by alluvium or by loess. It is found over limited areas on the high divides and quite generally along the stream ways. It may usually be seen in road cuttings on either side of the

ravines. As has already been indicated, the valleys are in the main earlier than the loess. The latter is found not only on the divides but runs down into the valleys so that frequently the drift is not exposed at all. The side ravines usually expose the drift, however, and it is not infrequently shown along the main streams since the pre-loessial contours seem on the whole to have been sharper than the post-loessial. The result is that any side wash has a tendency to reveal a line of drift, just as the indurated rocks because of their superior hardness form shoulders along the sloping valley sides.

IOWAN LOESS.

The loess present is of the usual character, being a fine, pebbleless, buff, silt-like material. It was described in the earlier reports as the "bluff deposit" and its presence east of the Missouri divide was recognized. It is here referred to as the Iowan loess, since it is believed to be the equivalent in this region of the Iowan drift farther north and now in part buried under the Wisconsin drift. It is believed that loess of widely different ages occurs in the Mississippi valley and probably in Iowa, and the qualifying term is added for the purpose of definitely fixing the age of this particular loess. The basis of the correlation is the fact that loess, apparently the same, may be traced around the southern limit of the Wisconsin to Marshall county where it comes into contact with the Iowan. It follows the border of the latter southeast, never lapping very far up on the drift, to Johnson county. Here its definite relationship to the Iowan drift is excellently shown.* Furthermore, the Iowan ice sheet, as shown by its border, probably marked a period of low level and clogged drainage such as is indicated by the relations of the loess in Guthrie county to the pre-existing river valleys. This period was between the Kansan and the Wisconsin as was also the period of loess deposition in this region, as is shown by the fact that the loess covers the Kansan and passes

* Calvin: Geology of Johnson county, Iowa Geol. Surv., vol. VII, pp. 88-89. 1897.

beneath the Wisconsin. It was separated by a considerable interval from the Kansan, as is proven by the large amount of erosion to which the latter was subjected before the loess was laid down. That it passes beneath the Wisconsin may be seen upon the hillsides west of Panora where the loess is covered by the kame gravels of the Wisconsin. The fact is also indicated by numerous wells back some distance from the drift border, and by ravines and stream cuttings all along the margin. It is furthermore well in accord with the facts observed in other counties.*

Upham† has suggested that the presence of the loess in Guthrie, Carroll, Sac and Buena Vista counties immediately west of the moraine and the fact observed by him that in places the loess rises fifty feet above the drift hills, proves the contemporaneity of the loess and moraine. It does not seem that this interpretation is necessary or indeed well in accord with the facts. If the explanation offered be true it would be expected that the loess should be found along the eastern front of the moraine as well as its southern and western. That it does not occur in this position is shown by Calvin in his report on Cerro Gordo county.‡ The loess is well developed outside the Des Moines lobe, where the latter has overlapped the Iowan, but not so far as now known, elsewhere. Again it should not be forgotten that the Wisconsin drift is persistently fringed by gravels and similar deposits indicative of free drainage, while the loess is indicative of conditions under which the water could not, or at least did not, carry anything but the finest material. The two deposits are mutually antagonistic. A drift sheet which is constantly fringed by gravel is to be differentiated from one constantly fringed by loess. The two must have required different conditions. The general altitude of the land in one case was higher than in the other. This is not of course to be interpreted as meaning that local exceptions may not occur, but applies to cases

*See Geology of Polk County, Iowa Geol. Surv., vol VII, pp 340-342. 1897.
†Geol. Nat. Hist. Surv., Minn., 1880, p. 338.
‡Iowa Geol. Surv., vol. VII, pp. 171-176. 1897.

where the conditions along an entire drift border are taken into account.

In the case in hand there is the additional fact that the loess passes directly under the Wisconsin drift wherever its relations have been made out. It is then older, and if difference in general erosion be any guide it is considerably more ancient than the Wisconsin drift. In Guthrie county no cases have been observed in which the loess stands higher than the Wisconsin. Such phenomena would not necessarily require the ice as a retaining wall. The loess covers the Mississippi-Missouri divide. The land rises from the east to the divide. This was apparently true before the Wisconsin ice invaded the region, so that the land west of the moraine would be expected to be higher, and where the moraine approaches the divide running parallel to it the difference might be locally great. This would be also true if the rise to the west be a function of recent elevation for which belief there is some evidence.

With regard to the length of time between the loess and the Wisconsin it may be said that, assuming the relative freedom of the drainage to be a function of the elevation of the region, an assumption well in accord with known facts and principles, the change in the general altitude of the land between the deposition of the loess and the Wisconsin is significant, and the time interval was probably considerable since epirogenic movements are not rapid.

The loess then was deposited at a time between the Kansan and the Wisconsin, and separated from each by a considerable interval. Conditions favorable to loess deposition prevailed when the Iowan ice occupied eastern Iowa, and this time accords well with that required by the facts in the case, so the loess of Guthrie county is referred to the Iowan.

In the northwest portion of the state there is a drift which is older than the Wisconsin and younger than the Kansan. In constitution, position and topographic development it resembles the Iowan of eastern Iowa, and it has been provisionally correlated* with that formation. There are many

*Iowa Geol. Surv., vol. VII, p. 20. 1897.

reasons in support of the view that this correlation is correct, and so the headwaters of the pre-loessial streams of Guthrie county were doubtless crossed by the Iowan ice; and in a period of general low level with greatly expanded rivers the conditions for the distribution of the loess over the territory in question would obtain.

The relationships of the loess found here to the loess of the Missouri valley are perhaps not certainly known. White and St. John* considered the two to be the same, and nothing to negative this opinion has come out in the present study, though the investigation of that phase of the problem is not yet so complete as is desirable.

WISCONSIN DRIFT.

The drift covering the northeastern portion of the county is, at the surface, light buff in color, it contains fresh pebbles, is marked by surface bowlders, and is free from a loess covering. It contains relatively little material of local origin, and much which has been transported. The large limestone masses found north of the Raccoon river near Rocky Bluff, and probably derived from near Mankato, Minnesota, are conspicuous examples of transported blocks. Occasionally the Wisconsin has incorporated not only pebbles from the lower till but blocks of the clay itself. Some distance southeast of Panora (Tp. 79 N., R. XXX W., Sec. 15, Se. qr.) in a road cut at the east end of a bridge over Middle Raccoon, this feature is excellently shown. The Wisconsin drift is here a gray to buff clay quite full of small pebbles. In it are some large patches of older till. Some of these included patches are as much as two feet in diameter. The older material is sandier and contains more Cretaceous material and is much more highly colored. The newer drift shows foliation around these inclusions.

The most distinctive feature of the Wisconsin is perhaps its topography which has already been described. The drift

*Geol. Iowa, vol. II, p. 97. 1870.

border is also highly characteristic. At certain points there is a well-developed moraine. This is best seen not far northwest of Fanslers (Tp. 81 N., R. XXXI W., Sec. 28, Sw. qr.). The general upland here is about 130 feet above the river. It is flat and covered by a thin sheet of Kansan drift over which the loess is spread. Rising abruptly from this plain is the moraine which attains an elevation of fifty feet. It is a ridge of markedly rough topography and is covered by large surface bowlders. Inside the moraine the characteristic saucer topography is developed, and the large bowlders, while frequent, are rarer than along the moraine.

Along other portions of the border there is no trace of a moraine, but instead the drift becomes thinner and thinner till it fades out altogether. Along still other parts, notably at Rocky Bluffs (Tp. 81 N., R. XXXII W., Sec. 22, Se. qr.), and along the lower portion of the Middle Raccoon valley, the ice pushed down into the valley and occupied one side of it. At only one point does it seem that it may have crossed. Opposite Panora, on the main Guthrie Center road (Tp. 80 N., R. XXX W., Sec. 31, Sw. qr.), water-laid gravels of kame-like character are found well toward the top of the hill distinctly above the loess. No till has been found with them, but the presence of the gravels far above the usual gravel terrace, and the kame-like form seems to suggest a temporary crossing of the ice. The gravels occur along the hillsides in a small amphitheatre drained by the stream entering the river from the west. They are more or less perfectly shown at several points and at one or two take an imperfect kame form with a general northwest-southeast direction of axis.

Just south of Panora, gravels are developed at lower levels and show a tendency toward the kame form of aggregation. The gravel terrace which lies at a still lower horizon is excellently shown in the same vicinity.

South of Bayard, and again from Panora southeast into Dallas county, there is lower land inside the drift border than along it. The accumulation along the edge does not, however,

seem to be morainic, since it is often not a thickening of Wisconsin drift, but is due in part to rock and in part to a special accumulation of older drift. This appearance is often confusing but the phenomenon is not strictly morainic. It seems rather to be the result of stream rearrangements. South of Bayard it seems to indicate that Willow creek was formerly the major stream.

Overwash plains have not been found in the county. Kames, as already noted, occur near Panora, though they are not so well developed nor so characteristic as the kame at High Bridge in Polk county.

There is a well marked gravelly terrace along the Middle Raccoon river. It rises usually twenty-five to thirty feet above the river, and may be seen at Rocky Bluff very sharply defined, near Fansler, in the vicinity of Clark's mine (Tp. 80 N., R. XXXI W., Sec. 24, Ne. qr.), and near Panora. It is constant for the whole river valley, but is conspicuous at the points named. At Rocky Bluff the terrace forms a triangular strip rising twenty-five feet above the river. At the Clark mine the terrace shows on the west side of the river, being a quarter of a mile wide and rising twenty feet above the bottom land. The material of which the terrace is composed is a moderately coarse water-laid gravel with more or less coarse sand. It contains a large amount of material evidently derived from the Cretaceous gravel beds. It does not show a close connection with the character of the underlying strata from point to point as does the till, particularly the older or Kansan till.

There is a well marked forest bed which is frequently encountered in wells in the northeastern part of the county, particularly near the edge of the Wisconsin drift. North of Yale on the Eastwood farm (Tp. 81 N., R. XXX W., Sec. 28, Sw. qr.) the section showed the following beds, the thickness being given only approximately:

		FEET.
6.	Yellow clay	10
5.	Blue clay	30
4.	Red clay	3
3.	Forest bed	2
2.	Blue and red clay	5
1.	Sand, clear white	10

In many of the wells of the vicinity the forest bed is not reported, since the water and gas for which the wells were put down are found over it. The country is not cut by drainage lines so that there are not many opportunities for examining sections and none are known which show the forest bed distinctly.

ALLUVIUM.

The river valleys of the extra-Wisconsin region have usually well marked alluvial bottom lands. The major development of the alluvium is shown upon the accompanying map. It is impossible to map the smaller areas without the aid of a topographic base map. Along the smaller streams the alluvium grades so imperceptibly into the loess and the hillside-wash from it that no line between the two can be drawn. The alluvial areas as mapped include the terrace along Middle Raccoon, since the two formations are not readily separated upon a map of this scale.

ECONOMIC PRODUCTS.

Coal.

The coal mined in Guthrie county comes from a number of different horizons. That worked at the Greenbriar mine in the northeastern portion of the county probably represents the lowest horizon now worked. Along Middle Raccoon from Panora north and west and on Brushy Fork are the two horizons, corresponding to numbers 37 and 33 of the general section, which have been opened up. Below number 33 is the coal found at the Thomas mine but not as yet encountered elsewhere. Southeast of Panora and west of Linden coal is taken from a thin bed near the surface which seems to

represent the Marshall coal, though this is not wholly free from doubt.

The Lonsdale coal, which has been mined at numerous points along Deer creek, is the highest coal mined in the county. It occurs in two and occasionally in three benches, and while thin, is a good persistent horizon which belongs to the upper division of the Des Moines beds. Two other seams of lesser importance outcrop in the vicinity, as will be seen from the general section. About 100 feet below the Lonsdale coal is the seam formerly worked at Glendon and now opened up at the Anderson mine. It is a clean, brittle coal with good roof and bottom and easily worked with the pick. It probably extends over a considerable territory in the vicinity mentioned.

Deeper coal seams have been encountered at several points but have not been opened up. In the northeastern townships the red and blue shales of the Des Moines formation are frequently encountered below the drift, which is usually 100 to 200 feet thick. In the Sutherland well (Tp. 80 N., R. XX W., Sec. 12, Se. Se.) a six-foot bed of coal is reported at 240 feet, with a second vein at 300 feet. Two seams at about the same depth were found at Dale City. The latter well, while located further down the slight dip, was begun on much lower ground. The Easton well, probably about twenty feet above Stuart showed coal at 248 and 428 feet, the seams being said to be four feet thick. This is a churn drill record of a well put down for water and hence is not of the highest value. In a well near De Soto the following seams were encountered:

DEPTH—FEET.	THICKNESS—FEET.
98	1
239	2
253	1½
350	3

At Van Meter coal seams are present at 574 and 564 A. T., at Commerce the bed worked lies at 717 A. T. and lower beds

are known to be present, and at Des Moines the principal workable horizons are usually found at 779, 705 and 635 A. T. These facts indicate that up to the outcrop of the Bethany limestone and for some distance at least beyond, the Des Moines is a coal-bearing formation. In the Stuart boring, sixteen inches of coal, divided by 11 inches of black slate, was found at a depth of about 290 feet, and a second seam 4 inches thick at 453 feet.

The complete record of the Stuart boring upon the Savage & Dosh farm, kindly furnished to the Survey by the Stuart Prospecting Co., is given below.

		FEET.	INCHES.
40.	Drift	4	
39.	Sand, water vein	4	
38.	Drift, water vein	145	9
37.	Sand	6	
36.	Drift	16	
35.	Sand, water vein	3	9
34.	Limestone		3
33.	Sand shale light, pyrite bands	92	
32.	Clay shale, light	3	
31.	Limestone, fossiliferous		8
30.	Shale, blue		10
29.	Limestone, fossiliferous	1	2
28.	Shale, blue	5	
27.	Limestone		8
26.	Shale, black	1	2
25.	Coal		6
24.	Shale, bituminous		11
23.	Coal		10
22.	Shale, light	3	
21.	Sandstone	8	
20.	Shale, blue, red and brown	31	
19.	Clay shale, light	5	10
18.	Black shale	4	
17.	Rock, gray		7
16.	Black shale	2	8
15.	White shale	6	
14.	Black shale	2	
13.	Blue clay shale	3	
12.	White clay shale	4	
11.	Blue sand shale	6	
10.	Red clay to brown clay	35	9

		FEET.	INCHES.
9.	Gray sand shale	4	
8.	Brown clay shale to red and blue clay shale	14	
7.	Blue clay shale	29	
6.	Black shale	1	8
5.	Coal		4
4.	White clay shale	3	
3.	Blue clay shale	10	
2.	Blue sand shale with water vein	29	
1.	Limestone, blue	1	
	Total	496	4

The mines of the county are drifts or shallow shafts. They are worked for local trade only, and are operated on small capital. They rarely control more than a few acres and most of them change hands frequently. The equipment is, in most cases, rather primitive, though serviceable and usually all that is warranted by the thin seams and the merely local trade. The plant of the Greenbriar Coal Co. includes a steam hoist, but the remainder of the mines are worked by horse power gins. Only a few of the mines work all the year. Many are closed entirely in summer, and others employ only one or two men. In many cases new drifts are made each fall and deserted in the spring. Under such circumstances the mining location is permanent, but the mine itself is evanescent. For these reasons it is impossible to get definite information about some of the mines, and in most cases very little could be learned. The list given below is not complete, but it includes all mines open during the field season of 1896, with notes upon certain others which, because of their location, are important, as indicating the distribution of the coal.

With regard to the future of the mining industry of the county it may be said the prospects are encouraging. There is a considerable amount of coal already in sight. The seams are thin but the quality is fair and the quantity ample for local use. The lower and usually more productive portion of the formation is concealed by drift, and has never been explored. There can be no doubt that it contains thick coal beds, which will in time be opened up. This work will require

larger capital than has yet been employed in the mining industry of the county, but it cannot be doubted that in time Guthrie county will prove to be a largely productive field. The expense will necessarily be somewhat heavy, as the drill holes may have to be carried as far as the Saint Louis limestone, and they must be numerous since there are no surface indications of value. For obvious reasons the area over which the Des Moines crops out offers the best inducements, though it is not unlikely that coal may be found under the other formations.

The Greenbriar Coal Co. operates a shaft located on Snake creek, a tributary of the Raccoon, about three miles northeast of Herndon, and near Jamaica. (Tp. 81 N., R. XXX W., Sec. 1, Ne. qr., Nw. ¼.) The mine has been operated for eight years. The shaft is sixty-eight feet deep, and the coal seam averages two feet four inches in thickness. It is covered by forty-seven feet of black slate. A portion of the fire clay below the coal is lifted to make entry room. A short distance east of here, at Dawson, there is an important mining industry, three seams being known, twenty-two inches at sixty feet, a three-foot vein at a depth of 115 feet, and a three and one-half to four foot vein at 165 feet. At Angus, still further to the east, deep mining has been carried on for some years.

Southwest of Linden (Tp. 79 N., R. XXX W., Sec. 36, Ne. qr.) a seventeen-inch seam has been worked at several points along the Raccoon. New mines have been opened from time to time, the Stapes and the Keeler being perhaps best known.

Half way between the Linden and the Panora mines is a small group, among which may be mentioned the Burgess, Fisher and Dygert mines (Tp. 79 N., R. XXX W., Secs. 16 and 21). The section at this point has already been given. At the Burgess mine a twenty-inch seam is reached by a shaft at a depth of fifty-four feet. A lower vein is said to occur.

Near Panora mining has been carried on for many years, the coal occurring along three horizons, as already noted. The section at the Reese mine is representative. Within the

past year a new shaft was put down by Mr. Reese. Near it on the east side of the road is the mine of Walker Emery, which was also opened in 1896. The White Ash mine is located on the west side of the river just north of town (Tp. 80 N., R. XXX W., Sec. 31, Nw. qr., Se. ¼). It is inadvertently omitted from the map. Still farther north (Tp. 80 N., R. XXXI W., Sec. 25, Se. qr.) coal has been mined at the Harris mine, the bed being twenty inches thick and reached by a shaft twenty feet deep. On the opposite, north side of the river (Sec. 24, Nw. qr.), is the Clark mine, a new shaft with well-built top works.

Fanslers has long been known as a mining locality. At present there are eight mines in operation, all gin shafts, reaching the same coal horizon. The Hughes mine (Sec. 9, Se. Se.) is eighty feet deep, the Thomas (Sec. 9, Sw. qr., Se. ¼) and the Butler (Sec. 9, Nw. qr., Sw. ¼) are of the same depth. The Renslow (Sec. 4, Sw. Sw.) is sixty feet, the Merchants (Sec. 4, Sw. qr., Ne. ¼) is 111. Near the latter mine is the Winter mine (Sec. 4, Nw. qr., Sw. ¼). About a mile and a half west are the Scott mine, at which, as has been said, two seams are present (Tp. 81 N., R. XXXI W., Sec. 31, Se. qr., Sw. ¼), and that owned by Mr. J. Thomas (Tp. 80 N., R. XXXI W., Sec. 6, Ne. qr., Nw. ¼). Numerous other mines have been opened up from time to time, but are now abandoned.

South of Bayard coal has been taken out at several points for many years. The Wales mine (Tp. 81 N., R. XXXII W., Sec. 32) and the Perkins (Sec. 29) are drifts. The Brushy Fork mine (Tp. 80 N., R. XXXII W., Sec. 5, Sw. Sw.) and the Burroughs, formerly the Hughes & Clark mines (Tp. 81 N., R. XXXIII W., Sec. 24), are shafts. The latter, omitted from the map by mistake, have been in operation for seven years, though new shafts have been sunk from time to time.

Near Guthrie Center the only coal found is at the Anderson mine (Tp. 79 N., R. XXXI W., Sec. 17, Se. qr.) opened this year. Coal was formerly worked on Beaver creek west of Glendon both by drift and shaft and a thin seam was at one

time worked by means of a drift northwest of Menlo (Tp. 78 N., R. XXXI W., Sec. 16). North of Stuart coal has been mined at several points along Deer creek and other tributaries of the Raccoon river. In the summer of 1896 the Driscoll (Tp. 78 N., R. XXXI W., Sec. 12, Sw. Sw.) and the Lonsdale (Tp. 78 N., R. XXX W., Sec. 18, Sw. Sw.) were the only mines open. Both were shafts operated, as usual, with gins and supply an important local trade. The Lamb and the Suggert & Saint mines were located in this district. The Muldoon mine (Tp. 78 N., R. XXX W., Sec. 12, Sw. Sw.) is located on Hog branch. All these mines take coal from the Lonsdale vein, which has also been from time to time opened up at many other points along Deer creek and the South Raccoon.

Clays.

The material available in Guthrie county for manufacture into clay goods is abundant. The Des Moines, the Cretaceous, the loess and the alluvium are all capable of furnishing material suitable for such work. The heavy shales especially desirable for the manufacture of vitrified brick and sewer pipe, and excellent for many other purpoes, must be obtained largely from the Des Moines beds. As has already been seen this formation is very generally made up of shales of great variety. It is now being used at a number of points, but its capabilities are by no means exhausted. Pottery, fancy face brick, and numerous other grades of goods may easily be made from it. The happy combination in the same formation of clay of wide variety and coal for fuel affords opportunities that must, in the future, commend themselves more generally than has yet been the case, to men of means and far-sighted business capacity.

The Cretaceous yields comparatively little clay, since arenaceous material predominates in the formation. Near the Anderson mine is a deposit which has been tested and found to yield a good grade of fire brick. West of Guthrie Center, near the fair grounds, are beds worthy of a test. The

Missourian formation as represented in the county is a limestone and hence has no value in this connection.

The loess is abundant and easily manipulated. Its distribution may be seen on the map of the surface deposits. Its character has already been described. The following analyses, made by Prof. G. E. Patrick, shows its composition:

	PERCENT
Hygroscopic water	2 78
Combined water	3 55
Silica $Si O_2$	68 62
Alumina $Al_2 O_3$	14.98
Iron oxides calculated as Fe O	4.16
Manganese oxide calculated as Mn O	.64
Lime Ca O	1.48
Magnesia Mg O	1 09
Soda Na O	1.86
Potash $K_2 O$	1.50
Total	100.66
Error	.66

The sample was taken from the pit of Mr. W. E. Berry at Guthrie Center and is apparently fairly representative for the region. The material will be seen to be less siliceous than is usual for loess and higher in alumina. It is adapted to the dry-press, but could aparently be also worked as a stiff mud. It should make an excellent face brick of good strength and color.

The alluvium, so commonly present along the streams outside the Wisconsin drift area, is, as usual, well suited for the manufacture of common stock brick by the hand process. It is easily and inexpensively worked and affords a cheap brick of good quality.

A considerable growth in the brick industry may reasonably be expected as the wealth of the region increases. This growth will probably result from the better treatment of the loess and the wider use of the shale both alone and in mixtures. In the northeastern portion of the county the loess is covered by the drift, which is not itself adapted to manufacture into brick, and in this region the main dependence

must be the coal measure shales and clays removed in mining works, together with occasional patches of surface soil accumulated in sloughs.

The treatment given the clays in the county is usually slight. The hand process or simple machinery alone is used, though the Berry plant at Guthrie Center is well equipped, and the Panora Brick & Tile works are contemplating extensive improvements. The details of processes and machines are given in the description of the individual plants.

The W. E. Berry brick works is located at Guthrie Center, near the Rock Island track, southeast of the depot. It was started as a hand yard eight or ten years ago. At the end of two years the "Eureka," a stiff mud machine, was put in, and brick were made by this process until 1893, when a Boyd dry-press was introduced. The material now used is loess obtained from a low slope, immediately adjacent to the plant. The top eighteen inches of soil is removed, the under material is plowed, and when dried is hauled to sheds. The perpendicular face of the clay is nineteen feet. Underneath the loess the Cretaceous sand bed lies exposed, the glacial deposits usually found between the Cretaceous and loess apparently being absent. The product from the first kilns was not promising, but by the close of the season, as less sandy loess was used, and the necessary treatment both in the machine and in the kiln became understood, the quality of the finished brick was improved. In burning the brick a down-draft kiln and one ordinary clamp kiln are used, most of the brick being burned in the down-draft. The brick are carried direct from the press to the kiln.

The Stuart Brick & Tile Works is about three-fourths of a mile north of the depot at Stuart. The raw material consists of ten feet of ordinary loess grading into soil at the surface. The base of the cut rests on coarse drift gravel, which is about three feet thick, and this rests in turn upon glacial clays. The product, structural brick, sidewalk blocks and draintile, are made on the Decatur machine and burned in

either a closed down-draft or a semi-clamp kiln. The ware has a dull red color, and is very firm. Farther up on the hillside near by, a test pit was put down, and underneath the yellow clay, a gray plastic loess, four feet thick, was penetrated. This lower bed has not been used, as it was found to contain much lime. The clay now used is worked as a stiff mud with a good deal of water. The ware is dried under sheds with very little cracking.

The Panora Brick & Tile Works includes quite a large plant just southeast of the city limits, along Middle Raccoon river. It has been in operation for a number of years, starting with a Eureka stiff mud machine. Later a Hoosier mill was substituted, and this in turn has given place to a Frey-Sheckler. A section of the pit has already been given. For ordinary work all the shale, with the exception of the bituminous portion, is mixed together, and occasionally a little surface clay is added. For fine red brick the upper shale alone is used. The clay is ground in a dry-pan made by the Des Moines Manufacturing Co., and then pugged on a mill made by the same company. The brick are loaded upon iron trucks, and either run under dry sheds of 70,000 capacity, or through a tunnel drier holding 25,000. Under the dry sheds about three days time is required, while the tunnel drier does its work in twenty-four to thirty hours. Four down-draft kilns with a capacity of 200,000 are used in burning; five days, with full blast for thirty-six to forty-eight hours being required.

Directly west of Panora on the Guthrie Center road (Tp. 79 N., R. XXX W., Sec. 6) is the Horton brick yard, where the loess, fourteen feet thick, is used in making hand brick, which are burned in cased kilns.

Mr. W. B. Simon & Son, the owners of the Greenbriar mine, operate a brick plant near the latter. They make both brick and tile, using three kinds of clay. The fire clay from below the coal is mixed with the black shale above it, and the surface soil taken to a depth of three feet from a hillside. The material is worked as a stiff mud, dried under sheds, and

burned in one round down-draft kiln. The brick are hard and of good color.

Building Stones.

Material suitable for building purposes may be obtained from all the formations in the county. From the Pleistocene may be taken bowlders of granite and similar rock; from the Dakota and Des Moines sandstones, and from the Des Moines and Missourian limestones may be obtained. With the exception of the limestones of the Missourian, none of these sources are likely to become important. The bowlders are scattered and the cost of collecting and dressing them is more than that of shipping in more easily obtained stone. In certain other counties in the state the drift bowlders have been more or less used for special work. In this region they are often called into requisition for foundations and well and cellar walls, particularly in the northeastern portion of the county where nothing else is obtainable.

The sandstones both of the Dakota and the Des Moines are soft and of but limited value. They afford, however, a sufficient supply of stone for local rough use. The gray sandstone at Panora has been quarried a little, but is not used for fine work.

The limestones of the Des Moines are thin and of limited distribution. They will not afford a supply of much importance. The Missourian formation is represented in the county by the Fragmental and Earlham limestones of the Bethany with a few beds of the Winterset. The Bethany is extensively quarried in Madison, Clarke and Decatur counties. It has been opened up at a few points along Raccoon river and Deer creek. The openings are not extensive enough to give much of an idea of the stone, but apparently it is of the same character as that at Earlham and Winterset. A total thickness of nearly sixty feet is known to occur, and a good portion of this is suitable for building stone.

Sand.

Sand suitable for building purposes may be obtained from the bottom lands along many of the streams and from the Dakota. The latter is an important source of such material. The section of the pit of Mr. Samuel McLune, in the northwestern portion of Guthrie Center, has already been given. The lower sand here is clean, white in color, and easily worked. About 150 yards of building sand have been taken from the pit. Sand is found in the Dakota at a number of other points but has not been extensively opened up.

The drift sand found near Stuart was formerly used in the manufacture of hand brick. Since the introduction of machinery and the employment of the loess the sand is not needed. It is clean and of even grain but is too well rounded to be of the highest utility as a building sand.

Gravel.

There are two sources of gravel in the county. The first is the gravel terrace along the Middle Raccoon and the second is the gravel or conglomerate bed of the Dakota. The terrace gravel has not been used within the county except for local work. At Coon Rapids, just outside the county, on one hand, the Chicago, Milwaukee & St. Paul railway has opened up extensive pits. In Dallas county, on the other, both the Chicago, Rock Island & Pacific railway and the Des Moines Northern & Western railway have opened up pits. The gravel from this horizon is hard, uncemented and easily worked, but is usually quite sandy.

The gravel or conglomerate of the Dakota is widely spread throughout the western three-fourths of the county. It is frequently so completely cemented as to be unavailable, but at other points is loose and easily worked. The Chicago, Rock Island & Pacific railway has opened up pits between Menlo and Glendon along the Guthrie Center branch. The gravel is very hard, being formed of the most durable material. It has sand beds interstratified with it, but is usually rather free

R XXXIII W

R XXXII W

R XXXI W

R XXX W

BAYARD

CHICAGO MILWAUKEE SAINT PAUL

BAGLEY

Herndon

Willow Creek

ORANGE

HIGHLAND

DODGE

RICHLA

Big Sby

Mosquito

DES MOINES

NORTH WESTERN

Yale

MIDDLE

Fork

Fanslers

Wichita

UNION

SELEY

VICTORY

CAS

PANORA

Creek

Seeley

GUTHRIE CENTER

RACCOON R.R.

Creek

Bear Grove

BEAR GROVE

BAKER

VALLEY

Tomlinson

Creek

Monteith

RACCOON

JACKSO

Bear

MIDDLE

Beaver Creek

CHICAGO ROCK ISLAND & PACIFIC

Glendon

Dale City

RIVER

THOMPSON

GRANT

RIVER

BEAVER

Deer

CHICAGO ROCK ISLAND & PACIFIC

MENLO R.R.

Adair

CHICAGO ROCK ISLAND

CASEY

IOWA PRINTING CO. DES MOINES.

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF GUTHRIE COUNTY, IOWA.

BY

H. F. BAIN

1897.

LEGEND

GEOLOGICAL FORMATIONS

- DAKOTA
- MISSOURI
- DES MOINES

INDUSTRIES

- MINES
- CLAY PITS
- ARTESIAN WELLS
- GAS WELLS BURNING
- GAS WELLS ABANDONED

DRAWN BY F. C. TATE

from sand within the gravel. It is an excellent material for railway ballast.

Natural Gas.

One of the most interesting features in connection with the drift is the occurrence of natural gas. At Herndon gas has been found in a number of wells, and while only two wells are now burning, a considerable area has been shown to be underlain by it. This was at one time the cause of a considerable boom in real estate, but it has recently received very little attention; less in fact than it deserves. According to Mr. J. E. Stout* the gas was first discovered in October, 1886, in a well put down for Mr. F. Gardner. The well was being bored for water, and at 120 feet gas was encountered. This well was shut off without being used, as was also the first one put down for Mr. H. C. Booth, in November of the same year. A second well put down for the latter gentleman furnished gas for heating and cooking for a year or more. A number of other wells were put down, all going to a depth of from 120 to 140 feet. In most of these gas was encountered and from many of them it was used. In no case did the wells penetrate anything other than the drift and in all cases a fine sand or mud with the gas gave trouble. This mud was never successfully cased off and would flow into the pipe until the gas below accumulated sufficient force to throw out the mud. This of course made an explosion and usually resulted in the gas pipes being taken out. The mud choked up the well within a few months in most instances, when it was necessary to put down another well in order to obtain a new supply. At present but two wells are burning, one near the railway station, and the other on the Leber farm a mile and a half west of town. Neither is in use. In one well on the Pierce farm near Yale, gas was encountered in 1887 above the artesian water, but was never used.

The pressure of the gas seems never to have been measured. According to Dr. Jones, now of Herndon, in one case a two-inch

*Rept. Stat. Mine. Inspector, 1887, 168-170.

pipe furnished gas for a flame twenty to twenty-five feet high and about eight feet across. At Dawson, a few miles east of Herndon, similar wells had a pressure of twenty-four to twenty-five pounds.* At Letts, in Louisa county, gas wells of the same type are said to have had a pressure of five to twelve pounds.† The Leber well now has a pressure which, judging from the size of the flame, must be considerably more than the pressure in ordinary city pipes. No analyses of the gas has been made. Call,‡ who visited these wells soon after the gas was first struck, referred the origin of the gas to the decomposition of the vegetal matter of the forest bed. McGee§ has concurred in this view. Most of the wells are not driven deep enough to encounter the forest bed, though it is known to be present and has been encountered in deeper wells. The origin assigned by Call is doubtless the correct one. It accords well with the facts observed in other regions, as at Letts,‖ Iowa; Bloomington, Kankakee and other points in Illinois and other states¶. In all these cases it will be observed that the gas is encountered near the edge of an overlying drift sheet. It is but a short distance southwest of Herndon to the edge of the Wisconsin drift. Letts is near the border of the Illinois drift and Kankakee is near a well developed moraine which seems to mark the border of the late Wisconsin. The forest beds when developed between drifts are more apt to be well preserved where they have been passed over by only a small portion of the succeeding ice. They are, in places, preserved far back from the edge of the overlying drift, but the chance of preservation decreases with the distance from that edge. These facts give a new economic significance to the tracing of the limits of the drift sheets.

*Leonard: Proc. Iowa Acad. Sci., vol. IV, p. 43. 1897.
†Witter: Proc. Iowa Acad. Sci., vol. I, pt. iii, pp. 68-70.
‡Mon. Rev. Iowa Weather Serv., Nov., 1892, pp. 6-7.
§Eleventh Ann. Rept., U. S. Geol. Surv., p. 595.
‖Witter, Loc. cit.
¶McGee: Op. cit., p. 595.

The area in the county in which gas wells may be found is not large. It is confined to the area of the Wisconsin drift. The numerous wells put down for water throughout the region show very clearly that the gas territory is only a small portion of the Wisconsin area. It is of course highly probable that gas will be encountered at points not now known, but the presence of many artesian wells showing either no gas or only small amounts narrows the area of probabilities.

It seems probable that the gas may have more of an economic importance than has been heretofore allowed to it. It is of good quality, sufficient pressure and cheaply obtained. While the quantity is not great, certainly not sufficient to warrant an attempt at piping it to other cities, there is no reason to believe the supply inadequate for local demand. Such gas is in use at other points both in this and neighboring states, and at certain points wells have been used for six or seven years with no apparent diminution of pressure. In the Herndon wells the trouble arose from the water and sand which filled the pipes. It certainly seems that adequate study would result in some device for clearing the gas and thus making available a highly valuable local fuel.

Water Supplies.

Guthrie county is well supplied with water. The numerous streams of the central and southwestern portion of the county and the miniature lakes of the northeastern portion afford an abundant supply of surface water. The drift deposits which cover the area contain numerous water horizons so that there is rarely any trouble in getting a good well. The base of the drift is usually a reliable horizon. At Stuart an excellent supply of water is obtained from a white sand lying below ninety feet of drift, the water being, however, charged with magnesia, which is deposited in the tanks and pumps. The water has been used for some years as a boiler water by the railway company, and has recently been adopted as a supply for the city water works.

The gravels, sands and loose sandstones of the Dakota may usually be relied upon to furnish water. At Guthrie Center the city water works draw their supply from a well in this formation. The limestone of the Missourian are not so reliable, and the Des Moines beds are apt to furnish mineralized water.

In the northeastern portion of the county near Bagley, Herndon and Yale there are numerous artesian wells, all obtaining their supplies from the drift. They are, in the main, of slight depth, but vary in that particular. The old Yale well is twenty-three feet, the Bartlett well is 140. At Bagley there are six wells inside the town all less than sixty feet deep. In some places the water is so close to the surface that it forms springs. The water has usually a fair but not high pressure. The Yale well fills a half-inch pipe with a strong stream. It is nine years old, and formerly filled a three-fourths inch pipe. The Eastwood well runs a two-inch stream, and will rise to twenty feet. Most of the wells rise only three to four feet above the surface. One of the wells near Bagley would throw an inch and a half stream twenty feet high. The stream is now reduced, and the water carried up to the house near by.

The source of the water is evidently local. The topography of the country is that of swells and basins, with a relief of twenty to thirty-five feet. The wells are located on the lower lands, and in no case do they throw water higher than the highest land of the immediate vicinity. Certain of the wells interfere with each other, but in general they do not seem to do so. During the recent dry years it was noted that some of the wells showed a slightly diminished flow.

There seems to be no single water horizon. It has not been found possible to relate the flow to any definite bed in the drift. The latter is here as usual quite heterogeneous. The beds of bowlder clay contain sandy and gravelly portions well calculated to catch and transmit water. These are present in the drift of the entire county, and for that matter are usual

throughout the state. They form the source of a large majority of the shallow wells of the state. The water here, as elsewhere, seems to be derived from local precipitation. The average annual precipitation for Guthrie county is probably about forty inches. Unfortunately there are no complete figures for the county, and the matter must be judged by measurements made in the surrounding region. At Atlantic the amount is 41.47, at Audubon, 43.75, and at Carroll, 41.83.*

A precipitation of forty inches would amount to a daily average of 1,600,000 gallons per square mile.

When water falls on the ground a portion is evaporated, a portion is absorbed by the ground, and a portion is carried away by streams. The amount which runs off through the streams is quite variable. It depends upon the slope, character of the rocks, distribution of the rainfall and other lesser factors. The best estimate for the streams of this region are those of Greenleaf,† who gives the run off of the Des Moines river as 20 per cent, and of the Skunk as 24 per cent. Of the total precipitation, then, at least 320,000 gallons per square mile is daily carried away by the ordinary streams of central Iowa. Any region of incomplete drainage has a surplus of water proportional to the imperfection of the drainage. This surplus must either stand on the surface till evaporated or soak down into the soil. Evaporation is more rapid in an undrained than a well drained area, other conditions remaining the same, but the ratio of increased evaporation is problematical. There is also large seepage, and the ground becomes more heavily charged with water. Such are the conditions which prevail in that portion of Guthrie county under discussion. As has been previously noted, the region covered by the Wisconsin drift is marked by few streams, and many ponds and shallow lakes. Very little of the water is carried off by surface streams, and the ground is at all times quite saturated. Upon each undrained acre there is an average annual surplus

*Ann. Rept. Iowa State Weather Serv., 1895.
†Tenth Census U. S. vol. XVII, pt. ii, p. 20.

of 1,825,000 gallons. Under such conditions the water will penetrate every stratum which is permeable, and will take advantage of every favorable condition for flow. With a local relief of thirty to occasionally forty feet, and strata containing many irregularly distributed beds of open texture alternating with stiff clays, there must be many points at which flowing artesian wells may be found. The number of the wells, the slight depth, the moderate flow, the occasional interference, the variation, though slight, with the rainfall and the structure of the region, all unite to show that this is the true explanation of the phenomena. In some cases the water probably goes to the base of the drift, and is carried by the gravel usually found along that horizon; in other cases the water is probably carried by the loess between the two drifts. In many cases it is carried by local sandy and gravelly beds in the drift itself.

Soils.

The soils of Guthrie county are its great source of wealth. They include all the main types which occur in drift covered regions. In the northeast is the drift soil itself, along the rivers are the rich alluvial bottom lands, and over the divides of the central and southwestern portion of the county is a top dressing of loess on the loose and weathered Kansan drift. The areas covered by each of these soil types are indicated upon the map of the surface deposits. The characteristics of the different beds have been suggested in the discussion of the Pleistocene. As soils their variations are mainly due to differences in texture and structure. The composition of each of the two drift sheets as a whole is probably not greatly different. The loess and the alluvium represent the finer portion of the drift gathered together. The composition is much the same but the texture is very different. The drift is heterogenous; the loess homogeneous, and the alluvium, sometimes one and sometimes the other. The fine texture, porosity and homogeneity of the loess greatly influences its behavior toward water. The latter is distributed more equally

through it and is furnished evenly to crops. In the drift region the water is irregularly distributed, and this, with the immature drainage, makes artificial ditching and tile drainage necessary over considerable areas. So sharp are the differences between the two areas that in Jasper county, where the same relations obtain, entirely different culture is found on opposite sides of the stream which flows along the drift margin. This extends even to the character of the plows, those on one side of the stream refusing to scour in the soil on the opposite side.

In this county, as in other portions of the state, it has been found that fruit does better on the loess than the drift soils, while, when the latter is suitably drained, wheat and even corn usually give a larger yield upon the drift. There are, of course, exceptions and other factors must be taken into account, but that these different formations have different soil values is abundantly proven. The determination of this value and the adaptabilities of the different types as well as the nature and causes of the differences is a matter which will require much future study.