GEOLOGY OF CARROLL COUNTY.

BY

H. F. BAIN.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Carroll county is located in the western portion of the state, Crawford and Monona counties being between it and the Missouri river. It contains the usual sixteen townships, 576 square miles, and is rectangular in form. Sac and Calhoun counties border it on the north, Greene county lies to the east and Audubon and Guthrie are its neighbors on the south. It includes a portion of the high upland region which divides the waters of the Mississippi from the Missouri. The Altamont moraine crosses it from northwest to southeast just east of the divide. The older, Kansan, drift is well displayed in the southwestern portion of the county. In the northwestern townships the drift exhibits certain peculiarities which, attracting attention in the summer of 1897, seemed likely to throw considerable light upon the geology of the surface formations of the northwestern counties of Iowa. It was with this in view that the study of Carroll county was at this time taken up.

PREVIOUS GEOLOGICAL WORK.

The earlier geological surveys, conducted by Owen and Hall, did not extend into this region. The White survey, however, covered the county and in the report issued in 1870 there is an excellent though brief description of its geology.* This was previous to the general awakening of interest in the surface formations which has been so marked a feature of

*Geol. Iowa, Vol. II, pp. 138-146, 1870.

geologic work in recent years. Accordingly the drift deposits of the county did not receive the interpretation which is now given to them. Nevertheless the more important phenomena were accurately described and certain of the generalizations quite clearly foreshadowed. The term moraine was not used, but the presence of drift ridges was clearly recognized. Mr. Warren Upham seems to have been the first distinctly to recognize the moraine in this county. In 1880 he traced it through Iowa and gave a brief description* of it as developed from Coon Rapids to Breda.

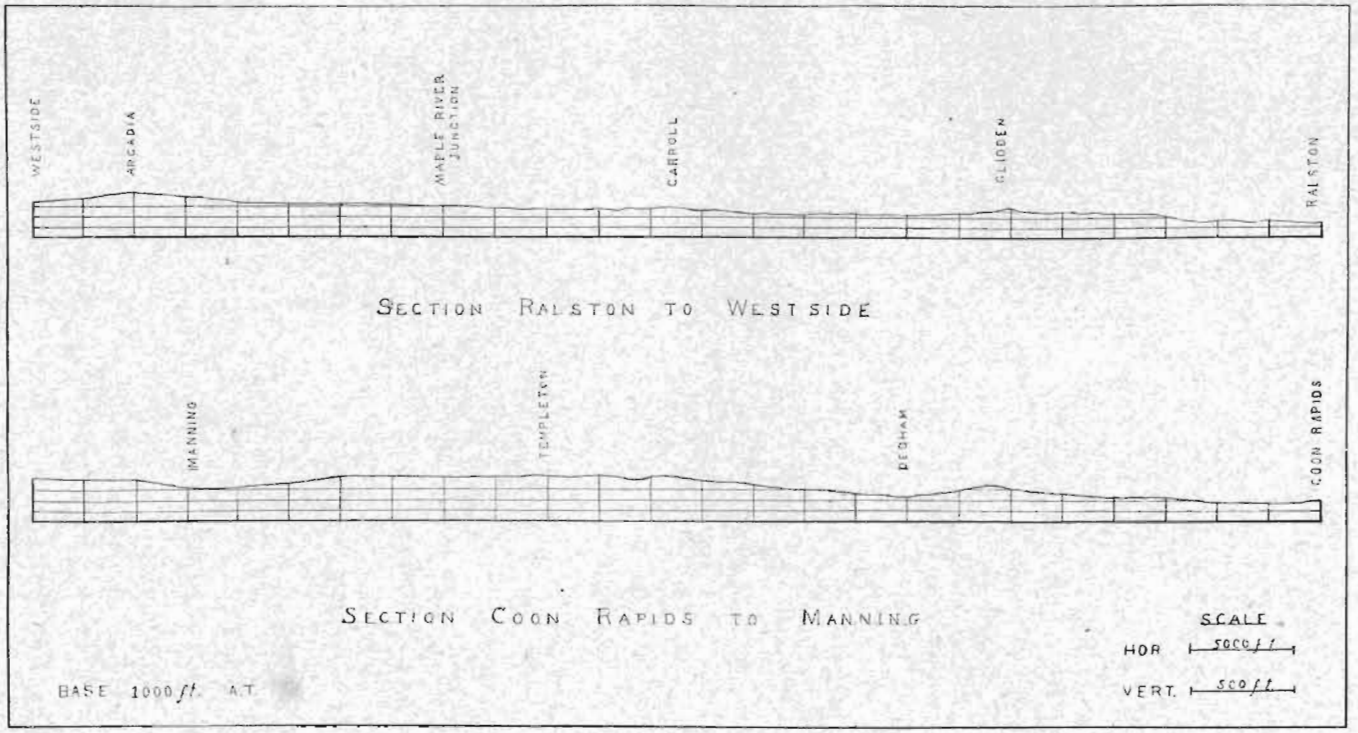
The present work has included certain brief reconnoissance trips in the fall of 1897 and more extended field work throughout the season just past. In the latter the Survey has had the benefit of field conferences with Mr. Frank Leverett, of the United States Geological Survey, who visited the most important exposures in company with the author.

PHYSIOGRAPHY.

TOPOGRAPHY.

Carroll county belongs to the great prairie plain of the middle west. It is not marked by any pronounced inequalities of surface. The maximum variation is about 360 feet, but individual slopes of more than 150 feet are exceptional. The general effect, away from the immediate neighborhood of the streams, is that of a gently undulating plain. This plain is, however, not quite level; neither is it tilted in a single direction. It has been warped so as to slope to the northeast and to the southwest, from a slightly sinuous line running approximately through Arcadia and Templeton. This line is the divide between the Mississippi and Missouri river systems. Plate ii shows two sections across the country, one following the line of the Chicago & Northwestern railway and accordingly running from east to west through the middle, and the other along the Chicago, Milwaukee & St. Paul rail-

*Geol. Nat. Hist. Surv., Minnesota, 1880, pp. 308-309.



CROSS-SECTIONS IN CARROLL COUNTY.

way, in the southern portion of the county. These cross-sections bring out fairly well the broad shield-like character of the divide, though this feature would be more pronounced if longer sections were taken. The fact that the major portion of the county lies on the eastern slope is shown, as well as the fact that the width of the area tributary to the Missouri increases to the south. The sections do not show the tabular character of the divide so well as one constructed regardless of drainage lines would. The railways have necessarily followed the latter for the sake of easy grades. Arcadia, Glidden and Templeton, however, stand practically on the upland. At Carroll the profile shows a considerable elevation, marking the Altamont moraine. This is, however, feeble, as compared with the actual profile, since the hills here rise 130 feet above the railway grade. The slope from Arcadia to Westside is too great, and gives an undue ridge-like aspect to the divide. At Arcadia the grade is but 45 feet below the general upland. At Westside it is considerably more. Coon Rapids is built on the out-wash plain of the moraine, and the hills, both north and south, rise 180 feet above the town.

The general flatness of the region is none the less shown by the profile, despite the fact that in the drawings the vertical scale is exaggerated to ten times the horizontal. The divide is not to be thought of as a narrow ridge, but as a broad, gentle swell. The opposing systems of streams lead up to it on opposite sides. They do not usually interlock to any notable extent. There is ordinarily a rather prominent belt of country between their headwaters, which is barely cut into. This debatable ground forms the real divide and is rather a bit of upland plain with imperceptible slopes than a narrow dividing ridge. It has itself a gentle slope to the south, from 1,476 feet on the higher flats north of Arcadia to 1,450 feet on similar flats west of Templeton. To the east the surface slopes off gently to the Mississippi, falling 850 feet in the 250 miles between Arcadia and Sabula, which lies approximately east of the latter place. The western slope is greater, as the fall

between Arcadia and Onawa, which lies fifty miles almost due west, is 391 feet. As measured from Templeton to Lyons the fall is 856 feet in 245 miles, and the corresponding slope to the west is 398 feet in the fifty-eight miles to Blencoe. The major slope, however, is not directly east or west, but rather to the southeast and southwest. This is sufficiently indicated by the direction of the drainage lines, but is readily proven as well by comparisons of levels. The upland surface is very slightly convex. The slope per mile increases both from the west and east as the median line is approached, though the increment is very slight. The surface is not, however, even. It has been etched by the streams, which have cut great gashes into it, and it bears on its surface the unreduced accumulations of the later geological epochs. The latter are piled up so as to form minor rugosites on the shield surface.

The stream valleys, cutting in from the west and the east and acting according to the well known law of river profiles, have longitudinal sections which are of increasing concavity as the sources are approached. This concavity of the river profiles, while slight, as shown in instrumental surveys, is great as compared with the much slighter convexity of the upland surface. The result, of course, is that the stream valleys are relatively deep and sharp near the divide though the same valley is both broader and shallower nearer its mouth. This gives to the country near the divide a relatively fresh and uneroded appearance. There are broad, barely sloping divides bounded by narrow, deep-cut ravines. There are, however, many reasons for the belief that the region of the divide belongs with the more eroded region of southern Iowa in age, at least so far as the part found in Carroll county is concerned.

The erosion topography, while more noticeable near the headwaters of the streams, is characteristic of all the area south and west of the edge of the Wisconsin drift, as traced on the accompanying map. This line divides the county into two areas which are topographically quite distinct. The

northeast part of the county has a typical drift-plain topography. The narrow median belt is morainic. The southwestern part is a region of typical erosion forms. Considering the morainic belt as belonging with the drift plain into which it merges, the area shows two sharply contrasted sets of topographic features. The one is almost wholly the result of ice action and the other is exclusively due to the long-continued work of rivers.

WISCONSIN DRIFT PLAIN.

The most striking topographic feature of the drift plain is the presence of undrained areas. While there are now no large lakes within the county there are numerous ponds and sloughs. Goose lake, in the western part of Richland township and a portion of Pleasant Valley, and Morris lake, in the northwestern part of Union township, are now drained but are reminders of a past but little removed. Goose lake was one and a half miles long by one-third as wide, and Morris lake covered nearly 200 acres. These are in the morainic belt near the edge of the drift. The smaller ponds and sloughs, however, are irregularly distributed from the very edge of the Wisconsin to the extreme northeastern corner of the county, and for that matter, for miles beyond. They vary considerably in size and depth but may all be fairly considered shallow and small. Many are now mere grassy swales, covered by water for only a portion of the year. In rainy seasons they expand and in prolonged wet weather a considerable area may be brought under water. Such a condition betokens extreme topographic youth and the increasing amount of land dry enough to cultivate regularly is due more to artificial ditching and drainage than to normal stream action. The whole country away from the immediate neighborhood of the major streams is one gently undulating plain of very slight relief, grass-covered where uncultivated, and dotted by the groves set out by the pioneers. The large valleys are marked by thin, straggling lines of native trees. The plain is made up

of interlocking and disconnected shallow basins with intervening swells of reverse contour. It is the type of topography characteristic of the Wisconsin drift plain, throughout the state,* and called the saucer topography, from the likeness of the basins and swells to irregularly placed saucers. The basins are of various outline and usually without outlet. Some are connected by narrow ditch-like channels through which run the sluggish waters of a young stream. Storm creek is really a series of such basins so connected.

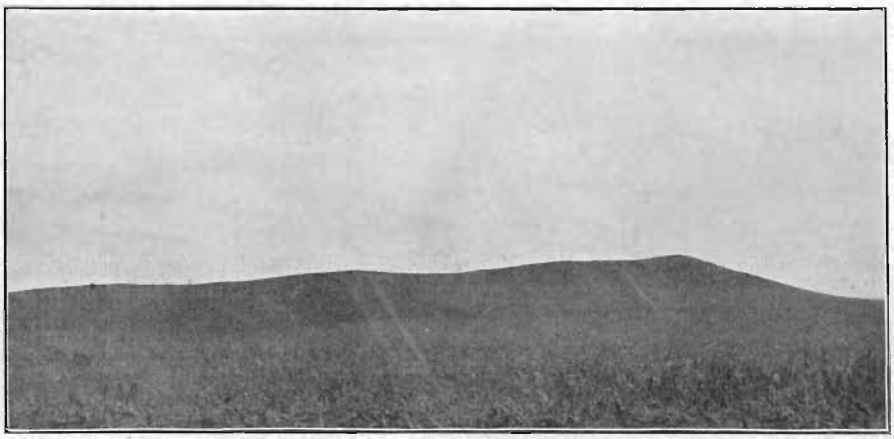


FIG. 1. Morainic knob in northwestern part of Carroll.

The swells rise normally but twenty to thirty feet above the adjacent low land. Southwest of Glidden there is a group rising quite sharply; one with three peaks forming a broken ridge. These are morainic in appearance, and are composed of drift. They seem to be detached, and do not apparently form a part of a connected series. Near Benan there is a small group of kames, which will be described later. Along the southwest border of the drift plain the swells become gradually more pronounced, the slopes steeper and the hills higher, until a well developed morainic topography is found. The morainic hills rise 60 to 70 feet above the drift plain proper, but do not stand up notably above the higher divides

*Geology of Polk County, Iowa Geol. Surv., Vol. VII, p. 270.

west of the Raccoon river. Near Carroll their tips rise to 1,400 A. T. At Breda, and in some portions of Carroll township, the outer slope of the morainic is well pronounced. In general, the inner border is not well defined. In Kneist township the country is slightly morainic as far east as Mt. Carmel. In Pleasant Valley township, where the moraine runs west of the Raccoon river, the border is much better defined, and from Carrollton to the southeast corner the bulk of the moraine is between the Raccoon river and a broad sag which seems to mark the former course of that stream. In general, the moraine covers a strip of country from one and a half to four miles in width. Upon the accompanying map its outer border is traced with some care. For the reason just given its inner border is generalized somewhat. The fading of the moraine into the drift plain is often so gradual as to make it a matter of opinion where the line should be drawn.

Mr. Upham's description of the moraine as found in the county may be quoted as being the first published, and also for its conciseness and clearness.*

"In Carroll county this belt, from one and one-half to three or four miles wide, continues northwestward by Coon Rapids, Carrollton, Carroll, and Maple Junction to Breda. From the southeast corner of the county to Gustine Grove, two miles beyond Carrollton, it consists of swelling hills of till, not so rough as to be typically morainic, which occupy a width of one and one-half to three miles along the northeast side of Middle Raccoon river, rising from 100 to 150 feet above it, and averaging seventy-five feet or more above the smooth sheet of till on the east. Between one and two miles northwest from Carrollton some of these hills, 100 feet above the river, consist of loess at the surface, free from pebbles to a depth of ten or twelve feet. This has the same yellowish color as the upper part of the till. Other hills near have many rock fragments, both large and small, being common till, but morainic in the abundance of bowlders. From Gustine Grove to Car-

* Geol. Nat. Hist. Surv. Minnesota, 1880, pp. 308-309, 1891.

roll the moraine holds its straight course northwestward, lying on the southwest side of the river, which here flows east and then south. Its height is from 100 to 125 feet above the river. A part of its mounds and hillocks through this distance are covered by loess, but mostly their surface is till, with numerous bowlders and pebbles. A lakelet two miles southeast of Carroll, and frequent sloughs, lie in the depressions of this formation. Beyond Carroll the Middle Raccoon river is again its southwest boundary, from which it reaches to Mount Carmel. It here consists of moderately rolling till, with crests thirty to fifty feet above its hollows; and this character continues to the north line of the county, where its course is through the northwest part of Wheatland township, with a width that reaches about a half-mile east and two miles west of Breda."

LOESS-KANSAN PLAIN.

South and west of the moraine a very different sort of topography prevails. There are no lakes, ponds or swales, except such as have been constructed by man, or an occasional bit of marshy ground on a river bottom land. The whole area is thoroughly drained by a well developed system of rivers. The valleys are cut deep into the drift and both they and the narrow, but usually flat, divides stand in obviously close relations to the present streams. There are no hills which rise above the general level and such hills as are present are but dissected portions of the inter-stream areas. The slopes are even and regular and usually are long and gentle. The peculiar hummocks of gravel and knob-on-knob hills which abound in the morainic area, and are occasionally found in the drift-plain area, are entirely absent. Everywhere it is the streams which are dominant and the topography has been carved by them out of the general upland plain already described. Standing on one divide one may look across a series of similar narrow tabular divides all rising to form this plain and together forming a skeleton net-work outlining its

former extent. One hundred to 180 feet below this the streams are now cutting. The minor branches are working back into the hills and their headwaters reach up the slopes usually to the base of the loess which constitutes the most usual underground-water level. Above that the slopes are gentler and of different contour as resulting from occasional wet weather erosion and continued atmospheric weathering rather than continued erosion alone. In their lower courses the larger streams are developing bottom lands. The latter are, however, relatively slight and it is doubtful whether any considerable portion represents permanent filling. The flat areas found along the streams belong rather in the category of straths, as defined by McGee.* The region is one of very delicate adjustment of the streams. They are just approaching maturity and while the upland is almost gone, the lowland has hardly begun to form. The streams are actively eating away the inter-stream divides. Occasionally they cut so close together that narrow knife-like divides and unstable forms occur. An instance of this may be seen about three miles east of Dedham (Sec. 14, Newton Tp.) where a narrow divide has been broken up into a series of knobs closely simulating in appearance some of the morainic hills.

The southwestern area, as contrasted with the northeastern, presents everywhere evidence of topographic maturity rather than topographic youth, of erosion rather than deposition, of stream action rather than ice work. It is clearly older and the land forms present must have been almost wholly developed before the Wisconsin ice came into the region.

DRAINAGE.

The streams of the county reflect the same differences that are shown in the topography. The North Raccoon, Purgatory, Elk, Storm and Willow creeks are young, have few branches, and flow in anomalous valleys. The Middle Raccoon, Brushy Fork, the two Nishnabotnas, and their branches are older, have many secondaries and, except in the case of

*Pleistocene Hist. N. E. Iowa, Eleventh Ann. Rept. U. S. Geol. Survey, pp. 261-262.

the first mentioned, normal, unterraced valleys. The Nishnabotnas and their tributaries, with the headwaters of East Boyer river and Beaman creek, belong to the Missouri drainage system. The remaining streams flow into the Mississippi through the Raccoon and Des Moines.

The best developed stream in the northeastern portion of the county is the North Raccoon. This stream has its headwaters in Buena Vista county and unites with the Middle Raccoon near Van Meter in Dallas county. As found in Carroll county it is a narrow, shallow, recent stream. It receives Elk, Buck and Doe runs from the west, and Purgatory creek from the east. Its banks are mainly Wisconsin drift, though there are exposures of the Dakota sandstone on the main stream and on Purgatory creek. The system has done considerable cutting, and at Benan the river is eighty feet below the upland to the west. The divide between the main stream and Purgatory creek in the same region rises seventy feet. Where the North Raccoon crosses the east county line the valley has been cut to a depth of ninety-five feet. There are terraces on the main stream and gravels along Purgatory creek, which will later be discussed.

Storm creek is in many respects the youngest looking stream in the county. It has no real valley, but winds in and out between the low drift swells, expanding to form a swale and then contracting to a narrow ditch. Through much of its course it catches the drainage, such as it is, of the back slope of moraine. It has, though, no system of feeders nor any of the marks of age. It is a typical consequent stream. It joins the Middle Raccoon where the latter flows inside the moraine west of Glidden.

Willow creek is a name applied with more or less authority to three separate branches within the county. The largest is a stream starting about a mile southeast of Glidden and flowing across the southwestern corner of Greene county to the Middle Raccoon, about three miles south of Bayard in Guthrie county. In its upper portion this stream is a recent, conse-

quent stream, similar in all respects to Storm creek. In its lower course it is an older, resurrected stream* occupying a part of a rock-cut valley out of which the Raccoon had been pushed by the ice. This valley is marked by a sag running across Union township and occupied in part by a tributary of Willow creek, to which the name of the parent stream is sometimes applied. The third Willow creek is a small tributary of Nishnabotna river joining that stream near Manning.

The most important river in the county is the Middle Raccoon, or Middle Coon as it is sometimes called. This stream has its headwaters within the county in the high upland region of Wheatland township. From Breda down to Maple River junction it is sometimes called Maple river. About half way between the two places it receives a rather important branch from the northwest, and near the junction it receives the stream followed from Arcadia by the main line of the Chicago & Northwestern railway. These three prairie streams together form what is usually considered as Middle river. From Carroll to Coon Rapids the river receives numerous branches from the west, each with well developed secondary and tertiary branches. A similar series of streams which doubtless once flowed into it from the east have been blotted out by the Wisconsin ice, and now Storm creek is the only important tributary from that direction. In general, Middle Coon flows just outside the altamont moraine, and usually in a valley older than the latter. In this it simulates the behavior of the older portions of the river in Guthrie,† Dallas‡ and Polk§ counties. In Carroll county the Coon has been more disturbed by ice than farther south. As far south as Carroll the valley is outside the theatre of action of the Wisconsin ice, and seems to have been uninfluenced by the latter. At Carroll it turns sharply to the east, cuts through the moraine, and reaches the broad low flat which lies just

*Bul. Geol. Soc. Am., vol. I, p. 549. Iowa Geol. Surv., vol. VI, p. 459.
†Iowa Geol. Surv., vol. VII, pp. 423-426.
‡Ibid, vol. VIII, pp. 60-62.
§Ibid, vol. VII, pp. 276-277.

inside the latter. There has been considerable filling in at this point, and it is not impossible that this portion of the river's course marks a temporary lake, obliterated by being filled up. After joining Storm creek the river runs south to Gustine's Grove where it cuts through the moraine in a narrow and impressive gap, and takes possession of the valley of an older but smaller stream coming from the west. It follows this valley to about a mile south of Carrollton, this portion of its course being beautifully terraced. At the last point mentioned it makes a loop into the moraine then out again, and finally, in Sec. 18 of Union township, it passes again into the moraine. From this point to Coon Rapids it has cut a deep, narrow trench among the morainic hills, and has all the marks of a very young stream. At Coon Rapids it has been pushed over into the valley of another small stream from the west, and it follows this valley to beyond the limits of the county to the mouth of Willow creek in Guthrie county.* In its

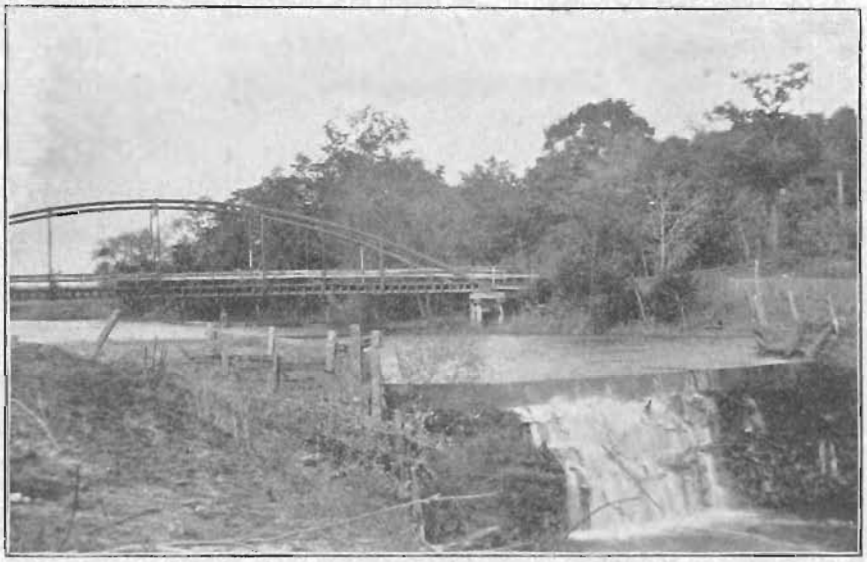


FIG. 2. The Middle Raccoon at Coon Rapids.

*See map of Superficial Deposits of Guthrie County, opp. p. 448, Iowa Geol. Surv., vol. VIII, 1897.

present form the stream is accordingly largely the result of the invasion of the Wisconsin ice sheet. Before the latter came into the region the streams were flowing to the southeast, and had, probably, symmetrically developed tributaries. Brushy Fork and Wichita creek in Guthrie county,* and portions of the Skunk river valley,† mark this old line of drainage. The southwestern front of the Wisconsin ice sheet met this direction of drainage at a slight angle, so that it crossed the successive streams in a north-south direction. Each stream, as it met the ice, was ponded till it found a gap into the next

FIG. 3. Middle Raccoon valley, southwest of Carrollton, with Altamont moraine in the background. Looking northeast. The trees mark the position of the river.

valley to the south. The latter would then be followed by the water till it in turn was blocked by the ice when a new outlet had to be found. As the ice retreated the waters occasionally followed the vanishing ice front until they were located on the low belt of land which in this region seems to be characteristically present just inside the moraine. Possibly in some cases they flowed temporarily under the edge of

*See map cited above.
†Geol. Polk County, Iowa Geol Surv., vol. VII, p. 284.

the ice when the volume of water to be so accommodated was not great. This may have been true for the present case from near Carroll to Gustine's Grove. At the latter point the waters were turned into a valley outside the ice. This same valley was crossed just south of Carrollton, and the water formerly flowing in it was carried along the ice front to Coon Rapids where, as already indicated, it was again turned into a small extra-morainic valley. The old valley proper runs from near Carrollton southeast to the mouth of Willow creek, and is occupied by the lower portion of that stream and the tributary already noted as sometimes called by the same name. The valley now shows as a prominent sag, marked by a line of artesian wells. The small stream flowing in it is wholly inadequate to its excavation, and is a resurrected stream. Coon river accordingly is made up of a series of bits of old captured valleys and new trenches which it has cut for itself. The lower portions of the older streams are cut off, and only in the case of the larger one have been resurrected.

Brushy Fork lies wholly outside the influence of the Wisconsin and shows accordingly what were probably the characteristics of the streams now united to form Coon river. It has a well developed valley cut at the south county line 220 feet below the upland, and has numerous tributaries. These are systematically developed, though those on the southwest are a trifle more abundant and vigorous. In the abundance of tributaries this portion of the stream differs a little from its lower course in Guthrie county.* It is, however, characteristic of the streams of the southwestern part of the county, which cover the area with a perfect net-work of branching and re-branching streams.

The Nishnabotna has two branches in the county, both having their sources within the limits. As developed here they are simple prairie streams of some age and in a heavily drift-covered country. They, with East Boyer river running from Arcadia west, and Beamans creek in the extreme north-

*Geol. Guthrie Co., Iowa Geol. Surv., vol. VII, pp. 424-425.

western part of the county, belong to the Missouri drainage system. Their lower courses have not yet been studied by the Survey.

Of the preglacial history of the streams of the county nothing is known. There are as yet too few facts relative to the rock surface to warrant any generalizations. In general, the streams of the southwestern part of the county are younger than the drift and older than the loess, in which they agree with the streams of most of southern Iowa.* There are minor branches which are younger than the loess and there are some even more recent changes, but the drainage as a whole is post-Kansan and pre-loessial. The streams east of the moraine are post-Wisconsin except the lower portion of Willow creek, already noted.

STRATIGRAPHY.

General Relations.

The surface formations of Carroll county belong entirely to the drift and associated deposits. These cover the entire county so completely that only a very few rock exposures are known. The later belong, with one exception, to the series of sandstones and clays which have been referred to the Cretaceous. Well borings in various parts of the county, as well as outcrops in the neighboring region, indicate that the Cretaceous covers almost the entire county immediately under the drift. At one point only, a different and probably older rock, which is provisionally referred to the coal measures, projects through the Cretaceous and is exposed at the surface. Quite possibly there are other cases of the coal measures running up through the Cretaceous, but if so, they are concealed by the drift.

In the subjoined tables the terrains found in the county are arranged in stratigraphic order.

*Geol. Washington county, Iowa. Geol. Surv., vol. V, p. 125; Geol. Appanoose county, Ibid, p. 374; Relations of Wis. and Kan. Drift Sheets, etc., Iowa Geol. Surv., vol. VI, p. 460; Geol. Johnson county, Ibid, vol. VII, p. 50; Geol. Polk county, Ibid, p. 277; Geol. Guthrie county, Ibid, p. 425; Geol. Dallas county, Ibid, vol. VIII, p. 61; Geol. Decatur county, Ibid, p. 265.

TABLE OF FORMATIONS.

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

CARBONIFEROUS.

DES MOINES.

The rocks which are here referred to the Carboniferous are, so far as is now known, exposed at but one point; about one mile southwest of Carrollton (Ne. qr. of Sw. ¼, Sec. 1, Newton Tp.) The exposure is on the southwest side of the Middle Coon river, not far below the wagon bridge which spans the river in the same quarter section. The outcrop is small and is at present very largely covered up. The rocks found include both shale and limestone. The shale is gray, thinly laminated, sandy and micaceous. Its thickness could not be measured. It is covered by the limestone, which varies a little but is about three feet thick. The rock has been quarried some and quite a pile of fragments are present. A careful search through this pile of material failed to show any satisfactory fossils, though one obscure fragment, which may represent *Productus costatus*, was found. Nothing of certain value, however, could be collected. The rock itself is nodular and more or less fragmental. The matrix is a brown, fine grained limestone, such as usually breaks with a clean, con-

choidal fracture. Here it is set with small, glistening particles, which at first sight may be taken for grains of sand. Nevertheless, many of them are soft enough to be calcite, and they are probably all or nearly all to be considered as small crystals of that mineral.

In general appearance the rock resembles closely certain limestones belonging to the middle coal measures or Raccoon river beds in Guthrie,* Dallas,† Madison,‡ and other counties to the south. In the latter region, however, the rock is usually fossiliferous. The fine grain of the Carrollton beds makes the material unfavorable for fossils and the limited outcrop makes it impossible to hope for another facies of the rock.

This exposure was first located and described by White,§ but no opinion was expressed as to its age. In considering the latter there are three hypotheses to be kept in mind. The rock may be (a) Carboniferous, (b) Cretaceous, or (c) Pleistocene. Considering the last first, it may be remarked that Pleistocene limestones are not uncommon in western Iowa. The loess and drift are very calcareous and the waters coming from them are heavily charged with lime. When, accordingly, such waters reach the surface through permeable sand or gravel beds, they quite frequently cement the latter into a hard ledge of rock. At Woodworth's Glen, in Monona county,‖ a ridge of this kind has led to the formation of a very pretty waterfall. Near Anthon, in Woodbury county,¶ there is a similar ledge. Near Fort Dodge a few years since, large masses of such limestone containing leaves of trees at present living in the vicinity, were collected by Mr. Frank Wilder. In Dubuque and Clayton counties the talus slopes along the Mississippi are cemented together so firmly as to be quite equal in hardness and strength to ordinary limestone of

*Iowa Geol Surv., vol. VII, p. 446.
†Ibid., vol. VIII, p 82.
‡Ibid, vol. VII, p. 509.
§Geol. Iowa, vol. II, p. 145, 1870.
‖Iowa Geol. Surv., vol. V, pp. 280-281.
¶Iowa Geol. Surv., vol. V, p. 281.

the region. In all these cases, however, the resulting rock would be classed rather as a conglomerate than a limestone. The calcareous matter has been deposited around and between particles of foreign matter and it seems not impossible that the presence of this foreign material may have had a certain amount of influence in inducing the deposition. It is known that deposition from super-saturated solutions is brought about by the introduction of foreign matter or by a change in the physical conditions of the solution. With favorable and uniform conditions, solutions may be overloaded to a notable degree without inducing deposition. It is something of a question, then, whether limestones would be deposited from simple fresh-water solutions except by the selective action of foreign material. On the other hand, it is easy to conceive that a conglomerate may be formed by the intense super-saturation induced by evaporation acting on a thin film of calcareous matter coating the pebbles or sand grains of the mass. The action would be similar to that in the case of the formation of stalactites. If, however, any such action took place it would be expected that the phenomena which Posepny has proposed to call "Crustification,"* would be present. There are, however, no signs of such phenomena in the rock in question. The limestone is largely a clean, brown to gray limestone, often almost wholly free from foreign matter, and with no pronounced banding. Furthermore the presence of the small films and grains of crystalline calcite seems to indicate an opportunity to crystalize out of a solution of considerable extent. The rock then does not have the structure or appearance of a spring deposit and is of such texture and composition as to make it difficult to conceive of its formation through the action of fresh-water solutions. It does, however, greatly resemble similar rock found not far away and known to belong to the marine Carboniferous. Other features of the case would be more favorable to the hypothesis of the Pleistocene age of the rock. Its

*Genesis of Ore Deposits, Trans. Amer. Inst., Ming. Eng., vol. XIII, p. 207.

apparently limited development, while it might be accounted for under either hypothesis, would be especially apt to be true if it were formed by spring action. The rock is covered by calcareous Wisconsin drift and rests on an impervious shale. The horizon is one of springs and seepage, and water is usually found seeping out of the bank along the top of the limestone. So far as was observed, however, this water was not more calcareous than elsewhere, where no limestone is present. No analyses were made, but a search for direct evidences of deposition such as are usually common in such cases, was fruitless.

Regarding the second hypothesis, that of the Cretaceous age of the rocks in question, but little need be said. The Cretaceous is the only indurated rock exposed within the immediate vicinity. It is, however, of a radically different lithological character and nowhere in the state has limestone of this type been found in the formation. The only limestones known are found in connection with the chalk beds of the Niobrara. These occur along the Big Sioux river,* the Floyd,† and on the North Raccoon, at Auburn,‡ in Sac county. They are always soft, fossiliferous and separated from the sandstone by a considerable body of fossiliferous shale. The beds at Auburn are of the same character as those on the Sioux, and if they should change so slightly in so great a distance it is hardly probable that in the distance between Auburn and Carrollton there would be an entire change in character. So far as the shales found with the limestone are concerned, they might readily be either Cretaceous or Carboniferous. It may be noted, however, that no such shales are known to occur in the Cretaceous of the region, though common enough elsewhere, while the type is one common in the Carboniferous.

There is, then, no good reason for referring the beds to the Cretaceous, though it can not be affirmed that such a refer-

*Iowa Geol. Surv., I, 147-161; III, 101-114; V, 273-275; VIII, 330.
†Iowa Geol. Surv., vol. VIII, p. 332.
‡Proc. Iowa Acad. Sci., II, 173.

ence would be wholly impossible. The reason for believing the beds are of coal measure age have been largely suggested in the foregoing. The resemblance of the material to the strata common to the coal measures of the region, the possible presence of *Productus costatus* and the apparent impossibility of referring them to any other series known to occur in the region, are the main reasons for the correlation. The limestone is about six feet above the river and the shales below it are largely covered by alluvium. The Cretaceous sandstone occurs at several points along the river, within sight of the exposure. The sandstone rises nearly twenty feet above the water and rests, according to White's observations*, upon some dark colored arenaceous clays, which were below water at the time of the present visits. Certain of the exposures nearest the limestone outcrop show cross-bedding dipping away from the later, which may, perhaps, be significant. The whole field evidence indicates unconformity and accords with the well known fact that there is a marked unconformity between the Carboniferous and Cretaceous.† Accordingly, while in the absence of good fossils the reference can only be provisional, it is best to consider the beds as belonging to the Carboniferous. More specifically, they may be referred to the upper part of the lower coal measures or Des Moines series. They represent, doubtless, some of the beds seen in Guthrie‡ and Dallas§ counties and which belong to the old middle coal measures. This particular facies is now known as the Raccoon river beds.‖ They represent the closing portion of the lower coal measures, the epoch immediately preceding the area of limestone formation represented by the quarry beds at Earlham and Winterset.¶

*Geol. Iowa, vol. II, p. 144.
†Geol. Guthrie Co., Iowa, Geol. Surv., vol. VII, p. 453, and map opp. p. 480.
‡Iowa Geol. Surv., vol. VII, p. 428.
§Ibid. vol. VIII, p. 63.
‖Jour. Geol., vol. VI, pp. 577-588.
¶Iowa Geol. Surv., vol. VIII, pp. 509-520, 524-531. Amer. Jour. Science (4), vol. V, pp. 433-439.

CRETACEOUS.

DAKOTA.

Along Middle Raccoon river near Carrollton and Coon Rapids, and on the North Raccoon and Purgatory creek near Benan, there are exposures of a soft sandstone with some associated clays and conglomerates which may be referred to the Cretaceous. As seen where the wagon road crosses a small stream coming into Raccoon river from the west, south of Coon Rapids (Se. qr., Sec. 34, Union Twp.), the rock is a soft orange colored sandstone, unfossiliferous, and much cross-bedded. It carries small, smooth and well rounded pebbles of white and pink quartz and black chert, such as is so abundant in the Guthrie county exposures. East of Coon Rapids, the railway at one point cuts into some bright red to orange sand, which doubtless represents the top of the formation. Southeast of the same place exposures of the sandstone are frequent, along both the Raccoon river and Willow creek.

At the mill in Coon Rapids the sandstone shows on both sides of the river, and probably originally formed a bar across the stream. It is the same soft yellow material, and carries the usual well rounded pebbles. Pink and white quartz, and black and white cherts were collected here. There are about four feet of sandstone exposed at the dam, the top being ten feet above the water. The stone shows some cross-bedding, and carries a thin band of clay. This band is not much more than an inch in thickness, but is remarkably clean and plastic, resembling putty in consistency. Similar material occurs near Rocky Bluff, southeast of Coon Rapids.* Near the dam there are several large blocks of this clay in the drift in such position as to indicate that they have not been carried far. The fact suggests that undisturbed beds of it may be found overlying the sandstone in the hill. Above the dam the sand-

*Iowa Geol. Surv., vol. VII, p. 452.

stone forms a pretty mural escarpment on the west side of the river, as shown in figure 4.

The Cretaceous exposures south of Carrollton are around the big bend in section 1 of Newton township. The stone shows at several points on both sides of the stream, forming

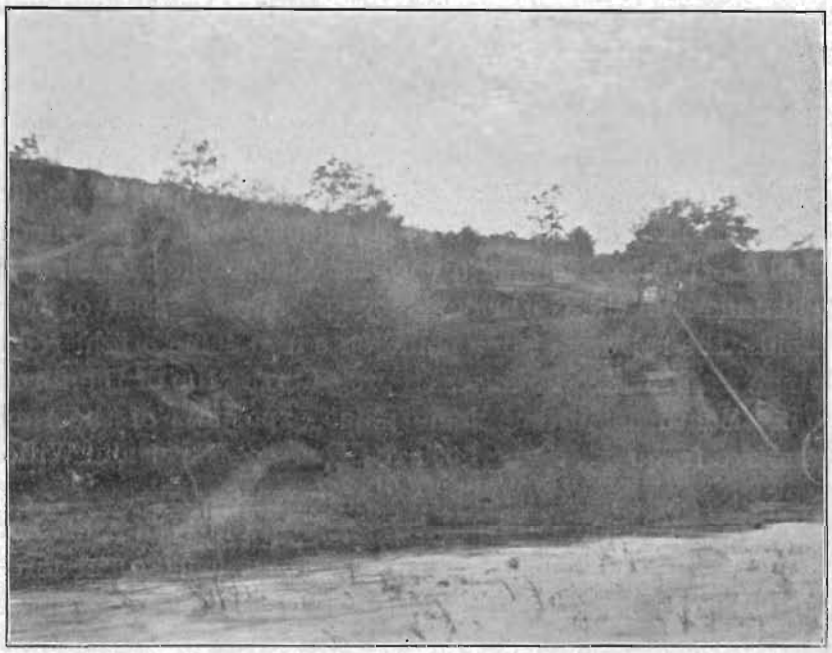


FIG. 4. Dakota Sandstone at Coon Rapids.

sharp bluffs twelve to fourteen feet high, with the tops rising to 1,165 feet above sea level. The stone is friable, lighter colored than at Coon Rapids, and not especially iron stained. It shows cross-bedding, and is cut by a system of great joints. In general appearance it closely resembles the Saint Peter sandstone as exposed along the Mississippi river.

The exposures on Purgatory creek and North Raccoon show similar material. The stone outcrops at the river's edge south of Benan, where a group of kames is cut through by the river. North of the town, at the ford where the old mill-dam was located, the rock is said to occur just below water

level. While it is not now exposed the evidence is considered sufficiently good to warrant mapping an exposure at this point.

West of the exposures noted there are no outcrops in the county so far as can be discovered. At Arcadia and other points the sandstone is struck in deep wells. The altitude of the rock at Arcadia is about 1,100 feet, and the rock surface seems to be fairly level throughout the county.

Exposures of the sandstone are found in Sac county (sections 12 and 14, Sac township) and in Greene county,* and outcrops are very abundant in Guthrie county.† It is in the latter county that the rock has been mainly studied. The conglomeratic facies is more pronounced there, and, in addition to the quartz and chert pebbles, numerous silicified Niagara and Devonian fossils are found imbedded in the rock. A few Cretaceous fossils have been collected, and thin lignite seams occur. While neither the fossils nor the lignites are found in Carroll county the other resemblances are so close as to make the correlation quite secure. The exposures near Auburn offer the additional evidence of good outcrops of undoubted chalk rock of the Niobrara in connection with the sandstone. The chalk rock has all the characters common to the same formation as exposed along the Big Sioux,‡ and carries abundant *Inoceramus labiatus*.

PLEISTOCENE.

Carroll county lies within the area which was in recent geologic time covered by a series of great glaciers or ice sheets. These ice sheets, having their birth in the Canadian uplands, crept slowly southward as far as the Ohio and Missouri rivers. All of Iowa, except a small portion in the extreme northeast, was covered at the period of the maximum extent of the ice. Parts of Iowa were covered several times, for it seems that the ice more than once retreated and

*Geol. Iowa (White), vol. II, p. 133. 1870.
†Iowa Geol. Surv., vol. VII, pp. 451-459.
‡Iowa Geol. Surv., vol. III, pp. 99-114.

re-advanced. Some of the later ice sheets did not advance so far to the south as the earlier ones, and there were occasional differences in the deposits made. The drift series in Carroll county includes deposits made by two separate ice sheets. The one covered the whole county and indeed extended for miles beyond its limits. The bowlder clay left by this ice sheet is known as the Kansan, since it has been extensively studied in the state from which the name is derived. The other covers only the northeastern portion of the county. It is known as the Wisconsin, from its magnificent development in that state. These drift sheets, as now exposed, show certain very striking differences, though in many particulars they are closely alike. When the Kansan ice retreated from the region it probably left the country in much the same condition as that is now which was covered by the Wisconsin. The differences in the two areas are mainly differences which have resulted from the weathering of the drift and the erosion by the streams in the post-Kansan interval. One exception to this occurs in the uniform presence over the Kansan drift of the soft, pebbleless loam or loess. This is a comparatively late deposit, laid down over the Kansan after most of the erosion of the area had been accomplished.

KANSAN DRIFT.

As has been stated the Kansan, when first exposed by the melting of the overlying ice, probably resembled greatly the present Wisconsin drift. The great valleys of the Nishnabotna, Brushy Fork, Middle Raccoon and their numerous branches and sub branches, were not present. The whole country was a fairly even plain at a level a little above the present hill tops. This plain probably showed the same sort of swales, ponds and lakes which now dot the country to the north and east. There was the same absence of streams and irregular grouping of hills. Probably heavy morainic belts crossed the area but these have since been cut away beyond

recognition, unless indeed the great Mississippi-Missouri divide be the much eroded remnant of such a master morainic belt. There is much evidence in favor of such a hypothesis since wells along this divide go down deep into drift and only occasionally strike rock at levels higher than the surrounding plain. At Arcadia the sandstone of the Cretaceous was struck at a depth of 130 feet in the creamery well, or at an altitude of 1,290 feet. This is about 150 feet above the level of the rock surface in the vicinity of Coon Rapids. At Odebolt wells are driven more than 350 feet in the drift, which would place the rock surface at about 1,100 feet, or a little below that, at Coon Rapids. At Adair the wells are very deep and in the drift. In southern Madison and northern Union county the divide represents an accumulation of drift 250 to 300 feet thick over a fairly uniform surface of rock. All these facts points to the hypothesis that the divide did not exist, at least as at present outlined, in pre-Kansan times, and probably originated as a great morainic belt. There is, however, nothing morainic in its present appearance, nor indeed in the surface of the Kansan, anywhere in the region.

The Kansan drift is a typical bowlder clay. It shows all the marks which are so characteristic of ice deposition as contrasted with water work. Material of all sizes is heterogeneously mixed together. The sorting out of fine and coarse, which everywhere marks water work, is altogether lacking. Fine clay, sand, pebbles and large bowlders are all kneaded together in one mass. The heterogeneity in size is matched by a similar heterogeneity of material. Amid abundant bits of rock derived from the formations of the immediate vicinity are pieces of clear quartz, of pink quartzite, gray and red granites, diorites, traps, and other greenstones, whose nearest outcrops are miles to the north. This northern material, picked up and frozen into the ice, has been shoved to the south and mixed with bits of chalk rock, sandstone, conglomerate and shale derived from the Cretaceous. A matrix for coarser material has been formed from finely ground rock

dust, rubbed off the surface rocks by the rock-studded ice. In its original condition this bowlder clay is drab to blue in color. Such a color is occasionally seen in the deeper railway cuts or in wells or in excavations. As ordinarily exposed this blue has given place to various tones of yellow, or even red and brown. The change is due to the oxidation of the iron disseminated through the clay, whereby it is changed from the blue carbonate and ferrus salts to the yellow or brown or red oxides. Frequently an exposure of the blue bowlder clay will show a series of interesting joints and cracks stained yellow to a distance of half or three-quarters of an inch from their walls. This change is the same as that noted on a larger scale where the upper portion of the drift is yellow and the lower is blue. Both phenomena point to an exposure to atmospheric agencies for a considerable time. As has already been stated, the large erosion and the complete development of the drainage system point in the same direction. In southern Iowa, where the Kansan is more characteristically displayed, there are certain other phenomena which mark this drift and which aid in its recognition. For reasons to be discussed later, some of these phenomena are but imperfectly developed in Carroll county, and their absence has caused some confusion to creep into the subject.

The exposures in southern Iowa usually show, in addition to the erosion and general change of color toward the surface, a corresponding decrease in lime and increase in rotted bowlders with the almost invariable development of what is called the ferretto* and the occasional presence of a forest bed or series of water-laid deposits between the drift and the loess. Of these phenomena the absence of lime and presence of ferretto are most widespread and most easily recognized.

The drift is very largely made up of mechanically prepared material. The finer parts consist of broken and finely ground rock. Inasmuch as the glaciers passed over vast areas of limestone, a fresh drift normally carries large quantities of

*Proc. Iowa Acad. Sci., vol. V, p. 90

crushed limestone. This, when touched by any of the commoner acids, has the property of effervescing. When limestone is exposed to weathering agencies the soluble material is carried off and that which remains is unacted on by ordinary acids. When a fresh drift containing small bits of limestone is exposed for a long time to weathering agencies, the same process takes place. After a time all the soluble part of the limestone particles is carried away, and the drift shows no reaction to the acid. It is thus possible, normally, to distirguish between an old, long exposed drift and a fresh one, and in southern Iowa it has been found that before the loess was laid down the Kansan drift was so long exposed to the agencies of solution that there is no reaction to the acid at its upper surface and only a feeble reaction to depths of five to nine feet below. On the other hand the younger drift sheets, with the rarest exception, show an effervescence up to the very grass roots.

Practically all rocks carry a greater or less percentage of iron. The amount while small, is usually the determining factor in the matter of color. As commonly found in the rocks, iron exists in four forms; the carbonate ($FeCO_3$ — Fe 48.27%), which affects various shades of blue; limonite ($Fe_2O_3 H_2O$ — Fe 59.89%) and the various earthy ochres which vary in shade from yellow to brown; hematite (Fe_2O_3 — Fe 70%) which, in the pulverized form, is red, and magnetite (Fe_3O_4 — Fe 72%), which is black. Magnetite is rarely an important constituent of sedimentary, though common in the igneous and metamorphic rocks. As will be seen from the chemical formulas the carbonate contains no oxide proper. If a rock whose color is determined by the iron content be subjected to oxidation, the color will pass progressively from drab or blue through yellow and brown to red. The latter color is the indicating mark of a high stage of oxidation.

Oxygen is one of the most active chemicals in the air and oxidation is one of the most widespread and prevalent processes to which rocks are subjected in weathering. In drift-

less areas, where the soil has been formed by the slow weathering away of the rocks, red soils are common. In the driftless area of Iowa and adjacent states the hard, blue limestones and dolomites of the Paleozoic have been leached and oxidized till a sticky, red clay called geest, alone remains. In many of the southern states, beyond the limits of glacial action, red soils of this genesis are common.

When drift is exposed to atmospheric agencies the processes of weathering are closely akin to those which take place in the weathering of ordinary rocks. The chemical activities are relatively more intense, as the material is already broken up, and there is no need to wait for the slow processes of frost action to shatter the rock. The finely comminuted rock flour is at once attacked by chemical agents, and decalcification, oxidation and ferrugination at once set in. Old drifts accordingly soon became highly oxidized. The iron assumes a deep brown to red color. This color is less and less intense from the surface downward. The iron segregates and, to a certain extent, sometimes cements the soil. This dark, iron-stained and highly oxidized band at the surface of the drift is what is called the ferretto. In southern Iowa it is widespread below the loess and at the surface of the drift, and can only be interpreted as indicating a considerable period of weathering between the deposition of the two.

The oxidation which produces the ferretto leads also to the breaking down of the bowlders at the old drift surface. It is a very usual thing to find the granites and other crystalline rocks, which at some depth in the drift are fresh and hard, thoroughly disintegrated at the contact between the Kansan and the loess. Often they may be crushed between the fingers. It is not very unusual to find rotted bowlders in any portion of the older drift, as would be expected from the fact that the older drift sheets had much rotted material to work with. But it is frequently possible to prove that the disintegration of the bowlders at the surface of the drift took place after they had been shaped by the ice, and furthermore

the number of rotted bowlders usually increases with the nearness to the surface. Accordingly this phenomenon accords with the decalcification and the development of ferretto in indicating a period of considerable exposure to weathering agencies.

In the study of Polk,* Dallas and Guthrie counties, it was found that the Wisconsin drift rested not on the next younger, Iowan, drift,† but upon the Kansan. In the northwestern part of Iowa there is, outside the limits of the Wisconsin, a drift sheet which has been provisionally correlated with the Iowan.‡ As the exact southern limit of this younger drift is as yet unknown it was necessary in taking up the work in Carroll county to keep in mind the hypothesis that the drift outside the moraine might be either Kansan, Iowan, or both. In the preliminary work some of it was assigned to the Iowan. The later studies have failed to confirm this correlation.

There are excellent exposures of the extra-morainic drift in the railway cuts along the Chicago, Milwaukee & St. Paul railway and the Chicago & North-Western line from Carroll to Manning. There is also a cut of interest at Arcadia, on the main line of the latter road. Along the streams the exposures show the drift in two facies, one, the normal Kansan exposure, showing ferretto, leaching, rotted bowlders, etc., and the other an abnormal type in which these phenomena are lacking. Selected outcrops of these two types are noted on the map in order to indicate their distribution. No attempt has been made to map every outcrop. The universal presence of the loess, often in great thickness, and the fact that the bulk of the erosion was earlier than that deposit, makes exposures relatively rare. This is especially true in the northwestern portion of the county where the streams are small and scattered, and there are no deep railway cuts.

*Iowa Geol. Surv., vol. VI, pp 433-476.

†See paper just cited with Geol. Johnson County; Ibid, vol. VII, 86-91; Cerro Gordo County, 174-176; Proc. Iowa Acad. Sci., vol. V, pp. 64-104.

‡Iowa Geol. Surv., vol. VII, p. 20; Ibid, vol. VIII, p. 28, pp. 335-351.

South and west of Coon Rapids exposures of the ordinary type of Kansan are frequent. The ferretto, rotten bowlders, and leached drift appear immediately below the loess at numerous points, both in Guthrie and Carroll counties. In the first deep railway cut east of Dedham (Sec. 16, Newton Tp.) the leaching has been carried to a depth of five feet and the ferretto is sixteen to eighteen inches in thickness. West of this point to Manning the exposures show only the abnormal facies or imperfectly developed ferretto, except in a small exposure near milepost 413 (Se. qr., Sec. 11, Warren Tp.). This exposure is well up on the divide, back a little from its edge (144 A. T.). It is near exposures of the unleached till. The section shown is sketched below.

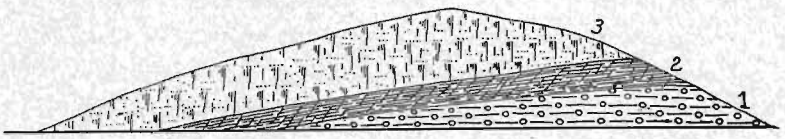


FIG. 5. Old soil east of Manning. Loess, 3, over soil, 2, which in turn lies on drift, 1.

The loess is quite the usual type, mantles the hill in ordinary fashion, and is about six feet thick at the crest. The old soil is a sandy, black material, resembling in some particulars certain phases of the white clays, but with abundant humus mixed with the rock material. It is about eighteen inches to ten feet thick. Below it the drift is only shown to a corresponding depth, but it is thoroughly leached and iron stained, a typical ferretto zone. West of Manning, between that place and Manilla, the drift is deeply stained, and near Aspinwall there are exposures showing a good ferretto. In the southwestern part of Manning and in the hills south of town the Kansan shows the high color indicative of iron staining.

From Dedham north to Carroll exposures of leached till are frequent and ferretto is found widely. In the northwest quarter of section 36, Carroll township, for example, the drift is leached to a depth of five feet, and the ferretto is fairly

well developed. Along the main road west from Carroll ferretto is seen at several points. In the railway cut immediately east of Arcadia, a little over one foot of ferretto is developed at the contact between the loess and the drift. In the southeast corner of Wheatland township the drift shows below the loess. It is reddish-yellow and has been leached. No great thickness of the drift is exposed here, but that present seems sufficient to fix the age of the deposit. The exposure is the more interesting because it is the farthest north of any in the county where the ferretto has been recognized.

The abnormal phase of the Kansan is not exposed in the extreme southeastern part of the county. In the northwest and southwest, however, the exposures of unleached till probably outnumber those that are leached. An excellent example of this drift may be seen in a group of exposures in some railway cuts about two miles southwest of Carroll (Sw. qr., Sec. 22; Nw. ¼, Sec. 27; Ne. ½, Sec. 28; Se. ¼, same; Sw. ¼, Sec. 33, Carroll Tp.). The exposures extend from where the railway first cuts into the hills to within about a mile of Halbur. The ordinary exposure is as sketched below. The

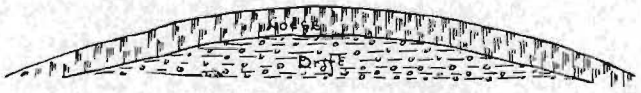


FIG. 6. Loess over Kansan drift.

drift is a yellow bowlder clay rising fifteen to twenty feet above the railway track. It is full of pebbles and bowlders up to a foot in diameter. Granites are common and there are a good many rotted bowlders, though the latter do not seem much more abundant at the top than the bottom. There are joint cracks in the clay, which are stained a deep orange color and yet react to the acid. There is no ferretto and the drift usually effervesces up to the contact with the loess. In no case is the drift leached to a depth of more than six inches, except in the southwest quarter of section 33, where, in

between two exposures of the type described, is one showing leached drift and a ferretto zone. In section 27 the loess does not show lime concretions and gives usually but a feeble reaction to the acid. It rarely extends over the crests of the drift exposures in any thickness, being usually less than three feet deep at such points, though there may be as much as eight feet on the flanks of the hills. Further south the loess thickens and becomes calcareous.

The non-calcareous, fresh looking drift is exposed at intervals along the railway to Manning, and from there east to Dedham. In the southeast quarter of section 15, Warren township, a cut shows ten feet of unleached and unstained drift below six feet of loess. In the southeast quarter of section 11, near the exposure of old soil already mentioned, twelve to fifteen feet of the unleached till, covered as usual by the loess, is exposed. On the township line (Se. qr. Sec. 12) the calcareous drift again shows and there are more exposures between Templeton and Dedham.

In the northwestern part of the county there are several good exposures of the calcareous drift. In the northwest quarter of section 36 of Wheatland township, about forty feet of the drift is exposed. It is very light colored and shows no staining at all. The erosion here is very active and the stream gorges quite sharp. About two miles south of Breda (Ne. of Se. Sec. 24, Wheatland) about twenty to thirty feet of fresh looking calcareous drift shows below loess of the usual aspect. The drift is light buff, carries many granites, shows no ferretto and reacts to the acid up to the loess contact. At one point in the drift there is a considerable patch of orange-colored sand, but not much of the material is seen. In the northwest quarter of section 9, of the same township, there is a small drift exposure on Beaman creek. The drift is yellow, effervesces freely and shows no ferretto, though the exposure is poor and it can not be certain that the original upper surface of the drift is exposed.

The exposures specifically noted, and others located upon the map, indicate sufficiently how intimately the two phases of the drift are inter-related. Excepting these in Wheatland township as possible examples of Wisconsin buried beneath wind-drifted loess, though this is not believed to be their explanation, the whole series belongs together. The most careful search in the field has so far failed to reveal any dividing line either vertical or horizontal. If there were two drift sheets in the region, one fresh and unleached and the other old and ferretto-covered, the younger drift could hardly have the patchy geographical distribution necessitated by the facts in the present case, except upon the hypothesis of its being thin and much eroded. Single exposures of more than thirty feet are, however, known and there is no evidence whatever that it has been eroded. No cases of super-position have been detected nor are there forest beds, buried loess sheets or other evidences of an interglacial period. Both sorts of drift have exactly the same relations to the loess, which in turn shows no evidence of being anything except a homogeneous deposit. Except that Wheatland township seems less eroded than the others, a fact explained by its position far from large streams, there is no apparent evidence in the topography of difference in the age of the various parts of the region. Accordingly, the two sorts of drift are believed to represent but differing phases of the Kansan. The unleached drift resembles closely the Kansan usually found five to ten feet below the base of the ferretto. It is as if a portion of the Kansan had been in places eroded, and that, in short, is believed to be the correct explanation of the phenomena.

It is obvious that the presence of the lime in the drift depends upon its original abundance and the degree to which it has been carried away. The former is wholly independent of the time the drift has been exposed, and the latter may or may not vary with the time, but, in the absence of specific evidence to the contrary, it may be fairly assumed to be

dependent on that factor. All the drift sheets of Iowa carry, when unaltered, enough lime to make the acid test a valuable one. The presence or absence of lime, then, in the upper portion may, unless good evidence of its exceptional nature be offered, be considered to indicate the amount of exposure which the drift has suffered. The amount of lime leached from a calcareous drift will depend upon the strength of the solvent and the amount passing through the drift in a given time. It will also depend upon the direction which the percolating waters take. In an arid region the excessive evaporation may locally cause the flow of ground water upward and lead to the deposition of soluble salts in the upper portion of the soil. This factor can, however, hardly be important in the present case. There is no reason to believe that the water soaking into the ground in one part of Iowa varies greatly in solvent power as compared with that in any other part, when considerable districts are considered. There are, of course, wide differences in detailed areas, but in general the rain water, which is the original source of the underground circulation, seems as likely to become charged with humus and other acids at one point as another. It is true, however, that the amount of water entering the ground varies widely. There are considerable differences in the rainfall in different part of the state, the variation in 1894 being from 15.65 inches to 27.57. In the northwest it ran from 15 to 20 inches, and in the southeast from 20 to 25, with areas running from 25 to 30.* The run-off also varies widely. There are no data relative to Iowa streams, but it is well known that the run-off is proportional to the character of the surface, the slope and the time distribution of the rainfall. It is greater in an area with a non-absorbent surface, on greater slopes, and when the rainfall is bunched. In the present case the surface of the Kansan drift seems not to vary in any systematic way with relation to its capacity to absorb water. The rainfall in Carroll county is probably as evenly distributed

*Rept. Iowa Weather and Crop Service, 1894, p. 52.

as in other parts of the state. There are, however, considerable differences in slope. It is to be remembered that the region represents the high upland between the Mississippi and the Missouri. The railway grades across the country are heavy and the stream grades are even greater. The drainage consists of the headwater portions of the streams only, and the water reaches them by running over the steep surface slopes rather than through the ground. Springs in the southwestern part of the county are almost unknown and seepage is rare. The whole series of evidences indicate that the water passes over, rather than through, the drift, and hence that solution is relatively slight. This seems to be one of the important factors in the failure of the leaching tests.

When the grades are high and the amount of surface water notably in excess, it must be obvious that erosion will be very active. This will be as true of the slower and less easily noticed surface erosion of the interstream areas as of the direct corrasion of the streams. It has already been suggested that stream action in the region is intense. It is also true that the erosion of the general surface is much greater than on the low, wide divides further south. The relations of the loess to the river valleys indicate that the latter occupied approximately the same position in the interval between the Kansan and the loess that they do now, so that erosion was probably, at least, as active then as now. This is probably the main explanation of the absence of the ferretto and leached drift in the region under discussion. Aside from the fact that there may have been less leaching here than in lower lying regions, the active erosion by which the stained and leached material has been carried away as fast as formed, is probably the main factor in the explanation. In very many instances where the more weathered portion of the Kansan is absent, the field evidence shows that its absence is probably due to the local intensity of erosion. The fact that erosion over a general surface presents the widest variation in intensity and effect from point to point, is not perhaps always appreciated

as thoroughly as it should be. A difference of five to ten feet in the amount of erosion on neighboring swells and divides is not unusual, but where the uppermost stratum happens to be so strongly marked as is the ferretto zone, the effects of this difference become very striking. On high land much cut up by streams, erosion is very active, and it seems reasonable to believe that these minor differences from point to point would be correspondingly magnified. These very conditions prevail now over most of the territory in question, and the stream history of the region, so far as it can be read, indicates that conditions were not greatly different before the loess was laid down.

The high divide in Madison and Union counties between Clanteen creek and Grand river shows a corresponding local variation in the amount of erosion. At numerous points the yellow, unleached drift of the Kansan is exposed at the surface in the heart of a region where leached drift and ferretto are widespread. In this case the erosion, since the exposures are loess covered, seems to be recent. In the case of the Carroll county outcrops the erosion would be mainly preloessial.

No attempt can be made here to fix the age of the extra-morainic and fresh looking drift found in the counties to the north. The work of the present field season has shown that the reference of this drift to the Iowan is probably wrong. The work in Carroll county has shown that there is no danger of confusing certain phases of the Kansan with the later drifts. It is possible that a limited extent of the northwestern part of Carroll county is covered by the later drift. The exposures are few, and such as are found are of the equivocal type. There are, however, no marked border phenomena, such as elsewhere denote the limits of a drift sheet, and the possibility of a later extra-morainic drift within the limits of the county is believed to be remote. Until, however, the counties to the north be studied in more detail than has so far been possible the absence of such later drift cannot be

positively affirmed. It may be said, however, that so far no extra-morainic drift is known in Carroll county which is not known to be Kansan, or which might not readily be assigned to that formation.

It is interesting to note that up to the present no traces have been found in this county of any drift older than the Kansan. The pre-Kansan, which is occasionally found in other parts of the state,* is not known to occur here, though it probably at one time covered the county. A fuller study of well records than has yet been possible would not unlikely show its presence.

THE LOESS.

Outside the area covered by the Wisconsin drift, and to a limited extent along the border of the latter, the surface formation is the loess. This is, as developed here, a buff, pebbleless clay, friable, and of limited plasticity. It is intermediate in character between the dust-like and highly absorbent type of loess developed along the Missouri river and formerly known as the Bluff deposit† and the very plastic, argillaceous, gray to white surface clay common in southern Iowa, northern Missouri and parts of Illinois, Indiana, and Ohio, and called by Leverett the White Clay.‡ The loess in Carroll county takes the usual sheet form, spreading over the drift as an irregular but usually thin mantle. It is not sufficiently thick to develop its own peculiar type of topography. It conforms everywhere to the inequalities in the surface of the Kansan drift, and exposures of the latter occur only when it has been cut through by recent erosion.

The relations to the Wisconsin drift are at first glance a little confusing. Near Coon Rapids the loess passes directly under the latter. There are two exposures near town which show this feature. One of these exposures is in a deep rail-

*Proc. Iowa Acad. Sci., vol. IV, pp. 54-66; vol. V, pp. 86-101.

†Swallow: Geol. Surv., Missouri, 1855, pp. 59-76. White: Geol. Iowa, vol. I, pp. 103-109. 1870.

‡Leverett: Amer. Geol., vol. X, pp. 18-24.

way cut about one mile east of the station. The surface around the cut shows the usual saucer topography characteristic of the Wisconsin drift plain, and the sides of the cut show the usual Wisconsin drift with a buff color, numerous pebbles and occasional lime balls. Below the drift and rising about two feet above the track is the loess. It is of the same type as is found west of town, and is unfossiliferous. In general appearance it closely resembles the matrix of the Wisconsin drift, but prolonged digging failed to show any pebbles in it. The Wisconsin is in this region made up largely of worked-over loess, but the loess seen in the cut is believed to be undisturbed. The exposure is about a half mile back from the edge of the Wisconsin drift.

The second exposure is about a mile south of town, near where the main wagon road crosses the river. The hills on the east side of the river are capped by a series of little gravelly knolls, such as form part of the gravel apron fronting the Wisconsin. Back of these knolls is the moraine and the regular bowlder clay. The slope toward the river shows the usual loess overlying the Kansan drift, so that the ice itself evidently failed here to reach the valley, though the outwash spread over the flanking hills.

In the northwestern part of the city of Carroll the same relations may be observed, though the exposures are not so satisfactory. The hill upon which the hospital stands is made up of ordinary Wisconsin drift and shows the usual surface bowlders. The next hill west is heavily coated with loess, which was at one time used for brick making. Traveling north on the road, in the northwest quarter of section 24, Carroll township, the loess is seen passing up the slope to the north line of the section. Soon a few pebbles are discovered on the slope. These become more common until a well exposed bowlder clay is found, from which the pebbles have evidently washed and rolled down over the loess. A good contact could not be found here, but the whole of the evidence seemed to indicate that this exposure falls in with those

observed near Coon Rapids, and that the relations are the same as those observed in Polk*, Guthrie† and Dallas‡ counties, where the loess passes well under the edge of the Wisconsin. Doctor Beyer's observations in Story county, detailed in this volume, greatly strengthen this hypothesis; so much, in fact, that the general matter may fairly be considered to have passed out of the realm of hypothesis into that of demonstrated fact.

North and west of Carroll the loess occasionally laps up over the edge of the Wisconsin for a short distance. This is true about the middle of the west line of section 29, Kniest township. At this point about twelve inches of loess covers the outer face of the moraine. In the southern part of section 29 of the same township, loess two feet thick is found overlying drift which can hardly be anything but Wisconsin. Upham mentions cases where as much as ten to twelve feet of loess is found mantling the morainic hills.§ No such thickness was observed in the present work, though hills of loess-covered Kansan were found among the morainic knobs. In every case examined by the writer where undoubted Wisconsin is covered by loess the latter is very thin and the situation is such as to invite the hypothesis that the wind has blown the loess from the west up onto the outer slopes of the morainic hills. It is believed that in Carroll county, as farther south, the loess is distinctly older than the Wisconsin and usually runs under the latter.

The age of the loess can not be positively fixed. In eastern Iowa, ‖ and the same is true in Illinois, the bulk of the loess seems to have been deposited contemporaneously with the maximum advance of the Iowan ice. The loess in Polk, Dallas and Guthrie counties has been considered to fall in the same category. There is no observable break between the loess of Guthrie and Carroll counties, and the natural refer-

*Iowa Geol. Surv., vol. VII, 340-343.
†Ibid, 463-466.
‡Ibid, vol. VI, 433-478.
§Iowa Geol. Surv., vol. VII, pp. 88-90.
‖Geol. Nat. Hist. Surv., Minnesota, 1880, p. 309.

ence for the latter would likewise be to the Iowan. It is known, however, that loess in northwestern Iowa probably belongs to more than one geological epoch,* and Professor Macbride's observations in Humboldt county† make it conclusive that the Iowan did not cover the region immediately north of Carroll county as has heretofore been believed. The correlation of this loess with the Iowan drift is accordingly open to considerable doubt. While it remains true that its most probable age is Iowan it can be assigned only to that period tentatively.

THE WISCONSIN DRIFT.

The northeastern portion of Carroll county lies within the limits of the Des Moines lobe of the Wisconsin drift. This lobe marks out the territory occupied by a long tongue of ice which crossed the north state line between Clear Lake and Spirit Lake, and covered all the territory south to its apex at Des Moines. This was the last ice sheet which entered Iowa.

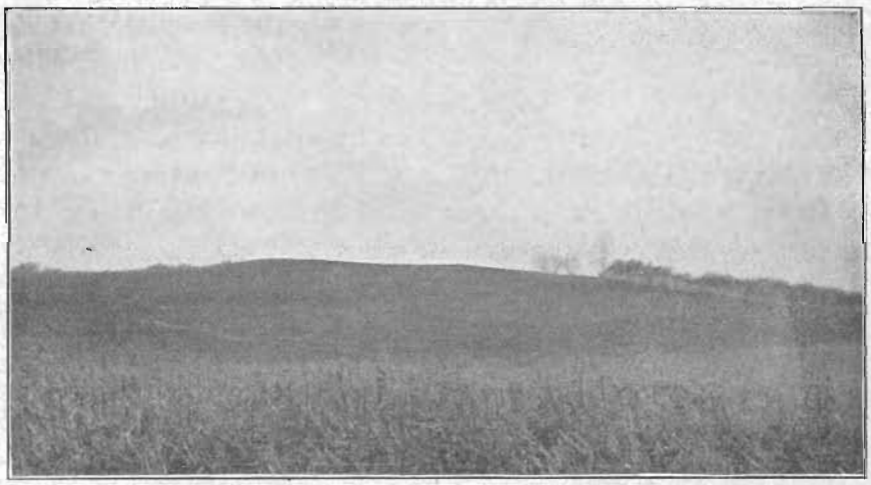


FIG. 7. Morainic hill in northwestern part of Carroll.

It occupied the territory at a time geologically very recent; measured, probably, by a few thousand years. The evidences

*Geol. Plymouth County, Iowa Geol. Surv., vol. VIII, pp 339-340.
†In this volume.

of the recency of this invasion are mainly to be found in the topographic peculiarities of the region already discussed. The drift itself is also of the fresh type. It has a gray to light buff color, and does not show the deep orange, brown and red

FIG. 8. Cretaceous clays in Wisconsin drift above the dam at Coon Rapids.

colors, which have been shown to be characteristic of the older drift sheets. It is wholly unleached, and the pebbles and bowlders found in it are usually hard and unweathered. The surface of the country is plentifully sprinkled with the

large surface bowlders commonly referred to as niggerheads. These are so widespread as to be everywhere observable, and so frequent as to be an occasional hindrance to agriculture. The farmers gather them up in great ridges along the fences, or bury them where they lie in the field. These surface bowlders are mainly granite, and several types are found. Limestones also contribute a notable percentage to the lot, and in early days the surface limestone bowlders were occasionally burned to lime.

The matrix of the till consists mainly of loess which has been picked up by the glacier and reworked. Pebbles, bowlders, sand and clay have been kneaded into it. Figure 8 illustrates how great masses of Cretaceous clay and other materials have been mixed together. The preponderance of the loess material, however, is sufficient to give the bowlder clay a buff color, and it is believed that the latter is due more to this cause than to any alteration in the iron content since the drift was laid down. The Wisconsin drift is usually associated with gravel and coarse sand deposits,* and this characteristic is well developed in the area under discussion. Surface knolls of gravel are common throughout the intermorainic area. They are especially characteristic features of the broad bottom land followed by the Middle Raccoon river for some five miles east of Carroll, and can be easily recognized by passengers on the railway. Near Glidden and at various points throughout the region they occur.

South of Benan (Se. qr., Sec. 3, Glidden Tp.) there is a group of gravel hills cut through by the river. These hills rise 130 feet above the river and project forty feet above the surrounding country. They are clearly constructional in form and may be referred to the type known as kames.†

*Geol. Wisconsin, vol. I, 284, 1883; Iowa Geol. Surv., vol. VI, pp. 442-443. 1897.
†Chamberlin: Third Ann Rept. U. S Geol. Surv., p. 300.

On the river here, there are a series of terraces as sketched below. These are gravel terraces of aggradation and seem

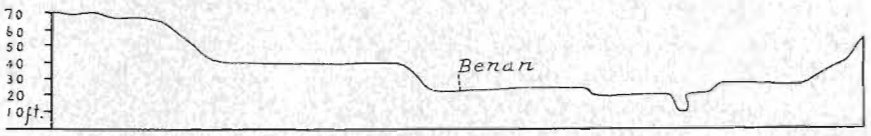


FIG. 9. Terraces on the North Raccoon at Benan.

to be gravel trains. They are probably to be correlated with some temporary halt of the ice in retreat, at some point a few miles above Benan. They do not extend down the river as far as the east county line, as the valley at that point shows no sign of them. Their regular form differentiates them from the gravel patches found throughout the vicinity and to which category the gravel on Purgatory creek belongs.

Along the Middle Raccoon river gravels are developed wherever the valley has been influenced by the ice. The river cuts through the moraine in section 26 of Pleasant Valley township and runs outside to section 1 of Newton township. This portion of the valley seems to have been ponded by the ice and formed a temporary lake. While in this condition it was filled up with gravel to a level sixteen feet above the present stream. Into this gravel the river has since cut till the old filling is represented now by remnants of a fringing terrace. At Coon Rapids, where the drainage of the ice was turned into the valley of the small stream coming from the west, a gravel terrace was formed, and the main part of the town is located on this terrace. Patches of the same terrace can be found along the river valley for some miles south of town. The terrace at its upper end rises fifty feet above the river, but to the south it declines until it eventually reaches the level of the flood-plain. This indicates that the terrace was produced by material supplied from an ice front above, rather than by ice damming it below. Most of the material of the gravels is hard and fresh, but some is rotted, and occasionally there are streaks which are iron-stained. A

section taken on the north side of the railway pit at Coon Rapids showed the following beds:

		INCHES.
4.	Stripping-loam, brown to black, with a few scattered pebbles	6–30
3.	Gravel, stained, much rotted material, sharply limited below	12
2.	Gravel, coarse, irregularly colored and bedded	60
1.	Gravel, fine, worked further south in the pit	12+

The layer of iron-stained and rotted gravel (No. 3) suggests a weathered zone akin to the ferretto, but the fact that it is so sharply limited below sets it off from this class of phenomena. It is probably a local accident of bedding. The weathered material is almost exclusively a coarse grained, micaceous granite or some other micaceous rock. One enumeration of weathered bowlders gave the following results: granite, 15; mica schist, 1; greenstones, 2; limestone, 1. It seems that the weathering is due more to the presence of easily decomposed minerals than to the position of the materials.

At first glance the gravels seem to contain a great preponderance of granitic material, and this is true if attention is directed to the larger sizes. An enumeration, however, of all the pebbles more than a half inch in diameter in a certain surface gave the following results:

	Limestone.	Granite.	Greenstone.	Quartzite.	Miscel.
Fresh	75	13	38	5	4
Weathered	0	8	4	0	0

The granitic appearance of the gravels is accordingly due to the fact that the basic rocks and the limestones have been more broken up. Altogether, some seventeen varieties of pebbles are fairly common in the gravel. These varieties include diorite, slate, greenstone, amygaloid, fine grained trap, mica schist, white quartzite, pink and clear quartz, black and white chert, limestone, Cretaceous conglomerate, limonite and a bit of taconyte, the rock associated with the iron ores of the Lake Superior region.

The gravel shows east of the river, where the railway cut crosses the little side lobes of the hills. It soon gives place to

the unassorted material of the bowlder clay. The latter contains much the same pebbles which are common in the gravel. The bowlder clay, except where patches of gravel occur, forms the surface material throughout the northeastern portion of the county. The stream cuts into it, and in the morainic area it is heaped up into the irregular hills and knobs characteristic of moraines. Elsewhere it spreads out into the gently swelling drift plains.

ECONOMIC PRODUCTS.

COAL.

Carroll county lies within the limits of the Western Interior coal field, though it is west of the portion which in Iowa has been shown to be productive. The nearest mines have been located near Grand Junction and Rippey in Greene county, and along the Middle Raccoon in Guthrie county. The coal mined at Grand Junction lies at an altitude of about 1,000 feet. The coal mined near Fanslers would be at about the same altitude. If there were no dip to the west, and a slight one must be allowed for, this would still be a considerable distance below the lowest point in the county.

As has already been stated, the coal measures in Carroll county are covered not only by the drift but by the Cretaceous beds. The full thickness of the latter is not exposed at any point in the county and may be expected to be somewhat irregular since the Cretaceous is uncomformable, not only with the drift above, but with the coal measures below. As shown southeast of Coon Rapids, on the Middle Raccoon, the beds have a thickness of about one hundred feet. This may be assumed to represent the average thickness for the eastern portion of the county. In the western portion the sandstone rises, in points at least, to 1,300 feet above tide, and probably is accordingly, 100 feet or more thicker. The drift in the region varies from nothing to as much as 516 feet. The maximum thickness of drift is not, however, found at the

same point with the maximum thickness of Cretaceous, and in general, the drift may be assumed to be from 100 to 200 feet in thickness. It will vary between wider limits but the larger portion of the area would probably show rock at that depth. It is obvious that in any prospecting for coal in this region it is desirable to stick to the lowlands so as to avoid, as much as possible, drilling through the drift. Coon Rapids, in the southeastern portion of the county, lies on a terrace at 1,173 feet above tide. The river itself has cut to about 1,118 feet. This is believed to be about the lowest point in the county. Allowing fifty feet for the dip, the horizons which carry coal to the east should occur at a depth of about 170 feet below water level at Coon Rapids, or 200 to 225 below the bottom land of the Coon river.

As has already been stated, the Cretaceous sandstone rests uncomformably upon the coal measures. The latter were exposed to erosion and their surface was cut up by streams before the later beds were laid down over them. The thickness of sandstone to be penetrated will accordingly vary from point to point. At the one outcrop already described the drill would at once go into the coal measures. The upper portion of the coal measures is, however, but sparingly productive, and it would in all probability be necessary to go at least to the horizon already mentioned as productive at Grand Junction and Dawson, in order to obtain coal. Coal may be encountered at any point in the coal measures, but the chances of thick beds increase toward the bottom. The base of the coal measures here would probably lie at from 550 to 600 feet above sea level, so that there is, in Carroll county, a considerable thickness of strata suitable for exploration with the drill.

The question whether or not the coal horizons which run under Carroll couuty would prove productive, is a difficult one, and one that can only finally be settled by the drill. There are in this region no surface indications of value whatever. With the exception of the outcrop of presumably Carbonifer-

ous limestone, all the rock exposed in the county is much later than the coal measures and wholly unrelated to them. The sandstone outcrops afford no basis whatever for the local belief that they indicate coal. The whole question is one which can be answered by systematic drilling, and by that alone. There are, however, certain indications of interest.

It is well known that with certain rare exception, the individual coal beds of Iowa do not have any great lateral extent. They pinch out from point to point, thicken and thin, pass over low rolls and are cut out by sandstone and shale. It has so far been impossible to construct a detailed vertical section of the measures that could lay claim to be of more than local value. While, however, the coal beds are not usually persistent, there are certain horizons which have usually proven productive, and which may be recognized over a considerable area. For example, the coal mainly worked in Keokuk, Mahaska, Wapello, Monroe and Lucas counties occurs at about the same stratigraphic horizon. The coal is not continuous from point to point and only perhaps 12 to 15 per cent of the entire area carries coal in workable thickness. Yet the horizon shows more or less coal for a distance of at least sixty miles back from its outcrop, and it is about as rich at its western known limits as at its eastern. How far under cover of the upper coal measures it will prove productive cannot yet be stated, but there is reason to believe that at least some of the area will show coal of merchantable thickness. This Wapello horizon, as it has been called, is the best known coal horizon in Iowa. It has furnished more coal and has been more extensively prospected than any other. It is probable that it is more extensive than many of the other horizons, but, none the less, its richness for a distance of at least sixty miles down the dip is of suggestive interest in connection with the probabilities of coal in Carroll county. Coal has been mined and is, in fact, now being mined within twenty-five miles east of the county line. The presence within the county of an exposure of the Raccoon river beds of the coal

measures shows that the latter have not been cut out by the erosion which intervened between the Carboniferous and the Cretaceous. It is, accordingly, altogether probable that workable coal beds underlie at least the eastern part of Carroll county. The commercial question resolves itself, accordingly, into a matter of the value of the coal and the probable cost of locating, opening and mining it.

It has already been stated that any prospecting in this region should be carried on with the drill. The experience of large mine operators in the southern part of the state indicates that for this work the core or diamond drill is better. The depths to which it would be necessary to go, and the fact that so little is known of the beds underlying the county, make it more than ever necessary that there should be no mistakes in the determination of the thickness and character of each stratum penetrated. The increased cost of diamond drill work is more than repaid by the increased certainty of the result. The cost of diamond drill work varies greatly with the depths, nature of the strata, skill of the manipulator, amount of work done, proximity to water, and the number of diamonds or other tools lost or injured. Several large contracts have been carried out in this state, where the depths were mainly from 100 to 400 feet, at an average cost of 75 cents to $1 per foot. Single holes will, of course, average very much higher, and the figures quoted cannot be attained except under favorable circumstances, and where 5,000 to 10,000 feet of drilling are to be done. It would probably require at least that much work here to locate coal with sufficient accuracy to warrant the further outlay incident to sinking a shaft and putting up top works. A single drill hole or even a dozen drill holes would probably not answer the purpose. The amount of money necessary to open up a mine here would be large, and the cost of prospecting would necessarily be considerably higher than in the counties to the east, where the coal lies nearer the surface and more is already known as to the region. A mine in this region, of course,

would have important advantage in reaching the western markets, and in the local trade. It is quite unlikely, too, that mines will be opened west of Coon Rapids and Dedham, as, in the region beyond, the drift is so thick as greatly to increase the cost of prospecting, and the distance from the outcrops of the coal so great as to make it very uncertain as to whether the beds have not altogether thinned out. The lower portion of the valleys of Brushy Fork and the Coon river, especially the latter, are the most favorable points in the county in which to prospect. Whether or not the chances are sufficiently favorable to warrant investment at present is something of a question. It certainly would not pay unless the company undertaking the work has sufficient capital to prospect thoroughly a considerable area.

CLAYS.

The Pleistocene series is the only one which yields workable clay in the county The Cretaceous clays are of excellent quality, but so far they have not been found in quantity sufficient to be valuable. As has been suggested, the large amount of Cretaceous clay in the drift at Coon Rapids indicates that a good bed of it occurs at some point in the vicinity, under the drift. It is possible that this may at some time prove workable. The only clay now used is the loess. This is widely distributed throughout the southwestern portion of the county, and is excellently adapted to the manufacture of several grades of brick. It may be worked by hand, as a soft-mud, or on the dry-press. It is especially well adapted to the latter treatment, and yields a good face brick of excellent color. While much of the loess is so filled with lime concretions as to be nearly useless for brick work, there are large bodies almost entirely free from lime. At present brick is made at but two points in the county, though brick plants have been in operation at other points, and the material is at hand over most of the county. The facts that coal must be shipped in, and that there is only a moderate demand for

brick, has so far prevented the growth of a large industry. The brick now marketed are of the cheaper grades. Dry-press work has not been attempted, the initial expense more than balancing the increased return on the probably limited output. With the growth of the towns and cities of the county, and the decreasing use of wood in building, these conditions will undoubtedly change in future. The plants now in operation are located at Carroll and Manning.

Carroll.—In the southwestern part of the town the firm of O'Neil & Kellenberg have the most important brick works in the county. The plant was started a little more than fifteen years ago by Mr. C. P. O'Neil, and has been enlarged from time to time. At present it includes one soft-mud Eagle machine, a Freese brick machine, 30 horse-power engine, 40 horse-power boiler, pump, drying-sheds, etc. The kilns are two in number, one a large cased kiln, and one smaller round, down-draft. The main portion of the output is burned in the former. In burning, about four days are allowed for water-smoking, and the whole burn is made in seven to nine days. About half the burning is done with wood. The drying is done on pallets, under open sheds with movable roof, and there is but little trouble with checking The brick are a good building brick, of salmon color and fair strength. The clay is taken from a hillside pit on the grounds, and is of two varieties, which are suitably mixed. A sketch of the pit is shown below.

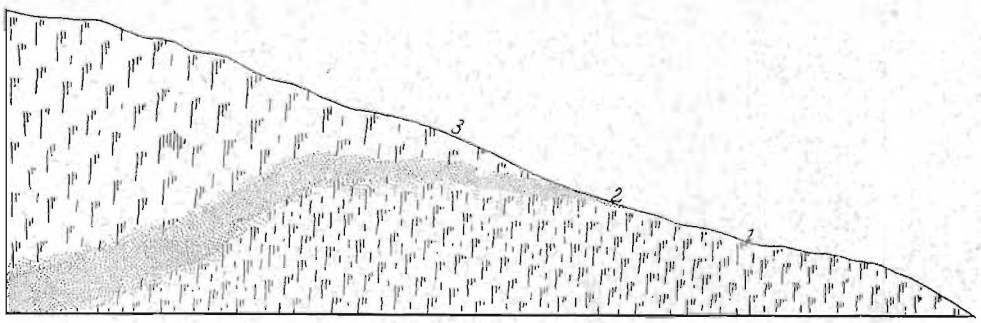


FIG. 10. Clays of the O'Neil Brick Yard, Carroll, Iowa.

The figures refer to the following beds:

		FEET.
3.	Loess, vertical jointing, considerable humus, buff color, ordinary character of the loess of the region	3-7
2.	Sand with clay streaks thickening to the left, horizontally bedded	1-3
1.	Fine grained blue, silt-like loess with horizontal bedding	5

In the northwestern part of Carroll, at a locality already mentioned, brick were for some years made by W. M. Boom. The loess was used to make a hard brick, but the work stopped in 1892.

Manning.—On the slope north of the Chicago & North-Western railway station is the brick yard of Mr. F. H. Long. The plant includes a New Quaker machine, the usual sheds and a cased kiln. The loess is used to make an ordinary building brick. Near this plant brick were formerly made by hand from the alluvium of the bottom land.

At Coon Rapids, between the station and the southern boundary of the county, Mr. E. Gibbons formerly ran a small hand brick yard. A short-grained brick of rather light color was made.

WATER SUPPLIES.

SURFACE WATERS.

The rainfall of Carroll county is abundant. The annual precipitation in 1897 was 28.80 inches at Carroll.* The immature drainage of the Wisconsin drift plain allows a considerable amount of this water to stand on the surface, and occasional small lakes and ponds afford convenient storage reservoirs. Outside of this area ponds can only be made by artificially damming some small stream or draw. The streams themselves, where they have cut below water level, carry abundant water for stock purposes. Many large stock farms, however, are supplied by means of wells and windmills. Dug wells are usually shallow and draw their supply from the base

*Rept. Iowa Weather Service, 1897.

of the loess or from the upper part of the drift. The stock wells are, however, usually drilled and reach deeper horizons. There seems to be no very general water horizon, but at varying depths, from 100 to 300 feet, beds of gravel are found in the drift. These are of irregular distribution but are good water horizons. A few of the wells in the western part of the county pass entirely through the drift and into the Cretaceous. The creamery well at Arcadia is an example. This well is 430 feet deep, the well head being at 1,430 A. T., and the sandstone being found at 130 feet. An abundant supply of excellent water is found. The creamery well at Mt. Carmel is said to be 260 feet deep and to end in gravel. South of Mt. Carmel there are several wells from 200 to 300 feet in depth. In the northwest of the northwest of section 11 is a well reported to be 305 feet deep, and in the southwest of the southeast, section 3, is one of 250 feet.

ARTESIAN WELLS.

There are no deep artesian wells in the county, but there are several shallow flowing wells which may perhaps be included under the title artesian. There is an area showing such wells east of Coon Rapids. The old drift-filled valley, previously noted as running through Union township, includes most of these. They are located on the accompanying map. The Hoffman well has been running for eleven years. It throws a vigorous stream from a two-inch pipe, and a small artificial lake has been made by the overflow. The well is at the foot of the slope into the old valley, and the well head is at 1,115 A. T. The Tom Campbell, John Glenn, and Henry George wells are in the neighborhood. In Coon Rapids itself is the Robertson & Martin well. Some of these wells go down to the level of the Dakota sandstone, but they do not seem actually to penetrate it. The hypothesis that they draw their supplies from the source is negatived by this and the further fact that the upper portion of the sandstone is not known to be especially aqueous in this region. Apparently

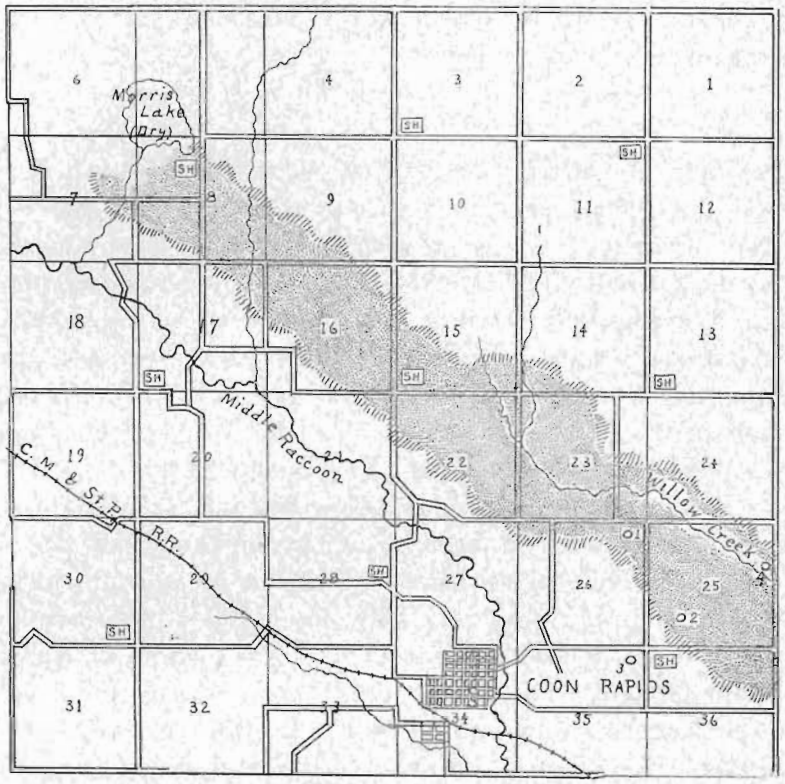


FIG. 11. Sketch map, locating old river valley and artesian wells near Coon Rapids; 1, Hoffman well; 2, Campbell well; 3, Glenn well; 4, George well; 5, Robertson & Martin well.

the wells are entirely similar to the local flowing wells common in Greene, Story and Guthrie counties.* These draw their supplies from the drift. Local gravel beds, or in the latter case, a buried loess forms the aquifer. The latter is probably the source of water in some of the Coon Rapids wells, while others are doubtless supplied by the old river gravels now buried beneath the drift. It is to be expected that more flowing wells will be found in the area covered by the Wisconsin drift, particularly near the moraine. The wells will, however, all be shallow. The deeper horizons, the various Paleozoic sandstones which supply the wells of northeastern Iowa,†

*Iowa Geol. Surv., vol. VII, pp. 483-486.
†Norton: Artesian wells, Iowa Geol. Surv., vol. VI, 113-428.

may in time be drawn on for water, but they will not afford flowing wells in this county.

SOILS.

The soils of Carroll county are of two general types, corresponding to the two drift sheets that occur in the area. In the northeast, in the region covered by the Wisconsin drift, is a typical drift soil. The upper six to twelve inches is usually composed of a fine black loam or sandy material. This material is usually coarser in texture than the loess of the southwestern portion of the county, and is accordingly often spoken of as the sandy soil, as distinguished from a loam, which term is locally more usually applied to the loess. The latter covers all the region south and west of the Altamont moraine, as marked on the accompanying map. It is a buff to yellow, fine pebbleless material, and is usually mixed with humus in its upper portion. The black soil is not ordinarily as deep over the loess as over the drift, except in cases of secondary wash. The loess found here is intermediate in type between the fine, pulvurent, dust-like material found along the Missouri and the stiff clays found in southern Iowa and northern Missouri. It stands dry seasons excellently and does not bake. The homogeneous texture of the loess gives it important advantages as a soil. The air spaces in it are so evenly divided that the tension of the water is equalized throughout the mass and the plants accordingly receive an even, regular supply of moisture.

Both the drift and the loess soils of the county are rich and largely productive. The drift-covered farms have the advantage of a more level surface, but face the difficulties of numerous surface bowlders and the common necessity for artificial drainage. The farms in the loess region have no difficulty in the matter of drainage or bowlders, but, on the other hand, the erosion of the region has been so vigorous that steep slopes interfere to some extent with easy cultivation of the ground.

R XXXVI W R XXXV W R XXXIV W R XXXIII W

T 85 N

T 84 N

T 83 N

T 82 N

WHEATLAND KNEIST SHERIDAN JASPER

ARCADIA CARROLL GRANT GLIDDEN

WASHINGTON ROSELLE VALLEY PLEASANT RICHLAND

WARREN EDEN NEWTON UNION

Breda
Mount Carmel
Maple River Jc
Arcada
Carroll
Glidden
Ralston
Halbur
Hillsdale
Willey P.O.
Gustine Grove
Carrollton
Templeton
Manning
Dedham
Coon Rapids
Benan P.O.

IOWA GEOLOGICAL SURVEY

MAP OF THE

SUPERFICIAL DEPOSITS

OF

CARROLL

COUNTY,

IOWA.

BY

H. FOSTER BAIN

1899.

Scale 1/125000

4 3 2 1 0 1 2 3 4 5 Miles

4 3 2 1 0 1 2 3 4 5 Kilometers

LEGEND

- WISCONSIN DRIFT
- ALTAMONT MORAINE — A
- KAMES
- LOESS (OVERLYING KANSAN DRIFT)
- NORMAL KANSAN EXPOSURES — 5
- ABNORMAL KANSAN EXPOSURES — X
- DAKOTA
- DES MOINES (Coal Measures)

INDUSTRIES

- CLAY PITS ▲

IOWA LITHO. CO.

DRAWN BY F.C. TATE

Samples of the various soils as found in the county have been taken and are now in the hands of the chemist for analysis. It was hoped that at least the preliminary results might be included in this report, but that has proven impossible, so that the matter must wait for the fuller discussion of the soils of the state now in preparation.