GEOLOGY OF WARREN COUNTY.

BY

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CONTENTS.

LOCATION.

Warren county is in the south central part of Iowa. It is in the third tier of counties from the southern boundary and in the center of the state east and west.

PHYSIOGRAPHY.

The weathering of the rocks supplies in various ways material which is gradually washed into the streams. The latter, working under the force of gravity upon strata of different hardness and dip, eroding here, depositing there, effected by the slightest crustal movement, writes the geographic history of the region in the landscape.

When once a broad plain has become subject to erosion, the gradual wearing away of the rocks would, after a period, reduce the country to a surface dotted with low rounded hills. The series of changes which a landscape undergoes as it thus wears away until it is again raised for erosion to begin its work anew, constitutes a cycle. Generally the changes of one cycle erase from the landscape much that resulted from preceding cycles; but in the area under consideration the oscillations that have occurred since the land was finally raised above the sea, each successive elevation marking separate incomplete cycles, seem to have aided erosion along lines first marked out and hastened the development of the present physiography.

The interpretation of the physical geography of Warren county must not only answer questions presented by the topography of the county itself, but also explain the phenomena presented in the adjoining counties. It must be in harmony with the facts observed in the great area now drained by the Missouri river. It must stand in proper relation to any explanation of the conditions existing in northeastern Iowa. It must allow a suitable explanation of the upper course of the Mississippi river as contrasted with its course farther south. All these physiographic features are expressions of the movements that have occurred in the

various parts of the Mississippi valley and the explanation of any one must be in harmony with a possible explanation of all.

DESCRIPTIVE PHYSIOGRAPHY.

General Drainage of the Region.—Along the eastern border of the state flows the Mississippi river, along the western the Missouri. These two great rivers are the master-streams of the entire west central region of the United States. A line passing through Clarke county, the southwestern part of Madison, through Adair, thence in a continued curve through Sac, Buena Vista and Dickinson counties, divides the state into two areas, the larger one to the east draining into the Mississippi river, the smaller area to the west draining into the Missouri. In the eastern area are large secondary rivers —in this case subsequent streams—some of them originating along this divide and gathering to their waters the numerous smaller streams that drain the adjacent territory. Two of these streams, the Des Moines and Skunk rivers, have selected their courses along the shales of the coal measures, draining an area between the heavy limestones of the Mississippian series to the northeast and similar limestones of the Missouri stage to the southwest.

Streams of Warren County.—Among the streams referred to are North river, Middle river, and South river, all of which take their rise along the crest of the divide in Clarke, Madison and Adair counties, and meet the Des Moines river near the northeastern corner of Warren county, together draining an area of approximately 1,440 square miles, including the whole of Warren county with the exception of the southeastern part where the drainage is into Whitebreast creek; another of the streams arising along the divide and flowing parallel to the three rivers mentioned to the Des Moines. It should be noticed that all the main streams of the county have a general direction to the northeast.

The areas drained by these rivers are as follows.

	Area drained outside the county.	Area drained within the county.	Total area drained.
South river	278	304	582
Middle river	352	114	466
North river	312	80	392
Whitebreast	329	69	398

General Character of the Streams as Illustrated by Middle River.—Middle river lies close to bluffs on the south along its entire course through the county, though departing here and there in sharp curves as it wanders across a flood plain excessively large.

In the long gentle slopes to the north of the river are but few well developed ravines. The few that exist are in Jefferson township. The bluffs along the south of the river are cut by numerous trenches, some running three to five miles into the uplands where they originate in numerous smaller ravines between the gently rounded knolls. One of these, Clanton creek, is of considerable importance, having a well developed valley of its own which in direction and size is analogous to that of Middle river. Only a portion of this stream, however, lies within the county. In the lower course of the river Butcher creek is developed parallel to the general course of the main stream, but reaches it only as that river is about to join the Des Moines. Butcher creek then, in the rank of its development, corresponds to Middle river rather than to a lateral ravine. With the exception of these two creeks, especially the latter, all the ravines extend laterally from the rivers.

This description of Middle river stands in a general way for both North and South rivers, excepting so far as relates to the particular lateral ravines that exist. From the uplands south of South river flow three large creeks, Coal creek, Otter creek and Squaw creek, while the river itself flows parallel to these creeks along the west side of White Oak township.

Escarpment Makers.—For the most part the strata consist of soft clay shale with interstratified calcareous sandstone.

The latter is quite thin, the beds being rarely more than about eighteen inches in thickness. The sandstone generally decomposes easily on exposure to the air because of oxidation of the contained iron, and the reaction between the sulphuric acid derived from the pyrites and the limestone.

Certain of the strata deserve especial attention. The heavy brownish sandstone that caps the bluffs along the Des Moines river in the northeastern part of the county, and extends some distance along the lower course of South river, gives a most interesting variation to the usual slopes where the river cuts into the hills. This rock is not resistant, and only forms very steep slopes where the river can wash away the rapidly accumulating talus.

At Spring Hill a sandstone which lies a few feet above the railroad track contains so much lime that the lower part of it well deserves to be called a limestone. This lower portion is especially resistant to atmospheric action and prevents the rapid wearing away of the hillsides. In the hills south of South river, especially in Otter township, is a layer of very desirable stone which occupies a position similar to that of the Spring Hill sandstone, and likewise aids much in protecting the underlying shales.

In the central and eastern part of White Oak, high sandstone bluffs again appear. While easily decomposed they form a conspicuous feature in the sections referred to, and seem to supply the material underlying the drift through the entire western part of White Oak. This sandstone is also to be found at various points of the county east and south of the bluffs here mentioned.

Across the central parts of Virginia, Squaw, and Liberty townships a heavy arenaceous limestone of about five feet in thickness outcrops. Here again the underlying soft strata are well protected. Where thus protected the strata stand out more prominently along the rivers and ravines, forming escarpments especially marked in comparison with those found elsewhere in the county.

Escarpments.—A topographic map of the county would show that lines of escarpment are to be found where these harder rocks exist, forming irregular fronts approximately at right angles to the general direction of the rivers and creeks, though the escarpment lines would be very faint. One escarpment is along the Des Moines river; a second extends northwestward through Otter township, then westward across the northern part of White Oak, finally northward through Jefferson and Linn townships, forming a very irregular front with outliers of high ground at and north of Indianola. The

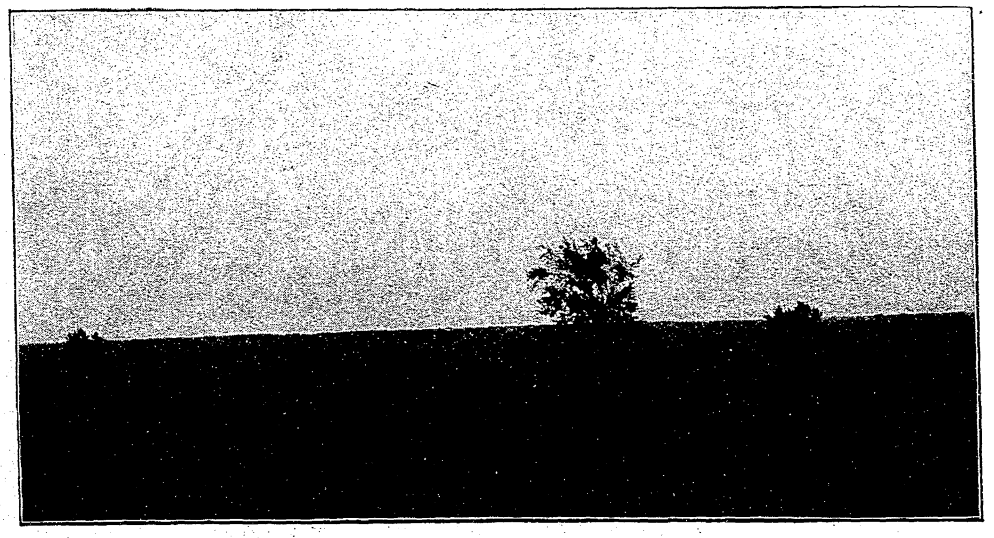


FIG. 44. The skyline as seen just south of Indianola, looking southeast across the bottom lands of South river towards Otter township. The brow of the hill in the foreground cuts off the view of the more gentle slope on the north side of the valley, as contrasted with the more abrupt slope in the distance.

third line of escarpment extends southeast to northwest across Virginia township, though this same escarpment is continued at a somewhat lower level across Squaw township to north of Liberty Center. The general trend of the escarpments is westward through the southern half of the county, and in a curve northward through the western part of the county.

The Skyline.—Looking out upon the horizon from the top of any of the hills the highest surface is seen to extend in all directions in a quite even skyline rising gradually to the southwest, though this general rise of uplands within the

county is scarcely perceptible to the eye. It is, however, perceptible along Middle river in the eastern part of Madison county, especially when looked upon from a distance to the north. Figure 44 is presented especially to illustrate the evenness of skyline, while figures 45 and 46 also bring out this feature.

Through the upland the larger streams flow along beds of even slope, only varied slightly here and there as they pass exposed broken edges of the harder layers of sandstone. In every direction the highlands are deeply cut by ravines that divide and subdivide till on close view nearly the whole country seems rounded and smoothed. Figure 45 brings out in a measure this branching of the ravines, and the rounding of land between them.

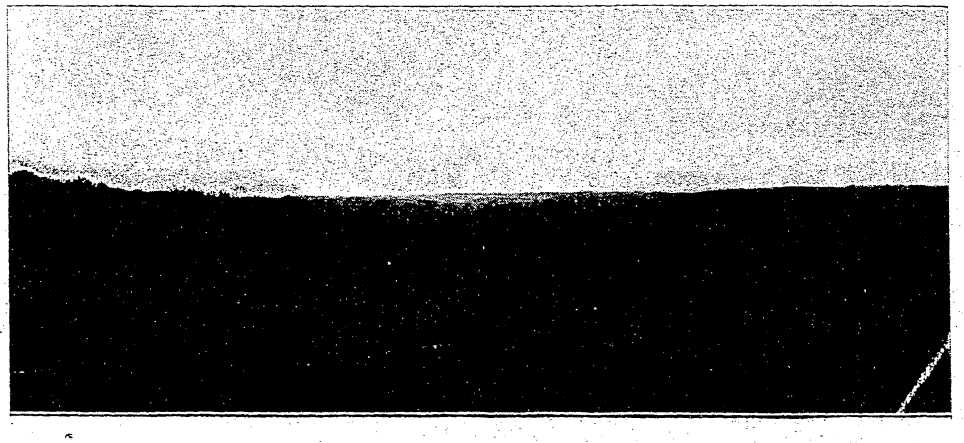


FIG. 45. View down one of the small ravines selected as a type to illustrate the branching and rounded sides of ravines. This ravine is on the southern outskirts of Indianola looking southwest.

Dip of Strata.—While there are escarpments progressively higher to the southwest ("retreating escarpments") and the strata of the county have an almost continuous, though slight, dip in the same direction, the rivers flow across these escarpments in a direction opposite the dip to join the Des Moines river.

EXPLANATION OF PHYSIOGRAPHY.

Since a correct interpretation of the physical geography of this county must stand in accord with all that surrounds it,

it is to be regretted that the details of the physiographic development of the large area to which the southwestern part of Iowa belongs, have not as yet been thoroughly worked out; but the following conclusions reached by geologists here mentioned present the best information at present obtainable concerning the part of the country in which Warren county is situated.

First.—It is commonly recognized that throughout Cretaceous times a part of Iowa and a vast region to the west was the bottom of a large sea extending from what is now the Gulf of Mexico, northwestward possibly to the Arctic ocean.

Second.—As stated by Upham* there is evidence of a general uplift of the country at the close of the Cretaceous period.

Third.—Todd† infers from evidence he finds that southwestern Iowa was at a low elevation up to the beginning of the Glacial epoch.

Fourth.—In the article mentioned by Upham the next general uplift is referred to the beginning of the Tertiary period and the next, "Between the general Tertiary cycle of baselevelling and the glacial period."

Fifth.—Westgate, in tracing the "Geographic Development of the Eastern Part of the Mississippi Drainage System,"‡ presents the conclusion that up to the close of the Cretaceous period the upper part of the Mississippi river, which is older than its more southern extension, had an outlet toward the west; and that from the close of the Cretaceous period the Missisippi came to flow in its present valley east of Iowa. While the uplifts mentioned affected nearly all, if not all, of the United States, they were more marked in the western than in the eastern part of the country.

To the above conclusion may be added another: whatever changes§ in altitude may have occurred since what is now

*Tertiary and Early Quaternary Baselevelling in Minnesota, etc., Am. Geol., Vol. XIV page 235. Minneapolis. 1894.

†Proc. A. A. A. S., Cleveland meeting, Vol. XXXVII. 1888.

‡Am. Geol., XI, pp. 245-260. 1893.

§For the change in elevation during the Carboniferous period, see Iowa Geol. Surv., Vol. II, p. 114.

Warren county first emerged from the waters in which the strata were deposited, the changes did not affect in any marked degree the horizontal position of the strata in central and southwestern Iowa. It is probable that the direction of drainage over the whole of the central and southwestern part of Iowa was toward the southwest, till the close of the Cretaceous period.

The features of the county already described find their most probable explanation in the following outline of events. Throughout Cretaceous times the surface was that of a low plain draining to the west, with lateral streams developing along the outcrop of the soft shales. These lateral streams would be called subsequent steams. At the close of the Cretaceous period the elevation, especially marked westward, gradually changed the drainage over a considerable portion of the state to the southeast, the lines of drainage following the direction of the subsequent streams already developed along the strike of the soft strata. To this group of subsequent streams flowing to the Mississippi as the master-stream, belong, among others, the Des Moines and the lower course of Chariton river. From these subsequent streams, other streams worked their way back on either side, those on the south working their way as obsequent streams in the valleys that formerly drained southwest. To this group of obsequent streams belong North, Middle and South rivers of Warren county, also Butcher creek and Whitebreast creek. At the present time the divide between these streams and those still flowing southwest, extends through Clarke county, southwestern Madison and through Adair.

The course of Chariton river exemplifies particularly well the results of such a history. It has worked its way back along the strike of soft strata to the city of Chariton as if beheading one stream after another. Above Chariton the course is from the southwest. The beheaded stream still continuing toward the northeast is Cedar creek. In Warren county a similar tendency to develop valleys parallel to the

strike of this same outcrop of soft strata is observed in all the streams. From the Whitebreast creek a ravine now extends along the strike of the soft strata with the head of the ravine even between Chariton river and Cedar creek. South river flows north along the west side of White Oak township and then turns east along the same series of soft strata, while another ravine just beyond a narrow divide continues the northward course to Middle river. During the Glacial epoch the land received its superficial deposit that clogged all the river valleys. Into this deposit the rivers have since cut their present trenches, though not to the depth of the preglacial valleys. The rivers and their larger tributaries are still in the preglacial valleys, but many of the smaller ravines have no relation to preglacial ravines.

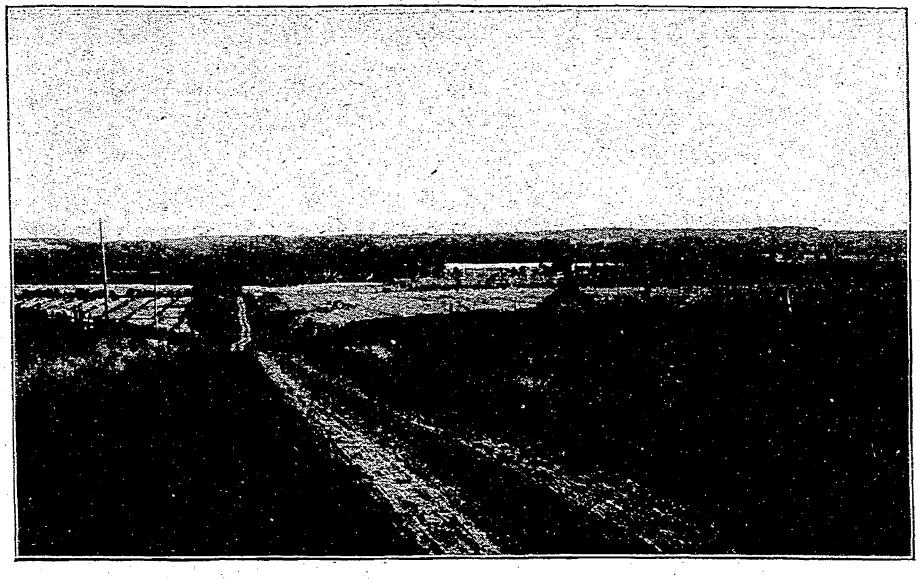


FIG. 46. The broad valley of the Middle river, as seen looking south toward Summerset. In the foreground the hill slopes gently toward the bottom land Beyond Middle river, along the distant margin of the lowlands, the hills rise comparatively abruptly.

Immensity of the Erosion.—The immensity of the erosion cannot fail to impress one who stands upon the hills overlooking Middle river at Summerset (see figure 46) and looks up and down the wide valley containing that stream, usually so insignificant.

South of Indianola the evidence of great erosion is no less marked as is shown by figure 47. These two illustrations serve as types of all the larger valleys in the county.

FIG. 47. The broad valley of South river, as seen looking northward toward Indianola. Here the river has left the steeper hills on the south of the valley and wandered over the flat lowlands of the valley itself. In the background the gradually rising hills can be seen below the distant skyline.

This erosion, immense though it is, is not yet completed. The landscape still presents much than can be eroded before the country is reduced to a peneplain. We have a landscape that is only approaching maturity of development.

TABLE OF ELEVATIONS.

As there is no topographical map of the county, the following records of altitudes are inserted as a basis for a study of the topography, a table for general reference, and a series of stations for use, should the preparation of a topographical map ever be undertaken.

The various levels obtained have been reduced to sea level at the Gulf of Mexico, Biloxi gauge, taking the record of the C., B. & Q. railroad station at Indianola as a central station assumed to be correct. By means of a barometer, the level of the C., R. I. & P. railroad station at Indianola was compared with the C., B. & Q. station at that place, thus eliminating the slight disagreement (five and a half feet) in the

railroad survey records. The record of the D. M. & K. C. railroad levels were then connected with the C., R. I. & P. railroad records by means of the crossing west of Lothrop. From these known levels the altitudes of the stream beds at different points were determined, either by a barometer or by a tape line, and the slope of the streams ascertained.

	FEET.
(Tp. 77 N., R. XXII W.)	
Section 12, Sw. qr., Sw. ¼, river bed of South river beneath the railroad bridge	735.7
Ford railroad station	759.74
Section 34, river bed beneath the wagon road bridge	759.44
(Tp. 77 N., R. XXIII W.)	
Section 2, river bed beneath railroad bridge over North river	760.45
Carlisle railroad station	787.1
Section 12, river bed beneath wagon road bridge	812.21
Section 15, river bed beneath wagon road bridge, Middle river	750.35
Summerset junction	799.1
Summerset station	802.1
River bed of Middle river, close to Summerset	775.1
(Tp. 77 N., R. XXIV W.)	
Section 18, Norwalk railroad station	982.15
Section 21, Ne. qr., Se. ¼, bed of North river	780.44
Section 30, river bed beneath railroad bridge	806.15
(Tp. 77 N., R. XXV W.)	
Section 36, where railroad crosses the township line	878.15
(Tp. 76. N., R. XXII W.)	
Section 4, river bed beneath wagon road bridge	768.31
Section 19, river bed beneath railroad bridge	805.87
(Tp. 76 N., R. XXIII W.)	
Indianola, C., B. & Q. railroad station	968.6
Indianola, Rock Island station	964.1
Ackworth railroad station	856.99
Section 25, river bed beneath railroad bridge	775.1
(Tp. 76 N., R. XXIV W.)	
Section 4, river bed beneath wagon road bridge east of Spring Hill	798.47
Spring Hill railroad station	839.1
Section 8, railroad beneath wagon road bridge south of Spring Hill	806.26
(Tp. 76 N., R. XXV. W.)	
Prole railroad station	989.15

	FEET.
Lothrop railroad station	847.1
Junction of Winterset branch and the D. M. & K. C. railroad	837.4
Des Moines & Kansas City railroad bridge over Middle river	842.15
River bed beneath the Des Moines & Kansas City railroad bridge	816.15
Bevington railroad station	868.1
River bed at Bevington	852.1
Wick railroad station	597.15
(Tp. 75 N., R. XXII W.)	
Milo railroad station	971.53
Top of recorded well boring, Sec. 19, Sw. qr., Nw. ¼	937.53
(Tp. 75 N., R. XXIII W.)	
Section 6, river bed beneath bridge south of Indianola	801.1
(Tp. 75 N., R. XXIV W.)	
Section 6, river bed beneath wagon road bridge	838.72
Section 31, river bed, Sw. qr., Sw. ¼	869.9
(Tp. 75 N., R. XXV W.)	
Railroad at crossing of road, one-half mile west of Saint Mary's	1,062.15
Section 19, railroad at county line	1,069.15
(Tp. 74 N., R. XXII W.)	
Section 13, creek bed of county line	787.74
Lacona railroad station	822.2
Section 35, creek bed at county line	806.43
Section 35, railroad at county line	854.48
(Tp. 74 N., R. XXV W.)	
Section 16, railroad bridge over South river	914.15
Section 16, river bed beneath railroad bridge	896.15
Section 19, railroad at county line	937.15
Section 19, river bed at county line	921.65
Section 21, railroad at road crossing on north section line	1,051.15
New Virginia, old railroad station	1,088.15
New Virginia, new railroad station	1,041.15
Section 33, railroad at county line	968.15

LEVELS OF POINTS OUTSIDE OF THE COUNTY CONSULTED IN DRAWING THE RIVER SECTIONS.

River bed near the mouth of North river, beneath the C., B. & Q. railroad bridge	752.24
Bed of Whitebreast creek, beneath C., B & Q. railroad bridge, about three miles west of Knoxville	723.7

	FEET.
Bed of Whitebreast creek, beneath C., B. & Q. railroad bridge, a mile south of Warren county line, on the Indianola branch	809.1
Bed of Whitebreast creek, beneath C., B. & Q. railroad bridge, a mile east of Cleveland, Lucas county	851.1
Low water mark, Raccoon river (datum level for the D. M. & K. C. railroad, survey reckoned from Indianola by means of levels on C., R. I. & P. railroad, Winterset branch, and the junction with the D. M. & K. C. railroad)	797.15

SLOPE OF RIVER BEDS.

NORTH RIVER.

Total fall of the river, from the D. M. & K. C. railroad bridge, in the western part of Greenfield township, to the C., R. I. & P. railroad near Carlisle	45.7
Fall per mile in a straight line (eleven and one-fourth miles)	4.06

MIDDLE RIVER.

Total fall from Bevington to Summerset	77.
Fall per mile, in a straight line (fourteen miles)	5.5

SOUTH RIVER.

Total fall in South river, from county line, Virginia township, to the C., B. & Q. railroad bridge, sec. 12, Richland township	185.95
Average fall per mile, in a straight line diagonally across the county (thirty-one and one-third miles)	5.93

WHITEBREAST CREEK.

Total fall within the county	18.69
Average fall per mile in a straight line (three and one-half miles long)	5.34

GEOLOGICAL FORMATIONS.

PLEISTOCENE.

The surface deposits of the county belong to two epochs. The alluvium represents the recent epoch, and the glacial deposit, consisting of loess and drift, the glacial epoch.

ALLUVIUM.

Upon the low ground along the streams a considerable amount of silt has been deposited. Over the higher portions of the low ground this deposit is very thin, scarcely more

than enough to mix with the loess and obscure the character of the latter. In the lower parts of the river valleys there are numerous swampy places, the partially filled lagoons left after the rivers have formed new trenches in the vicinity. These low grounds have received sediment washed from the adjoining higher ground or brought in by occasional overflow of the river. The material is frequently rendered black by abundance of vegetable material. All of these deposits may be classed as alluvium.

LOESS.

On the hilltops and in the valleys, even to the very banks of the river trenches, there is a fine, light, yellowish-brown deposit, largely made up of clay and fine sub-angular quartz.* The upper portions are black because of vegetable mould, the carbonaceous remains from decay of various plants. The fine material of the loess seems to have been washed from material brought by neighboring ice masses.

The exposure of loess at the Indianola Brick & Tile Co. plant, just northeast of Indianola may be taken as a typical exposure. At the surface two and a half feet are rendered black by vegetable mould. Beneath this mould there are two distinct deposits, the upper one, five feet thick, containing fossils characteristic of the loess (*Succinia obliqua* and *Mesodon multilineata* as identified by Professor B. Shimek). Beneath this loess, at a distance of about seven feet from the surface, is another clay deposit that for the present is here called the lower loess deposit. This lower deposit appears darker than the upper loess as seen in place. It does not contain fossils. The line of separation between these two deposits has a peculiar wavy appearance, suggesting a possible downward limit to present oxidation, or a disturbed surface on which the upper loess has been deposited. There is no dark line between the two to indicate a previous land surface, such as is sometimes found in deposits of loess.

*For analyses consult the tables given under clay deposits, in the latter part of this report.

The two deposits differ in composition in one important particular—the silica of the upper deposit is nearly all free, while that of the lower deposit is combined. This contrast is very marked when the two deposits are examined under a microscope. Samples collected from different levels above the line of separation between the two deposits present a uniform appearance, each sample containing an abundance of fine sub-angular quartz fragments. Below the line separating the two deposits the quartz fragments are far less numerous, the field of the microscope being largely occupied by dull, clayey material.

The differences in the composition of the two deposits suggest a possible difference in the sources of the material. The upper material may have been derived from a more loose sandy deposit, while the lower may have been derived from the disintegration of granite. Such a difference suggests further that the lower deposit may have been derived from the Kansan drift formation, which underlies the loess throughout the county. If it be true that the lower deposit is derived from the Kansan drift, the disturbed line between the two deposits represents an unconformity from which all evidence of vegetation, if such evidence existed, has been removed under the conditions which immediately preceded the deposition of the upper loess.

DRIFT.

In the eastern part of Greenfield township a sandy deposit extends southward to the divide between North and Middle rivers southeast of Spring Hill and a little to the north and west of Indianola. In Richland township the central sections are capped by a sandy material as if the deposit were a continuation to the south of a drift ridge east of Des Moines considered to be an esker. Between the two localities mentioned lie the gravel beds at Avon just north of the Warren county line. How much the early character of these deposits may be due to the soft sandstone and sandy shale just beneath the glacial deposits it is not possible to state.

The drift under the loess consists of a boulder clay or till containing pebbles of various sizes and shapes. These pebbles are of various kinds, granites, porphyry, quartz, agate, red quartzite and sandstone. The smoothed surfaces of some of these boulders are marked by peculiar scratches and gouges. A typical boulder may now be seen just northwest of Mrs. Watson's residence in the northwestern part of Indianola (Sec. 24, Sw. qr., Nw. ¼). This rock is a dense red quartzite with a rounded somewhat rectangular shape. It contains numerous pebbles revealing distinct planes of stratification dipping at present southwest, while on the eastern face the hard stone is scratched and gouged along lines at present almost perpendicular. The whole surface, scratches and all, is polished thoroughly. It is notable that this rock does not resemble the native Carboniferous sandstones; its planes of stratification do not correspond to the planes of stratification of the neighboring strata, and the glacial scratches are at right angles to the slope of the nearest ravine.

While this boulder, selected as a type, resembles Sioux quartzite, most of the boulders appear to be of granite. They are not very numerous on the surface of the ground, but, where the loess deposit is cut through, the boulders from the drift accumulate in the ravines.

The boulders mentioned are characteristic of the Kansan glacial formation that extends over the southern and western part of Iowa.

CARBONIFEROUS.

GENERAL DESCRIPTION.

In the preceding description of the physiography of the county the strata were referred to as an old shore deposit. The strata are in general clayey, or sandy shale, with here an arenaceous limestone and there a sandstone. The sandstones are generally ferruginous, sometimes dense and concretionary, sometimes soft, sometimes cross-bedded. The whole formation belongs to the great system of coal-bearing strata which extends from Iowa southwestward into Indian territory and Texas.

Relation of Strata to the Formation Below.—Immediately beneath the Carboniferous shales exposed in this county, lies the Saint Louis limestone. The borings put down at several points indicate that the surface of this Saint Louis formation on which the coal measures were deposited is uneven, like an old landscape with hills and valleys.

Conditions of Deposition.—During the deposition of the coal measures the conditions were at times favorable to the formation of swamps, and the vegetable material accumulated from the lepidodendrons, sigillarids and ferns that crowded the low swampy places. At times the region received fine clay sediments brought down by streams. At times conditions favorable to limestone formations spread a calcareous deposit over all. Again, the deposits, raised till exposed to erosive action were worn away here and there, only to again receive a deposit laid unconformably on the surface.*

Relation of Strata to the Formation Above.—As the seas advanced the heavy limestones of Madison and other counties west were laid down marking a condition of deep water more constant than had existed during the deposit of the shales. These limestones are, however, classified with the coal measures; for, while these were forming, Pennsylvania was receiving her stores of future wealth in the vegetable deposit† which later became coal. The difference between the conditions in which clays and sandy shales were deposited and those in which the heavy limestones were formed is so marked that it has been deemed advisable to classify these formations as separate subdivisions of the coal measures.

Classification of Strata.

GROUP.	SYSTEM.	SERIES.	STAGE.
Paleozoic.	Carboniferous.	Pennsylvanian.	Missouri. Des Moines.
		Mississippian.	Saint Louis Augusta. Kinderhook.

*For a record of these oscillations, see Iowa Geological Survey, Vol. I, p. 119.

†Dana's Manual, 4th ed., pp. 648 and 656.

The strata exposed in Warren county belong to the Des Moines stage of the Pennsylvanian series of coal measures. While the limestone of the Missouri stage, seen in Madison county almost touch the western border of Jackson township, they nowhere extend eastward across the county line.* Consequently all our strata belong to the same subdivision.

In the cross-sections along Middle and South rivers it will be seen that the limestone of the Missouri stage does not gradually change into shale as would be true if the present "lower coal measures" (Des Moines stage) were the shore equivalents of the present exposures of the Missouri limestone. While it is undoubtedly true the present exposures of the Missouri limestone did have a shore equivalent of shale when the limestone was deposited, that old shore equivalent has been eroded. The shales of the present Des Moines formation are now continued underneath the limestone of the Missouri stage. The sections outcropping along South and Middle rivers† are of special importance in their bearing because they are in a direction at right angles to the old shore line.

The variety of fossils that occur abundantly in the county is not very great. *Productus muricatus* is by far the most common, the small shells, half an inch long, forming the entire mass of the rocks in some places. In the heavier sandstones *Spirifer cameratus*, and *Productus costatus*, two of the larger shells about two inches long, frequently occur. In the thin layers of limestone to be found especially in the western half of the county occur crinoid stems, together with *Chonetes mesoloba*, *Athyris subtilita* and sometimes *Lophophyllum proliferum*.‡

*In the older geological reports of the state the thick bed of clay and sandy shale beneath the limestone was included with the limestone in the "Upper Coal Measures," and as thus defined; the Upper Coal Measures extend into Warren county; but the conditions under which this bed of clay and sandy shale was laid down were similar to those under which the strata beneath were deposited. The base of the heavy limestone marks the beginning of a deeper water formation in contrast with the shallow water deposits of the shales beneath. Hence it has been thought that the line of separation between the Des Moines and Missouri stages should be drawn at the base of the heavy limestone.

†For a continuation of the Middle river cross-section (Plate viii) to the Missouri stage limestone of Madison county, see "Geological section along Middle river in central Iowa," J. L. Tilton, Iowa Geol. Surv., Vol. III, p. 137.

‡On the coal measure fauna the following references are convenient:
U. S. Geological surveys west of the 100 meridian, Vol. IV, Paleontogy.
Missouri Geological Survey, Vols. IV and V. 1894.
Geol of Illinois, Vol. V.
Hayden's Final Report on the Geol. Surv. of Nebraska. Washington, 1872.

DETAILED SECTIONS ACROSS THE COUNTY.

The sections here given were obtained along the different ravines, carefully measured by a barometer or tape line and referred to the river beds as base lines. The slope of the river bed was in each case determined from railroad surveys.

It is to be regretted that there are not more records of borings accessible. There have been but four drill holes made, the records of which are now obtainable and of value in a study of our strata. The first was put down by the town of Milo (Tp. 75 N., R. XXII W., Sec. 19, Sw. qr., Nw. ¼). The record of the boring was published in the mine inspector's report, 1882-83, p. 67. The second boring is in Tp. 76 N., R. XXIV W., Sec. 9, Nw. qr., Se. ¼, southeast of Spring Hill. It was made by Earle Brothers who kindly furnished the figures and description from their records. The third is in Union township, Tp. 76 N., R. XXII W., Sec. 5, Sw. qr., Sw. ¼. The fourth boring is in Tp. 76 N., R. XXII W., Sec. 5, Sw. qr. Sw ¼. The latter were made by Mr. A. G. West, who furnished the record at the request of Mr. W. N. Bartholomew, for whom the work was done. In the absence of more borings the different outcrops must be connected, and the results considered as representing the general relation of strata in the neighborhood. In each plate of sections along the ravines, the location of outcrops is marked.

SOUTH RIVER CROSS-SECTION.

The best series of outcrops is that along South river. The slope of the river was determined as follows.

The records of the Chicago, Burlington & Quincy railroad survey show the altitude of the river bed beneath the railroad bridge at the mouth of the river and south of Ackworth; also the altitude of Indianola and Osceola. By means of a barometer the difference in level between the Indianola station and the bed of the river directly south was measured. From the survey of the Des Moines & Kansas City railroad the difference in level between the station at Osceola and the

point where the railroad crosses the west county line close to South river was ascertained, as well as the difference in level between the latter place and the bridge across South river, in section 16 of Virginia township. Since a river cuts through hard strata and fills with sediments the stretches from one hard stratum to the next till the entire slope of the river bed presents a slightly concave line, a knowledge of the altitude of the five points mentioned is sufficient to determine the slope of the entire river bed across the county.

FIG. 48. The Ford sandstone as seen in the north central part of section 24 near exposure 1. Here the dip is visible on the southwestern side of the low anticline found in the northeastern part of the county.

Among the outcrops that occur there are thirteen of especial value, because of their size, their freedom from settling, and their position along the line. These outcrops and their locations are as follows.

SECTION 1.

Exposure near the mouth of South river in Richland township (Tp. 77 N., R. XXII W., Sec. 24, Sw. qr., Ne. ¼). This

section is just northeast of the crest of a gentle anticline. The dip is here 10° to 15° to the northeast.

		FEET.	INCHES.
4.	Drift	12	
3.	Shale, clay and sand, thinner banded above, heavier below	32	
2.	Sandstone, red, heavy, cross-bedded, with much globular iron pyrite	14	2
1.	River		

SECTION II.

Richland township near the mouth of Coal creek (Tp. 77 N., R. XXII W., Sec. 25., Sw. qr., Se. ¼), offers the following exposures.

		FEET.
4.	Drift	
3.	Shale, bluish gray, finely laminated with sandstone in thin layers to bed of Coal creek	40
2.	Not exposed	9
1.	River	

SECTION III.

The following outcrop is seen in Richland township (Tp. 77 N., R. XXII W., Sec. 35, Nw. qr., Se. ¼).

		FEET.
5.	Not exposed	93
4.	Shale, black, exposed	2
3.	Coal	2
2.	Shale, gray, sandy	32
1.	River	

SECTION IV.

Union township (Tp. 76 N., R. XXII W., Sec. 3, Se. qr., Nw. ¼).

		FEET.	INCHES.
12.	Drift	15	
11.	Shale, clay, black	2	
10.	Coal	1	
9.	Shale, clay, gray	4	
8.	Limestone, gray, arenaceous, fossiliferous	2	
7.	Shale, clay, gray	8	
6.	Coal	3	7
5.	Shale, bluish gray	10	
4.	Shale, gray, sandy	24	
3.	Coal	1	1
2.	Shale, clay	2	6
1.	River		

SECTION V.

The following section shows beds which also appear in Union township (Tp. 76 N., R. XXII W., Sec. 9, Ne. qr., Nw. $\frac{1}{4}$).

		FEET.	INCHES.
8.	Drift	2	
7.	Limestone, blue, dense		2
6.	Shale, gray below and above, black through the center	19	
5.	Coal		6
4.	Shale, gray, fossiliferous below	11	
3.	Limestone, gray arenaceous shaly above; fossiliferous	2	6
2.	Shale, gray above, black below	14	
1.	River		

SECTION VI.

In Palmyra township (Tp. 76 N., R. XXII W., Sec. 5, Sw. qr.) is a boring to the depth of three hundred and sixty-seven feet and six inches, the top of which is one hundred and twenty feet above the bed of South river. The record of this boring as kept by Mr. A. G. West for Mr. W. N. Bartholomew is as follows.

		FEET.	INCHES.
35.	Soil	4	
34.	Clay, yellow with gravel below	20	
33.	Sandstone, yellowish	11	
32.	Shale, blue	3	
31.	Limestone, fossiliferous	4	
30.	Shale, black	4	
29.	Coal	1	8
28.	Fire clay	8	
27.	Sandstone	4	
26.	Shale, gray	12	
25.	Shale clay, black	2	
24.	Coal	1	4
23.	Fire clay	3	
22.	Shale, clayey	16	
21.	Shale, clayey, red running to brown, bed of South river	26	
20.	Shale, brown, sandy below	19	
19.	Slate, bituminous	2	
18.	Shale, clayey	14	
17.	Shale, clayey, black	6	

		FEET.	INCHES.
16.	Coal	3	8
15.	Fire clay	4	
14.	Shale, gray with hard bands	10	
13.	Shale, soft-blue, with bands of gravel	27	
12	Shale, sandy	11	
11.	Sandstone, compact	6	
10.	Shale, light, with ironstone bands	17	
9.	Shale, clayey, red, blue and brown	26	
8.	Sandstone, fine-grained	4	
7.	Shale, clayey, light above, dark below, very hard bituminous	23	
6	Coal	1	10
5.	Fire clay	2	
4.	Shale, clayey, black	16	
3.	Shale, light, with hard bands	7	
2.	Shale, gray, very hard and sandy	12	
1.	Saint Louis limestone	38	
	Total	367	6

A second boring was made a short distance south, the top being is 132 feet below the top of the boring just given. The record of the second is as follows.

		FEET.
23.	Black soil, wash and drift	37
22.	Sand and gravel	8
26.	Shale, clayey, light	6
20.	Shale, clayey, red	15
19.	Shale, clayey, black	3
18.	Shale with coal	2
17.	Shale, clayey, light	4
16.	Shale, clayey, gray	13
15.	Sandstone, light	6
14.	Shale, clayey, gray	10
13.	Shale, clayey, black, soft	1
12.	Shale, clayey, white, soft	6
11.	Shale, sandy, blue	8
10.	Sandstone, fine, white	30
9.	Shale, dark, sandy, with hard bands	11
8.	Shale, clay, dark	6
7.	Sandstone, fine-grained, with hard bands	6
6.	Shale, white	5
5.	Shale, sandy, gray, hard	15
4.	Sandstone, light-colored	4
3.	Shale, sandy, gray	3

		FEET.
2.	Shale, sandy, light-colored, with hard bands	32
1.	Saint Louis limestone	2
	Total	233

SECTION VII.

The measurements next given are from Union township (Tp. 76 N., R. XXII W., Sec. 17, Sw. qr., Nw. ¼).

		FEET.	INCHES.
13.	Drift	10	
12.	Shale, clayey, gray	2	
11.	Shale, clayey, black	1	2
10.	Coal	1	
9.	Shale, clayey	2	
8.	Limestone, gray, dense, arenaceous	1	
7.	Shale, clayey, gray, nodular	32	2
6.	Limestone, blue, arenaceous fossiliferous	1	2
5.	Shale, clayey, gray	7	
4.	Limestone, blue, dense		6
3.	Shale, clayey, blue, finely laminated	5	
2	Not exposed	5	
1.	River		

SECTION VIII.

East of Ackworth (Tp. 76 N., R. XXII W., Sec. 30). This section is made up from exposures on both sides of the hill just east of the river.

		FEET.	INCHES.
15.	Loess		
14.	Shale, gray, clayey, sandy	2	
13.	Sandstone	3	
12.	Shale, clay		6
11.	Not exposed	12	
10.	Shale, gray, sandy	18	
9.	Not well exposed, but undoubtedly shale, gray, sandy	12	
8.	Shale, clayey	3	
7.	Sandstone, gray		8
6.	Shale, clay, black	1	2
5.	Coal	1	6
4.	Shale, clay, black, not fully exposed	11	
3.	Sandstone, gray, dense, fossiliferous	1	3
2.	Shale, clay, gray to black		9
1.	Coal		

SECTION IX.

South of Ackworth (Tp. 76 N., R. XXIII W., Sec. 36, Sw. qr., Se. ¼), is a series of outcrops that occur along the ravine extending from section 36 to section 35.

		FEET.	INCHES.
16.	Loess		
15.	Limestone, dense, very fossiliferous	1	
14.	Shale, clayey, black	4	
13.	Coal		9
12.	Fire clay above, clay shale below	8	6
11.	Sandstone, shaly, irregular	1	6
10.	Shale, clayey	1	
9.	Sandstone, gray, thick-bedded, soft	1	4
8.	Shale, gray, sandy, thin irregular bands	6	8
7.	Sandstone, reddish		8
6.	Shale, clayey, gray above, dark below	6	8
5.	Coal		2¼
4.	Fire clay		6
3.	Shale, dark		4
2.	Not exposed	2	
1.	River		

SECTION X.

North of Hammondsburg (Tp. 75 N., R. XXIII W., Sec. 2), the outcrops from which this section is made are scattered for a considerable distance along a ravine.

		FEET.	INCHES.
14.	Loess		
13.	Upper part sandstone, gray, heavily-bedded, graduating below to gray shale, then to gray, sandy shale	39	
12.	Coal	1	4
11.	Shale, clayey, grayish	13	6
10.	Limestone, very fossiliferous	1	
9.	Shale, clayey, blue above, black below	5	6
8.	Sandstone, gray, concretionary, somewhat calcareous		6
7.	Shale, clay, black	1	
6.	Coal, dipping south		7
5.	Shale, clay, gray	5	
4.	Sandstone, reddish, soft		9
3.	Shale, gray, sandy, thin-bedded, exposed	20	
2.	Not exposed	22	
1.	River		

SECTION XI.

South of Indianola (Tp. 75 N., R. XXIII W., Secs. 1 and 12), the exposures here given are found along the sides of a ravine.

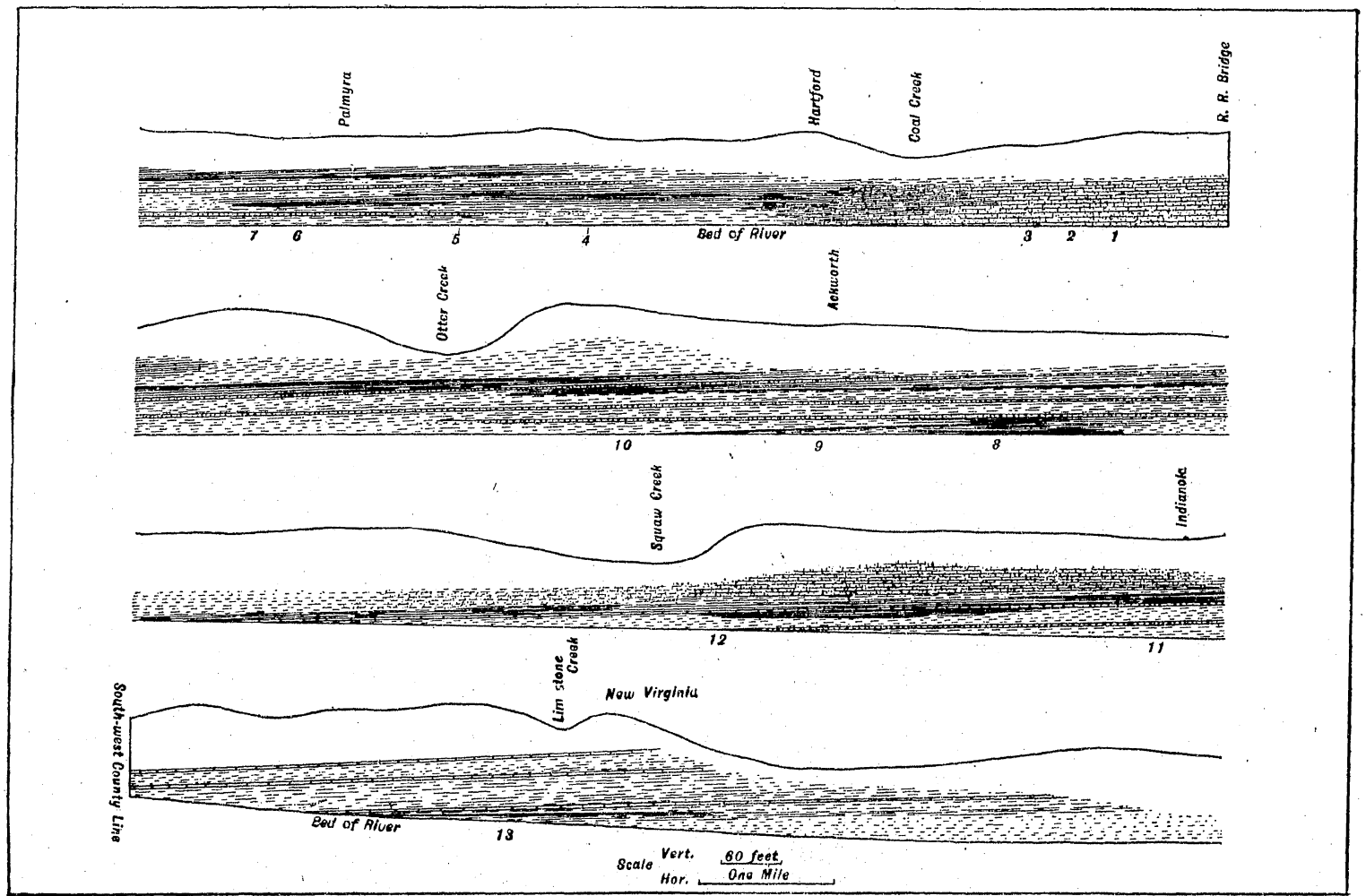
		FEET.	INCHES.
10.	Sandstone, gray, thin-bedded above, shale gray, sandy below	35	6
9.	Coal		7
8.	Fire clay		6
7.	Not exposed	6	6
6.	Limestone, shaly, arenaceous	1	6
5.	Shale, sandy, gray, lower part clay, gray, with reddish bands	21	
4.	Sandstone, gray	1	6
3.	Shale, sandy, gray	7	6
2.	Shale, clayey, dark	2	
1.	Not exposed	8	

SECTION XII.

The following exposure is near the "Quarries" on Squaw creek (Tp. 75 N., R. XXIV W., Sec. 22). A part may be found at the quarry itself, a part up a ravine a little to the north.

FIG. 49. The sandstone cliff at the old quarries in White Oak township (section 22).

		FEET.	INCHES.
9.	Sandstone, very massive, soft, grayish brown	14	
8.	Shale, gray, sandy above, clayey below; lower part not well exposed	11	
7.	Limestone, gray, very fossiliferous	1	1
6.	Shale, sandy, gray	1	
5.	Shale, clay, dark (exposed)	7	
4.	Limestone, concretionary		6
3.	Shale, clayey, black	1	2
2.	Coal	1	
1.	Not exposed	16	6



GEOLOGICAL CROSS-SECTION ALONG SOUTH RIVER IN WARREN COUNTY.

SECTION XIII.

This section is obtained from a combination of several series of outcrops on Limestone creek. The most important one is in section 17 (Tp. 74 N., R. XXV W.).

		FEET.	INCHES.
12.	Not exposed	54	
11.	Limestone, heavy above, shaly below	3	
10.	Shale, sandy, gray	30	
9.	Limestone	2	
8.	Shale, sandy, gray	10	
7.	Not exposed	15	
6.	Limestone, arenaceous	1	
5.	Shale, clayey	1	6
4.	Coal		4
3.	Shale, sandy, gray	15	
2.	Shale, black, carboniferous	1	
1.	River		

The outcrops above described, arranged each in its relative position, and the lines continued from one to the next, yield the general section seen illustrated in plate vii. In this diagram two slight gaps of a few feet occur, but from the field evidence the underlying strata at these points may be inferred without doubt. From the outcrops on Squaw creek, White Oak township, section 22, to those near Limestone creek, in Virginia township, there are no important outcrops, but the few that do occur, and the abundance of red sand to be found beneath the soil through much of the distance, give evidence of sandstone strata continued through most of this region.

WHITEBREAST CREEK CROSS-SECTION.

The section along Whitebreast creek in this county is quite short. One of the central outcrops will serve for the entire

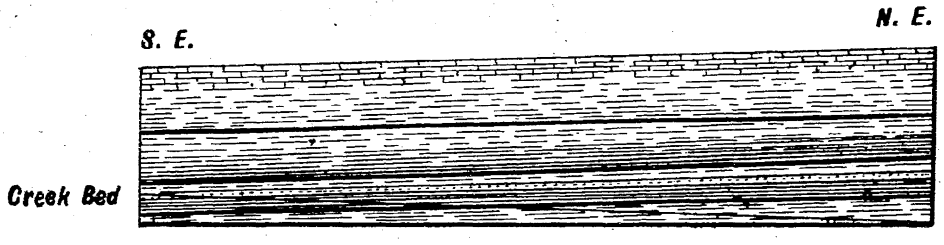


FIG. 50. Whitebreast Creek cross-section.

section. In fact, it is the only good outcrop to be found, though other small ones assist in correlation.

SECTION I.

Composite section for Tp. 74 N., R. XXII W., Sec. 26, Sw. qr.

		FEET.	INCHES.
15.	Sandstone, heavy, gray shale above, not well exposed below	62	
14.	Coal	1	5
13.	Shale, clayey, gray and blue, fire clay above	28	
12.	Shale, clayey, black	4	6
11.	Coal		9
10.	Clay, carbonaceous		4
9.	Clay, fire clay above, gray below	9	
8.	Sandstone, decomposed, calcareous		6
7.	Shale, sandy and clayey, gray		6
6.	Sandstone, very fossiliferous, gray		6
5.	Shale, gray, sandy	5	4
4.	Shale, clay, black	1	
3.	Coal, sulphur-bearing	1	8
2.	Fire clay	4	
1.	Creek		

MIDDLE RIVER CROSS-SECTION.

SECTION I.

The first outcrop to be considered is one mile east of Ford (Tp. 77 N., R. XXII W., Sec. 10). It is as follows.

		FEET.
9.	Drift and loess	20
8.	Shale	4
7.	Sandstone, soft, yellow	35
6.	Shale, bituminous	2
5.	Clay-shale, dark, sandy above	12
4.	Clay, white	3
3.	Sandstone, soft, heavily bedded	4
2.	Clay, white	4
1.	Shale, sandy and clayey (exposed to water)	25

This section is located at the crest of a low anticline. From this place to a point a mile west of Ford the strata can be traced in the bluff which forms the south bank of the Des Moines and Middle rivers. Beyond this point the exposures

are not so continuous, but the principal seam of coal which appears just above the railroad track at the station, comes to an end as it reaches the water level of Middle river, about one-fourth of a mile east of the bridge at Clarkson. At this point the upper part of the vein is well exposed. The overlying sandstone is present, but is not so thick as at Ford, and the dark shale and soft sandstone crop out in the bluff. Near this point another vein begins that may be traced three miles up the river, the bituminous shales which overlie it being especially noticeable near the bridge on the road to Carlisle.

SECTION II.

Just above the bridge between Carlisle and Palmyra the following section appears (Tp. 77 N., R. XXIII W., Sec. 15, Se. qr., Se. ¼).

		FEET.	INCHES.
12.	Shale, clayey	1	
11.	Coal		2
10.	Clay	5	
9.	Sandstone	1	8
8.	Shale, clayey		1
7.	Shale, clayey, black	2	9
6.	Coal		9
5.	Fire clay		1
4.	Shale, upper part with numerous nodular bands and several bands of sandstone	13	10
3.	Shale, clayey, dark	1	4
2.	Shale, clayey,	1	
1.	River		

SECTION III.

A short distance east of Summerset at the mouth of a ravine in which are situated the Jones and Benham coal mines (Tp. 77 N., R. XXIII W., Sec. 22, Ne. qr., Se. ¼) the outcrop shows.

		FEET.	INCHES.
8.	Clay, bluish	1	1
7.	Coal		6
6.	Fire clay		1
5.	Shale	6	7
4.	Sandstone coarse, reddish	1	8
3.	Shale, sandy	2	6
2.	Shale	3	8
1.	Shale, clayey (exposed to river)	1	

SECTION IV.

At the shafts of the mines referred to the following record was obtained. The upper coal corresponds with the coal mentioned as outcropping near the river.

		FEET.	INCHES.
19.	Drift, yellow sands and variegated clays	24	
18.	Limestone, blue, fossiliferous	1	1
17.	Shale, blue, argillaceous	7	
16.	Limestone, fossiliferous		4
15.	Shale, black, fissile	2	
14.	Coal	1	2
13.	Fire clay	3	4
12.	Sandstone, with nodules of black limerock	5	
11.	Shale, gray with streaks of red	7	
10.	Sandstone	8	
9.	Shale, argillaceous	10	
8.	Sandstone	5	
7.	Shale, argillaceous	10	
6.	Limestone		9
5.	Sandstone	3	
4.	Shale, argillaceous	6	
3.	Shale, black, somewhat fissile	2	
2.	Coal	2	10
1.	Fire clay (exposed)	2	

The sandstone above the seam of coal is a continuation of that which is so prominent in the upper part of the cliff at Ford. It disappears beneath the bed of the river just west of Summerset. The coal seam overlying the sandstone in the bluff at Summerset outcrops repeatedly in the hillsides for a distance of several miles to the east where it is "drifted." It thins out rapidly west of town.

SECTION V.

The Summerset section (Tp. 77 N., R. XXIII W., Sec. 31, Ne. qr., is as follows.

		FEET.	INCHES.
9.	Loess	13	9
8.	Sandstone, calcareous		9
7.	Shale, clayey	6	8
6.	Coal	1	2
5.	Fire clay	4	6
4.	Shale, sandy, gray	3	6

		FEET.	INCHES.
3.	Sandstone, gray	1	6
2.	Shale, gray	1	
1.	Sandstone, heavily bedded	2	

From Summerset to Spring Hill the outcrops in the immediate vicinity of the river are not very numerous.

FIG. 51. Exposure at Summerset (Section 31, Ne, qr., Ne. ¼).

Several thin veins of coal are found, the best natural exposure occurring about half way between the towns mentioned. A little to the south of the river the seams supply coal for local consumption.

SECTION VI.

Southeast of Spring Hill (Tp. 76 N., R. XXIV W., Sec. 2, Sw. qr., Ne. ¼).

		FEET.	INCHES.
15.	Not exposed		
14.	Shale, clayey, black	2	
13.	Sandstone, concretionary		6

		FEET.	INCHES.
12.	Shale, clayey, black	1	6
11.	Coal	1	6
10.	Not exposed	47	
9.	Shale, clayey, dark, exposed	1	
8.	Coal		2
7.	Fire clay	1	
6.	Shale, clayey, brown	17	
5.	Shale, clayey, red	15	
4.	Shale, clayey, black	3	
3.	Coal		3
2.	Clay, black	1	4
1.	Clay, white	2	8

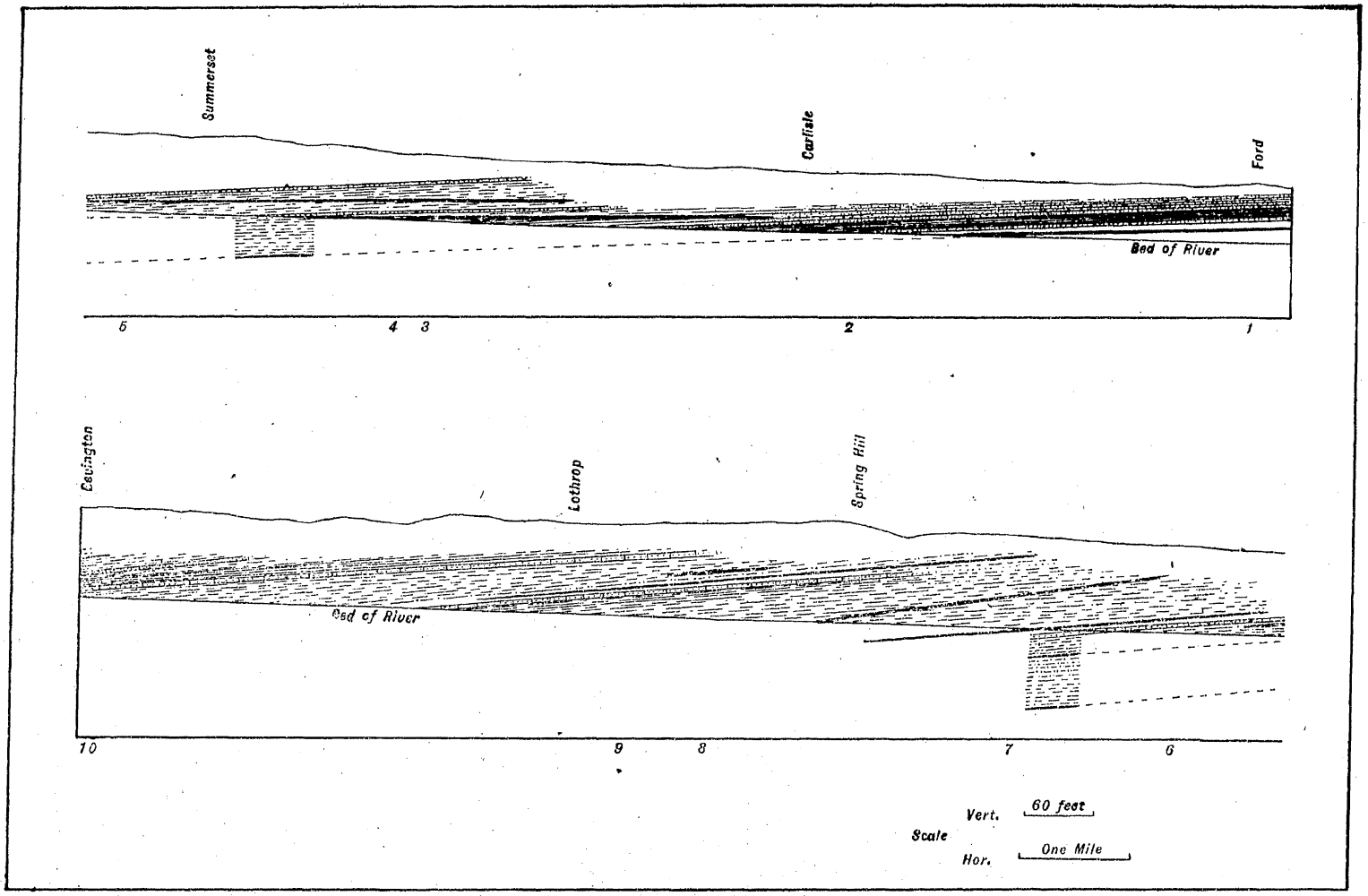
Two miles farther west, in section 9, Nw. qr., Se. ¼ of Tp. 76 N., R. XXIV W., the Earle Brothers have a coal lease. They have kindly furnished the following drill record. The top of this boring is 28 feet above the river bed, so that the first seam mentioned in this record is that which is found to pass beneath the river bed close by.

SECTION VII.

Earle Brothers' Boring.

		FEET.
18.	Soil	3
17.	Clay, yellow	5
16.	Shale, clayey, blue	6
15.	Sandstone	1
14.	Shale, clayey, dark	1
13.	Coal	1
12.	Fire clay	2
11.	Shale, sandy, hard	13
10.	Shale, clayey	4
9.	Sandstone	1¼
8.	Shale, clayey	12
7.	Shale, clayey, black	5
6.	Coal	2½
5.	Shale, sandy, hard	21
4.	Shale, clayey, red and blue	34
3.	Sandstone, dense	1½
2.	Shale, clayey, black	5
1.	Coal	4

Immediately west of Spring Hill an excellent section has been disclosed in opening a seam of coal. Northward in the



GEOLOGICAL CROSS-SECTION ALONG MIDDLE RIVER IN WARREN COUNTY.

ravines sloping into North River valley, and in a bluff by the stream itself, are exposures revealing shale and sandstone both above and below a narrow pocket of coal, the main axis of which is directed north and south, the stratum thinning out very rapidly east and west.

SECTION VIII.

A mile and a quarter west of the town (Tp. 76 N., R. XXV W., Sec. 12, Ne. qr., Sw. ¼) is the following section.

		FEET.	INCHES.
10.	Loess	2	
9.	Coal, badly weathered		6
8.	Shale, gray, with thin seams of sandstone	9	7
7.	Shale, blue above, black below	4	4
6.	Sandstone, nodular, calcareous		6
5.	Shale, gray, black	2	
4.	Coal	1	1
3.	Fire clay	4	4
2.	Sandstone, heavily bedded, gray	1	4
1.	Shale, irregular (exposed)	2	6

Between Lothrop and Bevington, an interval of three miles, few outcrops occur. The scarcity of exposures and the general relations of the strata indicate the absence of any layer that by resisting weathering would protrude through the overlaying loess or become exposed in the ravines. This, together with the fact that the lowermost stratum found above is argillaceous shale and the uppermost found below is a sandstone passing in places into a sandy shale, implies that the strata thus concealed are largely shales.

Two miles west of Greenbush is a section in a ravine where coal is at present obtained by "stripping." (Tp. 76 N., R. XXV W., Sec. 1., Nw. qr., Nw. ¼.) The upper half of the section is obtained about fifty yards west of the point at which the lower half is found.

SECTION IX.

		FEET.	INCHES.
12.	Sandstone, shaly	2	2
11.	Shale, clayey, gray	1	3
10.	Shale, clayey, reddish	2	3

9.	Sandstone, gray, shaly		5
8.	Shale, clayey, blue		9
7.	Sandstone, fossiliferous	1	3
6.	Shale, clayey, blue		7
5.	Shale, clayey	4	
4.	Limestone, arenaceous, fossiliferous		6
3.	Shale, clayey, black		7
2.	Coal		6
1.	Fire clay (exposed)		4

A short distance southwest of Bevington,* in the ravines and in the bluff near the river (Tp. 76 N., R. XXVI W., Sec. 36, Sw. qr., Nw. ¼), one of the best exposures is found.

SECTION X.

		FEET.	INCHES.
8.	Drift		
7.	Sandstone	1	3
6.	Sandstone, massive	1	2
5.	Unexposed	3	8
4.	Shale, black below	2	6
3.	Coal	3	
2.	Fire clay and light-colored shale	7	
1.	Shale (exposed)	40	

These sections with others referred to the bed of Middle river as a base line give plate viii, a diagram of the Middle river cross-section.

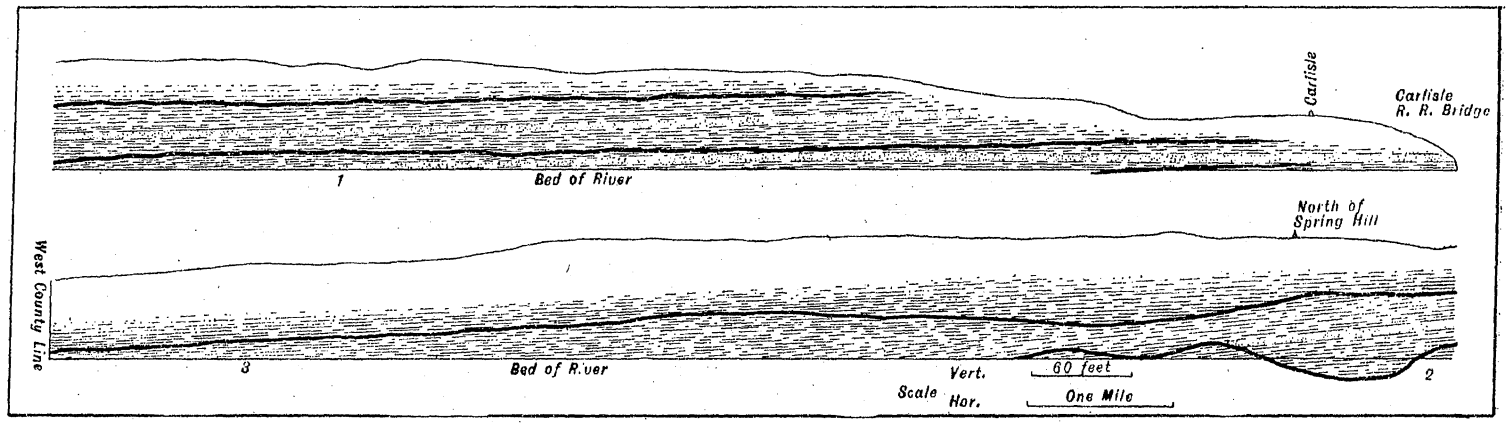
NORTH RIVER CROSS-SECTION.

The outcrops along North river are neither very high nor continuous. For the most part the hills along the south bank against which the river flows are not cut by ravines that offer good exposures for measuring. The best exposure to be obtained is in section 15 of Greenfield township, where a ravine cutting through the southwest quarter of the section offers the following exposures.

SECTION I.

		FEET.	INCHES.
17.	Concealed	49	
16.	Sandstone, gray	6	
15.	Shale, clayey, blue above, black below	5	

*For a continuation of this description of strata toward Winterset, see Geological Section along Middle river, J. L. Tilton, Iowa Geological Survey, Vol. III, pp. 144-145.



GEOLOGICAL CROSS-SECTION ALONG NORTH RIVER IN WARREN COUNTY.

		FEET.	INCHES.
14.	Sandstone, gray, fossiliferous		6
13.	Shale, clayey, black	1	3
12.	Coal, sulphur-bearing	1	
11.	Fire clay	1	
10.	Sandstone, gray, concretionary	1	
9.	Shale, clayey, reddish and blue	36	
8.	Sandstone, reddish-brown		7
7.	Shale, clayey, upper part blue, lower part gray to black with indications of coal	9	2
6.	Hematite		1
5.	Shale, clayey, sandy, gray	25	
4.	Sandstone, gray	1	3
3.	Shale, clayey	1	
2.	Concealed	5	
1.	River		

Where the river washes into a bluff north of Greenbush (Section 30, Sw. qr., Ne. $\frac{1}{4}$ of Greenfield township), an exposure appears that is continued up to the divide toward Spring Hill by several outcrops along a ravine. The exposure on North river is as follows.

SECTION II.

		FEET.	INCHES.
7.	Loess		
6.	Shale, clayey, white		6
5.	Coal, impure and decomposed		1
4.	Shale, hard above, soft below	30	
3.	Sandstone, gray		6
2.	Shale, clayey, blue, exposed	2	
1.	River with coal just below the river bed		

Beyond the last described section the outcrops are few, the best one occurring in section 32, Sw. qr., Se. $\frac{1}{4}$, Linn township.

SECTION III.

		FEET.	INCHES.
8.	Sandstone, gray, easily decomposed	1	6
7.	Shale, clayey, blue, jointed	5	
6.	Sandstone, very fossiliferous		7
5.	Shale, clayey, blue, jointed, sandy above		6
4.	Shale, clayey, black		4
3.	Sandstone, nodular, reddish		3
2.	Coal, very good	3	6
1.	Fire clay, exposed		4

Combining these and other smaller sections by their relation to the bed of North river, a section as shown in plate ix is found to exist along the north side of the divide between North and Middle rivers.

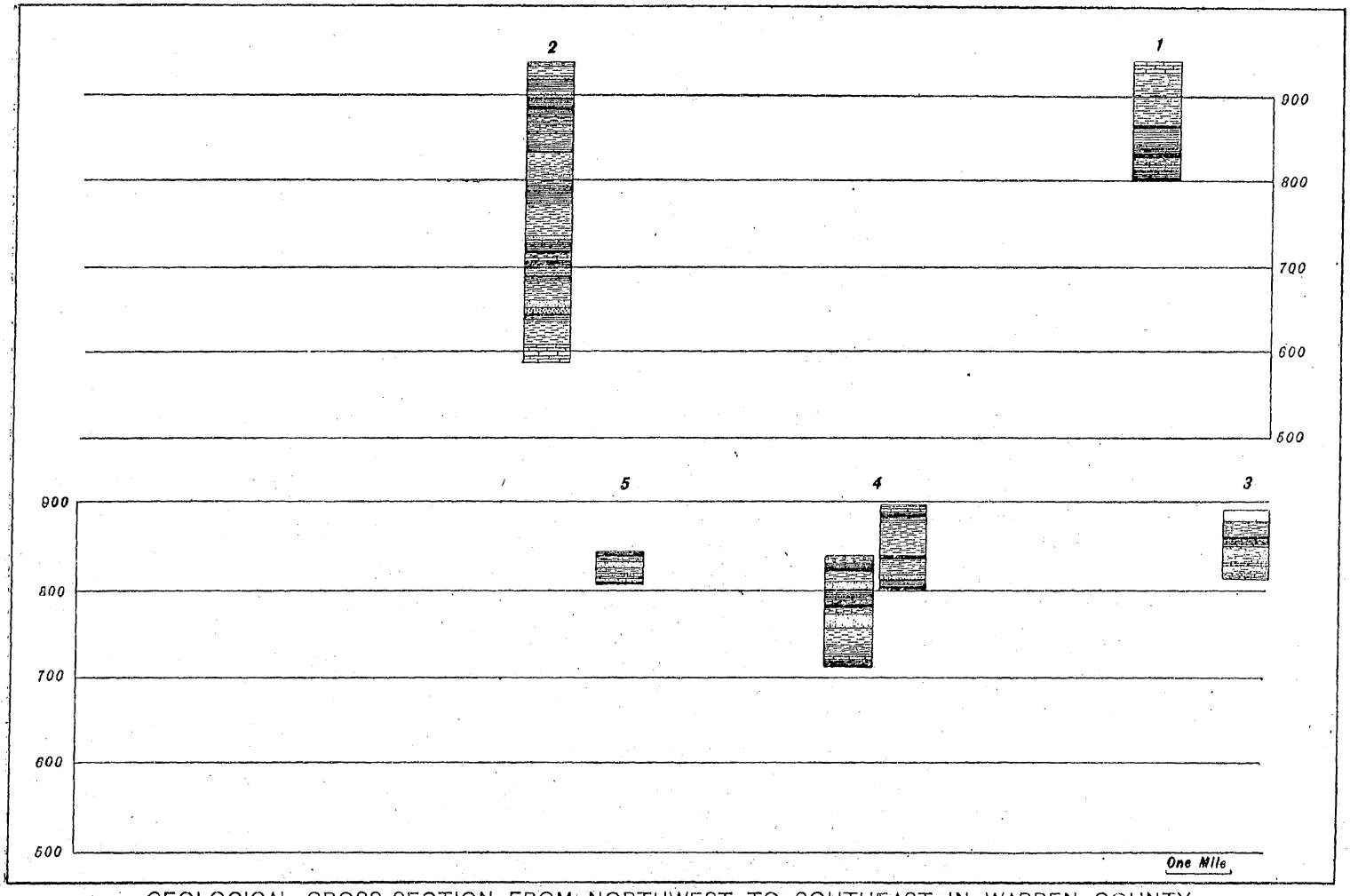
GEFERAL CROSS-SECTION FROM SOUTHEAST TO NORTHWEST.

The cross-section illustrated in plate x was obtained by combining the following records already described: (1) The outcrop southeast of Lacona, Whitebreast creek section; (2) the Milo well record given below; (3) the outcrop south of Indianola, section XI, South river cross-section; (4) the outcrops southeast of Spring Hill, and Earle Brothers' drill record, sections VI and VII, Middle river cross-section; (5) the outcrops west and northwest of Spring Hill, section II, North river cross-section.

The Milo well record is as follows.

STRATA PASSED THROUGH AT MILO, WARREN COUNTY, FOR THE MILO COAL AND MINING COMPANY.

		FEET.	INCHES
54.	Drift deposit	8	
53.	Gray shale	7	
52.	Blue clay shales	5	
51.	Brown sandstone	2	9
50.	Gray shales	4	6
49.	Dark sandstone with shaly partings	21	3
48.	Shale, light blue with bituminous shale at base	8	6
47.	Coal	1	
46.	Light gray shales	7	
45.	Thin-bedded fossiliferous impure limestone	1	
44.	Gray indurated shales	5	8
43.	Black fissile carbonaceous shale	1	
42.	Gray and blue clay shales	12	8
41.	Blue limestone	1	3
40.	Light blue marlite	1	
39.	Bluish clay shale	3	6
38.	Brown and red clay shale	3	3
37.	Shales variegated with thin beds of limestone	8	
36.	Dark carbonaceous shales	2	
35.	Bituminous shale	2	10
34.	Coal		8



GEOLOGICAL CROSS-SECTION FROM NORTHWEST TO SOUTHEAST IN WARREN COUNTY.

		FEET.	INCHES.
33.	Blue clay shale	10	
32.	Gray marl	2	4
31.	Blue limestone		8
30.	Light blue shales	16	6
29.	Fine-grained micaceous shale	7	4
28.	Gray clay shale	16	9
27.	Bluish shales	30	6
26.	Gray clay shales	5	
25.	Sandstone and shales	7	6
24.	Blue shales alternating with thin layers of limestone	18	3
23.	Compact gray limestone	2	2
22.	Bituminous shale		9
21.	Carbonaceous shales	2	6
20.	Light colored, siliceous, shaly marl, with black partings and impure coal and black jack	2	6
19.	Limestone with marl partings	1	6
18.	Clay shales	1	6
17.	Black sand shales	2	
16.	Bluish colored clay shales	6	
15.	Bluish impure limestone	3	
14.	Black clay shale	1	
13.	Dark colored shales with lime partings	1	8
12.	Blue sand shales with sulphur bands	6	3
11.	Blue sand shales	5	6
10.	Dark sandstone	2	6
9.	Black carbonaceous shales	1	8
8.	Gray clay shales	6	
7.	Blue clay shales	6	4
6.	Light blue sand and clay shales, with thin layers of fine-grained micaceous sandstone	16	
5.	Compact gray sandstone, with sulphur partings	6	6
4.	Dark, carbonaceous, sandy shale, alternating with thin layers of sandstone of same color, sulphurous	7	6
3.	Dark carbonaceous sandy shales	26	
2.	Dark blue-black shales	12	6
1.	Limestone, compact, blue and gray with sulphur bands	17	6
	Total	368	6

The top of this boring is thirty-four feet below the railroad station at Milo. The lowest limestone mentioned belongs undoubtedly to the Saint Louis formation underlying the coal measures.

ECONOMIC PRODUCTS.

COAL.

COAL HORIZONS.

Coal horizons are quite independent of the general relations of the strata because of the peculiar conditions under which coal is deposited. A limestone deposit, formed beneath the water under conditions constant for a long time will form a marked stratum over a large extent of country. A sandy shale formed in shallow water may, by slight oscillations of the earth's crust or even by the shifting of currents, become eroded and later perhaps filled in again.

Coal has been derived from vegetable matter deposited in swampy places. In some portions of the swamp a larger amount of vegetable material accumulated than in others. Seaward such a swamp would be bounded by the shore deposits; landward it would gradually thin out and be replaced by the clays alternating with gravels brought down by streams. So also laterally the swamp deposit would thin out though continued for miles as an impure carbonaceous deposit marking a horizon somewhere along which conditions were more favorable for the deposition and preservation of vegetable material.

In the coal of this county the stumps and trunks of trees are not found extending through the coal, but rather an accumulation of leaves, twigs and a broken carbonaceous mass is seen, with here and there, more usually in the shale, large branches, all of the usual type of vegetation belonging to the coal period. Remains of ferns and lepidodendrons are especially abundant. Undoubtedly in the swamps the stumps of large lepidodendrons did exist, but the soft character of the coal and the position of the stumps below the general

bottom of the seams of coal have caused their presence to be overlooked by miners.

If, after a time, oscillation, which is constantly going on in the earth's crust, should gradually raise such a swamp and allow it to drain, the vegetable material would gradually decay and disappear, except perhaps a thin black deposit of carbon mixed with earth which might remain to mark the position of the former swamp. If, however, the motion were downward, the vegetable material would become covered by a fine clay deposit, which, as the whole region later became raised above the water, would protect the underlying coal from oxidation. The coal seam may be represented in a general manner as a lenticular mass bent downward in the center where the old swamp was deeper* or along the lines occupied by the sluggish streams that flowed through the swamp.

During the time one swamp was accumulating its vegetable deposit, another a few miles away might exist, connected with the first by a faint carbonaceous streak over less swampy land between, or separated by a stream depositing its varied sediment. A condition of subsidence following, the sea would cover the entire region, and, if conditions were favorable, limestone with its corals, crinoids and brachiopods would form. Finally, all the different deposits, raised by an upward movement of the crust, might again be subjected to the force of erosion, till here and there along the various streams and ravines the coal and accompanying beds would become exposed. Coal may lie in an even seam with little change in thickness for many square miles; it may occupy a narrow winding channel marking the course of an ancient stream; it may mark a swamp of small extent and thickness; it may follow the uneven lines of an old landscape.

The irregularity of relation of one coal seam to another has been purposely emphasized in the above description since in this county the seams do not all belong to successive stages,

*Hence the meaning of the dip given in the table of mines in the county. The coal dips toward thicker parts of the seam and rises toward the margin of the seam.

each marking the prevalence of conditions favorable to the accumulation of vegetable remains over the entire county, and alternating with conditions unfavorable to such accumulations. The distribution of the seams is such that a description of coal horizons would be a description of the position and extent of each particular seam. Through the central part of the county, however, the seams have arranged themselves into groups, one at and below a level of 725 feet, the other at and above a level of 800 feet, while in the shales between these two belong the seams appearing along the ravines in the eastern part of the county.

It is to be regretted there is no topographical map of the county by means of which each outcrop of the various seams can be referred immediately to its proper level. As it is, the irregularity of the seams, the uncertainty of exact level and the lack of uniformity in accompanying deposits, frequently make it uncertain whether a given outcrop may belong to a main seam or to a smaller one just above or below it. At present the elevation of each must be estimated by reference to the table of altitudes and by comparison with records of seams so related to river beds that their exact altitudes are known.

Since all the strata dip with quite uniform regularity toward the southwest over almost the entire area of the county, a line along the strike, that is northwest-southeast, is that along which the strata are level. Consequently a comparison of coal indications afforded by plate x is of special value because of the location of borings along that line.

Coal Seams of the Lower Group.—In this line of strike the borings at Milo and in Tp. 76 N., R. XXII W., Sec. 5, southeast of Palmyra are the only ones, having accessible records, that have pierced the Saint Louis formation below the coal measures. The "Carbonaceous shale" at Milo, at a depth of about 328 feet from the surface or 609 feet above sea level,

marks the lowest horizon at which there is now any evidence of coal in the county. It might be regarded as the lowest possible horizon, were it not that the floor on which the coal measures rest is so irregular as to make possible the existence of other coal beds in deeper valleys cut in the old Saint Louis surface. On the other hand the boring at Milo may itself be at a point where the upper surface of the Saint Louis is lower than it is on the average and hence may give a coal horizon that is one of the lowest possible. Southeast of Palmyra, Tp. 76 N., R. XXII W., Sec. 5, the Saint Louis is 329 feet below the uplands or 546 feet above sea level. Records near Lucas to the south prove that in this direction the Saint Louis rises in places much nearer the surface.

The strata are nearly horizontal, the dip rarely reaching as much as two degrees southwest, but because of this slight dip to the southwest and the slope of the surface to the northeast, the several strata gradually approach the surface toward the northeast, and recede farther and farther from the surface toward the southwest. Southeast and northwest the old Saint Louis surface lies as nearly horizontal as any surface carved into ridges and valleys by erosion may be expected to lie.

About sixty-eight feet above this lowest horizon, 531 feet above sea level, are unsatisfactory indications of a second horizon; while a marked third horizon lies 712 feet above sea level, or 225 feet below the upland surface at Milo. This latter horizon is the upper one in the two groups found at and below the altitude of 725 feet above sea level, and marks the upper part of the group of strata in which coal has been found of greatest thickness, near Des Moines on the north and Lucas on the south. At this same level lies the lowest coal penetrated by Earle Brothers, in section 9, southeast of Spring Hill. At this same level also lies Caldwell & Cassidy's mine, in section 31, just west of Summerset; and in section 28, east of Summerset, Jones & Benham have mines where there is a local thickening of the coal, if not an independent basin.

To a continuation of this same horizon belongs the seam of coal in the bluff at Ford. This particular horizon, then, is marked by evidences of coal so widespread and of such thickness (two and a half to three feet) that the horizon may be considered as one especially rich in coal.

Coal Seams of the Upper Group.—All seams, evidences of which have been found above the horizon last described, outcrop along ravines at different points in the county. The first of these, the lowest of the group, is to be found in the central part of the county, at and above a level of 800 feet. It lies at the level of Middle river, east of Spring Hill, in section 2, and at the level of North river, in sections 19, 20, Greenfield township. On South river it is about on a level with the river bed* south of Indianola, but it dies out before reaching Milo. Another seam, a few feet below the position of the one last mentioned, is at Summerset, about the level of the railway tracks. East of Summerset it is frequently drifted as a surface seam. Another seam on this same horizon appears at the level of the Whitebreast creek, in section 35 of Whitebreast township.

These upper seams mark quite an important coal horizon. The coal, under favorable conditions, is quite uniformly eighteen to thirty inches thick.

Above this horizon, in the west central part of the county, two others exist over quite an area, the first about thirty-five feet above it, the second forty-five still higher up. The lower of these two seams furnishes an easily accessible supply of coal in Jefferson township, the upper seam appearing only at the higher points along the divides. The horizons of these two seams are also marked, in White Oak, Otter and Liberty townships, by indications of coal. The upper seam is drifted in a few places, while the lower of the two horizons is drifted in the vicinity of Milo and in the south central part of Belmont township. Both horizons appear in the ravine of

*Since the above statement was written a shaft has been sunk to this seam, near the river, south of Indianola.

section 26, southeast of Lacona, and the lower of the two is mined a mile north of Lacona.

Intermediate Coal Seams.—Between these two groups of seams, one at and below a level of 725 feet in the central part of the county, the other at and above 800 feet—belong the seams outcropping along the ravines in southern Richland, Palmyra and Union townships, where they are frequently drifted for local use. These latter seams frequently present a thickness of eighteen inches of good coal, and are more nearly related to the upper of the two groups of seams in the central part of the county than to the lower group.

The carbonaceous material found in the well at Milo at a depth of 150 feet from the surface, or at an elevation of 775 feet, suggests, together with the position of coal in Palmyra and Union townships, a coal horizon that may be looked for at a corresponding level in the southeastern part of the county.

A fair idea of the succession of the coal seams that reach the surface is obtained by an examination of the section along either South or Middle river. Along South river it will be observed coal seams outcrop at nine different levels.

In the southwestern part of the county the single coal seam that exists will not afford very profitable mining, nor are there local indications that there are seams to be reached by shafts of moderate depth. The nearest coal seam to the northeast would, if extended beneath Virginia township, lie about thirty feet beneath the river bed at the mouth of Limestone creek. To the east of Limestone creek nothing but sandstone appears till the vicinity of Squaw creek is reached.

To the west the succession of strata contain no coal beyond slight traces. There is merely the evidence that as the coal period progressed the land was here sinking, till finally open sea conditions prevailed. It is not known how far to the west open sea conditions existed when these strata were laid down since they are now covered up westward by the Missouri stage, and this, farther west is overlain by Cretaceous strata.

There is now no evidence whether in the progress of events strata now at a depth of one or two hundred feet were for a time favorably situated for the formation of coal.

A good record of a 200-foot diamond drill boring at the mouth of Limestone creek will furnish more important information than a record of a well sunk anywhere else in the county.

STATISTICS ON COAL MINING.

The following table indicates the points at which coal has recently been mined. Of these eighty-three places on which data are presented nineteen require shafts from fifteen to eighty feet deep, nine have slopes, and the remainder are drifts, or in some cases strippings. It is thus evident that most of the mines in the county are farmers' banks in the surface seams. Most of them are worked only in the winter time, each requiring from one to five or six men. In some cases the data express nothing but the fact that evidences of digging for coal were observed.

Table of Mines.

Township.	Range.	Section.	Qr.	¼.	OWNER OR MINER.	Thickness of coal.	Dip.	REMARKS.
77	22	8	SW	SE	Mr. McNeilly	3½ ft.	.....	Drift.
77	22	9	SE	SE	Fordville Coal Co.	3½ ft.	.....	Drift.
77	22	27	NW	NE	Mr. Miller	.....	.....	Drift.
77	22	35	NW	NW	F. Wellings	.....	.....	Drift.
77	22	35	NW	SE	Mr. Ghost	3-3½ ft.	.....	Drift.
76	22	2	NW	SE	S. A. Gose	.....	.....	An old drift.
76	22	9	NW	SE	Mr. Long	20 in.-3 ft.	S	Drift.
76	22	10	SE	NW	E. Coulslin	3 ft.	S	Shaft, 24 feet
76	22	12	NW	SE	Mr. Greenway	12 in.	.....	Slope, abandoned; long, E-W; narrow, N-S.
76	22	14	SW	SW	Mr. Spurgeon	14-16 in.	SW	Drift.
76	22	16	NE	SE	B. F. Heiny	18 in.	No dip	Drift.
76	22	20	NE	NE	Mr. Reeves	2 ft.	W	Drift.
76	22	15	SE	SE	Mr. McCormick	.....	.....	Drift; gave it up because of no roof.
76	22	26	NW	SE	Mr. Anthony	20 in.	.....	Drift.
76	22	26	SW	SW	Mr. Bassett	18-20 in.	SW	Drift.
76	22	27	SW	SW	Mr. Beaman	18 in.	N	Drift.
76	22	30	NE	SW	L. C. Hodson	18 in.	.....	Drift.
76	22	30	NW	S	S. G. Mosher	9 in.	.....	Drift.
75	22	1	SW	NW	A. W. Mosher	20-24 in.	No dip	Drift.
75	22	2	NE	NE	Mr. Sims	18-20 in.	.....	Drift.
75	22	4	NE	NW	Mr. Williams	16 in.	.....	Drift.
75	22	23	SW	NE	J. A. Killer	18 in.	SE	Drift.
75	22	23	SW	SW	J. E. Rawson	18 in.	SE	Drift.
75	22	25	SE	NW	Mr. Thompson	.....	NW	Drift; about level.
75	22	25	SW	NE	R. R. McNair	18 in.	E	Slope.
75	22	28	NE	SW	Mr. Griffin	2¼ ft.	W	Drift.
75	22	28	SW	NE	Mr. Hennen	2½ ft.	W	Shaft, 28 feet.

Table of Mines—Continued.

Township.	Range.	Section.	Qr.	¼.	OWNER OR MINER.	Thickness of coal.	Dip.	REMARKS.
75	22	33	NE	NE	Mr. Hannen	2½ ft.	W	Drift.
75	22	33	NW	SW	Mr. Williams	2½ ft.	N	Drift.
74	22	3	NW	NW	Mr. Horr	2 ft.	SE	Drift.
74	22	4	NE	NE	Mr. Clamer	2 ft.	SE	Drift.
74	22	9	SW	NW	Mr. Shaffer	3 in.-2 ft.		Drift.
74	22	21	NE	NE	William Smith			Slope.
74	22	22	NW	NW	Mary Higbee			Shaft, 26 feet deep.
74	22	24	SW	C	L. Fouch			Shaft.
74	22	35	NE	C	G. E. Sharp	16-18 in.		Drift.
77	23	7	SE	SW	William Lumsden	30 in.		Slope.
77	23	7	SE	SE	Mr. Moore			Slope.
77	23	8	NW	C	J. S. Anderson			Drift.
77	23	8	NE	C	J. S. Anderson			Drift.
77	23	21	SE	SW	O. H. Sayers			Shaft.
77	23	27	NE	W	L. D. McClintic			Drift.
77	23	27	NE	E	R. Wade			Drift.
77	23	28	NE	NW	W. S. Benham	2½-3 ft.		Shaft.
77	23	28	NW	NE	D. K. Jones	2½-3 ft.		Shaft.
77	23	31	NE	NE	Mr. Lumsden			Shaft.
77	23	31	NW	SE	Caldwell & Cassidy	3¼-4 ft.	N	Shaft.
77	23	35	NW	NE	G. C Gardner		S	Drift.
76	23	2	NW	SE	A. B. Creighton			Drift; mined years ago.
76	23	7	NW	C	J. Malone, Sr			Shaft.
76	23	32	NW	SE	J. Lord	15 in.	W	Drift.
76	23	36	NW	NW	I. Jamison			Shaft.
75	23	14	SW	NE	Henry Clark			Drift.
75	23	14	SW	SW	A. J. Conner			Drift.
75	23	21	SE	SE	Mr. Hutt	18 in.		Drift.
75	23	23	NW	NW	A. J. Conner	12-14 in.	NE	Drift.
75	23	23	SE	SE	Mr. Bales	24 in.		Shaft, 30 feet.
75	23	24	SE	NW	Mr. Whilliken		NE	Slope.
75	23	25	NW	NE	Joe Mitchell	18 in.	W	Drift.
75	23	25	NW	NW	Johnson & Bryant		NE	Shafts, 15 feet.
75	23	32	SE	E	J. H. Dyke			Drift.
75	23	34	NW	SW	Mr. Bales	18 in.	SW	Drift.
75	23	34	NW	SW	Mr. Bales	18 in.	SW	Shaft, 16 feet.
75	23	34	SW	NE	C. L. Burgit	14-16 in.	SW	Drift.
75	23	34	SE	SE	C. L. Burgit	14 in.	NW	Drift.
74	23	5	SW	SW	Mr. Williams	18 in.	E	Drift.
74	23	8	NW	NW	J. E Chittenden	14-18 in.	SW	Slope.
74	23	29	NE	NE	H. McNeil	16 in.	S	Drift.
74	23	29	NE	SE	Mr. Hall	16 in.	S	Drift.
77	24	19	SW	NE	Earle Bros.			Drift.
77	24	20	SE	SE	Faust, also Huffman	3. ft 8 in.	S	Slope.
77	24	21	SW	SW	George Dillard			Slope.
77	24	22	N		J. A. Bishop			Drift.
77	24	29	NE	NW	C. W. Reeves			Shaft.
77	24	30	SW	NE	J. A. Lockridge			Shaft.
76	24	2	SE	C	D. Beem			Drift.
76	24	2	SW	NE	E. Van Pelt			Drift.
76	24	9	NW	SE	Earle Bros.			Shaft.
76	24	14	NE	NW	J. H. & G. M. Basler			Drift.
75	24	10	NW	SW	John W. Randolph			Shaft.
76	25	2	SE	C	Jacob M. Dillard, Jr.			Shaft, also drifts.
76	25	12	SW	NE	Earle Bros.	13 in.		Drift.

The output of coal for each year is expressed in the following table, prepared from the mine inspector's reports for the various years. It will be noted that this estimate does not include all the country banks.

YEAR.	TONS.	YEAR.	TONS.
1881	12,987	1884	13,727
1882	11,081	1885	12,825
1883	12,828	1886	23,332

YEAR.	TONS.	YEAR.	TONS.
1887	24,796	1892	9,570
1888	17,013	1893	14,575
1889	15,583	1894	25,454
1890	17,923	1895	12,000
1891	15,604		

WATER SUPPLY.

RAINFALL.

The weather observations recorded for the county are as follows.

PRECIPITATION, WARREN COUNTY.*

MONTH.	1892	1893	1894	1895
January	1.21	.34	.68	1.15
February	1.24	.90	.77	.20
March	1.31	.80	2.99	.52
April	3.96	5.05	1.79	2.35
May	10.47	4.78	1.03	3.64
June	4.14	6.87	1.29	1.92
July	2.50	------	.40	------
August	1.92	------	.95	4.01
September	1.43	2.76	4.53	2.17
October	2.34	.20	1.09	.28
November	.79	1.68	.83	1.03
December	1.57	1.10	.90	3.55
Total	32.88	------	17.25	------

The following table gives the rainfall for Des Moines as recorded at the government office in that city. Since Des Moines is but five miles north of Warren county, the Des Moines rainfall may be taken as a fair average of rainfall in Warren county.

PRECIPITATION AT GOVERNMENT STATION, DES MOINES, 1879-1895.

MONTH.	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895
January..	.69	.70	1.55	.63	1.72	.85	1.00	3.47	.83	1.15	1.22	2.62	1.82	1.60	.56	1.09	1.30
February.	1.90	.17	2.68	1.21	2.51	1.92	.42	.52	1.65	1.51	.27	1.17	1.13	1.35	1.28	1.39	.60
March....	1.68	.70	1.78	2.28	.57	2.24	.04	1.41	1.79	3.09	.11	.91	2.25	2.47	1.15	1.78	.50
April.....	1.03	1.56	3.36	3.47	3.48	2.97	3.62	4.32	2.48	1.45	2.66	.78	2 12	3 36	5.61	1.70	3.41
May	4.74	5.84	3.82	8.53	9.76	4.34	1.70	4.01	2.31	7.84	4.84	3.00	3.29	8.77	2.84	1.41	2.86
June	6.69	4.11	15.79	12.16	7.75	3.84	5.03	1.21	2.25	2 32	4.39	4.91	5.60	3.41	4.69	1.67	5.26
July.....	.29	3.82	5.57	4.78	2.37	7.16	6.55	.27	1.94	3 42	4.37	1.10	2.78	8.64	3.55	.29	3.10
August...	1.98	6.69	5.29	3.14	2.83	3.84	5.10	1.10	2.66	4.52	2.25	3.35	4.22	2.45	1.60	1.89	3.57
Septemb'r	2.79	5.34	4.70	.15	1.88	5.46	4.82	7.93	5.36	.48	3.41	1.57	1.64	1.12	1.33	4.46	3.20
October..	3.15	4.90	6.45	5.94	4.42	5.33	4.18	2.62	1.40	.84	.52	4.48	2.41	2.54	.22	2.24	.29
Novemb'r	6 49	1.97	3.97	2.81	1.32	1.26	.61	1.86	.52	2.09	1.29	.74	1.34	.76	1.51	.99	.85
December	1.39	.86	1.85	2.50	1.08	1.93	1.96	.81	1.41	2.44	.57	.11	1.54	1.95	1 30	1.15	1.86
Total.	32.82	36.66	56.81	47.60	39.69	41.14	35.03	29.53	24.60	31.15	25.90	24.74	30 14	38.42	25.64	20.06	26.80

*These observations were made 1892-94 by the writer, and July, 1894, to July, 1895, by Prof. L. A. Youtz. The records for July and August are incomplete because of the absence of observers.

In studying these tables it is well to note that in the judgment of the office of the state weather bureau, if the ground is well wet in early spring, oats will mature a heavy crop if, during the two months oats are growing, there is a precipitation of four inches per month. A good crop of corn will mature if there is a precipitation of two inches per month during the months the corn is growing, provided the precipitation occurs at intervals as needed.

WELLS.

SURFACE WELLS.

Few wells in the county are more than thirty feet deep, consequently in some places they end in the drift and in other places in the coal measure shales just below the drift.

Pure well water contains no organic matter, but contains mineral matter dissolved from the strata the water has passed through. The wells that end in the drift contain in solution, gypsum (Calcium sulphate) together with a trace of carbon dioxide. If surface water has had access at all to the well a trace of chlorine and also of ammonia may be found. If, however, the well is polluted by wash from the surface the chlorine and ammonia become abundant, so much so that a determination of the amount of chlorine and ammonia (both free and combined in organic compounds) may be taken as an indication of the purity of the water for drinking.

Carelessness in the location and care of a well is of frequent occurrence. The purity of drinking water is of such great importance to health that too much emphasis can not be placed on the advisability of great care in the protection of wells from pollution. Not only may the material itself which washes into a well be objectionable, but even material that of itself seems unobjectionable, may in its decay furnish conditions favorable to disease.

There are two areas in the county where the strata are such as to have a marked influence on the wells. The first is in the northern part of the county from the eastern side

as far south as Hartford; westward to the center of Greenfield township. In this area the surface is underlain by a sandstone eastward and a sandy shale westward that receives water from the soil, leaving shallow wells quickly susceptible to drouth. In White Oak township west of Cedar creek the soil is underlain by sand for a moderate depth and this sand by clay. Evidently it is here desirable that the wells pass through the sand to the clay.

DEEP WELLS.

As the coal measures contain many beds of sandy shale and clay of irregular thickness and extent, all dipping south and west at an average rate of about two degrees, the conditions are favorable for finding water in the sandy shale, since the water works its way downward along the direction of dip. These conditions are so favorable that anywhere in the county it is fair to expect that a well from 150 to 250 feet deep will be quite sure of obtaining all the water necessary to meet the demands of any stock farm; but the water is just as sure to be "sulphur water."

Below the shales of the coal measures no single water horizon can be depended on to furnish a large supply, though various strata as far as the Saint Peter and Saint Croix sandstones may contribute more or less to wells passing through them.

From such data as is obtainable it may be estimated that the Saint Peter lies about 1,000 feet below sea level in the central part of the county, or from 1,800 to 2,000 feet below the surface of the uplands. About 200 feet below the Saint Peter sandstone lies the Saint Croix sandstone that furnishes a considerable portion of water to the Y. M. C. A. artesian well at Cedar Rapids, and to other wells in that part of the state. The measurements obtained, especially at Cedar Rapids, Sigourney, Centerville and Grinnell, indicate the rate of dip to the southwest and furnish other data from which it is possible to estimate the distance the sandstone is below the surface in Warren county. At Cedar Rapids the Saint Peter

sandstone is 212 feet below sea level; at Grinnell, 677 feet below sea level; at Sigourney, 615 feet below sea level, and at Centerville 627 feet below sea level. Sigourney and Grinnell are in the same line of strike and Centerville and Indianola also in another line of the strike. Sigourney is about half way between Cedar Rapids and Centerville, and Grinnell occupies the same position with reference to Cedar Rapids and Indianola. In the various borings that have been made it is found that the surface of the Saint Peter sandstone first dips rapidly southwest, then becomes more nearly horizontal. From Cedar Rapids to Sigourney the Saint Peter sinks 403 feet, from Cedar Rapids to Grinnell it sinks 465 feet. From Sigourney to Centerville the fall is but twelve feet, from Grinnell to Indianola probably something more than twelve feet. This would make the Saint Peter sandstone 1,668 feet below the surface at Indianola. This estimate may be considered an inside estimate, while that previously given, based on the thickness of the strata where they outcrop, may be considered an outside estimate. We may say then the Saint Peter sandstone is approximately 1,800 feet beneath the surface at Indianola. As other wells are sunk to the Saint Peter sandstone the correctness of these figures can be tested.

The quality of the water can be determined from analyses of samples obtained from the borings mentioned. An analysis of the water obtained at Grinnell yields the following.*

	Grains per gallon.
Calcium carbonate	7
Calcium sulphate	41.1
Magnesium sulphate	30
Sodium sulphate	27.34
Sodium chloride	.87
Silicate of iron and alumina	.7
Total solids at 120° C	120.75

This analysis indicates a water very "hard," even more objectionable than the ordinary well water for culinary pur-

*Record of the Grinnell deep boring, A. J. Jones, Proc. Iowa Acad. of Sci., 1894, p. 35.

poses and for use in boilers. As a drinking water the mineral constituents are no more injurious than those of ordinary well water. The water is absolutely free from organic impurity. The quantity obtained from the wells at Cedar Rapids and Grinnell is as follows: Cedar Rapids, 86,400 gallons every twenty-four hours; Grinnell, 12,800 gallons every twenty-four hours in the winter months, in the summer more without exhausting the flow.

OIL AND NATURAL GAS.

It has long been thought that at some time conditions favorable to the collection of oil and natural gas may be discovered in Iowa. So far as structure is concerned the following conditions must be satisfied: (1) there must be the unbroken crest of an anticline with (2) an impervious layer underlain by (3) a porous stratum in which the oil or gas as it rises can collect.

In the northeastern part of the county is the arch of an anticline extending through sections 10, 12, 13 and 24 of Richland township in a northwest and a southeast direction. Beneath the drift is a soft sandstone underlain by clay, and clays alternate with sandstones down to the Saint Louis. Here is the only place in the county where the conditions are at all favorable to the preservation of oil and natural gas, and yet it is by no means sure that these substances occur at this point. One condition only is known to be satisfied; the other equally important conditions may prove to be entirely unsatisfied.

MINERALS.

Minerals found in the county are such as commonly occur in the drift and in the coal measures of the state. In the drift, quartz and agate are common; rarely, pieces of copper and of iron pyrite have been found. In the coal measures are calcite, selenite, celestite, marcasite, pyrite, hematite and limonite in small quantities.

The decomposition of the sulphides of iron (pyrite and marcasite) sets free the sulphur and stains the water with the oxides of iron. None of the above minerals are in sufficient quantity and purity to be of commercial value.

BUILDING STONE.

Warren county is not well supplied with building stone. Nearly all the sandstone yields readily to oxidation, which, aided by frost, decomposes and disintegrates it very readily. There are, however, three strata that deserve especial notice because of the manner in which they withstand erosion. The first is the stratum of arenaceous limestone, fairly free from iron, that, where not eroded or covered up, may be found outcropping in the ravines from the northern part of Otter and White Oak townships northwestward into Greenfield and Jefferson townships. The outcrops of this sandstone are particularly marked in Tp. 76 N., R. XXII W., Sec. 30; Tp. 76 N., R. XXIII W., Sec. 36; Tp. 75 N., R. XXIV W., Sec. 14; Tp. 76 N., R. XXV W., Sec. 12 and Sec. 13. It is not easily accessible, except in various places along ravines and southeast of Ackworth, in the hills of section 30. This limestone is, on the average, about a foot thick, though where it grades into sandstone, in section 30, it occurs as a bed three feet thick. Farther southwest it should not be confounded with the eight inches of cap-rock that occurs above a seam of coal.

In section 22 of White Oak township occurs a large mass of sandstone. While resisting oxidation fairly well, it is too soft to make a good, permanent building stone.

In the northern part of section 17, in Virginia township, the sandstone has been quarried at several points. Another stratum, about thirty-five feet below the one opened up, is to be seen in section 18, near the road north on the eastern side of the section. The same two strata of rock are to be found on the south side of the river, where they occur five feet higher above the river bed and thirty-five feet apart. The best section is to be found in the ravine at Hilton's, in the

southern part of section 17. By comparing the strata in the neighborhood with those of section 17, the limestone seen in a ravine in the eastern part of section 19 is seen to be the upper one found in section 17. The limestone of section 28 and farther west on Limestone creek is also the upper one of section 17. The lower limestone of section 17 was found in a well on a hillside close to the eastern boundary of section 16. Eastward to Squaw creek these rocks are completely eroded, or are covered up by drift, but the heavy sandstone of section 17 (Tp. 74 N., R. XXIII W.), northwest of Liberty Center, is judged to be the equivalent of the lower limestone of section 17.

CLAYS.

While but little of the stone of Warren county is suitable for building purposes, the clays furnish an inexhaustible substitute. There is no satisfactory reason why the cheaper grades of hand-made brick may not be manufactured in each community to supply the local demand. There is also excellent material for the manufacture of brick of finer quality.

The clay that can be used is derived from three sources: first, the loess; second, the alluvial deposits along the rivers; and third, the coal measure shales.

Nearly all the soil is a part of the loess, blackened by a large amount of vegetable mould. This vegetable material burns out in the process of firing the brick, causing the latter to be too porous. If the black soil be first removed and the loess just beneath used for brick, one cause of the porous condition of the brick is avoided.

The loess just beneath the soil makes the best deposit of brick and pottery that we have. It is fine sediment, probably laid down at some time during the melting of the great sheet of ice that extended over the northern and eastern part of our continent.

The following analyses were made by Prof. G. E. Patrick, chemist to the survey. No. 1 is the loess taken just beneath the soil. No. 2 is the dark gray material found below the

upper or yellow loess. Both samples were taken from the pit of the Indianola Brick & Tile Co. (Tp. 76 N., R. XXIII W., Sec. 19, Sw. qr., Ne ¼).

	No. 1.	No. 2.
Hygroscopic water	1.70	3.76
Combined water	3.33	6.89
Silica $Si O_2$	72.24	63.31
Alumina $Al_2 O$	12.58	16.51
Iron oxides as $Fe_2 O_3$	4.02	4.06
Maganese oxide Mn O	0.00	0.49
Lime Ca O	1.40	1.11
Magnesia Mg O	.99	1.10
Soda $Na_2 O$	2.60	2.20
Potash $K_2 O$	1.54	.96
	100.40	100.36

Analyses of the same clays were made by Prof. L. A. Youtz and are published in the proceedings of the Iowa Academy of Sciences for 1895. The results were very similar to those given above though not so complete.

The lower loess differs somewhat from the upper loess in that its silica is combined; not free as in the upper loess. Other differences may be noted on comparison of the analyses here given, but any difference due to the amount of titanic acid present cannot be stated since the titanic acid is here estimated with the silicon dioxide.

Along the river valleys, especially along Middle river and the lower courses of North and South rivers, are numerous filled up lagoons. These were formed by the river, which at some time in shortening its course by cutting across a narrow strip of land, left the bend as a cut-off that at every high water was filled by the streams carrying an abundance of fine sediment. Various lagoons may be found representing all stages in the filling up process. This fine alluvial deposit is good material for brick.

The shales of the coal measures are very variable in character. Not only do the deposits themselves vary in composition so that a bed of clay in one place may found as a bed of sand in another, but they also alter on exposure to the

weather. Usually it is better to mix the shale with a portion of loess in the proportion of two parts of the clay to one of loess.

It is to be hoped that the durability of a good brick and its freedom from decay will lead to its universal use for well curbing, foundations for houses, and walls of cellars and caves.

The demand for tiling is at present largely supplied by manufacturers outside the county. Since January 1, 1893, there have been shipped into the county from outside sources about 253,720 feet of tiling in sizes as follows:

Sizes in Inches.	Feet.	Sizes in Inches.	Feet.
3	38,840	7	30,950
4	64,560	8	12,100
5	53,780	10	11,000
6	42,490		

If the movement toward the building of good roads now under discussion in various parts of our country ever receives attention in this county, the clay deposits may be looked to furnish either a cheap ballast, to make better roadbeds or vitrified brick for paving.

CLAY WORKING PLANTS.

POTTERY.

There are two places in the county where pottery is manufactured; Carlisle and Hartford. At both of these places the manufacturing is for the local market only. At Carlisle Mr. Burney burned 21,000 to 22,000 gallons in 1894. Generally he burns ten kilns, each kiln of 6,000 gallons capacity. At Hartford Mr. William Kurtz burns two kilns a year, each kiln of 2,500 gallons capacity.

BRICK.

Until recently the Indianola Brick & Tile Co. was engaged in the manufacture of brick. They used the loess and drift clay, first carefully removing the soil. For the preparation of the clay there is a plant consisting of a Penfield machine

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF WARREN COUNTY, IOWA.

BY

J. L. TILTON

1896.

Tp. 77 N.

Tp. 76 N.

Tp. 75 N.

Tp. 74 N.

R. XXV W. R. XXIV W. R. XXIII W. R. XXII W.

LEGEND

GEOLOGICAL FORMATIONS

DES MOINES (Coal Measures)

INDUSTRIES

- QUARRIES
- COAL
  - Stripping or drift
  - Shaft
  - Slope
- CLAY WORKS
- LIME KILNS

IOWA PRINTING CO. DES MOINES, IA.

DRAWN BY F. C. TATE

run by a twenty-five horse power engine, and in burning one up draft and two down draft kilns are used. This firm also has a pottery kiln witha capacity of 30,000 gallons.

At Glassock's Mills Mr. Glassock manufactures hand-made brick for local trade. The material used is an old alluvial deposit of Middle river.

In four localities hand brick are made from the soil: northeast of Spring Hill by Mr. H. I. Hoover (Tp. 77 N., R. XXIV W., Sec. 17, Ne. qr., Sw. $\frac{1}{4}$); south of Spring Hill by Mr. Faust (Tp. 76 N., R. XXIV W., Sec. 4, Sw. qr., Ne. $\frac{1}{4}$); at Milo by Mr. C. E. Gross; at Lacona by Mr. S. D. Kirkheart. The brick are hand made from loess, the soils being scraped off and thrown aside. The total amount of brick burned in the county in 1894 was 365,000. This represents the average production.

TILING.

The only tiling manufactured at present in the county is made by O. Fenton at Palmyra. The different sizes manufactured range from two to six inches in diameter.

SOIL.

The description of the drift was in a measure a description of the soil. The natural porosity of the soil and the ease with which it is tilled are due to the structure of the drift. The thousands of acres of corn with their rich increase are only possible because of the drift. Were coal and stone far more abundant and valuable than they are, still Warren county would exist as chiefly a region of fine farms. The broad, rich lowlands have not required much tiling, and the uplands are not too dry for fine crops. The soil over the entire county consists of loess modified in places by mixture with underlying shales.

MAP.

The data for the streams and various ravines represented on the accompanying map were obtained from the map of the original government survey now in the auditor's office at Indianola, and from a county plat-book. The data of the roads were obtained from an atlas of Warren county (Harrison and Varner) and the county records to date at Indianola.