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The Paleozoic Stratigraphy of Lorain County, Ohio

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THE PALEOZOIC STRATIGRAPHY

OF

LORAIN COUNTY, OHIO

By

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T A B L E   O F   C O N T E N T S

THE PALEOZOIC STRATIGRAPHY OF LORAIN COUNTY, OHIO

PART I

INTRODUCTION

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INTRODUCTION

PRELIMINARY STATEMENT

During the course of the school year 1936-37 spent at Oberlin, which is situated near the center of Lorain County, Ohio, the writer had the opportunity to study the outcrops and to gather records of wells in this area.

A study of the strata of this county is confusing because the same rocks have been described under different formational names. Originally many of these strata were traced northward from type sections in central Ohio or westward from type sections near Cleveland. At a later date many of the strata were reclassified and assigned to formations which had been traced westward from Pennsylvania.

OBJECT

The object of this thesis is two-fold: first, to describe the strata as classified by the most recent studies in the region, with both the extent and the individual characteristics of these formations given, and second, to determine the conditions under which the strata were deposited.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the kind assistance of Dr. Fred Foreman, who had general supervision of the thesis and who gave many helpful suggestions regarding the conduct of the investigation and the writing of the manuscript. To Dr. Frost and to Dr. Stumm the author is indebted for helpful suggestions regarding the manuscript before it reached its present form.

Thanks are due to Mr. Schuster of Elyria and to Dr. Stout of the Ohio Geological Survey for well records and other data regarding unexposed strata in this county.

LOCATION OF THE AREA

Lorain County is situated in central northern Ohio on the south shore of Lake Erie. It is bounded on the east by Cuyahoga and Medina Counties, on the south by Ashland County, and on the west by Huron and Erie Counties. The city of Elyria is the county seat and is located near the center of the county. It is twenty five miles southwest of Cleveland. The total area is approximately 400 square miles. Figure 1[1] is

[1]Modified from R. B. Frost, Physiographic Map of Ohio, published by the Geographical Press, Columbia University.

a map of Ohio showing the location of Lorain County.

GENERAL GEOLOGY AND GEOGRAPHY OF THE REGION

Physiographic Divisions

Northern Ohio is divided into three major physiographic regions. First, the glacial Lake Plains borders Lake Erie and extends inland for a distance of from two to five miles. Second, the Till Plain covers the western part. Third, the glaciated Appalachian Plateau occupies the eastern part. In its general geologic relationships the county forms a part of the Lake Plains, of the Till Plain, and a very small part of the glaciated Appalachian Plateau. (See figure 1). In central northern Ohio the boundary between the Lake Plains and the Till Plain is the beach formed by glacial Lake Maumee. It trends almost northeast and southwest roughly parallel to the shore of Lake Erie. Usually it is a well defined ridge, four or five miles inland from the lake. Since early roads were built on this and

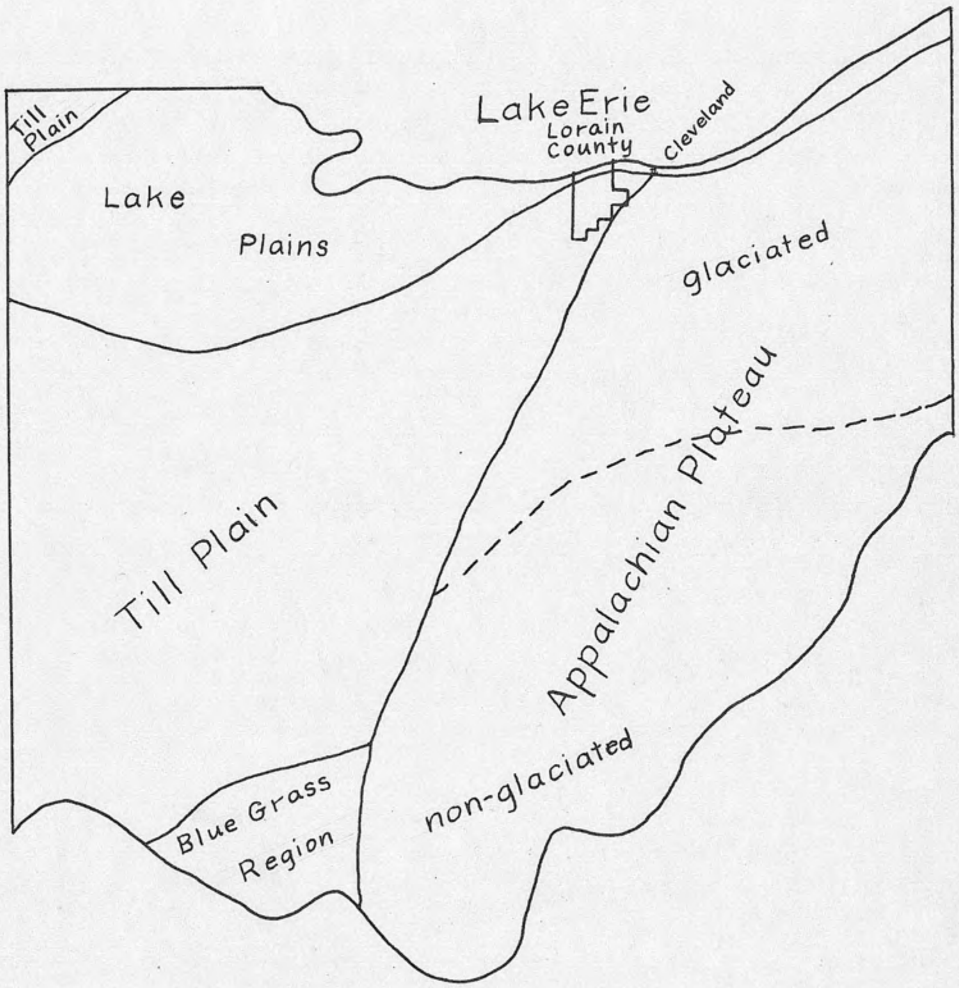

Fig. 1. Physiographic Divisions of Ohio showing the location of Lorain County.

similar ridges, the boundary can often be seen on the map as the southernmost road trending with slight irregularity to the northeast and southwest parallel to the lake shore. The boundary between the remaining two provinces is mainly one of altitude. The narrow strip of till plain, widening toward the west and south, is bounded on the southeast by the Portage Escarpment which separates the plain from the plateau by an increase of 300 to 400 feet in altitude within a distance of two or three miles. This division is most marked south and east of Cleveland.

Topography

Lorain County lies mostly in the Till Plain. A belt of Lake Plain borders it on the north. The edge of the Allegheny Plateau touches the extreme southeastern portion of the county in Columbia Township.

The Lake Plain consists of the floors of three post-glacial lakes. These lake floors are underlain in part by varved clays. The plains are bordered on the south by sandy beach ridges. The altitudes of these plains are, respectively, Lake Warren Plain--590 to 635 feet, Lake Whittlesey Plain--670 to 720 feet, and Lake Maumee Plain--720-770 feet above sea level. In addition to these boundary beaches and either parallel or at right angles to them are several intermediate ridges, ranging from two to seven miles in length, a hundred yards to a quarter of a mile in width, and up to thirty feet in height. The plains are dissected by the gorges of the Vermilion River, Beaver Creek, and the Black River. Occasional sandstone hills and ridges surmount the plains. Except for these few interruptions the level Lake Plains are quite continuous.

The Till Plain is slightly more rolling than the Lake Plain. It is cut by the gorges of Rocky River, Black River, and Vermilion River and is interrupted by sandstone hills and ridges. However, even the hills and ridges are rounded and gently undulating. In the southern part of the county the Defiance Moraine causes more relief than elsewhere on the plain, and the tributaries of the above named rivers have cut numerous small valleys in the moraine.

In contrast to the plains the glaciated Allegheny Plateau in this part of Ohio presents a greater relief. It is capped by a resistant conglomerate and underlain by soft, easily eroded shales. The result is deep dissection of the edge of the plateau by both preglacial and postglacial streams. To some extent this great relief has been lessened by glacial cut and fill. The southeastern corner of Columbia Township is composed of the sharply dissected foothills of the plateau. These hills are by far the most distinct topographic features of the county but do not attain the highest altitude. They are 920 feet above sea level at Beebetown, while the Defiance Moraine in the southern part of the county reaches 1110 feet.

The river valleys are post-glacial, narrow, and steep sided when cut through solid rock. This occurs mostly in a belt bordering the lake and extending inland for three miles. The thin-bedded shales afford excellent material for cliffs and gorges. The stream gradient is less than the rise of the plains southward. Therefore the gorges are deeper upstream. Falls and rapids in the streams of the county are not numerous. The falls of the East and of the West Branches of the Black River at Elyria are the only large examples. However, the outer edge of the Berea sandstone is usually marked by a steep gradient. When flowing in glacial drift, the rivers meander widely and the valleys are wide, though they still retain distinct bluffs.

Drainage

The central northern part of Ohio is drained into Lake Erie by short straight streams originating thirty or forty miles inland. The main streams flowing through the county are the Vermilion River, Beaver Creek, the Black River, and Rocky River. One characteristic of these larger streams is that they usually divide into east and west branches. In addition to these rivers are several smaller streams which flow parallel to the larger ones. They empty directly into the lake and do not form parts of the systems of the larger streams. By virtue of a system of artificial drainage the country is surprisingly well drained for a region of such low relief. However, swamps do exist and were numerous before man drained them.

No natural lakes except Lake Erie large enough to appear on the topographic maps occur in this area.

General Structure

The strata were deposited as nearly horizontal sediments but have since been slightly folded, faulted, and tilted toward the southeast and east. The tilting was caused by the uprising of the Cincinnati Anticline which extends southwest from the west end of Lake Erie through western Ohio, Indiana, and into Kentucky, and by the sinking of the Pittsburgh Syncline, which forms a trough in southwestern Pennsylvania, southeastern Ohio, and northwestern West Virginia. The strata also dip southward away from the Canadian Shield. The result has been a general eastward dip in central Ohio. This dip increases and becomes southeasterly in the northeast part of the county. Lorain County is affected by both tilts.

Many individual folds and faults are considered to be purely local and do not show a great deal of deformation. The better exposures of these folds and faults are in the Bedford, the Cleveland, and the Chagrin shales along the lake shore and in the gorges of the main rivers. However, small folds do occur in the higher formations in other parts of the county.

At Avon Lake the Chagrin shale is folded into an east-west trending anticline four feet high and thirty feet wide. The overlying Cleveland shale is a little faulted above the fold. A half mile to the west along the lake shore the shale is sharply folded into an anticline trending N 50° E.

Along the banks of the Black River one mile south of Lorain the shales have been compressed into four or five gently undulating folds about thirty feet high and five hundred feet from crest to crest. These folds trend east and west.

A half mile north of Henrietta in the banks of Chance Creek below the bluffs the underlying blue Bedford shale is thrust faulted over the overlying red Bedford shale. The strike of the fault is about N 40° W.

Three-fourths of a mile north of Beebeville the Meadville shale is folded into a small east-west trending anticline. The small exposure does not reveal the total amount of the deformation, but the fold is small. Nearby strata are level.

Thus it is seen that the small folds and faults occur in various directions and in all the incompetent strata. Some of the folds may be due to ice shove, but this origin does not seem to be adequate in most cases. All the folds and faults are small and local. The structure of the region is determined by broad warping, as described at the beginning of this section.

General Stratigraphy

The bed rock in Lorain County is shale and sandstone and is of Devonian and Mississippian age. It is underlain by Silurian and Ordovician sediments. The Silurian rocks are from 700 to 750 feet thick and consist chiefly of shale in the lower third and of limestones and dolomites in the upper two-thirds. Above this are the Devonian limestones and shales. The Mississippian strata are composed of shales and sandstones, which are overlain unconformably to the south by later Mississippian and by Pennsylvanian rocks. The boundaries between the different systems in this part of the country are still unsettled. The Monroe limestone may be either Silurian or Devonian. The Cleveland shale and the Bedford shale may be either Devonian or Mississippian, probably the latter[2].

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[2]R. C. Moore considers the Cleveland to be Mississippian in <u>Historical Geology</u>, p. 270 (1937).

Most previous classifications placed the Cleveland in the Devonian.

The bed rock is covered by till, lake deposits, and post-glacial alluvium.

Geologic History

During Ordovician time there were two land masses--one to the north called Laurentia, and the other to the south and east of Ohio called Appalachia. From these two ancient continents, the Ohio strata, which formed a basin between them, received all of their sediments. During the time subsequent to Ordovician time the low warp known as the Cincinnati Anticline slowly rose in the west central part of the state.

In Silurian times there were long periods with no diastrophic movement. Life was abundant. First muds and then limes were deposited; these later became shales overlain by beds of fossiliferous limestone. At the close of Silurian time regional uplift created lagoons which formed salt and gypsum deposits. Subsequent sinking in Middle Devonian time caused deposition of new sediments over the old as the sea again entered the basin. Most of the sediments were limes. During Upper Devonian times muds were the characteristic deposits. Few fossils have been found in most of the resulting shales. This mud deposition was uninterrupted for a long time and the shales formed from these muds are very thick. Tilting toward the east must have taken place because the shales thicken eastward from 800 feet at Elyria to 1,862 feet at Akron--a distance of 35 miles. An uplift closed Chagrin deposition, causing an erosional unconformity. This unconformity is considered to represent the break between Devonian and Mississippian sedimentation[3].

[3]Chadwick, George H., The great Catskill Delta, and revision of Late Devonian succession: Pan-Am. Geologist, vol. 60, p. 280, 1933.

Moore, R. C., Historical Geology, p. 270, 1933.

Erosion was followed by a new invasion of the sea and deposition of sediments in Mississippian time. The sea shore fluctuated back and forth. As a result sands were interbedded with muds. The sands, being heavier than the muds, sank into them and with a new covering of more sand formed thick lenses. These lenses are known to have reached a thickness of 225 feet[4]. At least one

[4]Buckeye Quarry, South Amherst, Personal communication from the watchman in charge.

well record indicates a greater thickness--245 feet[5].

[5]Well of George Schaefer. See page 95.

Further uplifts brought the Mississippian to a definite close, and marked the beginning of Pennsylvanian times. There are no Pennsylvanian strata in Lorain County. During Pennsylvanian times vast amounts of vegetal matter accumulated in swamps and formed the present coal beds of eastern Ohio.

After Pennsylvanian time we have no record of any marine deposition in northern Ohio. Subsequent uplift and erosion formed a series of cuestas and isolated ridges or hills from these indurated sediments.

Immediately preceding the Pleistocene the country was more rugged than now. During the Pleistocene two or more invasions of ice moving from a center in Labrador modified the surface, filling up depressions and scouring down hills. In places, however, the relief was accentuated slightly and many of the sandstone hills in central northern Ohio are supposed to have been left in an increased contrast to the softer surrounding shales which the ice to some small degree scooped out.

As the last ice sheet retreated a succession of marginal lakes were formed.

At the present time the land is undergoing fluvial erosion and small uplifts. Occasional earthquakes in this state bear witness to these small diastrophic readjustments.

Climate and Vegetation

Due to the retarding influence of Lake Erie to the north, the climate of Lorain County is milder than that of other places at this same latitude and not near a large body of water. The July temperature is 71 degrees. Only three months have average temperatures below freezing. The precipitation reaches a maximum in July although it is fairly well distributed throughout the year, no month having less than two inches.

The region was at one time covered with swamps and forests of mixed hardwood trees, but at present the forests have been removed and the swamps have been drained. Maples, elms, and oaks occur in a few wood lots. Fruit trees and pasture grasses are the present principal forms of vegetation.

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PART II

STRATA OF LORAIN COUNTY

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ROCKS NOT EXPOSED

The unexposed rocks of the county are known from well records and from their extensions westward where they crop out along the shore of Lake Erie. They consist of a lower horizon of limestones overlain by an upper horizon of alternating grey and brown and black shales. Since the limestones are good bearers of gas, they are the principal horizon sought by drillers. In well records these strata are known as the "big lime". Frequently the depths to and through intervening formations are not recorded.

The limestones are of Silurian and Early Devonian age and belong to the Niagaran, Monroe, Columbus, and Delaware formations. When acid is applied to well borings from some of these limestones, due to bituminous and sulfide impurities a disagreeable odor is produced.

The shales are of Late Devonian age[6] and belong to

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[6]Baker, Roger, The age of the Olentangy is proved to be Late Devonian in an unpublished master's thesis, University of Iowa, 1938.

Moore, R. C., Formations below the Cleveland are considered to be Devonian in Historical Geology, p. 270, 1933.

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the Olentangy formation and the lowest member (Huron) of the Ohio shales. The Olentangy is a soft grey shale. The Huron is a black, bituminous, slaty shale containing many siderite and pyrite concretions. The latter formation is a good source of natural gas.

ROCKS EXPOSED

Ohio Shales

The Ohio shales are divided in this part of the state into a lower slaty black (Huron) shale, a middle soft grey (Chagrin) shale, and an upper slaty black (Cleveland) shale.

The term Ohio shale was given by Andrews[7] in 1870

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[7]Geol. Surv. Ohio, Part II, p. 62, 1870.

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to the black slaty shales in central and southern Ohio. The name has also been applied to practically equivalent strata in northern Ohio. In 1870 Newberry[8] divided

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[8]Geol. Survey of Ohio, Part I, Rept. Prog., pp. 19-21, 22, 1869.

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strata equivalent to the Ohio shale in the northern part of the state into the Huron, the Erie, and the Cleveland shales. However, the name Erie was preoccupied by formations in other parts of the United States and the name Chagrin was substituted by Prosser in 1903[9].

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[9]Jour. Geol., vol. 11, pp. 521, 533, 1903.

Chagrin Shale (Devonian)

The middle member of the Ohio shale was named Chagrin from good exposures along the Chagrin River near Cleveland. The Chagrin shale is exposed along the shore of Lake Erie in Avon, Sheffield, and Brownhelm Townships in Lorain County, but the best outcrops are in deep river valleys and along the lake shore to the east in Cuyahoga County. It is predominantly a soft blue-grey or green-grey thin-bedded shale easily weathering into a sticky grey mud. An outstanding characteristic is its lenses of argillaceous siltstone ranging from a fraction of an inch to four inches in thickness. It is very difficult to break these siltstones. They are very fine-grained and are composed of compressed clay, fine silt, and lime. They are very resistant to erosion and form distinct bands on exposed shale banks. The specimens examined did not contain fossils nor the cone-in-cone structure so common in similar beds of the overlying Cleveland shale. Most of the Chagrin shale is below the level of Lake Erie and reaches a maximum exposed thickness of 25 feet, two miles west of Cuyahoga County line on the shore of Lake Erie at Avon Point. ɪhere it forms the entire wave-cut cliff, an exposure of 25 feet. It is not known how far southward from this place the Chagrin continues to form the bedrock. Glacial material covers the contact between the Chagrin and the overlying Cleveland in this section of the county. Elsewhere in Lorain County the Chagrin is almost conformably overlain by the Cleveland. There is a slight nonconformity. The Chagrin shale is exposed along the lake shore both in the eastern and in the western parts of the county. At the mouth of French Creek it dips eastward from below the Cleveland shale. West of French Creek it extends along the lower part of the Black River in South Lorain. Well records show it to range from 100 to 250 feet in thickness throughout the county, the greatest thickness being in the southern part. (See part IV of this thesis).

No fossils were found by the author in Lorain County although in the Cleveland area to the east numerous species and genera have been described[10].

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[10]Cushing, Leverett, and Van Horn, Geology and mineral resources of the Cleveland area: U. S. Geol.

Survey, Bull. 818, p. 35, 1929.

The shale has no known economic uses.

Section at mouth of French Creek, Sheffield Township

7.	Cleveland shale. Slaty black shale. Gypsum stars and pyrite concretions with yellow sulphate decomposition products abundant. There are a few layers of grey shale.	25 ft.	
6.	Chagrin shale. Soft weathered shale, increasing in thickness to the eastward.		10 in.
5.	Soft thin-bedded grey shale. A few layers of hard slaty black shale.	5 ft.	
4.	Hard siltstone layer, very resistant to erosion, well-cemented.		3 in.
3.	Soft grey shale.		2 in.
2.	Hard flagstone layer. Same as no. 4.		3 in.
1.	Soft grey shale.		4 in.
	Creek level	Total 31 ft.	10 in.

A slight nonconformity exists between the two formations. The Cleveland shale overlies the youngest Chagrin beds to the west. That is, the Cleveland beds have a greater eastward dip than the underlying Chagrin beds. This eastward dip of the strata is due to a low north-south anticline extending through East Lorain. The mouth of French Creek is on the east limb of this anticline. No fossils were found in the shale.

Section on the shore of Lake Erie

at the Lorain-Cuyahoga Co. line

3.	Soil and till.	5 ft.
2.	Cleveland shale. Thin-bedded, tough, black shale which rapidly weathers brown, especially along joint planes. No bands of siltstone.	37 ft.
1.	Chagrin shale. Soft grey shale, containing many bands of silty limestone ranging up to an inch in thickness and often occurring at vertical intervals of 3 or 4 inches. No fossils are present. A line of grey clay separates this formation from the above.	10 ft.
	Lake level	Total 52 ft.

Two typical sections of the Chagrin shale in this county are given above. The latter is the better place to study the Chagrin and to contrast it with the overlying Cleveland shale. The contact and the contrast between the two formations at French Creek and in the western part of the county is less distinct than in exposures along the lake shore in the eastern part of the county. This is because with increasing longitude the shales become less pure. The lower part of the Cleveland shale contains layers of soft grey shale, and the upper part of the Chagrin contains layers of hard slaty black shale. Along the lower part of the Vermilion River the Cleveland shale contains numerous soft grey layers. These layers weather to a soft grey mud which coats the outcrops and conceals the true nature of the outcrops. They look like exposures entirely of soft grey shale, whereas in reality they are mostly of slaty black carbonaceous shale.

At the point of contact between the two formations in the eastern part of the county and at the mouth of French Creek there is usually a band of soft grey mud ranging in thickness from nothing up to five inches. The average thickness is much less than five inches. Where a nonconformity occurs between the two formations, this layer is found to represent the upper limit of the Chagrin formation. It probably represents the weathered surface of the Chagrin shale just before Cleveland mud was deposited[11]. This contact between

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[11]Cushing, Leverett, and Van Horn, Ibid., p. 39.

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the two formations was followed along the lake shore, and in the westernmost part of the county the top of the Chagrin dips below the level of Lake Erie. Since most of the strata of Lorain County dip southward and southeastward, the Chagrin shale, also, must dip southward below lake level and would not be exposed in any part of the Vermilion River valley. Consequently, the shales exposed in this river valley near its mouth must be basal Cleveland and not Chagrin.

This lack of a sharp boundary line between the Chagrin and the Cleveland is even more noticeable in well records, where layers of grey, brown, and black soft and hard shales are intermingled. (See the well records in part IV of this paper). The Cleveland and the Chagrin grade into each other to the south and west so that in central Ohio the two formations are not differentiated but are considered to belong to the Ohio shale. Lorain County seems to be the western limit where subdivision of the Ohio shales is possible, at least as far as the Cleveland and the Chagrin are concerned.

Cleveland Shale (Mississippian)

The Cleveland shale, the uppermost member of the Ohio shales, was named by Newberry[12] in 1870 from good exposures at Cleveland. Part of this shale was originally included with the Huron shale in the "Black Slate" which was described as extending from the mouth of the Huron River southward to the mouth of the Scioto River, and east of Sandusky to Avon Point in Lorain County. The presence of an intervening grey member apparently was not recognized at that time, and in

[12]Geol. Survey of Ohio, Part I, Rept. Prog., p. 22, 1869.

Lorain County the upper (Cleveland) shale was included with the lower (Huron) formation.

The Cleveland shale is a fine-grained, thin-bedded, carbonaceous black shale much resembling slate in hardness and in its ability to split into thin layers. An analysis of Cleveland shale made at Columbus is here given. The locality is not known, but the sample is in all probability representative of the formation.

Analysis of a sample of Cleveland shale, by Lord

Silicic acid	60.35 %
Alumina and oxide of iron	21.20
Carbonate of lime	2.95
Carbonate of magnesia	3.33
Volatile and organic matter	10.70
Moisture	.70
Total	99.23 %

Also a little sulfur in combination with the iron[13].

[13]Report of the Geological Survey of Ohio, vol. 6, Economic Geology, p. 32, 1888.

"The mineral basis of all these shales (Ohio and Bedford), whether black, brown, blue, grey or red, is essentially one and the same thing, viz., a fine-grained clay, derived from the waste of distant land. As supplied to the sea basin, it was originally blue or grey, but a small percentage of peroxide of iron goes a great way in coloring such deposits red, and in like manner, organic matter that colors these shales was probably derived in large part, as Newberry has suggested from the products of growth and decay of sea-weeds by which these seas were covered like the Sargasso seas of our own day".[14]

[14]Report of the Geological Survey of Ohio, vol. 6, Economic Geology, p. 27, 1888.

The lower portion is characterized by thin lenses or zones of lenses possessing cone-in-cone structure. This has been explained by pressure and solution acting on crystalline limestone layers.[15] No matter what the

[15]Tarr, W. A., Origin of Cone-in-Cone: Treatise on Sedimentation, 2d ed., pp. 725-733, 1932.

origin, in Lorain County it seems to be limited to the Cleveland shale, especially to its lower portion. This fact is a valuable aid in differentiating it from the underlying Chagrin shale which also contains thin calcareous bands but which at the same time, does not possess the cone-in-cone structure.

A second feature observed only in the Cleveland shale is the septarian structure. This is due to contraction of concretions, formation of tension cracks, filling with some vein material, and subsequent weathering away of the softer material between the veins, leaving the latter standing out as ridges. Frequently the shale, not the concretions, is weathered most along certain intersecting minute joints so that a resulting mottled effect is formed. These shale surfaces resemble turtle shells and have given rise to what is often spoken of as "fossil turtles" found in some of the shales. Pyrite concretions are common. They are frequently coarsely crystalline and arranged in concentric zones which average three inches in diameter.

The top of the Cleveland formation is usually covered by a zone of two or three calcareous siltstone layers. This is only an arbitrary boundary drawn between the Cleveland and the overlying Bedford shale, but it is by far the most easily recognized in the field, and seems accurately to separate the lower slaty Cleveland beds from the upper soft grey Bedford formation. If the Bedford shale was deposited under changed land conditions, this calcareous siltstone would be formed in a preceding period of quiet and would belong to the preceding (Cleveland) formation. No disconformity separates the Bedford from the Cleveland.

The shale frequently becomes rusty on exposure and contains "gypsum stars" in weathered portions with yellow alum or other sulphate efflorescences on the surface. These stars are due to the decomposition of pyrite in the shales and their subsequent reactions with water, lime, and clay. These sulfates are not peculiar to the

Cleveland formation but are found in less amounts in other shales, which contain less pyrite and less bituminous matter. The association of the pyrite with the bituminous material is noteworthy. The pyrite seems to have resulted from the reduction of sulfates in solution by the carbon in the shales.

$$4FeSO_4 + 7C = 2FeS_2 + 2FeO + 7CO_2$$

Fossils are abundant in two horizons, one in the topmost siltstone layer at the top of the formation and the other in a layer about four to ten inches below this. The fossils collected were in the main small brachiopods, gastropods, and pelecypods. Some of the best preservations of the Devonian(?) _Dinichthys_ fish are in the Cleveland shale of Lorain County. A few specimens of shark's teeth _(Ctenacanthus vetustus)_ were collected a mile and a half north of Elyria in the bluff of the Black River on the south side of Cherry Ridge. The fossils in the shale are easy to extract, but those in the overlying siltstone layer are in a very tough matrix, and it is very difficult to extract the fossils without breaking them.

Section in Chance Creek one-half mile northeast of Henrietta, 1,000 ft. downstream from the bridge.

Bedford	6.	Thin-bedded grey shale.	5 ft.
Cleveland	5.	Calcareous siltstone horizon.	5 in.
	4.	Thin-bedded grey shale.	10 in.
	3.	Thin beds of calcareous siltstone. Beds are one inch thick. Purple on weathered surfaces; nearly white on fresh surfaces. Pyrite concretions are very numerous between this horizon and the shale above.	6 in.
	2.	Grey, slaty shale.	16 in.
	1.	Coarsely bedded grey shale. Contains pyrite concretions.	3 in.
Creek level		Total	8 ft. 4 in.

Generalized section in upper part of Chance Creek

Pleistocene	9.	Till.	thickness variable
Berea	8.	Deformed siltstone with a mud-flow structure. Many siltstone concretions.	2 ft.
	7.	Grey shale.	2 ft.
	6.	Red shale grading into dark shale at the base.	40 ft.
	5.	Grey shale.	5 ft.
Cleveland	4.	"Upper siltstone". Beds are one or two inches thick. Weathers to a purple.	1 ft.
	3.	Grey shale.	1 ft.
	2.	"Lower siltstone". Overlain by numerous flat pyrite concretions. Weathers to a purple. Contains some fossils. Cut by vertical cylindrical joints.	1 ft.
	1.	Grey slaty shale with a brown phase one foot below the top. The brown phase is only two or three inches thick and is characterized by fossils and a few pyrite concretions.	1 ft.

The Cleveland shale extends in a broad band two to six miles wide along most of the lake shore and is exposed for a greater distance inland in all of the rivers. The shale is exposed in the Vermilion River between Lake Erie and Elyria--a distance of six miles. Well records show the thickness of the shale to vary from 100 to 150 feet; the thickness increases toward the south.

The Cleveland shale is often folded into small sharp anticlines or into broad gentle folds. Some of these are undoubtedly due to ice shove during glacial advances, but others must be due to regional shortening of the strata in a north-south direction. The folds are admirably developed in exposures along the bluffs of the Black River for a distance of several miles south of Lorain. The shale is frequently jointed in vertical or nearly vertical directions. When one side of the joint is weathered away, the structure has the appearance of a fault with a throw of several feet. No large faults have been found in the Cleveland shale.

Bedford Shale (Mississippian)

The Bedford shale was named by Newberry[16] in 1870

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[16]Geol. Surv. Ohio, Part I, Rept. Progress in 1869, p. 21.

from its exposure at Bedford, Cuyahoga County. Prosser[17] gave it a thickness of 50 to 150 ft. The

[17]Prosser, C. S., Jour. Geol., Sept. - Oct., 1903, pp. 520-521.

well records of this county show a variation of from 8 to 196 feet (see part IV of this report). In some areas the Bedford is entirely lacking, having been eroded away in pre-Berean times or entirely pinched out by the overlying Berea sand during settling of the sand in the clay. Most of the Bedford outcrops strike in a narrow band parallel to the lake separating the Cleveland shale from the Berea sandstone. The width of outcrop ranges from less than a mile in most places to about two miles near Elyria. The outcrops of Bedford shale also extend up the main rivers for some distance. Recent investigation by the author, mainly with well records, shows that the outcrop is much more extensive than has been formerly supposed. Most of the area is covered with till. Inliers of Bedford shale commonly appear through Berea sandstone. For example, east of the schoolhouse in South Amherst Village (Amherst on map) and east of the Children's Home in Oberlin, Russia Township, are large areas several miles in extent in which the Berea sandstone is lacking and Bedford shale is the bed rock. In other parts of the county, especially for a few miles west of Elyria and for a few miles west of Grafton, the Bedford shale inliers are smaller, and the sandstone is described by drillers as "spotted". These regions in which the shale contains patches of sandstone and vice versa are denoted as "spotted" on plate II. Probably much of the bedrock assigned on the map either to the Bedford or to the Berea is spotted with patches of the other formation. Only the well drill can locate these spots.

In Lorain County the Bedford shale is composed of two distinct phases, an upper red and a lower grey. In most of the literature the formation is described as red or blue. Both phases are soft thin-bedded shales, usually free from pyrite concretions and flagstone layers. The gradation from one phase to the other is rather indistinct and some of the red Bedford contains thin layers of grey shale. The main difference between the phases seems to be in color. Both are distinct from the Cleveland shale in being softer and more easily eroded. The brilliant hue of the red phase has given "Cherry Ridge" a mile and a half north of Elyria its name. Circular concentric jointing in which round bits of shale, no harder than the rest of the mass, weather out, is found only in the red Bedford. (Fig. 2, plate IV).

The exact age of the Bedford has been in some doubt. Except at the base of the formation fossils are rather rare. In 1888 Dr. White placed the red Bedford with the overlying Berea in the same age--the Catskill age of the Upper Devonian.[18] In 1905[19] and again in 1928[20]

[18]Bull. of Denison University, vol. IV, pp. 100, 106, 1888.

[19]Prosser, C. S., Revised nomenclature of the Ohio geological formations: Geol. Surv. of Ohio, 4th ser., Bull. 7, p. 2, 1905.

[20]Cushing, Leverett, and Van Horn, Ibid., p. 28.

it was mapped as either Devonian or Mississippian. However, due to the fact that the underlying Cleveland shale has since been placed at the base of the Mississippian,[21] the Bedford is now regarded as lower

[21]Chadwick, George H., Ibid., p. 280.
Moore, R. C., Ibid., p. 270.

but not as basal Mississippian. It is so mapped here.

The nature of the Bedford-Berea contact has been a classic problem in Ohio geology. The contact is shown in figure 3, plate IV and in figures 1 to 4, plate V. In almost all places the base of the Berea sandstone consists of fine siltstone resting on an irregular surface of minutely folded and faulted soft shales. A fuller discussion of the contact is given in the description of the Berea formation on pages 36-38.

Elsewhere than at its upper contact the Bedford shale is usually horizontally bedded or is deformed into gently undulating anticlines and synclines in accordance with those found in the underlying Cleveland shale. These folds are due to the regional shortening of the strata. Evidence of ice shove was not found, possibly because the soft Bedford would be gouged out by horizontal rub rather than be deformed. In Chance Creek one-half mile northeast of Henrietta, 500 feet downstream from the bridge, an overthrust fault of several feet displacement has forced blue Bedford up over red Bedford.

The only fossils found in the Bedford shale were near its base at North Amherst, Amherst Township, in the east branch of Beaver Creek, 400 feet north of the railroad bridge. The main types were small pelecypods found in concretions at the base of the shale. In the museum at Oberlin College are several fossils, presumably from this same exposure of the Bedford[22], among which are

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[22]The lithology of the specimens is the same as that of the exposed cut. Several years ago, according to Dr. Hubbard, a large collection for the college was made there.

Stenochisma sappho, Macrodon hamiltoniae, Rhynchonella sp., and Lingula melie.

It has been reported that in some places the Bedford is hard enough to quarry, but most of it has no commercial use. It is valuable as a soil derivative. Wells drilled in the Bedford do not yield good water either in amount or in quality.

Berea Sandstone (Mississippian)

The Berea sandstone was named by Newberry[23] in 1870 from its best exposure in the quarries at Berea in Cuyahoga County. The Berea is a fine-grained sandstone, grey to white on fresh surfaces, and usually weathering to a buff color. For this reason the stone is much in demand for building purposes. The sandstone is reasonably free from impurities and forms a good reservoir for water. When overlain by an impervious clay or shale the sandstone is also a good reservoir for oil. The Berea sandstone has by far more outcrops than any other formation in the county. In the progess of weathering and erosion the sandstone has been left behind in hills and ridges. Much of the overlying

[23] Geol. Survey of Ohio, Part I, Rept. Prog., p. 22, 1869.

shales have been removed by erosion while the sandstone has remained. At South Amherst the Berea sandstone reaches a thickness of 225 feet while in other places the sandstone may be totally lacking. An average of 60 feet in thickness is given by a number of well logs (see part IV of this thesis).

The plan of Berea outcrops is a broad band ten to twelve miles wide and extending across the county parallel to the lake shore. Numerous outliers seem to exist in the shales to the north as well as numerous inliers of shale within the borders of the sandstone. This irregularity of Berea outcrops is due to the resistance of the sandstone to weathering and erosion and to the very irregular basal contact of the Berea with the underlying Bedford. The upper limit of the Berea is usually quite level. The nature of the lower contact has been mentioned before on page 33. The contact is characterized by a zone of concretionary sandstone ranging from a foot to several feet in thickness.

Below is a sketch of the base as seen in Kipton Quarry. The shale is distorted at the contact due to minute folds and faults. The lower part of the sandstone shows movement occurred while the rock was still in the plastic condition. "Mud flow" would be the best term applied. Bits of black and of grey shale are included in the sandstone beds. Yet the beds are practically horizontal. They are even ripple-marked at the bottom

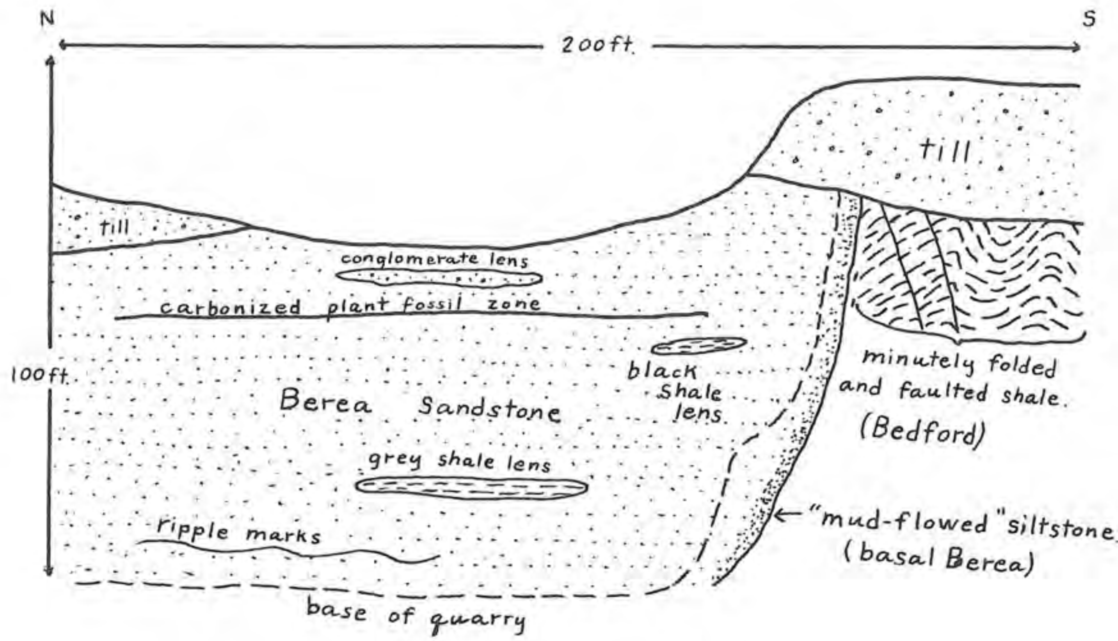

Fig. 2. North-south Cross-section of Kipton Quarry near Kipton.

(Idealized. Compare with figs. 3, 4 plate IV)

as though laid down in a shallow sea by strong eastward-moving currents. Figure 3, plate IV is a view looking east at the south end of the quarry. The base of the sandstone borders the crumpled shales. Figure 4, plate IV is a view looking northward at the base of the quarry. In the center of the picture is a lens of grey shale included in the horizontal beds of sandstone.

Another view of the contact is given in figures 2, 3, and 4, plate V, taken at North Amherst in the east branch of Beaver Creek. There the shale is distorted and bits of concretionary sandstone have seemingly been rolled into the shale while both were still in the plastic condition. The shale has even been squeezed between bits of rolled sandstone. These concretions are very similar in nature to the "sides of beef" seen in the distorted southern quartzite limb of the Baraboo Syncline of southern Wisconsin. These latter are long rounded fragments of quartzite included in slate and are explained as being formed by movement between the beds during the formation of the Baraboo Syncline. One quartzite bed slid over another (where a small slate lens formed a zone of weakness), and fragments of quartzite were rounded much as balls of sticky clay can be rubbed into shape between one's fingers. The same thing seems to have happened at the base of the Berea sandstone except that sandstone and shale instead of quartzite and slate are the materials, the movement occurred before hardening of the sandstone (since it is not at all brecciated), and rolling of the sandstone fragments was not caused by simple movement on the limbs of a syncline. Instead, rolling occurred during settling of heavy overlying sand in lighter underlying soft clay. The deformed sandstone masses included in the shale range from a few inches to several feet in diameter.

The larger sandstone masses usually show twisted bedding. A good example of this twisted bedding is shown in the pictures taken at North Amherst, figures 2, 3, and 4, plate V. In the bank of the East Branch of the Black River about two miles north of Grafton, fig. 1, plate V, the inclusion of "rolled" rounded sandstone again presents its puzzling appearance beneath the roots of the tree. At practically no place is the contact between the Bedford and the Berea level. In other parts of the state also the base of the Berea is uneven, but at no place does the Berea present lenses of such great depth. To the south and east the formation is so continuous that most well-drillers use it as one of the most reliable datum horizons.

"The Berea sandstone does not present great variations in composition. The proportion of silica (SiO_2) is usually in excess of 90%, the remaining part consisting of calcium oxide, magnesium oxide, alumina, and iron, but occasionally less common bodies are found".[24]

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[24]Bownocker, J. A., Building stones of Ohio: Geol. Survey of Ohio, 4th ser., Bull. 18, p. 74, 1915.

Analyses of Berea Sandstone

From South Amherst, Lorain County Quarry No. 6 of the Cleveland Stone Co. Analyst, Prof. D. J. Demorest, of the Ohio State University.

SiO_2	92.15 %
Al_2O_3	3.85
Fe_2O_3	1.40
TiO_2	.40
CaO	.50
MgO	.20
Loss on ignition	1.70
	100.20 %

Analysis of the best grade of Berea sandstone.

SiO_2	92.95 %
Al_2O_3	3.14
FeO	1.22
CaO	.13
MgO	.37
Alkalies	.65
Water (combined)	.80
Carbonic acid	.74
	100.00 % [25]

[25] Burroughs, W. G., Economic geology of the Berea sandstone formation of northern Ohio: Econ. Geol., vol. 8, pp. 469-481, 1913.

The Berea sandstone is bounded by two zones of pyrite. This is probably due to the presence of nearly impervious, reducing, carbonaceous shales on both sides which reduce any sulfates (which undoubtedly exist in minute quantities in solution) to sulfides and which might in other ways precipitate iron sulfides from waters containing them. Scattered in some horizons

$$[4FeSO_4 + 7C = 2FeS_2 + 2FeO + 7CO_2]$$

are nodules of pyrite. In the sulfide form the iron is not very evident, but weathering produces rusty alteration products. Another effect of the pyrite or of sulfates is the formation of hydrogen sulfide in well water. The result is a disagreeable odor and taste. Wells in Oberlin, Nickelplate, and Shawville are all affected in this way. In many other localities such as South Amherst, Elyria, and Lorain the sandstone is free from this gas and the drinking water is excellent. The cement of the sandstone is usually silica. In only one instance was a noticeable lime cement found. That was in the well of Charles Heckert, three miles northwest of Elyria. A rough analysis (by the author) of the water in May, 1937 showed:

Al	negligible
Fe	distinctly present (actual amount was not determined)
Ca	120 parts per million
Mg	negligible

As the analysis shows, both lime and iron compounds may have formed the cements. Red Bedford shale was struck in this well as it was deepened soon after this water was tested. The sample must have come from a basal calcareous phase of the Berea.

The best exposures of the Berea are in quarries. These quarries are very common throughout the county. In them the sandstone is found to be massive to thin-bedded, usually thinner-bedded where it has not been protected from weathering. The beds are usually horizontal although minor dips in various directions have been noted. Cross-bedding occurs in some layers and affects the quality of the sandstone as a building material. Ripple marks are common in certain horizons, especially near the base of the formation where the rock is more argillaceous. These ripple marks are usually simple and range from two to six inches from crest to crest. One remarkable fact is that nearly all were formed by a current moving nearly due east. At Avon and in the southeast corner of North Amherst secondary ripples cross in other directions.

Sharp folding is unknown. This is probably due to the great rigidity of the sandstone as compared with that of the underlying shales. Minor faulting occurs in some quarries. Probably major faults in the sandstone occur where it is less thick. This would occur in places now covered by glacial material and hence not exposed.

The sandstone is nearly pure quartz sand. Among the heavy minerals Dr. Foreman[26] has found tourmaline

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[26]Personal communication from Dr. Foreman, 1937.

and leucoxene. Undoubtedly shifting of sand by wind or by water sorted nearly all the other minerals. A muscovite-rich type occurs three miles northwest of Elyria. H. Thomsen[27]has found that the sandstone grains

[27]Thomsen, H., Textural variations of the Berea sandstone: Master's Thesis, Oberlin College, 1935.

are finer toward the east and south. Lenses of shale are rarely found, the two main exceptions being in the quarries at Kipton and at Columbia Station. A conglomeratic phase exists in an exposure at Elyria, but it is not impressive; the pebbles are small pure white quartz. Most of the sand must have been deposited in a very extensive sea in which constant wave action sorted out the different sized particles.

Fossils have been found in the upper beds at Berea in Cuyahoga County and a remnant of a brachiopod was found in a quarry one mile south of Westview. This was also near the top of the formation. Carbonaceous plant fossils are numerous and in places form nearly solid layers. Some resemble Annularia. These layers are quite extensive laterally but may be found in any horizon in the formation. At such widely separated places as Kipton, near Westview, and South Amherst these carbonaceous strata are very abundant.

The theories as to the manner of deposition of the sandstone have been numerous. In 1911, W. G. Burroughs[28]

[28]Burroughs, W. G., Jour. Geol., vol. 19, p. 659, 1911.

noted that at the base of the sandstone lenses in the horizon of the red Bedford shale is a soft dark-blue shale three to four feet thick, not found where the sandstone is thinner. He said that this was once alluvium in pre-Berean valleys in the Bedford shale and that the Berea was once a deposit of sand in erosion valleys. This theory is further substantiated by the horizontal beds of the sandstone and by the blocks of shale in the sandstone. However, Dr. Foreman in studying the Buckeye quarry and associated quarries in South Amherst found that the "erosion channels" were enclosed and were merely basins. Also, at the base of the sandstone is a siltstone zone which was deformed while still a plastic mud. The underlying shale has been much pushed out of place. This evident movement has led some to believe that the sands were deposited on a nearly level shale floor. The weight of the sandstone or sands allowed the heavy sands to sink in the soft shales, squeezing the latter to one side, and making room for more sand deposition, which caused more sinking, etc. This theory would explain the sandstone lenses existing in the quarries at South Amherst and elsewhere in which no continuous erosion channels are found. These lenses are thick enough to make quarrying possible, and with the exception of Henrietta Hill and one or two minor elevations, these lenses are nearly all marked by quarries, active or abandoned.

The author has reached the conclusion that both erosion valleys and "isostatic adjustment" played important parts. However, before stating conclusions regarding the manner of deposition of the Berea sandstone, one should review the known facts.

1. The lower contact of the Berea sandstone is very irregular with differences in depth in some localities of at least 200 feet.

2. The depressions in the underlying Bedford shale and filled by the Berea sandstone are not all connected.

3. At the contact seen in most places the underlying soft Bedford shale has been distorted into numerous small faults and folds.

4. The base of the Berea always consists of a fine siltstone which has been distorted before consolidation and which possesses a mud-flow structure.

5. At the base of one of the deepest quarries several feet of shale differing from both the Berea sandstone and the Bedford shale separates the two formations.

6. Although ripple-marked horizons occur in the center of the formation they are very characteristic of its base. Most were formed by eastward moving currents.

7. Bits of older Cleveland black shale are occasionally enclosed in the lenses of sandstone.

8. Most of the Berea strata are nearly horizontal. This is especially true of the thick lenses exposed in quarries.

9. The Berea formation to the southeast has a more uniform thickness.

10. There is a decrease in grain size toward the southeast.[29]

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[29]Thomsen, H., Ibid.

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11. The Berea sandstone in Lorain County is characterized by lenses. As is well known to well drillers, inliers of Bedford shale in Berea sandstone are numerous.

12. In several places bits of Berea sandstone have been rolled into the underlying Bedford shale. (See fig. 2, plate V).

13. The texture is quite uniform. Conglomerates are very rare.

14. Marine fossils are very rare.

15. Two arms of sandstone extend northward into regions where older Cleveland shale is the bed rock. They are in South Lorain and one mile east of Vermilion. They may be either outliers or prolongations of outcrop. East-west folding has occurred in these arms. The cause of the folding is not known. Cross-bedding in the arm near Vermilion shows that the sands were laid down by a southward moving current.

16. A map of Lorain County shows that the largest quarries and the most prominent sandstone hills, and the two northward projecting sandstone arms form a distinct pattern. This county has been settled a long time and has been well-prospected for sandstone lenses in which quarries might be excavated. As a result almost all of the lenses have been discovered and are marked by quarries, active or abandoned. They occur in four zones roughly paralleling the shore of Lake Erie and the strike of the formations. The lenses also occur in northeastward and northward trending series nearly at right angles to the zones just postulated.

With the above facts in mind the writer has reached the following conclusions. The Berea sandstone in Lorain County is a shore phase of the formation which extends to the south and east. The sands were brought from northern sandstones or crystallines by rivers which had distinct valleys in the underlying Bedford and

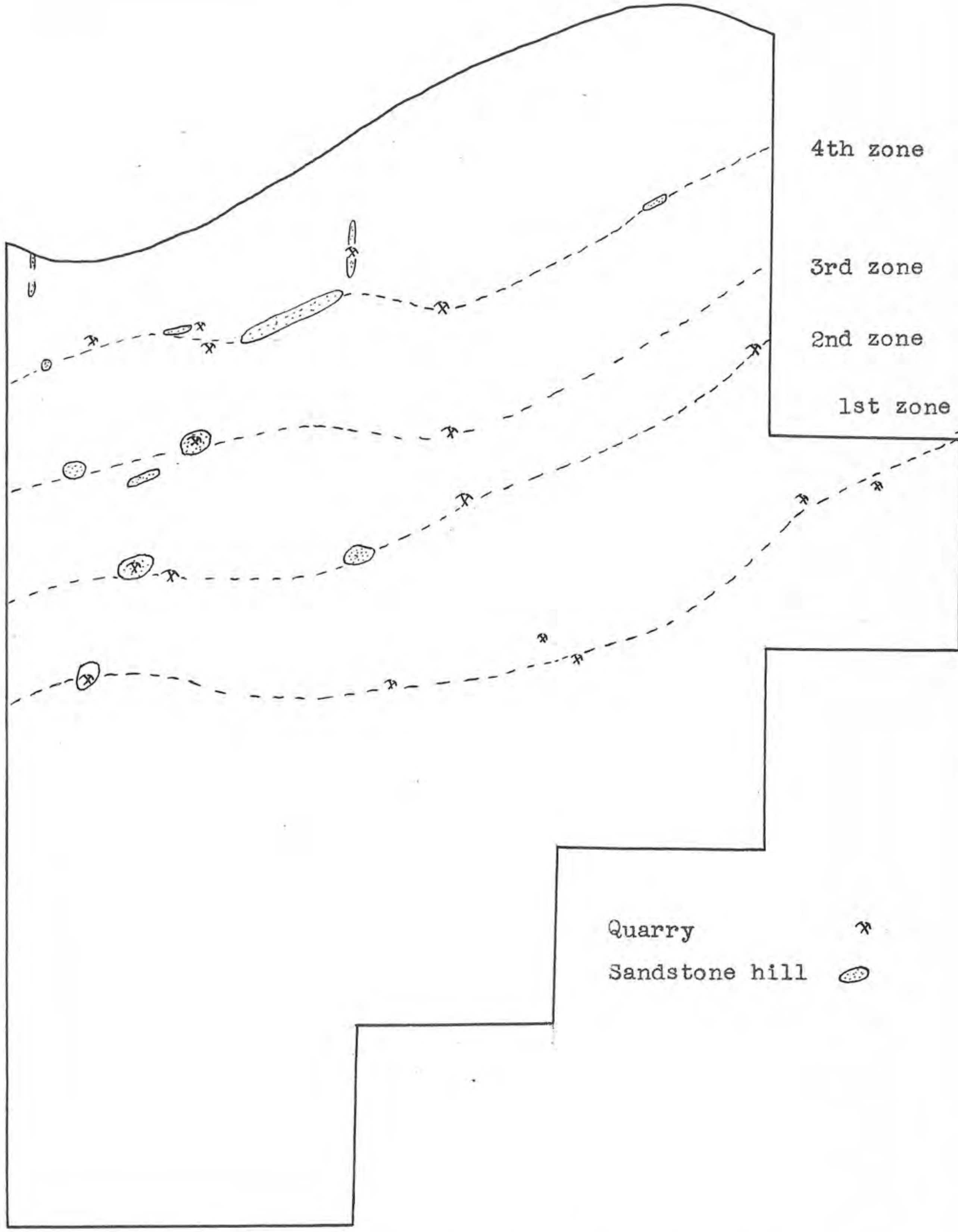

Fig. 3. Map of Lorain County showing zonal distribution of quarries and prominent sandstone hills.

Cleveland shales. Fragments of the resistant Cleveland shale were occasionally torn loose from the banks and transported with the other river sediments. Two remnants of these river valleys are preserved, one at South Lorain and the other one mile east of Vermilion. The shore line was one of gradual submergence. Some of the sediments remained in the river beds, but most were dumped at the mouths of the rivers. However, the sea was so shallow that deltas were not formed. The sediments were sorted and distributed by eastward-moving longshore currents, waves, and wind. When a deposit was large enough, the heavy sand sank into the lighter underlying soft clay, crumpling the clay, producing the mudflow structure in the basal sands, and occasionally rolling bits of the sandstone into the clay. This sinking provided room for more sand accumulation, and thus lenses of sand were formed. The sinking of the sand was so slow that all internal structures were preserved; only the lower and the side surfaces were distorted. The sea advanced with at least four major halts. During these halts sands were deposited at the mouths of rivers, sorted, transported a short distance, and redeposited to form lenses. Each major halt is recorded in an east-west zone of lenses. Each major southward flowing stream is recorded in a north-south series of lenses. As the sea advanced, it covered or removed these littoral and shallow water deposits. The only traces we now have of these river valleys are in the bottoms of the deepest lenses and in the two northward extending arms of sandstone.

This hypothesis differs from the preceding ones only in making the Berea sandstone lenses due both to deposition in post Bedford erosion valleys and to the gradual sinking of the heavy sand into the soft mud as deposition continued.

The Berea sandstone is the most valuable rock in this section of the state. Its greatest commercial use is as a building stone. In part III its economic phase is given in more detail. Its second greatest commercial use is due to its porosity. At Belden small amounts of oil have been found in the sandstone. This is the oil-bearing stratum most commonly sought in the oil fields of southeast Ohio. The Berea may have contained oil northwest of Belden at one time, but any amounts which accumulated have escaped because there is no capping of an impervious shale to hold the oil. Very good drinking water is found in most of the sandstone. The abandoned quarries are nearly all filled with water and those now in operation have ample supplies of good water for the quarry men. Its porosity has its disadvantages, too. At South Amherst the active quarries lower the water table a great deal, so much so that at some places nearby wells have gone dry.

Cuyahoga Group (Mississippian)

Between the Cuyahoga group proper and the Berea sandstone are strata once called Sunbury shale. However, the formation is very thin in this county and has all been mapped with the basal member of the Cuyahoga group.

The term "Cuyahoga group" was originally applied to the next younger formations which underlie the Sharon conglomerate (Pennsylvanian). In 1903, C. S. Prosser[30]

[30] Prosser, C. S., Nomenclature of the Ohio formation: Jour. Geol., vol. 11, pp. 520-521, 1903.

decided that "possibly later studies may decide that for eastern Ohio it will be better to drop the name 'Cuyahoga formation' and use the classification of western Pennsylvania for the rocks between the top of the Berea grit and the base of the Sharon conglomerate, which in ascending order are Orangeville shale, Sharpsville sandstone, Meadville shales, and Shenango sandstone, all named and described by Dr. I. C. White in 1880, with the exception of the Meadville shale which was described and named in 1881".

Orangeville Shale (Mississippian)

The Orangeville shale was named by I. C. White[31] from exposures of soft dark shale at Orangeville on the Ohio-Pennsylvania line. The formation is essentially a soft thin-bedded grey shale much resembling the blue Bedford in appearance. Its basal contact was not found in Lorain County. At Berea, a few miles to the east in Cuyahoga County, the base was found to consist of a sandy pyrite zone, a few inches thick, overlain by soft grey shales containing many specimens of Orbiculoidea and Lingula. Gypsum stars are very common as well as efflorescences of alum and other sulfates. Its exposures in the county are limited to one or two square miles in the southeastern and eastern parts of Columbia Township, where it is exposed by tributaries of the Rocky River. It is also known by well records to occur in the southern part of the county in a band extending northeast and southwest through Wellington, Belden, and Columbia Center. The exact nature of the shale and the exact area that it covers in these places are not known because glacial till covers it quite completely. Well records describe

[31] Second Geol. Survey of Penn., Rept. of Progress in 1878, QQQ, p. 63.

it merely as grey, black, or blue shale. The log of one well, two and a half miles south of Huntington--no. 23, part IV of this report, has given it a thickness of 274 ft. In its outcrops in Columbia Township the Orangeville is a homogeneous, thin-bedded, grey shale, forming steep banks where stream cutting has been recent and soil-covered slopes elsewhere. Numerous springs issue from its upper contact, because the ground water is unable to seep down into the shale.

At Berea one and one-half miles northeast of the county line, in Cuyahoga County, the shale was found to be quite fossiliferous. It therefore should be fossiliferous within Lorain County, but lack of exposures is a handicap to investigation.

Sharpsville Sandstone (Mississippian)

The Sharpsville formation was named by I. C. White[32]

[32]Second Geol. Survey of Penn., Rept. of Progress in 1878, QQQ, pp. 61-62.

from an exposure of alternating beds of sandstone and shale and a bed of limestone near the base at Sharpsville, Pennsylvania. The Sharpsville sandstone is characterized by a series of alternating grey shale and flagstone. The latter is a fine-grained siltstone, very resistant to weathering. Sphalerite is found in concretions at some horizons.

The only known exposure of this formation in Lorain County is in the southeasternmost section of Columbia Township, although it may occur beneath till in the southern part of the county. The Sharpsville has been estimated to be about 40 ft. thick.

In Columbia Township it forms a few small waterfalls in one of the tributaries to Rocky River. Numerous boulders of this hard sandstone are strewn along the creek bed downstream from the exposure for a distance of half a mile. The surface of the layers is usually marked by the "rooster tail" structure which in this county is limited to this formation. The structure consists of spirally radiating lines which form a pattern about four inches across. The origin of this structure is not known. It may have been formed by a sea weed, twisted about on its stem by the currents and leaving trails on the sand surface near its base.[33]

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[33]Alluded to in Second Geol. Survey of Penn., Rept. of Progress in 1878, QQQ, p. 61.

Remains of fucoids also, are common; they form rods about half an inch in diameter and are several inches long. The exposure examined (fig. 1, plate VI) was strongly jointed in two directions at right angles. The extremely rigid sandstone could meet stresses in no other way. No fossils were found at this locality.

The formation has no known commercial use.

Meadville Shale (Mississippian)

The Meadville shale was named by I. C. White[34] from exposures at Meadville, Penn. It is the upper member of the Cuyahoga group. The Meadville shale is a soft blue shale resembling the blue Bedford and the Orangeville shale, but it contains sandy layers, much muscovite, and many concentric clay concretions. Certain phases are highly fossiliferous. In Lorain County it outcrops in the southeastern two sections of Columbia Township and in a band of undetermined width extending east and west of Huntington. In various localities the strata are either horizontal, tilted slightly to the east, or locally sharply folded. The thickness of the shale is not known; 113 feet at least, is reported in the well of Orin Dirlan near the southern county line (no. 34 on plate II, and in Part IV). Since the included concretions seem to be cored with rounded Sharpsville siltstone fragments, there is probably an erosional unconformity between the Sharpsville and the Meadville.

[34] Second Geol. Survey of Penn., Rept. of Progress in 1878, QQQ, p. 61.

A highly fossiliferous phase was found in a creek bank one-third of a mile west of Huntington. Some of the fossils appear in fig. 2, plate VI.

Section in creek one-third mile west of Huntington

3.	Soft brown shale.	1 ft. 6 in.
2.	Very fossiliferous shale zone. Contains *Fenestella* and brachiopods of the *Spirifer* type.	1 in.
1.	Alternating bands of soft shale and siltstone less than an inch to two inches in thickness. Seaweed fossils on the surface of the siltstone. The siltstone contains large amounts of mica.	4 ft.
	Total	5 ft. 7 in.

Nearly due east of the above locality one-half mile south of Spencer in Medina County a horizon much resembling this one is exposed in the bluff of Coon Creek. The bryozoan (*Fenestella*) is a very common fossil and marks most of the fossiliferous horizons. Among other horizons are a few pelecypods, several brachiopods, and numerous remains of trilobites which probably belong to the genus *Phillipsia*.

At Dirlan's store two miles southwest of Huntington another outcrop yielded *Fenestella* but no other fossils.

This formation has no known commercial use.

SUMMARY

The stratigraphy of Lorain County is mapped from field observations and from quarry and well records. Advice has been sought from both geologists and well drillers familiar with the area. Much of this report is based upon their data and their interpretations.

It is found that large areas of bed rock, hitherto assigned to the Berea sandstone, do not contain this formation. It is also concluded that the Berea sandstone was formed largely as a beach deposit on the edge of a sea which advanced from the south and from the southeast with at least three major halts. During these halts large lenses of sand were deposited, (the heavier sand sank into the soft mud). Each formation is described and its area of outcrop is estimated. A few descriptions of individual quarries and a tabulation of a number of well records supplement the report.

Among problems yet to be solved are:

1. Is the evidence of a disconformity at the base of the Berea conclusive?

2. What forces caused folding in most of the strata and in which directions were they applied?

3. Is the base of the Mississippian system at the base of the Cleveland? Further heavy mineral analyses

and paleontological collections will help to establish the ages of the strata with exactness.

4. Is there any symmetry in pattern of the inliers of Bedford shale in the Berea sandstone? Was the Berea eroded away or was it never deposited at these places?

THE PALEOZOIC STRATIGRAPHY OF LORAIN COUNTY, OHIO

PART III

QUARRIES OF LORAIN COUNTY

THE PALEOZOIC STRATIGRAPHY OF LORAIN COUNTY, OHIO

PART III

QUARRIES OF LORAIN COUNTY

INTRODUCTION

The most economically important stratum of the county is the Berea sandstone, which has been quarried extensively. Rock from no other formation is quarried.

Much of the following material is taken from "Building stones of Ohio" by J. A. Bownocker, Geological Survey of Ohio, 4th series, Bulletin 18, (1915), pp. 72-99.

All of the quarries mentioned have been visited. In addition to the quarries mentioned in the above bulletin a number of newer and of less important ones have been added.

For over a century the Berea sandstone has been quarried for building stones, grindstones, sidewalks, and other uses. The sandstone seems to occur in lenses, reaching a maximum known thickness of 225 feet in Buckeye Quarry in South Amherst (Amherst on the map). In many other places it is completely lacking. This has led quarrymen to speak of the sandstone as forming islands (for they are very uncertain of its extent).

Practically all of the quarries, both those now in operation and those abandoned, are in sandstone lenses, and a study of the sandstone, if limited to these quarries, leads to a false impression of its abundance. Because of its great resistance to erosion as compared with that of the shales, the sandstone forms most of the exposed bedrock of the county where it occurs near the surface.

Quarrying is carried on both by blasting and by channeling-machines, depending on the type of rock and the ultimate product. The former is for rip-rap; the latter is for dressed stone, including building blocks, sidewalks, and grindstones.

The sandstone is usually nearly pure silica. Minor amounts of alumina and of ferric iron also occur. The only objectionable bodies are iron compounds in the form of nodules ranging from the size of a grain up to several inches in diameter. Upon weathering, the iron decomposition products form ugly brown blotches, nearly ruining the block containing them for a building stone. Films or thin layers of carbonaceous material also exist and may ruin the stone for building and most other purposes. It is coarse-grained to fine-grained; pebbles are extremely rare.

The color is generally a uniform buff when the sandstone has been long exposed at the surface of the earth or covered with thin drift. The normal color is due to oxidation and hydration of iron or iron compounds. The unexposed lower portions are blue-grey approaching white. The blue-grey usually becomes buff in buildings and is displeasing when not uniform.

Quarry usage has divided the sandstone into five types on the basis of structure. Shell-rock consists of thin layers whose surfaces are at low angles or are parallel. It is always buff in color. This structure is due both to breaks in deposition and to subsequent weathering. It is usually found near the surface. The maximum thickness is 32 feet in the Schirben quarry four and a half miles west of Oberlin. Such rock is used only for ballast and similar purposes.

Split rock is rock which splits into thin layers. It shows distinct lines parallel to the bedding plane and is due to deposition of sand in even layers. It is used for all purposes to which the Berea is adapted.

Liver rock is a homogeneous mass in which the sand grains were not oriented or sorted at the time of deposition. It works as easily in one direction as in another and is especially suited for grindstones.

Spider-web is similar to split-rock except that fine cross-bedding has made the lines of deposition at various angles to the bedding. It is good for grindstones, building stones, curbings, and flaggings. The best examples are at South Amherst 25 to 50 feet below the surface.

Cross-bedded or "cross-grained" rock, as the quarrymen call it, is very common in most of the quarries and is rock in which the beds run in straight or slightly curved lines with frequent changes in direction of strike and dip. The irregularity of the bedding is due (1) to an initially uneven or a sinking bed, (the beds in the center of a sinking lens would remain horizontal but marginal strata would be tilted), (2) to depositing currents whose velocities and directions changed (they may have been long shore currents), and (3) to continually changing sources of sediments. Cross-bedded sandstone is used for grindstones and structural purposes.

The crushing and transverse strength is about the same in all directions except in spider-rock in which the edge is weaker than the bed. At South Amherst the apparent specific gravity of the dry sandstone varies from 2.143 in spider-rock to 2.189 in split-rock. The porosity (per cent of the block which the pores occupy) varies from 16.23 % in spider-rock to 15.87 % in split-rock.[35]

[35]Bowkocker, J. A., Building stones of Ohio: Geol. Survey of Ohio, 4th ser., Bull. 18, p. 77, 1915.

The Berea sandstone is usually massive. This makes quarrying of blocks of almost any desired size easy. Horizontal breaks are few and discontinuous. Vertical breaks are still less common. "Cutters" (cracks at sharp angles) visible by oxidation (buff), or by vein deposition of silica (grey), or at times invisible frequently make the rock useless except for rip-rap. These fissures frequently yield streams of water, excellent for drinking purposes.

The dips in nearly all quarries vary, forming local basins or domes, due either (1) to the original deposition of the sands in sinking lenses or (2) to subsequent crustal movements.

INDIVIDUAL TOWNSHIPS

Brownhelm Township

One mile northwest of Brownhelm the first Berea sandstone quarry[36] in this part of the state was opened.

[36]Carney, Frank, The abandoned shorelines of the Vermilion Quadrangle, Ohio: Denison Univ., Sci. Lab., Bull. 16, p. 244, 1910-11.

It is now the property of the Cleveland Quarries Company and is abandoned. About fifty feet of sandstone are exposed, grading both laterally and vertically from massive beds to shell rock. The beds dip toward the south. Cross-bedding and ripple-marks show that the sandstone was deposited under disturbed near-shore conditions.

Black River Township

Near the southern limits of Lorain an old abandoned quarry has been converted into a city park with a swimming pool located in the old pit. The quarry was in an arm of sandstone which extended northward into the region of black Cleveland shale. This arm is anticlinal with a north-south axis. At no place is it more than a few hundred feet wide.

Amherst Township

"Approximately one and one-half miles west from (North) Amherst is the quarry of the Breakwater Company. This was opened about 1904 by the Independence Stone Company, who disposed of it, perhaps in 1909, to the present holders".[37]

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[37] Bownocker, J. A., Ibid., p. 94.

Section in quarry of Breakwater Co., North Amherst.

Glacial Drift.	2 ft.
Berea Sandstone	
Shell-rock, (thin, parallel beds).	2-12 ft.
Split-rock, (very thin even beds). Sawed for flagging; used also for capping in breakwater.	1/2-4 ft.
Cross-grained (cross-bedded). Used for breakwater purposes.	6-8 ft.
Spider-web (very thin-bedded with fine cross-bedding). Sawed for flagging; also used for breakwater.	8 ft.
Sandstone and soapstone (shale). Worthless.	2 ft.
Spider-web (very thin-bedded with fine cross-bedding). Sawed for flagging; also used for breakwater.	3 ft.
Bedford Shales	

"The stone in this quarry is used for two purposes, flagging and breakwater. Formerly it was a source also of building stone, curbing, and grindstones. Much of it, however, was not suited to these, and gradually its use was restricted to flagging and breakwater ... The stone varies in structure, and in places large proportions are cross-bedded. Ripple marks are common, and the stone dips at a sharp angle, occasionally thirty degrees ... shale is included in the rock. From what has been stated it is clear that the rock in this quarry is not first class, but it answers the purposes for breakwater, and the best of it yields excellent flagging. When the Independence Stone Co. started work in this locality, operations were about 1,500 feet west of the present quarry. At that place 75 feet of rock were worked without reaching the base of the formation. The poor quality of the stone caused its abandonment and the opening of the present quarry".[38]

[38]Bownocker, J. A., Ibid., p. 94.

The ridge immediately to the northwest is also of sandstone. Numerous small pits show where quarrying on a small scale has been attempted along this ridge.

"Two miles northeast of Amherst is a quarry that was closed or abandoned in 1911. It belongs to the Cleveland Stone Co., and was a large source of grindstones. The formation at the top consists of 12 ft. of shell-rock, succeeded by five feet of cross-bedded, which in turn is underlain with an equal thickness of a rotten or shaly variety of stone. The formation at greater depths was concealed by water. The quality of this stone appears unfavorable and doubtless it was this that closed the quarry".[39] The sandstone is white to buff, and fragments

[39]Bownocker, J. A., Ibid., p. 95.

collected contain fine to very fine, rounded grains. Assortment is rather poor. Specks of brown hematite are common. The beds are cut by high angle joints and dip toward the southeast.

About halfway between North and South Amherst there is a small abandoned quarry measuring about 100 ft. by 50 ft. by 10 ft. The sandstone is coarse-grained and friable. A few feet away Bedford shale is the bedrock. This is just another case of a small lens of sandstone, yielding a rock thick enough for a quarry.

South Amherst is "the most important locality for quarrying the Berea sandstone in Ohio. It is also the principal source of building stone from the Berea horizon for the rock is freer from iron spots than at any other place in Ohio. The sandstone in places is barely covered with drift ... ".[40]

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[40] Bownocker, J. A., Ibid., pp. 91-94.

Section in the No. 6 Quarry of the Cleveland Stone Co. at South Amherst

3.	Glacial Drift.	4-10 ft.
2.	Berea Sandstone	
	Shell-rock (thin, parallel beds).	15-20 ft.
	Buff rock, in places shelly.	10 ft.
	Discolored rock. Buff with brown spots.	8 ft.
	Spider-web (very thin-bedded with fine cross-bedding).	16 ft.
	Cross-bedded.	10 ft.
	Split-rock, (very thin even beds). This is marketed under the name "Grey Canyon sandstone".	25-30 ft.
	Cross-bedded.	12 ft.
	Split-rock (very thin even beds). "Grey Canyon sandstone".	26 ft.
	Spider-web (very thin-bedded with fine cross-bedding). "Grey Canyon sandstone".	10-12 ft.
1.	Base of quarry (not Berea). Total	134-152 ft.

"As the section shows, the top of the rock is shelly, but below that it is massive. This (exposure) contains numerous horizontal cracks which extend for perhaps fifty feet and then disappear ... Vertical cracks known as seams are present, but they are neither conspicuous nor numerous and play but little part in quarrying ... ".[41]

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[41]Bownocker, J. A., Ibid., pp. 91-94.

"The color of the stone varies. Not being covered with shales or any other impervious body, the upper part of the sandstone has been oxidized to a buff, whose shade varies horizontally and vertically. Below the discolored bed the rock is everywhere blue-grey, and the shade is uniform.

"Section in Buckeye Quarry, South Amherst

Glacial Drift.	4-10 ft.
Berea Sandstone	
Shell-rock, (thin, parallel beds).	6-15 ft.
Spider-web, (very thin-bedded with fine cross-bedding).	35-40 ft.
Split-rock, (very thin even beds).	15-35 ft.
Cross-bedded.	8-25 ft.
Spider-web (very thin-bedded with fine cross-bedding).	6-12 ft.
Split-rock, (very thin even beds).	95 ft.
Cross-bedded and with dark spots.	6 ft.
Total	212 ft.

"The above section represents the rock as seen in the east end of the quarry. The shell-rock is buff and all below is blue-grey. However, in the west end of the quarry, ten feet of good buff were found, though in the northwest corner the same bed was blue-grey. The rock changes more rapidly in ... (structure) than it does in color, split-rock to spider-rock or cross-bedded, and vice versa, so that it is not possible to forecast many feet in advance what the nature of the rock will be.

"Hard spots, called "hard heads" by the workmen, are occasionally found. They may have the same color as the enclosing rock, that is, blue-grey, or rarely buff or brown. They are always harder than the body of the rock. (This is probably due to a better cementation--a concentration of pyrite). Small dark "bird shot" or "buck shot" are occasionally found. As may be surmised, these are small concretions of iron (probably pyrite) and are highly objectionable where the stone is used for building purposes".[42]

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[42]Bownocker, J. A., Ibid., pp. 91-94.

In the Buckeye Quarry at South Amherst "cracks are uncommon and appear to be most numerous at depth. Cutters or closed cracks are occasionally found, especially in the west end of the quarry, and their color is buff or light grey. The dip of the rock is from the two ends of the quarry toward the center. What was said about horizontal cracks in the No. 6 Quarry applies equally well to this one ... Black carbonaceous films or thin layers are occasionally found in all these quarries ... The maximum thickness of the sandstone found in the Buckeye Quarry is given at 212 feet. All in all, it is the finest deposit of this kind of rock known in Ohio".[43] In 1936, 225 feet

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[43]Bownocker, J. A., Ibid., pp. 91-94.

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of sandstone had been quarried in the Buckeye Quarry.

Elyria Township

One half mile southwest of Vincent is a moderately-sized abandoned quarry of very fine-grained sandstone. It is on the southwest limb of an anticline, the beds striking about N. 50° W., and ranging in dip from 10° to 20° SW. About eight feet are exposed above the water level. The upper layers contain ripple marks, four inches in width, formed by eastward-moving currents. The quarry is near the easternmost end of a prominent sandstone ridge.

Along the northwest edge of Elyria one block north and one block west of the B and O depot is Quarry No. 20

of the Cleveland Stone Company. The rock is massive and cross-bedded. In 1937 the quarry had been abandoned for some time and the walls were blackened. Several acres had been exposed by shallow quarrying. The glacial covering is not more than ten or fifteen feet thick. As a result the sandstone has weathered to a buff color. The sandstone is friable. Its grains are poorly sorted.

A few blocks to the south on the west side of the railroad tracks is a small quarry measuring about 100 ft. by 200 ft. It is reported to be quite deep. Massive grey sandstone blocks surround the edges. It was abandoned in 1929 and is now completely filled with water.

On the bank of the West Branch of the Black River in Elyria is a quarry marked by a depression on the topographic map. Sandstone forms the riverbed nearby. The beds grade from massive to thin-bedded and all in this exposure dip towards the west. The quarry is now abandoned and the rock surfaces are blackened by smoke.

Ridgeville Township

"Quarry No. 2 of the Middleburg Stone Co. is located about three miles northeast of Ridgeville, Lorain County ... The product is buff stone that is used for making large grindstones. The glacial drift varies from one to three feet in thickness, and below this lies from four to six feet of the desired buff liver-rock (massive with unsorted grains) though in places it changes to the cross-bedded variety. Beneath this is found from two to four feet of shell-rock (thin- parallel beds), and then the blue-grey variety, which doubtless continues (down) to the base of the formation. Only the buff stone, which lies immediately below the glacial drift, is quarried".[44] In 1937 this quarry, also, was abandoned and was filled with rubbish and water. The beds are horizontal and massive. The stone is quite friable. This quality would account for its greater use as a grindstone than as a building stone.

[44] Bownocker, J. A., Ibid., pp. 98-99.

Henrietta Township

About four and a half miles northwest of Oberlin is Quarry No. 18 of the Cleveland Stone Co., known also as the Schirben Quarry. Formerly, it was known as the Kipton Quarry and references to the Kipton Quarry in the geologic literature of the state refer to this quarry. It is shown on the topographic map of this region. However, another quarry has been opened on the edge of Kipton and is now commonly known as the Kipton Quarry.

"This plant was opened about 1889 by the landowner, Marshall Schirben, who quarried building and bridge stone, but in 1896 he sold the property to the Cleveland Stone Co., who now own almost 200 acres at this place.

Section in the Schirben Quarry

Glacial Drift.	3 ft.
Berea Sandstone	
Shell-rock (thin, parallel beds). Buff color with numerous brown iron streaks. Used for ballast and breakwater.	32 ft.
Split-rock (very thin, even beds). Has too many carbonaceous streaks for building stone. In places this becomes cross-bedded.	30 ft.
Spider-web (very thin-bedded with fine cross-bedding) ... Contains numerous flakes of white mica.	$7\frac{1}{2}$ ft."[45]

[45]Bownocker, J. A., Ibid., p. 96.

The quarry is now abandoned and entirely covered by water except the upper fifteen feet. There the strata dip slightly in various directions and form part of a dome. Work was stopped about 1913 because the stone was too friable.

Russia Township

A mile and a half east of the Schirben Quarry is a small abandoned quarry measuring about 75 ft. by 50 ft. by 8 ft. Two feet of till covers the top. The sandstone is coarse-grained and friable. The beds dip slightly northward. An abandoned quarry is reported to have existed on the southeast edge of Oberlin, but it must have been small. No traces of it remain now.

Carlisle Township

About one mile northwest of Grafton is Quarry No. 24 of the Cleveland Stone Co.[46] The quarry is shallow, twenty feet deep on the average, and covers an area of several acres.

A small quarry located four miles west of Laporte has been abandoned and all except one foot is covered with water. The part that is exposed is massive and horizontally bedded. It forms part of a sandstone ridge extending north and south for several miles.

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[46] A good description is given in Ohio Geol. Survey Bulletin 18 by Bownocker. Little can be added except that the quarry was abandoned some twenty-odd years ago because of its inferior stone as compared with that of South Amherst.

Columbia Township

About one-half mile northeast of Columbia Station is the quarry of the Columbia Stone Co. Bownocker in bulletin 18 of the Ohio Geol. Survey gives a good section of the quarry and adds ... "In a number of places unusual breaks for the Berea sandstone were found. These consisted of beds of shales from six inches to three feet in thickness, with ... (inclusions) of sandstone, some angular and others rounded. Some of these pieces are brown with iron stains, and others show a concretionary structure. The masses cut across the sandstone to a depth of perhaps six feet, at an angle of from ten to twenty degrees. The contact with the sandstone above and below is very uneven, and in places the transition from shale to sandstone is sharp, while in other places it is gradual". The inclusions of concretionary sandstone of which he speaks are probably basal Berea. The quarry now belongs to the Cut Stone Columbia Stone Company of Cleveland. Active quarrying has ceased although rock already quarried is still being dressed and sold. 135 feet are exposed. The high grade of the stone is due to its ability to be cut in any direction. The upper layers are not thin-bedded, --perhaps due to protection from weathering by the thick drift. The strata are horizontal and in some of the lower portions have crumbled away. Perhaps this is due to the included shale layers. The sandstone is grey, friable, and glistens in the sunlight due to the crystalline quartz grains. There are also many grains of pink and green minerals. The color and the glistening property make it a beautiful building stone.

A quarry a few feet to the east is filled with water, but blocks lining its edge are of the same type as the other.

Three miles north of Copopa the Cleveland Stone Quarries Company owns a quarry on the east bank of the Rocky River. The sandstone is grey and massive. Among the beds were found bands of carbonized fossils, of fine conglomerate, of shale, and layers containing brachiopods, plant fossils, and pyrite concretions. The quarry has been recently worked.

Camden Township

A quarter of a mile northeast of Kipton a quarry has been opened in the top of a sandstone hill. Figures 3 and 4, plate IV are photographs of parts of the quarry. The rock is quite white on fresh surfaces and can easily be ground up into a pure, fine, white sand. Grindstones are the chief product. Work in the quarry has been temporarily stopped. At the north end of the quarry the contact between the rock and the soil is very sharp due to glacial scour. About thirty-five feet below the top is a thin zone made up largely of carbonized plant fossils. This zone is widespread although other zones may occur. Numerous lenses of conglomerate are found in the upper half of the quarry. The matrix is of friable white sandstone, and the pebbles are of shale and siltstone, two to three inches in diameter being the average size. The shale is usually red and sandy. It is saturated with iron compounds and resembles balls of clay. Because of its higher sand and iron content the shale does not resemble the soft Bedford shale, but looks more like argillaceous travertine or dripstone.

In the Kipton Quarry about fifteen feet below the top of the south wall a lens of black, coarse-bedded shale (probably Cleveland) was found. The lens shape of the sandstone is well shown by its base. At the extreme southern part of the exposure, the sandstone is tilted upwards and acquires a mud-flow structure. South of it are about four feet of soft grey shale and then about twenty feet of exposed Bedford shale. The shales are much distorted. A further description is given on page 37 of this paper. At the base of the west wall is a horizon of ripple-marked shaly sandstone dipping slightly northward. The ripples are about five inches wide and were made by an eastward-moving current.

La Grange Township

About four miles southeast of Oberlin is a quarry generally known as the Nickel Plate Quarry. It is located on Elk Creek about a mile from the West Branch of the Black River. A section and an accompanying description are given by Bownocker in the Ohio Geol. Survey, bulletin 18. The quarry is abandoned at the present time and all except five feet is covered with water. In a small quarry a few feet to the west the rock is massive, white to grey, and contains red bands of hematitic sandstone. Float contains three inch thick bands of pyrite such as is usually found at the extreme top or at the base of the Berea formation. It is quite likely that almost none of the formation has been removed by erosion at this place and that the entire section still remains.

Grafton Township

On the southeast side of Grafton is an abandoned quarry. At one time it was 180 feet deep , but now it is filled with water. The strata are nearly horizontal although there are a few very gentle dips. The bedding is massive at depths and thin-bedded near the surface. The lack of more thin beds may be due to the fact that most pre-glacial surface thin beds would tend to be scoured away by the ice sheets.

THE PALEOZOIC STRATIGRAPHY OF LORAIN COUNTY, OHIO

PART IV

<u>WELL RECORDS OF LORAIN COUNTY</u>

WELL RECORDS OF LORAIN COUNTY

In order to supplement information gained from quarries and natural exposures the following well records were collected. They were very useful in determining the thicknesses and the outcrop areas of the various formations. Each well is located on the map, plate II, by the number given here.

Ridgeville Township

1. M. and H. Standen, 1/4 mile north of Sugar Ridge (1930); /Ohio Geol. Survey office records/.

Formation	Description	Thickness	Total Thickness
Glacial	Shale, grey, soft	40 ft.	40 ft.
Berea	Sand, grey, hard	20	60
Bedford	Shale, red, soft	5	65
	Shale, grey, hard	10	75
	Shale, red, soft	25	100
Bedford and Cleveland	Shale, black, soft	200	300
Chagrin	Shale, white, soft	175	475

2. Chas. S. Mills, corner of Case Road and Middle Ridge (1899); /Notes of A. A. Wright, Oberlin College, 1901-1903/.

Formation	Description	Thickness	Total Thickness
Glacial	Drift clay	50 ft.	50 ft.
Berea	Sandstone	2	52
Bedford	Red clay	48	100
Cleveland	Black shale	160	260
Chagrin	"Erie" grey shale	170	430
Huron	Brown shale	200	630
	Black shale, hard	130	760
	"Erie" and "Huron" (grey and brown)	40	800

Avon Township

3. Kenzel, No. 1, SE 1/4 of Avon Township /Taken from: Bownocker, J. A. The Bremen oil field: Geol. Survey of Ohio, 4th ser., Bull. 12, pp. 63-64, 1910 (exact location not known)/.

Formation	Description	Thickness	Total Thickness
	Drive pipe	63 ft.	63 ft.
Bedford and Ohio	Shales	957	1020
Delaware and below	"Big lime"	1325	2345
Clinton	Clinton sand		2420
	Bottom of well		2480

(No Berea is found here)

Sheffield Township

4. West of Avon near the Lorain and Electric Railroad, 1/2 mile from the southern line of the township; [Taken from: Bownocker, Ibid., pp. 63-64].

Formation	Description	Thickness	Total Thickness
Glacial and Ohio	Shales and drift	840 ft.	840 ft.
Delaware and below	"Big lime"	1230	2070
Clinton	Sand		2204
	Bottom of well		2405

5. Sheffield on the lake shore; [Taken from: Report of the Geological Survey of Ohio, Vol. VI, Economic Geology, p. 437, 1888]. (Exact location not known, probably at Lake Breeze).

Formation	Description	Thickness	Total Thickness
Cleveland and Chagrin	Black shale	280 ft.	280 ft.
	Light-blue and grey shales	110	390
	Light-grey shale, soft	15	405
Huron	Black shale, very hard	10	415
	Reddish-brown shale	84	499
	Black shale, hard	10	509
	Light-grey shale, soft	40	549
	Dark-grey shale	25	574
	Darker shale	23	597
Olentangy	Dark impure limestone, filled with minute shells of pyrite	17	614
	Soft, light-grey shale	18	632
	Dark-grey shale	41	673

Gas was found all the way down but no more than traces of oil. 182 feet of limestone which contained salt water were next penetrated.

Brownhelm Township

6. Brownhelm Hollow, in the valley of the Vermilion River; [Taken from: Report of the Geological Survey of Ohio, Vol. VI, Economic Geology, pp. 437-438, 1888]. (Exact location not known, probably at Rugby).

Formation	Description	Thickness	Total Thickness
Cleveland and Chagrin	Shales, mixed black and blue	60 ft.	60 ft.
	Shales, black or brown (gas and brine at 150 ft.)	90	150
Huron	Black shale	60	210
	Blue and soft shale	30	240
	Brown shale	6	246
	Blue and brown shale, mixed	27	273
	Blue shale	8	281
	Very dark shale	40	321
	Reddish-brown shale	30	351
	Blue shale	6	357
	Slate mixed, blue and brown	53	410
Olentangy	"Soapstone"	100	510

Amherst Township

7. Swartz Well No. 2, 2 1/2 miles east and 1/4 mile south of South Amherst (Amherst on the map), a few feet northeast of road Y. (1901-1902); [Notes of Prof. A. A. Wright, Oberlin, 1901-1903].

Formation	Description	Thickness	Total Thickness
Glacial	Drift	30 ft.	30 ft.
Berea	Sandstone	80	110
Bedford	Red shale, mud, dry	65	175
Cleveland	Black shale	100	275
Chagrin	Grey shale	150	425
Huron	Black shale	125	550
	Grey shale	50	600
	Black shale	120	720
Olentangy	Grey shale	130	850
Delaware	Shell limestone	12	862
	White shale	48	910
	Limestone, white	298	1208
?	Sand rock, water	42	1250
	Limestone, darker	65	1315
	Shale	5	1320
	Limestone, light	110	1430

Bottom still in limestone. No gas or oil gained below about 1200 feet. Fair gas at 1200 feet, equals 2000 to 3000 cu. ft. per day.

Russia Township

8. E. P. Johnson, 111 Forest St., Oberlin, Ohio (1901); /A. A. Wright, Ibid, p. 37.

Formation	Description	Thick-ness	Total Thick-ness
Glacial	Yellow clay	8 ft.	8 ft.
	Blue clay	40	48
	Red clay, Bedford in drift	13	61
Berea	Sandstone, solid	30	91
	Shelly sandstone and mixed red and blue mud	22	113
	Sandstone	17	130
Bedford	Light grey shale	18	148
Cleveland	Black shale, sharp line	102	250
Chagrin	Grey shale	98	348
Huron?	Brown shale	120	468
	Lighter shale	70	538
	Black shale	14	552
	Light shale	28	580
	Brown shale	147	727
Olentangy	White shale "soapstone"	148	875
Delaware	Limestone, 10 ft. to bottom of well		885

A promising supply of gas at two or more levels.

9. T. H. Rowland's well in rear of 41 S. Main St., Oberlin (1901); [A. A. Wright, Ibid, p. 57].

Formation	Description	Thickness	Total Thickness
Glacial	Drift clay. No red.	42 ft.	42 ft.
Berea	Sandstone	8	50
Bedford	Red clay	65	115
	White, solid gritty stuff	25	140
	Soft light shale	10	150
Cleveland	Black shale		
	Brown shale		

10. J. W. Steele, 420 E. College St., Oberlin; [A. A. Wright, Ibid, p. 57].

Formation	Description	Thickness	Total Thickness
Glacial	Drift	38 ft.	38 ft.
Berea	Sandstone	76	114
Down to Delaware			878
Delaware	Bottom of well in Delaware limestone	12	890

11. J. B. Hart, 130 N. Main St., Oberlin (1902);
[A. A. Wright, Ibid., p. 19].

Formation	Description	Thickness	Total Thickness
Glacial	Yellow clay	10 ft.	10 ft.
	Blue clay	27	37
Berea	Shell sandstone	7	44
	Good sandstone	15	59
	Solid sandstone with some hard streaks	86	145
	Clay, grey then brown	5	150
	Sandstone tough	55	205
Cleveland	Grey clay shale	11	216
	Black shale	74	290
Chagrin	Grey shale	115	405
Huron?	Black shale	45	450
	White shale	70	520
	Black shale	20	540
	White shale	30	570
	Black shale		

Much water at 60 ft. and below.

12. Prof. Currier, 105 Elm St., Oberlin (1902);

[A. A. Wright, Ibid., p. 17].

Formation	Description	Thick- ness	Total Thick- ness
Glacial	Yellow clay	10 ft.	10 ft.
	Blue clay with gravel	30	40
Berea	Shelly sandstone, Berea	10	50
	Solid sandstone	20	70
	Very hard sandstone	10	80
	Solid sandstone	10	90
Bedford	Red shale	35	125
	Grey or white shale, brittle, with sandstone shells	83	208
Cleveland	Black shale	100	308
Chagrin	White (grey) shale	75	383
Huron	Dark brown shale	67	450
	White grey shale	25	475
	Black shale	15	490
	White grey shale	50	540
	Black grey shale	185	725
Olentangy	White grey shale	150	875
Delaware	Bottom in Delaware limestone	14	889

13. Mrs. Mattles, 166 Elm St., Oberlin (1902);

[A. A. Wright, Ibid.].

Formation	Description	Thickness	Total Thickness
Glacial	Yellow clay	8 ft.	8 ft.
	Blue clay	22	30
	Red clay	13	43
	White clay	10	53
	Red and white, with gravel	12	65
Berea	Sandstone	20	85
Bedford	Red shale	65	150
Cleveland	Black shale	110	260
Chagrin	Bluish shale	90	350
Huron	Black shale	25	375
	Blue shale	50	425
	Black shale	100	525
	Blue shale	75	600
	Black shale	145	745
Olentangy	Grey shale	125	870
Delaware	Bottom in limestone	10	880

Yield 1400 cu. ft. per day.

Columbia Township

14. Well record at Westview, on the town edge; [Bownocker, J. A., Building stones of Ohio: Geol. Survey of Ohio, 4th ser., Bull. 18, p. 89, 1915].

Formation	Description	Thickness	Total Thickness
Glacial	Clay	15 ft.	15 ft.
Berea	Berea sandstone	52	67
Bedford	Shale, red	68	135
	Shale, light	15	150
Cleveland	Shale, "Cleveland"	100	250
Chagrin	"Erie shale"	380	630
Huron	"Huron shale"	386	1016
Olentangy	White shale	39	1055

15. Henry E. Cletzer #1; [Ohio Geological Survey Office].

Formation	Description	Thickness	Total Thickness
?	?	72 ft.	72 ft.
Berea	Sandstone	80	152
Bedford	Slate		

16. Wm. and Ella Rundle; /Ohio Geological Survey Office/.

Formation	Description	Thick-ness	Total Thick-ness
Glacial	?	40 ft.	40 ft.
Berea	Sand and slate	20	60
	Grit	70	130

Pittsfield Township

17. Terry C. Whitney (1930); /Ohio Geological Survey files/.

Formation	Description	Thick-ness	Total Thick-ness
Glacial	Shale and gravel, blue, grey, soft	105 ft.	105 ft.
Bedford	Shale, red, soft	40	145
Cleveland	Shale, black, soft	110	255
Chagrin and below	Alternating grey and brown soft shale	450	730

"Correlated logs of sixteen wells show no sandstone below the drift and above the Ohio and Bedford shales in a triangular area containing two square miles on a side three miles southeast of the square in Oberlin. 78 to 153 ft. of glacial drift is underlain by 740 to 822 ft. of shale including most of the Bedford which is generally greenish or purple and all of the thin-bedded Ohio shale, which is usually black with a bluish or greenish soft phase in the middle portion".[47]

[47]Hubbard, G. D., Gas and oil wells near Oberlin, Ohio: Econ. Geol., vol. 8, pp. 681-690, 1913.

La Grange Township

18. Wm. Schubert (1922); /Ohio Geological Survey files/.

Formation	Description	Thickness	Total Thickness
?	?	20 ft.	20 ft.
Berea	?	20	40

19. Albert Bring (1923); /Ohio Geological Survey files/.

Formation	Description	Thickness	Total Thickness
?	?	70 ft.	70 ft.
Berea	Sandstone	20	90

20. Wesley Tran (1929); /Ohio Geological Survey files/.

Formation	Description	Thickness	Total Thickness
?	?	38 ft.	38 ft.
Berea	?	37	75

21. Charles H. Opfer (1934); /Ohio Geol. Survey office records/.

Formation	Description	Thickness	Total Thickness
Glacial	Sand	30 ft.	30 ft.
	Gravel	15	45
Berea	Sand	10	55
Cleveland?	Slate		

Grafton Township

22. Duke Welburn (1923); [Ohio Geol. Survey office records].

Formation	Description	Thickness	Total Thickness
Glacial and Orangeville	Gravel and sand	43 ft.	43 ft.
	Sand and slate	117	160
Berea	?	30	190
Bedford and below	Slate	1150	1340

23. George Schaefer; [Ohio Geol. Survey office records].

Formation	Description	Thickness	Total Thickness
?	?	110 ft.	110 ft.
Berea	?	245	355

24. Wm. Pfeiffer (1924); [Ohio Geol. Survey office records].

Formation	Description	Thickness	Total Thickness
Glacial	?	17 ft.	17 ft.
Orangeville	Sand and slate	158	175
Berea	Grit	100	275

25. Fred Klinert (1924); /Ohio Geol. Survey office records/.

Formation	Description	Thickness	Total Thickness
Glacial	?	29 ft.	29 ft.
Orangeville	Sand and slate	96	125
Berea	Grit	125	250

26. Generalized section around Belden; /Report of the Geological Survey of Ohio, Vol. VI, Economic Geology, pp. 332-333, 1888/.

Formation	Description	Thickness	Total Thickness
Glacial	Drift	5- 15 ft.	10 ft.
	Blue soapstone	70- 80	85
Orangeville	Dark shale, almost black	10- 25	100
Berea	Oil sand, grit (average thickness is 50-60 ft.)	7-170	155
	White clay or putty streak	2- 5	158
Bedford	Red soapstone. Shale	30- 50	200

Wellington Township

27. Well #1 in Wellington; [Report of the Geological Survey of Ohio, Vol. VI, Economic Geology, p. 349, 1888]. (Exact location not known).

Formation	Description	Thickness	Total Thickness
Glacial	Yellow clay	10 ft.	10 ft.
	Blue clay	41	51
	Quicksand	45	96
	Blue clay	6	102
	Gravel	23	125
	Blue clay	3	128
Orangeville	Dark shale	30	158
Berea	Mud rock	8	166
Bedford	Shale, red	96	262
Cleveland	Black shale	145	407
Chagrin	Blue shale	235	642
Huron	Shales, alternately black and blue	320	962
Olentangy	Light-blue shale	103	1065

28. Well #2 in Wellington; /Report of the Geol. Survey of Ohio, Vol. VI, Ibid, p. 349, (exact location not known)7.

Formation	Description	Thick-ness	Total Thick-ness
Glacial	Blue clay	40 ft.	40 ft.
	Quicksand, red	25	65
	Gravel	15	80
	Blue clay	5	85
Orangeville	"Cuyahoga and Berea" shale	50	135
Berea	Grit	30	165

Gas was derived from the red quicksand and was probably due to gas from the Cuyahoga and Berea shales escaping to this horizon and then being stopped by the overlying blue clay.

29. Well at J. H. Shelley's, Wellington (1902); [Wright, Prof. A. A., Notes at Oberlin College (1901-1903), p. 15, (exact location not known)].

Formation	Description	Thickness	Total Thickness
Glacial	Yellow clay	15 ft.	15 ft.
	Blue clay	50	65
	Gravel	5	70
	Blue clay	35	105
	Gravel	5	110
Orangeville	Dark grey shale	40	150
Berea	Sandstone	15	165
Bedford	Shale, red	90	255
	Light shale	45	300
Cleveland	Black shale	100	400
Chagrin	Blue shale	240	640
Huron	Brown shale	300	940
Olentangy	Light grey shale	130	1070
Delaware	Bottom in lime rock	10	1080

30. Well on farm at Wellington; /Ohio Geological Survey Office records (exact location not known)/.

Formation	Description	Thickness	Total Thickness
Glacial	Drift	128 ft.	128 ft.
Orangeville	Dark shale	30	158
Berea	Mud rock, grit	8	166
Bedford	Shale, red	196	362
Cleveland	Black shale	145	507
Chagrin	Blue shale	235	742

31. Well at Wellington; /Ohio Geological Survey Office records (exact location not known)/.

Formation	Description	Thickness	Total Thickness
Glacial	Blue clay	40 ft.	40 ft.
	Quicksand, red	25	65
	Gravel	15	80
	Blue clay	5	85
Orangeville	"Cuyahoga and Berea" shale	50	135
Berea	Grit	30	165

Penfield Township

32. H. H. Sooy (1910); /Ohio Geological Survey Office records (exact location not known)/.

(No Berea).

Huntington Township

33. Elmer Wadsworth (1910); /Ohio Geological Survey Office records (exact location not known)7.

Formation	Description	Thickness	Total Thickness
?	?	250 ft.	250 ft.
Berea	?	12	262

34. Orin Dirlan (1922); /Ohio Geological Survey Office records7.

Formation	Description	Thickness	Total Thickness
Glacial	Clay	77 ft.	77 ft.
Meadville	Blue shale	113	190
Orangeville	Black shale	274	464
Berea	Berea shell	22	486
	Berea sand	13	499
Bedford	Blue shale	3	502

(Pay at 486 ft.)

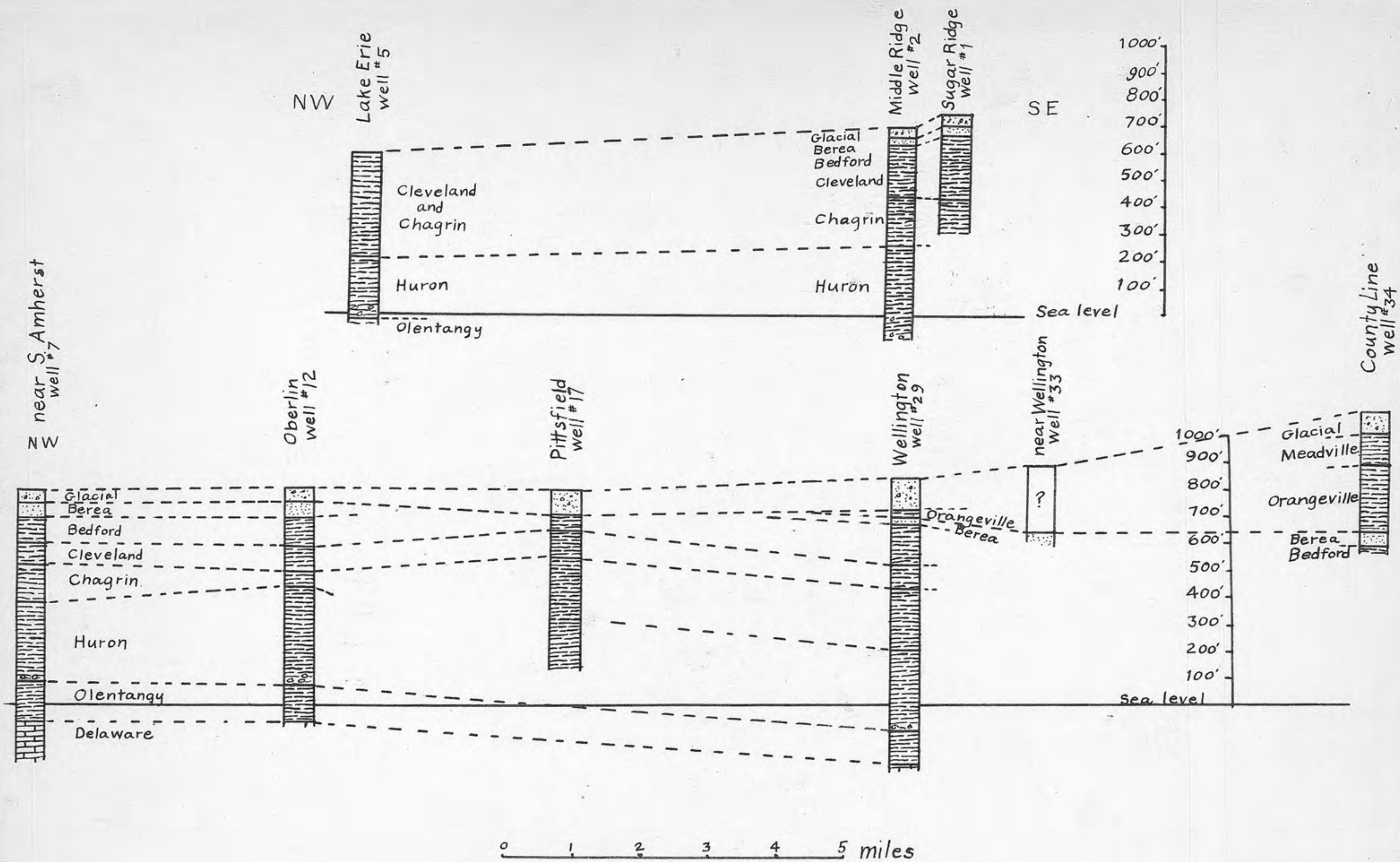


Fig. 4 Correlation of Well Logs

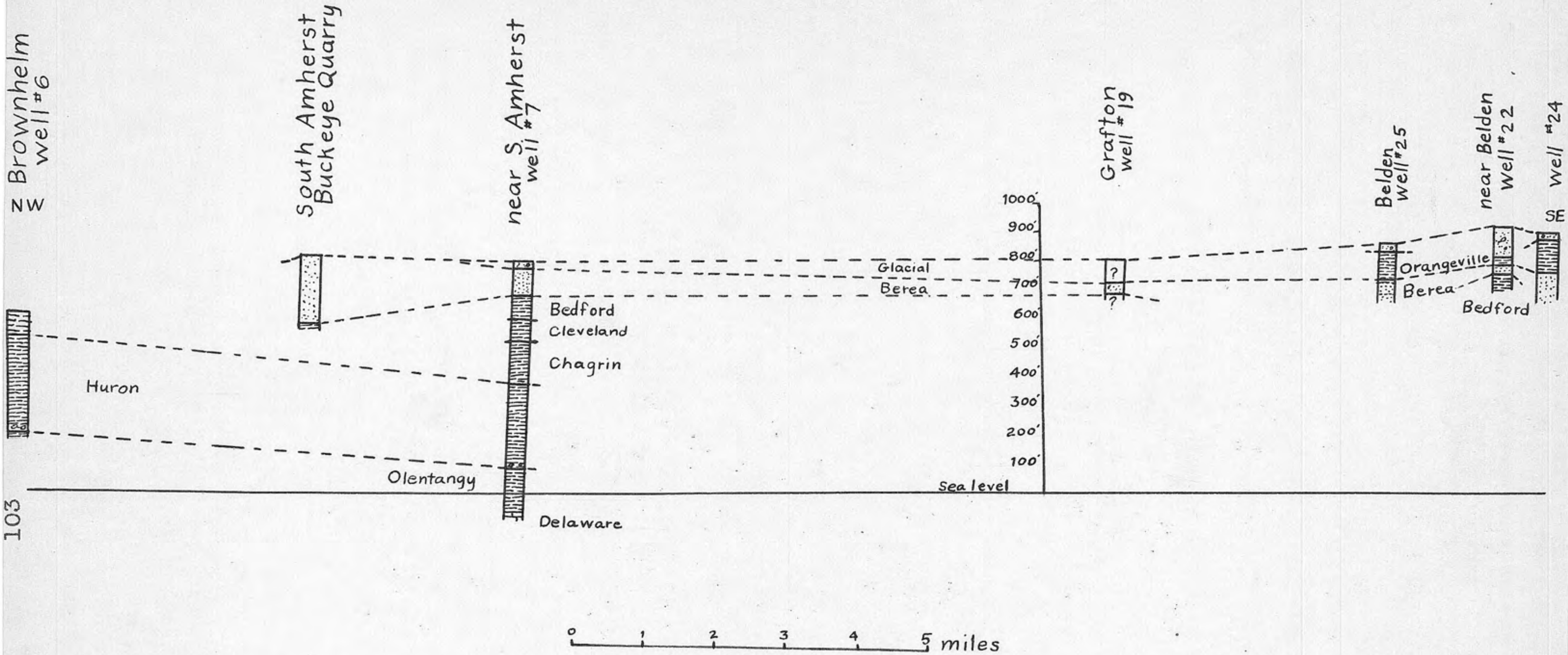
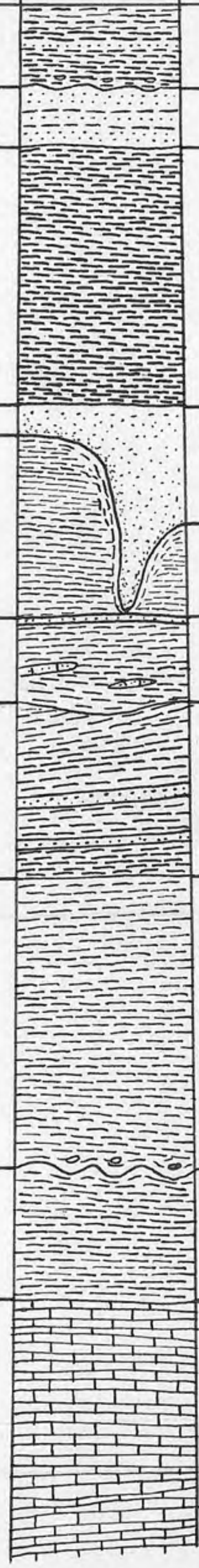
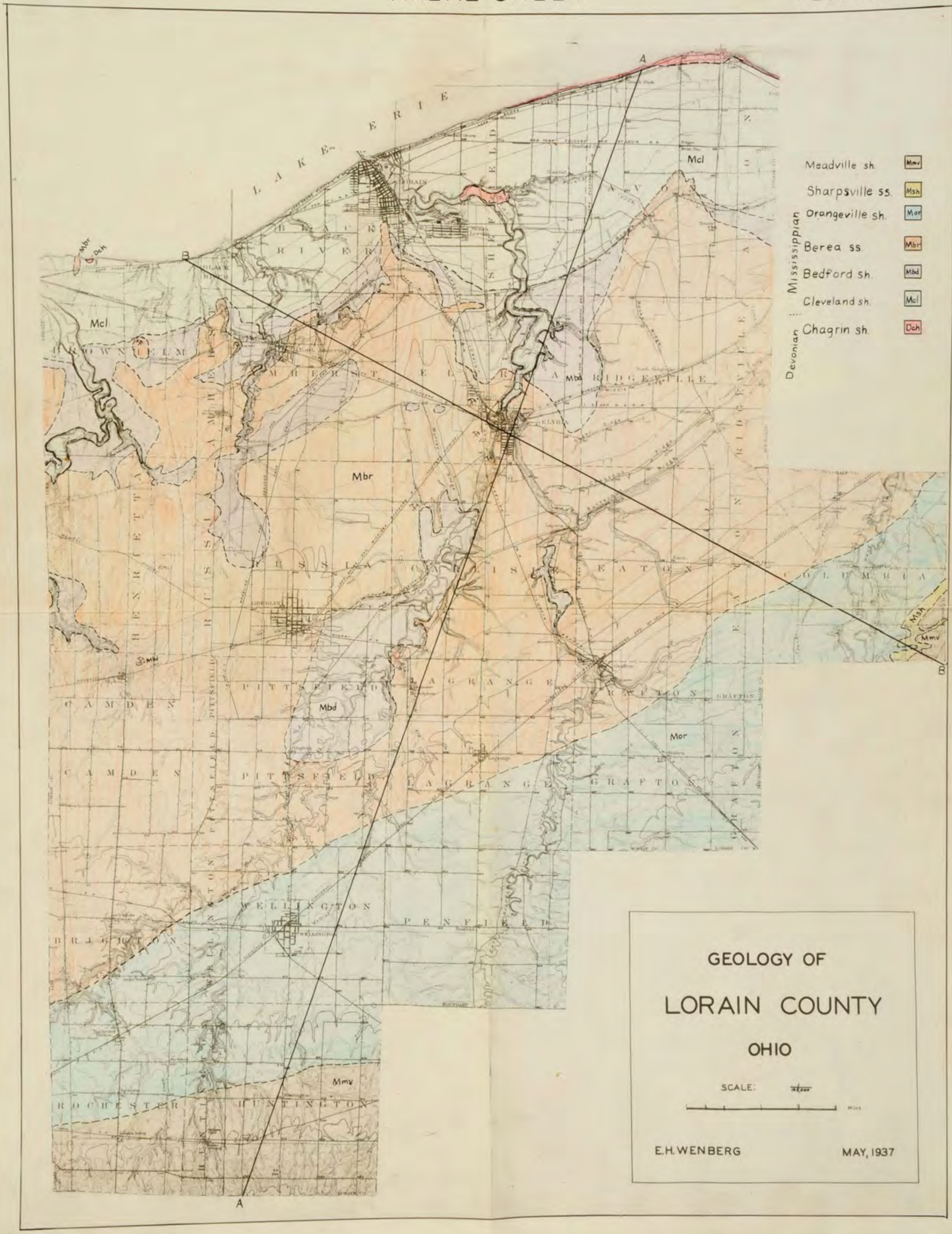


Fig. 5. Correlation of Well Logs



Age	Group	Formation	Column	Thickness	Description
Mississippian	Cuyahoga Group	Meadville		113±ft.	Soft blue shale with sandy layers, clay concretions, and mica.
		Sharpsville		40±ft.	Alternating grey shale and silts.
		Orangeville		274±ft.	Homogeneous soft grey shale.
		Berea		8 to 225 ft.	Nearly pure quartz sandstone; grey on fresh surfaces; buff on weathered Basal part is "mud-flowed".
		Bedford		196 to 0 ft.	Soft thin-bedded shale. Upper part is red; lower part is grey.
Devonian	Ohio Shales	Cleveland		100 to 150 ft.	Hard, carbonaceous, black, slaty shale. Upper siltstone zone.
Exposed / Not exposed		Chagrin		90 to 380 ft.	Soft, blue-grey or green-grey, thin-bedded shale. Contains numerous bands of siltstone.
		Huron		260 to 395 ft.	Black, slaty, carbonaceous shales. Many siderite and pyrite concretions.
		Olentangy		103 to 150 ft.	Soft grey shale. Often called "soapstone".
	"Big Lime"	Delaware		Much greater thickness than shown here.	Bituminous and dolomitic limestones.
		Columbus			
—?—		Monroe			
Silurian		Niagara			

AREAL SHEET PLATE I



DATA SHEET PLATE II

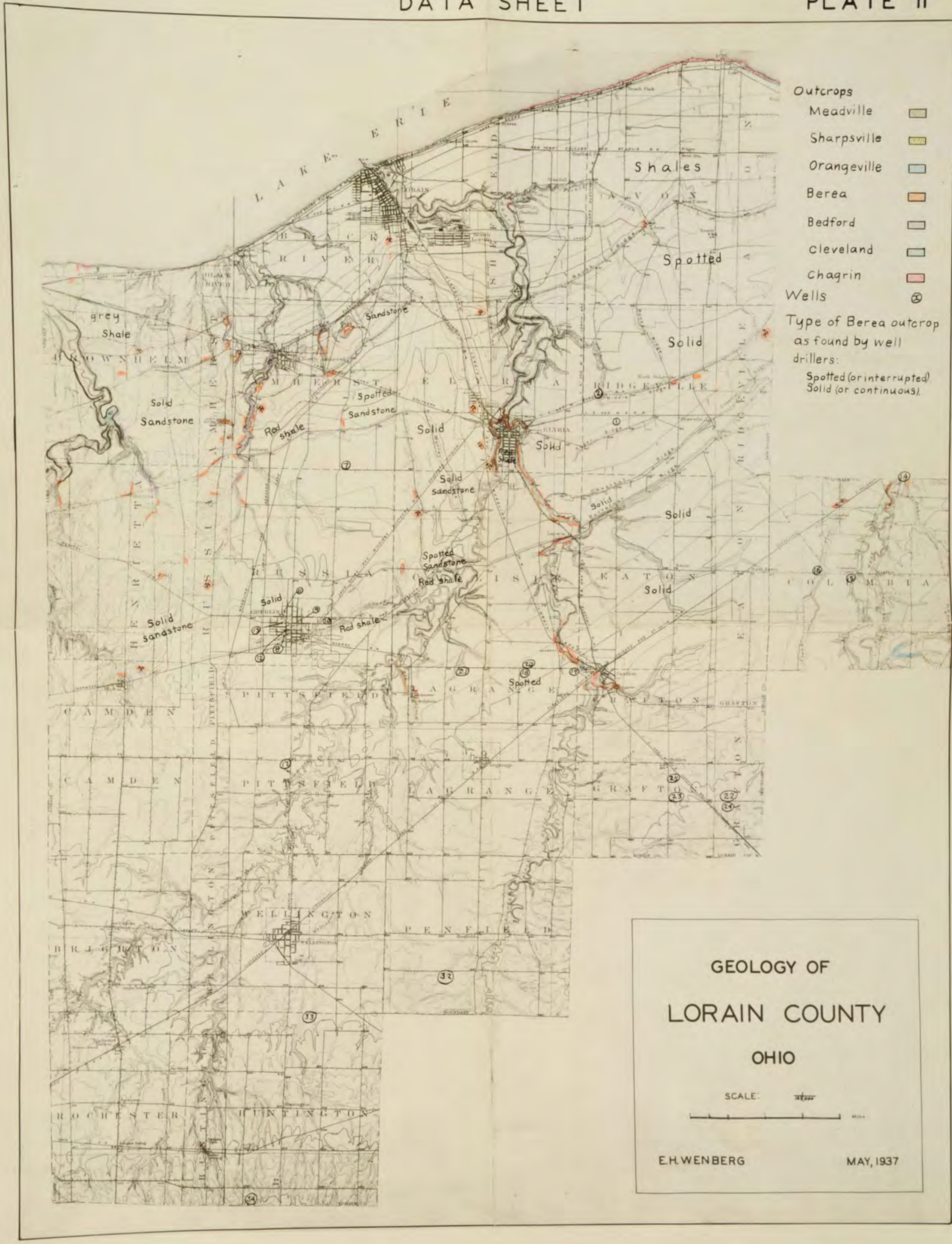
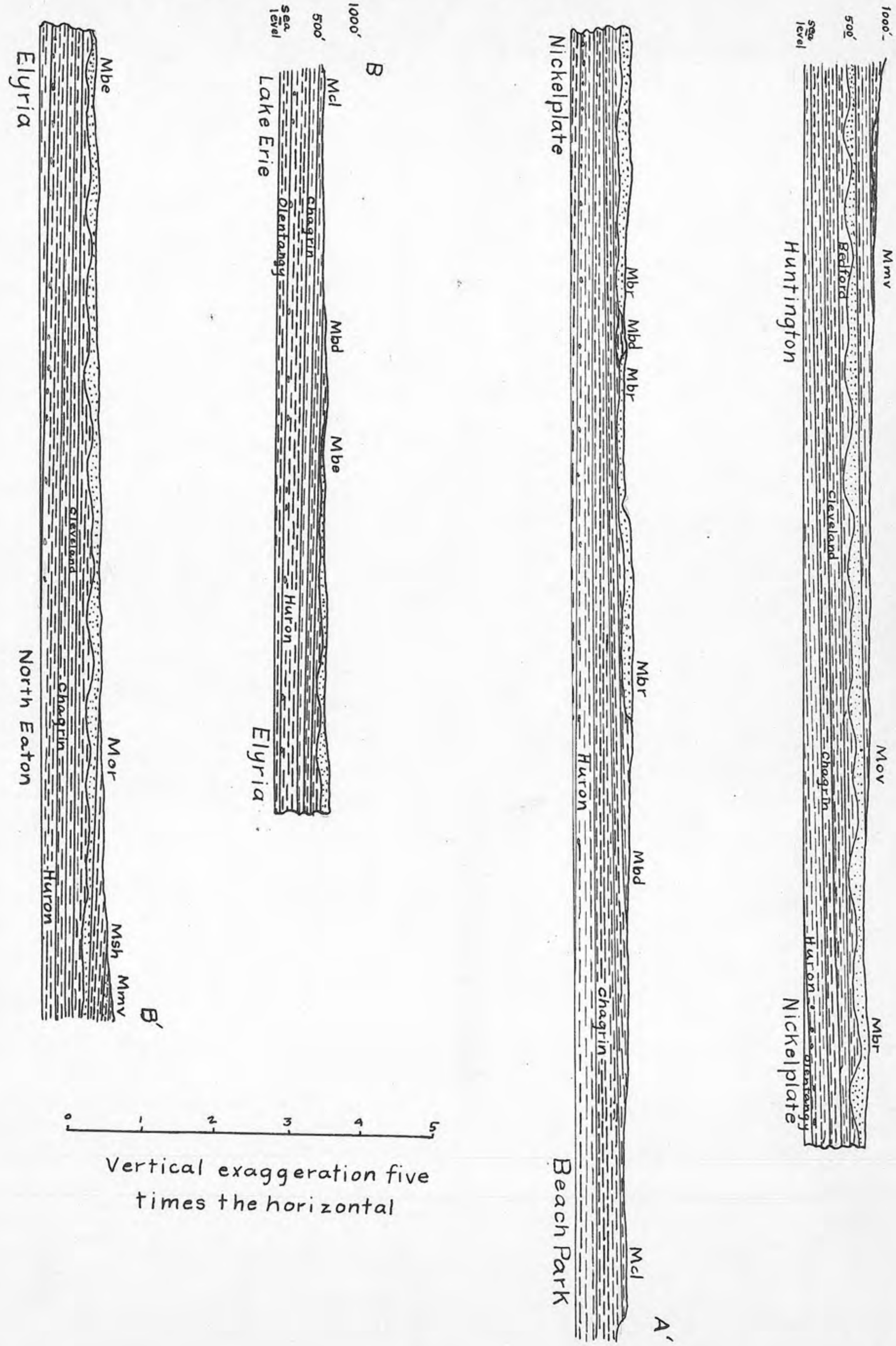


PLATE III

CROSS SECTIONS



Vertical exaggeration five times the horizontal

PLATE IV

Fig. 1. Cleveland and Chagrin shales at the mouth of French Creek. Note the siltstone flags at the creek level. Hammer and notebook are at the contact between the formations.

Fig. 2. Circular jointing on a horizontal surface of Bedford shale, one mile southwest of North Amherst.

Fig. 3. Bedford-Berea contact at Kipton Quarry. See fig. 2, text p. 37.

Fig. 4. Grey shale lens in Berea sandstone at the bottom of Kipton Quarry. See fig. 2, text p. 37.

PLATE V

Fig. 1. Bedford-Berea contact near Grafton. Note the rounded sandstone lenses below the tree root and the conformable shale-sandstone contact in the right background.

Fig. 2. Bedford-Berea contact at North Amherst. Note the rounded, rolled sandstone fragments in the shale.

Fig. 3. Bedford-Berea contact at North Amherst. Note the mud-flow structure of the basal sandstone.

Fig. 4. Bedford-Berea contact at North Amherst.

PLATE VI

Fig. 1. Sharpsville sandstone in the southeast corner of Columbia Township. Note the jointing and the "rooster-tail" structure.

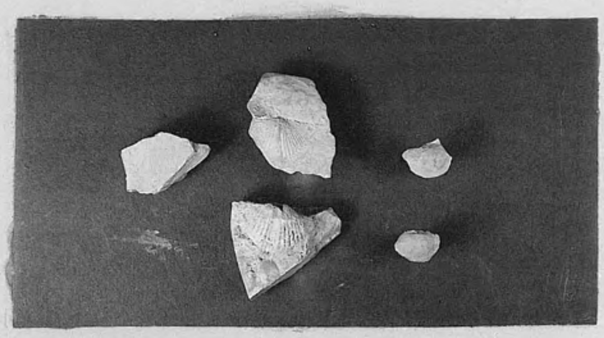


Fig. 2. Fenestella and brachiopods of the Spirifer type from the Orangeville shale, one-third of a mile west of Huntington. (x 1/2).

Fig. 3. Ctenacanthus vetustus Newberry, from the Cleveland shale, two miles north of Elyria. Lateral and end views of a portion of a tooth. (x 1/2).