CLEAR TECHNICAL REPORT NO. 309

Field Guide to the Geology of the Lake Erie Basin

Part 1. Devonian-Mississippian Sequence of Lorain and Erie Counties, Ohio

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INTRODUCTION

North Central Ohio is underlain by Devonian and Mississippian bedrock formation ranging from massive limestones on the west to sandstone and shales on the east, each with its own characteristic depositional and post-consolidation features. These rocks have been eroded by ice and stream action, blanketed by glacial till, and further buried by lacustrine deep-water and beach deposits. This document is intended as a brief field guide to some of the geologic features in Lorain and Erie Counties, Ohio (Figure 1).

The Devonian and Mississippian strata of North Central Ohio typically dips to the southeast at approximately 20-25 feet per mile. In most exposures the shale beds appear flat-lying or only gently warped. However, in the vicinity of sandstone channels the shale beds are commonly folded, faulted and sometimes contorted or interbedded with the basal sandstones. Several investigators have studied the Devonian-Mississippian rock sequence in North Central Ohio (Newberry, 1871 and 1874; Stauffer 1907, 1909, and 1916; Prosser 1912; Cushing _et al_ 1953; Pepper _et al_ 1954; Nelson 1955; Hoover 1960; Hartley 1962; and Herdendorf 1962, 1963, 1966, 1967, 1973, and 1977a,b; Herdendorf and Struble 1975). Most reports contain some mention of bedrock deformation but very little information is available on the intensity, distribution or the causes of these structures.

PHYSIOGRAPHY

In North Central Ohio, the land surface that lies within approximately 5-10 km of the Lake Erie shore is nearly level to undulating plain broken by several deep, steep-sided stream valleys, sandstone escarpments and isolated hills, and well-developed abandoned beach ridges. Known as the Lake Erie Plain, this surface was covered by the waters of six former glacial lakes (Maumee, elevation 238-232 m; Whittlesey, 224 m; Arkona, 216-210 m; Warren, 207-203 m; Wayne, 201 m; Lundy, 195-187 m). Conspicuous sand and gravel ridges 3 to 6 m above the plain and 30 to 50 m wide mark the beaches of these lakes (Figures 2 and 3). The beaches, created between 12,000 years B.P., form a series of more or less parallel ridges from 3 to 10 km south of the present shoreline of Lake Erie (elevation 175 m).

STRATIGRAPHY

The age of the bedrock exposed in the study area (a rectangle roughly bounded by Sandusky-Lorain-Oberlin-Norwalk) is Late Devonian and Early Mississippian (Tables 1 and 2). This area is part of a wide belt of Upper Devonian and Lower Mississippian rocks that extends westward from New York and Pennsylvania across northeastern Ohio to the vicinity of Berlin Heights, Ohio, where the belt swings southward along the eastern flank of the Cincinnati-Findlay arch and continues across the Ohio River into northern Kentucky (Figures 4 and 5). This

TABLE 1

DEVONIAN ROCKS EXPOSED IN EASTERN ERIE COUNTY, OHIO

System	Formation	Member	Thickness	Lithology	Occurrence
Upper Devonian	Ohio Shale	Cleveland Shale	0-80 ft.	Shale, dense, hard, platy to fissile; black, carbonaceous; pronounced vertical joint system, in two directions at near right angles; contains pyritic concretions; thin, persistant limestone layers with cone-in-cone structure; resistant to weathering, gray to brownish-gray on weathered surface.	Occurs in bluffs of Vermilion River and other major streams of area. Only lower part of Cleveland Shale is exposed in Lake Erie bluffs, where it interfingers with gray Chagrin Shale (see below).
		Cleveland-Chagrin-Huron Shale interfingerings	400-600 ft.	Shale, alternating black, hard, carbonaceous, and gray, soft, argillaceous layers; large spherical concretions and more fissile lower part; contains pyrite concretions; interbedded siltstone in gray shale; upper black shale layers identical to Cleveland Shale above; well-developed vertical joint system; black shale resistant; gray erodes rapidly. Changes to dominantly gray shale eastward in Cuyahoga County; thickens eastward to over 1500 ft. in Summit County.	Occurs as surface rock along the lake shore from Huron east; exposed in the bluffs east of Vermilion River; occurs as surface rock from Lake Warren shoreline north.

TABLE 2

MISSISSIPPIAN ROCKS EXPOSED IN EASTERN ERIE CONNTY, OHIO

System	Formation	Thickness	Lithology & Character	Occurrence
Lower Mississippian	Berea Sandstone	0-260 ft.	Quartzose sandstone, medium-to fine-grained, dense, hard, gray, blue or buff; thin layered to massive; cross-bedded, ripple-marked; fills many channels in Bedford and Cleveland Shales; primary flow structure near base; highly erosion resistant; forms ridges and bluffs. Shows a complex folded, faulted and overturned structure along its northern exposure in Erie and Lorain Counties. Quarried at South Amherst where it reaches 260 feet in thickness as a channel filling.	Occurs over Bedford Shale from Huron River eastward; forms much of Lake Warren shoreline across Vermilion Quadrangle; occurs on Lake Erie shore in one limited area at two miles east of Vermilion River. Forms numerous sandstone hills on Till Plains.
	Bedford Shale	0-150 ft.	Clay shale, soft; red upper zone, gray basal portion, laminations between; contains fine grained sandstone and siltstone lenses in lower portion; weathers rapidly; highly variable in thickness due to channeling; recognized in many places by red coloring of soil, stains rocks red stratigraphically below, on outcrops. Euclid member, 0-3 ft. thick, argillaceous, buff-colored siltstone; concretionary; small pelecypods in concretions; forms lenses in lower portions of Bedford formation between red and gray shale. Tentatively correlated with the Euclid Siltstone member of Cuyahoga County.	Occurs over Cleveland Shale from Huron Rive east, not continuous due to channeling and Berea Sandstone fills; does not occur on lake front, reaches nearest to shore on flanks of Berea Sandstone headland in Vermilion; surface rock bordering much of Vermilion Rive valley.

sequence is predominantly marine clastics composed of black, gray and red shales, siltstones, sandstones and thin limestones (Figure 6). These beds overlie Middle Devonian limestones (Stop No. 10) and shale and dip gently southward and eastward beneath rocks of younger Mississippian and Early Pennsylvanian age.

Overlying the Delaware Limestone (Middle Devonian) and the Hamilton Formation (Plum Brook Shale and Prout Limestone which correlate in part with the Olentangy Shale of Central Ohio) is the Ohio Shale (Upper Devonian). The Ohio Shale sequence is dominantly a black or brownish-black carbonaceous shale interbedded with blue-gray, argillaceous shale, thin limestones and siltstones. In north central Ohio the Ohio Shale consists of three members; oldest to youngest, the Huron Shale, the Chagrin Shale, and the Cleveland Shale. The stratigraphic relations of the Huron and Cleveland Members to the undifferentiated Ohio Shale of southern Ohio and to the Chagrin Shale of northeastern Ohio are not completely known. The shales of the Huron and Cleveland Members interfinger with and are in part correlative in age with the Chagrin Shale Member (Figure 7).

The contact of the Ohio Shale with the overlying Bedford Shale (Lower Mississippian) is rather indistinct (Stop No. 4). The Bedford Shale is a red argillaceous shale, gray in the basal part, interbedded with siltstone layers (Figure 8). The thickness of the Bedford Shale in northern Ohio is irregular because of post-Bedford erosion and channeling.

In North Central Ohio the Bedford Shale is overlain disconformably by the Berea Sandstone, the youngest formation exposed within the area (Figure 9). The paleogeography at the time of deposition of the Devonian-Mississippian beds is shown in Figures 11 and 12. A large interior sea occupied much of the Great Lakes region during these periods. The Berea Sandstone is a medium to fine-grained quartzose sandstone which in northern Ohio commonly occurs from bottom to top as (1) a massive channel sandstone, (2) a cross-bedded sandstone, and (3) a thin-bedded marine sandstone (Figure 10). To the south and east of Erie County the Berea Sandstone is overlain by Sunbury Shale and the Cuyahoga Formation respectively.

STRUCTURAL GEOLOGY

Features of the Ohio and Bedford Shales

Of the several geologists who have investigated the Devonian-Mississippian rock sequence in northern Ohio, Cushing (1931) was the only one who mentioned unusual local deformation of shale beds in association with Berea Sandstone channels:

> "The soft shales of the district (Cleveland) in many places exhibit minor disturbances, both folding and thrust faulting. These are all of small extent, some of them old and some very recent, and they have arisen from different

> causes. The shales at the base of the Berea are very liable to be disturbed, especially in the vicinity of the large channels. They are variously tilted and in some places are faulted. These disturbances were effected by the currents that brought in the Berea sands, the underlying mud being shifted about and slumping along the channel sides. The recent disturbances are all very local and surficial and may be due to expansion brought about by weathering."

The susceptibility of the shale beds to slumping is demonstrated by a recent slide in the red Bedford Shale on Chappel Creek south of Darrow Road (Stop No. 6b). It appears to the present writer that much of the localized deformation in the Ohio and Bedford Shales is related to geologic processes immediately before and during the time the scour channel in these formations were being filled by Berea sands. In addition to slumping, the added weight of the sands on the underlying semi-plastic mud beds may have caused them to be down-folded in the center of the channel. This feature can be observed at several locations on both Chappel and Old Woman Creeks (Stops No. 6b and 8) and at the shore of Lake Erie near Vermilion (Stop No. 3a). It is easy to predict the location of a Berea channel-fill because of this association. Whenever the normally flat-lying shale beds begin to dip strongly a channel sandstone is normally in close proximity and in most cases the shale beds dip under the sandstone, except in the vicinity of overturned beds at Chappel Creek.

The Ohio Shale, particularly the Cleveland Shale Member, has a well-developed vertical joint system in two directions at nearly right angles (N 50° E and N 50° W). The valley walls of many of the streams are joint planes, accounting for the rectangular shape of the valleys in cross-section. Because the two main vertical joint systems are nearly at right angles, the valleys have an irregular rectangular drainage pattern as they follow one joint system and then another.

Another peculiar structural feature exhibited by the Ohio Shale is a curved or arcuate joint pattern (Stops No. 6b and 8). Generally this feature is observed near sandstone channels but not in all cases. Two possible explanations occur to the writer: (1) this fracture may also be related to the forces generated at the time of channel sand deposition at the point source therefore resulting in a concentric fracture zone or (2) arcuate joints may be the result of the structural nose in the Berlin Heights area which caused the strike of the beds to swing from a near north-south direction to an east northeast-west southwest trace, therefore causing the curves which correspond to such a shift. Hoover (1960) suggested that these joints may have resulted from bending and twisting of the beds after partial or complete solidification.

Cone-in-Cone Structure

In Erie and Lorain Counties, the Ohio Shale is dominantly a black or brownish-black carbonaceous shale interbedded with blue-gray, argillaceous shale, thin siltstones, and thin cone-in-cone limestones. From oldest to youngest, the Ohio Shale of Erie County consists of three members: Huron Shale, Chagrin Shale, and Cleveland Shale. The black shale of the Cleveland and Huron members interfinger with and are, in part, correlative in age with the blue-gray Chagrin member. The lower-most cone-in-cone limestone layer has traditionally been used to designate the base of the Cleveland Shale (Hoover, 1960).

Karhi (1948) studied the occurrence of cone-in-cone structures in the Ohio Shale and concluded that they are of epigenetic origin and formed by effects of pressure and solution upon diagenetically developed calcareous layers. He considered these structures to be the result of a calcareous ooze, which was later affected by pressure and solution to form the cone-in-cone, probably in the late Paleozoic. Of the several theories reviewed by Hoover (1960), this one appeared to best fit the observed facts.

Twenhofel (1950) concluded that the load of overlying sediments is the only source of adequate pressure for the formation of cone-in-cone structure. The factors that he used to support this conclusion are: (1) cone-in-cone is largely in horizontal or little-inclined strata, (2) cones are mostly on the upper sides of cone-in-cone layers and have bases upward, (3) if cones are on the undersides of layers they are smaller and have bases downward, (4) sharp blows with a hammer on fibrous calcite produce percussion cones that approximate cone-in-cone, (5) solution and rearrangement of fibers are present along minor faults that cut the fibers, (6) slickensided phenomena are present between the cones, and (7) solution is shown in the clay in annular depressions and in the films between cones.

Herdendorf (1977a) uncovered cone-in-cone limestone layers within the fault zone, at angles quite different from the normal interbedded layers and equal to the fault scarp (Stop No. 6b). The cone-in-cone limestone in the fault zones is similar in appearance, structure, and thickness to horizontal layers in adjacent beds. Both limestones effervesce freely in dilute hydrochloric acid and both possess conical structures that were perpendicular to the upper surface of the layer with the larger bases of the cones upward. This latter situation is true of the cone-in-cone limestone found along the fault scarps even though the upper surface of the layers were inclined up to 35°. The lower and upper surfaces of the cone-in-cone limestone in the faults appear to be casts of the irregular shale surfaces with which they were in contact.

In the valley of Chappel Creek (Stop No. 6b), some bed are displaced abount 2 to 3 m near the level of the stream but the displacement appeared to diminish upward and the fault cannot be traced to the top of the bluff. Cone-in-cone limestone occurs only in the lower portion of the fault scarp. At other locations on Chappel Creek, displacement is minimal to non-existent and the faults again die out before reaching the surface. Cone-in-cone is well developed along these fault scarps. At the shore of Lake Erie, east of Vermilion (Stop No. 3b), a fault appears to be a thrust of several feet and extends up to the contact with the glacial till. No cone-in-cone occurs in the fault zone at this location.

A glacial origin for these structures appears to be unlikely for a number of reasons: (1) cone-in-cone layers in the Ohio Shale and correlative unit extend well beyond the glacial boundary in to southern Ohio and Kentucky, (2) none of the faults in which cone-in-cone occurred extended to the surface (it is anticipated that glacially induced faults would extend to the surface of the rock), and (3) thrust faults on the Lake Erie shore are considered to be related to ice shove, but they do not exhibit cone-in-cone limestone in fault scarp, although horizontal cone-in-cone beds were found flanking the faults.

The present writer is of the opinion that the most likely time of formation of the cone-in-cone structures in the fault scarps is early diagenesis, similar to that of the horizontally bedded cone-in-cone. Under this hypothesis, a calcareous ooze flowed into fairly deep-settled separations or faults, thereby taking on the surface features of the shale as it solidified. Pressure from the overlying beds, probably in the late Paleozoic, resulted in the cone-in-cone structures within the horizontal calcareous beds. An explanation of the development of cone-in-cone structures within the inclined beds is not as simple. Apparently the force was toward the upper surface of the beds and perpendicular to them in order to form the cone with the bases upward. Crustal readjustment appears to be the most likely source of such forces. In general, it appears that faults containing cone-in-cone structure are old and unrelated to glacial activity. The horizontal and the fault associated limestone layers probably had a similar time and mode of formation, but the forces creating the conical structures may have been different.

Carbonate Concretions

The lower part of the Ohio Shale is characterized by the presence of large carbonate concretions (Stop No. 9). Laterally, these concretions are found at definite horizons in an outcrop. They range from 15 cm to 3 m in diameter, but are generally 2 m or less. The smaller ones are nearly spherical, whereas the larger ones are somewhat ellipsoidal. Many of the larger ones are concave on the top and bottom. The outer surfaces often have a protrusion around the middle. The bedding of the shale is bent above and below the concretions, and where a concretion is broken vertically it is seen that the shale laminae pass through the concretion in the same fashion as, but to a lesser degree than, the enclosing shale. The main body of the concretions consists of horizontal laminae as a series of light and dark bands, each band being from 1 to 15 cm thick. Due to differential weathering, the light bands, which contain more chert than the dark bands, remain as ridges on the surface. The smaller concretions are solid to the center, but the centers of the larger ones frequently possess a septarian structure with the fissures filled with either secondary calcite or barite. The concretionary material is usually secondary crystals of calcite, dolomite, quartz, pyrite, barite, and sphalerite incorporated in a nonindentifiable fine-grained matrix of carbonate, silica, and organic matter. Plant and animal matter is common throughout the concretions. Fish bones, conodonts, fossil wood, and ostracods often serve as the nucleus about which the concretion grew, many sharks and the large fish (Titanichthys and Dinichthys) have been obtained from these concretions, which have made Ohio Shale world famous from a paleontological standpoint (Hoover 1960).

Two schools of thought on the origin of these concretions prevailed: (1) Newberry (1874) and Orton (1878) felt that the concretions were syngenetic, whereas (2) Stauffer (1916) regarded these concretions as epigenetic. The first research to utilize both field and laboratory relationships in developing a theory of the origin of these concretions is the work performed by Clifton (1957) who developed the penecontemporaneous theory of origin for the carbonate concretions in the Ohio shale. Clifton found the evidence suggests that the concretions formed after the deposition of the enclosing sediments but before complete compaction of the muds. Crystallization began around a nucleus and spread outward. Replacement and secondary growth of crystals were important processes during the development of the concretion. Horizontal banding in the concretion is an expression of the compaction of the mud, frozen by crystallization. Addtional compaction, as recorded by laminae bending toward the center plane, squeezed out the water and halted further growth. Because water in the compacted mud would tend to circulate in horizontal planes, the larger concretions grow faster laterally, resulting in flattened ellipsoids. The smaller concretions were not effected by this, as the charged water could more easily reach all points on the surface. The arching of the shale above and below the concretion is due to the compaction and shrinkage of the mud around the solid object.

Flow-Rolls and Interbedded Materials

Interbedded shales, sandstones and siltstones can be observed at several locations in Erie and Lorain Counties. In all cases the beds are highly contorted and associated with basal Berea Sandstone channel-fills or basal Bedford Shale. The explanation given by Pepper _et al_ (1954) for such features seems adequate:

> "Several relatively thin zones of intensely

> deformed rocks are present in the northern and western outcrops of the Bedford and Berea Formations in Ohio. The zones are characterized by many elongate ellipsoidal masses of thin ripple-marked siltstones, sandstones, and intercalated gray, red, and at some places black shales. The sediments have been squeezed into masses resembling sofa cushions have been rolled while in a plastic state into cylindrical masses that resemble jelly rolls.

Because of the characteristic rolled appearance of these features and because the deformation of the strata occurred prior to complete lithification of the rocks they are often referred to as "flow-rolls".

Pepper _et al_ (1954) concluded that the formation of flow-rolls depends more upon the horizontal flowage of sediment in response to either unequal loading of the softer substratum or unequal unloading of the more mobile substratum of mud than to the initial slope of the surface upon which the sediment was deposited. Apparently flow-rolls were formed mainly by horizontal pressures built up by irregular deposition of the basal Bedford silts or the basal Berea sands upon a plastic formation. The pressure caused the mud to flow through ruptures in the silt or sand, often carrying part of the overlying sand including ripply-marks, and produced involutely coiled flow-rolls oriented roughly parallel to the axis of the scour channels. The presence of flow-rolls at elevations below adjacent outcrops of relatively undisturbed black shale of the Cleveland Shale Member of the Ohio Shale, as in the valleys of Old Woman and Chappel Creeks (Stop Nos. 8 and 6b), suggests the filling of shallow channels by lateral flowage of relatively soft materials into existing scour channels.

Berea Sandstone Channels

The Bedford Shale is overlain unconformably by Berea Sandstone. The Lorain-Erie Counties area lies within the region of maximum channeling of the Bedford Shale. In many places the erosional channels have cut entirely through the Bedford Shale into the underlying Ohio Shale, leaving Berea Sandstone fillings in contact with the Ohio Shale (Figure 13). The deepest channeling is found at South Amherst where the Cleveland Quarries Company reports core drillings that have penetrated 80 m of Berea Sandstone with the Bedford Shale near the surface at either side (Stop No. 1).

The plan of the Berea Sandstone outcrops is a broad band extending across the southern half of eastern Erie County, with its northern limit forming a rather sharp escarpment (Stops No. 2 and 7). Numerous Berea Sandstone outliers and narrowly connected outcrops exist as sandstone hills in the shale area to the north of the main sandstone outcrop. This irregularity of the Berea outcrop is due to the resistance of the sandstone to weathering and erosion and to the very irregular basal contact with underlying shales.

The Berea Sandstone can be divided into three parts in the study area. The lower division is a channel sandstone present only in isolated areas where the Berea Sandstone fills erosion channels in the Bedford and Ohio Shales. The channel fills are characterized by steep walls, sinuous alignment, and rounded basal profiles (Stop No. 5). The middle part of the Berea Sandstone is more massive than the uppper beds and strongly cross-bedded. The upper 6-10 m of formation is a thinly bedded marine sandstone, with the upper surface of these beds showing many distinct oscillation-type ripple marks.

The channel sandstones range in thickness from a few feet to at least 80 m. In South Amherst at the Buckeye Quarry (Stop No. 1), 72 m of Berea Sandstone have been quarried (Figures 14 and 15). West of South Amherst the thickness of the channel sandstone decreases, but the amount of thinning is obscured because the rock is hidden by glacial drift. At the Nicholl Stone Company operation near Kipton, quarrying has exposed 53 m of Berea Sandstone (Figure 16). The lower part of one of these channel sandstones is exposed on the shore of Lake Erie approximately 3 km east of the Vermilion River, where the resistant sandstone forms a narrow headland that juts out into the lake nearly 6 m (Stop No. 3a). This channel can be traced inland about 0.8 km to an abandoned quarry on the north side of

U.S. Rt. 6 where over 15 m of sandstone are exposed. Most of the channel sandstones appear to have a north-south trend except for one near the village of Berlin Heights, which seems to run northeast-southwest. At the abandoned Baillie Stone Company quarry northeast of this village, over 30 m of sandstone is exposed (Stop No. 7).

Within the study area the Berea Sandstone exhibits a variety of structural peculiarities. Local and intense deformation has occurred along its northern outcrop. The intensity appears to be at its peak along Chappel Creek, where faulting and overturning have jumbled the Berea Sandstone (Stop No. 6a) and older shales into a relatively complex relationship. Eastward from Chappel Creek deformation becomes less intense, but evidence of folding can be seen in the Vermilion River valley north of Birmingham. Southward, the Berea Sandstone is generally flat-lying or only very gently warped.

Normal and Thrust Faults

Faults can be observed in all three formations exposed in the study area. The shale in the vicinity of Sunnyside Beach in Vermilion is broken by several normal and high angle thrust faults (Stop No. 3b). The normal faults strike east-west, nearly paralleling the shore, and all have dips of 40° to 50°. More than a dozen reverse faults have been mapped in this area and westward toward the Vermilion River. The reverse faults strike in various directions with dips varying from 22° to 53°. On Chappel Creek, south of Darrow Road Bridge, the Ohio Shale has been thrust over beds of the same formation resulting in a 2 m displacement (Stop No. 6b). Northeast of Henrietta in the banks of Chance Creek an apparent thrust fault of about 1 m displacement has thrust the underlying gray Bedford Shale over the overlying red Bedford Shale. The fault strikes N 40° W. Normal faulting can also be observed in the Berea Sandstone in the bed of Old Woman Creek (Stop No. 8). This fault appears to have a maximum displacement of 1 m.

All of the faulting appears to be minor with no displacements reaching 3 m. This deformation probably resulted from three factors: (1) regional deformation earlier than the Pleistocene, probably during the late Paleozoic Era, caused by horizontal compression from the east, (2) stresses resulting from the down-folding adjacent to the sand channels and (3) ice shove during the Pleistocene glaciation.

Overturned Berea Sandstone

In North Central Ohio the Berea Sandstone exhibits numerous structural anomalies. Local, and in some cases intense, deformation has occurred along the northern outcrop of the Berea, whereas several miles to the south the formation is only gently warped. The most striking structural feature along this northern outcrop is between the Huron and Vermilion Rivers in the valley of Chappel Creek about 3 km north of Florence. Here, overturning and faulting have jumbled the Berea Sandstone (Stop No. 6a). One sandstone slab, 3 m thick and 100 m long, appears to have been overturned by glacial action producing a unique structural feature for North Central Ohio (Figure 17).

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FIGURES

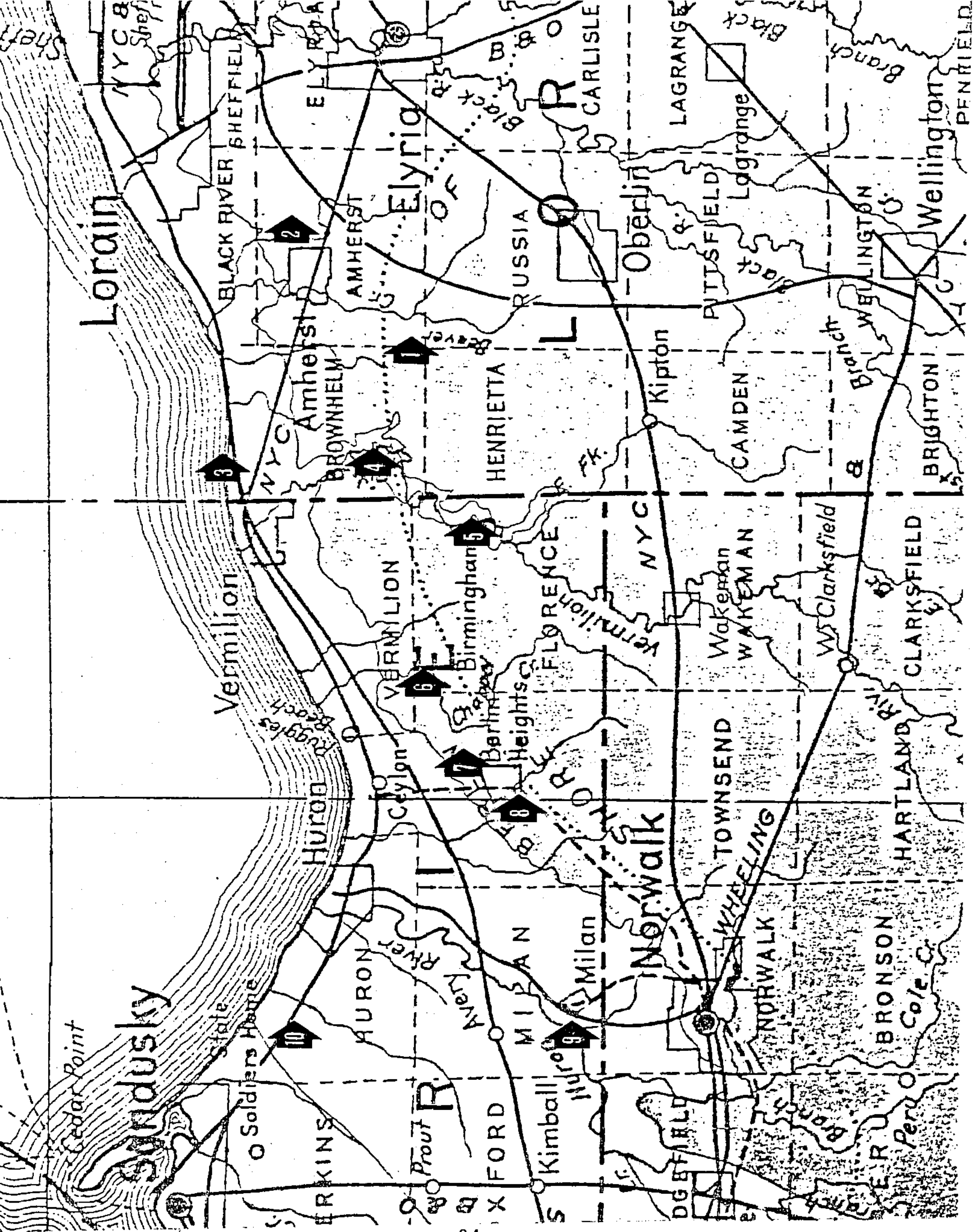
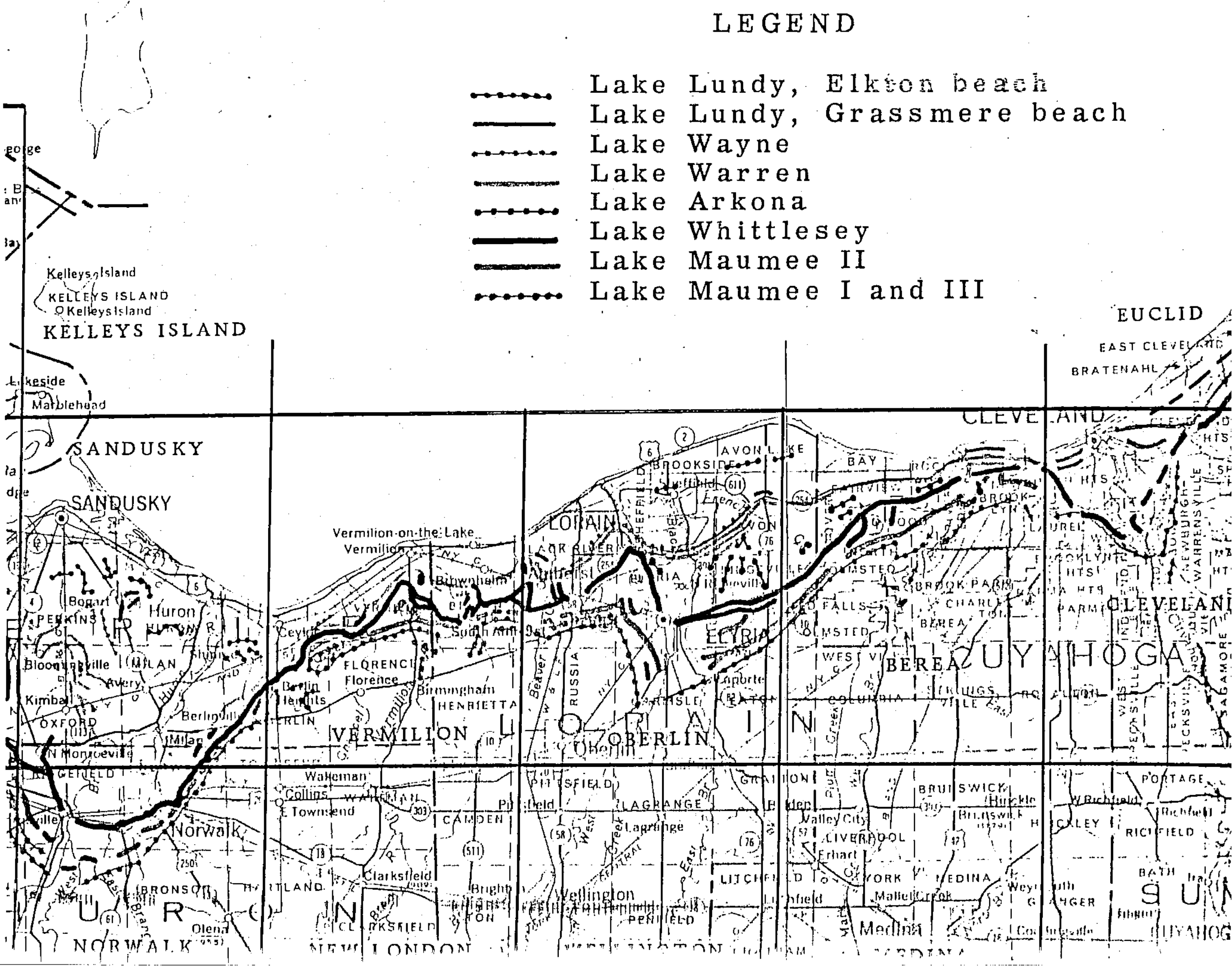
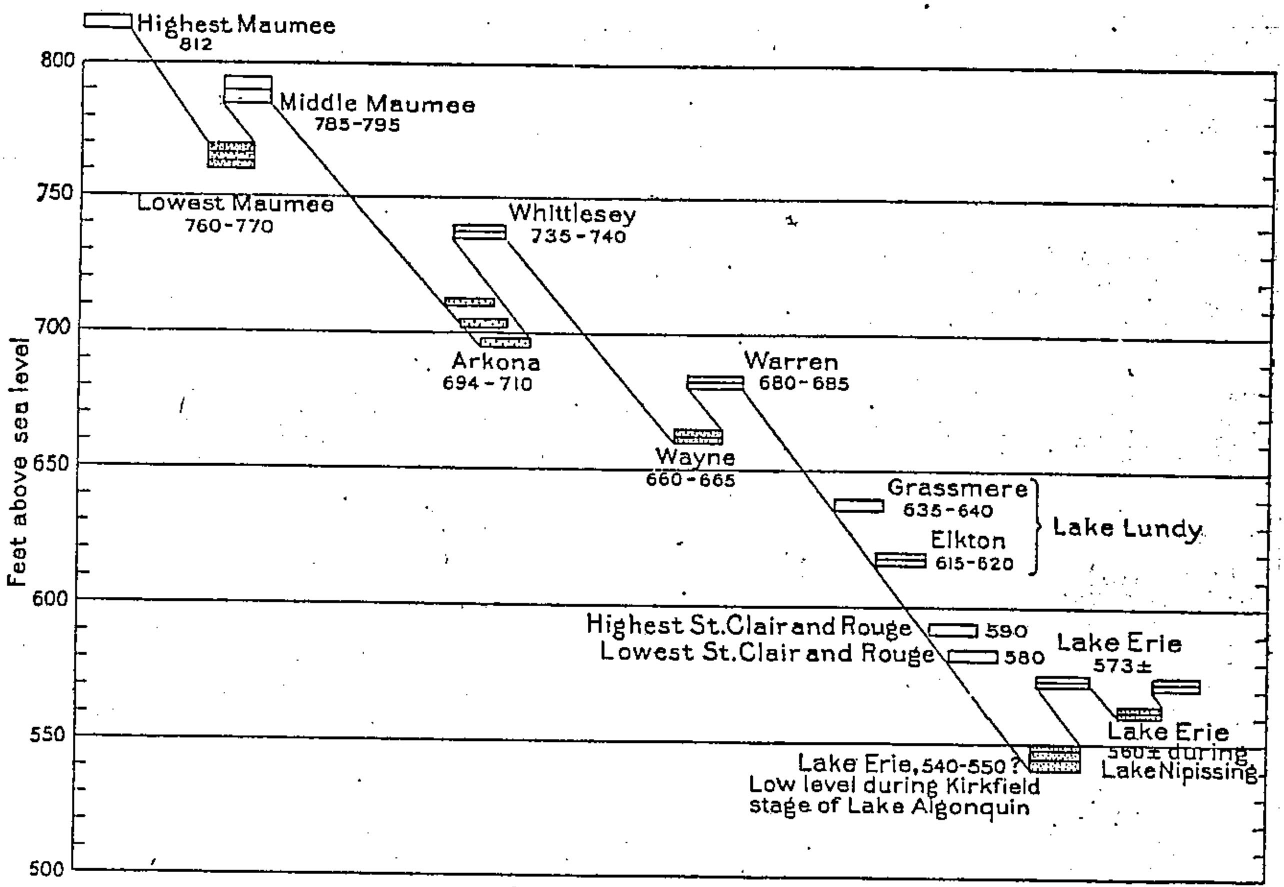


Figure 1. Location map for field trip.

Figure 2. Beach ridges of the glacial lakes in North Central Ohio (after Forsyth 1959).





Falling and rising stages of lake waters in the Erie Basin. Oldest at left. Beaches submerged by later expansion of the ponded waters indicated by dotted pattern

Figure 3. Water level stages of the glacial lakes in North Central Ohio (after Cushing _et al_ 1931).

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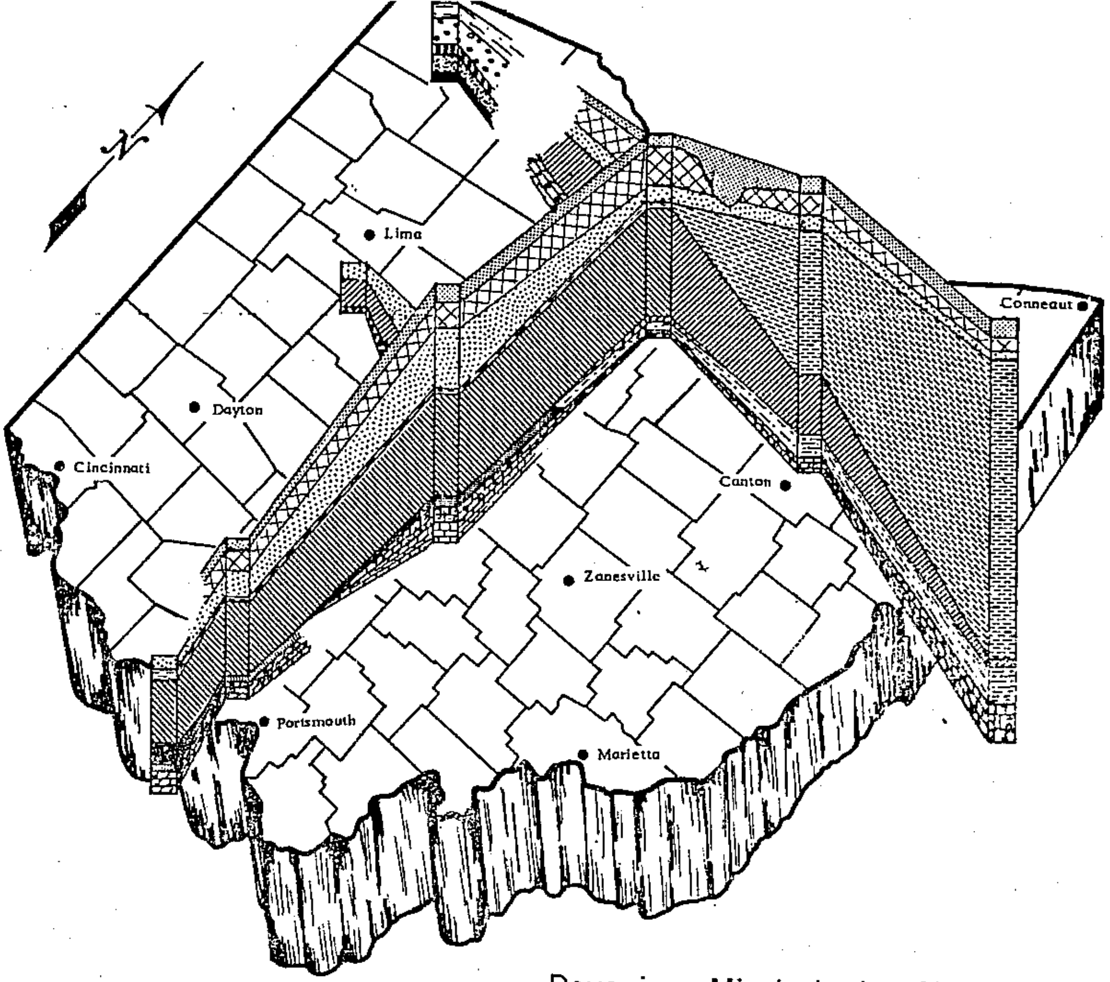
Figure 4. Outcrop pattern of Devonian-Mississippian shales in Ohio (after Hoover 1960).



Devonian - Mississippian Shale sequence

Legend

- ▒ Berea Sandstone
- ▦ Bedford Shale

} ▤ Bedford-Berea (Mississippian - Undifferentiated)

- ░ Cleveland Shale
- ▤ Chagrin Shale
- ▨ Huron Shale

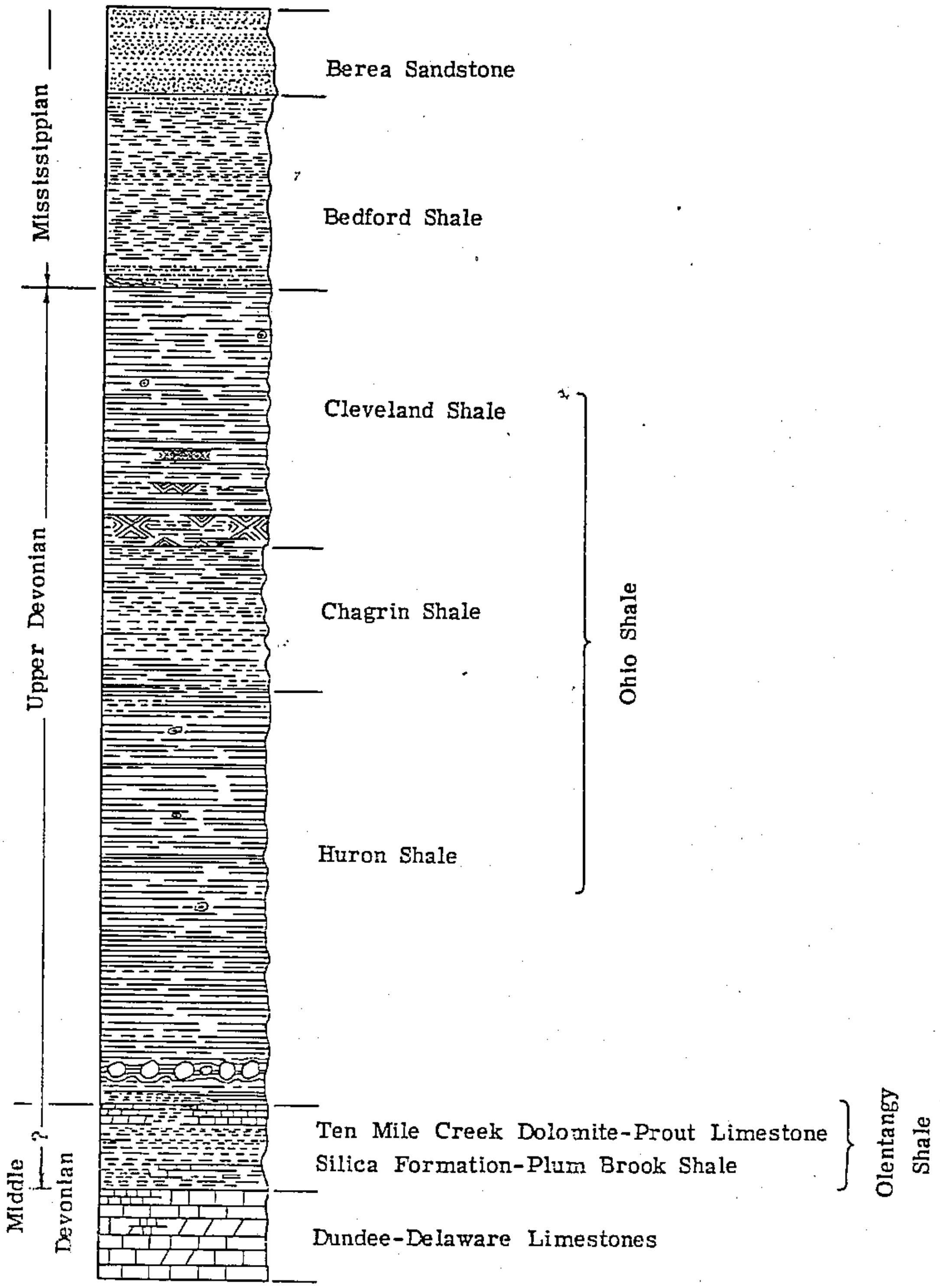
} Ohio Shale } ∴ Antrim Shale

- ▓ Olentangy Shale { ▨ Prout Limestone, ▤ Plum Brook Shale } { ▥ Ten Mile Creek Dolomite, ▒ Silica Shale
- ▦ Delaware Limestone
- ▓ Dundee Limestone
- ▦ Columbus Limestone
- ▥ Hillsboro Sandstone
- ▦ Greenfield Dolomite

0 500 1000 1500 Feet

Vertical Scale

Figure 5. Devonian-Mississippian Shale sequence (after Hoover 1960).



Generalized columnar section of the Devonian-Mississippian shale sequence.

Figure 6. Generalized columnar section of Devonian-Mississippian rocks in North Central Ohio (after Hoover 1960).

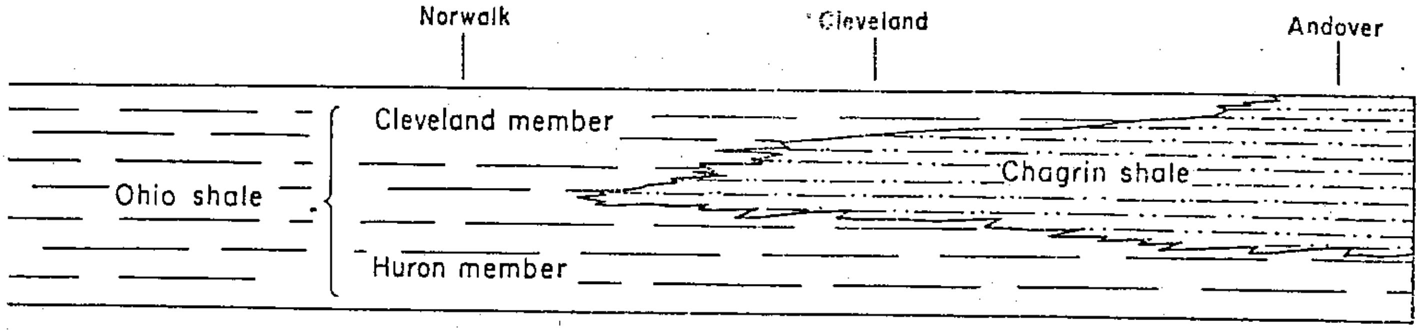


Figure 7. Schematic cross-section of the Ohio Shale in Northern Ohio, showing the relationship of the Huron, Cleveland, and Chagrin Shale members (after Pepper *et al* 1954).

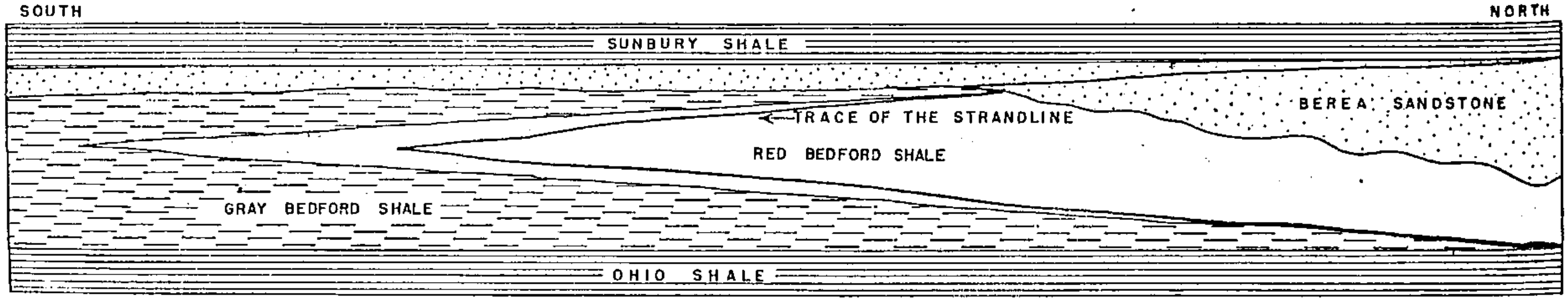


Figure 8. Schematic cross-section from Lorain County, Ohio to Wayne County, West Virginia, showing the relative position of the ocean strand during the deposition of the Bedford and Berea sediments. The heavy black line joins successive points occupied by the strand line; terrestrial and subaerial deposition occurred north of this line (Pepper et al. 1954).

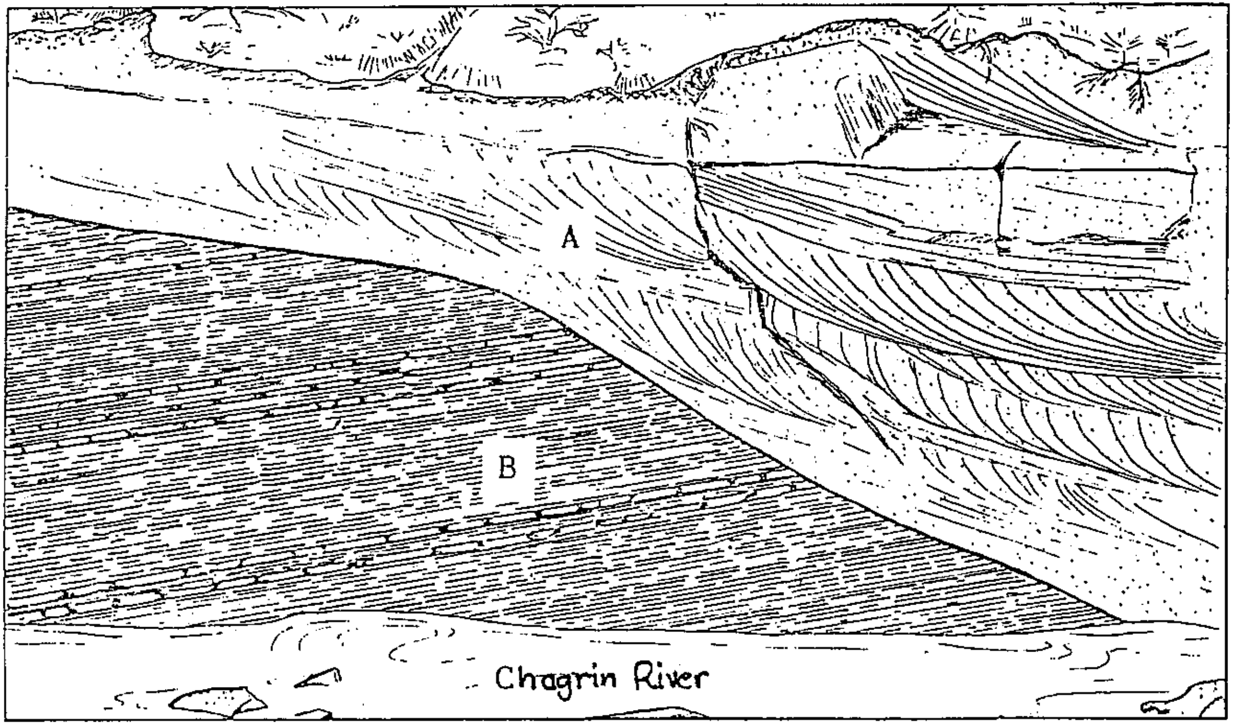


Figure 9. Sketch of the unconformable contact between the Berea Sandstone (A) and the Bedford Shale (B) in Chagrin Falls Township, Cuyahoga County. Note cross-bedding in channel-fill (after Winslow _et al_ 1953).

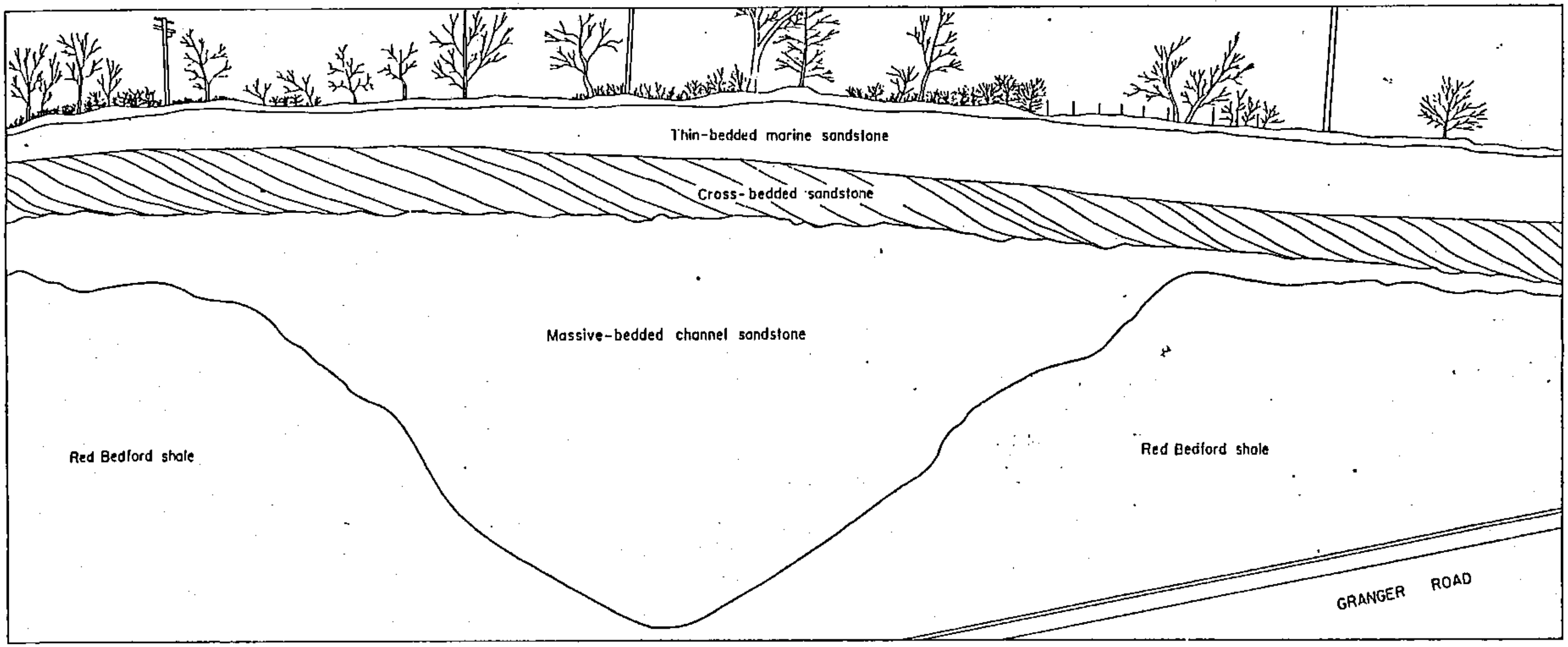
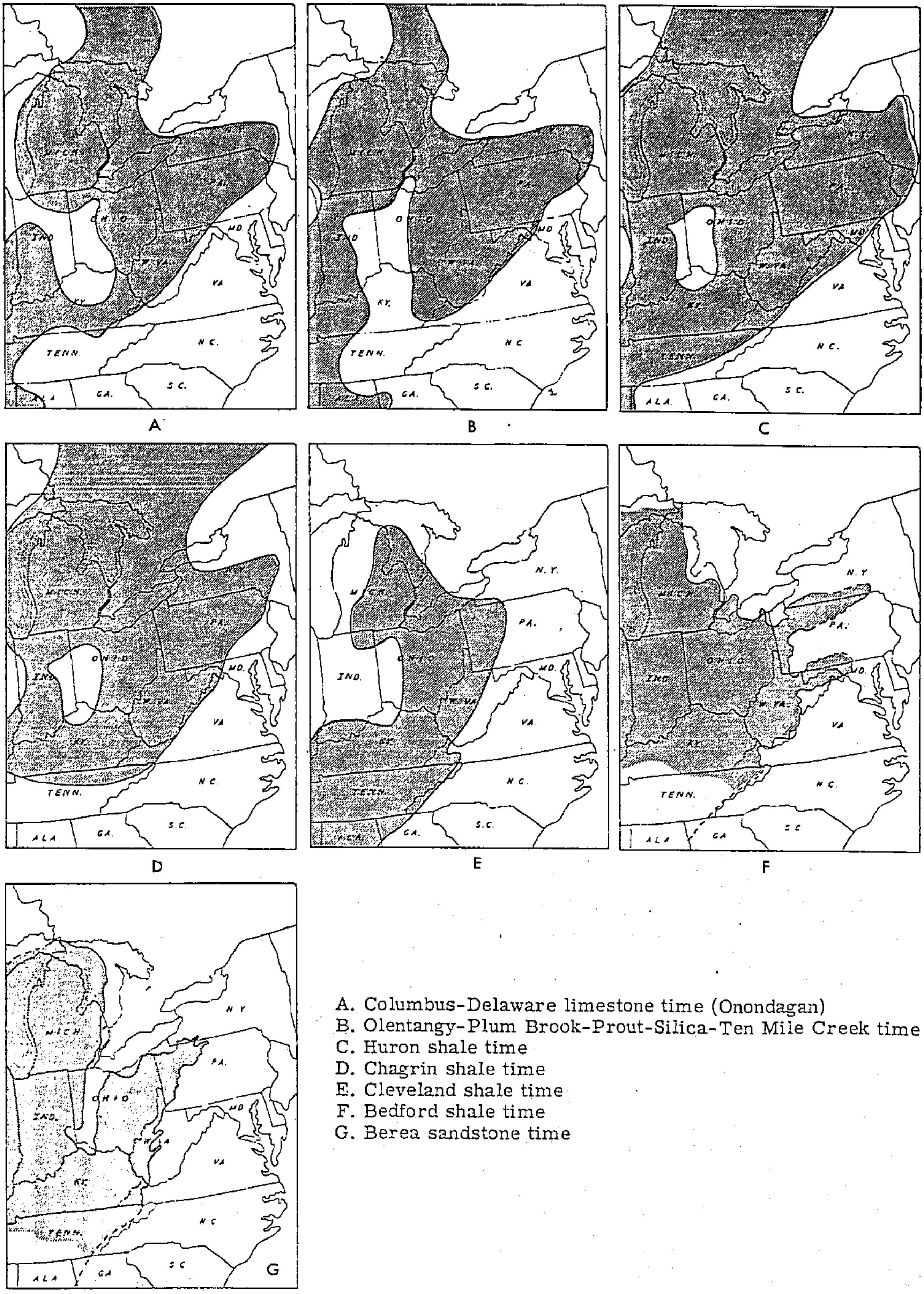


Figure 10. Sketch showing the three phases of Berea Sandstone in North Central Ohio (after Pepper et al. 1954).



A. Columbus-Delaware limestone time (Onondagan)
B. Olentangy-Plum Brook-Prout-Silica-Ten Mile Creek time
C. Huron shale time
D. Chagrin shale time
E. Cleveland shale time
F. Bedford shale time
G. Berea sandstone time

Figure 11. Paleogeographic maps of the Ohio region during part of the Devonian-Mississippian time. Shading indicates areas covered by marine waters (after Hoover 1960).

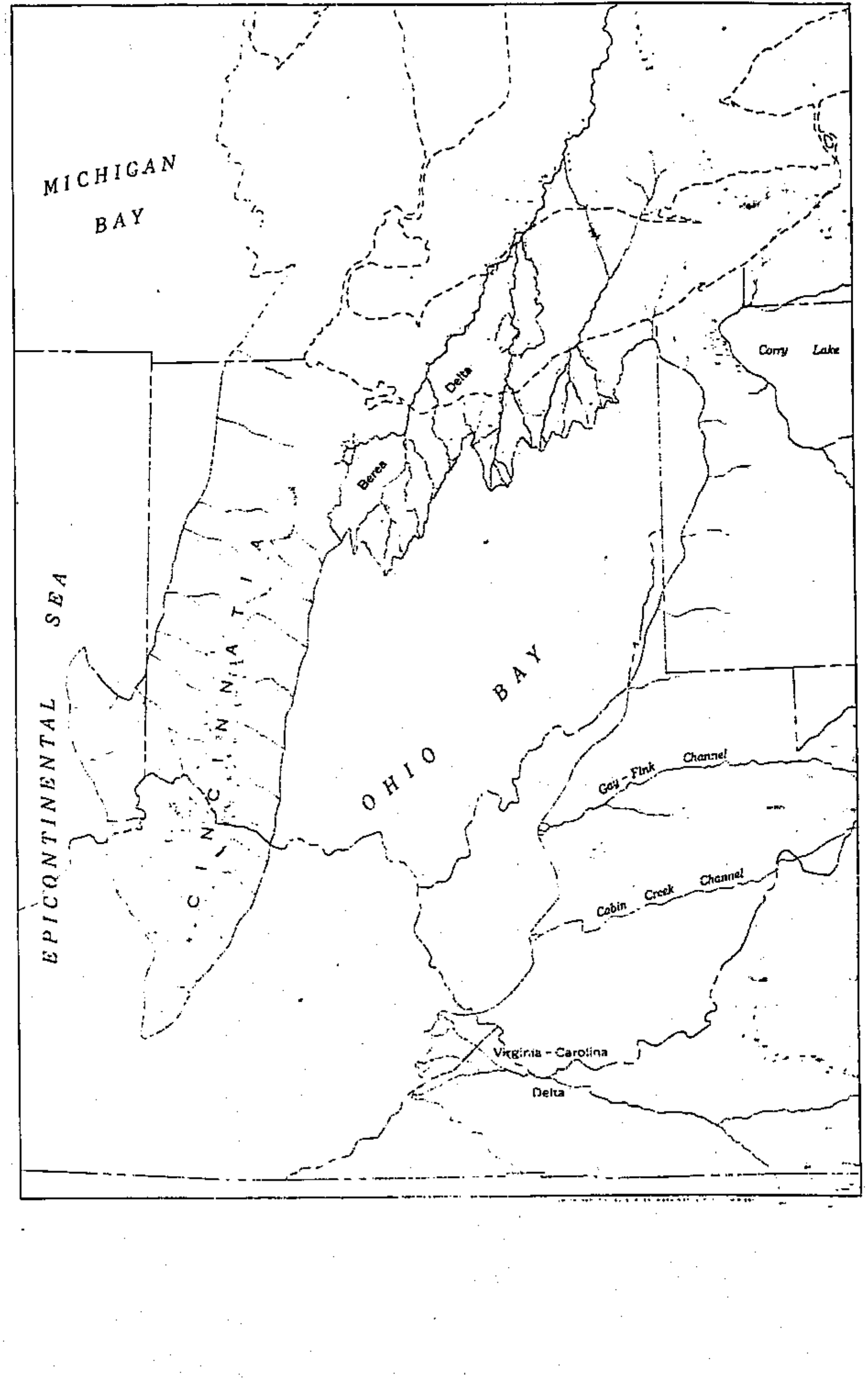


Figure 12. Paleogeographic map of Early Berea Time, showing development of the Berea Delta in North Central Ohio (after Pepper et al 1954).

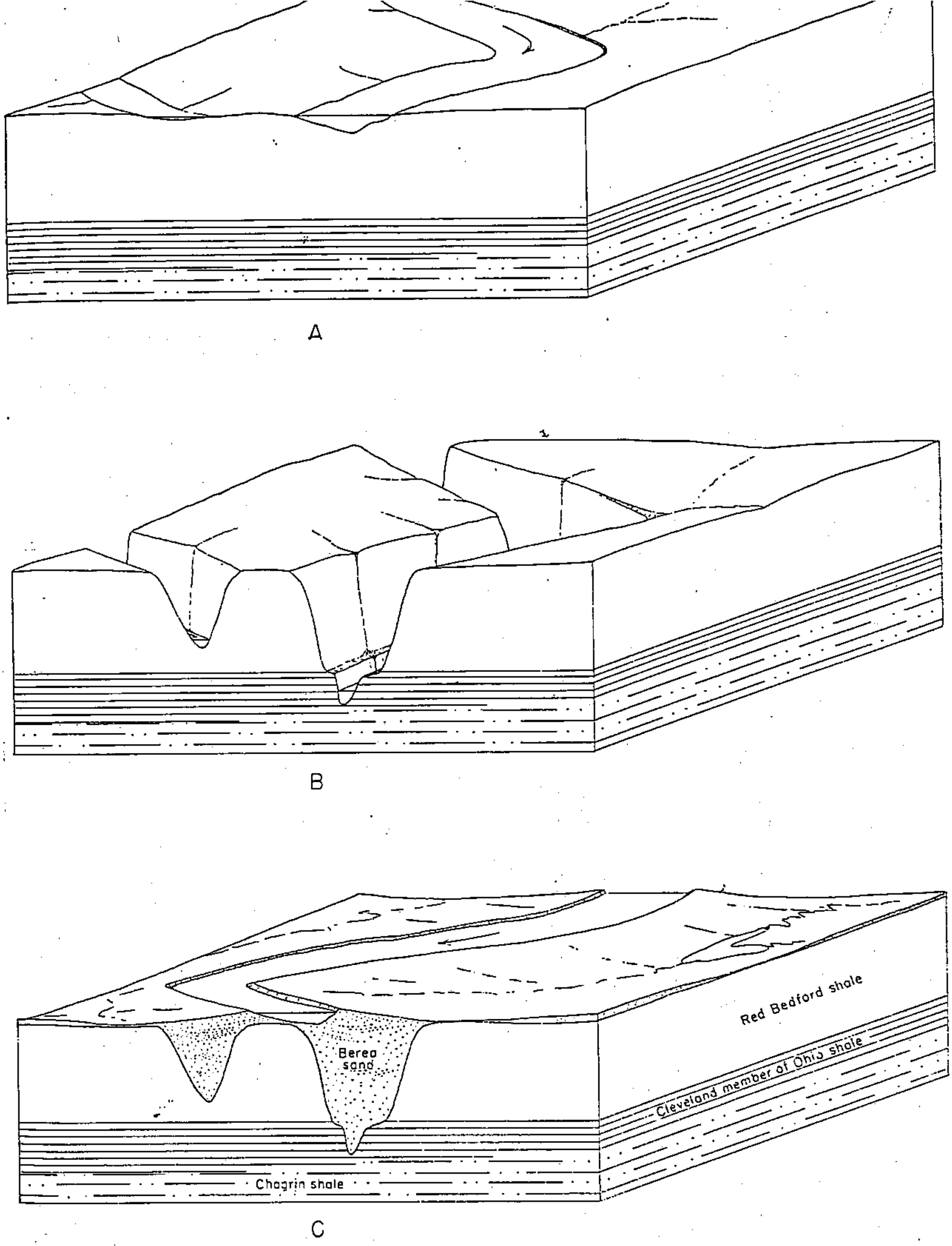


Figure 13. Schematic diagram which shows the development of the sand-filled channels during Berea time in northern Ohio. The upper block "A" shows the low undulatory land surface on the northern part of the Red Bedford Delta in late Bedford time. The middle block "B" shows the steep-walled channels at the time of maximum down-cutting. The lower block "C" shows the sand-filled channels covered by the relatively thin sheet sandstone; note that drainage pattern changed after channels were filled (after Pepper *et al* 1954).

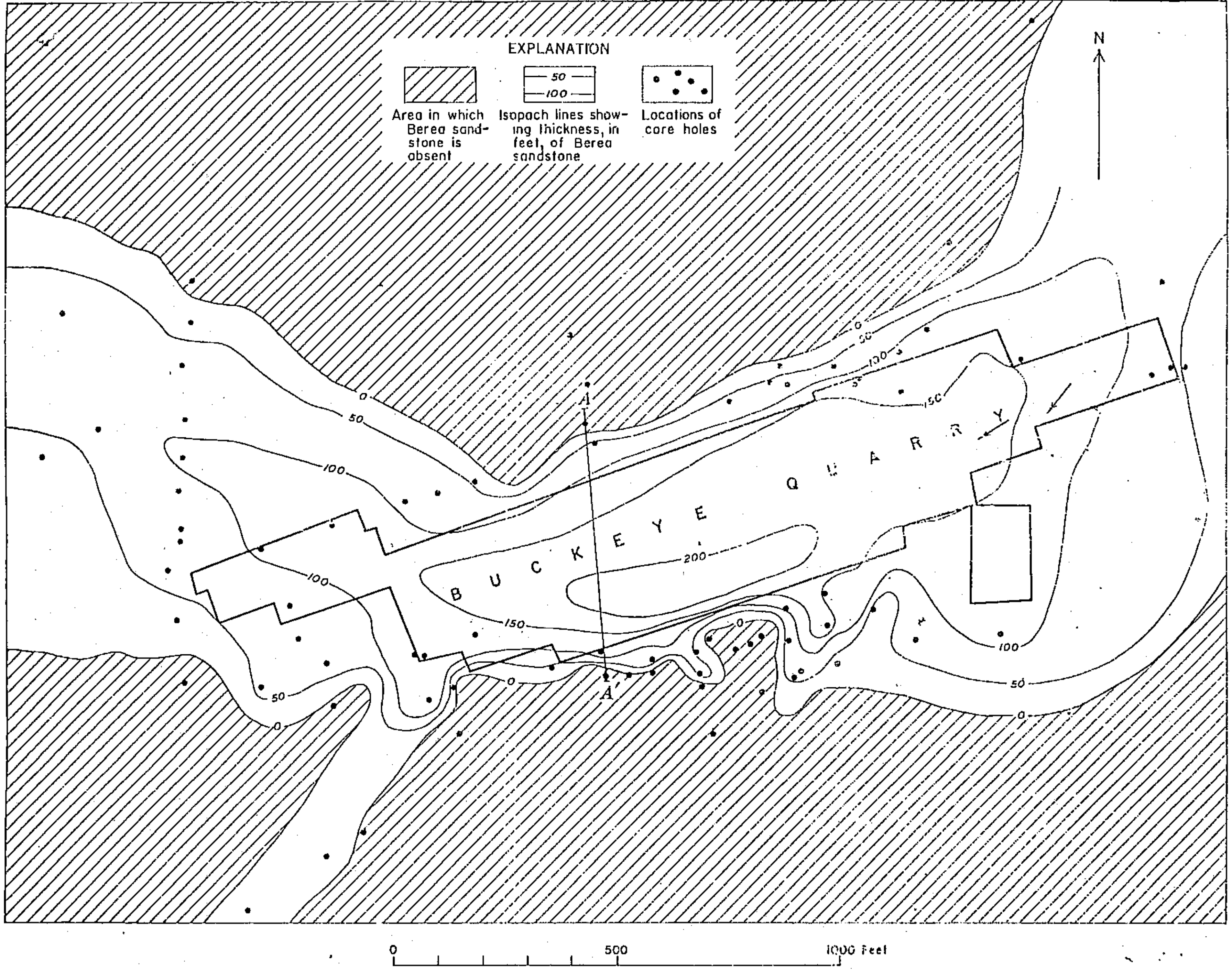


Figure 14. Map of the Buckeye Quarry in South Amherst, showing the thickness of the Berea Sandstone (after Pepper et al. 1954).

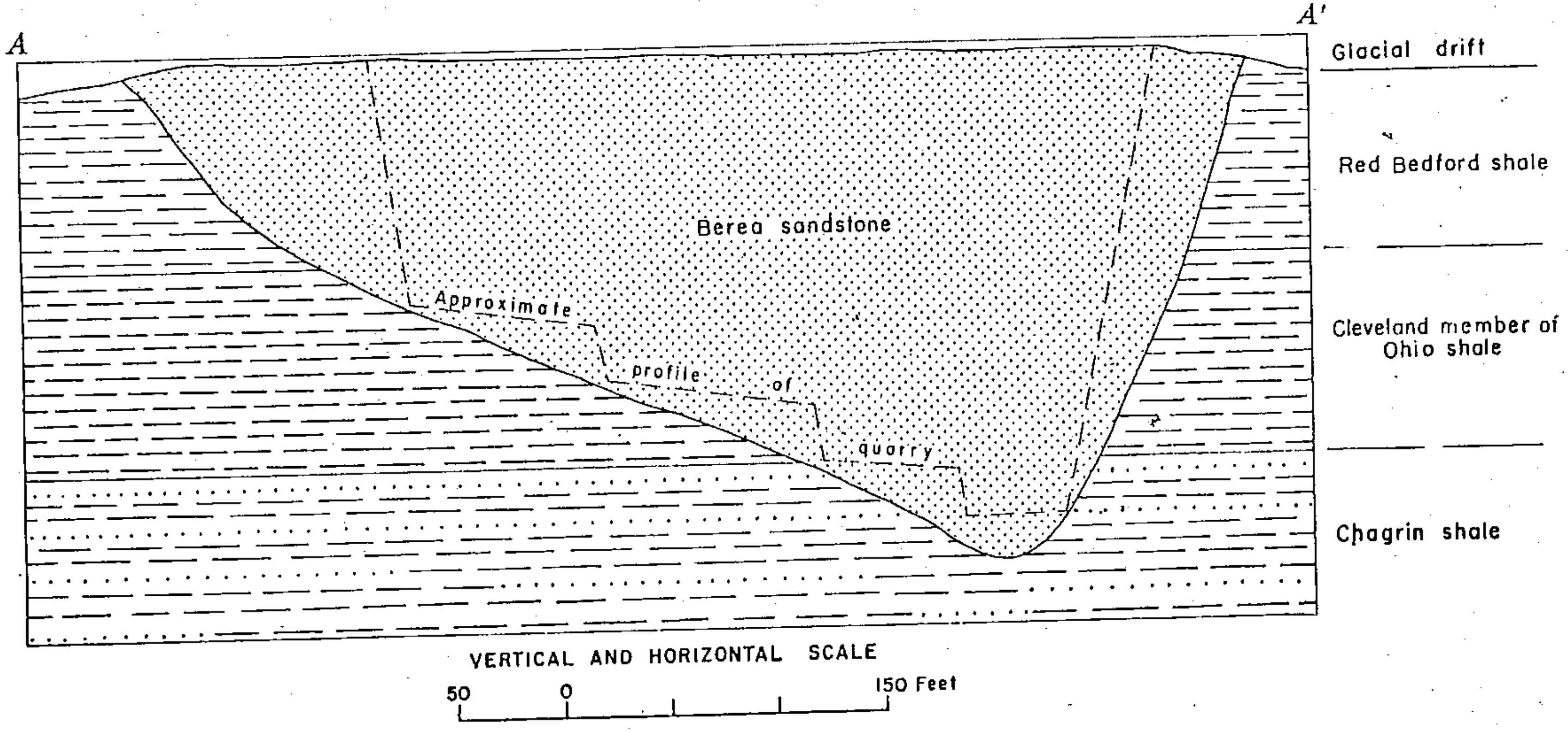


Figure 15. Cross-section of Buckeye Quarry in South Amherst. Location of cross-section (A-A') shown on Figure. Note that the deepest fill in channel and the steepest wall is near outside of meanderlike curve and that the channel is deepest in its narrowest stretch and shallowest in its widest stretches (after Pepper et al. 1954).

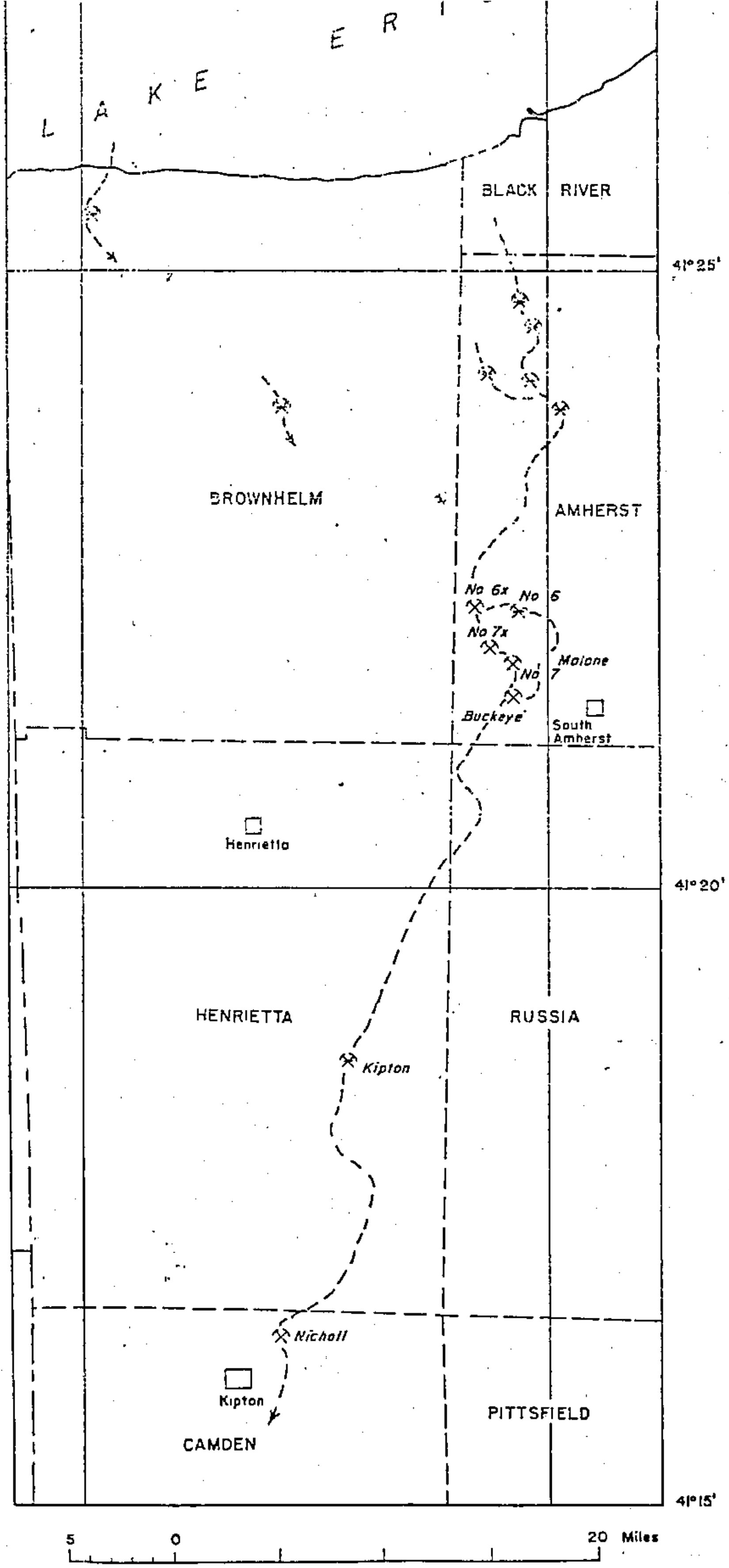


Figure 16. Map of western Lorain County showing the probable course of the Berea channel system as revealed by sandstone quarrying (after Pepper _et_ _al_ 1954).

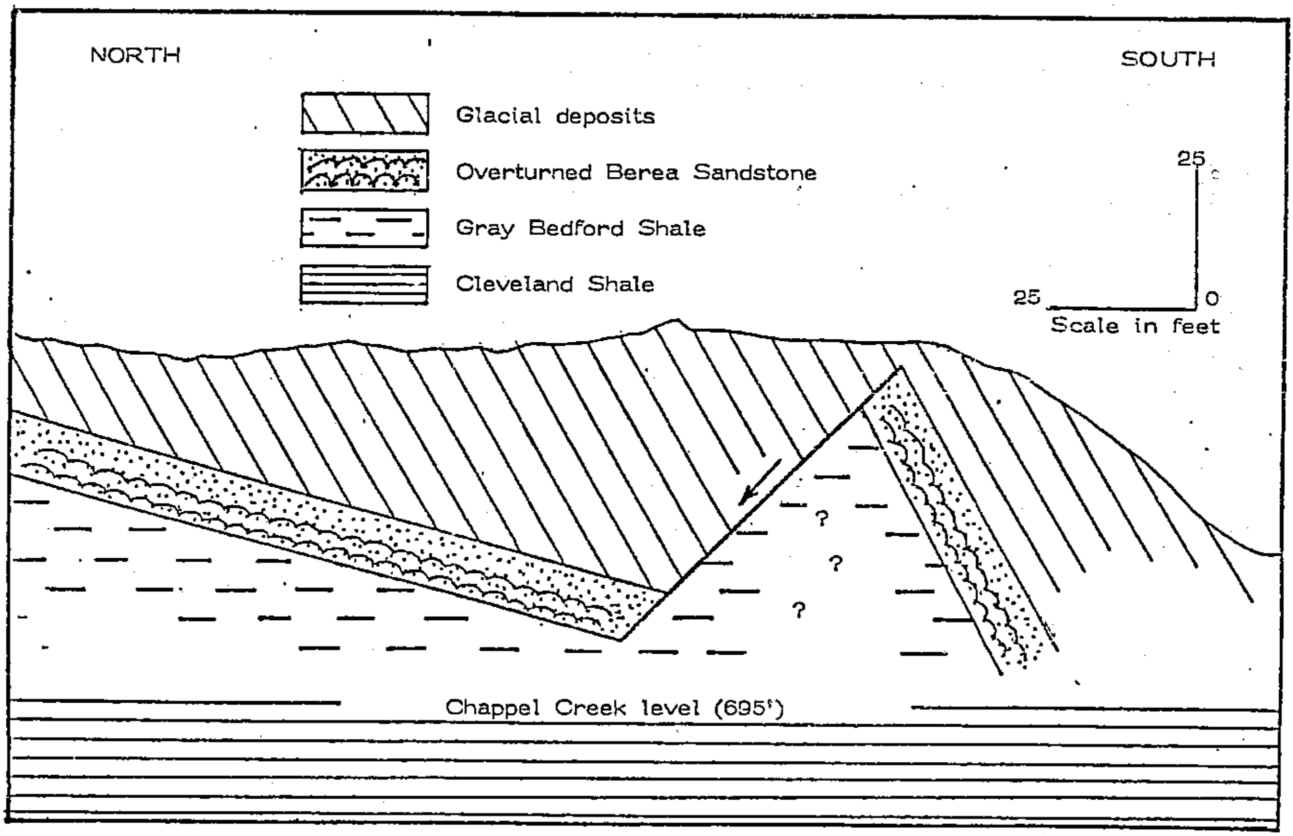


Figure 17. Cross-section along the east bank of Chappel Creek north of Furnace Rd. bridge, showing overturned Berea Sandstone (after Herdendorf 1963).

GUIDE TO FIELD TRIP STOPS

The following section is a field trip guide to 10 stops within the study area, Lorain to Sandusky, Ohio (Figure 1). A location map (portion of the appropriate U.S.G.S. 7 1/2 min. topographic map) follows the explanation of the features to be seen at each stop. At the end of this guide is a Road Log of the entire trip.

STOP NO. 1 -- BEREA SANDSTONE QUARRIES

Location

- South Amherst, Lorain County
- Kipton Quadrangle (41°22', 82°15')
- Buckeye Quarry located northwest of the intersection of Ohio Rt. 113 and Quarry Rd. and Gray Canyon Quarry (No. 6) located 1.5 km north of intersection on west side of Quarry Rd.

Contact

Mr. R. C. Bectel, President
Mr. J. O. Kamm, Chairman of the Board
Cleveland Quarries Company
South Amherst, OH
(216) 986-4501

Explanation

Buckeye Quarry, acclaimed to be the deepest sandstone quarry in the world, is about 75 m deep, 180 m wide, and 550 m long (Figures 14 and 15). The quarry was opened in the 1920s. Although not as deep as Buckeye Quarry, Gray Canyon Quarry (No. 6) is the largest quarry in South Amherst (reputed to be the largest sandstone quarry in the world) with of depth a about 50 m, width of 320 m, and length of 940 m. The circumference of this quarry is over 2.5 km. During its more than 100 years of operation, it has produced approximately 15,000 cubic meters of sandstone.

The sandstone is quarried as rough dimension blocks which weigh typically up to 20 tons, although blocks weighing 40 tons have been produced for special purposes. Quarrying is carried out by channeling machines and to a lesser extent by blasting.

The blocks are hoisted to the surface by means of large derricks. From there they are transported by train or truck to mills and fabricating plants on the Cleveland Quarries Company property. Here the blocks are subjected to gang saws, diamond saws, and planing machines. Several million cubic feet of sandstone were quarried and fabricated in the South Amherst area annually in the late 1970s. Attention was first drawn to the Berea Sandstone in the 1840s because of its suitability as grindstones.

Because of its high heat resistance, today, the sandstone is used as a lining for Bessemer converters, chemical vats, soaking pits for steel manufacture, and ladles. It is also used extensively in foundries for cupola lining and as refractory sand. Much of it is used for construction purposes as cut stone, building stone, building facings, garden stone, sidewalk stone, curbing, step treads, and crushed stone. In addition a large amount of it has been used for the construction of breakwater walls along the Great Lakes (such as Lorain and Cleveland harbors).

For the first decade the rock was quarried almost entirely for the manufacture of grindstones, which became a major industry in this part of Ohio. During the period from 1850 to 1870 the rock was developed as a building material once it was recognized that it was extremely uniform and highly durable.

Sandstone quarried in this area was used in public buildings, churches, commercial buildings and college buildings, including Orton Hall on the Ohio State University campus, which is the home of the Geology Department and the former home of the Ohio Geological Survey.

The origin of the sandstone in the quarries is clearly that of sands filling erosion channels in the Bedford and Ohio Shales. The channel fills are characterized by steep walls, sinuous alignment, and rounded basal profiles (Figure). The channel sandstone at Buckeye Quarry is at least 80 m thick.

Notes

OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)
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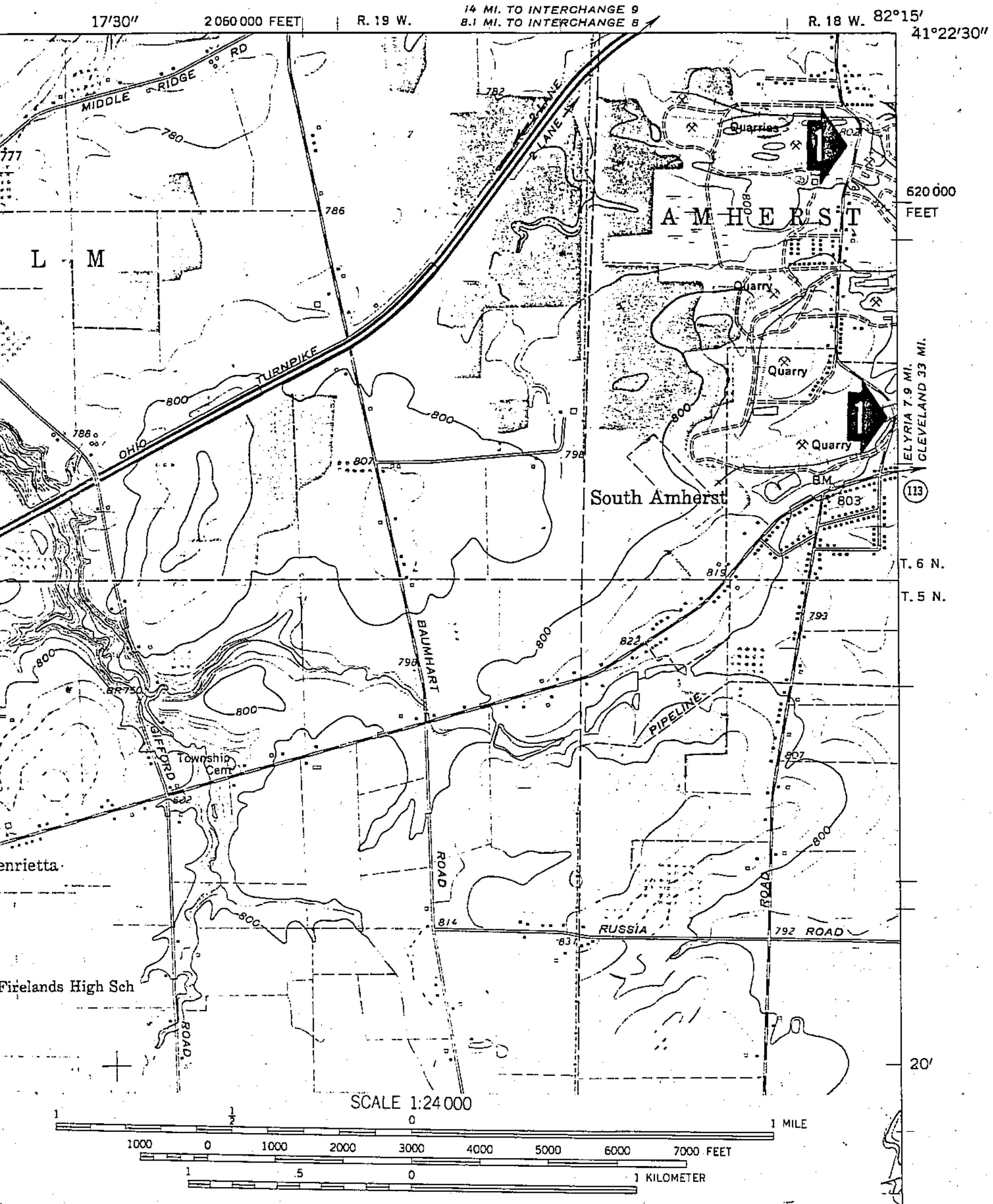

CONTOUR INTERVAL 5 FEET
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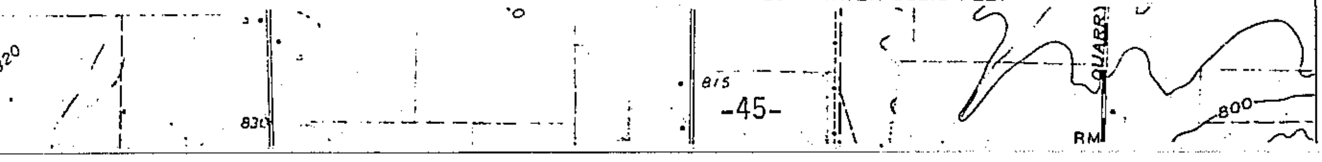
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS LOW WATER 568.6 FEET



STOP NO. 2 -- CLIFF PHASE OF LAKE WHITTLESEY SHORELINE

Location

- Amherst Township, Lorain County
- Lorain Quadrangle (41°24', 82°12')
- Sandstone ridge lies 0.5 km east of intersection of North Ridge Rd. and Dewey Rd.

Contact

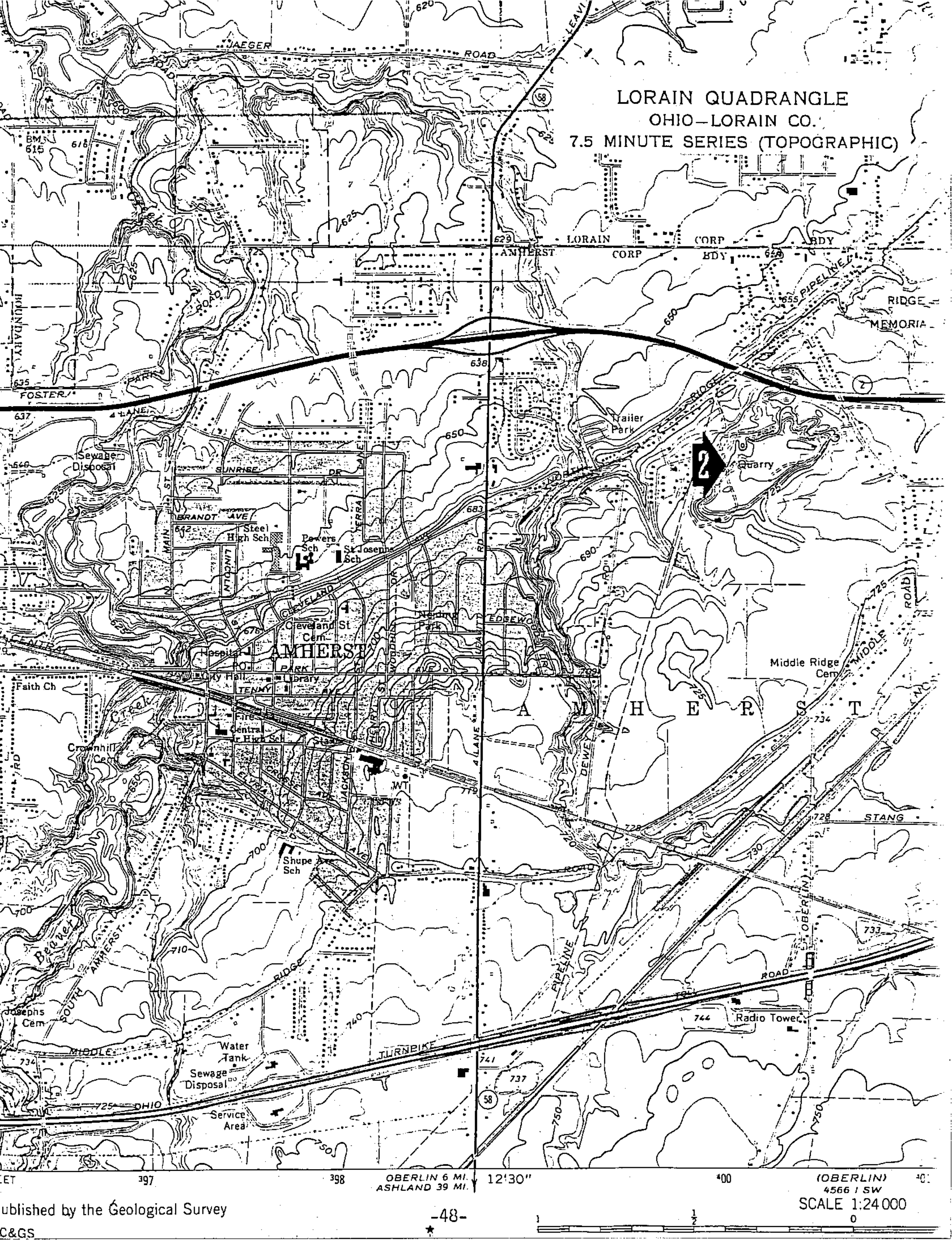
Mr. Rodney Nixon
6020 Oberlin Rd.
Amherst, OH 44001
(216) 233-5036

Explanation

Wherever an ancient shoreline coincided with the outcropping Berea Sandstone, lake waves produced headlands, cliffs, and in some areas, shore platforms, stacks, sea caves, and arches. This abandoned sandstone quarry in Amherst Township provides excellent examples of these wave erosion features.

The Berea Sandstone outcrop is one of two sandstone outliers which were islands in the early part of the Lake Whittlesey stage. Tombolo-type spits appear to have developed from the shore to each of the islands, eventually uniting the islands and forming a broad cape (Carney 1911).

Notes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BOUNDARY
Trailer Park
Quarry
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NORTH
RIDGE
Sewage Disposal
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STOP NO. 3a -- BEREA SANDSTONE CLIFF ON LAKE ERIE SHORELINE

Location

- Vermilion-on-the-Lake, Lorain County
- Vermilion East Quadrangle (41°26', 82°19')
- On lakeshore, 3.4 km east of Vermilion River mouth on Edgewater Drive

Contact

Vermilion-on-the-Lake Lot Owners Association
Mrs. Wyeth (for Key)
3799 Edgewater Drive
Vermilion, OH
Clubhouse at Ft. of Delaware
(216) 967-4118
also Aunt Ruth's store has information on access.

Explanation

This is the only known outcrop of Berea Sandstone on the shore of Lake Erie. The sandstone is massive and forms a prominent headland flanked by exposures of Bedford Shale and Ohio Shale. The outcrop represents Berea sand filling an erosion channel in the red Bedford Shale. Broken flow-roll structures can be seen at the base of the sandstone. The cliff is 7 m high and the channel sand is underlain by steeply dipping (40°) red and light gray bands of shale. These beds are in turn underlain by contorted beds of Ohio Shale. The contortion is very localized; nearly flat-lying of Ohio Shale are found a short distance to the east.

Notes

STOP NO. 3b -- THRUST FAULT IN OHIO SHALE

Location

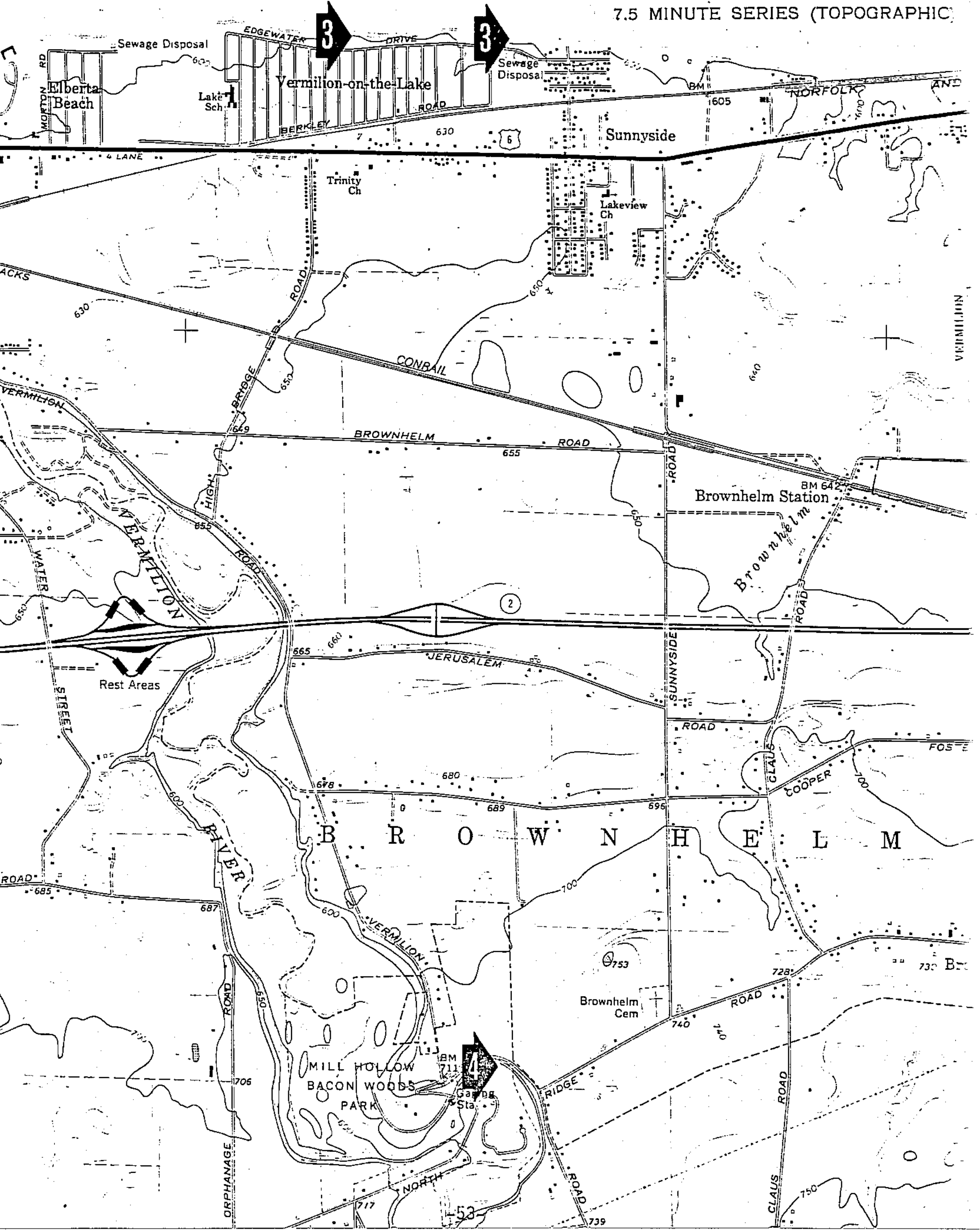
- Vermilion-on-the-Lake, Lorain County
- Vermilion East Quadrangle (41°26', 82°18')
- On lakeshore, 4.2 km east of Vermilion River mouth on Edgewater Drive at community park

Explanation

This thrust fault in the Ohio Shale (Huron Shale member) is exposed along in the lake bluff. The force for this high angle thrust fault (68°) appears to have been from the west, pushing beds of this block over the beds of the east block. The fault does not extend upward into the overlying glacial drift which forms a thin cap on the bluff at this location. The displacement appears to be about 1 m. To the east, the upper surface of the shale dips below the level of Lake Erie and does not reappear in the lake bluff for 16 km where it again crops out in Sheffield Lake (this feature may be a surface expression of the Lorain-Parkersburg Syncline). Here, the bluff is composed of two tills, probably 2 m of blue-green Illinoian ground morain overlain by 6 m of gray-brown Wisconsin deposits.

Notes

VERMILION EAST QUADRANGLE
OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)



STOP NO. 4 -- MISSISSIPPIAN-DEVONIAN CONTACT

Location

- Brownhelm Township, Lorain County
- Vermilion East Quadrangle (41°23', 82°19')
- Vermilion River bluff at intersection of North Ridge Rd. and Vermilion Rd. in Mill Hollow-Bacon Woods Metropolitan Park

Contact

Lorain County Metropolitan Park
Mill Hollow Park Maintenance Shop
Manager (Jack)
(216) 967-7310

Explanation

A bedrock thickness of 40 m is exposed in the bluffs of the Vermilion River. The contact between Mississippian (Bedford Shale) and Devonian (Cleveland Shale) rocks can be seen at this location. The following section of rocks have been measured at this location (Herdendorf 1973):

MISSISSIPPIAN SYSTEM

Bedford Shale	Unit Thickness (m)	Cumulative Thickness (m)
Upper Beds		
10. red, clay shale	2.51	40.05
9. gray, clay shale	0.08	37.54
8. red, clay shale	3.20	34.46
7. gray, clay shale	4.67	34.26
Euclid Siltstone Member		
6. brown, siltstone	0.58	29.59

Basal Beds		
5. gray, clay shale	0.83	29.01
4. brown siltstone	0.41	28.18
3. gray, clay shale	1.88	27.77
DEVONIAN SYSTEM		
Ohio Shale		
Cleveland Shale Member		
2. black, hard, fissile shale	15.09	25.89
Cleveland-Chagrin Shales Interfingering		
1. alternating black and gray thin shale layers	10.80	10.80

A small Berea Sandstone channel-fill can be seen directly behind the park maintenance area at the top of the bluff where Vermilion Rd. interects North Ridge Rd. Here, the sandstone outcrop shows an unusual, fluted erosion patter, probably the result of wind abrasion.

Notes

STOP NO. 5 -- BEREA SANDSTONE CHANNEL-FILL

Location

- Florence Township, Erie County
- Kipton Quadrangle (41°20', 82°21')
- Vermilion River bluff at Rt. 113 bridge, Birmingham

Contact

Mr. Earl Barchert
Barchert's Market
Birmingham, OH
(216) 969-4088

Explanation

About 0.4 km north of the Birmingham bridge, in the west bank of the Vermilion River, an interesting channel-fill structure occurs that simulates the structure of syncline. The structure plunges in a northeastward direction. Here about 3 m of Berea Sandstone, overlies 8 m of gray Bedford Shale which in turn rests on 6 m of Cleveland Shale. The basal sandstone contains flowage masses.

Notes

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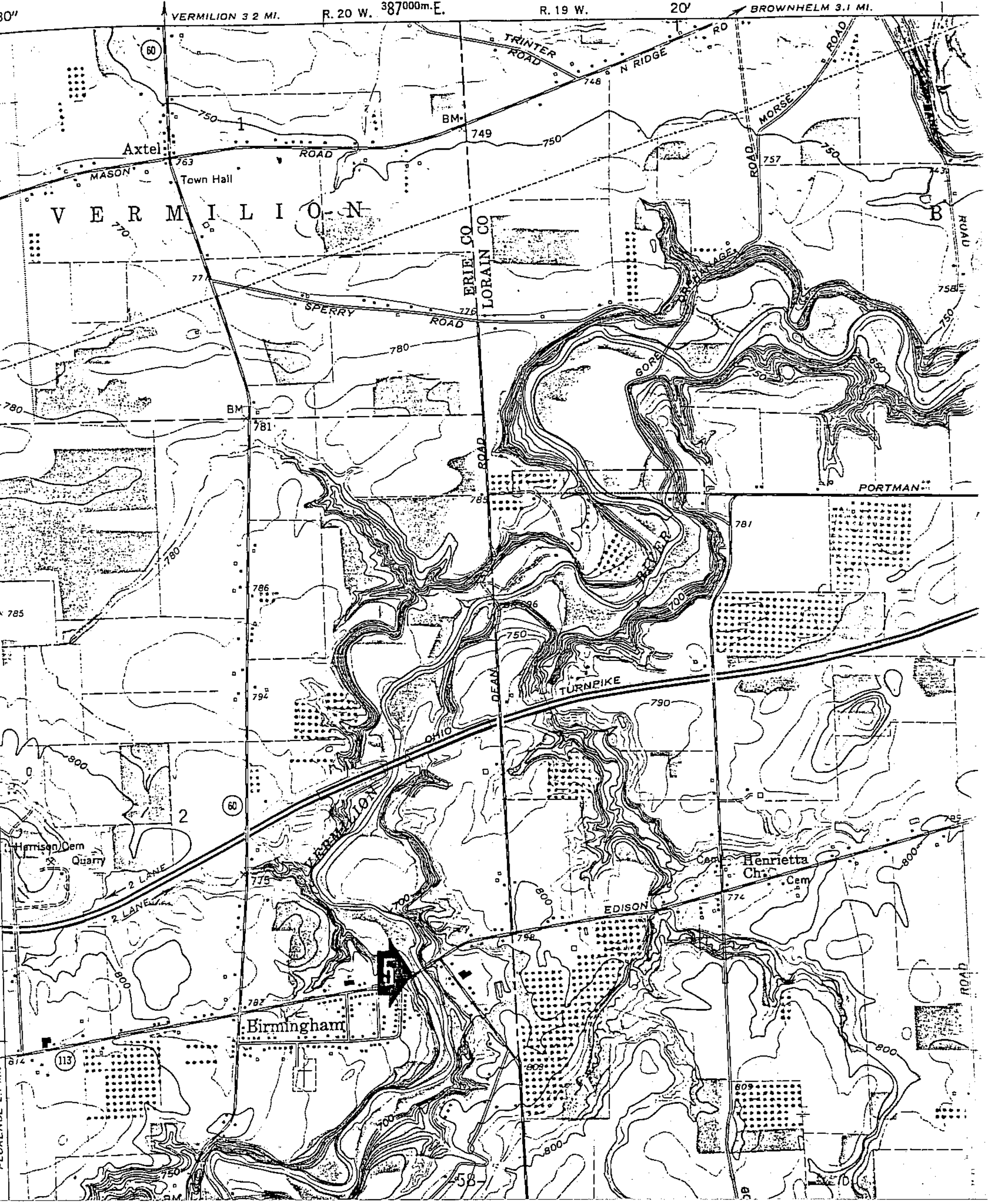
OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)



STOP NO 6a -- OVERTURNED BEREA SANDSTONE

Location

- Florence Township. Erie County
- Berling Heights Quadrangle (41°21', 82°26')
- Chappel Creek at Furnace Rd. bridge

Contact

Mr. Gary Stack
9517 Furnace Rd.
Vermilion, OH 44089
(216) 965-7788
(216) 965-7211

Explanation

Ohio Shale, Bedford Shale, and Berea Sandstone are exposed in the bluff of this creek, north and south of the bridge. On both sides of the stream, about 100 m north (downstream), overturning and faulting have placed large slabs of Berea Sandstone in unusual attitudes. Here, the beds dip 56°, S 20° W and approximately 30 m farther north the dip is only 10° in the same direction. The first outcrop is 3 m thick and 15 m long, extending at a steep angle from the creek bed to the top of the bank. The second outcrop, which is separated by a covered interval of glacial till, is about the same thickness and also persists from the stream bed to the top of the bluff, but because of its more gentle dip it is nearly 100 m long. On close inspection of these outcrops it was concluded from up-side-down oscillation ripple marks and cross-beds truncated downward that both were overturned strata, the first being overturned 124° from its normal horizontal position and the second 170° (Figure 17).

This overturning appears to be very local, for a 100 m farther north similar beds are right-side-up near the top of the valley bluff and 100 m to the south, sandstone beds are in a normal position in the bed of the creek.

The explanation for this unusual strcuture may lie in the fact that in pre-glacial times the Berea Sandstone probably extended across north central Ohio as a terrace-like landform, cut only by northward flowing streams, which must have presented a formidable barrier to ice movement. If the glacial advance can be assumed to have been from the north or northwest, as indicated on the glacial map of Ohio (Goldthwait et al 1967), the maximum deformation and movement would be expected toward the south and southwest. When the sandstone was finally over-ridden, large blocks and slabs of rock may have been broken up and dislodged from the northern edge. Such a process may account for the overturned strata in the Chappel Creek valley. As the ice dislodged the slab, it could have been easily pushed or dragged across the surface of the plastic clay shale of the underlying Bedford Formation. The slab may have moved only a short distance before being overturned which caused the fracture separating the two blocks. The force of the frictional drag along the bottom surface of the ice sheet may have also caused the broken, rumpled and faulted shale beds at various places between Lake Erie and the sandstone outcrop, particularly along the shore near Vermilion, Ohio (Stop No. 3b).

Notes

STOP NO. 6b -- SANDSTONE AND SHALE STRUCTURES

Location

- Vermilion Township, Erie County
- Berlin Heights Quadrangle (41°22', 82°26')
- Chappel Creek at Darrow Rd. bridge

Explanation

Downstream (north) and upstream (south) of the Darrow Rd. bridge the sandstone and shale beds exhibit a number of interesting structural features. Downstream about 30 m, a sandstone channel-fill shows flow-rolls and oscillation-type ripple marks. Farther downstream the Cleveland Shale beds are nearly horizontal but become progressively steeper upstream toward the channel-fill (42°). In the bed of the creek, the Cleveland Shale exhibits a peculiar curved joint system.

Upstream about 300 m, a slump block of red Bedford Shale (15 m wide and 6 m high) has been displaced about 10 m downward. Flow-rolls can be seen in the basal part of the Bedford Shale. Within the next 100-200 m upstream, features such as the interfingering of the Chagrin Shale member, cone-in-cone limestone, thrust faults, north-south joint system, and a gentle anticline can be observed. All three members of the Ohio Shale can be seen together at the crest of the anticline.

Notes

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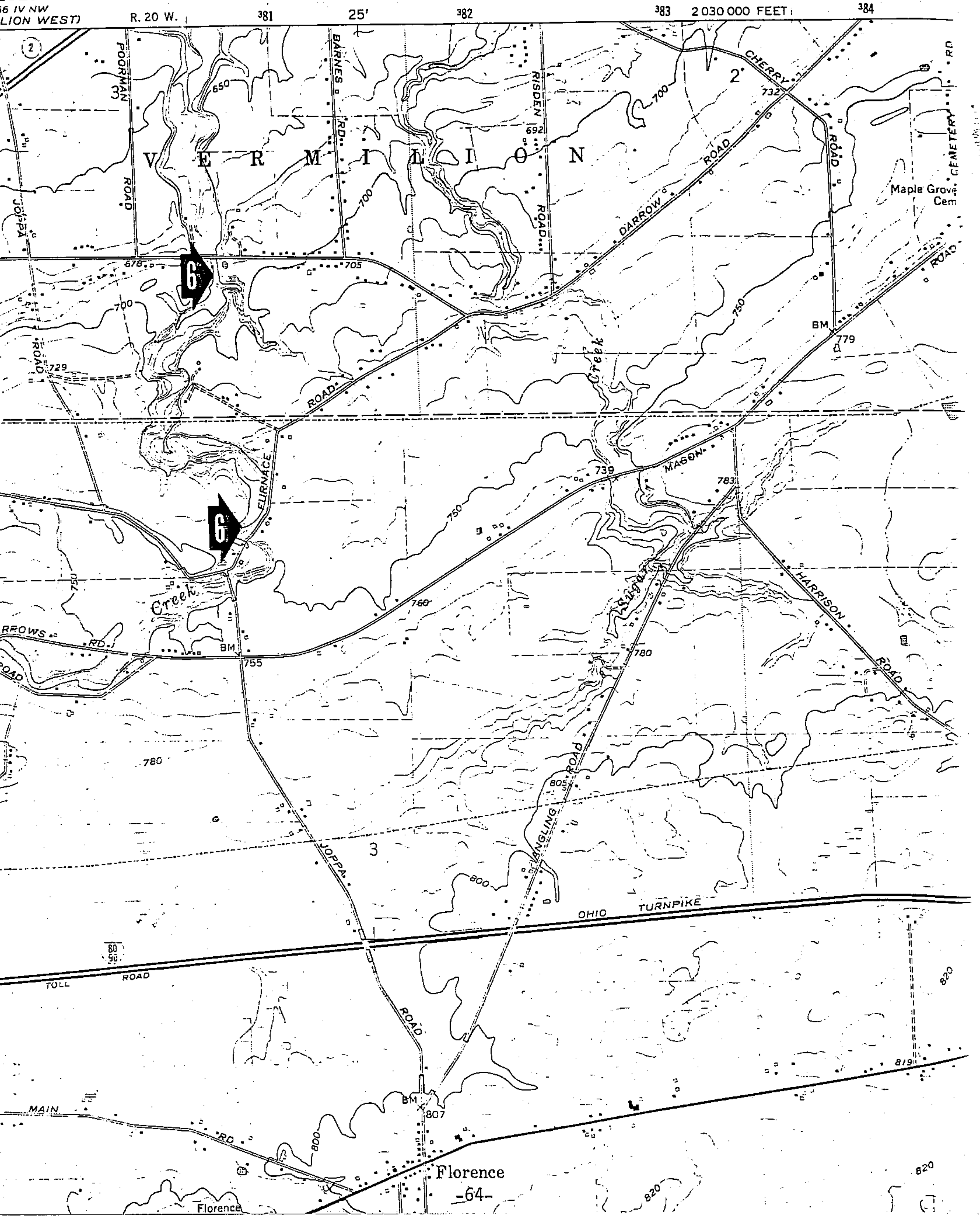
7.5 MINUTE SERIES (TOP



STOP NO. 7 -- BEREA ESCARPMENT

Location

- Berlin Township, Erie County
- Berlin Heights Quadrangle (41°20', 82°29')
- Berea escarpment about 0.5 km west of junction of Humm Rd. and Mason Rd.

Contact

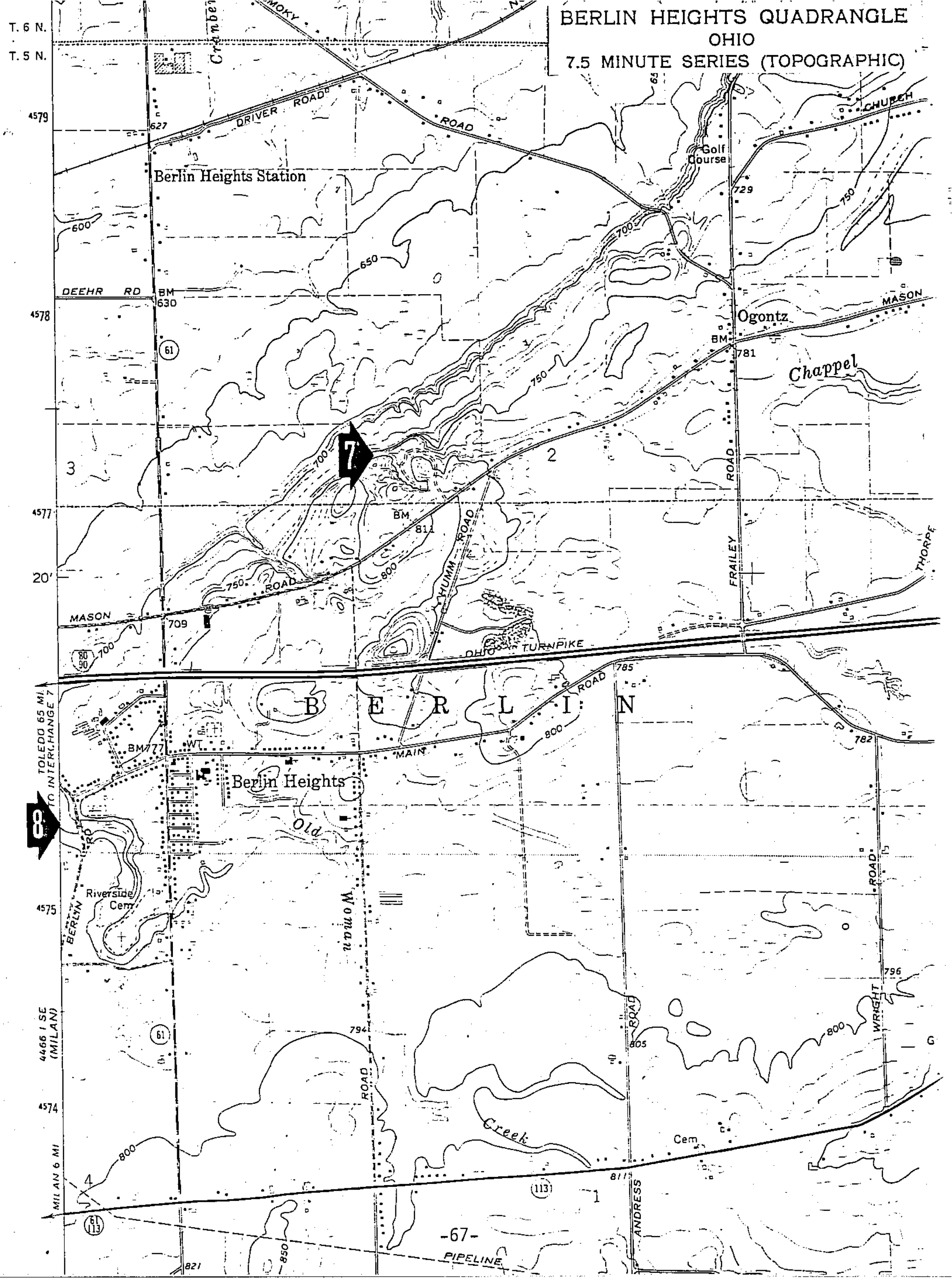
Mrs. William Gammie
Quarry Hill Orchards
8403 Mason Rd. (at Humm Rd. intersection)
Berlin Heights, OH
(419) 588-2232

Explanation

The abandoned Baillie Quarry is located at the end of an orchard lane leading from Darrow Rd. Here, the escarpment created by the northern edge of the Berea Sandstone forms a conspicuous feature, rising over 50 m from the lake plain. Cliff phases of the Lake Maumee, Lake Whittlesey, and Lake Warren shorelines are etched into the sandstone. Lake Maumee wave-cutting can be seen in the quarry. The lake formed in the abandoned quarry is noted for its rather rare population of freshwater jellyfish, *Craspedacusta sowerbyi*. This is one of the few freshwater coelenterates with a true medusa stage.

Notes

BERLIN HEIGHTS QUADRANGLE
OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)



STOP NO. 8 -- FLOW ROLLS IN BEREA SANDSTONE

Location

- Berlin Township, Erie County
- Berlin Heights Quadrangle (41°19', 82°30')
- Old Woman Creek valley at Berling Rd. bridge, Berlin Heights

Contact

Mr. Alex Gammie
Berlin Rd. at Old Woman Creek
Berlin Heights, OH
(419) 588-2191

Explanation

The valley of Old Woman Creek, on the west and southwest sides of Berlin Heights, provides an opportunity to observe a number of structural features of Berea Sandstone. The most striking features are the large (up to 3 m diameter) flow-roll structures in the east and west valley walls of the creek near the Berlin Rd. bridge. About 300 m downstream the basal portion of a Berea Sandstone channel-fill can be observed in the east bank. Flow-rolls are also prominent in the underlying Bedford Shale. In this same area arcuate joint planes can be seen in the Ohio Shale. About 500 m upstream of the Berlin Rd. bridge, a normal fault is visible in the sandstone. Here, a displacement of 1 m occurs in the west bank and only 0.3 m in the east bank of the creek.

At the top of the bluff south of the bridge a recent sand and gravel pit has been opened to furnish material for the Ohio

Rt. 2 Huron Bypass. Over 5 m of coarse sand and gravel are exposed in the massive pit. These are likely Lake Maumee beach materials.

Notes

STOP NO. 9 -- HURON SHALE AT ITS TYPE LOCALITY

Location

- Milan Township, Erie County
- Milan Quadrangle (41°18', 82°37')
- Bluff of the Huron River at the junction of Ohio Rt. 113 and U. S. Rt. 250

Contact

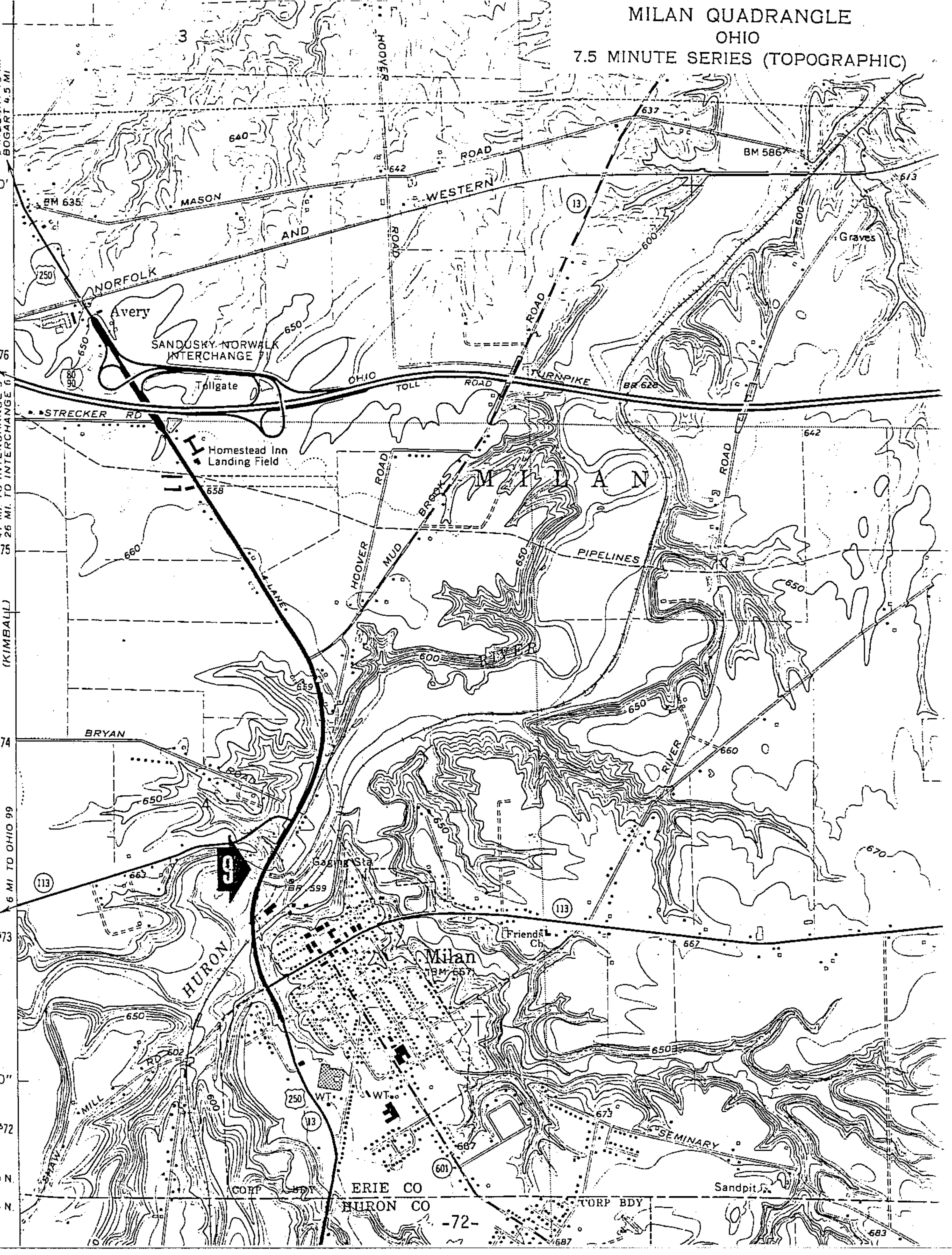
N.A.

Explanation

The Huron Shale, the lowest member of the Ohio Shale sequence, is exposed in the cliffs of the Huron River between Norwalk and Milan where it was designated as the type locality by Newberry (1871, p. 19). Here the Huron Shale is a grayish-black, carbonaceous, hard, fissile, shale containing many large concretions in the lower part. The large concretions are spherical septarian nodules with carbonate veins, generally ranging from 15 cm to 1 m in diameter, but a few are as large as 3 m. The overlying Cleveland Shale is characteristically smaller concretions which are also septarian, but have quartz and chalcedony fissure fillings; others are flat, disc-shaped concretions composed of pyrite and marcasite (Herdendorf 1962). Along the Huron River the overlying upper member of the Ohio shale, the Cleveland shale, is very similar lithologically to the Huron member but differs in that it contains thin limestone layers with cone-in-cone structure and alternating gray and black shale beds in its basal part. This alternation of beds probably extends down into the Huron member, because the contact of the two members is arbitrarily drawn below the lowest cone-in-cone layer and above the uppermost zone containing the large concretions. The gray shale beds are probably interfingering of the Chagrin Shale member from the east. The Chagrin Shale, as a distinct mappable unit, is not exposed in the study area. It is represented by soft, gray argillaceous shale beds, containing concretionary siltstone layers, which alternate or interfinger with the black shale beds of the Huron and Cleveland members.

Notes

MILAN QUADRANGLE
OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)



STOP NO. 10 -- PROUT LIMESTONE - OHIO SHALE CONTACT

Location

- Huron Township, Erie County
- Huron Quadrangle (41°25', 82°37')
- Exposure in railroad right-of-way along U.S. Rt. 6 (Cleveland Rd.), 0.2 km east of junction with Camp Rd.

Contact

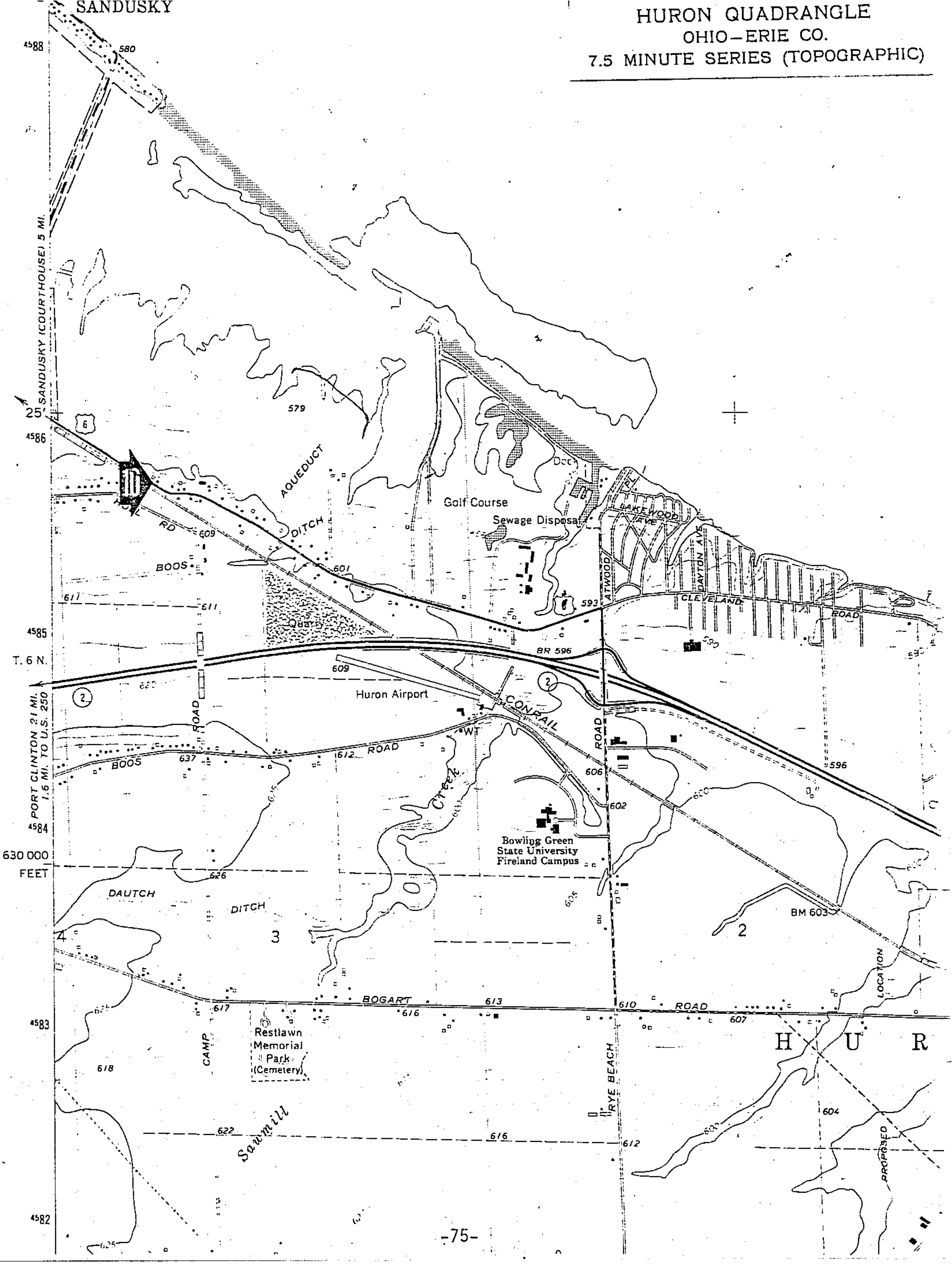
Barnes Nursery and Garden Center
3511 Cleveland Rd. West
Huron, OH 44839
(419) 433-5525
(800) 421-8722

Explanation

This outcrop (known as "Slate Cut") provides a view of the rarely exposed contact between the Ohio Shale (Huron Shale member) and the Prout Limestone. The Huron, a hard, black, fissile shale is underlain by the dense, hard, fossiliferous Limestone of the Prout Formation. The grayish-white limestone has been stained reddish brown on the surface from iron oxide leached from pyrite in the shale.

Notes

HURON QUADRANGLE
OHIO–ERIE CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



ROAD LOG

Trip will start in South Amherst at the intersection of Ohio Rt. 113 and Quarry Rd. (NE corner of Kipton Quadrangle).

Mileage

0		STOP NO. 1 - after viewing the quarries, proceed east on Ohio Rt. 113 (Lake Maumee beach ridge).

Kipton Quadrangle
Oberlin Quadrangle

2.3	2.3	Turn north (left) on Ohio Rt. 58

Oberlin Quadrangle
Lorain Quadranlge

3.8	1.5	Pass Middle Ridge Rd. (Lake Whittlesey beach ridge)
5.0	1.2	Turn east (right) on North Ridge Rd. (Lake Warren beach ridge)
6.2	1.2	Turn south (right) on Oberlin Rd.
6.6	0.4	STOP NO. 2 - Turn west (right) on Nixon Lane and park at end of lane. After viewing sandstone outcrop return to intersection of North Ridge Rd. and Ohio Rt. 58 (Leavitt Rd.)
8.2	1.6	Turn north (right) on Ohio Rt. 58
8.8	0.6	Turn west (left) on Ohio Rt. 2
9.8	1.0	Beaver Creek (Ohio Shale outcrop)
10.3	0.5	Lake Lundy beach ridge (Grassmere beach) to the north (right)
10.9	0.6	Lake Wayne beach ridge

Lorain Quadrangle
Vermilion Quadrangle

14.5	3.6	Exit onto Jerusalem Rd., proceed west (right)
15.0	0.5	Turn north (right) on Vermilion Rd. (Vermilion River bluff)
15.5	0.5	Turn northeast (right) on High Bridge Rd. (Ohio Shale in R.R. cut under old bridge)

Mileage		
16.7	1.2	Turn east (right) on U.S. Rt. 6 (Erie Ave.)
17.0	0.3	Turn north (left) on Overlook Dr. (1st stoplight) road and proceed to Lake Erie shoreline.
17.3	0.3	STOP NO. 3a and 3 b - turn west (left) on Edgewater Dr. and park at Vermilion-on-the-Lake Lot Owners Association clubhouse (Ft. of Delaware Dr.), 3a is located here and 3b is 0.4 miles to the east at a community park. After viewing shore bluffs, continue east on Edgewater Dr. to Woodside Dr., then south (right) to intersection with U.S. Rt. 6
18.2	0.9	Turn east (left) on Rt. 6
18.5	0.3	Turn south (right) on Sunnyside Rd.
21.2	2.7	Turn west (right) on North Ridge Rd.
21.7	0.5	Vermilion River bluff
22.3	0.6	STOP NO. 4 - Mill Hollow-Bacon Woods Park. After viewing bluff proceed southwest on North Ridge Rd.
22.8	0.5	Turn south (left) on Morse Rd.

Vermilion East Quadrangle
Kipton Quadrangle

23.5	0.7	Merge, continuing south, with Gore Orphanage Rd.
24.0	0.5	Bear right onto Serry Rd.
24.7	0.7	Turn south (left) on Dean Rd.
25.5	0.8	Vermilion River bridge (Ohio Shale outcrop)
26.6	1.1	Turn west (right) on Ohio Rt. 113
27.1	0.5	STOP NO. 5 - Vermilion River at Birmingham. After viewing the bluff proceed west on Ohio Rt. 113
28.4	1.3	Turn north (right) on Harrison Rd.

Kipton Quadrangle
Berlin Heights Quadrangle

30.8	2.4	Turn southwest (left) on Mason Rd. (Lake Maumee beach ridge)

Mileage

32.5	1.7	Turn north (right) on Joppa Rd.
32.8	0.3	Turn northeast (right) on Furnace Rd.
34.9	0.1	STOP NO. 6a and 6b - Chappel Creek. After viewing overturned Berea Sandstone beds (6a), either continue walking downstream for about 1.4 miles to Darrow Rd. bridge (6b), or continue northeast on Furnace Rd. (Lake Arkona beach ridge) to Darrow Rd. (1.1 miles) then turn northwest (left) to the Chappel Creek bridge (0.8 miles). After viewing these beds, return to intersection of Joppa Rd. and Mason Rd.
35.3	0.4	Turn west (right) on Mason Rd.
37.1	1.8	Ogontz (Lake Maumee beach ridge).
38.1	1.0	STOP NO. 7 - Turn north (right) on orchard lane and park. After viewing Berea Escarpment continue west on Mason Rd.
39.1	1.0	Turn south (left) on Ohio Rt. 61.
39.5	0.4	Turn west (right) on Main Rd. in Berlin Heights.
39.8	0.3	Turn south (left) on Berlin Rd.
39.9	0.1	STOP NO. 8 - Old Woman Creek. After viewing sandstone structures continue southwest on Berlin Rd.

Berlin Heights Quadrangle
Milan Quadrangle

39.3	1.4	Turn west (right) on Ohio Rt. 113
44.5	5.2	Turn north (right) on Ohio Rt. 13/U.S. Rt. 250 in Milan
44.9	0.4	STOP NO. 9 - Huron River valley. After viewing shale beds continue north on U.S. Rt. 250.
47.3	2.4	Turn northeast (right) on Huron-Avery Rd.
50.2	2.9	Turn north (left) on Rye Beach Rd.

Milan Quadrangle
Huron Quadrangle

50.9	0.7	Lake Lundy beach ridge (Elkton Beach)

Mileage		
53.0	2.1	Turn west (left) on U.S. Rt. 6 (Cleveland Rd.)
53.2	0.2	Sawmill Creek, note concretion at base of west bank on north (right) side of roadway
54.5	1.3	STOP NO. 10 - "Slate Cut," contact of Prout Limestone and Huron Shale
		End of Trip