THE GEOLOGY OF THE NORTHEAST QUARTER
OF THE
POWELL, OHIO QUADRANGLE

by

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requirements for the
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ABSTRACT

The area is underlain by limestones and shales of Middle and Upper Devonian age. Formations from oldest to youngest are Columbus Limestone, Delaware Limestone, Olentangy Shale, and Ohio Shale. Columbus Limestone is gray, medium-grained, and fossiliferous. The Delaware is a brownish gray, argillaceous and cherty limestone with few fossils in the lower part and a thin, highly fossiliferous unit in the upper part. Olentangy Shale is bluish gray, argillaceous mudstone with several thin beds of limestone. Ohio Shale is a fissil black shale with many large spherical carbonate concretions. The Columbus and Delaware crop out along the Olentangy River. The Olentangy and Ohio crop out in the ravines of the tributary streams on the east side of the Olentangy River. The area was glaciated during Wisconsin time and the present topography is a combination of glacial deposits and subsequent stream erosion. Glacial erratics are found along the Olentangy River and many of the tributary streams. They consist of an interesting array of igneous and metamorphic types. The contours of the bedrock surface give some evidence of the pre-glacial topography.

ACKNOWLEDGEMENTS

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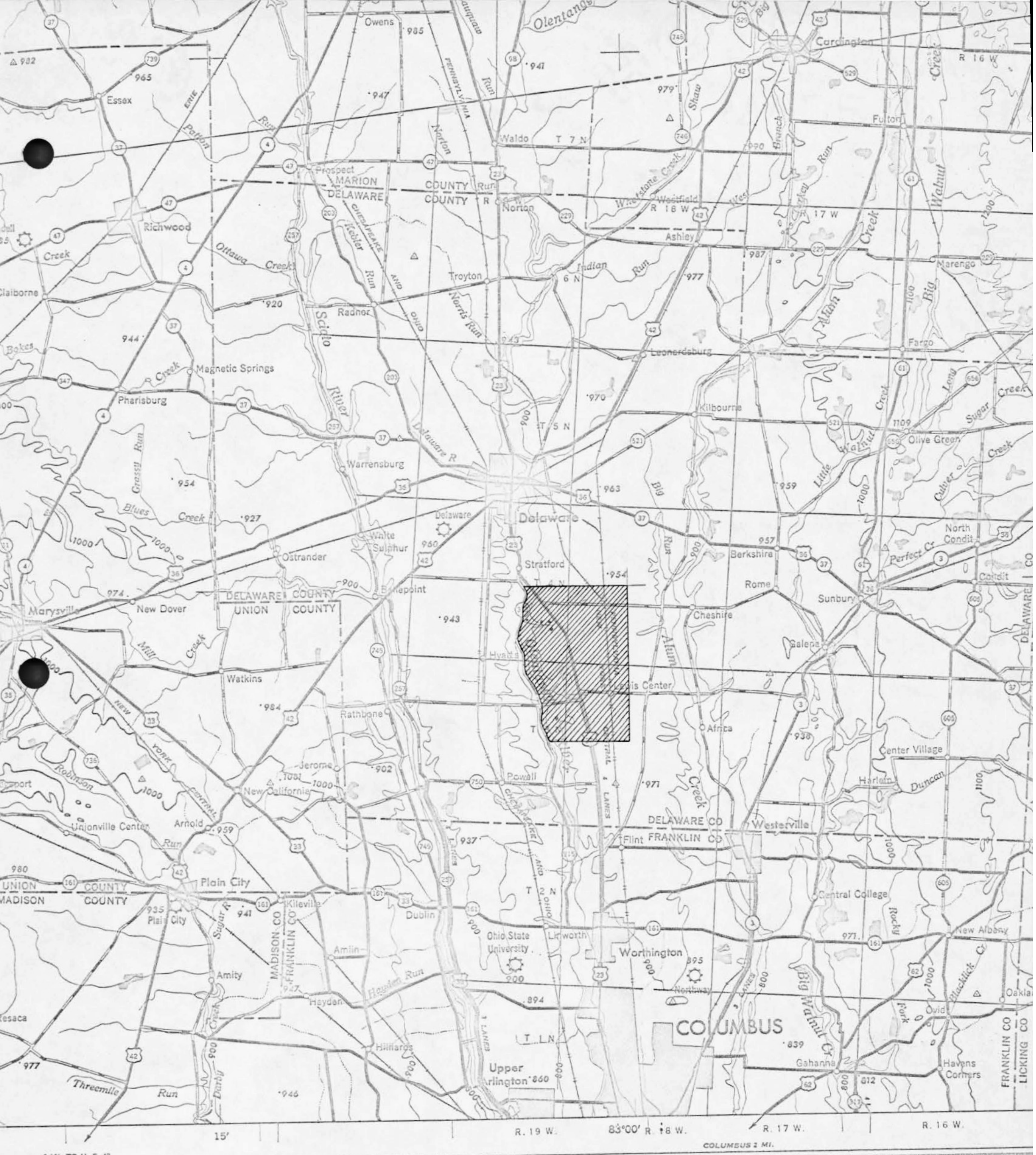

LOCATION MAP

Scale 1:250,000

PLATE 1

5 0 5 10 15 20 Miles

5 0 5 10 15 20 25 30 35 Kilometers

5000 0 5000 10000 15000 20000 25000 30000 35000 Yards

CONTOUR INTERVAL 100 FEET

DATUM IS MEAN SEA LEVEL

TRANSVERSE MERCATOR PROJECTION

LOCATION

The area makes up the northeast quarter of the Powell $7\frac{1}{2}'$ topographic quadrangle. It is bounded on the north by 40° 15' N lat., on the east by 83° W long., on the west by the Olentangy River, and on the south by Orange Road (see map, plate 1). The area is located between Delaware, Ohio, and Worthington, Ohio, in Delaware county and covers about 16 square miles.

The east half is flat upland drained by few streams. Streams all drain west into the Olentangy River except for one in the extreme northeast which drains east into Alum Creek. The west half of the area is the valley of the Olentangy River which flows south. The main tributary streams which empty into the Olentangy River have cut ravines into bedrock. These ravines are from 50 to 75 feet deep and provide most of the rock exposures in the area. Scattered exposures are visible along the Olentangy River.

The slopes of the river valley are mostly wooded or used for pasture. There is some farming on the wider terraces of the Olentangy River. The flat upland is almost entirely used for farming and pasture with a few scattered stands of trees.

REGIONAL GEOLOGIC SETTING

The area is underlain by rocks of Middle and Upper Devonian age. The Columbus Limestone is the oldest exposed rock formation in the area. Only the very top of this formation is exposed in places along the Olentangy River. The Delaware Limestone overlies the Columbus Limestone and the entire thickness is visible in outcrops along the Olentangy River and a few of the more deeply cut streams. The Olentangy Shale is the next younger formation. The outcrops of the Olentangy Shale are restricted to the ravines of the larger streams. The Ohio Shale overlies the Olentangy and is the youngest formation in the area. Most of the area is underlain by the Ohio Shale, but the outcrops are limited to the ravines of the streams flowing into the Olentangy River. The entire upland area is covered by glacial drift.

The regional dip in this area and throughout central Ohio is about 25 feet per mile or about $\frac{1}{4}$ of one degree (Westgate, 1926). Small folds in the bedrock account for the rather spotty occurrence of the Columbus Limestone along the Olentangy River (see Fig. 1).

Figure 1. A gentle fold in the Delaware Limestone. East bank of the Olentangy River .45 mile north of Hollenback Run.

STRATIGRAPHIC COLUMN

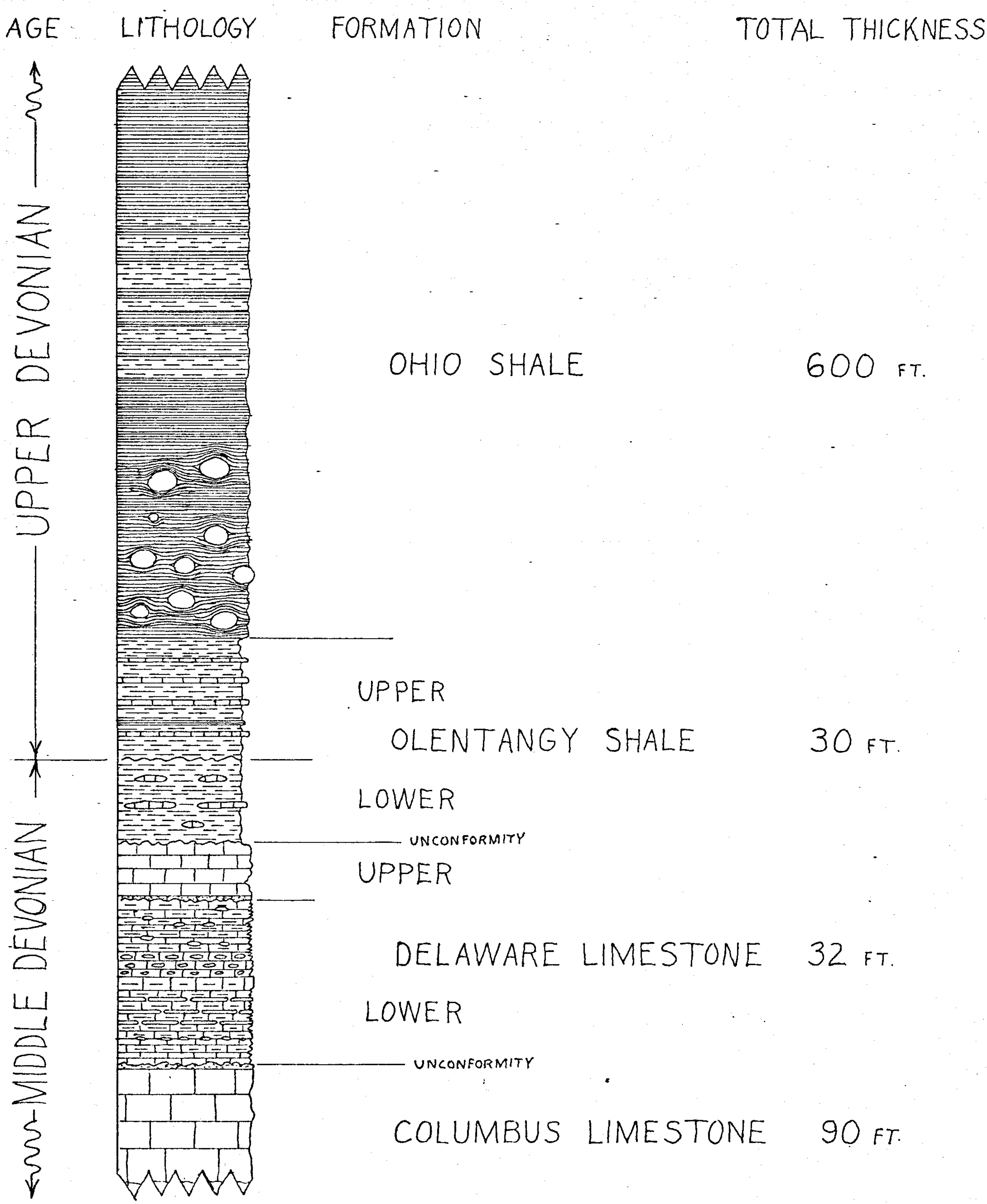

PLATE 2

SEDIMENTARY RECORD

Bedrock is composed of sediments of Middle and Upper Devonian age. These rocks are mainly limestones and shales. Each of the four formations exposed in the area is fairly constant in thickness. The only formations exposed in their entirety are the Delaware Limestone and the Olentangy Shale.

The area was previously studied by N. H. Winchell in 1874, C. R. Stauffer in 1909, J. A. Bownocker, G. D. Hubbard, and C. R. Stauffer in 1911, and L. G. Westgate in 1926

COLUMBUS LIMESTONE

The Columbus Limestone was named by W. W. Mather in 1859 (Stewart, 1955). The type section is at the Marble Cliff quarries on the Scioto River west of Columbus, Ohio (Westgate, 1926). The formation has a total thickness of 90 feet (Carman, 1927) and is composed of calcareous and magnesian deposits (Stauffer, et al, 1911).

The upper 65 feet of the Columbus consists of a highly calcareous crystalline gray limestone which is very fossiliferous (Stauffer, et al, 1911). In quarries, this part of the formation is quite massive. In natural outcrops, however, the limestone weathers into thin slabs. This part of the formation is called the Delhi Member. It takes its name from the village of Delhi (now Radnor) in Delaware county (Winchell, 1874).

The Columbus Limestone is correlated to the Onondaga of New York, the Detroit River Group of northwestern Ohio, and the Jeffersonville of Indiana and Kentucky (Oliver, et al, 1968). The Columbus crops out in Ohio along a narrow band running roughly north-south from Sandusky, through Columbus, and south to southern Pickaway county. It is exposed in the Bellefountaine outlier in Logan county and on Kelly's Island in Lake Erie (Stauffer, 1909).

The Columbus Limestone is exposed as an inlier along the Olentangy River in Delaware county. The northernmost outcrop found is along the Olentangy River at Camp Lazarus. This outcrop occurs at the crest of a small anticline (Stauffer, et al, 1911, p. 15) and is visible only when the river is at a low level. This outcrop is shown in Fig. 2. The lower, massive-looking, lighter colored Columbus Limestone is contrasted quite easily with the shaly, darker colored Delaware Limestone overlying it. The bone bed, a layer

Figure 2. The contact between the Columbus Limestone and the Delaware Limestone. The end of the Jacob's staff is resting on the contact. East bank of the Olentangy River just north of Lazarus Run.

composed of fragments of fish bones and plates and other fossil fragments, is present at this location. This outcrop extends north along the east bank of the river for about 100 yards until it dips beneath the river level. The maximum thickness of the Columbus Limestone exposed at this location is about 12 inches. Fossils found were identified as *Atrypa spinosa* and one *Leptaena* about 8 inches beneath the bone bed. Specimens of *Platyceras dumosum* were found on a loose slab of limestone beyond the north end of the outcrop. It appears that the bed of the Olentangy River is on the Columbus Limestone as far north as the dam about ½ mile south of Stratford and south to about ¼ mile below Bartholomew Run.

Another outcrop of Columbus Limestone on the east bank of the Olentangy River occurs about ¼ mile south of Lazarus Run next to the old mill. The rock found there is Columbus limestone, but it is difficult to tell if it is in place.

The best outcrop in the area is also on the east bank of the river just north of Delaware county road 123. Here the Columbus Limestone is exposed in a 12 foot cliff from just below the level of Chapman Road to the river level. This outcrop is only accessable at low water. The top of the Columbus is covered by the road. The total exposure is about 15 feet.

The top of the Columbus Limestone is generally described as a bone bed. This bone bed is a layer that locally contains numerous plates and teeth of fish. The layer is usually restricted to the uppermost 6 to 8 inches of the formation. Specimens of *Platyceras dumosum*, a very distinctive spiny gastropod, are almost always found within a few feet of the bone bed and are useful in locating the Columbus-Delaware contact. It is also possible to determine the contact by the change in lithology. The Columbus is a gray, crystalline limestone with medium sized grains and abundant fossils. In contrast, the Delaware Limestone is brownish gray, fine grained, and has few fossils. However, one layer of the Delaware about 36 inches above the contact with the Columbus is highly fossiliferous. This layer is only about 1 inch thick and contains almost exclusively specimens of Mucrospirifer consobrina and Leptaena rhomboidalis and can easily be mistaken for Columbus limestone. The change in fauna from the Columbus to the Delaware indicates that there is an unconformable relationship between the two formations (W. C. Sweet, oral communication, 1969).

The Columbus contains a wide variety of well preserved fossils. An excellent description and illustration of the fossils found in the Columbus Limestone is contained in Stauffer, et al, 1911, pp. 37-38.

DELAWARE LIMESTONE

The Delaware Limestone was first given that name by Edward Orton in 1888 (Miller, 1919). The type section of the formation is at Delaware, Ohio, on the south bank of Delaware Run, just east of the Chesapeake and Ohio Railroad (Westgate, 1926).

In the area studied the formation is about 32 feet thick. This thickness is fairly constant throughout the area. The lower part of the Delaware is an argillaceous, cherty, blue-gray limestone and calcareous shale with interbedded chert. This lower 25 feet of the Delaware is sparingly fossiliferous in most places and is composed of about 50% calcite (Westgate, 1926). This part of the formation is shaly toward the south and becomes more massive to the north. The upper 8 feet of the Delaware is a medium grained, highly fossiliferous, gray limestone. This limestone is composed of about 90% calcite. The fossils are crystalline calcite while the rest of the rock is soft, fine grained, and easily weathered. The fossils, mostly corals and crinoid stems, stand out in relief on the weathered surfaces of the limestone. Weathering is cavernous in places. A bone bed, with abundant Hadrophyllum d'orbignyi, divides the two limestone facies (Conklin, 1969).

The upper part of the formation is quite different from the lower in both lithology and fauna. On account of its striking differences and widespread distribution (Stauffer, 1909), the upper part could be given the status of a distinctive member within the Delaware Formation. Hereafter the highly fossiliferous limestone beds which make up the upper 8 feet or so of the Delaware Limestone will be refered to as the Upper Delaware. The remainder of the formation, composed of argillaceous limestone and calcareous brown shale with interbedded and nodular chert, will be called the Lower Delaware.

The Delaware limestone can be approximately correlated with the Dundee of northwestern Ohio and Michigan and the Marcellus of New York and Pennsylvania (Oliver, et al, 1968). In Ohio, the Delaware crops out in a band paralleling the Columbus to the east.

Outcrops of the Delaware Limestone in the area studied are along the Olentangy River. These outcrops form cliffs in many

Figure 3. Outcrop of the Lower Delaware Limestone. East bank of the Olentangy River .25 mile north of Case Run.

Figure 4. Waterfall in Lazarus Run formed in the Delaware Limestone.

places. Fig. 3 shows an outcrop on the east bank of the Olentangy River about ¼ mile south of Liberty Road. About 15 feet of the formation is exposed at this location. Another good outcrop is exposed in the cliffs on the east bank of the Olentangy River and on the bed of the stream at Camp Lazarus. Just east of Chapman Road the limestone forms a small waterfall (see Fig. 4). Only the top 2 feet of the formation is covered in the stream bed. The outcrops are discontinuous above the falls. The following section of the Delaware Limestone was measured on the east bank of the Olentangy River and a short distance up Lazarus Run.

Delaware Limestone

14. Limestone, light brown to light gray, cherty. - 1' 0"

13. Limestone, dark brown to brown-gray, thinly bedded to shaly. Many joints. - 3' 2"

12. Cherty limestone, light gray to light brown with thin, irregular bedding. Beds up to 4" thick. Many chert nodules. - 3' 1"

11. Calcareous mudstone. Very soft and finely laminated. - 0' 1"

10. Limestone. Light brown-gray to dark brown gray, thinly bedded. Some chert beds. Many joints. - 4' 10"

9. Limestone. Very finely laminated, light gray to medium gray-brown. - 0' 1"

8. Limestone. Light gray to light brown, thinly bedded, shaly towards top. Forms a reentrant with the above unit. - 1' 7"

7. Cherty limestone. Light brown-gray, fine grained, thickly bedded. Forms the vertical part of the waterfall in the stream. <u>Tentaculites</u> present in this unit. - 3' 0"

6. Limestone. Light brown-gray, fine grained, thin, irregular bedding. - 4' 10"

5. Limestone. Light gray-brown, fine grained. <u>Leptaena</u> and <u>Mucrospirifer</u> very abundant in a single layer about 1 inch from the top. - 1' 1"

4. Shaly limestone. Medium gray-brown, fine grained. Some fossils. - 2' 6"

continuation of section

Columbus Limestone

3.	Fossiliferous limestone. Light gray, medium to coarse grained.	-	0' 4"
2.	Bone bed.	-	-
1.	Limestone. Light gray, sub-crystalline. Platyceras dumosum and Atrypa spinosa present.	-	0' 8"
Total measured		-	30' 3"

The best exposure of the Delaware Limestone in the area is along a stream on the east side of the Olentangy River about ½ mile south of Liberty Road. This stream is located on the Meier farm. Stauffer, in his 1909 report, called this stream Case Run and measured and described the outcrops he saw along the stream. The following is his section.

Ohio Shale

16.	Black shale with some large spherical concretions.	-	27' 8"

Olentangy Shale

15.	Bluish gray, soft, argillaceous shale.	-	3' 8"
14.	Layer of blue limestone concretions.	-	0' 3"
13.	Soft bluish shale.	-	3' 6"
12.	Occasional flattened limestone concretions.	-	0' 4"
11.	Soft bluish shale.	-	2' 0"
10.	Layer of bluish limestone.	-	0' 4"
9.	Soft bluish shale, mostly covered.	-	21' 0"

continuation of section

Delaware Limestone

8.	Zone M. Massive, hard, blue limestone with but little chert.	- 8' 6"
7.	Zone L. Granular layer containing <u>Hadrophyllum d'orbignyi</u>. This zone is exposed just below the barn.	- 0' 3"
6.	Zone K. Layers of blue limestone, six inches in thickness, and thin shaly layers with much grayish chert.	- 7' 6"
5.	Thin bedded blue limestone with some chert.	- 3' 6"
4.	Zone J. Massive bluish brown limestone with no chert.	- 2' 0"
3.	Thin shaly brown limestone alternating with layers of black chert.	- 5' 10"
2.	Thin bedded brown limestone with some irregular nodules of chert.	- 2' 0"
1.	Zone I. Thin bedded blue limestone to bottom of run at highway bridge.	- 3' 8"
Total measured		- 92' 0"

(Stuaffer, 1909)

Stauffer's zones L and M make up the Upper Delaware Limestone while his zones I, J, and K comprise the Lower Delaware Limestone. His zone M weathers into a soft, yellowish gray colored limestone, but the fresh rock is hard and of a bluish gray color. Zone L is yellowish brown to gray in the fresh rock and weathers to a soft, yellowish limestone with the fossils standing out in relief.

Four bone beds have been recognized within the Delaware Limestone at the bases of Stauffer's (1909) zones I, K, L, and M (Conklin, 1969).

The contact between the Delaware Limestone and the overlying Olentangy Shale is marked by the change from the fossiliferous limestones of the Upper Delaware to the soft bluish gray argillaceous mudstones of the Olentangy. Although the contact is poorly exposed, it was easy to identify because of the sharp change in lithology. The ages of the conodonts found in the Upper Delaware and the lower part of the Olentangy indicate that the contact is unconformable (N. J. Ramsey, oral communication, 1969).

The Lower Delaware Limestone is not generally very fossiliferous. There is one layer about 36 inches above the top of the Columbus Limestone which is composed almost entirely of Mucrospirifer consobrina and Leptaena rhomboidalis (see Fig. 5). Mucrospirifer is distinguished by a well developed delthyrium (see Fig. 6). The genus was formerly called Delthyris consobrina (Stauffer, et al, 1911). This bed is best exposed on the east bank of the Olentangy River at Camp Lazarus. The Mucrospirifer layer was not recognized elsewhere in the area. Mucrospirifer and Leptaena are found throughout the lower part of the formation, but appear to be confined to the more massive beds. Other fossils found in the Lower Delaware are Chonetes mucronatus, Leiorhynchus limitare, Lingula manni, Martinia maia, Orbiculoidea lodiensis, Rhipidomella vanuxemi, Stropheodonta perplana, and Tentaculites scalariformis. All of these fossils were found at Case Run and many of them were also found at Camp Lazarus. Many of the weathered

Figure 5. A slab of Delaware limestone from a bed 36 inches above the base of the formation with many specimens of <u>Mucrospirifer consobrina</u> and <u>Leptaena rhomboidalis</u>.

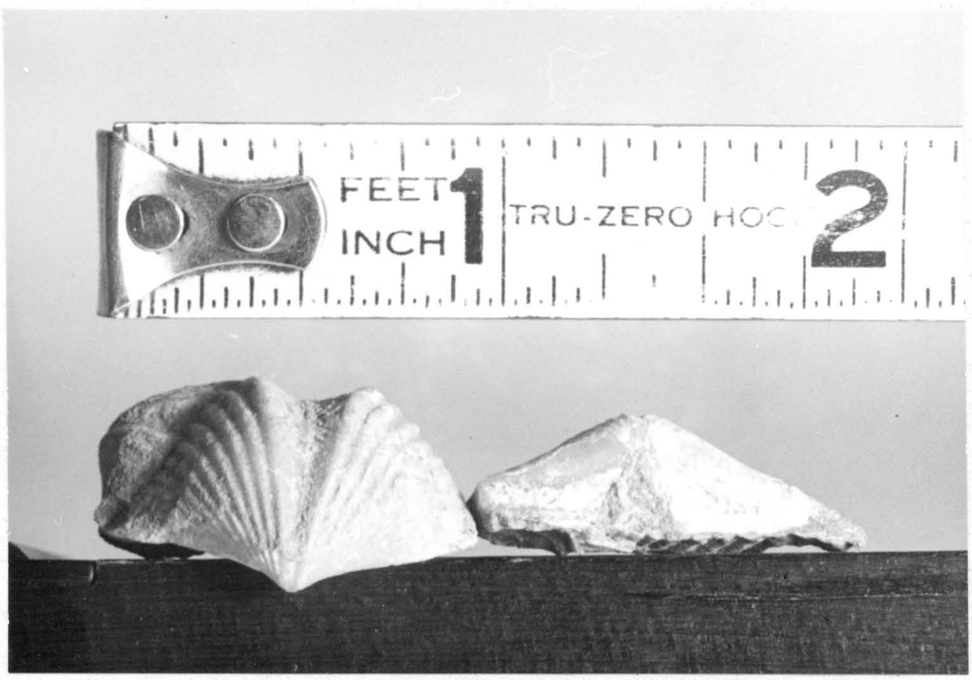

Figure 6. <u>Mucrospirifer consobrina</u>. Note the well developed delthyrium.

bedding surfaces in the Lower Delaware have swirled markings of unknown origin.

The highly fossiliferous Upper Delaware Limestone is quite a contrast from the Lower Delaware and contains many fossils not found in the lower member. Hadrophyllum d'orbignyi, a very distinctive "button" coral, is abundant in the basal unit of the Upper Delaware. Aulopora serpens, a loosely colonial coral, can be clearly seen on the weathered surfaces of some beds. Cystodictya gilberti and Stropheodonta perplana were also found in the Upper Delaware. One specimen of Proetus rowii was found in a loose block of Upper Delaware limestone. By far the most prevalent fossils found in the Upper Delaware are crinoid stems. None of them could be identified to genus. In addition to the simple, disk-shaped stem segments, three different types of pentagonal segments were found. The crinoid stems have been replaced by crystalline calcite and can be seen as glittering cleavage faces on the fresh surface of the rock. The preservation of the fossils is very good. Not only are many small details retained, but the softer limestone weathers away leaving the fossils exposed at the surface of the rock. All of the fossils that were found in the Upper Delaware Limestone were collected at Case Run.

OLENTANGY SHALE

The Olentangy Shale was named by N. H. Winchell in 1874 for the exposures on the east bank of the Olentangy River at Delaware, Ohio (Westgate, 1926), ¼ mile south of the railroad bridge (Stauffer, 1909).

The Olentangy Shale is a bluish gray mudstone with indistinct laminations. The lower part of the formation contains many flat limestone concretions. Several layers of greenish gray, fine grained limestone in the upper part of the formation are persistent over a broad area. There is one 4 inch layer of black shale 12 feet from the top of the formation. In the area studied the formation is about 30 feet thick. On the basis of ostracods found in the Olentangy Shale, the boundary between the Middle and Upper Devonian is placed at 17' 10" from the top of the formation at Camp Lazarus. This divides the Olentangy into two distinct stratigraphic units separated by an unconformity (Tillman, 1969).

The Olentangy Shale occurs in Ohio along a narrow band from Delaware county south to Adams county. In northern Ohio, the formation is called the Plum Brook Shale (Hoover, 1960). In northern Ohio it is much thicker and is overlain by the Prout Limestone.

The Olentangy Shale crops out in the ravines of the larger streams east of the Olentangy River. In most places, the outcrops are restricted to the beds of the streams. On the south branch of Hollenback Run the upper 20 feet of the formation crops out as a cliff on the south bank of the stream about 200 yards upstream from the fork. The overlying Ohio Shale makes up the uppermost 5 feet of the cliff. Beds of limestone within the Olentangy are clearly visible in the stream bed of the south branch. About 300 yards further upstream a large mass of calcareous tufa has been formed by a spring occurring at the contact between the Olentangy Shale and the Ohio Shale. Along the north branch of Hollenback Run, the Olentangy Shale makes up the lower part of the cliffs on the west side of the stream. The contact between the Olentangy and the Ohio is visible in many places along these cliffs. There is seepage of water along most of the contact. One small spring is visible on the west side of the stream about 20 feet above the stream bed, 200 yards upstream from the fork. Here, however, no tufa has formed. There is another good seepage of water along Case Run at a place known as "Dripping Rock" (Stauffer, 1909). There is also a good outcrop of the Olentangy Shale at Camp Lazarus. The limestone beds are shown quite well and the jointing in the shale is clearly visible (see Fig. 7). There are two sets of joints striking N40°W and N40°E.

Figure 7. Olentangy Shale. Limestone bed above and jointed shale underwater. Lazarus Run.

Figure 8. The contact between the Olentangy Shale and the Ohio Shale showing a depression formed by an Ohio Shale concretion. South branch of Hollenback Run.

The contact with the overlying Ohio Shale is sharp in most places and is easily recognized in most of the ravines in the area. In many places the contact is marked by a small waterfall in the stream bed. The Ohio shale is more resistant than the Olentangy and forms a projection over the underlying, easily eroded Olentangy shale. Figure 8 shows the contact on the south branch of Hollen-back Run. There the stream flows across a small depression formed by an Ohio Shale concretion which has since been removed. The differential compaction of the sediments around the concretion resulted in the warping of the shale (Clifton, 1957). Because of the inter-bedded relationship between the Olentangy and the Ohio, the contact is considered to be conformable. The lack of any faunal break confirms this (W. C. Sweet, oral communication, 1969).

Fossils found within the Olentangy Shale were some plant remains, spore cases, and a few worm trails. The plant remains were in the form of coalified wood of the genus Callixylon (see Fig. 9). This coal material was found in the 4 inch black shale bed about 12 feet below the Olentangy-Ohio contact. This bed has an unusual joint pattern that gives it the appearance of a brick road. The bed is exposed in Lazarus Run about 100 yards downstream from Eagles Rock. The jointing is shown very well where the stream flows over this bed of shale (see Fig. 10). The coalified plant remains can be found in almost every joint block of the black shale.

Figure 9. Coalified Callixylon newberryi. Olentangy Shale.

Figure 10. "Brick road" joint pattern in the black shale bed of the Olentangy Shale. Lazarus Run, 100 yards downstream from Eagles Rock.

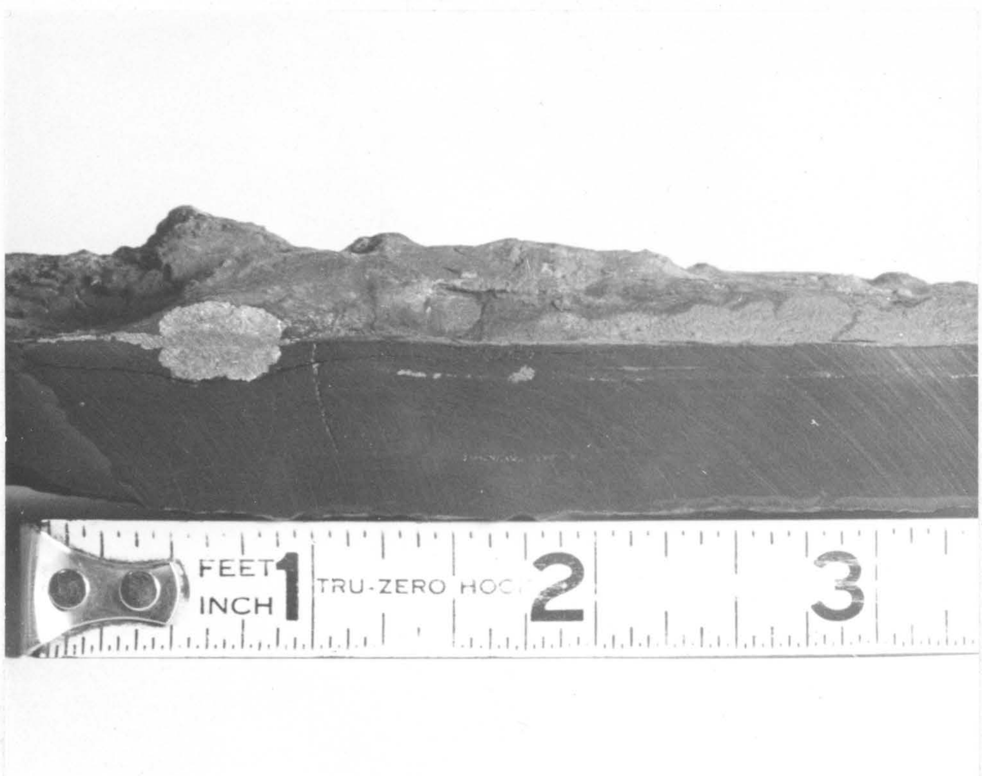

Figure 11. Pyrite tube-filling in black shale. Olentangy Shale.

In some places the wood has been replaced by pyrite. In the pyritized wood the criss-cross vascular structure typical of conifers is excellently preserved. The vascular pitting characteristic of Callixylon is visible with a microscope (Delevoryas, 1962). In the coalified wood, however, the internal structure has been almost completely obliterated by compaction. This indicates that the pyrite replacement took place before the sediments were compacted. The rest of the black shale also contains considerable quantities of pyrite and marcasite. The sulfides occur in small crystalline nodules, flattened concretionary masses, cylindrical masses which appear to be fillings of worm tubes, and as very fine crystals which are disseminated throughout the shale (see Fig. 11). The nodules are as much as 1 inch in diameter and show good octahedral crystals. About 4 pounds of iron sulfide nodules were removed from one 20 pound block of black shale. The spore cases were also found in the black shale. They are of the genus Tasmanites and are identical to those found in the Ohio Shale. The worm trails are visible as flattened tubes of gray clay in the top of the black shale bed. Conodonts and ostracods are abundant in the Olentangy and are useful in determining the age of the formation.

The bed of black shale occurs over a fairly wide area and it is possible to correlate individual layers in cut blocks of the shale collected from different locations. One sample was collected from Lazarus Run and another sample was collected from a gully on the west side of the north branch of Hollenback Run about 400 yards upstream from the fork. The blocks of shale both had lighter colored bands 2.2 cm, 4.0 cm, and 6.7 cm from the bottom of the bed. The upper parts of both blocks of shale contained greater amounts of iron sulfide than the lower parts. The black shale is composed mostly of silt. The typical bluish gray mudstone of the Olentangy is composed almost entirely of clay-sized particles of kaolin, dolomite, and quartz (Westgate, 1926).

OHIO SHALE

The Ohio Shale was named in 1877 by N. S. Shaler and takes its name from the Ohio Valley (Miller, 1919). Its age is said to be Upper Devonian although the top of the formation may be Mississippian (Hass, 1947). In Ohio the Ohio Shale occurs along a broad north-south band from Erie county to Scioto county. In northeast Ohio the formation is broken down into the Huron Shale, Chagrin Shale, and Cleveland Shale (Hoover, 1960). The formation also extends into Kentucky where it is called the New Albany Shale. The Ohio Shale is equivalent in age to the Towanda and Sunfish of New York, the Catskill of Pennsylvania, and the Chattanooga of Tennessee (Oliver, et al, 1968).

The Ohio Shale is composed mostly of dense, fine grained, slightly gritty, deep chocolate-brown to brownish black shale. Freshly broken rock emit a strong petroliferous odor. The rock usually weathers to a gray to bluish gray color and becomes very fissile. Weathered surfaces and joints are comonly iron stained. A section of the Ohio Shale was measured at Eagles Rock in Camp Lazarus.

Ohio Shale

14.	Glacial drift to top of hill	- 2' 0"
13.	Thinly bedded black shale with some interbedded, bluish gray, irregularly bedded mudstone. Covered near top of cliff.	- 14' 3"
12.	Very thinly bedded dark gray shale. Some mud-filled joints, becomes more thickly bedded toward top.	- 0' 8"
11.	Bluish gray mudstone with blocky weathering to a yellow-brown color. The exterior of some fragments are black with a slickenside surface. This unit is distorted throughout. Some flattened, dark bluish gray dolomitic concretions up to 9 inches thick and 2 feet in diameter. Disseminated marcasite present.	- 1' 7"
10.	Interbedded black and bluish gray shale. Black shale has thin, even bedding and many joints. Forms a resistant layer. Bluish gray shale has thin irregular bedding and weathers easily into small blocky fragments.	- 4' 7"
9.	Very finely bedded black shale. No jointing.	- 1' 0"
8.	Very finely bedded black shale. Two prominent sets of joints striking N90°W and N45°E. Weathers orange-brown.	- 5' 10"
7.	Very finely bedded black shale. No jointing.	- 0' 5"
6.	Black shale with fine bedding and prominent joints. Jointed surfaces appear massive. Weathers orangish brown. Many large carbonate concretions in this interval.	- 15' 5"

continuation of section

5.	Fine, even bedded black shale with some jointing.	-	2' 1"
4.	Irregularly bedded black shale. Weathers bluish gray to orange-brown.	-	1' 11"
3.	Very thinly bedded black shale with interbedded yellow-brown med. Mostly covered with shale fragments and clay.	-	5' 9"
2.	Covered interval.	-	7' 2"
Olentangy Shale			
1.	Covered interval to the bed of Lazarus Run.	-	4' 0"
Total measured		-	68' 8"

The formation crops out in every ravine on the east side of the Olentangy Valley. The cliffs of these ravines are held up by the Ohio Shale. The formation underlies the entire eastern 2/3 of the area, but it is covered by drift. The total thickness of the Ohio Shale is about 650 feet in Delaware county (Westgate, 1926). Only the bottom 80 feet of the formation is exposed in the area.

The lower 60 feet of the Ohio Shale contains many spheroidal carbonate concretions. Concretions are composed mostly of dolomite and calcite and they vary in size from 1 foot to as much as 12 feet in diameter. Concretions seem to have been formed after the muds, which later formed the Ohio shales, were deposited, but before the sediments were compacted. The concretions were formed by deposition of mineral matter around a nucleus by ground water (Clifton, 1957). The central part of many concretions contain

Figure 12. Calcite and siderite from the core of an Ohio Shale concretion.

sizable masses of minerals. One mass of crystals was found in Lazarus Run and is shown in Fig. 12. The white mineral is calcite with good rhombohedral cleavage. The dark mineral is dark brown to brown in color with a hardness of about 4. Where crystal faces are visible, they are almost always curved and there is poor rhombohedral cleavage. These characteristics should identify the mineral as siderite, except that it effervesces in HCl every bit as vigorously as calcite. Also the brown mineral gives off a very strong petroleum smell while effervescing although the calcite does not. The specimen shows a transitional area between the calcite and the siderite(?) and a sharp contact with the fine grained matrix material of the concretion. Another specimen from a concretion had well developed quartz crystals and calcite intergrown. It appears as though the quartz formed first with the calcite filling in the spaces. The matrix material of the concretions is gray to blackish brown and appears to be primarily dolomitic.

In many places the deformation of the shale surrounding the concretions can be seen. On the south branch of Hollenback Run there are many depressions and domes present where the shale is exposed along the bed of the stream (see Fig. 8). Figure 13 clearly shows the manner in which the shale is bent around a concretion. Even the Olentangy Shale, which is visible at the

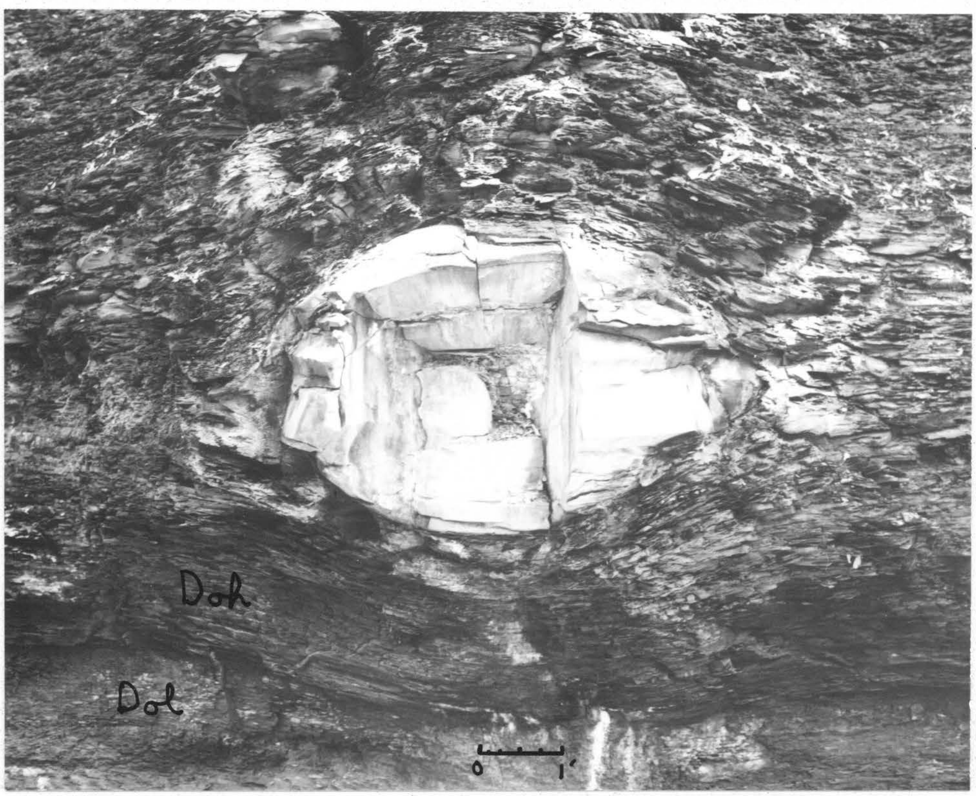

Figure 13. Ohio Shale concretion showing warping of the beds of shale. The Ohio-Olentangy contact is visible at the bottom. North branch of Hollenback Run.

bottom of the photo, is deformed slightly. This deformation of the bedding in the shale gives some hint as to the formation of the Ohio Shale concretions. If the concretion grew within the lithified shale, growth would have taken place along the path of least resistance. This would be horizontally along the bedding planes, not vertically to form a sphere. However, if the growth of the concretions took place when the shale was still unconsolidated mud and there was little overburden, there would have been little impedence to growth vertically. Later during compaction, the muds would be compressed much more than the solid concretions. So, the warping of the shale around the concretions is most likely a case of differential compaction. The finding of undeformed spore cases within the concretions also indicates that they were formed before the compaction of the shale (Clifton, 1957).

The concretions, both whole and fragments, can be seen in all of the ravines in the area. They can be seen in place both in stream beds and on the faces of cliffs. In place concretions are eroded out and fragments can be found several hundred yards downstream from the outcrops. Most of the concretions are 3 to 5 feet in diameter. The top of one concretion about 12 feet in diameter is visible in Lazarus Run just west of the trading post. The concretions appear to occur in "swarms." In some places the lower part of the Ohio Shale has few or no concretions while in other places the concretions occur in great numbers. The largest swarms are found on the south branch of Hollenback Run and in Lazarus Run.

There are also many iron sulfide concretions in the Ohio Shale. These concretions are from 1 to 4 inches in diameter. The outer portion is usually coarsely crystalline pyrite. Pyrite crystals normally show only octahedral and cubic faces and the crystals can be as large as $\frac{1}{4}$ inch across. Cores of the sulfide concretions are fine grained marcasite. The marcasite is paler in color than the pyrite and is more likely to be weathered. When the marcasite is exposed to moist air it decomposes spontaneously to sulfuric acid and fine white crystals of melanterite. There are fine particles of marcasite scattered throughout the shale. Undisturbed surfaces of the rock are often coated with fine crystals of melanterite where the marcasite has decomposed. These sulfide concretions are common along the south branch of Hollenback Run just upstream from the Ohio-Olentangy cantact. They are also found on the spillway of the upper dam at Camp Lazarus.

The Ohio Shale is highly jointed in most places. In the south branch of Hollenback Run there are two sets of joints, one striking N65°E and the other N29°W. At Camp Lazarus, in a cliff just south of the trading post, the two sets of joints are well exposed (see Fig. 14). The more prominent set strikes N55°E and dips 70°-90° to the south. The other set has a strike of N29°W and dips 50°-60° to the east. Figure 14 also shows the slumping of the joint blocks of shale on the cliff face.

Fossils are sparse in the Ohio Shale. Coalified wood of the genus <u>Callixylon</u> has been found in the lower part of the formation. One log measuring 11 feet, 7 inches was found along Hollenback Run (Lewis Center Run) in 1938 (Hoover, 1960). This log may be seen in the Geology Museum at the Ohio State University. By far the most common fossils in the Ohio Shale are the spore cases <u>Tasmanites</u>. These spore cases can be seen with a hand lens as amber colored discs about .1 mm in diameter. They are abundant throughout the area, although they are not easily seen. Conodonts are also found throughout the formation (W. C. Sweet, oral communication, 1969).

Figure 14. Jointing in the Ohio Shale. Lazarus Run south of the trading post.

GEOMORPHOLOGY

The area is covered by Wisconsin glacial till that varies in thickness from about 5 feet to as much as 100 feet. Well logs in the area indicate that there is, in most places, a layer of gravel about 1 to 4 feet thick between the bedrock surface and the overlying till. The ground water in this permeable gravel makes it the most important aquifer in the upland area. The Powell Moraine crosses the southeast corner of the area (Stauffer, et al, 1911). It is marked by some low, irregular topography at the edge of the very flat till plain of the uplands.

The bedrock surface contour map gives some hint as to the pre-Wisconsin surface. This map was compiled from well logs of the area that were obtained from the Ohio Department of Natural Resources, Division of Water. Locations of wells and the elevations of the bedrock surface are given. There are some buried valleys in the vicinity of Lewis Center. These valleys are about 80 feet deep and from their direction and configuration they were probably formed by streams. If this is so, they were most likely formed during Yarmouth or Sangamon times. The well records in this area are few, so it is difficult to tell much more about the preglacial topography. The map does illustrate the progressive downstream developement of the Olentangy Valley and shows that the tributary streams cut their ravines after the Olentangy Valley was formed.

The Olentangy Valley was probably carved out by meltwater from the receeding glacier. One level of rock terraces crop out along the sides of the valley (Westgate, 1926). The present course of the river is incised into the rock terraces about 15 to 20 feet. Contemporary floods rarely, if ever, touch the terraces. The actual flood plain of the river is only about 100 to 150 yards wide and it does not attain an appreciable width until about the Franklin county line. There is not much outwash material deposited in the valley, although some of the terraces are covered by a thin veneer of gravel (Westgate, 1926). In the river channel itself there are large boulders accumulated in many of the rapids. These boulders are as large as 10 feet in the longest dimension and are mostly crystalline rocks of a granite or granite-gneiss compostion. Smaller boulders litter the banks of the river near rapids where they have been droped by floods. These smaller boulders are up to 2 feet in diameter, are well-rounded, and are usually granitic, although some unusual metamorphic types are also present. Slabs of limestone up to 3 feet across can also be found along the rapids. They were also carried during times of flood, but probably only a short distance.

The river reaches its highest level in winter following a period of thawing. The following estimations were made at the rapids in the Olentangy River just north of Lazarus Run on 31 Dec. 1968: depth - 4 to 5 feet, width - 75 feet, velocity - 15 feet/sec, discharge - 4500 cu ft/sec $\pm$ 500. At this stage the river was probably capable of moving boulders up to 3 feet in diameter. There were large standing waves formed downstream from the rapids probably because of the accumulation of boulders and cobbles there as the water became deeper and slower moving. During the winter the river often freezes over during long cold spells. The rapids usually remain free of ice throughout the winter. If the ice becomes thick enough, the ice jams which result when the river thaws can cause considerable damage to the banks. Low water period for the river is late summer and early autumn. At the same rapid near Lazarus Run in early November the discharge was about 50 cu ft/sec. North of Delaware, the Olentangy River is held back by the Delaware Dam. This dam controls the river so that the difference between the low and high water is not as great as it would be otherwise.

The tributary streams have cut deep ravines into the Ohio and Olentangy Shales and smaller gullies into the Delaware Limestone. The upper parts of the ravines are narrow and the stream channel is closely confined. There is some evidence of entrenched meandering especially in the north branch of Hollenback Run (see Stauffer, et al, 1911, pp. 103-104). The lower parts of the ravines below the Ohio-Olentangy contact are much wider and there are well developed flood plains. Here the streams are actively meandering where there is sufficient alluvial material on the floor of the ravine. The alluvial material is almost exclusively small fragments of Ohio shale. The gullies cut into the Delaware are narrow and the stream channel is closely confined within the sides of the gully. The stream runs over a clean bedrock surface with little or no accumulation of alluvium.

Many glacial erratics show up in the ravines and in the lower reaches of the tributary streams near the Olentangy River. The erratics are up to 2 feet in diameter. they show some evidence of water transportation, but little more than just the smoothing off of corners. The rocks only show chemical weathering to a depth of about $\frac{1}{4}$ inch. Most of them probably originated in the glacial till in the upland areas close to the streams and were subsequently transported, in times of flood, to their present positions. These erratics are all crystallines that originated in the pre-Cambrian shield area of Canada. In Case Run a granitic pegmatite was found showing a sharp contact with a hornfels. A garnetiferous banded gneiss was also found at this location. Some of the granite-gneiss erratics in Lazarus Run below the falls show the injection of numerous feldspathic veins.

Most of the tributary streams are intermittant and their periods of flow are restricted to late winter and spring and after a few of the larger summer thundershowers. The larger streams, like Lazarus Run and Hollenback Run, flow the year round, but in summer they are reduced to a trickle. The mouths of several streams are clogged by gravel and alluvium so that the flow of water disappears before it reaches the Olentangy River. During the summer the water in Lazarus Run enters a deposit of gravel and boulders just east of the highway bridge near the river. The stream bed under the bridge is dry during the summer because the water flows through the gravel. During the winter, when the flow is greater, about 1 foot of water flows under the bridge. The mouth of Lazarus Run is normally blocked by a small alluvial fan of shale fragments. During periods of thawing in the winter, the flow of water from Lazarus Run completely removes the deposit. In the spring, when the flow slackens and the stream begins to resume its summer course through the gravel, a new alluvial fan is deposited at the mouth.

The same is true for other streams along the Olentangy River. Many of the small intermittant streams have formed alluvial fans on the sides of the valleys into which they flow. An excellent one can be seen in the open field north of Hollenback Run 600 yards from the Olentangy River.

GEOLOGIC HISTORY

1. Columbus Limestone - Deposition of carbonates, mostly organic, took place in a stable, shallow shelf area below wave base. The seas were warm, clear, and quiet with many corals and crinoids living on the bottom. Deposition was halted when the seas became shallower and the bottom was subjected to subaqueous erosion by waves. This unconformity is marked by a bone bed of fragmentary fossils.
2. Lower Delaware Limestone - Deposition of carbonates was renewed, but the water was cooler and slightly muddy. Erosion of the Appalachian land area to the east added mud to the shallow sea. The Cincinnatian land area to the west partially enclosed the sea. The bottom was below wave base, but conditions allowed only brachiopods to flourish in any numbers. The water was rich in silica, possibly from volcanic activity in the land area to the east. Concentrations of silica formed chert beds and nodules in the limestone. Deposition was halted when the seas again became shallower so that the bottom was above wave base.
3. Upper Delaware Limestone - During the short period of subaqueous erosion, Hadrophyllum d'orbignyi and some crinoids were able to flourish. Carbonate deposition again resumed as the shallow sea deepened slightly so that the bottom was below the wave base. The sea was slightly less muddy and warmer so that corals and crinoids were able to flourish. A period of non-deposition began when the seas retreated.
4. Lower Olentangy Shale - Appalachia was uplifted, adding fine

sediments to the seas which once again covered the area. Argillaceous muds were deposited in this period. There were some localized accumulation of carbonates. Conditions were not very good for life and the fossil record is sparse. The seas again retreated and a period of non-deposition again took place.

5. Upper Olentangy Shale - The shallow, warm seas again covered the area. The uplifted Appalachian land area was deeply eroded forming the Catskill Delta in the east and depositing muds across Ohio. The Cincinnati Arch was above the sea level and restricted the circulation of water in the sea. The muddy seas were not very favorable for life, so the fossil record is sparse. There were a few short periods of deposition of carbonates and silty mud rich in organic matter.

6. Ohio Shale - The seas became more enclosed and poorly aerated allowing the accumulation of much organic matter. The sediments changed to silty mud as the Appalachian area continued to be eroded. The stagnated waters were not favorable for life during this period. Ground waters rich in disolved minerals circulated through the unconsolidated muds precipitating carbonates and sulfides to form the concretions of the Ohio Shale. The deposition of clastics continued into Mississippian times.

7. A period of erosion followed the Mississippian deposition forming a major unconformity between the Mississippian and the Pennsylvanian. Pennsylvanian times were characterized by numerous periods of cyclothemic deposition.

8. During the Late Pennsylvanian or Early Permain, the area was regionally uplifted initiating a long period of erosion that continued until the Pleistocene.

9. In Pleistocene times the area was subjected to at least two, possibly as many as four, major periods of continental glaciation.

10. During the retreat of the glaciers at the end of the Wisconsin glaciation, the material forming the Powell Moraine was piled up and till was deposited in the upland areas. Meltwater from the retreating glacier also carved out the Olentangy Valley.

11. Continued erosion by the Olentangy River caused it to carve its channel in the valley floor and the tributary streams cut ravines into the Ohio and Olentangy Shales. The land surface was eroded to its present contours.

(Wells, 1947 and Oliver, et al, 1968)

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