FIELD EXCURSION 10, GUIDEBOOK

LOWER AND MIDDLE PALEOZOIC GEOLOGY OF SOUTHERN OHIO

24, August

By: J. Rytel and S. M. Bergström

SIXTH GONDWANA SYMPOSIUM

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The Ohio State University
Columbus, Ohio

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Guidebook for Field Trip

by

Jenny Rytel and Stig M. Bergström

with contributions from Hallan C. Noltimier and Mark Kleffner

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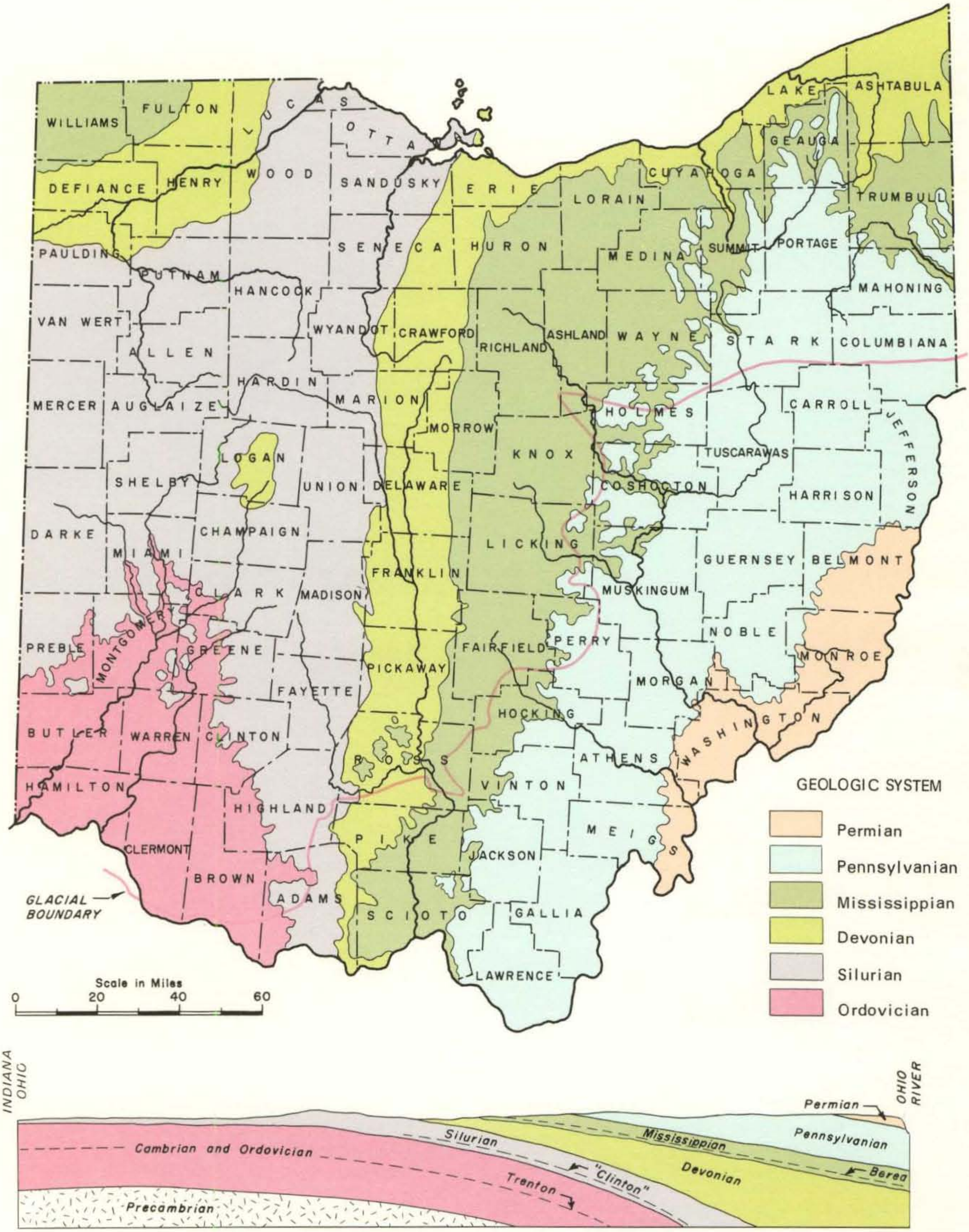

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GEOLOGIC MAP AND CROSS SECTION OF OHIO

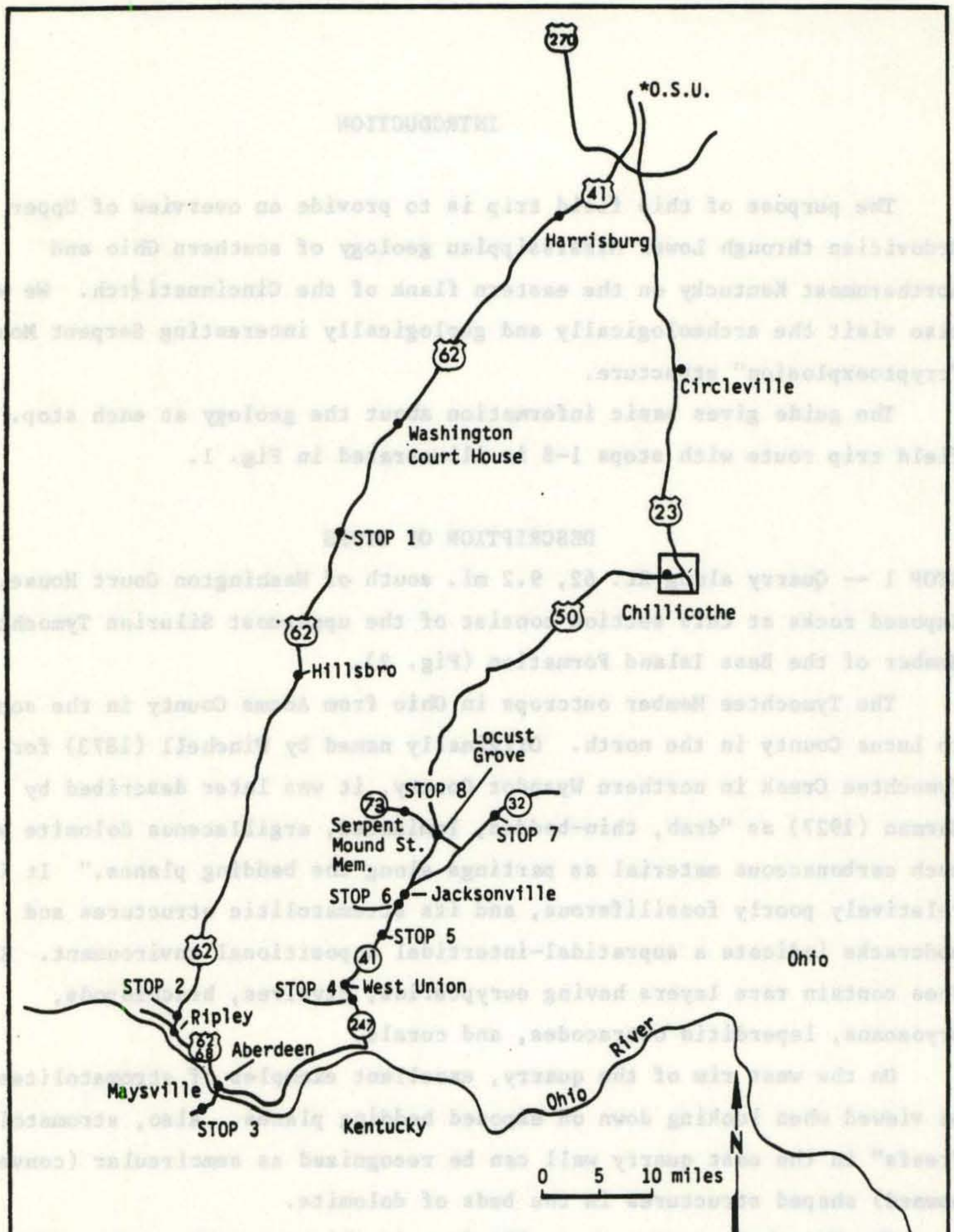


Fig. 1. Sketch map showing the field trip route and the location of Stops 1-8.

INTRODUCTION

The purpose of this field trip is to provide an overview of Upper Ordovician through Lower Mississippian geology of southern Ohio and northernmost Kentucky on the eastern flank of the Cincinnati Arch. We will also visit the archeologically and geologically interesting Serpent Mount "cryptoexplosion" structure.

The guide gives basic information about the geology at each stop. The field trip route with stops 1-8 is illustrated in Fig. 1.

DESCRIPTION OF STOPS

STOP 1 -- Quarry along Rt. 62, 9.2 mi. south of Washington Court House. Exposed rocks at this section consist of the uppermost Silurian Tymochtee Member of the Bass Island Formation (Fig. 2).

The Tymochtee Member outcrops in Ohio from Adams County in the south to Lucus County in the north. Originally named by Winchell (1873) for Tymochtee Creek in northern Wyandot County, it was later described by Carman (1927) as "drab, thin-bedded, laminated, argillaceous dolomite with much carbonaceous material as partings along the bedding planes." It is relatively poorly fossiliferous, and its stromatolitic structures and mudcracks indicate a supratidal-intertidal depositional environment. It does contain rare layers having eurypterids, bivalves, brachiopods, bryozoans, leperditid ostracodes, and corals.

On the west rim of the quarry, excellent examples of stromatolites can be viewed when looking down on exposed bedding planes. Also, stromatolite "reefs" in the east quarry wall can be recognized as semcircular (convex upward) shaped structures in the beds of dolomite.

The Tymochtee ranges up to 150 feet in thickness and rests conformably on, and grades into, the Greenfield Dolomite. This transition is exhibited as an increase upwards in the relative content of argillaceous and carbonaceous material compared to the calcium carbonate content.

The Tymochtee has not yielded stratigraphically diagnostic fossils but on the basis of its stratigraphic position above the Greenfield Dolomite, Berry and Boucot (1970) tentatively considered it to be of Pridoli (youngest Silurian) age. It is clearly a regressive unit, representing the

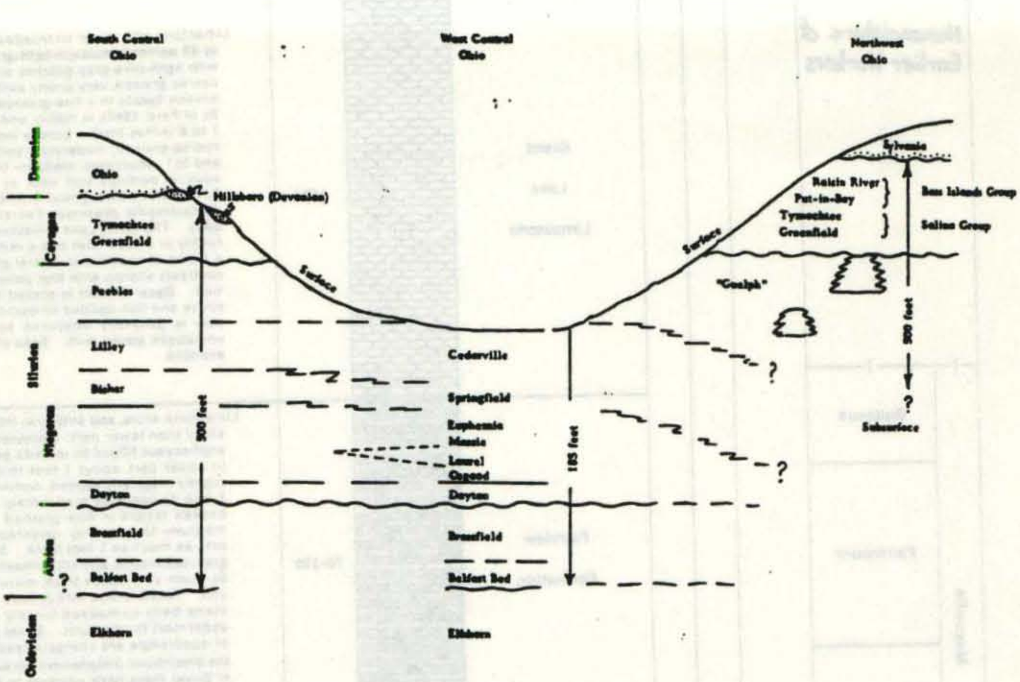


Fig. 2. Stratigraphic relationships of Silurian units in the Silurian outcrop area in Ohio. (From Summerson, 1963.)

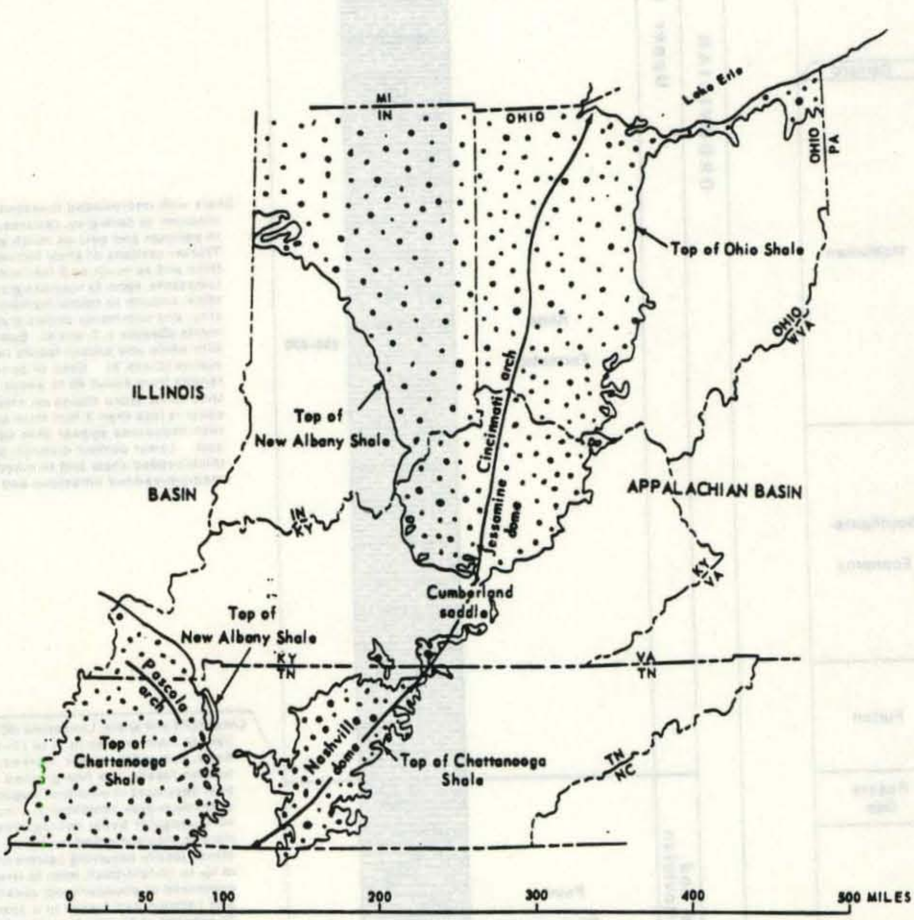
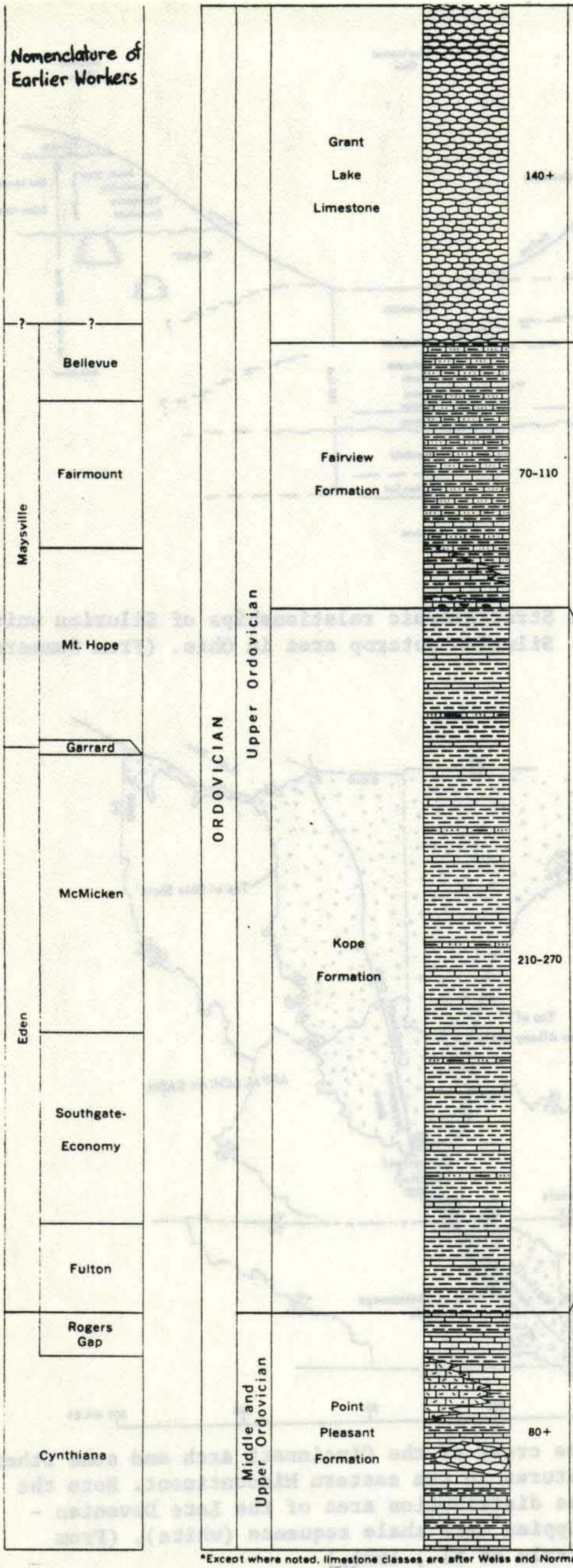


Fig. 3. Location of the crest of the Cincinnati Arch and some other structural features in the eastern Midcontinent. Note the boundary of the distribution area of the Late Devonian - Early Mississippian dark shale sequence (white). (From deWitt in Kepferle et al., 1981.)



Limestone with minor interbedded mudstone: Limestone (75 to 85 percent), medium-light-gray to medium-gray, mottled with light-olive-gray patches and streaks; very fine to very coarse grained, very poorly sorted; composed of whole and broken fossils in a fine-grained argillaceous matrix (Class 3c of Ford, 1967); in rubbly and irregular to lenticular beds 1 to 8 inches thick. Locally includes even beds of fine- to coarse-grained, moderately sorted limestone (Classes 1, 4, and 5).* Mudstone, medium- to medium-dark gray, calcareous; in partings and sets as much as 4 inches thick. Fossiliferous throughout with brachiopods very abundant, *Platystrophia ponderosa* Foerste being the most conspicuous. The Grant Lake Limestone weathers to a distinctive rubbly or slabby float and a reddish-brown clayey soil with a fabric of equant polyhedral grains as large as 5mm; soil contrasts sharply with that developed on underlying formation. Basal contact is placed between rubbly limestone above and thin-bedded limestone and shale below; in Ohio, unit is generally obscured by as much as 25 feet of unmapped glacial drift. Base of unit in Ohio is very poorly exposed.

Limestone, shale, and siltstone, interbedded; upper part more shaly than lower part: Limestone, light- to medium-gray, argillaceous (Class 5); in beds generally 1 to 4 inches thick in upper part, about 1 foot thick in lower part, evenly to slightly irregularly bedded, commonly ripple marked (Classes 1 and 4); contains moderately to well-sorted whole and broken fossils in fine-grained matrix (Class 3). Shale, medium- to dark-gray, calcareous, fissile, in partings and sets as much as 1 foot thick. Siltstone, light- to medium-gray, calcareous, and silty limestone (Class 6), in even beds as much as 3 inches thick, more abundant in upper part of unit. Fossiliferous throughout; several argillaceous limestone beds composed largely of *Rafinesquina* occur in uppermost third of unit. Basal beds along southern edge of quadrangle are characterized by a great abundance of the brachiopod *Strophomena planoconvexa* Hall; in the vicinity of Dover these beds coalesce to form a prominent ledge as much as 6 feet thick. Base of this ledge-forming unit lies on thick shale and marks basal contact of formation. Slopes on the Fairview Formation are conspicuously flatter than those on underlying unit. Formation weathers to yellowish-brown soil with platy texture containing abundant thin flakes of siltstone.

Shale with interbedded limestone: Shale (70 to 80 percent), medium- to dark-gray, calcareous, laminated, even-bedded; in partings and sets as much as 6 feet thick; fossiliferous. Thicker sections of shale include lenses as much as 1 inch thick and as much as 3 feet wide of argillaceous limestone. Limestone, light- to medium-gray, in even beds 1 to 6 inches thick, smooth to ripple-marked; dominantly micrograined, silty, and commonly shows graded bedding of fossil fragments (Classes 1, 2, and 4). Subordinately, fossil-fragmental with whole and broken fossils in a fine-grained argillaceous matrix (Class 3). Base of zone of abundant *Sowerbyella* ranges from about 40 to about 80 feet above base of unit. Unit forms steep slopes on which slumping is active. Soil cover is less than 3 feet thick on slopes, and unweathered rock exposures appear blue against the brownish-yellow soil. Lower contact distinct, placed to separate thin- to thick-bedded shale and thin-bedded limestone above from medium-bedded limestone and thin-bedded shale below.

Limestone and shale: Limestone (60 to 70 percent), dominantly light to medium gray in 1- to 12-inch-thick, even to irregular beds, commonly ripple marked; composed of whole and broken fossils in a fine-grained matrix (Classes 1 and 3); best developed in vicinity of Augusta. Subordinate amounts of medium-gray limestone in 1-inch- to 3-foot-thick, even to very irregular beds; micrograined, silty, sparingly fossiliferous, ripple marked, contains large flow rolls (Class 5). Minor, locally occurring calcarenite, light- to medium-gray, in ½- to 10-foot-thick, even to irregular beds, crossbedded; composed of abundant and conspicuous crinoid columnals and comminuted fossils in a sparry matrix (Classes 1 and 2); exposed at or near top of formation along Bracken Creek and along bank of Ohio River east of Augusta. Shale, medium- to dark-gray, calcareous, laminated, even-bedded; in partings and sets as much as 8 inches thick; contains thin partings of mudstone and siltstone; fossiliferous throughout. Forms steep slopes and cliffs; ledges that crop out on hillsides generally have squared edges. Base of unit not exposed, but at Carntown, Ky., about 15 miles down the Ohio River, the unit is about 105 feet thick (Luft, oral communication, 1970).

*Except where noted, limestone classes are after Weiss and Norman (1960)

Fig. 4. Stratigraphic column of upper Middle and Upper Ordovician rocks at Stops 2 - 5. (From Gibbons and Weiss, 1972.)

uppermost part of the Tippecanoe depositional sequence, and its deposition was followed by a land period that in Ohio extended to near the end of the Early Devonian. This regression can be traced over much of North America.

GENERAL INTRODUCTION TO STOPS 2-4

The rocks exposed in the Cincinnati Arch area range in age from middle Middle Ordovician through Pennsylvanian. The Middle Ordovician (Mohawkian Series) will not be studied during this trip but at Stops 2-5, there are outcrops of Upper Ordovician (Cincinnatian Series) rocks.

The Cincinnatian in this region is subdivided into three stages, from oldest to youngest the Edenian, the Maysvillian, and the Richmondian. Stop 2 exhibits formations of the Edenian and Maysvillian, and at Stops 3, 4, and 5, there are rocks of Richmondian age.

The Cincinnati Arch is a topographic high in the surface of the Pre-Cambrian crystalline basement of Ohio, Indiana, Kentucky. Its extension into northern Ohio is referred to as the Findlay Arch (Fig. 3). Information derived from strata on, and around, the arch, suggets that the structure did not become a structural high until the Silurian. Petrographic, isopach, and structural contour data indicate that the Devonian sediments are thinner, and deposited in shallower water, in areas close to the center of the arch, and are thicker, and deposited in deeper water, in more distal regions. This suggests that there probably was an uplift during the Silurian.

STOP 2 -- This stop consists of a series of four outcrops within a two mile streach of Ohio Route 62-28, 0.25 mi. north of Ripley, Ohio. These are described in a downsection sequence, Stop 2A-2D, in a southerly direction toward Ripley.

The formations at this location are Edenian through Maysvillian in age (Figs. 4, 5, 6). The literature on Cincinnatian strata along the Cincinnati Arch contains a plethora of formational names for these rocks (Fig. 7), but the names used on this trip are employed by the United States Geology Survey, and are accepted by most recent workers.

The contact between the Fairview and the overlying Grant Lake can be seen at Stop 2A (Fig. 5). This contact is expressed as a change in the

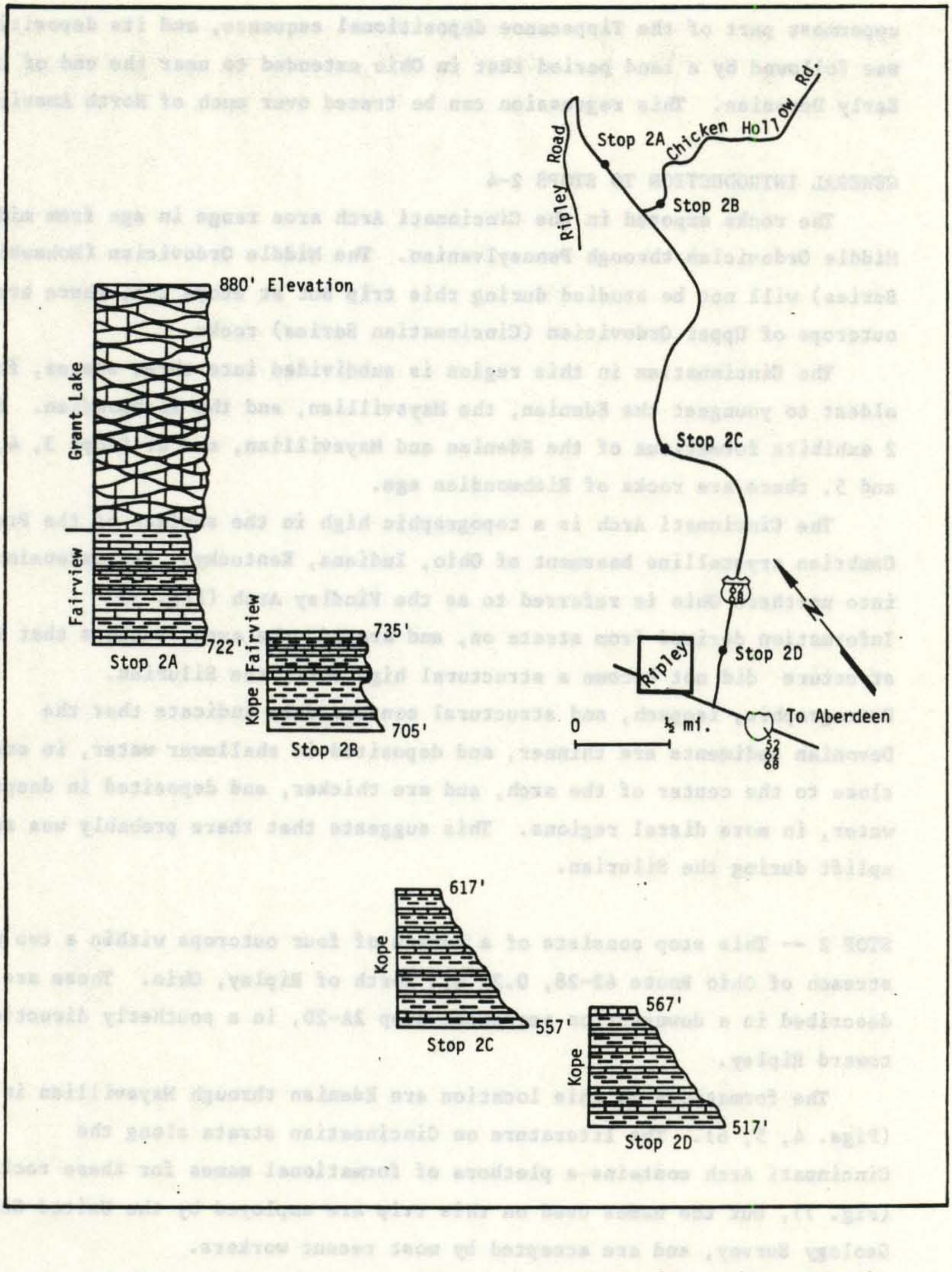


Fig. 5. Schematic columnar sections of stratigraphic units exposed at Stops 2A-D along Rt. 62-68 north of Ripley, Ohio. The location of individual sections is shown in sketch map. (From Rytel, in prep.)

weathering profile, the Fairview being more recessive than the Grant Lake. The physical characteristics of the Grant Lake limestone beds are very different from those of the Fairview (Fig. 4). The Grant Lake limestones are wavy bedded, argillaceous, highly fossiliferous, and are laterally discontinuous. The limestone beds are also thin, very irregular, and display rubbly-weathering. Between the beds of limestone are calcareous shale partings which range in thickness up to 8 inches in this section.

The most conspicuous Grant Lake fossils are brachiopods. The unit is famous for the abundance of the Platystrophia ponderosa. Some other common taxa are Rafinesquina ponderosa, R. nasuta, Platystrophia cypha, P. laticosta, and Hebertella sinuata. Complete crinoids and trilobites are not uncommon and bryozoans, bivalves, gastropods, and conodonts are very common.

The Grant Lake limestones have been described as "poorly sorted" with "jumbled large fossil fragments and whole fossils" (Peck, 1966). The texture along with other petrographic characteristics indicate a high energy environment of deposition, perhaps in the wave agitated shoals of a sloping shelf (Weir and Peck, 1968).

The third outcrop north of Ripley (Stop 2B) exposes the contact between the Kope and the Fairview which is located in the section where the recessive uppermost shale beds of the Kope grade into the lower cliff-forming thicker limestone beds of the Fairview (Fig. 5).

As also described in Figure 4, the Fairview is a sequence of interbedded silty shale and limestone, each constituting about 50% of the formation. The shale beds are, as an average, about three inches thick and the limestones 1 1/2 feet thick, and these beds are more laterally continuous than the limestone beds of the Kope. At this location the Fairview is about 65 feet thick. The limestone beds of the Fairview contain more broken and abraded fossil material than those of the Kope although the size of the Fairview fossils is, in most cases, much greter than those in the Kope. Although the fauna is more diverse, good specimens are harder to come by than in the Kope because the Fairview specimens tend to be preserved along the bedding planes of the thicker limestone beds, which have very few shale partings. The brachiopod Strophomena planoconvexa is extremely abundant in the limestones a few feet above the Kope-Fairview

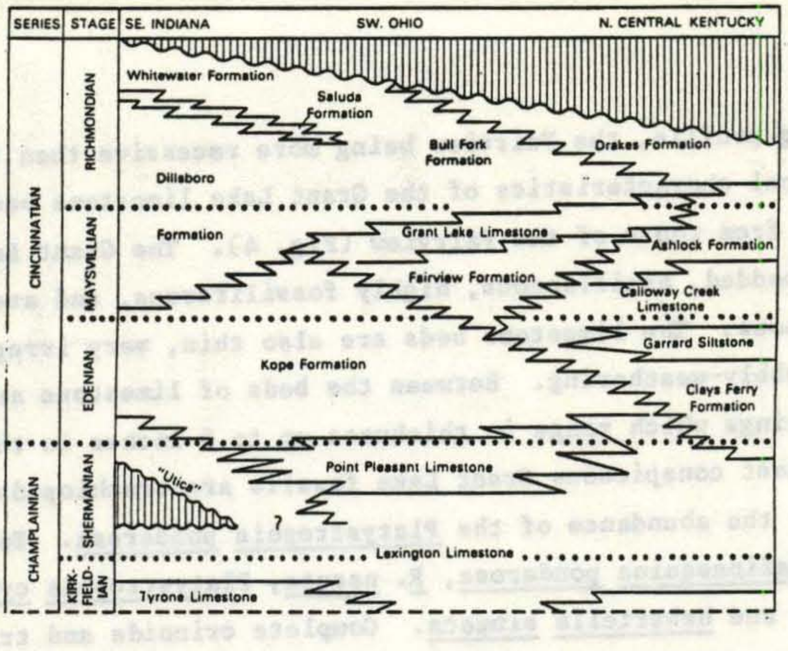


Fig. 6. Stratigraphic relationships of upper Middle and Upper Ordovician rocks in the Cincinnati region. (From Sweet, 1979.)

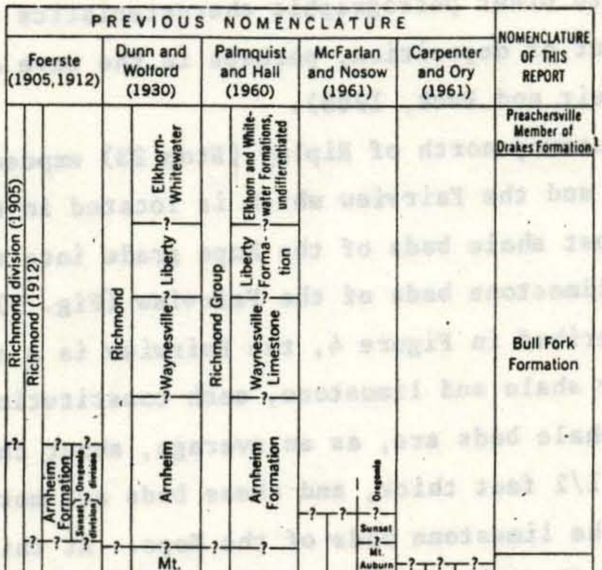


Fig. 7. Stratigraphic nomenclature of Upper Ordovician rocks above the Kope Formation in the Maysville area, Kentucky. (From Peck, 1966.)

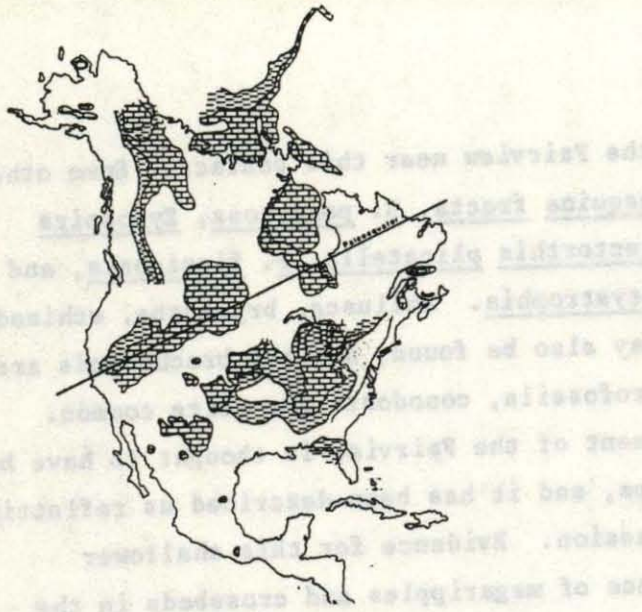
and it is always present in the Fairview near this contact. Some other common brachiopods are Rafinesquina fracta, R. ponderosa, Zygospira modesta, Z. kentuckyensis, Plectorthis plicatella, P. fissicosta, and species of Hebertella and Platystrophia. Molluscs, bryozoans, echinoderms, graptolites, and trilobites may also be found, but the brachiopods are far more abundant. Among the microfossils, conodonts are quite common.

The depositional environment of the Fairview is thought to have been shallower than that of the Kope, and it has been described as reflecting a shallowing upward in the succession. Evidence for this shallower environment is e.g. the presence of megaripples and crossbeds in the limestones along with a decrease in the clastic content.

STOP 2C-D -- The basal part of the Kope Formation is exposed at Stop 2D.

The Kope - Point Pleasant contact is conformable, but it is currently not well exposed at this location (Fig. 5). As indicated in Figure 4, one of the characteristics that distinguishes the Point Pleasant from the Kope is the greater thickness of its limestone beds.

As described in some detail in Figure 4, the Kope is a sequence of interbedded shale, limestone, and siltstone varying in thickness from 200 feet in southeastern Indiana to about 240 feet at this location. The formation is defined on two main criteria, the relative percentage of shale and limestone, and the relative thickness of the shale and limestone beds. Calcareous shale, which comprises 70-80% of the formation, generally contains few megafossils except graptolites. Individual shale beds reach a maximum thickness of 6 feet although 1-4 feet is average. Limestone beds comprise 20-30% of the formation, and many of these are highly fossiliferous. These beds reach a maximum thickness of 8 inches but 2-5 inches is average. The limestone beds contain a large amount of fossil debris, from whole unbroken specimens to sand size fragments. Although these limestone beds at first glance appear to be continuous over great distances, an astute obsever will notice that when a single bed is traced a few yards, it will, in most cases, prove to be discontinuous and hence lenticular in nature.



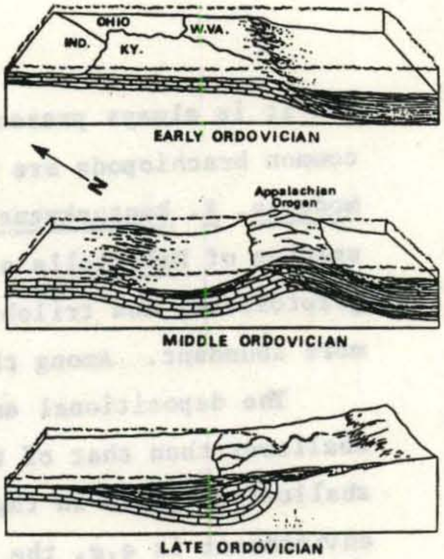
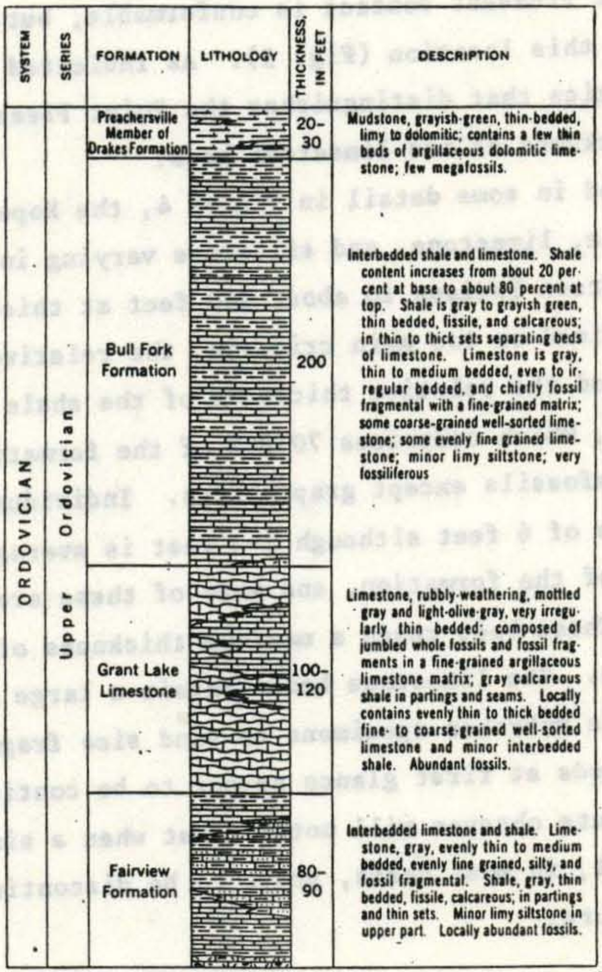


Fig. 8. Distribution of major lithofacies types during Cincinnatian time in North America. (From Meyer and Tobin, 1981.)

Fig. 9. Major regional tectonic elements during Ordovician time in the eastern Midcontinent and central Appalachians. (From Meyer and Tobin, 1980.)



SYSTEM	SERIES	FORMATION	LITHOLOGY	THICKNESS, IN FEET	DESCRIPTION
ORDOVICIAN	Upper Ordovician	Preachersville Member of Drakes Formation		20–30	Mudstone, grayish-green, thin-bedded, limy to dolomitic; contains a few thin beds of argillaceous dolomitic limestone; few megafossils.
		Bull Fork Formation		200	Interbedded shale and limestone. Shale content increases from about 20 percent at base to about 80 percent at top. Shale is gray to grayish green, thin bedded, fissile, and calcareous; in thin to thick sets separating beds of limestone. Limestone is gray, thin to medium bedded, even to irregular bedded, and chiefly fossil fragmental with a fine-grained matrix; some coarse-grained well-sorted limestone; some evenly fine grained limestone; minor limy siltstone; very fossiliferous
		Grant Lake Limestone		100–120	Limestone, rubbly-weathering, mottled gray and light-olive-gray, very irregularly thin bedded; composed of jumbled whole fossils and fossil fragments in a fine-grained argillaceous limestone matrix; gray calcareous shale in partings and seams. Locally contains evenly thin to thick bedded fine- to coarse-grained well-sorted limestone and minor interbedded shale. Abundant fossils.
		Fairview Formation		80–90	Interbedded limestone and shale. Limestone, gray, evenly thin to medium bedded, evenly fine grained, silty, and fossil fragmental. Shale, gray, thin bedded, fissile, calcareous; in partings and thin sets. Minor limy siltstone in upper part. Locally abundant fossils.

Fig. 10. Stratigraphic section of post-Kope Upper Ordovician rocks in the Maysville area, Kentucky. (From Peck, 1966.)

The environment of the deposition of the Kope is thought to have been shallow enough (20-90m) that the wave base during severe storms may have reached the bottom, and reworked the sediments and faunal remains. The silts and clays may be viewed as the very distal lithologic equivalents of the Queenston Delta-Martinsburg Formation in the Appalachians, whose clastic source was the Taconic uplands in the northeastern United States (Fig. 8-9). The limestone beds of the Kope are thought to represent periods when clastic influx was at a minimum allowing pioneer organisms to colonize the substrate in a patchy fashion. Particularly important among these organisms were brachiopods, molluscs, bryozoans, trilobites, graptolites and echinoderms. The Kope fossils at this stop and at Stop 3 include the brachiopods Sowerbyella rugosa, Rafinesquina fracta, and Zygospira modesta along with several species of Strophomena and Onniella. The trilobite Cryptolithus tesselatus is also found although whole specimens are extremely rare. There are also graptolite-bearing intervals, Climacograptus typicalis being the dominating species.

STOP 3 -- Outcrop behind the Pepsi-Cola warehouse in the southeastern outskirts of Maysville, Ky.

At this location is exposed a more fossiliferous outcrop of the upper part of the Kope Formatin than at Stop 2. Particularly notable fossils found here are graptolites (mostly Climacograptus typicalis) and trilobites (Flexicalymene meeki).

STOP 4 -- Small road section just north of bridge along Route 247, 2.5 mi. south of West Union, Ohio.

The rocks exposed at this top belong to the Bull Fork Formation, which is described in Figure 10. Fossils are abundant here and excellently preserved, hence beautiful specimens of several brachiopod species can easily be found weathered out. Note also the presence of the horn coral Grewingkia rustica.

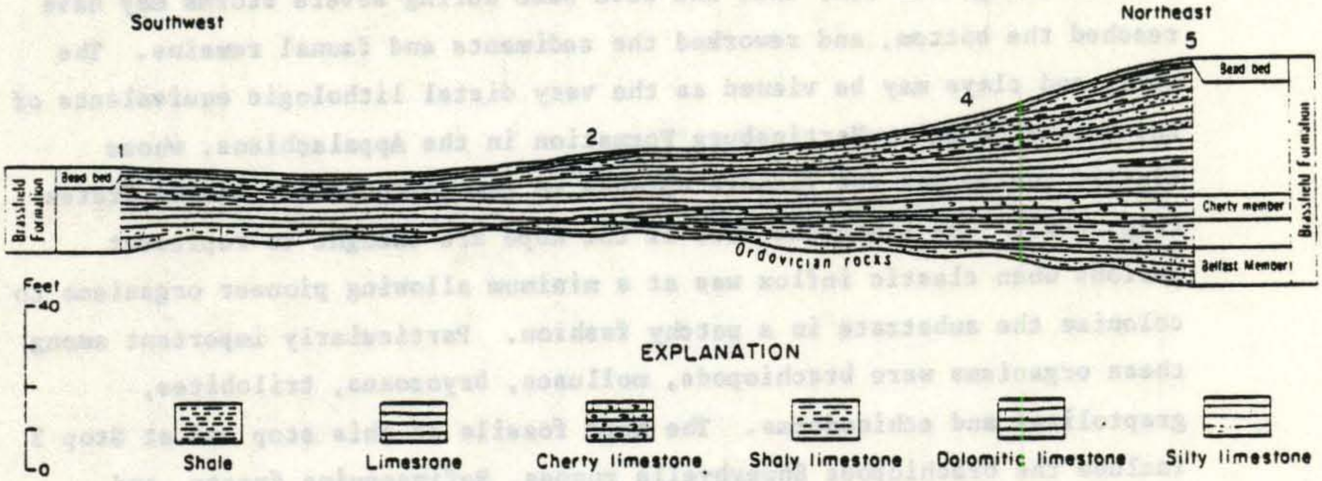


Fig. 11. Schematic cross section of the Brassfield Formation from north-central Kentucky to southern Ohio showing relationships of lithologic units and the unconformable Ordovician-Silurian contact. From Rexroad and Kleffner (1984).

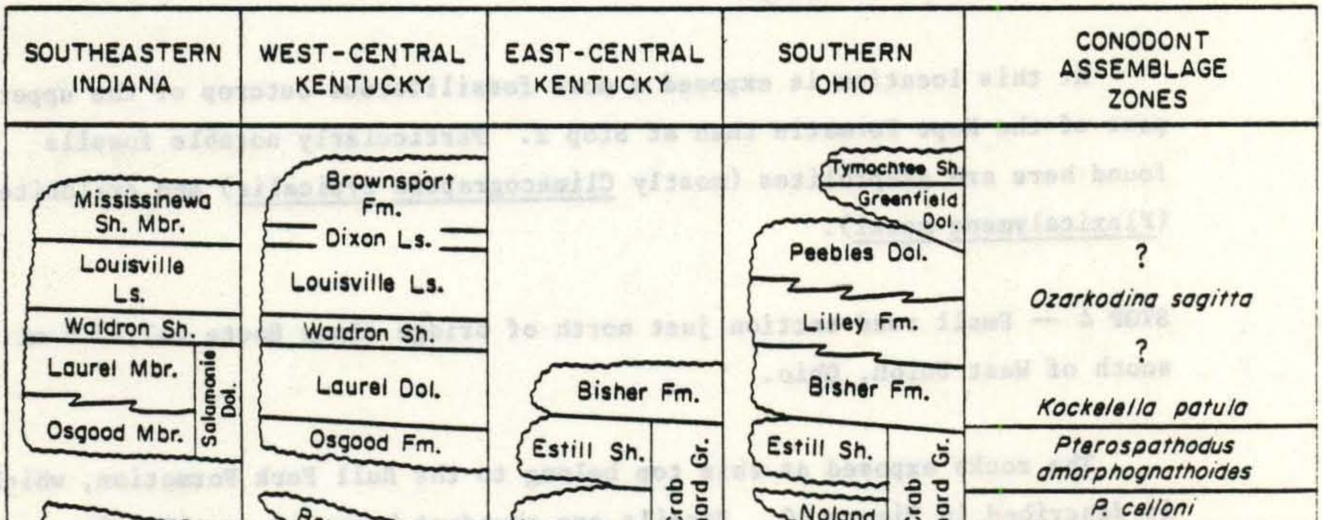


Fig. 12. Correlation of Silurian formations in the Cincinnati Region. From Rexroad and Kleffner (1984).

STOP 5 -- A series of road sections along Route 41 between West Union and Ohio Brush Creek provide excellent exposures of the Ordovician-Silurian contact and adjacent strata.

The lower part of the section represents the uppermost member of the Drakes Formation, the Preachersville (Fig. 10). This member is the youngest Richmondian unit on the east side of the Cincinnati Arch. As described by Peck (1966), it "consists of grayish-green calcareous to dolomitic mudstone and minor dolomitic limestone and dolomite. It is about 25 feet thick near Maysville and thickens southward. Mudstone makes up about 90% of the formation, is chiefly grayish-green but locally reddish purple near the top (as in this section), thin bedded, fissile to blocky, and locally silty. Dolomitic limestone and dolomite are gray to brown, fine to medium grained, argillaceous to silty, and occur as thin lenses and irregular beds." Megafossils are not as abundant as in older Richmondian sections on the flanks of the arch, but bryozoans, "Lingula", corals, and a few brachiopods are present at this exposure.

The Brassfield Formation of Early Silurian (Llandoverian) age overlies the Preachersville. The contact between the two appears conformable, and locally even gradational (Peck, 1966). However, faunal evidence shows that there is a considerable stratigraphic gap (about four graptolite zones) between the Preachersville and the Brassfield corresponding to the uppermost Ordovician and the lowermost Silurian (Figs. 11, 12). This section illustrates well that such an important unconformity does not need to be marked by a distinct erosion surface, conglomerate, etc.; it may be hidden at an inconspicuous bedding plane as it is in this section! Such a contact has been called a paraconformity. Gray and Boucot (1972) interpreted this paraconformity to reflect very shallow marine conditions, and a period of nonmarine environment is likely to have occurred at the systemic boundary. This regression was apparently caused by the Gondwana glaciation.

The Brassfield is a time-transgressive formation (Fig. 12) that ranges in age from early-middle to late Llandoverian. It varies lithologically, but generally consists of limestone or dolomitic limestone alternating with beds of shale or dolomite. At most locations east of the Cincinnati Arch the basal part of the Brassfield consists of several feet of silty

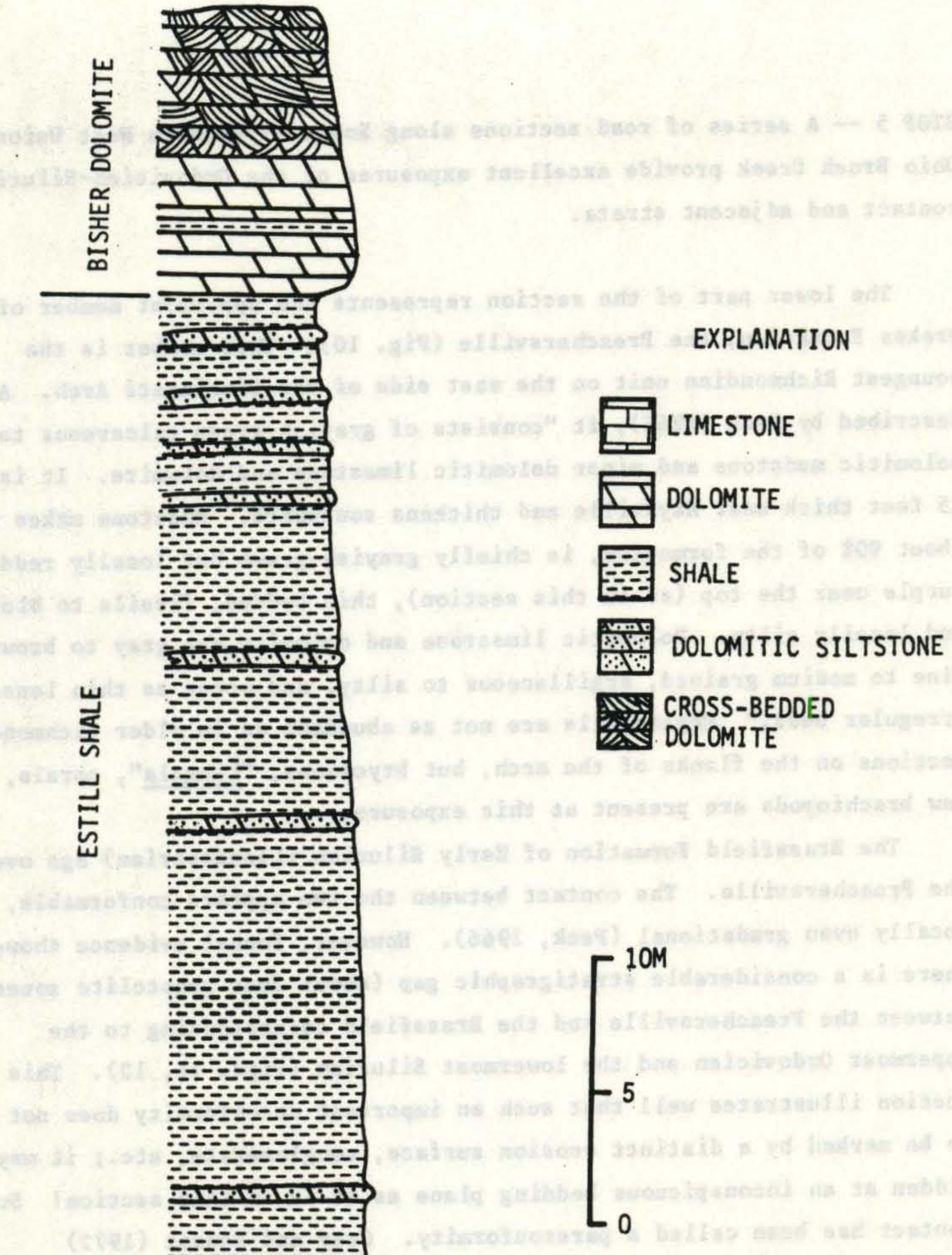


Fig. 13. Schematic section of Silurian stratigraphic units at Stop 6, along Rt. 41 near Jacksonville, Adams County. (From Kleffner, 1979.)

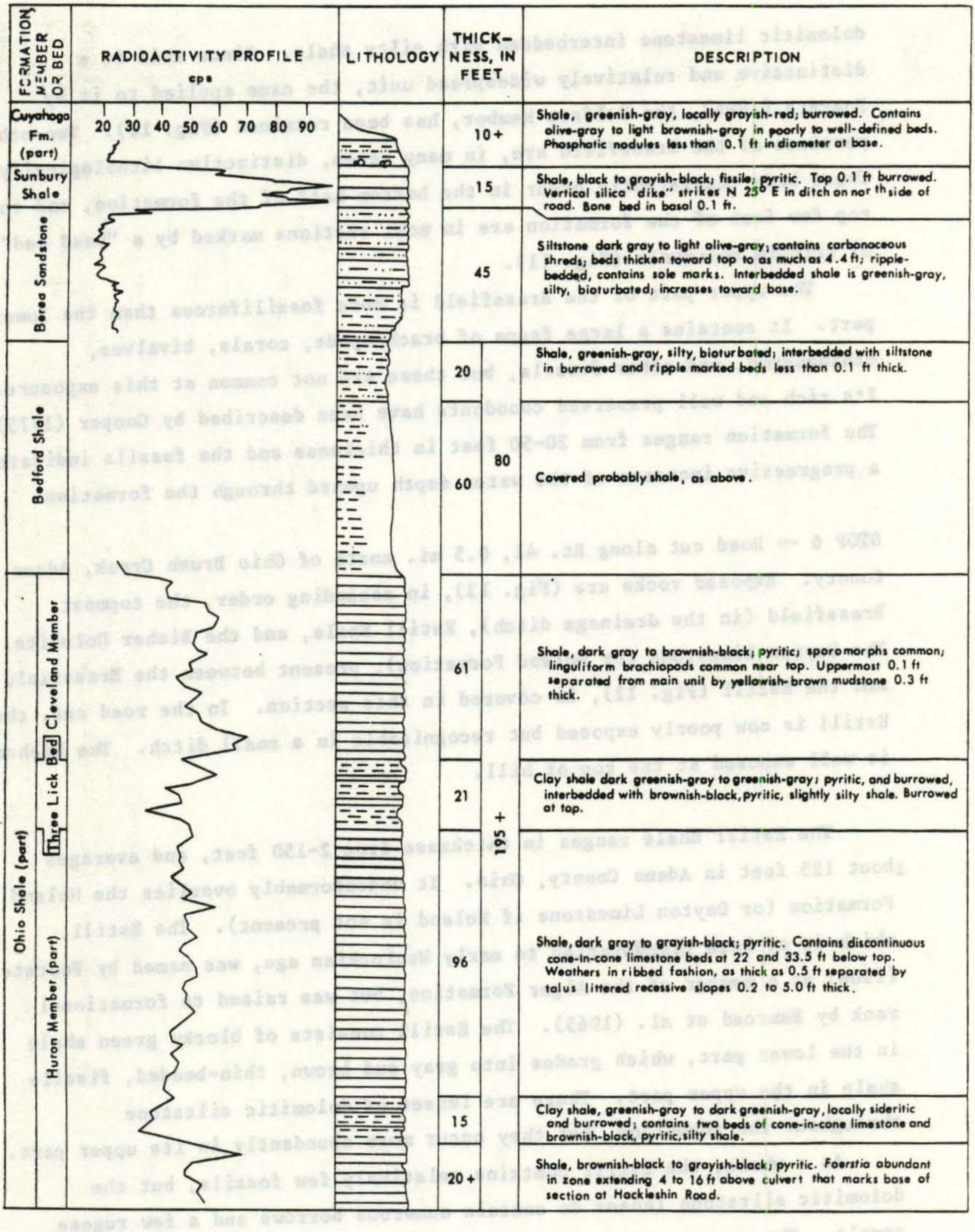
dolomitic limestone interbedded with silty shale. Since this is a distinctive and relatively widespread unit, the name applied to it by Foerste (1896), the Belfast Member, has been retained (Fig. 12). Two other portions of the Brassfield are, in many cases, distinctive lithologically. Chert beds consistently occur in the bottom half of the formation, and the top few feet of the formation are in most sections marked by a "bead bed" of crinoid columnals (Fig. 11).

The upper part of the Brassfield is more fossiliferous than the lower part. It contains a large fauna of brachiopods, corals, bivalves, echinoderms, and other fossils, but these are not common at this exposure. Its rich and well-preserved conodonts have been described by Cooper (1975). The formation ranges from 20-50 feet in thickness and the fossils indicate a progressive increase of the water depth upward through the formation.

STOP 6 -- Road cut along Rt. 41, 0.5 mi. north of Ohio Brush Creek, Adams County. Exposed rocks are (Fig. 13), in ascending order, the topmost Brassfield (in the drainage ditch), Estill Shale, and the Bisher Dolomite. The Dayton Limestone (or Noland Formation), present between the Brassfield and the Estill (Fig. 12), is covered in this section. In the road cut, the Estill is now poorly exposed but recognizable in a small ditch. The Bisher is well exposed at the top of hill.

The Estill Shale ranges in thickness from 2-150 feet, and averages about 125 feet in Adams County, Ohio. It unconformably overlies the Noland Formation (or Dayton Limestone if Noland is not present). The Estill, which is of late Llandoverian to early Wenlockian age, was named by Foerste (1906) as a member of the Alger Formation, but was raised to formational rank by Rexroad et al. (1965). The Estill consists of blocky green shale in the lower part, which grades into gray and brown, thin-bedded, fissile shale in the upper part. There are lenses of dolomitic siltstone throughout the formation, but they occur more abundantly in its upper part.

As a whole, the Estill contains relatively few fossils, but the dolomitic siltstone lenses do contain numerous borrows and a few rugose corals. The upper part of the Estill has yielded some fossils at a few localities. Conodonts from this unit belong in the amorphognathoides Zone of late Llandoverian to early Wenlockian age (Kleffner, 1979).



FORMATION, MEMBER OR BED		THICKNESS, IN FEET		DESCRIPTION
Cuyahoga Fm. (part)		10+		Shale, greenish-gray, locally grayish-red; burrowed. Contains olive-gray to light brownish-gray in poorly to well-defined beds. Phosphatic nodules less than 0.1 ft in diameter at base.
Sunbury Shale		15		Shale, black to grayish-black; fissile, pyritic. Top 0.1 ft burrowed. Vertical silica "dike" strikes N 25° E in ditch on north side of road. Bone bed in basal 0.1 ft.
Berea Sandstone		45		Siltstone dark gray to light olive-gray; contains carbonaceous shreds; beds thicken toward top to as much as 4.4 ft; ripple-bedded, contains sole marks. Interbedded shale is greenish-gray, silty, bioturbated; increases toward base.
Bedford Shale		20	80	Shale, greenish-gray, silty, bioturbated; interbedded with siltstone in burrowed and ripple marked beds less than 0.1 ft thick.
		60		Covered probably shale, as above.
Ohio Shale (part)	Cleveland Member	61	195 +	Shale, dark gray to brownish-black; pyritic; sporomorphs common; linguliform brachiopods common near top. Uppermost 0.1 ft separated from main unit by yellowish-brown mudstone 0.3 ft thick.
	Three Lick Bed	21		Clay shale dark greenish-gray to greenish-gray; pyritic, and burrowed, interbedded with brownish-black, pyritic, slightly silty shale. Burrowed at top.
	Huron Member (part)	96		Shale, dark gray to grayish-black; pyritic. Contains discontinuous cone-in-cone limestone beds at 22 and 33.5 ft below top. Weathers in ribbed fashion, as thick as 0.5 ft separated by talus littered recessive slopes 0.2 to 5.0 ft thick.
		15		Clay shale, greenish-gray to dark greenish-gray, locally sideritic and burrowed; contains two beds of cone-in-cone limestone and brownish-black, pyritic, silty shale.
		20+		Shale, brownish-black to grayish-black; pyritic. *Foerstia* abundant in zone extending 4 to 16 ft above culvert that marks base of section at Hackleshin Road.

Fig. 14. Geology of the Tener Mountain section in roadcut along Ohio Route 32 near Peebles, Adams County, Ohio. (From Kepferle et al., 1981.)

The next younger unit is the Bisher Dolomite (Fig. 13). The Bisher outcrops from Kentucky northward through Highland County, Ohio, but it has not been recognized in outcrop north of Highland County. The Bisher averages 40 feet in thickness in Adams County but ranges from 25-85 feet in thickness elsewhere, generally thinning to the north and west. The Bisher rests with apparent conformity on the Estill Shale, but recent conodont data (Kleffner, in preparation) may show that the contact could be a paraconformity. The Bisher is Wenlockian in age.

The Bisher has a variable lithology, but in most areas it consists of medium to dark gray, fine-grained, silty to argillaceous dolomite that weathers to a yellow-brown or buff color. At some localities bioclastic or dense limestone may predominate over the dolomite. There are also thin interbedded fissile silty to silty dolomitic shales. Characteristically, there is a fossiliferous zone about 3-9 feet above the base of the formation. (This can be observed at the base of this road cut.) The upper half of the Bisher is cross-bedded and contains scattered chert nodules.

STOP 7 — A series of road cuts along Ohio Route 32 from Union Hill Road to the junction of Ohio Route 73, Pike and Adams County. The succession exposed ranges in age from Late Devonian through Early Mississippian. The lowermost unit exposed is the Ohio Shale, which is overlain by the early Mississippian Bedford Shale, Berea Sandstone, and Sunbury Shale (Fig. 14).

Regionally the Devonian-Mississippian black shale sequence unconformably overlies strata of Middle Ordovician to Middle Devonian age. In most cases, the surface of the unconformity is relatively flat and smooth and the basal part of the black shale units typically has a basal "lag sandstone" or "bone bed" varying in thickness from a few millimeters to a few meters. Phosphatic pebbles have been found at the top of the Sunbury here, and a siliceous dike-like structure appears in this formation in the ditch northeast of the junction of Route 32 and Union Hill Road near the top of the hill. Siderite concretions are present in the greenish-gray clay shale in the Huron Member of the Ohio Shale just above the Foerstia zone, and are found in the Bedford Shale.

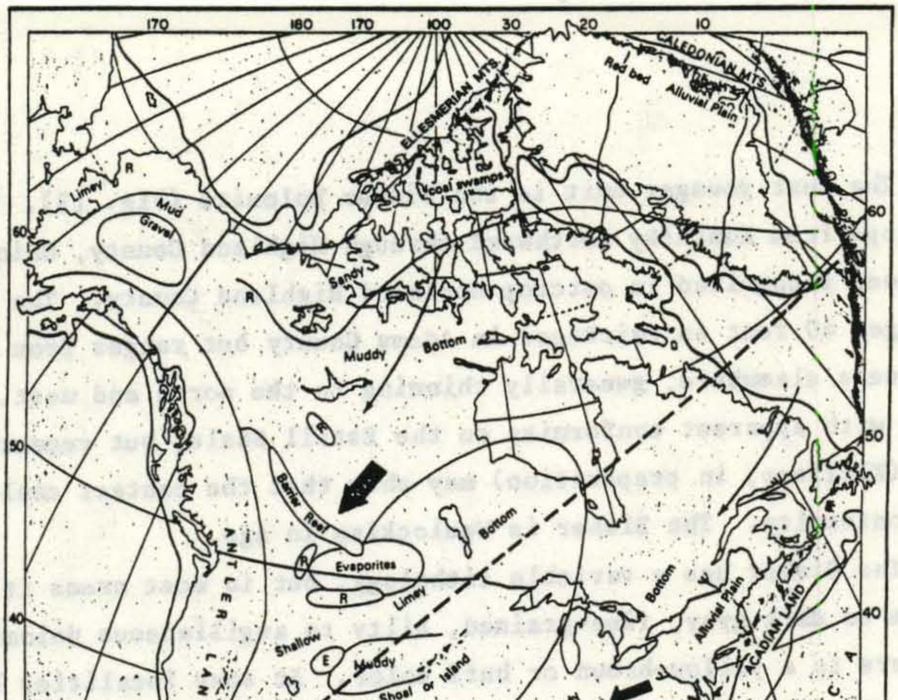


Fig. 15. Sketch map showing Late Devonian paleogeography. From Dott and Batten, 1981.

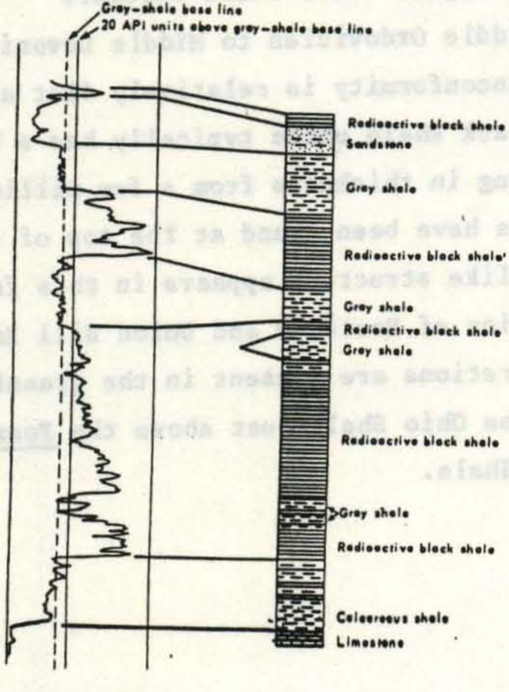


Fig.16.

Comparison of a gamma-ray log and a lithologic log showing the relationship of the log response to various types of rock. From Kepferle et al., 1981.

Although black shales are common in the geologic record, the Devonian-Mississippian black shale sequence of North America is unusual in its widespread distribution and apparent homogeniety. This black shale sequence, though known by many stratigraphic names, forms a significant and easily recognized stratigraphic interval that is continuous throughout much of the Midcontinent United States. These shales are thickest in the area of the Appalachian Basin where they may comprise as much as one fourth of the Devonian sedimentary sequence, and they are unusual because of their high organic matter content, radioactivity, and paucity of fossils, especially benthic forms. In addition they are an important source for metals, as well as some forms of synthetic fuel" (Ettensohn and Barron in Kepferle et al., 1981).

This upper Devonian through lower Mississippian black shale sequence is laterally equivalent to other black shales in the Appalachian Basin, i.e. the Chattanooga Shale of Tennessee, and the New Albany Shale of Indiana and Illinois. These deposits represent the fine distal clastics of the Catskill delta of the eastern portion of the Appalachian Basin (Fig. 13). This clastic wedge is the result of the Acadian orogeny in the northeastern Appalachians. Because of the relatively high quantity of radioactive elements in these shales (Fig. 14, 16) their gamma characteristics can be used for correlation over great distances in conjunction with conodonts, spores, and a distinctive plant megafossil, Foerstia.

The organic material in these shales consists primarily of spores, algae, woody material, "opaque macerals", and organic films on clay particle aggregates. The clack shales have high concentrations of microscopic phosphorite in the upper portions of the deposit.

Benthic megafossils are extremely rare, and pelagic megafossils are relatively rare. Where benthic forms do occur they are always found near the base of the sequence.

The environment of deposition of this black shale sequence was an inland equatorial sea (Fig. 15) during a time of low clastic input. The small amount of clastics may have been due to a "rain shadow" on the western side of the Acadian Mountains (trade winds blow east to west). The Catskill delta to the east shows a transgression-regression cyclicity that

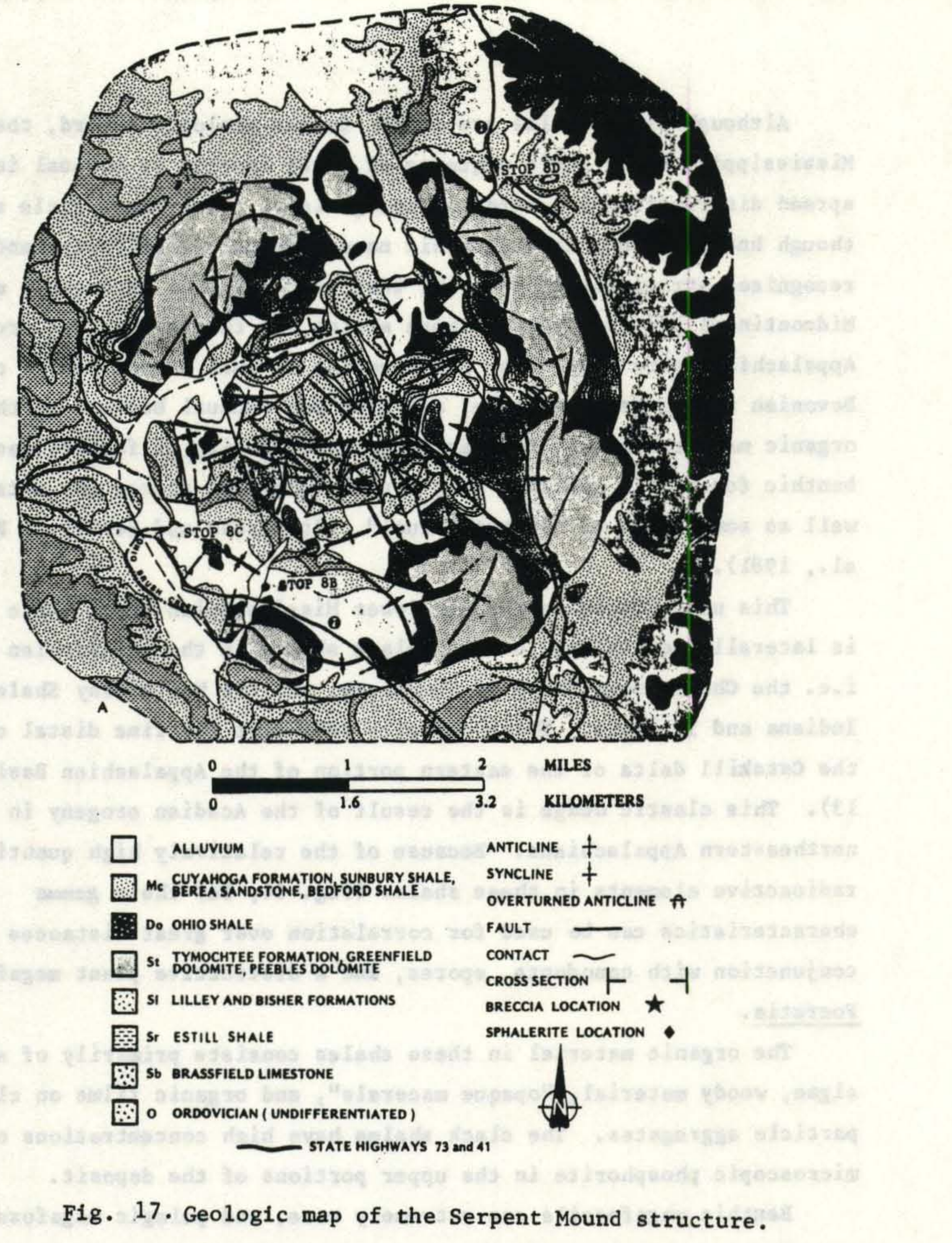
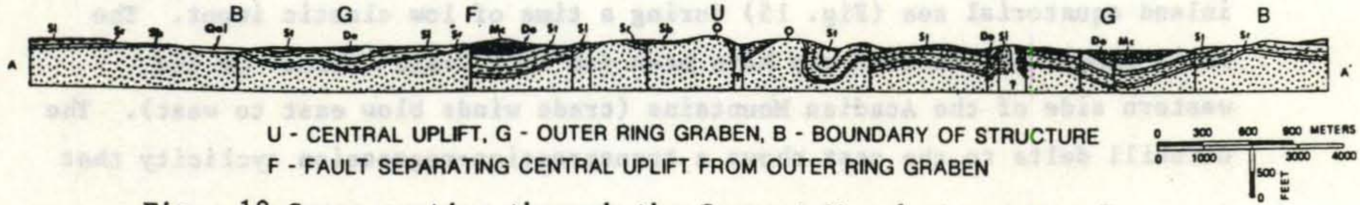


Fig. 17. Geologic map of the Serpent Mound structure. From Kepferle et al., 1981.



U - CENTRAL UPLIFT, G - OUTER RING GRABEN, B - BOUNDARY OF STRUCTURE
F - FAULT SEPARATING CENTRAL UPLIFT FROM OUTER RING GRABEN

Fig. 18. Cross section through the Serpent Mound structure. See Fig. 15 for explanation of symbols. From Kepferle et al., 1981.

has been related to periods of tectonic quiescence and activity, the times of activity causing a rain shadow (Ettensohn and Barron in Kepferle et al., 1981). The high amount of organic productivity in the Ohio Shale environment is typical of anaerobic conditions at the bottom of this semirestricted sea. It may be speculated that the depth of this sea may have been in the order of several hundred feet.

GENERAL INTRODUCTION TO STOPS 8A-D — Serpent Mound "Cryptoexplosion" Structure and Indian Mounds.

If time permits, in addition to the Serpent Mound State Park, we will visit three exposures where structural and stratigraphic disruptions can be observed.

The Serpent Mound "cyptoexplosion" structure is located in northernmost Adams County and portions of Highland and Pike Counties. The structure is circular with a diameter of about four miles (Fig. 17). It is named for a serpent-shaped mound constructed on the southwest margin of the circular structure by the Adena or Hopewell indian culture about 1000 B.C. - 400 A.D. (Fig. 20). This circular feature contains Middle Ordovician to Middle Mississippian strata that are highly faulted, folded, and brecciated (Fig. 19).

The earliest reference to the anomalous nature of the Serpent Mound area is in Dr. John Locke's contribution to the Second Annual Report of the Geological Survey of the State of Ohio (1836, p. 266). He noted the "stratigraphic disruption, faults, and upturned layers of rocks" in the area.

There are three major structural subdivisions (Fig. 18); a central uplift, a downdropped outer ring-graben, and an intermediate transition area (Reidel and Koucky, 1981). Reidel and Koucky (1981) states that "The central uplift consists of seven radiating anticlines separated by high angle faults and grabens, while the outer ring-graben is a series of doubly plunging, fault bounded synclines and basins with concentric and radial faults and folds." The youngest disturbed unit is the Sunbury Shale of Middle Mississippian age, which is unconformably overlain by Illinoian glacial drift. Thus the age of the disturbance is bracketed by a great expanse of time.

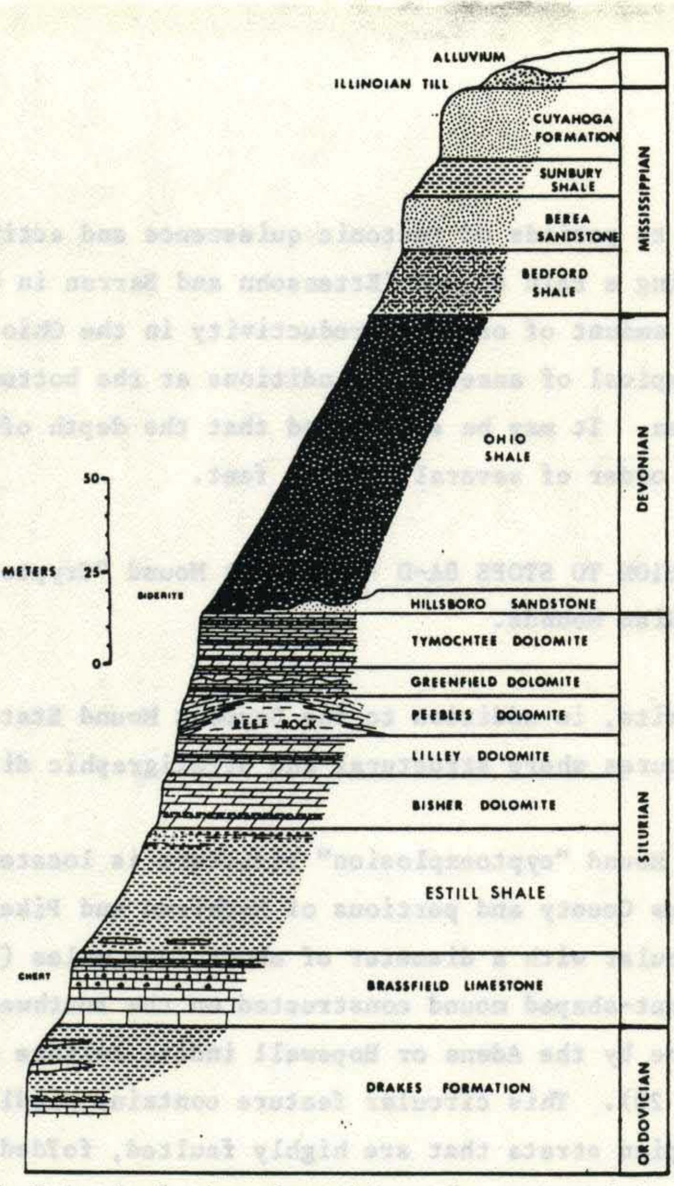


Fig. 19. Principal stratigraphic units exposed in the Serpent Mound structure. From Reidel & Koucky, 1981.

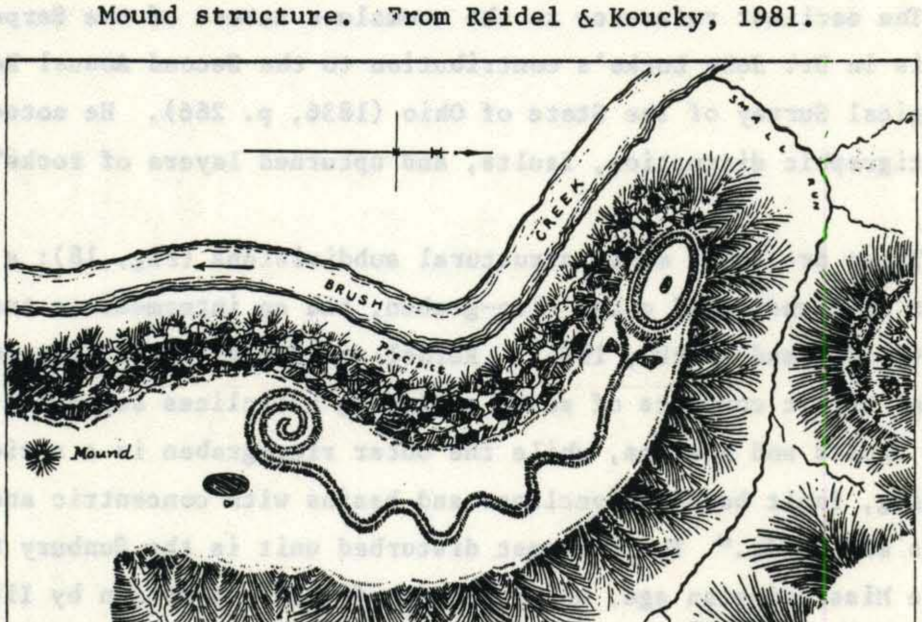


Fig. 20. Sketch map of the Serpent Mound Indian burial area. From Summerson, 1963.

The oldest rocks of the structure are Ordovician and Silurian and occur in the central uplift (Fig. 17). In relation to the horizontal strata distal to the Serpent Mound structure, the vertical displacement of the central uplift is about 800 feet. Nearly all of the faulting in this structure is vertical (Fig. 18).

The intermediate transition area is also folded and faulted, and in both concentric and radial direction in relation to the central uplift.

According to Reidel and Koucky (1981) "The periphery of the structure is characterized by a series of doubly plunging, generally fault bounded synclines and basins with nearly concentric axes" (Fig. 17). The boundary of this peripheral zone is marked by faults that are broken at four locations (Fig. 17). The strata outside the structure, but proximal to it, dip toward the disturbed area.

The fault contacts are in many cases sharp and may have zones of breccia, and locally, they are associated with occurrences of sphalerite (a common Mississippi Valley Type mineral). This mineral has a paragenesis showing two periods of deformation (Reidel and Koucky, 1981). In the central uplift, there are shatter cones which are the only shock metamorphic feature definitely found at Serpent Mound. Coesite, a very high temperature, high pressure quartz polymorph often used to indicate conditions only found in rocks that have undergone meteorite impact, was reported by Cohen and others (1961). Subsequent workers have made repeated unsuccessful attempts to find it again. Reidel and Koucky (1981) noted that the disturbance lies near the intersection of a northeast-trending fault zone that predates the structure, and at the convergence of a monocline, an inflection in the Precambrian basement, and is associated with regional gravity and magnetic anomalies. Based on this and other information (2-stage deformation, lack of coesite, etc.) they believe that the structure as caused by some type of volcanic or tectonic process.

A large amount of work has been done to assess the nature, age, and origin of the forces that created this structure and two major hypotheses have been presented. Bucher (1936) was the first to suggest that it may have been the result of a sudden liberation of volcanic gasses (geobleme). Dietz (1960) suggested that the disturbance was due to the impact of a comet or meteorite (astrobleme).

Fig. 21. Quadrangle map showing topographic expression of the Serpent Mound "cryptoexplosion" structure.

RECENT GEOPHYSICAL RESULTS BEARING ON SERPENT MOUND (By H. C. Noltimier)

Geophysical data concerning Serpent Mound consist of a surface survey of the vertical magnetic field (Sappenfield, 1950), the gravity survey of Ohio (Heiskanen and Uotila, 1956), the gravity survey of Serpent Mound (Zahn, 1965; Bull, Corbato, and Zahn, 1967), a paleomagnetic study of the Tymochtee and Brassfield Formations (Isotok, 1978), and an aeromagnetic survey of the total geomagnetic field at 1000 feet above the surface (Patterson, 1980).

None of these studies has answered the question about the origin of the feature, but all have contributed to a generally consistent geological framework in which Serpent Mound represents an integral part related to the tectonic history of the region. The data at hand suggest it is not a structural feature superimposed upon a pre-existing structure as would be consistent with an origin related to meteorite impact.

Sappenfield (1950) obtained results on the vertical geomagnetic field suggesting an anomaly due to a near-surface ultramafic intrusion. Patterson (1980) obtained total geomagnetic field results which are distinct from, but consistent with, Sappenfield's vertical field results and likewise support the possibility of a near-surface ultramafic intrusion. Patterson's results clearly show the boundary between the volcanic and granitic terrains in the basement rocks because the boundary is associted with a marked 1600 gamma magnetic anomaly. Cutting this 1600 gamma anomaly almost at right angles is another marked, but lower, amplitude anomaly which is believed to mark the extension of the Cambrian Hickman-Bryan Station Fault Zone northeastward into Ohio from northcentral Tennessee. Serpent Mound lies very near the intersection of these two basement features which results in regional magnetic anomalies at the surface.

The gravity survey by Zahn (1965) and discussed by Bull, Corbato and Zahn (1967) poses a curious relationship between the gravity and magnetic results. That is, the magnetic highs and the gravity highs are nearly at right angles from each other within the Serpent Mound structure. This circumstance is plausible if a northwest-trending ultramafic intrusive slab carries a reversed remanent magnetization oriented southwest by northeast and acquired during Triassic or Jurassic time. The paleomagnetic study by Isotok (1978) suggests this based upon the direction of stable magnetization in the Tymochtee and Brassfield. The Tymochtee and

Brassfield are Silurian in age but carry two components of remanent magnetization in the Serpent Mound structure which are of Carboniferous and Triassic affinity, respectively. The Carboniferous direction appers to be related to the original deformation or formation of the structure, while the Triassic magnetization appers to be related to the later hydrothermal event which emplaced iron and zinc bearing gluids within the zones of brecciation. This paleomagnetic study appears to have introduced the most detail into the sequential historical development of the Serpent Mound structure although it does not address itself to the main issue about the specific mechanism of origin.

STOP 8A -- Locust Grove Cemetary 1 mi. south of Locust Grove. Observation point to view the topographic expression of the Serpent Mound structure (Fig. 21).

STOP 8B -- Small quarry on north side of Rt. 73, 7 mi. northwest of the junction with Rt. 41. Here, greatly tilted and fractured beds of upper Middle Silurian dolomites can be observed.

STOP 8C -- Serpent Mound, 1 mi. northeast on Rt. 73 from Stop 8B.

STOP 8D -- Section along Rt. 41, 5 mi. north of the junction with Rt. 73.

These outcrops are just outside of the outer-ring graben on the northeast flank of the structure (Fig. 17, 21). Exposed in three closely spaced road cuts are highly fractured and tilted (18°SW) upper Middle Silurian dolomite beds at the same elevation as tilted Upper Devonian shale beds (20°SW) and basal Mississippian sandstone beds. Separating the Silurian dolomites from the Devonian and Mississippian outcrops is a fault whose topographic expression is a small stream valley.

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STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY

GENERALIZED COLUMN OF ROCKS IN OHIO

TIME-STRATIGRAPHIC UNITS		ROCK UNITS				
SYSTEM	SERIES	GROUP	FORMATION *Units found in the subsurface only are indicated in italics*		PRINCIPAL MEMBERS OR BEDS	DRILLERS' OR INFORMAL NAMES
PERMIAN		Dunkard	Greene Fm			
?			Washington Fm		Upper Marietta ss Creston-Reds Lower Marietta ss Washington coal Mannington ss Waynesburg ss	No. 12 coal
PENNSYLVANIAN		Monongahela			Waynesburg coal Uniontown coal Benwood ls U. Sewickley ss Meigs Creek coal Pittsburgh ss Pittsburgh coal	No. 11 coal No. 10 coal Goose Run No. 9 coal No. 8 coal
		Conemaugh			Connellsville ss Morgantown ss Gaysport ss Ames ls Saltsburg ss Cow Run ss Cambridge ls Buffalo ss Brush Creek ls Mahoning ss	Mitchell Wolf Creek Vincent Peeker 1st Cow Run Buell Run Macksburg 300'
		Allegheny			U. Freeport coal U. Freeport ss M. Kittanning coal L. Kittanning coal Clarion ss Putnam Hill ls Brookville coal	No. 7 coal 2nd Cow Run No. 6 coal No. 5 coal Macksburg 500' No. 4 coal
		Pottsville			Homewood ss U. Mercer ss L. Mercer coal L. Mercer ss Massillon ss Quakertown coal Sciotoville ss Sharon coal Sharon ss, cong	Macksburg 700' Germantown No. 3 coal Schram Salt No. 2 coal Brill No. 1 coal Maxton
MISSISSIPPIAN			Maxville Ls			Jingle Rock
			Logan Fm		Vinton Ss Allensville Cong Byer Ss Berne Cong	Keener
			Cuyahoga Fm		Black Hand Ss Portsmouth Sh Buena Vista Ss Henley Sh	Big Injun Squaw Weir Hamden
			Sunbury Sh			Coffee shale
			Berea Ss			1st Berea
			Bedford Sh		Cussewago Ss	2nd Berea
DEVONIAN	Chautauquan ?|		Ohio Sh		Cleveland Sh Chagrin Sh Huron Sh	Little Cinnamon Gordon Big Cinnamon
	Senecan	Traverse	**NORTHWESTERN OHIO** Tenmile Creek Dol	**EASTERN OHIO** Olentangy Sh		
			Silica Fm			
	Erian		Dundee Fm	Delaware Ls		Corniferous
	Ulsterian	Detroit R.	dolomite and Sylvania Ss	Columbus Ls		LIME **EASTERN OHIO** Onondaga lime
			rocks absent because of erosion or nondeposition	*Bois Blanc Fm*		
				Oriskany Ss		1st Water
				Helderberg Ls		
SILURIAN	Cayugan		Bass Islands Dol (outcrops in Ottawa County only)			
		Salina	**WESTERN OHIO** dolomite	**EASTERN OHIO** G unit (outcrops in Ottawa County only)		BIG
				F unit		
				D and E units		
				C unit		
				B unit		
			Tymochtee Fm	*A unit*		
			Greenfield Fm			
	Niagaran	Lockport	**NORTH-CENTRAL OHIO** Guelph Dol	**EASTERN OHIO** *Lockport Fm undifferentiated*		Newburg 2nd Water
			Goat Island Dol			
			Gasport Dol			**EASTERN OHIO** Keefer
			Rochester Sh			Niagaran shale
			Dayton Fm			Packer Shell
	Alexandrian		unnamed shale			
			unnamed dolomite			
		Cataract	**WESTERN OHIO** Cabot Head Fm.	**EASTERN OHIO** *sandstone and shale*		Stray Clinton Red Clinton White Clinton Medina sand
			Brassfield Fm.			
ORDOVICIAN	Cincinnatian		**SOUTHWESTERN OHIO** limestone and shale	**NORTHERN AND EASTERN OHIO** Queenston Sh		Red Medina
				shale and limestone		
			Fairview Fm			
			Kope Fm			
	Champlainian		Trenton Ls			
			Black River Ls			
			Glenwood Fm (Wells Creek Fm)			St. Peter
	Canadian		*Knox Dol*			Beekmantown Rose Run Copper Ridge
? **CAMBRIAN**	St. Croixan		*Kerbel Fm*			
			WESTERN OHIO *Eau Claire Fm*	**EASTERN OHIO** *Conasauga Fm*		
				Rome Fm		
			Mt. Simon Ss			basal sand
PRE-CAMBRIAN			*basement complex*			granite

sh	shale	dol	dolomite	U.	Upper
ss	sandstone	cong	conglomerate	M.	Middle
ls	limestone	fm	formation	L.	Lower

〜 unconformity

Devonian and older portions revised by A. Janssens 1972