NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

EAST - CENTRAL SECTION

Annual Meeting
September 23-24, 1989

Earlham College
Richmond, Indiana

GUIDE TO FIELD TRIPS

by
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1. Saturday Afternoon, September 23 -- Ordovician Stratigraphy & Paleontology.

2. Sunday Morning, September 24 -- Glacial and Silurian Stratigraphy of Richmond, Wayne Co., Indiana.

INTRODUCTION TO FIELD TRIPS

FIELD TRIP 1: Saturday afternoon.

The focus of the Saturday field trip will be the fossiliferous Upper Ordovician limestones and shales exposed at two localities. At Stop 1 we will see the Waynesville Shale and Liberty Members of the Brookville Formation (Dillsboro Formation of Shaver and others, 1986) exposed just west of the Fairfield Causeway over the Brookville Reservoir in Franklin County, Indiana. Stop 2, stratigraphically higher than the rocks at Stop 1, will be at a roadcut on U.S. 27 about one mile south of Richmond, Indiana in Wayne County where the lower part of the Whitewater Formation is exposed. Fossils belonging to three assemblages are abundant and easy to collect from these weathered outcrops. There will be discussion of the several lithofacies exposed at these localities and interpretation of the depositional environments that they represent.

FIELD TRIP 2: Sunday morning.

The Sunday field trip will include outcrops of glacial deposits and Silurian bedrock with attention in the roadlog to some environmental concerns and glacial geomorphology along the route. The glacial deposits at Stop 1, the American Aggregates section northeast of Richmond, include an Illinoian till overlain by two Wisconsinan tills that are separated by an interstadial silt. Freshwater mollusks and pollen of cold climate species of plants have been collected from this silt. This is an excellent outcrop that we use in our Introductory Geology course to introduce principles of stratigraphy, the nature of glacial deposits, and the evidence for Pleistocene glaciations. The Silurian Brassfield Limestone and Osgood Member of the Salamonie Dolomite are exposed at Stop 2 at the DeBolt Quarry southeast of Richmond. The Brassfield is a fossiliferous limestone, although fossils are more difficult to collect than at the Ordovician localities due to the more coherent nature of the rock which lacks shale. The Osgood is a dolomite, quite possibly formed in a near shore environment.

FIELD TRIP #I

UPPER ORDOVICIAN STRATIGRAPHY AND PALEONTOLOGY

The outcrops we will see are within the type area of the Richmondian Stage of the Cincinnatian Series. These are the uppermost Ordovician rocks of the area and are unconformably overlain by the Silurian Brassfield Limestone to be seen during the Sunday morning field trip. Figure 1 shows the relationships of several Ordovician rock stratigraphic classifications that have been applied within the Ordovician outcrop area of Indiana, Ohio, and Kentucky. The Waynesville Shale and Liberty Members of the Brookville Formation are exposed at Stop 1 and the Whitewater Formation at Stop 2.

LITHOLOGY

The strata in the outcrops we will see are primarily thinly bedded bioclastic limestones interbedded with very thin to thick calcareous shales with the thicker shales in the lower part of the section. The shales are composed of terrigenous clay and silt derived from erosion of the Late Ordovician mountains to the east, carbonate material ranging from sand to clay size produced in the depositional basin, and authigenic minerals including pyrite, silica, and phosphates (Hay, 1975). Although all of the shales contain carbonates, the insoluble percentage of the shales is highest (greater than 90%) in the Waynesville Shale Member of the Brookville Formation, decreases upward through the Liberty Member, and is lowest (50% or less) in the part of the Whitewater Formation that we will see. Phosphates and pyrite occur in both shales and limestones in the lower part of the section, then decrease in abundance and disappear upward as authigenic silica increases.

The most common limestone type (Hay, 1975, 1981, Martin, 1975) is packstone (Dunham, 1962) or biomicrosparrudite (Folk, 1962) although a broad spectrum of limestone types occurs. The limestones of the Waynesville Shale and Liberty Members of the Brookville Formation are lowest in percentage of insoluble material, generally well under 10%. The insoluble fraction in the Whitewater limestones tends to be higher and the shales are more calcareous. This mixing of clastics and carbonates in the Whitewater Formation makes it difficult to decide if a given sample should be called a calcareous mudstone or an argillaceous limestone. In contrast, in the Waynesville Shale and Liberty Members, shale beds are separated from limestone beds by rather sharp bedding contacts although the limestones commonly grade to fine upward and have silty upper bedding surfaces.

FACIES

A facies classification developed through detailed study of outcrops near Brookville and Richmond (Hay, 1975) was modified and applied to Upper Ordovician strata throughout southeastern Indiana and southwestern Ohio (Hay, 1981). This classification has proven useful both for lithologic correlation and environmental interpretation.

Five of the 12 designated facies are represented in the outcrops we will visit. An abbreviated description of these 5 facies follows:

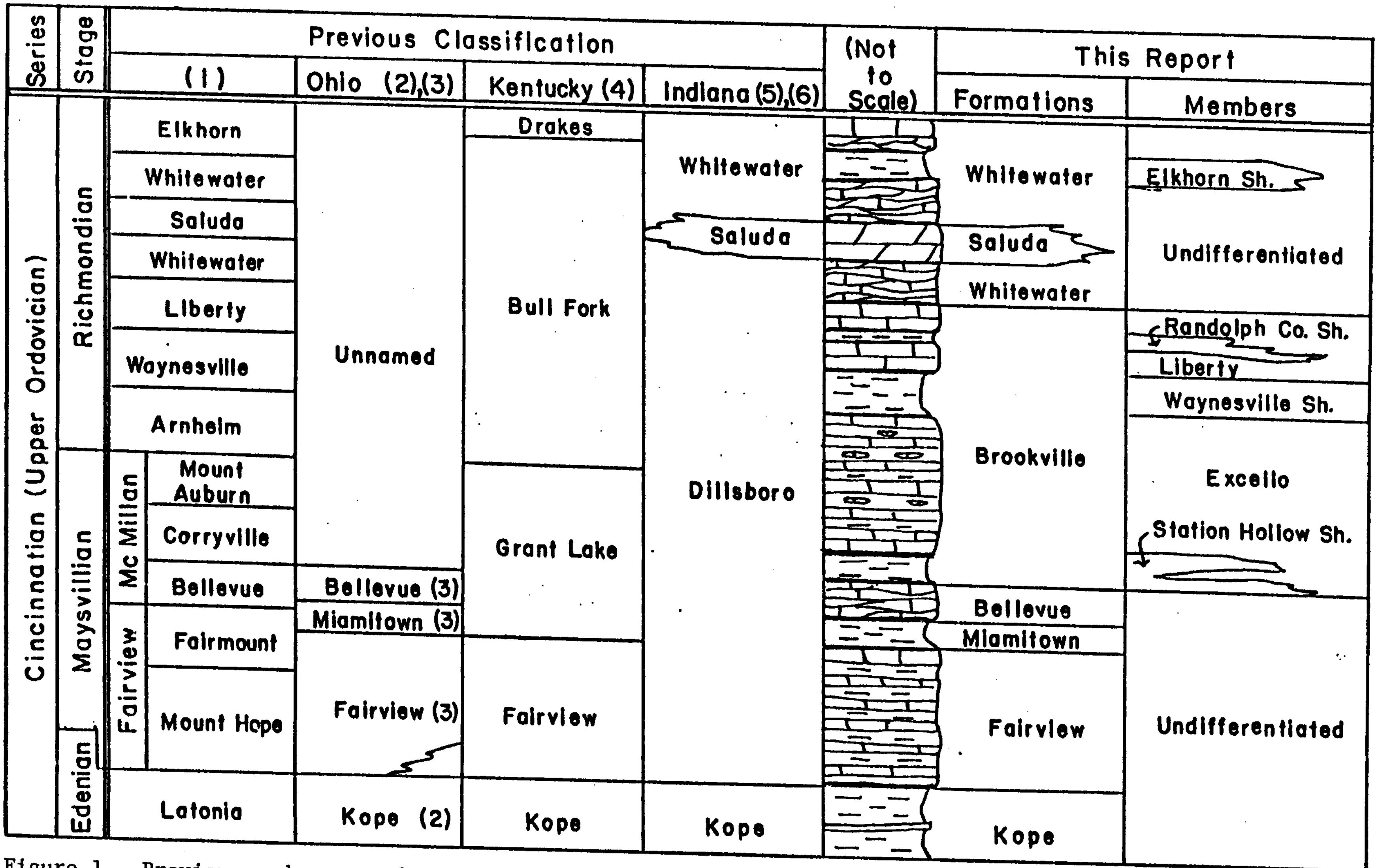

Figure 1. Previous and proposed stratigraphic classification. (1) Caster, Dalvé, and Pope. 1955; (2) Weiss and Sweet, 1964; (3) Ford, 1967; (4) Peck, 1966; (5) Brown and Lineback, 1966; (6) Gray, 1972; Shaver and others, 1986. From Hay, 1981.

Facies 1a: Greater than 70% shale. Well-bedded mostly thin limestones and medium to thick fissile to blocky shales. This class includes massive units of 100% shale. Bedding contacts are sharp. Low diversity fauna, particularly in brachiopods.

Facies 2a: Like facies 1a except shale percentage is 55-70% and faunal diversity is greater.

Facies 3a: Less than 55% shale. Diverse fauna. Otherwise like facies 1a.

Facies 3b: Less than 55% shale. Well-bedded limestones with or without intermixed rubbly or nudular limestones. Shales with limestone nodules and/or lenses. Diverse fauna.

Facies 3c: Less than 55% shale. Very thin, rubbly weathering, argillaceous limestones and very thin, limey shales. Bedding contacts are indistinct. Diverse fauna. Compared with other facies, the limestones of facies 3c contain a higher percentage of larger fossil debris relative to finely broken debris; the other facies have a larger component of fine biogenic matrix between the larger fossils.

To summarize facies 1a, 2a, and 3a differ in the percentage of shale: facies 1a has more than 70% shale, 2a has 55-70% shale and 3a has less than 55% shale. Facies 3c also has less than 55% shale, but the limestones are argillaceous and weather to a rubble rather than to slabs, and the shales are highly calcareous. Facies 3b is intermediate in character between 3a and 3c.

Facies 1a, 2a, and 3a occur at the causeway section and facies 3b and 3c occur at the U. S. 27 roadcut. The stratigraphic sequence from bottom to top is facies 1a, 2a, 3a, 3c, and 3b. The environmental interpretation of this sequence is discussed in more detail below, but it can be said now that at least the 2a, 3a, 3c portion of the sequence is interpreted to indicate a regressive phase (Hay, 1981).

STOP 1: FAIRFIELD CAUSEWAY. Waynesville Shale and Liberty Members of the Brookville Formation.

The outcrop near the parking area just at the west end of the causeway is facies 1a, the Waynesville Shale Member of the Brookville Formation, with a probable transition to facies 2a, the Liberty Member, in the upper few feet. Up the hill toward the west is a second outcrop that is entirely within the Liberty Member, facies 2a in the lower part and 3a in the upper part. The rock at the causeway sections is quite weathered which makes it difficult to determine facies accurately from these sections alone, but facies can be assigned with some confidence by correlation with other outcrops near Brookville and by the apparent increase in limestone upward in the sections.

Figure 2 shows the correlation of the causeway outcrops with the Brookville North and Bon Well Hill sections which are located nearby on Ind. 101 between the Fairfield Causeway turnoff and Brookville, Indiana. The Ind. 101 roadcuts have been described previously in several places (Hay, 1975, 1977, 1981; Hay, Pope and Frey, 1981).

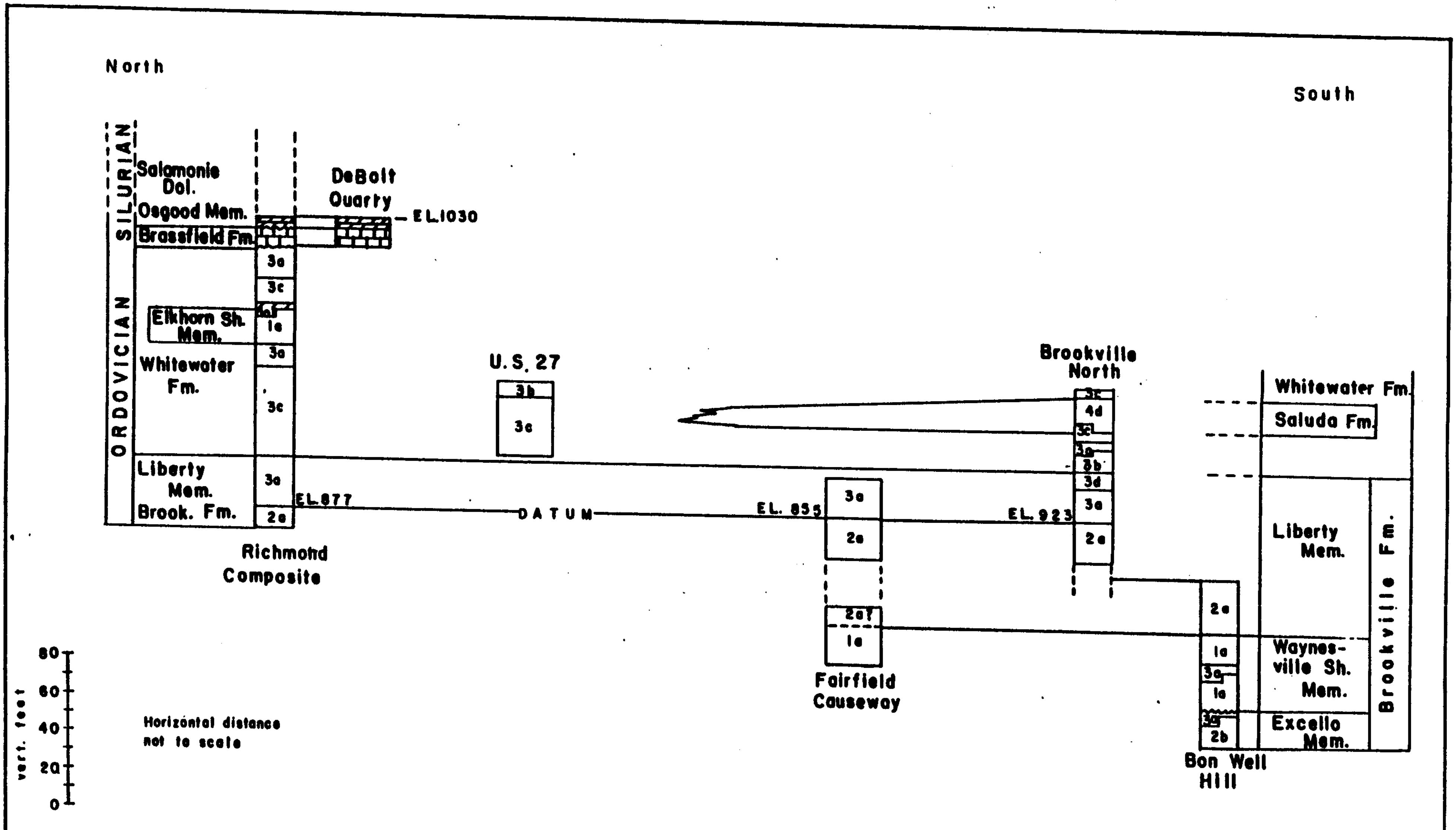

Figure 2. Facies correlation of field trip stops with Richmond composite section roadcuts near Brookville, Indiana on Ind. 101. Field trip #1: Stop 1 Fairfield Causeway, Stop 2 U. S. 27 roadcut; Field trip #2: Stop 2 DeBolt Quarry, (Richmond and Brookville sections modified from Hay, 1981).

The weathering of the rock makes this an excellent locality for collecting fossils and the fossil assemblages of the lower and upper roadcuts are markedly different. The assemblage of the lower section is dominated by the small orthid brachiopod genus, Onniella, that covers bedding planes. Other brachiopods are Rafinesquina and Zygospira. In contrast, the upper section has much higher brachiopod diversity including these genera: Leptaena, Platystrophia, Hebertella, Plaesiomys, Lepidocyclus, Glyptorthis, Strophomena, Thaerodonta, and Rafinesquina. The Thaerondonta peak zone, which occurs regionally, is in the upper part of the upper roadcut. Mollusks occur in both sections although the lower section has larger numbers and greater diversity of clams whereas the upper section seems to have more gastropods. Cephalopods occur in both. The upper section has three corals, Streptlasma rusticum (the common horn coral), S. divaricans (a smaller horn coral that is usually found in clusters of two or three joined at the base), and the small colonial coral, Protarea that encrusts the shells of other animals. Corals are lacking in the lower outcrop. Crinoids, bryozoa, and the trilobites, Flexicalymene meeki and Isotelus are found in both outcrops; crinoids are more common in the upper section. The best place to find whole enrolled trilobites and possibly whole crinoid calyces is in the lower half of the upper section where they have weathered out of the shales.

In summary, there is a correspondence of lithofacies changes and faunal assemblages upward through the section. As described earlier, the facies sequence upward at the causeway section is from 1a to 2a and then to 3a at the top, a decreasing proportion of shale relative to limestone upward. The lowest brachiopod diversity but high bivalve diversity is in the shaley facies 1a. Then upward through 2a to 3a there is a major faunal change with increased brachiopod diversity. Onniella, the dominant brachiopod in facies 1a, disappears from the assemblage in facies 2a at the upper roadcut. The simplest interpretation of this correspondance, but not the only one possible, is that the muddy environment of facies 1a favored bivalves but only a few braciopods were adapted to those conditions and that an increase in water clarity upward allowed many brachiopods to migrate into the area. The high proportion of shale might be due to a high rate of supply of terrigenous clay and silt. Another possibility is that the rate of supply of terrigenous clastics remained constant and that the increase in limestones upward was due to the greater rate of production of the bioclastic material of which the limestones are composed, this increased production controlled by some other environmental factor such as improved water circulation or more stable and/or favorable water chemistry.

Relevant to the interpretation of environments is the part of the stratigraphic sequence at Bon Well Hill that lies below the base of the causeway section (Figure 2). There is a possible disconformity at Bon Well Hill about 20 feet below the base of the causeway section at the contact between the Waynesville Shale and Excello (Arnheim) Members of the Brookville Formation (Cumings and Galloway, 1912; Hay, 1981). Facies 1a just above this surface is nearly barren of fossils, then there is a gradual increase in fossils upward to the abundance we see at the causeway in the lower outcrop. If the disconformity is correctly interpreted, then the muds above it were probably derived from weathering and erosion of a low lying emergent area and deposited near the shoreline. The lack of fossils in the lowest few feet may have been caused by fluctuating and unfavorable water chemistry, perhaps brackish water; there is no evidence of hypersalinity. The facies 1a to 2a sequence at the causeway section would then be best interpreted as a transgressive phase evolving from stressful physical and chemical conditions and relatively low faunal diversity in facies 1a to the more stable normal marine environment and great faunal diversity of facies 2a. Facies 3a at the top of the causeway and overlying facies including the Whitewater Formation to be seen at Stop 2 represent a regressive phase to be discussed below.

Although this occurrence of facies 1a in the Waynesville Shale Member is best interpreted as having formed in very shallow water, other intervals of facies 1a in the Upper Ordovician probably formed in deeper water. The Kope Formation (Figure 1) is dominated by facies 1a and has a faunal assemblage similar to the Waynesville Shale Member of the Brookville Formation except for the presence of the flat brachiopod Thaerodonta in the Kope, a fossil that occurs at the causeway in facies 2a. It seems likely that this brachiopod may be controlled by water depth which could explain its presence in the Kope but not in the Waynesville Shale Member of the Brookville Formation.

STOP 2: U. S. 27 ROADCUT - Whitewater Formation.

Figure 2 shows the correlation of this roadcut with the Brookville sections. It is entirely within the lower part of the Whitewater Formation at Richmond. Most of the outcrop is facies 3c with the upper 5 feet or so reasonably classed as facies 3b. Facies 3c is assigned to very thin, rubbly, argillaceous limestones separated and interwoven with very thin limey shale seams. Facies 3b has less argillaceous limestone beds interbedded with very limey shales. These facies, particularly 3c, are characteristic of the Whitewater Formation and are used to define the base of the formation at the first occurrence of either facies 3b or 3c.

Figure 2 shows the stratigraphy of the entire Whitewater Formation as it occurs at Richmond. The upper part of the Whitewater Formation is exposed along Elkhorn Creek between Straightline Pike and Ind. 227 south of Richmond. The top of the outcrop at Stop 2 is about 70 feet below the top of the Ordovician as shown in Figure 2.

At the Brookville North section (Figure 2), about 3 miles southeast of the Causeway, the Whitewater Formation underlies and overlies a tongue of the Saluda Formation that has the massive colonial coral Tetradium at its base overlain by a burrowed micritic limestone with an unusual fauna composed of algae, octracodes, microscopic gastropods, and little else. Farther south toward Versailles and Madison, Indiana the coral are overlain by a mudcracked dolomite that is probably syngenetic dolomite that at times was subaerially exposed (Hatfield, 1968). The vertical and lateral facies relationship of the Whitewater Formation with the various Saluda facies strongly suggests that the Whitewater formed in very shallow water, more shallow than the underlying facies of the Liberty Member of the Brookville Formation. Therefore, the facies sequence 2a, 3a in the Liberty Member to 3c in the Whitewater Formation is reasonably interpreted as a regressive phase.

Although the Whitewater Formation was deposited in shallow water it was probably not a highly agitated environment. This interpretation is supported by the poor sorting and argillaceous character of the limestones and the smaller percentage of fine bioclastic matrix compared with the underlying facies. A reasonable model is one of a shallow broad platform over which wave energy would be damped by comparison with higher energy conditions that existed at the margins of the platform where facies 3a formed. The Saluda may represent the central part of this platform where hypersaline conditions developed aided by the coral masses which would have impeded circulation of normal marine water over the interior of the bank.

The normal marine fauna of the Whitewater is extremely diverse and abundant. Bryozoa dominate the fauna with both ramose and rather massive encrusting forms common. Mollusks are also diverse and abundant, algae are common and oncolites occur in a zone near the top of the outcrop in facies 3b. The corals include Streptelasma rusticum, S. divaricans, and Protarea as in the Liberty Member of the Brookville Formation. Echinoderms are common. Brachiopods include Platystrophia, Hebertella, Rhynchotrema, Lepidocyclus, Holtedahlina, Rafinesquina, and possible Strophomena.

Holtedahlina is not facies controlled, so appears useful for time correlation. Here at Richmond it occurs in facies 3c but at Manchester, Ohio it is found in a much shalier facies also near the top of the Ordovician. On the other hand, brachiopods Thaerondonta and Leptaena which were found in the Liberty Member are facies controlled as demonstrated by the fact that they reappear in the Whitewater Formation in an interval of facies 3a that lies just above the top of the Stop 2 outcrop.

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ROADLOG FIELD TRIP #I (Ordovician Stratigraphy and Paleontology)

The general location of the Ordovician outcrops is as follows: To find Stop 1, starting from Richmond, proceed south on U. S. 27 for about 12 miles to Liberty, Indiana, then take Ind. 101 south about 9 miles to the Fairfield Causeway turnoff . (Note: this turnoff is south of the Fairfield Ramp road). Turn right and proceed to the reservoir, cross the causeway and park in the parking area on the right side of the road. There is outcrop across from the parking area and a second exposure farther up the hill toward the west. Stop 2 is a roadcut about one mile south of Richmond on U. S. 27.

Mileage (in miles) Interval	Cumulative	
0.0	0.0	Leave parking lot at east end of Dennis Hall, Earlham College campus, turn right (south), then left (east) to College Avenue.
0.1	0.1	Turn right (south) on College Avenue and proceed to S.W. G St.
0.2	0.3	Turn left (east) on S.W. G St. and proceed to Abington Pike.
0.3	0.6	Turn right (south) on Abington Pike. The road is on an Ordovician bedrock terrace that parallels the Whitewater River and was cut by the river during the late Pleistocene prior to excavation of the gorge in which the river now flows. The slight rise in the road marks the rise onto a till surface. Proceed to Test Road junction.
1.1	1.7	Turn left (east) on Test Road and descend across a Pleistocene terrace to the Whitewater River.
0.3	2.0	Cross Whitewater River. Proceed to Liberty Avenue.

0.3	2.3	Turn right (south) on Liberty Avenue. The walls of the Whitewater River valley are poorly exposed Ordovician bedrock and the valley floor is mapped as Quaternary alluvium. Proceed to the junction with U. S. 27.
1.9	4.2	Turn right (south) on U. S. 27. (We'll stay on U. S. 27 to Liberty, Indiana where we take Ind. 101).
0.6	4.8	The knoll to the right about 1/2 mile west of U. S. 27 and just south of Liberty Hill Farm is a kame.
0.1	4.9	Small Silurian (Brassfield Formation) outcrop on right. The elevation of the Ordovician/Silurian contact here is at about 1010 feet although the contact is not exposed.
0.3	5.2	Junction with Woods Road.
0.1	5.3	Meltwater channel to right. This is parallel to the Elkhorn Creek valley, a large meltwater valley that we cross ahead.
0.3	5.6	Small outcrop of Whitewater Formation on the left. Edrioasteroids have been collected here.
0.5	6.1	Outcrop of Liberty Member of the Brookville Formation (upper Dillsboro Formation) on right as the road descends into Elkhorn Creek valley.
0.2	6.3	Elkhorn Creek bridge. From south of this valley south to Liberty the route crosses glacial till.
1.6	7.9	Pottershop Road junction.
0.5	8.4	Wayne/Union County line.
6.0	14.4	Liberty city limits. Proceed south to second traffic light to junction of U. S. 27 with Ind. 101.
0.4	14.8	Junction with Ind. 101. Proceed south (straight ahead) on Ind. 101.
0.2	15.00	Cross railroad.
1.5	16.5	Whitewater State Park entrance.
1.7	18.2	Quakertown Recreation Area sign; Dunlapsville Road intersection.
0.5	18.7	Ordovician bedrock on both valley sides (Hanna Creek).
2.0	20.7	Dubois Creek.
0.6	21.3	Turnoff to Hanna Creek ramp. Continue on Ind. 101.

0.4	21.7	Fairfield Ramp road.
1.1	22.8	Union/Franklin County line.
0.5	23.3	Bath Road junction. Proceed south to Fairfield Causeway Road.
0.4	23.7	Turn right (west) on Fairfield Causeway Road.
0.5	24.2	Cross Templeton Creek.
1.8	26.0	Enter causeway. Proceed to parking area at west end of causeway.
0.6	26.6	Park in parking area for Stop 1, the outcrops on the south side of the road and westward up the hill.

TO PROCEED TO STOP 2:

Retrace route to Ind. 101, then turn left (north) and return to Liberty, Indiana. Begin mileage at junction of Ind. 101 and U. S. 27 in Liberty.

0.0	0.0	Take U. S. 27 north toward Richmond.
6.5	6.5	Wayne/Union County line.
0.5	7.0	Junction with Pottershop Road/Ind. 122.
1.5	8.5	Cross Elkhorn Creek.
2.2	10.7	Junction with Liberty Ave.
0.4	11.1	Base of U. S. 27 roadcut - Stop 2. Park at top of hill on right side of highway.

TO RETURN TO EARLHAM COLLEGE FROM STOP 2 continue north on U. S. 27.

2.2	13.3	Junction with South L Street at stoplight. Turn left (west) on South L.
0.4	13.7	Junction of South L with South 5th Street. Turn right (north) on South 5th Street.
0.3	14.0	Junction of South 5th Street with South G Street at stoplight. Turn left onto South G Street and cross the bridge. Proceed around the traffic circle at west end of the bridge and continue on South G Street around the south end of the Richmond High School grounds. (If the bridge is closed for repair, follow alternative route provided at conclusion of roadlog.
0.5	14.5	Junction with Abington Pike. Continue west on Southwest G Street.

0.3	14.8	Junction with College Avenue. Turn right (north) on College Avenue.
0.2	15.0	At junction of College Avenue and Southwest D Street turn left (west) on D Street and return to parking lot at east end of Dennis Hall.

ALTERNATIVE ROUTE IF G STREET BRIDGE IS CLOSED: Proceed north on South 5th Street to Main Street. Turn left (west) and follow U. S. 40 signs to return to the Earlham Campus. Dennis Hall is to the left (east) as you come in the main drive to the campus. Park at the east end of Dennis Hall.

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FIELD TRIP 2--GLACIAL AND SILURIAN STRATIGRAPHY OF RICHMOND, WAYNE COUNTY, INDIANA

Jon Branstrator, Glacial Stratigraphy and Road Log
Helen Hay, Silurian Bedrock

This field trip visits the Old American Aggregates gravel quarry (Pleistocene) and the abandoned DeBolt bedrock quarry (Silurian) on Richmond's east side, and traverses and discusses Pleistocene meltwater sluiceways and Richmond's vital Short Creek aquifer (See Fig. 1). Stop 1 displays the type section in the type area of Gooding's (1963) Whitewater Till.

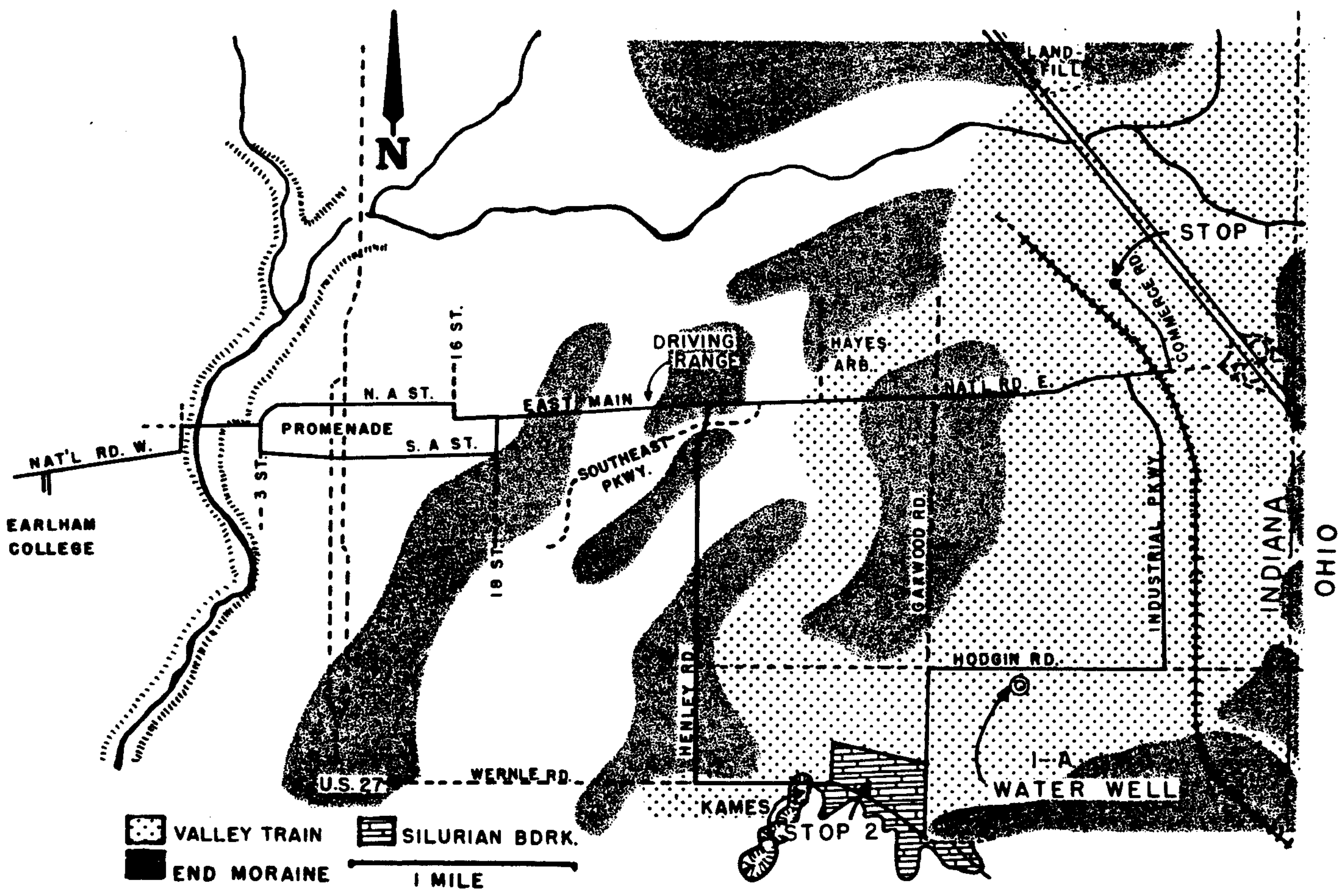

Fig. 1 - Map of field trip area (modified from map by Thorp,1983).

Gooding (1963) identified two Illinoian and five Wisconsinan tills, some with superimposed loess, and several interglacial deposits overlying Ordovician and Silurian marine bedrock in the Richmond Area (See Fig. 2). The city is built largely on end moraine deposits of the Late Wisconsinan Tazewell Stade which have been dissected by NE-SW trending Champlain meltwater sluiceways, by post-glacial fluvial action, and by human activities.

STAGE	STADE/INTERSTADE	UNIT
WISCONSINAN	Tazewell Stade	Bloomington drift Champaign loess Champaign drift Shelbyville loess Shelbyville drift
	Connersville Interstade Fayette Stade New Paris Interstade Whitewater Stade	
SANGAMON INTERGLACIAL		
ILLINOIAN	Richmond Stade Abington Interstade Centerville Stade	

Fig. 2 - Wayne County's Pleistocene Stratigraphy according to Gooding, 1963. Subsequent reports on Ohio sections in the region by Goldthwait et al. (1981) and others do not emend the sequence of Gooding's stratigraphic scheme.

ROAD LOG

Interval	Cumulative	Description
		Line up on the East side of Earlham's front drive, heading north toward U.S. 40 (National Road).
0.0	0.0	Turn Right (East) on National road.
0.2	0.2	U.S. 40 drops down onto Champaign meltwater "scoured" bedrock terrace.
0.3	0.5	Traffic light. Turn left (north) following U.S. 40 along rim of Whitewater gorge, developed during and since retreat of Richmond's last glacier (Wisconsinan Stage: Champlain Stade). The Bloomington ice sheet stalled several miles north of the city.
0.2	0.7	Traffic light. Turn right (east) following U.S. 40 across the Whitewater gorge bridge. Stay in the right lane.
0.2	0.9	Traffic light at South 3rd Street. Turn right (south) on one-way street. Stay in the middle lane.
0.1	1.0	Turn left to middle lane of South A Street (one-way street).
0.3	1.4	Continue straight past Radisson Hotel on left at South 9th and A Streets. Beyond South 11th Street stay in left lane.
0.7	2.1	Turn left (north) on one way South 18th Street.
0.2	2.3	Turn right (east) on East Main Street (U.S. 40).
0.3	2.6	U.S. 40 begins drop down west side of a shallow-filled, south-sloping Champaign meltwater sluiceway, an east terrace of which is well-displayed in the distance at golf driving range ahead on left at mile 2.8. (Find this and sluiceways ahead in Fig. 1) The present East Fork of the Whitewater River flows generally westward about three-forths of a mile north of here. Tributaries have cut back into this and other high, south-flowing sluiceway channels, thus causing reversal of drainage.

0.7	3.3	Overview ahead of another minor shallow-filled Champaign meltwater sluiceway cut into till.
0.4	3.7	Hayes Arboretum on left (north). Overview ahead of minor Champaign sluiceway now holding valley train deposits.
0.7	4.4	Overview of a major early Champaign meltwater sluiceway which occupied a pre-existing northflowing fluvial channel and in which now lies the Short Creek aquifer, a major source for Richmond's water supply (to be discussed between Stop #1 & Stop #2). Modern Short Creek valley was the pre-Champaign course of the East Fork of the Whitewater river which originally flowed southeast of the modern city site, but now loops through Richmond before continuing its southward course.
0.8	5.2	Turn left (north) on Commerce Road, immediately past railroad elevation.
0.3	5.5	Landis Plastics on the left, Richmond's newest major industry built over Champaign valley train deposits. Richmond's landfill is approximately 1 mile NNW of this site (See Fig. 1) and located over a valley which dissects end moraine, valley train and bedrock deposits.
0.1	5.6	Stop I. Stop along right (east) side of road before turn-around circle. Wait for fieldtrip leaders (See Pg. 17 for Stop #1 locality description.)
	5.6	Traffic turn-around circle. Return to U.S. 40.
0.5	6.1	Stop sign. Turn right on U.S. 40, but move quickly and carefully to left lane for a left turn at the first traffic light onto Industrial Parkway.
0.1	6.2	Traffic light. Turn left (south) onto Industrial Parkway.

Industrial Parkway lies on valley train deposits which fill a major pre-Champaign fluvial valley and early Champaign glacial meltwater sluiceway. (The valley train filled Short Creek Valley was beheaded by the development of the present East Fork Valley to the north sometime during the melting of the Champlain glacier.) Periglacial and postglacial peat and muck lacustrine deposits overlie valley train deposits at the valley's southern end.

Sediments beneath the now largely channelized Short Creek serve as a major aquifer for Richmond. Near the south end of this valley the Indiana-American Water Company currently draws about about 0.7 million gallons each day from a siphon (cistern) well in which the water level stands 15 feet below ground level (see Fig. 2). The well has produced as much as 1.2 million gallons per day in the past, but with a somewhat greater cone of depression. Auger and borehole data document that the water table is shallow (4.5 feet) in the south end of the valley, but much deeper (36 feet) in the vicinity of the Kemper Plant (Mile 6.8), and that the floor of the valley which holds the aquifer slopes to the north, with a clay-rich plug near U.S. 40. The filled valley was hence originally cut by a north-flowing stream which was likely impounded by advancing glacier(s) which also plugged the north end of the valley with till. Limited subsurface sampling suggests that his clayey plug marks the northern limit of the shallow water table in the Short Creek aquifer. This, in turn, suggests that water recharge is from a somewhat limited area to the south, rather than from the north where lie Landis Plastics and the Richmond landfill.

Earlham's geology faculty has expressed concern over the development of this industrial area since it was suggested in the early 1970's because of a general lack of knowledge of the geometry and hydrogeology of this vital aquifer and because of potential problems with the installation of storm sewers to by-pass part of the aquifer, as well as with possible industrial pollution, dewatering of the shallow aquifer and overdraft of the aquifer by industries with their own wells.

Engineering reports commissioned by the City of Richmond in early 1973 temporarily allayed concerns of persons responsible for zoning, but emphasize the need for more factual information on the nature of the aquifer and its recharge, and called for control over the types of industrial development in the area.

Little further geological research has apparently occurred. As you can see, a variety of light industries now occupy the development. Storm sewer problems have already occurred over the aquifer.

0.8	6.8	Kemper (cabinets, etc) plant & training center on right.
0.8	7.6	Stop sign. Turn right (west) on Hodgin Road.
0.3	7.9	Driving onto thin veneer of lake peat & muck.
0.3	8.2	Indiana-American Water Company wells drilled in the late 1920's and early 1930's are about 200 feet south of road in small clump of trees.
0.4	8.6	Stop sign. Turn left (south) on Garwood Road.
0.1	8.7	Shallow water table indicated by cattails in modern bog on left (east). In the drainage ditch to the left of road rich growths of watercress in 40°-50°F. water are present on the coldest of winter days, indicating ditch water is effluent (from water table).
0.5	9.2	Lake in Silurian bedrock quarry on right (west). Note in Fig. 1 that quarry operations have exposed Silurian bedrock along property lines. A portion of the quarry site is currently a repository for smokestack scrub from the coal-burning, municipally-owned Richmond Power and Light.
0.2	9.4	Stop sign. Turn right (west). Small waterfall in Short Creek on your immediate left at the turn spills over relatively resistant Silurian rocks. This waterfall was nearly one-half mile wide and 30 feet high as the last glacier began to wane in the Richmond area.
0.3	9.7	Stop 2. Old DeBolt quarry entrance on right. Pull into quarry entrance. Wait for fieldtrip leaders. (See Pg. 19 for Stop #2 locality description.)
0.2	9.9	Driving up on glacial kame. Northern-most one of several contiguous ones aligned NE-SW and deposited on ground moraine surface. Note overview of NE-SW meltwater sluiceway now partially filled with valley train on right (north).
0.5	10.4	Turn right (north) on Henley Road. Look back up sluiceway to NE (right).

0.3	10.7	Driving onto end moraine till.
0.7	11.4	Back onto ground moraine till.
0.3	11.7	Back onto end moraine till.
0.3	12.0	Small cut-through sluiceway along Southeast Parkway to right and left.
0.1	12.1	Traffic light. Turn left (west) on East Main (=U.S. 40). (You will follow U.S. 40 back to Earlham College.)
1.0	13.1	Traffic light at 16th Street. Turn right (north) on U.S. 40.
0.1	13.2	Turn left (west) on U.S. 40 (= North A Street).
0.8	14.1	Follow U.S. 40 to south around Richmond City Hall, staying in center or right lane.
0.1	14.2	Traffic light. Turn right (west) on Main Street.
0.2	14.4	Cross Whitewater gorge. Stay in left westbound lane.
0.1	14.5	Traffic light. Turn left (south) at Miller's Cafeteria on SW 1st Street.
0.1	14.6	Traffic light. Turn right (west) on National Road West.
0.5	15.1	Turn left into Earlham College front drive. End of Fieldtrip.

STOP #1: OLD AMERICAN AGGREGATES

Measured and described by Ansel Gooding in 1958 in the east side of a railroad cut at the American Aggregates Corporation gravel quarry in the north-central part of Sec. 36, T. 14 N., R. 1 W., at the NE edge of Richmond, Wayne County, Indiana (Fig. 1 of Gooding, A.M., 1963). The description in this field guide is modified from NAGT 1964 East-Central Annual Meeting Field Trip Guide. Units 1 and 3 [Illinoian] crop out along a tributary of the East Fork of the Whitwater River NE of the old quarry railroad cut. Units 9 through 11 [Wisconsinan: Tazwell] were identified by Gooding in the woods SE of this same cut.

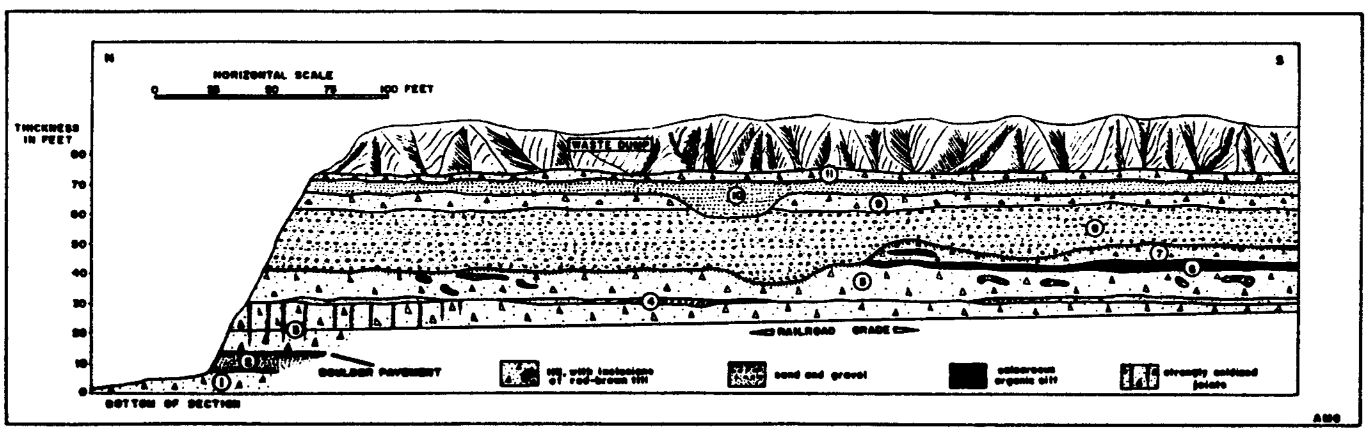

Fig. 1. Diagram of American Aggregates Section in east bank of old railroad cut (Gooding, 1964).

Unit	Thickness feet	Thickness meters	Description
			WISCONSINAN STAGE Surface soil removed.
11	2-4.0	0.6-1.2	Till - calcareous, buff (oxidized).
10	4.0	1.2	Sand - and gravel, calcareous, limonite stained.
9	5.0	1.5	Till - calcareous, buff (oxidized).
8	20.0	6.1	Sand - and cobble gravel, calcareous, some cementation at top. Strong limonite and manganese oxide stain toward bottom.
7	3-4.0	0.9-1.2	Till - calcareous, gray (unoxidized), contains sand lenses. Top few inches yellowish-brown (oxidized). Top is an irregular erosional surface and till is eroded through in places.
6	1-2.0	0.3-0.6	Silt - and find sand, calcareous, stratified, gray to black, contains finely divided plant remains, twigs and mollusks. Unit traced for several hundred feet on both sides of cut. Carbon 14 has yielded a variety of dates for this unit, including humic acid from wood: 23,100 ±1500 & 31,800±2500 and alkali-treated wood: >40,500 (Olson and Broecker, 1961) and >50,000 (Liu, Riley and Coleman,1986). Gooding (1963) named this unit the New Paris Interstadial deposit for New Paris, Ohio, 1.5 miles northeast of this site, but he did not designate a type section. He described his New Paris Interstadial deposit largely from characteristics present here.
5	10.0	3.0	Till - calcareous, brownish-gray (unoxidized), blocky. Contains inclusions of a calcareous red-brown till and pieces of wood. This is the type section of Gooding's Whitewater Till. Not yet dated here, wood from elsewhere on this unit yield dates from 33,600 (±2800) yrs. to >43,000 yrs (Gooding, 1963).
4	0-3.0	0-0.9	Silt and fine sand, calcareous, gray (unoxidized).
			ILLINOIAN STAGE
3	17.0	5.2	Till - calcareous, tough, gray (unoxidized) except for several inches parallel to deeply penetrating joints which are oxidized and cemented with limonite. Basal portion of till contains many white to bluish-gray angular chert cobbles. Striations made by this till on boulder pavement below strike N 23° E.
2	6.0	1.8	Sand - and fine gravel, calcareous, stratified, brightly stained with limonite and manganese oxide. Boulder pavement at top.
1	5.0	1.5	Till - calcareous, gray (unoxidized).

American Aggregates: Gooding's (1964) Comments and Additional Data

The separation of Wisconsinan and Illioian drift in the American Aggregates section is interpreted to be between units 3 and 4 because (1) till containing red-brown till inclusions and overlain by a calcareous, organic rich deposit (units 5 and 6) occurs over the Sangamon soil at several other localities, and (2) deep, oxidized joints in till (unit 3) are believed to be vestiges of the Sangamon soil, which in other sections occurs at this stratigraphic position.

Mollusks.

Molluscan species identified by Nave and La Rocque from the calcareous organic silt (unit 6) of the New Paris interstadial are as follows:

> Fossaria parva (Lea), (Lymnaea parva of others), Succinea gelida (Baker), Vertigo morsei (Sterki), and Vertigo elatior (Sterki).

V. morsei and V. elatior are land snails that exist today in wet or moist situations. S. gelida is a land snail limited to Pleistocene deposits. F. parva is a fresh-water pulmonate which is common in wet, marshy places, generally out of water. V. morsei and F. parva have a rather widespread distribution, but V. elatior is confined presently to more rigorous climate zones in northern latitudes and occurs south of Canada only in mountainous areas. This suggests that the environment represented by unit 6 was a wet, marshy area during a time when the climate was considerably colder than at the present time (Nave and La Rocque, written communication to Gooding).

Pollen.

Although the frequency is low, a coniferous pollen assemblage of spruce, pine and fir is contained in the New Paris interstadial unit 6, supporting other data which indicate that the interval was short and cold (Kapp and Gooding, 1964).

Strata Identification and Correlation.

Various workers have attempted to find the ideal criteria by which stages, stades and interstades might be identified with ease and certainty. They have attempted to employ paleontological content, till fabric (orientation of elongated clasts), clay mineralogy, variations in total carbonate, depth of leaching, concentrations of particular rock types and till inclusions, till color and change of color at contacts (Prichard, 1980) and trace element concentration (Prichard, ibid.) as well as stratigraphic sequence in attempts to identify and correlate units. The conclusion of Goldthwait, and others (1981) that the tills and interstadial deposits of this area do not have unique characteristics by which they can be distinquished and correlated seems somewhat justified at present, but the search for definitive charasteristics continues.

STOP #2: BRASSFIELD LIMESTONE AND OSGOOD MEMBER OF THE SALAMONIE DOLOMITE

The outcrop at the Debolt Quarry exposes about 8 feet of the Brassfield Limestone overlain unconformably by about 5 feet of the Osgood Member of the Salamonie Dolomite (See Fig. 2, Field Trip 1). The elevation of the top of the quarry is 1030 feet. At some localities in southeastern Indiana and southwestern Ohio the limestone beds of the Brassfield comprise the basal unit above the Ordovician/Silurian disconformity, but here in eastern Wayne County the basal unit is a few feet of greenish gritty shale and dolomite that tends not to be exposed because it weathers back under the typically more resistant limestones of the Brassfield. This shale and dolomite, a unit called the Belfast, was recognized as a member of the Brassfield Limestone in the Compendium of Paleozoic Rock-Unit Stratigraphy in Indiana in 1970 (Shaver and others, 1970), but is no longer recognized as a formal unit in the revised edition (Shaver and others, 1986). The Brassfield is Late Early Silurian (Alexandrian) and the Salamonie Dolomite including the Osgood Member is Middle Silurian (Niagaran) in age (Shaver and others, 1986, Plate 2).

Where creeks cross the Ordovician/Silurian contact there are waterfalls due to the greater resistance to weathering and erosion of the Brassfield compared with the underlying Belfast and Whitewater. An example of such a falls is at the southeastern corner of the quarry and south of Wernle Road where the lake drains under the road (Mile 9.4 on road log). This is a good place to see the weathering characteristics of the Brassfield in contrast to the fresh exposures in the quarry. Just south of the quarry and extending across the wide meltwater valley, there is a dry waterfall that marks the Ordovician/Silurian contact.

The Brassfield is a wavy bedded echinoderm calcarenite with some flaser bedding where ripple troughs are filled with a greenish, hard, dolomitized shale that weathers orange. The dominant limestone is a sorted echinoderm biosparite or biosparrudite where larger fossils are present. Other limestones have a microsparite matrix rather than spar cement. The Brassfield contains replacement dolomite rhombs which increase in abundance up the section toward the unconformity that separates the Brassfield from the Osgood. The fauna is diverse and abundant although the Brassfield contains a smaller proportion of large relatively whole fossils than the Whitewater below. In addition to the abundant crinoid fragments, it contains the colonial corals Halysites and Favosites, bryozoa, and numerous brachiopods.

Brassfield lithology varies throughout the outcrop area in Indiana and Ohio. At Madison, Indiana it is dolomite (Totten and Hay, 1987); at Manchester, Ohio (Hay, 1981) and farther north in the vicinity of Peebles and Hillsboro, Ohio it has a basal bed of dolomite (Belfast) overlain by echinoderm calcarenite and some cherty beds.

The biggest difference between the Silurian and Ordovician rocks of eastern Indiana is the lack of shale in the Silurian. Apparently by the time these sediments were deposited, the eastern mountains were sufficiently eroded so they they no longer supplied terrigenous clastics to this area. The Brassfield sediments were deposited in a shallow open sea with sufficient wave and current energy to sort and rework the carbonate sediments.

The contact between the Brassfield Limestone and the Osgood Member of the Salamonie Dolomite is abrupt, but otherwise there is little field evidence in this geographic area of the disconformity reported to exist (Shaver and others, 1986) between the two units. However, Hovorka (1973) thought clay pockets in the top of the Brassfield may indicate weathering and infilling related to the disconformity. The Osgood is a fine grained dolomite, light gray, but yellow weathering, sparsely fossiliferous, with calcite nodules and poikilitic calcite cement. The bedding is even and regular in contrast to the wavy bedding of the Brassfield. Fossils are more common in the lower few beds and may be reworked Brassfield fossil debris. It seems possible that the Osgood is a transgressive syngenetic dolomite and that the calcite nodules and poikilitic calcite cement may be replacements of gypsum or anhydrite nodules in the original sediment. However, the Brassfield also has some calcite nodules, especially in the upper few feet, which might not be expected if the above hypothesis is correct unless those nodules are filled weathering cavities in the Brassfield. It is possible that the replacement dolomite rhombs in the Brassfield may have formed at the time the Osgood syngenetic sediments were being deposited in view of the fact that they increase in abundance near the top.

North of Richmond at the operating Middleboro Stone Corporation quarry, the Brassfield Formation and the Osgood Member of the Salamonie Dolomite are exposed at the base of the quarry and are overlain by dolomitic limestone of the Laurel Member. A middle zone in the Laurel is cherty, and at the top of the section there is a replacement dolomite containing the Silurian brachiopod Pentamerus and other normal marine fossils. The Middleboro quarry is the major local supplier of both crushed stone and building stone.

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