ORDOVICIAN STRATIGRAPHY, AND THE PHYSIOGRAPHY OF PART OF SOUTHEASTERN INDIANA

by

JOHN B. PATTON, THOMAS G. PERRY, AND WILLIAM J. WAYNE

Indiana Department of Conservation

GEOLOGICAL SURVEY

Field Conference Guidebook No. 6

1953

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CONFERENCE SPONSORED BY

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ORDOVICIAN STRATIGRAPHY, AND THE PHYSIOGRAPHY OF PART OF SOUTHEASTERN INDIANA

By John B. Patton, Thomas G. Perry, and William J. Wayne

INTRODUCTION

Within recent years field conferences sponsored by the Geological Survey, Indiana Department of Conservation, and the Department of Geology, Indiana University, have reviewed outstanding exposures and aspects of parts of the Silurian, Devonian, Mississippian, and Pennsylvanian systems in southern Indiana. This conference is concerned, in part, with the stratigraphy and paleontology of the Ordovician rocks exposed in southeastern Indiana.

Sites of physiographic interest have not been emphasized in previous conferences. Ordovician rocks in southern Indiana are exposed in a region that is stimulating to the physiographer and Pleistocene geologist. Consequently, in addition to the stratigraphy and paleontology of the Ordovician bedrock, this conference directs attention to prominent physiographic features in this area, many of which owe their origin to Pleistocene glaciation, and to concepts regarding their development.

Ordovician rocks in southern Indiana are paleontologically attractive because they are so richly fossiliferous. Well-preserved specimens may be readily collected in weathered exposures and in the soft shales of the Cincinnatian (Upper Ordovician) series (pl. 1). The highly fossiliferous rocks of the Cincinnati area have inspired many men, among whom may be mentioned E. O. Ulrich and Charles Schuchert, to seek careers in paleontology. The proximity of the conference route to the type locality of the Cincinnatian series in the vicinity of Cincinnati, Ohio, should be an added attraction.

Southeastern Indiana has not yielded mineral commodities as plentifully as other parts of the state. Nevertheless, two stops and several observation points along the route of the caravan draw attention to some of the industrial minerals found in this area.

The authors take pleasure in expressing their appreciation to members of the Conference Committee who willingly have devoted their time to the constructive criticism of the itinerary. In addition, Dr. G. T. Wickwire and Mr. Guy Campbell of Hanover College acquainted us with the excellent collecting locality at Jefferson Lake and assisted in other ways.

This conference is designed to present as coherent a view as time will permit of the geology of southeastern Indiana. The stops have been carefully selected to show features of stratigraphic, paleontologic, physiographic, or economic interest. Informal discussion among participants will contribute greatly to the success of the conference.

SYSTEM	SERIES	GROUP	FORMATION OR MEMBER	LITHOLOGIC DESCRIPTION	CHARACTERISTIC FOSSILS	
SILURIAN	NIAGARAN	UNNAMED	Louisville 0' to 10'	Limestone: Gray-tan, finely crystalline to dense, dolomitic.	Halysites catenularia	Calymene niagarensis
		CLINTON	Waldron 0' to 10'	Shale: Blue-gray, knotty, calcareous. Locally fossilliferous.	Eospirifer radiatus, Camarotoechia whitei, Eucalyptocrinites crassus	
			Laurel 27' to 40'	Limestone: Pale tan to gray, dense to finely crystalline, thin-bedded, cherty, moderately dolomitic. Weathers rough and pitted.	Fossils rare	
			Osgood 13' to 23'	Limestone and shale: Tan, dense, argillaceous limestone, and light-gray, calcareous shale. Weathers yellow.	Fossils rare	
	ALBION	MEDINA	Brassfield 0' to 11'	Limestone: Mottled greenish-gray to salmon pink, coarsely crystalline, massive, hard.	Fossils rare, Orthis flabellites	
ORDOVICIAN	CINCINNATIAN	RICHMOND	Elkhorn 0' / Whitewater 4 to 35'	Limestone: Blue-gray, rubbly, argillaceous; contains thin shale beds.	Stromatocerium huronense, Batostoma variabile, Monticulipora epidermata, Rhynchotrema dentatum, Platystrophia acutilirata, Leperditia caecigena	Rhombotrypa quadrata, Streptelasma rusticum
			Saluda 40' to 65'	Limestone: Drab-gray, granular, massive to thin-bedded, impure, dolomitic. Weathers to banded, buff and salmon surface. Coral masses at base.	Columnaria alveolata, Tetradium approximatum, Homotrypa	
			Liberty 50'	Limestone and shale: Alternating thin (2 inch) layers of gray, argillaceous limestone and gray, soft shale.	Streptelasma rusticum, Rhynchotrema capax, Dinorthis subquadrata, Strophomena planumbona, Hebertella occidentalis	
			Waynesville 65' to 75'	Shale and limestone: Blue, soft shale and thin, platy limestone beds.	Dalmanella meeki, Sowerbyella clarksvillensis, Zygospira modesta, Hebertella insculpta, Leptaena richmondensis, Homotrypella hospitalis, Platystrophia cumingsi	
		MAYSVILLE	Arnheim 70' to 80'	Shale and limestone: Blue, soft shale and thin, platy limestone beds.	Calymene meeki, Cyclonema bilix, Dinorthis carleyi, Pterinea demissa, Rafinesquina alternata, Bryozoa	Hallopora ramosa, Heterotrypa frondosa
			Mount Auburn 3' to 20'	Limestone: Irregularly bedded, rubbly, argillaceous.	Platystrophia ponderosa auburnensis	
			Corryville 20' to 45'	Limestone and shale: Blue, dense to crystalline limestone beds and blue-gray, soft, clay shale.	Chiloporella flabellata, Platystrophia crassa	
			Bellevue 25' to 35'	Limestone: Blue to dark-gray, irregularly bedded, rubbly, highly argillaceous limestone; contains shaly partings and abundant fossils	Platystrophia ponderosa, Hebertella sinuata, Monticulipora mammulata, Monticulipora molesta, Platystrophia laticosta	
			Fairmount 30' to 60'	Limestone: Blue, thick-bedded at top; contains minor amount of shale.	Constellaria florida, Strophomena planoconvexa, Platystrophia laticosta, Hallopora dalei, Peronopora vera, Homotrypa curvata	
			Mount Hope 25' to 45'	Shale: Blue, soft, calcareous; contains a few thin beds of limestone.	Dekayia aspera, Amplexopora septosa	
		EDEN	McMicken 60' to 80'	Shale and limestone: Blue- or greenish-gray, soft shale and drab-gray, irregular beds of impure limestone.	Heterotrypa (Dekayella) ulrichi, Coeloclema commune, Amplexopora septosa	Hallopora oneallii, Dalmanella multisecta
			Southgate 70' to 120'	Shale: Blue, soft, thinly laminated; contains irregularly spaced, thin layers of limestone. Weathers drab-tan.	Batostoma jamesi, Climacograptus typicalis, Bythocypris cylindrica	
			Economy 50' to 80'	Shale: Blue-gray, soft; contains scattered thin beds of drab limestone. Weathers drab-tan.	Aspidopora newberryi, Amplexopora persimilis	
	MOHAWKIAN	TRENTON	Cynthiana 40' to 50'	Limestone: Blue-gray, crystalline to dense, medium-bedded, generally impure; contains minor amounts of shale.	Cryptolithus tessellatus, Hormotoma gracilis	Constellaria fischeri

Compiled by J. J. Galloway, J. B. Patton, and T. G. Perry. April 1953

GENERALIZED STRATIGRAPHIC COLUMN OF ORDOVICIAN AND SILURIAN ROCKS EXPOSED IN JEFFERSON AND SWITZERLAND COUNTIES, INDIANA

SUMMARY OF PROGRAM

Headquarters for the conference is Clifty Inn, Clifty Falls State Park, near Madison, Indiana. Clifty Inn offers a commanding view of the Ohio River Valley, which is particularly scenic at this time of the year. Short talks that concern aspects of the geology of southeastern Indiana will be given Friday evening, May 8, in Clifty Inn. The caravan will depart for the field from the parking lot at Clifty Inn at 8:00 A. M. on May 9 and 10.

A welcoming address by Dr. Charles F. Deiss, State Geologist, will formally open the conference at 8:00 P. M. on Friday, May 8. Brief talks then will be given by Professor G. T. Wickwire, Hanover College; Professor W. H. Shideler, Miami University, Ohio; and Dr. J. S. Templeton, Illinois State Geological Survey. The renewing of acquaintances and informal discussions among conference participants will bring the Friday evening program to a close.

On Saturday morning the caravan will depart (pl. 2) from Clifty Inn and will proceed to the grounds of the Madison State Hospital (Stop 1). At this scenic vantage point approximately 400 feet above the Ohio River, Professor W. D. Thornbury, Indiana University, will acquaint the group with the development of the regional physiography. Participants interested in photography will find this stop to their liking.

The caravan then will proceed in a northeasterly direction to Jefferson Lake (Stop 2), which is located about 6 miles northeast of Madison. Paleontologists will appreciate this stop because a 3-year-old cut on the south side of the lake affords excellent fossil collecting, as does the spillway on the east end of the lake.

Participants then will drive to the northeast corner of Jefferson County (Stop 3). Exposures of Waynesville and Liberty beds in Wilson's Fork immediately left (west) of Indiana Highway 62 yield many corals, brachiopods, and bryozoans. Saluda fossils may be found in float on the hillsides west of the creek and about 40 feet above creek level.

After paleontologists have been rounded up from the creek bed and the adjoining hillsides, the caravan will travel to the quarry of the Tri-County Stone Company (Stop 4), which is located in the northwest corner of Switzerland County. (Participants are urged to exercise caution here. The stone company will not be liable for any accidents on its property.) This stop is particularly interesting because the disconformable contact between the Whitewater and Brassfield formations is strikingly revealed. Further, this section includes one of the thickest known exposures of the Brassfield limestone in southern Indiana. Lunches will be brought out to the caravan from Clifty Inn at this stop.

After lunch the caravan will proceed eastward over the Dearborn upland to a lengthy stratigraphic section (Stop 5) located on the

left side of Indiana Highway 56, about 2.5 miles southwest of Rising Sun, Ohio County. Here a section that extends for 0.35 mile along the left side of the highway exposes beds from the Corryville down to the McMicken. The section exhibits the contact between the Eden and Maysville groups. Some participants may be dismayed to find that the most abundant fossils are bryozoans, although the brachiopod Dalmanella multisecta is plentiful in the McMicken beds.

The caravan then will travel southward to an exposure of the Cynthiana (?) formation (Stop 6) about 2.2 miles south of Patriot, Switzerland County. Here the group may examine the oldest rocks exposed in southeastern Indiana.

The caravan then will continue in a southwesterly direction to about 1 mile beyond Florence, Switzerland County. The caravan will halt here (Stop 7), and participants will observe a seismographic determination of depth to bedrock in the Ohio Valley. Professor Judson Mead, Research Advisor, Geophysics Section, Geological Survey, will comment briefly upon the geophysical method used for this determination. The depth to bedrock undoubtedly will be of particular interest to physiographers and Pleistocene geologists.

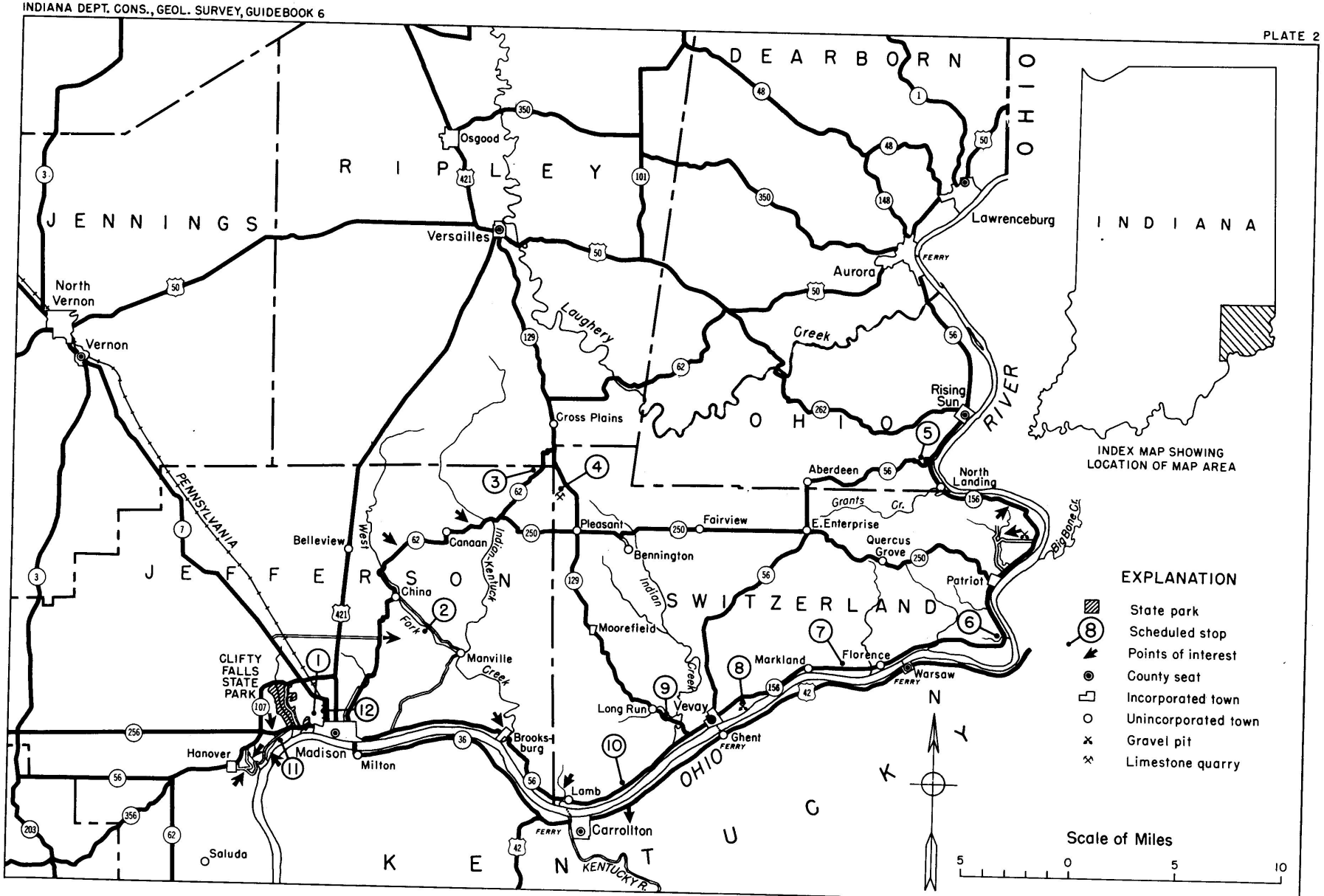
The group will continue to the Gaudin gravel pit (Stop 8), which is located about 1.6 miles east of Vevay, Switzerland County. Dr. W. J. Wayne, Head, Glacial Geology Section, Geological Survey, here will acquaint the group with features of geologic interest that are shown in this operation.

The caravan then will proceed to Indiana Highway 129 and will travel northward on this highway for a distance of 1.6 miles, where a dissected lacustrine terrace (Stop 9) is developed in the valley of Long Run Creek. A few fragmentary gastropods of Wisconsin (Pleistocene) age may be collected here.

The caravan will return to Indiana Highway 56 and continue in a southwesterly direction to a brief halt (Stop 10) in the southwest corner of Switzerland County. Participants will remain in their cars. The attention of the group will be directed to the abandoned valley of the Kentucky River.

The caravan will proceed to Clifty Inn. A program has not been planned for Saturday evening. Some of the localities visited during the day undoubtedly will provoke informal discussion among the participants.

On Sunday morning the caravan will depart from the parking lot at Clifty Inn at 8:00 A. M. Prior to the first stop the caravan will tour the picturesque country west and southwest of Madison. The group will ascend an excellent Ordovician section shortly after leaving the south entrance of the park; travel over the Muscatatuck regional slope; visit the scenic campus of Hanover College, which affords an imposing view of the Ohio River; pass exposures of the Brassfield, Laurel, and Osgood formations; and will observe such physio-



MAP SHOWING ROUTE OF FIELD CONFERENCE IN SOUTHEASTERN INDIANA

April 1953

graphic features as lacustrine terraces and the Devil's Backbone.

A visit to the site of the new Ohio Valley Electric Corporation plant (Stop 11) has been tentatively planned but will not be made if conditions are unsuitable.

The caravan next will halt in the northwest part of Madison, and 2 hours will be allowed for examination of the excellent exposures in Riley Creek, in the cuts along the Pennsylvania Railroad, and along Indiana Highway 7 (Stop 12). The railroad cuts are especially interesting because they are richly fossiliferous and expose a section that extends from the Arnheim to the Laurel. The attention of the participants is called to Hanging Rock, developed in the Saluda limestone, that overhangs a sharp turn on Indiana Highway 7.

After these exposures have been examined, the party will convene at the cars, and brief remarks by Dr. Charles F. Deiss will formally conclude the conference.

ITINERARY

Saturday, May 9, 1953

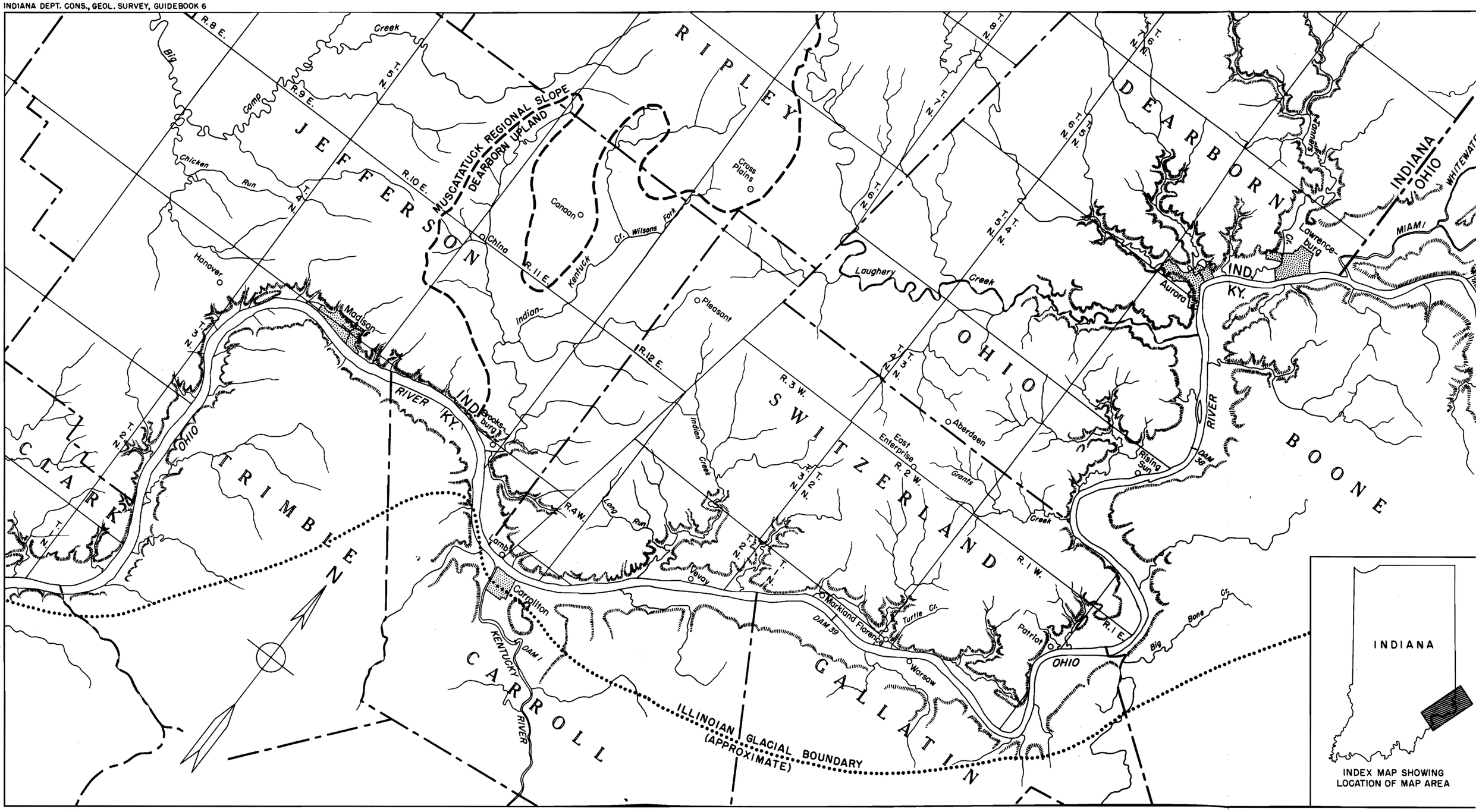
Mileage between stops	
0.0	The caravan will assemble on the parking lot at Clifty Inn. Departure will be at 8:00 A. M. Please check speedometers before leaving and at each scheduled stop during the conference so that you may determine your location at any time. Cars will follow the road that leads toward the north entrance of Clifty Falls State Park.
1.2	A small waterfalls to the left of the road descends over the Brassfield limestone.
1.6	Look to the left to see the V-shaped gorge of Clifty Creek as it enters the Ohio River Valley.
3.4	Clifty Falls may be seen across the valley from the lookout point on the left side of the road.
4.1	North entrance of Clifty Falls State Park. Turn right (east) on Indiana Highway 107.
4.5	Note the lack of dissection on this upland. The surface is not bevelled toward the Ohio Valley, which lies only

Mileage between stops	
	1.5 miles to the south.
5.3	Junction with Indiana Highway 7. Turn right.
6.3	North entrance to Madison State Hospital. Turn right through the arch. Note again the flat upland surface. Would you expect from this topography that a major valley 1 mile in width is cut more than 400 feet below this surface within 1 mile to the south?
7.3	Angle to the right at Y intersection.
7.8	Park the cars in a double row (fill both lanes) between the two driveways at the hospital Administration Building. Return on foot 250 feet east to the limestone lookout platform on the bluff of the Ohio River.

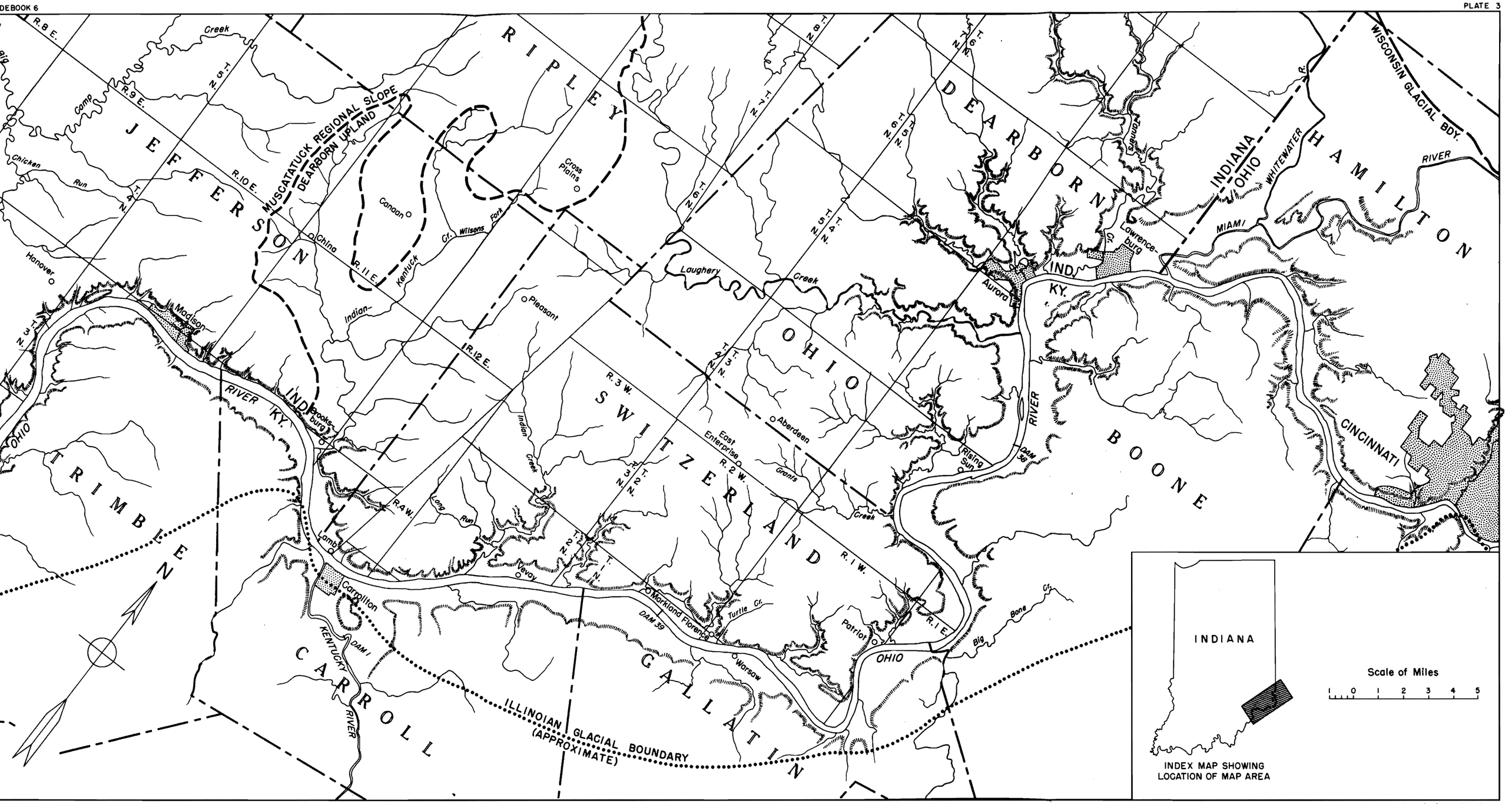
STOP 1. Lookout point at Madison State Hospital. 20 minutes. Location: NW1/4NE1/4SW1/4 sec. 34, T. 4 N., R. 10 E. (Madison West quadrangle)

The group will assemble at the observation platform. The bench mark at the platform shows an altitude of 826 feet, and pool level of the Ohio River in the valley below is 420 feet. Professor W. D. Thornbury will use the public address system to acquaint the group with the physiographic history of the Ohio River and the two physiographic provinces which make up the Madison area.

From the observation platform one can observe that the Ohio River here flows through a relatively narrow valley and that the bluffs and adjacent uplands on either side of the valley are almost completely undissected. The drainage divide between the Ohio and Wabash basins practically follows the crest of the bluffs at Madison, and streams which drain into the Wabash River head within 1 mile of the precipitous Ohio Valley bluffs (pl. 3). Physiographically, this is part of the Muscatatuck regional slope (Malott, 1922, p. 86). It is essentially a dip slope formed on the resistant Laurel (Niagaran) limestone. Eastward a short distance, where the Laurel limestone has been removed by erosion, long, narrow fingers of upland and steep, rounded slopes characterize the Dearborn upland (Malott, 1922, p. 84), which is underlain by limestones and shales of Cincinnatian age. During the late Tertiary, this upland was part of the Lexington peneplain. The entire area lies only a short distance north of the Illinoian glacial boundary (pl. 3) and probably was reached by at least



MAP SHOWING PHYSIOGRAPHY AND DRAINAGE BETWEEN CINCINNATI, OHIO, AND MADISON, INDIANA



INDEX MAP SHOWING LOCATION OF MAP AREA

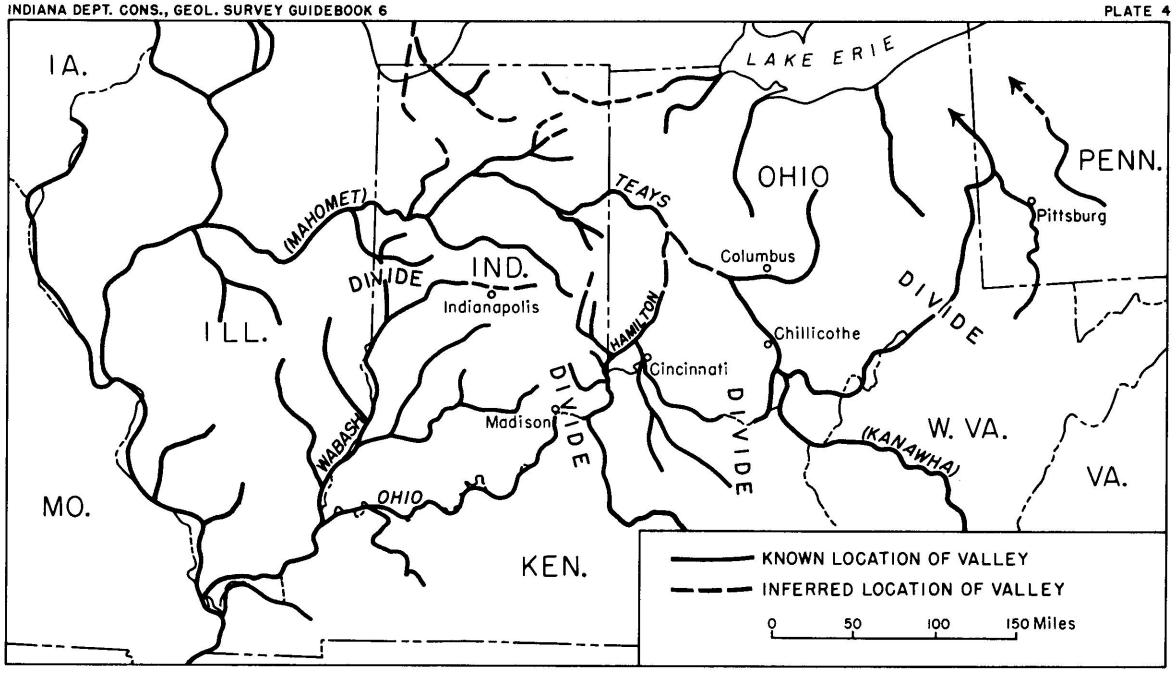
MAP SHOWING PHYSIOGRAPHY AND DRAINAGE BETWEEN CINCINNATI, OHIO, AND MADISON, INDIANA

Compiled by W. J. Wayne
April 1953

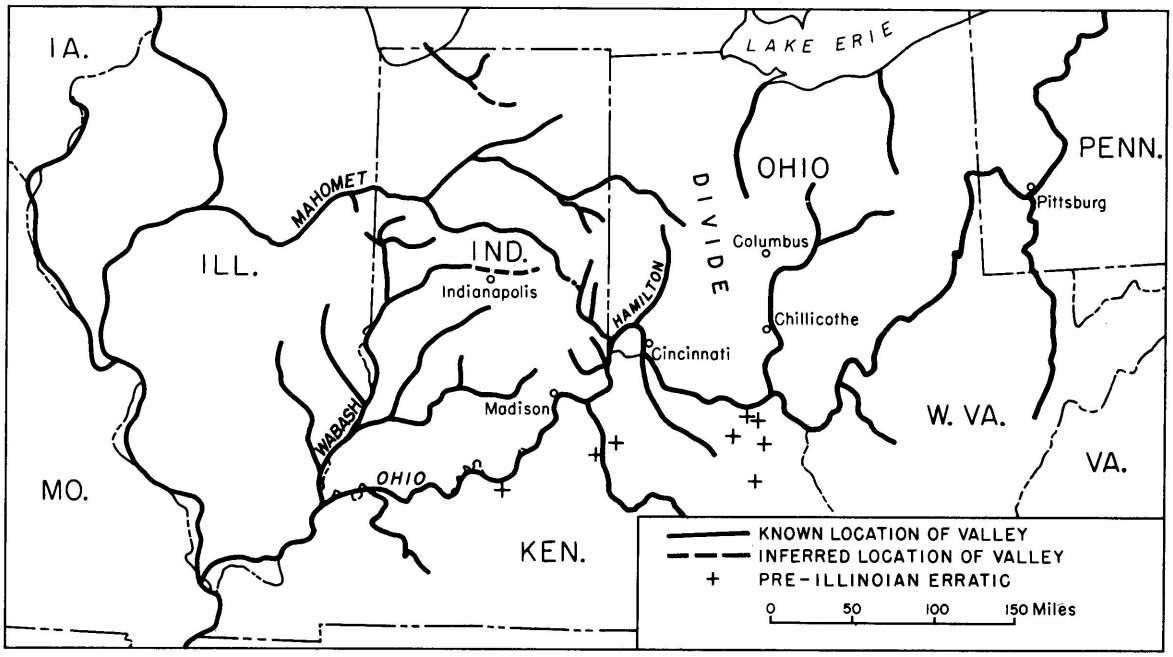
one earlier ice sheet during the Pleistocene epoch.

A controversy exists regarding the location of the headwaters of the Ohio River prior to the Pleistocene. Malott (1922, pp. 136-138), Fowke (1933, pp. 121-130), and Wayne (1952, pp. 576-579) have presented evidence to support the hypothesis that the divide at Madison separated drainage to the north into the Teays River from the Ohio River (pl. 4, A). However, Leverett (1902, pp. 116-118), Fenneman (1916, pp. 118-119), Ver Steeg (1938, pp. 657 and 659), and Klaer and Thompson (1948, pp. 12-13) thought that a divide did not exist at Madison, but that the divide between these two river systems was present upriver from Cincinnati, Ohio. A river that followed essentially the same course as the present Ohio was formed by the integration of parts of several drainage systems by a pre-Illinoian ice sheet (Tight, 1903, pp. 50-57) (pl. 4, B). Illinoian and Wisconsin modifications have formed the present Ohio Valley.

Mileage between stops	
0.0	Check mileage. The caravan will proceed to the north gate of the hospital grounds.
1.4	North gate of Madison State Hospital. Turn left on Indiana Highway 7.
2.5	Junction with Indiana Highway 107. Turn right (east) and proceed to junction with U. S. Highway 421.
4.1	Turn left on Highway 421.
5.7	Junction with county road. Turn right (east). The upland over which we are travelling is a peneplain remnant (Lexington peneplain) mantled with 5 to 30 feet of Illinoian till.
7.7	Junction of county road with Indiana Highway 62. The broad lowland to the east is the valley of the west fork of Indian-Kentuck Creek. The caravan now is travelling along the eastern boundary of the Muscatatuck regional slope, which here is developed on the Laurel limestone. The more dissected topography to the east is part of the Dearborn upland, carved on the Cincinnatian limestones and shales (pl. 3).
8.7	The road begins to descend into the valley of the west



A. PRINCIPAL VALLEYS AND DIVIDES DURING LATE TERTIARY



B. PRINCIPAL VALLEYS DURING EARLY PLEISTOCENE

MAPS SHOWING LATE CENOZOIC VALLEYS IN INDIANA AND ADJOINING STATES

(MODIFIED AFTER WAYNE, 1952, P. 577)

Mileage between stops	
	fork of Indian-Kentuck Creek through typical Dearborn upland topography.
9.9	The small cemetery on the right is on a Pleistocene (Wisconsin) lacustrine terrace.
10.0	Village limits of China.
10.2	Leave Highway 62, which turns left, and proceed straight ahead across the west fork of Indian-Kentuck Creek.
11.4	Bridge and road junction. Take the fork to the right.
12.3	Turn right on a narrow crushed stone road where a small arrow sign points south to Jefferson Lake. Cross the ford.
12.5	Park the cars on level ground below the dam.

STOP 2. Jefferson Lake. 30 minutes. Location: NW corner NW1/4SW1/4 sec. 9, T. 4 N., R. 11 E.

Walk up the crushed stone road that parallels the south side of the lake. A section approximately 20 feet in thickness extends 500 feet along the south side of the road that borders the lake. The beds exposed are part of the Maysville group, which can be identified by the bryozoan Hallopora ramosa. The section consists of interbedded thin limestone and shale that are part of the Corryville formation. The cut is approximately 3 years old and is moderately weathered and slumped.

The Corryville formation is richly fossiliferous at this locality, and the following fossils have been collected:

Corals

Calapoecia (not in place)
Columnaria (not in place)

Bryozoans

Amplexopora filiosa, r
Amplexopora septosa, c
Bythopora gracilis, a

Bryozoans

Ceramoporella distincta, c
Chiloporella flabellata, r
Hallopora ramosa, aa
Heterotrypa frondosa, c
Peronopora vera, c

Brachiopods

Hebertella sinuata, a
Platystrophia crassa, c
Platystrophia laticosta, a
Platystrophia ponderosa, aa
Platystrophia unicostata, c
Rafinesquina alternata, aa
Rafinesquina alternata fracta, c
Rafinesquina alternata nasuta, c

Nautiloids

"Orthoceras" sp., c

Trilobites

Calymene sp. (mostly pygidia), r

(aa - very abundant, a - abundant, c - common, r -rare)

The bryozoan Chiloporella flabellata is the index fossil of the Corryville formation, although it is not found in abundance here.

Good exposures that extend deeper into the section may be seen at the spillway at the north end of the dam. A 70-foot section is exposed, although the uppermost part is not accessible. The narrow cut through which the water is flowing is probably in the Bellevue, and the massive limestone beds that cause the lower falls may be the upper part of the Fairmount. The material that was excavated from the spillway is sufficiently weathered to permit the collection of free fossils in large numbers. Platystrophia ponderosa occurs very abundantly.

Mileage between stops	
0.0	Check mileage. The caravan will reassemble and return to China by the route covered previously.
2.3	Rejoin Indiana Highway 62 and turn right over the bridge.
4.0	Cross west fork of Indian-Kentuck Creek.
4.7	SLOW DOWN. The Waynesville formation is exposed on the opposite bank of the creek, which probably flows in the upper part of the Arnheim formation.
6.3	A cut on the left exposes Saluda, Brassfield, Osgood, and the lower few feet of the Laurel. At the top of the grade, the road again crosses the till plain. The cuts along the road expose weathered Illinoian till.
8.0	Village limits of Canaan.

Mileage between stops

8.4 Observe the flat upland surface of this east edge of the Muscatatuck regional slope.

9.9 Directly ahead is an excellent view from the Laughery escarpment (Malott, 1922, p. 85) of the topographic break between the Muscatatuck regional slope to the west and the dissected Dearborn upland to the east.

10.8 Cross Indian-Kentuck Creek and turn right. Note the lacustrine terrace.

11.4 Junction with Indiana Highway 250. The caravan will continue on Highway 62 and ascend the valley of Wilson's Fork.

14.7 Park cars clear of pavement on the left side of the road.

STOP 3. Waynesville-Liberty exposures in Wilson's Fork. 30 minutes. Location: NE1/4NW1/4 sec. 5, T. 5 N., R. 12 E., 2 miles south and half a mile west of Cross Plains.

About 30 feet of section is exposed through 900 feet of distance along the creek bed. The contact between the Waynesville and Liberty formations is exposed in the low cut on the right (east) side of the road and in the bed of Wilson's Fork. The Richmond group is characterized by the bryozoan Rhombotrypa quadrata, which may be collected at this locality. The brachiopods Dalmanella meeki, Sowerbyella clarksvillensis, Zygospira modesta, Hebertella insculpta, and Leptaena richmondensis are commonly found in the Waynesville formation. The Liberty formation is identified by the presence of the cup coral Streptelasma rusticum, and the brachiopods Rhynchotrema capax, Strophomena planumbona, and Hebertella occidentalis. The limestones and shales found in the creek bed to the west of the road are particularly fossiliferous. The following fossils were collected from the Liberty formation at this locality:

Corals

Streptelasma rusticum, aa

Bryozoans

Hallopora subnodosa, c
Homotrypella hospitalis, r
Rhombotrypa quadrata, r-c

Brachiopods

Hebertella insculpta, a
Leptaena richmondensis, aa
Rafinesquina alternata, aa
Sowerbyella clarksvillensis, c
Strophomena planumbona, aa
Rhynchotrema capax, aa

The brachiopods Dalmanella meeki and Zygospira modesta, which are found at other localities at this horizon, do not appear, or are rarely found, here. The coral Tetradium approximatum, characteristic of the Saluda limestone, has been found in float about 40 feet above creek level on the hillsides adjoining the west bank of the creek.

Mileage between stops	
0.0	Check mileage. The caravan will proceed north on Highway 62, passing the Jefferson-Ripley county line 0.2 mile beyond stop 3.
1.3	Junction with Indiana Highway 129. Turn right on Highway 129.
1.5	Enter Switzerland County.
3.1	Turn right on county road.
3.2	Enter property of Tri-County Stone Company. Leave the cars in line in the stockpiling area near the crushing plant.

STOP 4. Tri-County Stone Company quarry. 1 hour, 20 minutes. Location: NE1/4NW1/4 sec. 9, T. 5 N., R. 12 E., Switzerland County.

Proceed on foot 100 yards to the quarry, which lies south of the crushing plant. This quarry displays an extensive exposure of the Ordovician-Silurian contact. The Silurian beds include the Brassfield limestone and the basal part of the Osgood formation. The Ordovician beds are part of the Whitewater formation. The following section was measured at this quarry by Ned M. Smith:

Unit	Description	Thickness in feet
Pleistocene		
6	Weathered Illinoian till.	5.0
Osgood formation		
5	Clay: Greenish-gray, structureless, soft, unctuous.	1.5
4	Impure limestone: mottled, tan, gray, and pinkish; medium crystallinity; sandy and shaly; deeply weathered.	1.6
	Total thickness of exposed Osgood formation	3.1

Unit	Description	Thickness in feet
Brassfield limestone		
3	Limestone: Mottled and streaked tan, pink, and gray; crystallinity is coarse to medium, with large calcite crystals in small masses and sugary calcite along fractures and partings; pyritic. Bedding is essentially massive, but rock quarries and weathers in slabby beds.	11.6
Whitewater formation		
2	Limestone and shale interbedded: Limestone black, partially crystalline, thick-bedded, argillaceous; shale black, fissile; occurs in 0.1- to 0.3-foot beds. Lighter gray shale and more coarsely crystalline, fossiliferous limestone occur in top 0.4 to 0.7 foot of unit; top surface is slightly irregular.	4.2
	Limestone: Dark-gray to black, finely crystalline, fossiliferous. Thin laminae of black shale are dispersed throughout. A few medium-sized crystals are present as scattered grains or in lensing interbeds.	10.0
	Total thickness of exposed Whitewater formation	14.2
	Total thickness of measured section	33.9

The Brassfield at this place is thicker than normal for southeastern Indiana. Typical thickness of the Brassfield is 3 to 5 feet. The salmon color which distinguishes the Brassfield in much of Indiana is well-exemplified here and stands in strong contrast to the drab-gray beds of the Whitewater formation. This quarry is located in an outlier of the Brassfield limestone which is separated from the main

outcrop belt to the northwest by a distance of 2 or 3 miles.

If several thin beds of dark, soft shale near the top of the Whitewater formation are used as datum planes, about 2 feet of disconformity can be observed at the Ordovician-Silurian contact.

North of Cross Plains the Brassfield is missing locally, and the Silurian Osgood formation rests on the Whitewater, as described by Foerste (1904). Beds of Silurian age, generally represented by the Brassfield limestone, progressively overlap the Ordovician formations in southeastern Indiana. In the Richmond area, about 65 miles north of stop 4, the Brassfield rests upon the Elkhorn formation. From northern Ripley County southward, the Silurian beds rest disconformably upon the Whitewater formation, which progressively thins to the south and is 4 feet or less in thickness at Madison.

This is not particulary a paleontologic stop as the fresh quarry walls do not afford ideal collecting. Nevertheless, the ostracod Leperditia caecigena may be found in some abundance in the Whitewater formation but does not extend above the Whitewater-Brassfield contact. Further, Stromatocerium huronense, a large stromatoporoid, has been collected within 2.0 feet below the contact. The brachiopod Rhynchotrema dentatum, characteristic of the Whitewater, should be sought.

The Tri-County quarry was opened about 2 1/2 years ago and produces agricultural lime and crushed stone. The production ranges between 500 and 600 tons per day, about one-half of which is agricultural lime. The mixture of Brassfield and Whitewater gives a satisfactory calcium carbonate equivalent that averages about 85 percent.

LUNCH. The group will have a picnic lunch served at or near the Tri-County quarry. The food will be brought out from Clifty Inn to meet the caravan at 12:00 noon. The examination of the quarry should be completed before lunch as the caravan will leave as soon as the group has finished eating.

Mileage between stops	
0.0	Check mileage. Leave the quarry and return to Highway 129.
0.2	Indiana Highway 129. Turn right.
2.4	Junction with Indiana Highway 250 at the village of Pleasant. Turn left (east) on Highway 250.

Mileage between stops	
4.6	Fork in blacktop road. Take the left fork, remaining on Highway 250.
8.5	Village limits of Fairview.
13.5	Village limits of East Enterprise.
13.8	Junction with Indiana Highway 56. Turn left (north) on Highway 56.
15.8	Enter Ohio County.
16.2	Turn right (east) in center of a village named Aberdeen. Through the succeeding 6 miles note the increasing dissection as the Ohio River is approached. The road follows one of the long, flat-topped spurs characteristic of the Dearborn upland.
22.1	Road begins to descend into the Ohio Valley.
22.5	Passengers will disembark at the upper end of a lengthy exposure which may be seen by walking down the gentle grade to the point at which the cars will be parked, a distance of 0.35 mile.

STOP 5. Eden-Maysville exposures near Rising Sun. 30 minutes. Location: E1/2SW1/4 sec. 16, T. 3 N., R. 1 W., 3 miles southwest of Rising Sun. (Aberdeen quadrangle)

All exposures are on the left side of Highway 56. The upper part of the exposed section is part of the Corryville and consists of yellow, weathered shale that contains layers of limestone. Fossils are found sparingly at this location. Below the Corryville the Bellevue is poorly exposed as beds of yellow limestone and shale, considerably weathered. Platystrophia ponderosa, typical of the Bellevue, is present but rare. Beneath the Bellevue, the Fairmount is well-exposed and consists of yellow, weathered shale with thin layers of limestone. The upper part contains the bryozoans Constellaria florida, Homotrypa curvata, and Heterotrypa frondosa in abundance. In the lower part the bryozoans Peronopora vera, Hallopora dalei, and Hallopora subplana may be readily collected. The Mount Hope lies beneath the Fairmount and includes yellow, weathered shale with a few layers of limestone. The brachiopods Platystrophia sp. and

Zygospira cincinnatiensis, as well as the bryozoan Batostoma implicatum, are readily collected from these beds. All beds down to this horizon are of Maysville age, although the index bryozoan Hallopora ramosa is not commonly found here. The Eden-Maysville boundary is considered to lie at the base of prominent limestones which immediately overlie soft, blue-gray shales in the cut which occurs at the sharp turn where the cars will be parked. The Eden beds are part of the McMicken formation and consist of blue shale which weathers yellow. The brachiopod Dalmanella multisecta, an index fossil of the Eden group, is abundant, as is the bryozoan Heterotrypa ulrichi.

The toal thickness of the beds exposed at this stop is 115 feet, of which the upper 85 feet are Maysville and the lower 30 feet Eden. The creek gorge south and east of the sharp highway curve penetrates deeper into the Eden group, probably exposing the Southgate formation, but time will not permit examination of these lower exposures during the stop.

Mileage between stops	
0.0	Check mileage. The caravan will proceed on Highway 56.
0.5	Junction with Indiana Highway 156. Turn right (south).
2.1	Enter Switzerland County.
3.0	SLOW DOWN. A county road enters from the right, and moderately fresh Eden shales are exposed in the slumping cut south of the side road.
4.3	SLOW DOWN. The slumped road cuts on the right are in the Eden shales.
5.4	SLOW DOWN. A gravel pit on the right exposes Pleistocene valley train material.
5.7	SLOW DOWN. On the right glacial conglomerate composed of coarse, rounded gravel may be seen. Gravel terraces of Wisconsin age are exposed directly to the right of the highway.
6.7	SLOW DOWN. The terrace that appears about 30 feet above the one on which the road is built is composed of outwash gravel and sand of Wisconsin age. Although

Mileage between stops

stratigraphic relationships are not known, these two terrace levels seem to represent valley trains of two Wisconsin sub-stages, perhaps Tazewell and Cary (Goldthwait, 1952, pl. 1).

7.7 Natural gravel exposures and an abandoned gravel pit can be seen to the left of the road.

8.2 SLOW DOWN. An active gravel pit about 800 feet west of the highway exposes the upper 20 feet of valley fill beneath a terrace surface that stands about 80 feet above normal pool level of the Ohio River. Note that farther west about 1 mile, a valley 1,500 feet wide cuts through an older, higher-level terrace and the bedrock upland. The creek that cuts this valley now turns southward and no longer flows through the trough across the terrace. The size and shape of this abandoned valley segment suggest that, prior to the last glaciation during which the Ohio Valley was a major sluiceway, Goose Creek entered the Ohio through this opening. Goose Creek was dammed by large amounts of outwash in the Ohio Valley, and its ponded water rose sufficiently to overflow southward. When the meltwater flood ceased, incision in the new outlet was so deep that Goose Creek did not return to its former course. Lacustrine sediments underlie the terraces in the middle and upper reaches of Goose Creek.

9.4 An abandoned gravel pit to the left (northwest) of the highway exposes coarse, rounded gravels in the upper part of the valley train along the Ohio River.

10.8 City limits of Patriot.

13.9 Park cars clear of pavement on the left side of the highway.

STOP 6. Exposures of Cynthiana (?) formation (Upper Trenton) near Patriot. 10 minutes. Location: 2.2 miles south of Patriot, in the SE1/4NW1/4SW1/4 sec. 30, T. 2 N., R. 1 E. (Patriot quadrangle)

A 24-foot section of dark-gray, crystalline limestone, interbedded with a few layers of shaly limestone, and occurring in beds

2 feet and less in thickness, lies beyond the fence on the right (west) side of the highway and in a small gully that descends the hill. Although the age of these beds is uncertain, fossils indicative of Eden age have not been found at this exposure. Because these beds have not been extensively weathered, collecting is not good at this exposure, but the following fossils have been found:

Bryozoans

Bythopora sp.

Brachiopods

Dalmanella rogata
Sowerbyella sp.

Gastropods

Hormotoma gracilis
Unidentified murchisonoid forms

Trilobites

Cryptolithus tessellatus

The general aspect of this fauna is suggestive of Trenton age rather than Eden age. In addition, such limestones are not commonly encountered in the Eden. If these beds are correctly identified as Cynthiana, they are the oldest exposed rocks in southern Indiana. Silty, drab-gray shales and impure thin beds of limestone occur above this exposure and appear as float on the hillside and in the small gully. The age of these upper beds cannot be confirmed because they are relatively unfossiliferous, but they are considered to be Eden.

Mileage between stops	
0.0	Check mileage.
2.7	Road cut in water-laid, cross-bedded sand. The material underlies the high terrace.
3.6	Cross Bryant Creek.
5.7	Warsaw Ferry. The town across the river is Warsaw, Kentucky.
6.4	Cross Turtle Creek. Note the lacustrine terrace on the right.
6.6	City limits of Florence.
7.8	Park cars on the right shoulder.

STOP 7. Seismographic determination of depth to bedrock. 20 minutes. Location: SW1/4NE1/4 sec. 1, T. 1 N., R. 2 W., 0.9 mile west of center of Florence. (Florence quadrangle)

Here Highway 156 lies near the center of the Ohio Valley, which is 6,500 feet wide in this area. The general aspect of the physiography and the several terrace levels show the aggradational origin of the valley floor materials. The high slope of the valley walls gives no hint of the depth of the bedrock floor. To determine the depth of bedrock in such partially filled valleys, as well as in completely obscured pre-Pleistocene bedrock valleys, the Indiana Geological Survey uses the refraction seismograph because of the relative speed and economy of the method. Refraction seismograph equipment will be at the site when the caravan arrives. The party will hear a brief explanation of the method from Professor Judson Mead, Indiana University, after which the shot will be fired, the graphic record developed, and the depth of valley fill calculated. If the valley fill is deep at this site, the bedrock floor should be cut in some part of the Trenton limestone, and the velocity recorded should be distinctly higher than would be expected in rocks of the Eden group.

Mileage between stops	
0.0	Check mileage.
1.4	Dam 39 of the Ohio River inland waterways navigation system lies to the left.
2.3	Village limits of Markland.
5.9	Turn left on a gravel lane.
6.2	Park cars in a circle on the floor of the gravel pit.

STOP 8. Gaudin gravel pit near Vevay. 15 minutes. Location: SW1/4SW1/4 sec. 7, T. 1 N., R. 2 W., 1.6 miles east of Vevay. (Vevay North quadrangle)

The granular materials that constitute much of the Ohio Valley fill are well-exposed in the active face of this gravel pit. The deposits here indicate at least three phases of deposition. The following section was measured in this pit by W. J. Wayne:

Unit	Description	Thickness in feet
3	Sand: Orange-brown, fine-grained, sub-angular to	

Unit	Description	Thickness in feet
	rounded, grading to silty sand and soil in the upper weathered part.	8.0
2	Gravel: Coarse, rounded, well-sorted, horizontally stratified.	16.0
1	Sand and gravel: Grayish-yellow, moderately well-sorted, sand ratio high; exhibits cut-and-fill cross bedding. Base of unit concealed.	18.0
	Total thickness of measured section	42.0

Mileage between stops

0.0 Check mileage.

0.3 Indiana Highway 156. Turn left.

1.7 City limits of Vevay.

2.2 Junction with Indiana Highway 56 in center of Vevay. Continue straight ahead, following Highway 56.

4.3 Junction with Indiana Highway 129. Turn right (north).

5.2 Cross Indian Creek. Note Wisconsin lacustrine terraces. Indian Creek, along with most of the tributaries which entered the Ohio River before the Wisconsin glacial stage, was dammed by valley train sediments deposited along the Ohio sluiceway. Post-Wisconsin stream erosion has left these Pleistocene lake bottoms as terraces that stand from a few feet to more than 40 feet above Recent alluvium (Thornbury, 1950, pp. 14-16).

5.9 Park cars along the right side of the highway, leaving as much roadway clear as possible.

STOP 9. Wisconsin lacustrine deposits in valley of Long Run Creek. 20 minutes. Location: SE1/4NW1/4SE1/4 sec. 16, T. 2 N., R. 3 W., 2 miles west of Vevay, about 500 feet north of Highway 129. (Vevay South quadrangle)

Calcareous, laminated clay and silt of lacustrine origin are exposed in a bluff 40 feet high and approximately 200 feet long. A few scattered specimens tentatively identified as the gastropod Amnicola cf. emarginata (Küster) have been recovered from a zone 28 feet below the top of the bluff. The matrix in which these fragile shells are embedded is such a tenaceous clay that identifiable specimens are difficult to obtain. Wisconsin age is indicated for the deposit by the depth of leaching and the extent of dissection of former lake bottom sediments.

Mileage between stops	
0.0	Check mileage. Proceed straight ahead on Highway 129.
0.9	Make U-turn in Y intersection at the Long Run Pilgrim Church. Return to the Ohio River Valley by way of Highway 129.
3.3	Junction with Indiana Highway 56. Turn right (west).
4.2	Cross Indian Creek.
7.5	Country school on the right. Cars will stop in line on the right side of the highway. Do not disembark.

STOP 10. Abandoned mouth of Kentucky River. 5 minutes. Location: NW1/4NE1/4 sec. 6, T. 1 N., R. 3 W., 5.3 miles southwest of Vevay.

The deep notch on the south side of the Ohio River is the former mouth of the Kentucky River (pl. 3). Diversion of the Kentucky River into its present position probably was caused by Illinoian glaciation. Illinoian till (Leverett, 1929, p. 53) is interbedded with lacustrine clays in exposures at the north end of the abandoned valley segment. A lacustrine terrace, probably underlain by Wisconsin sediments, extends from the south margin of the till to the Kentucky River. The isolated triangle of upland which stands between the abandoned valley and the new course of the Kentucky River is mantled with loess, as is much of the bluff along the Kentucky side of the Ohio River.

Mileage between stops	
0.0	Check mileage.

Mileage between stops	
1.6	SLOW DOWN. The gap through which the Kentucky River now flows may be seen on the south side of the Ohio River at Carrollton, Kentucky. The bluffs on the east side of the Kentucky River are part of the upland that was isolated by the diversion in drainage (pl. 3) discussed above.
2.3	A bridge over the Kentucky River near its juncture with the Ohio can be seen to the left.
2.6	Note the gravel banks of Green Valley Creek at the village of Lamb. Through the next few miles note that the dissection of the bluffs and valley wall diminishes.
3.9	Enter Jefferson County.
7.2	Cross Indian-Kentuck Creek. Brooksburg is located to the right of the highway on lacustrine terraces of Wisconsin age.
14.1	City limits of Madison. Proceed straight through Madison on Highway 56.
15.9	Junction with Indiana Highway 7. Continue straight ahead on Highway 56.
17.1	South entrance of Clifty Falls State Park. Turn right.
18.0	Parking lot at Clifty Inn. End of tour for the day.

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0.0	The caravan again will assemble on the parking lot at Clifty Inn. Departure will be at 8:00 A. M. Please check the speedometer. Cars will follow the road that leads to the south entrance to Clifty Falls State Park.
0.2	The road descends through a stratigraphic section that includes the Laurel, Osgood, Brassfield, Saluda, Liberty, and Waynesville formations.

Mileage between stops	
0.9	Road junctions with Indiana Highways 56 and 62 at the south gate of Clifty Falls State Park: Turn right (west).
1.4	To the left appears the main excavation for the footings of the new power plant. The earth-moving on the valley floor is mainly to create dikes that will protect the plant and its coal and ash storage yards from high water. The courses of Clifty, Little Clifty, and Crooked Creeks have been altered, and these streams will flow to the river between dikes.
1.5	Cross Clifty Creek. A shallow exposure of the Bellevue may be seen in the stream floor about 400 feet upstream.
1.7	Pass through a low cut in the Waynesville formation.
1.9	Another cut in the Waynesville.
2.1	A long cut on the right exposes the Waynesville.
2.4	The caravan enters a long cut and ascends the hill past exposures that range from Liberty to Laurel.
2.9	Junction with Highway 256. Bear left at Y intersection on Highways 56 and 62.
3.1	Junction with Indiana Highway 107. Continue straight ahead on Highway 56 and 62. The caravan now has reached the upland and is travelling on the Muscatatuck regional slope.
4.0	Turn left into the grounds of Hanover College.
4.3	The road begins to descend along Happy Valley Creek. The Laurel limestone forms canyon-like walls beside the road. Large slumped blocks of Laurel rest at high angles along the right side of the road.
5.2	Intersection with campus drive. Turn left.
5.4	Goodrich Hall, which lies to the right, houses geology and other sciences at Hanover College.

Mileage between stops	
5.5	The view of the Ohio Valley, particularly downstream, is impressive from these bluffs.
5.8	Overlook platform on left.
6.2	Turn acutely to the left at a sign which points to Hanover Beach. Change gears. The road descends through exposures of the Laurel and Osgood. Slumped material covers most of the Ordovician rocks.
6.9	Junction with the River Road. Angle to the left.
7.6	The sharp profile of the Devil's Backbone can be seen straight ahead.
7.7	Flat-topped lacustrine terraces stand about 35 feet above the alluvium along Hog Trough Creek.
9.5	Note the present drainage divide between Hog Trough Creek, flowing to the southwest, and minor gullies draining eastward directly to the Ohio.
9.8	Rejoin Highways 56 and 62. Turn right. Beds of Corryville age have been exposed to the right by stripping for fill material. The Corryville exposures appear as blue surfaces in the yellow to brown alluvial material.
10.3	Turn right into the parking lot at a construction office.

STOP 11. Site of Ohio Valley Electric Corporation plant. 15 minutes. Location: SW1/4SW1/4 sec. 33, T. 4 N., R. 10 E., 0.8 mile west of Madison city limits. (Madison West quadrangle)

This stop will be made if the excavation shows features of geologic interest and is sufficiently dry at the time of the field conference to permit examination. The main excavation at its deepest stage will expose more than 50 feet of valley fill materials. Test drilling has shown these materials to be interbedded alluvium, silt, and low-quality gravels.

Mileage between stops	
0.0	Check mileage. Leave parking lot and turn right (east) on Highways 56 and 62. Proceed east toward Madison.
0.5	Pass south entrance to Clifty Falls State Park. Continue eastward toward Madison.
1.7	Junction with Indiana Highway 7. Turn left at stop light.
1.9	Turn left from Highway 7 on a crushed stone lane that leads into a trailer park.
2.0	Park cars on a crushed stone road in trailer park.

STOP 12. Riley Creek, Pennsylvania Railroad cuts, and cuts along Indiana Highway 7. 2 hours. Location: NW1/4SE1/4 sec. 34, T. 4 N., R. 10 E., in the northwestern part of Madison.

Walk westward to Riley Creek and ascend the creek through exposures of the Bellevue and Corryville for a distance of about 1,000 feet. This locality is famous for the abundance of the brachiopods Platystrophia ponderosa and Hebertella sinuata and the bryozoans Monticulipora moiesta and M. mammulata in the shale banks of the creek and the creek bed.

Return downstream along Riley Creek to the point where the railroad embankment may be seen to the west. Leave the creek and walk westward to the railroad. Ascend the railroad grade to the first cut.

The cuts through which the Pennsylvania Railroad descend to Madison were excavated before 1847 and have long been noted Ordovician collecting localities. Measured sections of the two cuts were given by Cumings (1908, pp. 637, 639-641), who listed the faunas but did not give formational names in the Ordovician.

The rock exposed in the south cut is mainly Arnheim and consists of blue, soft shale interbedded with platy limestone. The top of the cut exposes heavier beds of Waynesville. Many fine specimens of the trilobite Calymene meeki have been collected from this cut, although they are not abundant. Several of the platy limestone beds contain abundant trilobite fragments. The brachiopod Dalmanella meeki, characteristic of the Waynesville formation, occurs prolifically in the upper part of the cut. The following fossils are among those found in the Arnheim portion of the south cut:

Bryozoans

Hallopora ramosa, a
Bythopora gracilis, a
Homotrypella hospitalis, a

Brachiopods

Dalmanella meeki, a
Refinesquina alternata, a
Hebertella sinuata, a

Gastropods

Cyclonema bilix, a
Hormotoma, c

Pelecypods

Byssonychia, a
Opisthopteria casei, c
Anonmalodonta gigantea, c
Pterinea demissa, c

Trilobites

Calymene meeki, r-c
Isotelus gigas, r-c

The two cuts are separated by a ravine. The drainage passes through a culvert beneath the track. The upper cut begins in the top of the Waynesville formation, but the first good exposures are beds in the Liberty formation, as indicated by the brachiopods Strophomena planumbona, Rhynchotrema capax, Dinorthis subquadrata, and Hebertella occidentalis, and the cup coral Streptelasma rusticum.

Sheer walls of the massive, dolomitic Saluda limestone tower above the Liberty formation. The base of the Saluda is marked by the large colonial coral Columnaria alveolata and the bryozoan Homotrypa. Approximately 50 feet of section intervenes between the top of the Liberty formation and the base of the Brassfield (Silurian) limestone. The greater part of this thickness is within the Saluda limestone. The upper 14 to 19 feet, consisting of dark, platy, unfossiliferous limestone, is assigned to the Whitewater formation by J. J. Galloway (personal communication, 1953).

The Ordovician beds are overlain by the Brassfield limestone, which here is only 1 foot thick. The Ordovician-Silurian contact is disconformable over large areas in southeastern Indiana. The Brassfield is overlain by a 17-foot thickness of the Osgood formation, and the top of the cut contains 20 feet of Laurel limestone.

At the top of the cut the party should leave the railroad and cross to Indiana Highway 7. Turn right at the highway and walk down the grade past exposures of beds that range from Laurel down to Bellevue. The prominent undercut waterfalls overhanging a sharp turn in the highway is called Hanging Rock and is developed in the Saluda limestone. At the base of the hill leave the highway and cross into the trailer park to the parked cars.

CONCLUDING ASSEMBLY. The group will convene at the cars at 11:30, and participants will be given an opportunity to express

views on the geology that has been covered in the conference. Brief remarks by Dr. Charles F. Deiss, State Geologist, will formally conclude the conference.

REFERENCES CITED

Cumings, E. R. (1908) The stratigraphy and paleontology of the Cincinnati series of Indiana, Indiana Dept. Geology and Nat. Res., 32d Ann. Rept., pp. 605-1190, 55 pls., 16 figs., 5 maps.

Fenneman, N. M. (1916) Geology of Cincinnati and vicinity, Ohio Geol. Survey, 4th ser., Bull. 19, 207 pp., 12 pls., 59 figs., 2 maps.

Foerste, A. F. (1904) The Ordovician-Silurian contact in the Ripley Island area of southern Indiana, with notes on the age of the Cincinnati geanticline, Am. Jour. Sci., 4th ser., vol. 18, pp. 321-342, 1 pl., map.

Fowke, Gerard (1933) The evolution of the Ohio River, The Hollenbeck Press, Indianapolis, 273 pp., 30 maps.

Goldthwait, R. P. (1952) The 1952 field conference of Friends of the Pleistocene, Columbus, Ohio, 14 pp., 3 pls.

Klaer, F. H., Jr., and Thompson, D. G. (1948) Ground-water resources of the Cincinnati area, Butler and Hamilton Counties, Ohio, U. S. Geol. Survey Water-Supply Paper 999, 168 pp., 15 pls., 22 figs.

Leverett, Frank (1902) Glacial formations and drainage features of the Erie and Ohio basins, U. S. Geol. Survey Mon. 41, 802 pp., 25 pls., 8 figs.

---------- (1929) The Pleistocene of northern Kentucky, Kentucky Geol. Survey, ser. 6, vol. 31, pp. 1-80, 15 figs.

Malott, C. A. (1922) The physiography of Indiana, in Handbook of Indiana geology, Indiana Dept. Cons. Pub. 21, pt. 2, pp. 59-256, 3 pls., 51 figs., 1 table.

Thornbury, W. D. (1950) Glacial sluiceways and lacustrine plains of southern Indiana, Indiana Dept. Cons. Div. Geology Bull. 4, 21 pp., 2 pls., 3 figs.

Tight, W. G. (1903) Drainage modifications in southeastern Ohio and adjacent parts of West Virginia and Kentucky, U. S. Geol. Survey Prof. Paper 13, 111 pp., 17 pls., 1 fig.

Ver Steeg, Karl (1938) Thickness of the glacial drift in western Ohio, Jour. Geology, vol. 46, pp. 654-659, map.

Wayne, W. J. (1952) Pleistocene evolution of the Ohio and Wabash Valleys, Jour. Geology, vol. 60, pp. 575-585, 5 figs.