PITTSBURGH GEOLOGICAL SOCIETY

FIELD GUIDEBOOK OF APPALACHIAN GEOLOGY

PITTSBURGH TO NEW YORK

PITTSBURGH GEOLOGICAL SOCIETY
PGS

FIELD TRIP

MARCH 26 - 27, 1955

In Conjunction With

Annual Meeting
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

New York, New York
MARCH 28-31, 1955

GENERAL INSTRUCTIONS

PLEASE READ CAREFULLY

The field trip officially begins at 7:30 A.M., Saturday, March 26 and ends at the Hotel Statler in New York City at about 5:00 P.M., Sunday, March 27. In order to prevent delays and confusion, each person on the trip is asked to carefully follow the instructions given below. Because there will be considerable driving and numerous stops, the schedule that is outlined must be strictly observed. Your cooperation in following directions and in being prompt will be appreciated.

1. **BAGGAGE:** All baggage should be labeled with tags which will be supplied to you. A special committee will handle your baggage and place it in your hotel room at the Penn Harris Hotel in Harrisburg Saturday night. Baggage will be checked at the Hotel Statler in New York upon arrival Sunday afternoon and should be claimed there. In order that your baggage can be collected each day, please follow the directions given below under "Special Instructions For Each Day."

2. **HOTEL RESERVATIONS:** All hotel reservations are to be made individually. Should you arrive in Pittsburgh Friday, March 25 and stay overnight at either the Schenley Park Hotel or the Webster Hall Hotel, you will find both of these hotels adjacent to the starting place of the trip, the University of Pittsburgh (Cathedral of Learning). Reservations should be made at the Penn Harris Hotel in Harrisburg for Saturday night. To prevent delays Sunday morning, it is hoped that on Saturday night you will pay for your room at the Penn Harris. Don't forget to leave your room key at the desk upon leaving.

3. **BREAKFAST:** Sunday morning breakfast will be served at the Penn Harris Hotel beginning at 6:30 A.M. The field trip fee includes the cost of this breakfast.

4. **LUNCHES:** Box lunches will be provided at the lunch stop each day. They are included in the field trip fee.

5. **DINNER:** A group dinner will be served at the Penn Harris Hotel Saturday night, the cost of which is covered by the field trip fee.

6. **EXPENSES:** The field trip fee covers all expenses **except** the cost of your room at the Penn Harris Hotel Saturday night. The fee includes: (1) transportation, (2) guidebook, (3) meals, (4) the handling of baggage, and (5) gratuities.

7. **TRANSPORTATION:** Travel will be by chartered Greyhound Bus. Please remain in the same bus throughout each day to prevent delay in loading and unloading. Boarding your bus a few minutes ahead of time will facilitate prompt departure.

8. **GROUP LEADERS:** A group leader in each bus will call out the mileage points along the route, describe geological features in view, and will answer questions. An amplifier will be used in each bus.

9. **STOPS:** Because of the long distance to be covered both days, stops are necessarily limited in time and number. We will stop at localities where regional geology can best be studied. An amplifier will be used at each stop so that the field leader can be heard by the entire group. There will be a mid-morning and mid-afternoon rest stop each day.

SPECIAL INSTRUCTIONS FOR EACH DAY

SATURDAY, MARCH 26

Baggage: If you stay at either the Schenley Park Hotel or the Webster Hall Hotel Friday night, leave baggage in lobby by 7:15 A.M. All others should bring their baggage to the buses at the starting place by 7:15 A.M.

Starting Time and Place: 7:30 A.M., University of Pittsburgh (Cathedral of Learning). Buses can be boarded in the Schenley Plaza Parking Area across Forbes Street from the Cathedral at the Information Booth.

SUNDAY, MARCH 27

Baggage: Leave by 7:15 A.M. in the lobby of the Penn Harris Hotel. Upon arrival at the Hotel Statler in New York, claim your baggage in the check room.

Starting Time and Place: 7:30 A.M. from in front of the Penn Harris Hotel.

Field Leaders:

In Pennsylvania—CARLYLE GRAY, C. E. PROUTY, BRADFORD WILLARD
In New Jersey—M. E. JOHNSON, H. P. WOODWARD

FIELD GUIDEBOOK

OF

APPALACHIAN GEOLOGY

PITTSBURGH TO NEW YORK

Sponsored by

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Annual Meeting

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

New York, New York

1955

PITTSBURGH GEOLOGICAL SOCIETY

ORGANIZED OCTOBER, 1944

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The guidebook contains several maps, structure sections, and columnar sections. Reference to these will allow the reader to orient himself geologically and geographically at any place along the route. Shown on the structure sections and maps are the positions of stops for geology and the field trip route. The illustrations are listed below and are conveniently grouped to show first the maps of general interest, and then those pertaining to the various segments of the trip.

MAPS OF GENERAL INTEREST

PITTSBURGH TO HARRISBURG ILLUSTRATIONS
(Mileage, 0.00 to 237.15)

HARRISBURG TO EASTON ILLUSTRATIONS
(Mileage, 237.15 to 350.55)

EASTON TO NEW YORK ILLUSTRATIONS
(Mileage, 350.55 to 432.75)

ACKNOWLEDGMENTS

The preparation of this field trip and guidebook involved a great deal of work by a large number of individuals. Acknowledgment is hereby given each person who participated in this effort. Much credit is due Mr. G. C. Grow, Jr., and others who prepared the Field Conference Guidebook, Northern Portion of the Appalachian Basin (1948). The present guidebook has in part been patterned after that used for the 1948 Conference, a conference sponsored by the Pittsburgh Geological Society in conjunction with the Midyear Meeting of the American Association of Petroleum Geologists held in Pittsburgh in October, 1948.

The log of the 1955 trip was prepared as follows:

(1) Pittsburgh to Harrisburg: Dr. C. E. Prouty, Head, Department of Geology, University of Pittsburgh; Dr. N. K. Flint, Department of Geology, University of Pittsburgh.

(2) Harrisburg to Easton: Dr. Carlyle Gray, Acting Director, Pennsylvania Topographic and Geologic Survey; Dr. Bradford Willard, Head, Department of Geology, Lehigh University.

(3) New Jersey: Mr. George C. Grow, Jr., Transcontinental Gas Pipeline Corporation; Mr. Meredith E. Johnson, Director, New Jersey Geological Survey; Dr. H. P. Woodward, Professor of Geology and Dean of the College of Arts and Sciences, Rutgers University at Newark.

Published reports, on which descriptive geology along the route is based, are listed in a bibliography on page 114. Dr. A. B. Cleaves' report on the geology along the Pennsylvania Turnpike between Irwin and Carlisle deserves special mention because it has been used so extensively.

The general discussion of Paleozoic sediments between Pittsburgh and Harrisburg, as well as the geologic descriptions at Stops 2, 3 and 7, were written by Dr. F. M. Swartz. Geology of Lower Paleozoic strata between Harrisburg and Easton was contributed by Carlye Gray and Bradford Willard; and that of pre-Cambrian rocks in Pennsylvania by Dr. T. V. Buckwalter, Department of Geology, University of Pittsburgh. The physiographic and stratigraphic summaries for New Jersey were written by Meredith E. Johnson.

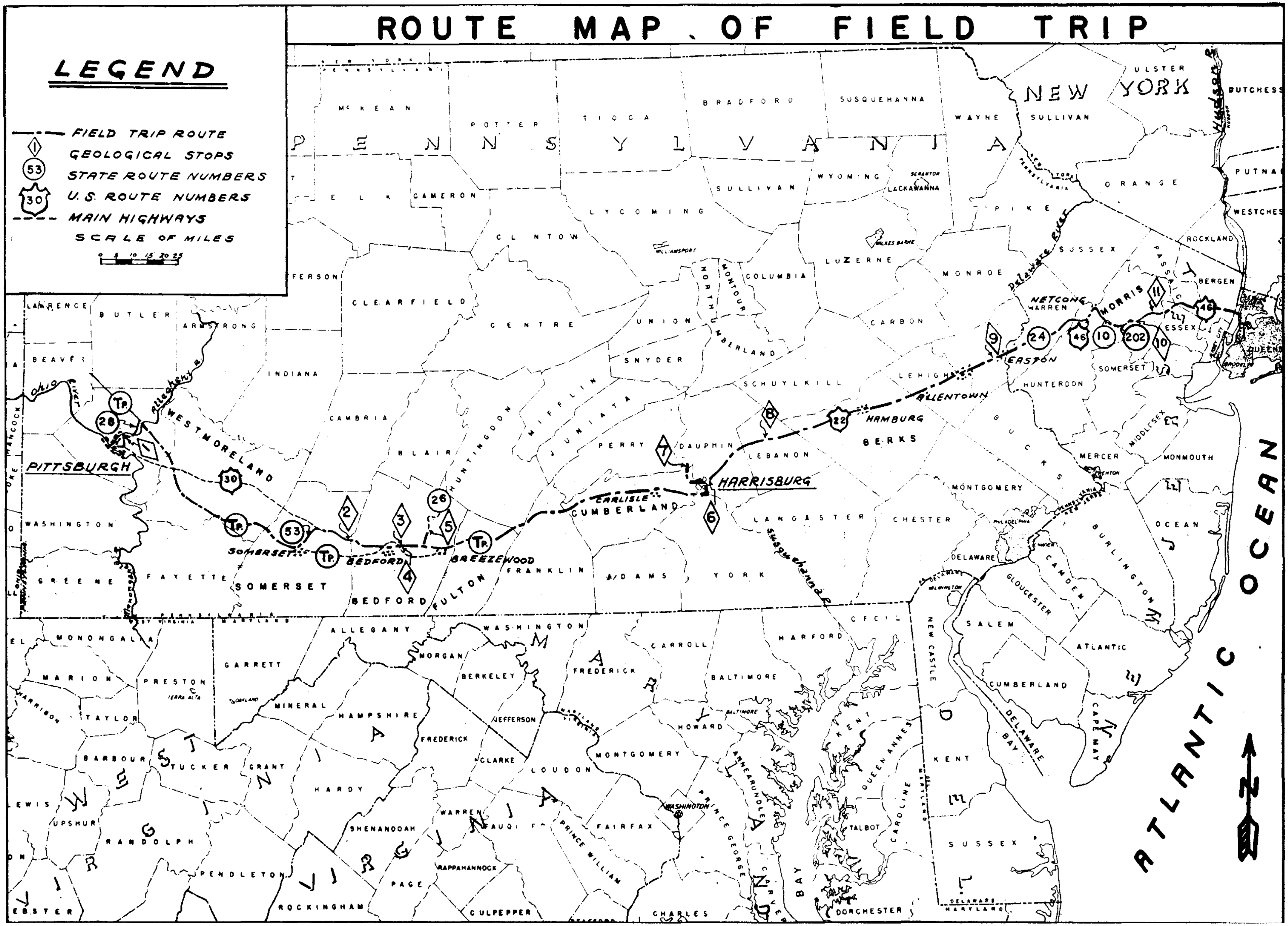
The Pittsburgh Geological Society greatly appreciates the cooperation given by the Pennsylvania Topographic and Geologic Survey and by the New Jersey Geological Survey, both of which were most helpful in many phases of the work.

Acknowledgment also goes to several companies for making available certain employees to plan and execute the trip; to plan and edit the guidebook; and for manuscript typing. Those who assisted in drafting were Miss Lillian Heeren, Mr. Carl Moore, Mr. Robert Norton, and Mr. Nickala Nickoloff.

Special credit is due members of the Publications Committee of the Pittsburgh Geological Society, C. P. Cook (Chairman), C. P. Duncan, P. W. Garrett, Jr., J. Weart Kelley, and Sexton Linger, who spent much time in assembling and editing the guidebook.

The assistance of Dr. J. B. Currie, Mr. A. I. Ingham and Mr. H. W. Heck in handling the mailing and financing is also gratefully acknowledged.

Credit is given within the guidebook to those people who authored the various maps, geologic sections, and diagrams.


ROUTE MAP OF FIELD TRIP
LEGEND
FIELD TRIP ROUTE
GEOLOGICAL STOPS
STATE ROUTE NUMBERS
U.S. ROUTE NUMBERS
MAIN HIGHWAYS
SCALE OF MILES
0 5 10 15 20 25
PENNSYLVANIA
NEW YORK
MARYLAND
WEST VIRGINIA
VIRGINIA
DELAWARE
NEW JERSEY
ATLANTIC OCEAN
PITTSBURGH
HARRISBURG
ALLENTOWN
EASTON
NETCONG
HAMBURG
CARLISLE
SOMERSET
BEDFORD
BREEZEWOOD
WASHINGTON
Delaware River
Susquehanna R.
Hudson R.
Allegheny R.
Ohio
DELAWARE BAY
N

INTRODUCTION

THIS field trip has been planned so as to provide a regional picture of the geology of the eastern portion of the United States. The route of the trip traverses one of the major physiographic divisions of North America—the Appalachians. From Pittsburgh the route crosses the eastern portion of the Appalachian Plateau and its structurally simple carboniferous rocks, continuing eastward through the folded and faulted Paleozoics in the Valley and Ridge Province. Here is afforded a fine opportunity for studying Appalachian structure, stratigraphy, and geomorphology. The complex basement rocks of pre-Cambrian age, along with infolded Paleozoics, are seen in northern New Jersey in the southwestern extension of the New England Upland. Finally the route leads into the lowlands west of the Hudson River and New York City, where exposures of red beds and diabases of the Triassic are lying in fault contact with the pre-Cambrian rocks. A road log has been prepared to point out the geology as well as sites of historical and cultural interest along the way.

The northeastern part of the Appalachian Basin has received much attention, particularly since 1950, as a deep oil and gas area. Although this activity has been focused almost entirely on the Lower Devonian section, the unexplored Silurian, Ordovician and Cambrian, all of which contain oil and gas source and reservoir beds, are receiving increasing attention. The growing demand for oil and gas, coupled with modern drilling methods, which make it possible to drill to greater depths in the well-indurated rocks of the basin, will inevitably lead to testing the older Paleozoic strata.

THE ITINERARY SUMMARIZED

SATURDAY, MARCH 26, 1955—FIRST DAY

Leader: C. E. PROUTY

Extent of trip: Pittsburgh to Harrisburg; overnight stop in Harrisburg. Mileage about 235 miles.

Principal geologic features: At Pittsburgh, the field trip starts in the abandoned Pleistocene valley of the Monongahela River. For the first 90 miles, in the Allegheny Plateau Province of the Appalachian Highlands, the surface is veneered by the gently folded 1500-foot sequence of coal-bearing Pennsylvanian rocks. The most conspicuous folds are the Chestnut Ridge and Laurel Hill anticlines forming pronounced topographic ridges and exposing Mississippian beds in their crestal areas. The highest stratigraphic units seen are those of the basal Permian, exposed in one of the deeper synclines.

At the Allegheny Front there is a striking change between the Allegheny Plateau to the west and the Valley and Ridge Province to the east. The Valley and Ridge is composed of 25,000 feet of tightly folded, faulted strata, mostly Middle and Lower Paleozoic in age. Major and minor anticlines, some overturned, will be observed, together with associated faults. Most faults dip southeastward as do the axial planes of most of the folds. Resistant sandstones form conspicuous, generally parallel, even-crested ridges whose accordant summit levels are evidence of former peneplanation.

Leaving Blue Mountain Tunnel there is a fine panoramic view of the Great Valley, a broad marginal valley at the southeast edge of the Valley and Ridge Province. Flooring the Great Valley are structurally complex limestones and shales of the Cambro-Ordovician age. Flanking it on the southeast is South Mountain of the Blue Ridge Province, composed of Lower Cambrian quartzite and a pre-Cambrian crystalline complex.

Near Harrisburg we travel along the contact zone between Lower Paleozoic carbonate rocks and the redbeds of the Triassic which has been faulted into position. The day's trip ends in Harrisburg at a physiographic vantage point from which Susquehanna Water Gap in Blue Mountain, and other ridges north of Harrisburg will be viewed.

Stops for geology:

1. In Pittsburgh at Brilliant Cut, a highway and railroad excavation on the south wall of the Allegheny River Valley. Cyclical sedimentation in the Conemaugh series, and landsliding phenomena will be discussed. Fossils may be collected from the marine Ames limestone.

2. On the east-facing escarpment of the Allegheny Front is an exposure of the Mississippian Pocono (Big Injun) sandstone. Eastward from the escarpment there is a commanding view of the Valley and Ridge Province across which we will subsequently drive.

3. At Bedford where Raystown Branch of the Juniata River cuts through Evitts Mountain to see an excellent exposure of overturned Upper Ordovician and Lower Silurian strata. Beds in the same stratigraphic position, but of different facies, will be seen Sunday at Susquehanna Gap.

4. At the New Enterprise Stone and Lime Company quarry east of Bedford to see steeply dipping Middle Ordovician carbonate rocks.

5. At an Oriskany (Lower Devonian) sandstone quarry north of Everett to see the Oriskany, an important gas reservoir rock in the Appalachian area. The sandstone is quarried for glass, molding and traction sands, and for use as an abrasive in grinding.

6. At Reservoir Hill in Harrisburg, a rather prominent knob supported by a sandy phase of the Ordovician Martinsburg formation to see the physiographic expression of differentially eroded Paleozoic rocks north of Harrisburg, and to discuss peneplanation.

SUNDAY, MARCH 27, 1955—SECOND DAY

Leaders: C. E. PROUTY, CARLYLE GRAY, BRADFORD WILLARD, MEREDITH E. JOHNSON and H. P. WOODWARD

Extent of trip: From Harrisburg, Pennsylvania to the Statler Hotel in New York City, a distance of about 195 miles.

Principal geologic features: To the north of Harrisburg we will observe the Susquehanna Water Gap, a gap through Blue or Kittatinny Mountain. This hogback mountain, supported by sandstone and flanking the Great Valley on the northeast, represents an abrupt topographic change from the lower relief on the Martinsburg shales in the valley.

From Susquehanna Gap, the route is retraced to Harrisburg, and from there eastward, we travel for 70 miles along strike through the structurally complex, lithologically diversified Upper Ordovician Martinsburg formation. In places, water gaps in Blue Mountain will be visible on the north, and to the south will be seen the pre-Cambrian Reading Hills, a southwestern extension of the New England Upland. At one place the generally continuous ridge of Blue Mountain is offset by a west-plunging syncline and a complimentary anticline. In the Allentown-Bethlehem-Easton area we again see limestones and dolomites of Cambrian and Ordovician age. The Ordovician Jacksonburg limestone formation is the raw material that supports the thriving Lehigh Valley portland cement industry. The route continues nearly along strike in New Jersey for 25 miles in valleys of infolded and faulted Lower Paleozoics, composed mostly of the Cambro-Ordovician Kittatinny limestone. Then we turn eastward and cross the New Jersey Highlands whose highest elevations are supported by pre-Cambrian crystalline rocks. One of the ridges crossed in the Highlands is Schooley Mountain, for which the Schooley peneplain is named.

After crossing the Border Fault separating pre-Cambrian from Triassic rocks, the remainder of the trip to the George Washington Bridge is in continental beds of the Triassic Newark series. Occurring within these predominantly red continental clastic rocks are three basaltic flows, which because of their relative resistance form the Watchung Mountains, conspicuous topographic features of northern New Jersey.

In places morainic deposits left by Pleistocene glaciers are crossed as is the flat floor of glacial Lake Passaic. At the George Washington Bridge, the well known Palisades, a westerly dipping sill of Triassic diabase, form the columnar-jointed west wall of the Hudson Valley.

The detailed geologic description ends at the Hudson River, but buses will continue to the Statler Hotel in New York.

Stops for geology:

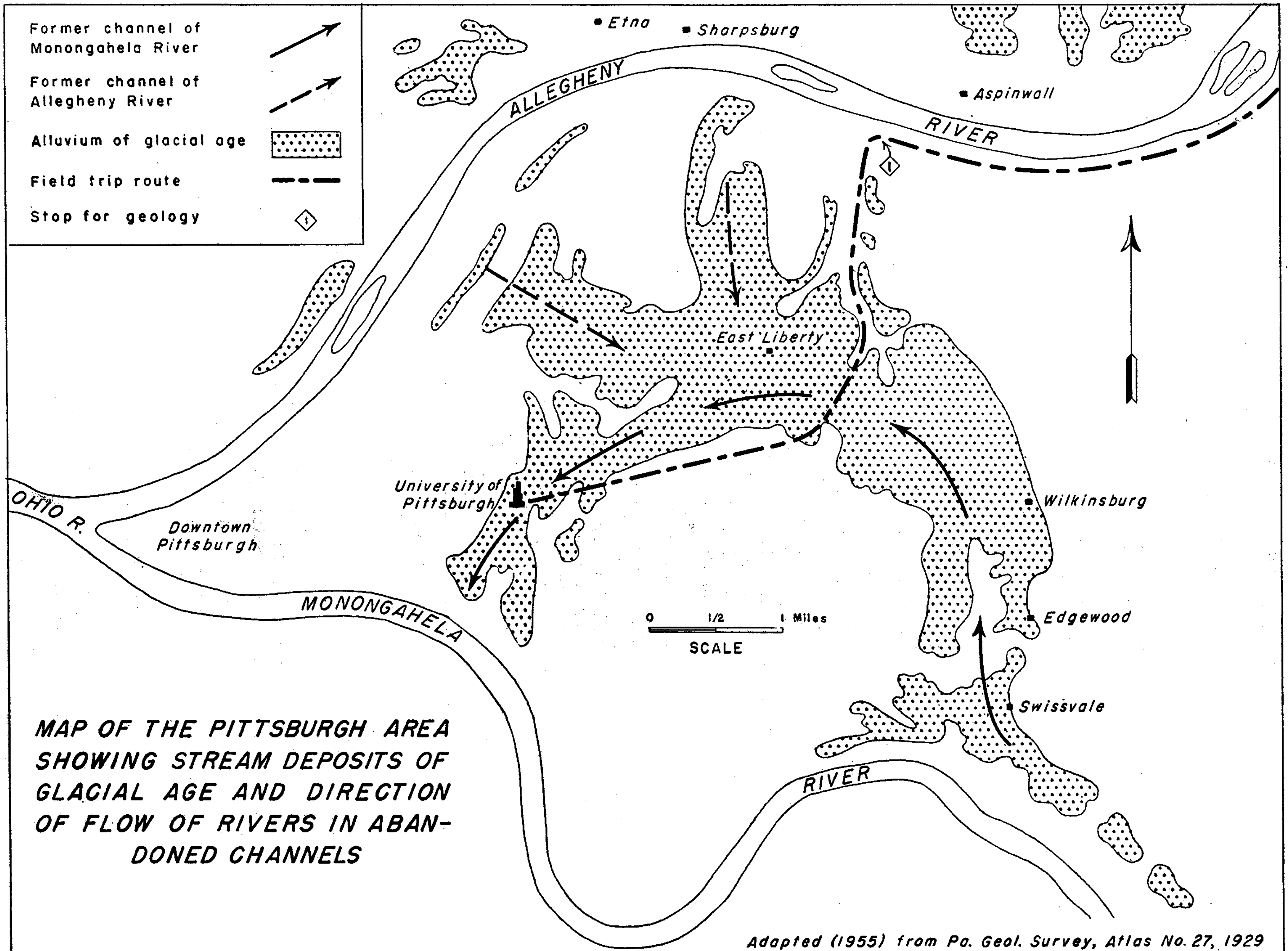
7. Susquehanna Water Gap in Blue (Kittatinny) Mountain where Ordovician and Silurian strata will be compared lithologically and in thickness with those seen at Bedford on Saturday.

8. About 10 miles west of Hamburg, Pennsylvania to see the Ordovician Martinsburg shale at one of the few localities where graptolites can be collected. Regional geology, including the proposed "Hamburg klippe," will be discussed.

9. At Easton, Pennsylvania to see a newly exposed section of Upper Cambrian limestone.

10. West of Dover, New Jersey to see a pre-Cambrian granite gneiss and to discuss regional geology.

11. At Hook Mountain, southwest of Paterson, New Jersey, to see a lava flow of Triassic age.



MAP OF THE PITTSBURGH AREA SHOWING STREAM DEPOSITS OF GLACIAL AGE AND DIRECTION OF FLOW OF RIVERS IN ABANDONED CHANNELS

ITINERARY

FIRST DAY'S TRIP

Pittsburgh to Harrisburg

MILEAGE	
0.00	Leave Schenley Park Plaza (at Information Booth) across Forbes Street from the Cathedral of Learning (University of Pittsburgh), 7:30 a.m. Face vehicles toward the Cathedral so they can proceed directly onto Forbes Street and **turn right.** Set odometer at 0.00. In view at the starting place are the Cathedral of Learning, Stephen Foster Memorial, Heinz Chapel, Carnegie Museum, Schenley Park Hotel, and Forbes Field (home of the Pirates and Steelers). Here, at the starting place, we are in the Oakland district of Pittsburgh, the Civic Center. Physiographically the Oakland area lies in the bottom of an abandoned stream valley, a former meander of the Monongahela River. The valley, at an elevation of 900 feet, lies 200 feet above the present drainage level and is bottomed by about 50 feet of alluvium. The alluvium was probably deposited during the Illinoian glacial stage when the terminus of the Illinoian ice sheet stood to the north in northwestern Pennsylvania. For about 2½ miles our route follows the abandoned valley eastward. Other examples of this 900-foot erosion surface are seen as we drive up the Allegheny River.
0.10	**Turn left** on South Bellefield Avenue.
0.20	Mellon Institute of Industrial Research on right with large monolithic columns. This building is constructed of Indiana limestone, the stone which is also used in the Cathedral of Learning and Heinz Chapel.
0.25	**Turn right** on Fifth Avenue. Continue straight on Fifth Avenue for about 2½ miles.
1.70	Home on left made of Triassic brownstone.
2.10	Former Andrew Mellon estate on right. **Get into left lane.**
2.45	**Bear slightly to left** and stay on Fifth Avenue. **Keep straight** at Frankstown Avenue intersection. Fifth Avenue becomes Washington Boulevard here.
3.20	Lincoln Avenue—stone bridge over Washington Boulevard.
3.25	Note evidence of landsliding on steep valley walls on both sides.
3.60	Larimer Avenue bridge over Washington Boulevard.
3.65	On left, notice joint-controlled slumping in PITTSBURGH redbeds (CONEMAUGH) at excavation for truck parking area.
3.95	**SLOW.** Landslide on left. Classed as the debris-flow type. It occurred in April, 1948 after a week of rain with a total fall of more than 4 inches. For many years various types of fill were dumped into a ravine in order to level the topography at the upper end of the slide area. The fill material, upon becoming saturated and unstable, slid to its present position within a few minutes after it started.
4.05	On right, entrance to Veteran's Hospital, where Dr. Peter Lindstrom, former husband of Ingrid Bergman, is chief neurosurgeon.
4.10	Most trees on right lean toward road because of soil creep. **Stay in right lane.**
4.70	**Turn right** on Allegheny River Boulevard which passes under the tracks of the Pennsylvania Railroad.

STANDARD SEDIMENTARY CYCLOTHEMS FOR THE CONEMAUGH SERIES OF THE PITTSBURGH AREA

After W. N. Tindell, W. L. Sheafer II, A. J. Newmyer, Jr.

Lower Conemaugh

Unit number

11. Shale, brownish red, with iron claystone concretions.
10. Shale, dark gray to black, containing iron concretions.
9. Limestone, fossiliferous.
8. Shale, gray to black.
7. Shale or claystone, gray.
6. Coal, or black shale.
5. Underclay.
4. Shale or claystone, gray or brownish red.
3. Limestone, fresh-water.
2. Shale or claystone, gray or brownish red.
1. Sandstone, micaceous.

Middle Conemaugh

Unit number

10. Shale, red, with iron claystone concretions.
9. Shale, grayish green, with iron claystone concretions.
8. Limestone, fossiliferous.
7. Shale or claystone.
6. Coal, or black shale.
5. Underclay.
4. Limestone, fresh-water.
3. Shale or claystone.
2. Shale or claystone.
1. Sandstone, micaceous.

Upper Conemaugh

Unit number

9. Shale, with gray claystone or limestone concretions.
8. Shale, black, locally coaly.
7. Limestone, commonly brecciated.
6. Shale, black.
5. Underclay.
4. Shale, gray with a few limestone concretions.
3. Limestone, fresh-water.
2. Shale, with gray limestone concretions.
1. Sandstone, locally shaly.

MILEAGE

5.10 **STOP 1. BRILLIANT CUT**

Buses will unload in semi-circular parking area off Allegheny River Boulevard. Discussion of CONEMAUGH-TYPE cyclical sedimentation and landsliding. Brilliant cut exposes MIDDLE CONEMAUGH rocks from the UPPER SALTSBURG sandstone up to the MORGANTOWN sandstone.

A detailed section of the strata in the cut is as follows:

PENNSYLVANIA SYSTEM

Conemaugh Series

		ft.	in.
*(1)	Sandstone, **Morgantown**	?	?
(3) (and)	Claystone, gray	1	7
(2)	Claystone, red, with limestone nodules. **Wellersburg**	14	11
(1)	Shale, grayish green, sandy	3	9
(10)	Shale, red, with limestone nodules. **Schenley redbeds**	6	2
(9)	Shale, grayish green, with iron claystone concretions. **Birmingham**	45	0
(7)	Shale, black, fissile, containing plant fragments	5	6
(5)	Clay, yellowish gray		½
(3)	Claystone, gray, **Duquesne**	2	3
(2)	Claystone, red, with nodular limestone	10	10
(1)	Shale, grayish green, sandy, **Grafton**	4	2
(10) (and) (9)	Shale, red and grayish green, with iron claystone and limestone concretions	17	3
(8)	Limestone, slightly shaly, containing marine fossils, **Ames**	3	4
(6)	Coal smut, **Harlem**		½
(5)	Clay, bluish gray		½
(3)	Claystone, gray	3	4
(2)	Claystone, variegated red and olive, with nodular limestone, **Pittsburgh redbeds**	23	2
(1)	Sandstone, gray, micaceous, **Upper Saltsburg**	17	3

*Numbers in parentheses indicate the unit equivalents of the standard section of cyclical sediments for the Middle Conemaugh series.

Brilliant Cut has been the site of three landslides since 1930. The first two occurred in August, 1930 and in April, 1931, respectively, during excavation operations for relocation of the railroad tracks and for construction of the highway. A third slide, the rock-slump type, occurred in March, 1941. Its immediate cause was presumably the large lateral pressure exerted on the slump block by water which, as the result of a thaw, had accumulated in a large vertical fissure extending from the top of the hill down through the Birmingham shale. Water could not drain from the fissure because the outlet at the position of the Duquesne coal was blocked by ice which had not thawed. The movement was rapid and with a backward rotation, totaling about 15 feet at the head of the slump.

5.30 Across the Allegheny River to left, note two topographic levels, one about 50 feet above the river; the other, 200 feet higher. The upper surface is the Parker strath erosion level developed just prior to Illinoian glaciation, according to Leverett. The name is derived from the settlement of Parker's Landing 50 miles up the Allegheny River where the erosion surface is well shown. The Cathedral of Learning, the starting place of our trip, is at the same elevation. About 50 feet of Illinoian outwash veneers the Parker strath in the Allegheny drainage system. The lower terrace on which the water-pumping stations are built is composed of outwash from the Wisconsin glaciers which, like the Illinoian, terminated to the north. Since this outwash is about 130 feet thick and the river has cut into it only 50 feet, it must cut down 100 feet more before reaching bedrock. In the downtown Pittsburgh area the permeable Wisconsin outwash sand and gravel yield large supplies of groundwater which is used extensively for air conditioning.

MILEAGE	
5.50	**Slow.** In exposure on right note the evidence for an ancient landslide in the discordant shales dipping between 20° and 25° and underlying the nearly horizontal SALTSBURG sandstone. Such non-tectonic, discordant bedding is rather common in the Pittsburgh area. Exposures for the next four miles are mostly LOWER CONEMAUGH shales and sandstones.
5.70–6.00	On right, the same shale-sandstone contact is concordant in most places.
6.15	LOWER SALTSBURG sandstone on right.
6.40	Nadine Pumping Station on right. On left, across river, is a good view of the Parker strath level.
6.55	On right, near road level, thin layer of nodular WOODS RUN limestone. Fossiliferous shale containing *Sowerbyella* brachiopods lies below the limestine. The Woods Run limestone is one of four persistent marine units in the CONEMAUGH of the Pittsburgh area.
6.95	Note evidence for landslide. The highway has been "blacktopped" over slide area. Like the Washington Boulevard landslide, the one at this locality was triggered by heavy rainfall in April, 1948. Besides the rainfall, other contributing factors were (1) the steep undercut bank of the Allegheny River; (2) previous soil creep or slumping which disturbed the mantle so as to allow easy saturation; (3) additional weight from talus debris at the head of the slide; (4) funneling of surface drainage into a bowl-shaped ravine, and (5) redbed-type bedrock which becomes slippery when wet. Movement occurred over a period of four days at the rate of about one inch per hour. It displaced the highway and the railroad tracks a lateral distance of 12 feet and made the house unsafe for occupancy. This landslide is classed as the earthflow type.
7.20	Blawnox community (named for Blaw-Knox Company) across river. Good view of Parker strath beyond.
7.90	Trees on right lean toward road because of soil creep and slumping.
8.50–8.85	On right BUFFALO (LOWER CONEMAUGH) shales and sandstones.
8.95	VERONA, PA.—Continue straight.
9.80	OAKMONT, PA.—Continue straight.
10.55	**Turn left** on Hulton Road and cross railroad.
10.80	Bridge over Allegheny River.
11.15	**Turn right** at north end of bridge in village of Harmarville on Pennsylvania Route 28.
11.35	Harmar Coal Company mine on left. UPPER FREEPORT (ALLEGHENY) coal, 7½ feet thick, is mined. It is the so-called "thick Freeport bed" found within an area measuring about 8 by 15 miles. Elsewhere the bed averages 3 to 4 feet in thickness. The coal, lying 100 feet below surface at the mine, is reached by a shaft and is loaded directly into river barges at the mine tipple.
11.85	Junction, Pennsylvania Routes 28 and 910. **Keep right** on Route 28.
12.35	Gulf Research and Development Company laboratory built on Parker strath level to left.

MILEAGES Total	Trip	
12.60		**Bear right** at entrance to Pennsylvania Turnpike.
12.85	47.40	Allegheny Valley Interchange ticket booth, Pennsylvania Turnpike. The Pennsylvania Turnpike now extends from the Ohio line to the Philadelphia area. The highway has no intersections, sharp curves, or steep slopes. Entrance to and exit from the Turnpike is by 25 conveniently spaced cloverleaf interchanges such as this one. Seven tunnels, totaling 6.7 miles in length, cut through the highest ridges of the Appalachian Mountains, thus saving about 9,000 feet of vertical climb.

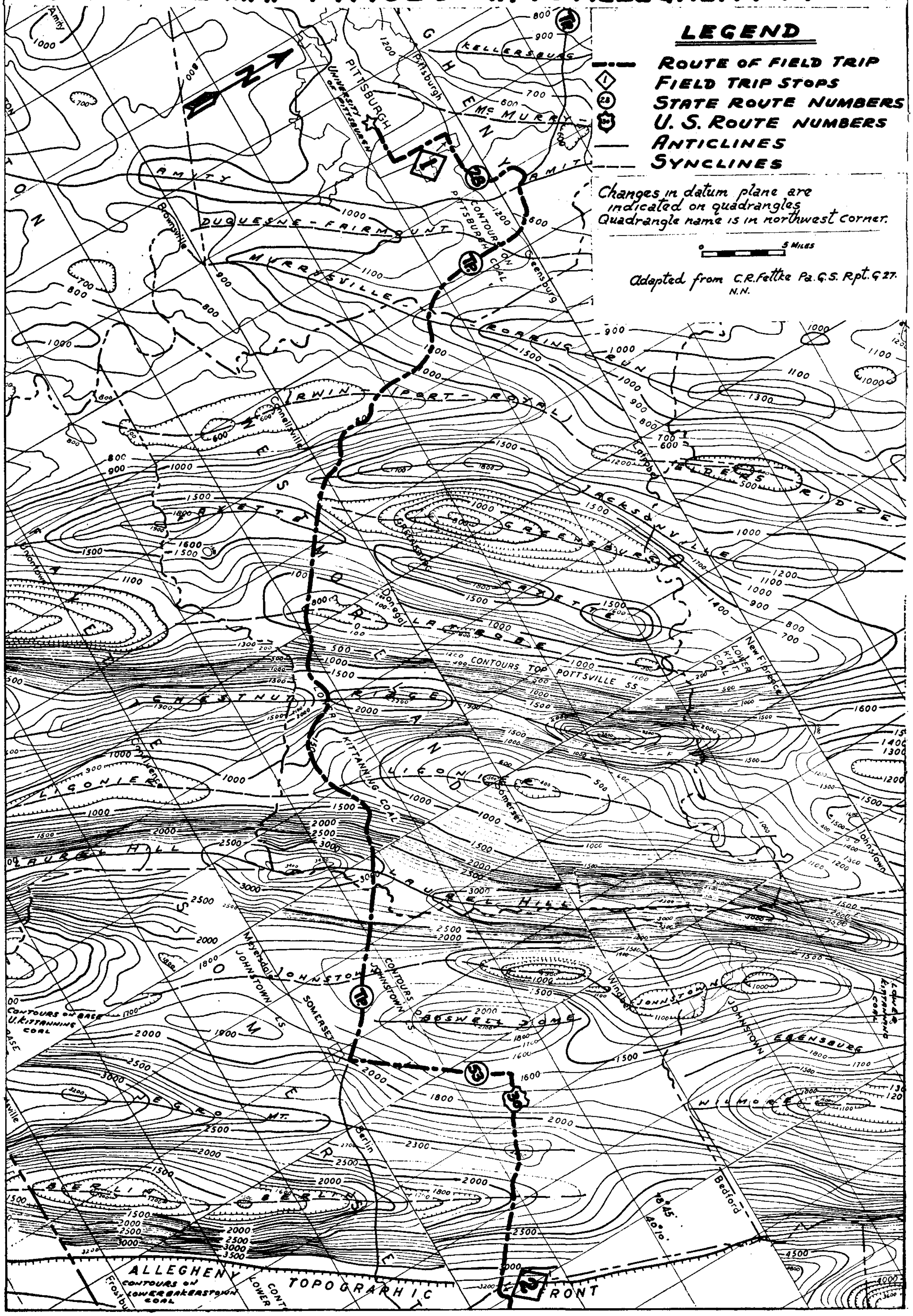
Extensive geologic work was done along the route prior to and during construction by Dr. A. B. Cleaves, Turnpike Geologist. A "Guidebook to the Geology of the Pennsylvania Turnpike, Carlisle to Irwin" has been published by the Pennsylvania Topographic and Geologic Survey (Bulletin G24, 1949; Cleaves and Stephenson).

Most of the material used for the Turnpike portion of the itinerary between Carlisle and Irwin has been taken directly from Dr. Cleaves' work. The Pittsburgh Geological Society gratefully acknowledges the use of this information.

Note: Re-set odometer at Turnpike mileage 47.40, the distance between the Allegheny Valley Interchange and the Ohio line, so that mileage can be read directly from the Turnpike mile posts. Note that the mile posts are situated in the line of delineators, or reflector markers, on right side of highway. In addition, every 1/10 (one-tenth) mile is stenciled on delineator posts just beneath reflector buttons, e.g., 7.5, 7.6, etc. (Some of these 1/10 mile markers have been removed during repairs on shoulders and by accidents). With these aids, all stations noted in the itinerary should be easily located.

MILEAGES Total	Trip	
12.90	47.45	**Keep right** toward Philadelphia.
12.95	47.50	One-foot coal seam (LOWER CONEMAUGH, between BRUSH CREEK and AMES marine limestones) exposed in bank to left. Wisconsin glacial outwash exposed at end of bridge to left (top of cut) about 100 feet above river level.
13.15	47.70	Turnpike bridge across Allegheny River.
13.65	48.20	South end of bridge. Same coal as at mileage 12.95 exposed in highway cut. Sandstone above coal grades laterally into sandy shale. Strata here rising about 20 feet per mile south-southeast toward the crest of the Amity anticline which lies ¾ of a mile to the south.
14.05	48.60	On left, at top of cut, ILLINOIAN glacial outwash.
14.45	49.00	Axis of AMITY ANTICLINE.
14.80	49.35	Oakmont restaurant and service station.
15.50	50.05	Cut on left exposes marine AMES (MIDDLE CONEMAUGH) limestone lying within the PITTSBURGH redbeds. Terrace is at base of BIRMINGHAM shale. The DUQUESNE coal, a few inches thick, underlies the BIRMINGHAM shale and is exposed at the southeast end of the cut.
15.75–16.15	50.30–50.70	Thin DUQUESNE coal in cuts on left.
16.30	50.85	Massive MORGANTOWN (MIDDLE CONEMAUGH) sandstone at top of cut. BIRMINGHAM shale at road level. Note prominent jointing.
16.65	51.20	MORGANTOWN sandstone at road level. Base is disconformable.
16.70–17.10	51.40–51.80	Redbeds above MORGANTOWN sandstone.
17.30	52.00	Bridge over Plum Creek. Approximate axis of DUQUESNE SYNCLINE.
17.80	52.50	UPPER CONEMAUGH gray shale and red claystone.
18.90	53.60	CONEMAUGH-MONONGAHELA series contact (at base of PITTSBURGH coal). Exposed at top of cut on left at end of bridge over Turnpike. Coal is six feet thick.
19.35	54.05	Top of PITTSBURGH coal in north end of cut. LOWER MONONGAHELA shale and sandstone above.
19.95–20.25	54.65–54.95	LOWER MONONGAHELA shale and sandstone. Pittsburgh coal strip mine right, just before cut.

STRUCTURE MAP PITTSBURGH TO ALLEGHENY FRONT



MILEAGES Total	Trip	
20.30	55.00	On left, strip mine in PITTSBURGH coal directly southeast of overpass. Turnpike built on fill in former strip mine.
20.50	55.20	On right, subsidence of surface shale over mined-out PITTSBURGH coal.
20.70	55.40	Former PITTSBURGH coal strip mine. Contour of hill has been mostly restored by back-filling. Coal blossom of Pittsburgh bed on right.
21.50	56.20	Gray and red shale (LOWER MONONGAHELA).
21.65	56.35	Bridge over U. S. Route 22. Continue straight on Turnpike.
21.75	56.45	Exit to Highway 22, Pittsburgh Interchange, Pennsylvania Turnpike.
22.70	57.40	UPPER CONEMAUGH shale.
23.00	57.70	On right, cut exposes BIRMINGHAM shale above shaly DUQUESNE coal (MIDDLE CONEMAUGH). The strata are rising gently southeastward toward the crest of the MURRYSVILLE ANTICLINE.
23.20	57.90	Marine AMES limestone in cut on left. Note slump near east end of cut.
23.50	58.20	UPPER SALTSBURG sandstone (MIDDLE CONEMAUGH) on left.
24.00	58.70	BUFFALO shale and sandstone.
24.25	58.95	Bridge over Turtle Creek. Westmoreland County line; leaving Allegheny County.
24.35	59.05	Cut on right exposes a one-foot bed of marine BRUSH CREEK (LOWER CONEMAUGH) limestone above BRUSH CREEK coal (six inches).
24.85	59.55	Bridge over Turnpike. Cut on right shows MAHONING (LOWER CONEMAUGH sandstone above MAHONING coal (about five inches). Note small thrust fault that offsets coal. This exposure is at the approximate axis of the MURRYSVILLE ANTICLINE.
25.20	59.90	Pipeline (Equitable Gas Company, 10-inch line) crosses Turnpike and Lyons Creek.
25.65	60.35	LOWER CONEMAUGH sandstone with slight dip to southeast into IRWIN (PORT ROYAL) SYNCLINE.
25.75	60.45	Pipelines (N. Y. State Natural Gas Corporation) cross Turnpike. One 12-inch line and one 16-inch line.
25.95	60.65	BRUSH CREEK coal horizon. Marine BRUSH CREEK (LOWER CONEMAUGH) black shale and thin limestone above.
27.30	62.00	Strip mine on hill to left in PITTSBURGH coal (BASE OF MONONGAHELA).
27.50	62.20	PITTSBURGH limestone (fresh-water) in cut on right.
		PITTSBURGH coal strip mine higher on hill.
28.20	62.90	Massive SEWICKLEY (LOWER MONONGAHELA) sandstone above interbedded shale and sandy shale.
28.35	63.05	BENWOOD (MIDDLE MONONGAHELA) fresh-water limestone and shaly limestone at underpass. Massive sandstone overlies limestone.
28.55	63.25	Harrison City maintenance building on left.
28.85	63.55	Pleasant Valley restaurant and service station on left.
29.95	64.65	Cut in BENWOOD limestone on left.
30.35 30.90	65.05–65.60	Poorly exposed BENWOOD limestone on left.
31.15	65.85	Bridge over Brush Creek. Village of Irwin to right.
31.20	65.90	MIDDLE MONONGAHELA shale, sandstone, and fresh-water limestone.

MILEAGES Total	Trip	
31.70	66.40	Cut in UPPER MONONGAHELA shale. This is at the approximate axis of the IRWIN (PORT ROYAL) SYNCLINE. Beds are near PENNSYLVANIAN-PERMIAN contact.
32.10	66.80	Cut in lowermost PERMIAN beds. Thin coal is probably WAYNESBURG A and is the highest Paleozoic stratigraphic unit seen on the trip.
32.45	67.15	Irwin Interchange, Pennsylvania Turnpike. Toll gate to right. Continue east on Turnpike.
32.50	67.20	Cut on left exposes WAYNESBURG coal, the boundary between the PENNSYLVANIAN and PERMIAN systems. Note that there is complete conformity at the contact. The original systematic subdivision was made on a floral basis. A section of the cut is as follows:

	ft.	in.
PERMIAN SYSTEM		
Shale, gray, sandy, weathered at top	22	0
PENNSYLVANIAN SYSTEM		
Coal—WAYNESBURG		11
Clay—WAYNESBURG		11
Coal—WAYNESBURG	1	10
Clay—WAYNESBURG	1	11
Coal—WAYNESBURG		9
Clay and shale		11
Sandstone, thin-bedded, micaceous		5

34.50	69.20	REDSTONE (LOWER MONONGAHELA) fresh-water limestone poorly exposed in cut on right. Channeling at base of overlying sandstone cuts out limestone in places.
35.25	69.95	Abandoned PITTSBURGH coal strippings left and right of Turnpike. Backfilling has restored the topography somewhat. Dip is northwest here on northwest flank of the GRAPEVILLE ANTICLINE.
35.55	70.25	Large dump at PITTSBURGH coal mine visible to right. Strip mine in same coal ahead.
35.65	70.35	Bridge over Turnpike. The cut exposes the following UPPER CONEMAUGH beds:

	ft.	in.
Sandstone, CONNELLSVILLE, gray, cross-bedded with interbedded sandy shale	18	0
Carbonaceous shale and coal stringers	2	6
Coal, LITTLE CLARKSBURG		8
Limestone, gray, brecciated, with secondary nodular siderite	2	0

35.95	70.65	Arona Viaduct over Little Sewickley Creek and the Hempfield Branch of the Pennsylvania Railroad.
36.20	70.90	Arona cut. This high cut was made because of a slump which occurred during construction. Movement of sandstone blocks above shale was facilitated by intersecting vertical joints. CLARKSBURG (UPPER CONEMAUGH) limestone, interbedded with red shale is overlain by 20 to 30 feet of sandstone. The beds are rising southeastward toward axis of GRAPEVILLE ANTICLINE.
37.10	71.80	Approximate axis of GRAPEVILLE ANTICLINE. Shale and sandstone (UPPER CONEMAUGH).
39.35	74.05	Axis of GREENSBURG SYNCLINE. Occasional exposures of CONEMAUGH shale.
40.00	74.70	Hempfield restaurant and service station.
40.30	75.00	BUFFALO (LOWER CONEMAUGH) sandstone on left. Underlain by dark BRUSH CREEK marine shale and BRUSH CREEK coal (16 inches) in creek bed right of road.
40.55	75.25	West end of New Stanton Interchange. BRUSH CREEK coal and shale again exposed.
41.15	75.85	MAHONING (BASAL CONEMAUGH) sandstone and interbedded shale at axis of the FAYETTE ANTICLINE which separates the GREENSBURG and LATROBE-CONNELLSVILLE SYNCLINES

MILEAGES Total	Trip	
41.30	76.00	Bridge over Turnpike.
41.40	76.10	ALLEGHENY-CONEMAUGH series contact. MAHONING sandstone and shale underlain by the 4-foot UPPER FREEPORT coal. Top of coal is the series boundary.
41.60	76.30	Extensive strip mining on right in UPPER FREEPORT coal. Note back-filling of mined area.
41.80	76.50	Pipeline (Manufacturers Light and Heat Company, 8-inch line) crosses Turnpike.
42.10	76.80	New Stanton restaurant and service station. UPPER FREEPORT coal has been extensively stripped left of Turnpike, just east of station. Dip is east.
42.50	77.20	BRUSH CREEK (LOWER CONEMAUGH) shale poorly exposed. The shale is black, calcareous and contains marine fossils.
42.80	77.50	CHESTNUT RIDGE appears straight ahead in distance.
43.50	78.20	UPPER CONEMAUGH platy sandstone underlain by red shale containing three 1- to 2-foot fresh-water limestone beds. Dip is 6° east on east flank of FAYETTE ANTICLINE.
43.70	78.40	Bridge over Turnpike.
44.10	78.80	PITTSBURGH coal beneath Turnpike immediately west of bridge. Extensive mine subsidence exists at this locality. During Turnpike construction the strata were excavated to a level below the coal and the area was back-filled. Note evidence of former entry in PITTSBURGH coal and a more recent opening in REDSTONE coal on hill above.
44.40	79.10	REDSTONE (LOWER MONONGAHELA) coal approximately 44 inches thick, underlain by 5 feet of REDSTONE limestone. Dip is 2° east.
45.45	80.15	Bridge over Turnpike.
45.60	80.30	Bridge over Turnpike.
45.70	80.40	BENWOOD (MIDDLE MONONGAHELA) limestone in cut on left. Good view of Chestnut Ridge ahead. Chestnut Ridge is a topographic feature resulting from the CHESTNUT RIDGE ANTICLINE, the westernmost of the conspicuous foreland folds of the Appalachians.
46.10	80.80	PITTSBURGH coal-mine shaft north of Turnpike. Road crosses axis of the LATROBE-CONNELLSVILLE SYNCLINE.
46.50	81.20	BENWOOD limestone on west flank of CHESTNUT RIDGE ANTICLINE.
47.00	81.70	Mine subsidence area. Note "dips" in the Turnpike. Pittsburgh coal lies about 150 feet below the surface. Strata exposed along the highway and in the railroad cut include, in descending order, BENWOOD fresh-water limestone, SEWICKLEY sandstone and coal (4 feet), and FISHPOT fresh-water limestone, all of which belong to the MONONGAHELA series.
47.45	82.15	REDSTONE (LOWER MONONGAHELA) coal (5½ feet) and REDSTONE fresh-water limestone (5 feet) below. Note extensive stripping operations in both the REDSTONE coal and the underlying PITTSBURGH coal (8½ feet) on both sides of the Turnpike. This is the easternmost occurrence of PITTSBURGH coal along the Turnpike. The coal here dips 4° northwest.
48.20	82.90	UPPER CONEMAUGH exposure. PENNSYLVANIAN SYSTEM

Conemaugh Series	ft.	in.
Sandstone and shale, interbedded, CONNELLSVILLE	12	0
Coal, LITTLE CLARKSBURG		3
Sandstone, shaly	19	0
Shale, black, thin-bedded	1	0
Sandstone, shaly	3	0
Limestone, fresh-water, with siderite concretions, CLARKSBURG	2	8
Shale, with siderite concretions	1	7

MILEAGES Total	Trip	
48.40	83.10	Mt. Joy cut, exposing MIDDLE CONEMAUGH beds. The cut is 97 feet deep, 1,200 feet long and nearly 300 feet wide at the top. From it 500,000 cubic feet of rock was excavated. Strata exposed from the top down are MORGANTOWN sandstone (75 feet), massive, cross-bedded, medium-grained; WELLERSBURG (ELK LICK) coal underlain by clay with nodular limestone and interbedded shale and sandstone with local coal lenses. Note steepening of dip on northwest flank of CHESTNUT RIDGE ANTICLINE.
48.85	83.55	Bridge. SALTSBURG (MIDDLE CONEMAUGH) sandstone, platy to medium-bedded.
49.20 **49.40**	83.90– 84.10	Cut exposes LOWER CONEMAUGH and UPPER ALLEGHENY beds. The section may be tentatively divided into cyclothems as follows:

PENNSYLVANIAN SYSTEM

	ft.	in.
Conemaugh Series		
Brush Creek Cyclothem		
Shale, BRUSH CREEK, carbonaceous, fossiliferous, marine	12	0
Coal, BRUSH CREEK		7½
Clay shale, gray, BRUSH CREEK	15	0
Sandstone, grayish, fine-grained	4	0
Mahoning Cyclothem		
Shale, variegated red and green	10	0
Shale, with limonitic concretions and nodules	4	0
Sandstone, MAHONING, fine-grained	0 to 15	
Allegheny Series		
Upper Freeport Cyclothem (Marine phase absent)		
Coal—UPPER FREEPORT (channeled by Mahoning sandstone)	1	10
Shale—UPPER FREEPORT (channeled by Mahoning sandstone)		1
Coal—UPPER FREEPORT (channeled by Mahoning sandstone)	1	1
Shale—UPPER FREEPORT (channeled by Mahoning sandstone)		1
Coal—UPPER FREEPORT (channeled by Mahoning sandstone)		11
Shale, with limonite nodules	15	0

Note: South of the Turnpike and below highway grade there are two accessible, abandoned openings in the LOWER FREEPORT coal.

49.60	84.30	ALLEGHENY SERIES. Dip is 10° west. Contact between ALLEGHENY and POTTSVILLE is concealed, but the HOMEWOOD sandstone, top member of the Pottsville series, is well exposed immediately to the east.
49.90 **50.15**	84.60– 84.85	POTTSVILLE series exposure. Medium-bedded to platy sandstone, black shale, clay shale, and occasional thin coal seams dipping about 8° west. Note the well-developed cross lamination.
50.50	85.20	Contact between POTTSVILLE (PENNSYLVANIAN) series and the MAUCH CHUNK (MISSISSIPPIAN) formation occurs here but is concealed. Upper part of the MAUCH CHUNK is exposed on left in a 5-foot cut. Red shale at top and bottom of cut separated by greenish gray shale and sandstone in the middle.
50.60	85.30	Top 4 feet of GREENBRIER (MISSISSIPPIAN) limestone brought to the surface by local fold on west flank of CHESTNUT RIDGE anticline. The light gray, massive limestone is exposed close to road level on left. In this area the limestone is about 15 feet thick. It thickens southwestward toward the type locality in Greenbrier County, West Virginia, where it ranges between 475 and 750 feet in thickness. Stratigraphically, the marine Greenbrier limestone on Chestnut Ridge is separated from the base of the Mauch Chunk formation by about 50 feet of red shale and sandstone. Twenty-five

MILEAGES Total	Trip	
		miles southeast (southern Somerset County, Pennsylvania) where the Mauch Chunk is 500 feet thick, it contains two marine limestones, one of rather local occurrence at the extreme base, the other about 200 feet higher. The upper bed is believed to be the correlative of the limestone exposed here on Chestnut Ridge.
51.45	86.15	GREENBRIER limestone at road level, near crest of CHESTNUT RIDGE ANTICLINE. Massive, fossiliferous, gray limestone 14-feet thick underlain by interbedded gray calcareous shale and thin limestone layers.
51.55	86.25	Turnpike crosses axis of CHESTNUT RIDGE ANTICLINE. Note that the axis of the fold does not coincide with the topographic crest. The Summit gas field is located about 25 miles southwest along the axis of this anticline on a very prominent dome. There were originally 27 producing wells in the field which has an overall length of 9 miles, but contains a central unproductive area. At present there are 23 producing wells. The largest of these had an open flow of 50 million cubic feet per day. Total production to date is 35 billion cubic feet. Gas is obtained mostly from the Onondaga chert of Middle Devonian age. Drilling in the Summit field revealed a much more complicated faulted structure in depth than was indicated by surface geologic data.
52.15	86.85	Contact between MAUCH CHUNK and overlying POTTSVILLE series.
52.40	87.10	Contact between POTTSVILLE and ALLEGHENY series. Strata dip about 4° east. POTTSVILLE sandstone forms abundant float and the rugged topography of Jacobs Creek valley on the east flank of Chestnut Ridge. Jacobs Creek flows under the Turnpike at this locality, and coal beds in the lower part of the ALLEGHENY series may be seen between the creek crossing and the overhead bridge.
52.60	87.30	Strip mine on left in a MIDDLE ALLEGHENY coal.
53.05	87.75	ALLEGHENY-CONEMAUGH contact. In this cut and just east of the bridge over the Turnpike the MAHONING (BASAL CONEMAUGH) sandstone directly overlies the UPPER FREEPORT (UPPERMOST ALLEGHENY). The coal ranges from 10 to 18 inches in thickness.
54.25 55.00	88.95– 89.70	BRUSH CREEK (LOWER CONEMAUGH) fossiliferous shale underlain by 6-inch BRUSH CREEK coal, dipping 3° east, poorly exposed. Laurel Hill in distance.
55.50	90.20	Donegal cut, immediately west of Donegal Interchange. In this deep cut the beds of nearly horizontal BUFFALO shale and sandstone (LOWER CONEMAUGH) are exposed.
55.95	90.65	Donegal Interchange. In cut to left of Turnpike, BRUSH CREEK shale and BRUSH CREEK coal horizon.
56.55	91.25	BRUSH CREEK coal and shale. Cut, immediately east of bridge over Turnpike at east end of interchange exposes a 9-inch seam of Brush Creek shale.
56.70	91.40	Rolling hills of Ligonier Valley to left.
57.05	91.75	BRUSH CREEK shale.
57.20	91.90	WOODS RUN (LOWER CONEMAUGH) marine limestone. The limestone is 3 feet thick, nodular and is underlain by variegated red and green shale. Dips 2° east and disappears beneath grade of road at bridge.
57.40	92.10	Approximate axis of LIGONIER SYNCLINE.
57.60	92.30	LOWER BAKERSTOWN (LOWER CONEMAUGH) coal adjacent to overhead bridge. Strata exposed from top down are black, fissile, marine FRIENDSVILLE shale (10 feet); LOWER BAKERSTOWN coal (8 inches); gray, plastic clay (12 feet).
58.00	92.70	View of Laurel Hill, a topographic ridge resulting from LAUREL HILL ANTICLINE. Note dip slope on northwest flank.
58.10 59.30	92.80– 94.00	LOWER CONEMAUGH. Beds nearly horizontal.

MILEAGES Total	Trip	
61.15	95.85	UPPER KITTANNING coal exposed in cut east of bridge over Turnpike. Dip is 5° west. The section in the cut is as follows:

PENNSYLVANIAN SYSTEM

Allegheny Series

	ft.	in.
Shale, sandy	10	0
Shale, carbonaceous, fissile	6	0
Coal—UPPER KITTANNING	1	6
Shale—UPPER KITTANNING		3
Coal—UPPER KITTANNING	4	6
Sandstone, buff		5
Limestone, dark gray, nodular, JOHNSTOWN	2	6
Fire clay	8	0
Sandstone, fine-grained, medium-bedded, grades eastward into shale		

62.00	96.70	POTTSVILLE series. The contact with the overlying ALLEGHENY series is concealed here but just to the east the POTTSVILLE is excellently exposed. It is characterized by strongly cross-bedded slabby sandstone which is locally conglomeratic. The HOMEWOOD sandstone at the top of the series is quite massive.
62.40	97.10	Contact of Pennsylvanian POTTSVILLE series and Mississippian MAUCH CHUNK formation. MAUCH CHUNK here composed of interbedded blocky sandstone and red shale. The dip is 7° west on the west flank of LAUREL HILL ANTICLINE.
62.75	97.45	Sandy LOYALHANNA (MISSISSIPPIAN) limestone poorly exposed on left.
63.10	97.80	BURGOON sandstone, top member of the Mississippian POCONO formation, exposed on left. The sandy LOYALHANNA limestone, together with the BURGOON sandstone, are logged as BIG INJUN sand by drillers in southwestern Pennsylvania oil and gas fields. BURGOON sand has been a prolific producer of natural gas with some oil in Greene and Washington Counties, Pennsylvania.
64.55	99.25	Crossing axis of LAUREL HILL ANTICLINE.
64.60	99.30	LOYALHANNA limestone quarry on right. This quarry was opened and operated during the construction of the Turnpike. The LOYALHANNA is described as either sandy limestone or calcareous sandstone of fine to medium grain size. A conspicuous feature of this rock is its intricate cross-bedding which is most evident on weathered surfaces, but can even be detected in a hand specimen. Its color ranges from bluish gray to greenish gray to pale red. Because of its distinctive lithology the formation is an important key bed for both surface mapping and subsurface correlation. Drillers usually report the top of this formation with accuracy. The contact with the underlying non-calcareous BURGOON is sharp. At the quarry 62 feet of the Loyalhanna is exposed. Dip is 2½° east.
64.85	99.55	**SLOW** at West Portal of Laurel Hill Tunnel. The LOYALHANNA is well exposed on left at the portal. Note cross-bedding.
65.70	100.40	MAUCH CHUNK exposed in long cut on left, starting at east portal of tunnel. Lithology is red shale and greenish sandstone.
66.30 67.40	101.00– 102.10	MAUCH CHUNK, interbedded red and green shale and sandstone.
67.45	102.15	Contact Mississippian MAUCH CHUNK formation and Pennsylvanian POTTSVILLE series. Red MAUCH CHUNK shale overlain by platy medium-bedded POTTSVILLE sandstone. Dip is 3° east.
67.75	102.45	POTTSVILLE-ALLEGHENY contact(?). Low cut exposes 3 feet of shaly coal (BROOKVILLE?) about 5 feet of sandstone (HOMEWOOD?).
68.10	102.80	Laurel Hill service station, now closed.
68.40	103.10	ALLEGHENY-CONEMAUGH contact. UPPER FREEPORT coal (3½ feet) formerly mined on left. Because of the danger of Turnpike subsidence into the mine workings, the coal was completely removed and the area back-filled.

MILEAGES Total	Trip	
68.80	103.50	BRUSH CREEK coal (12 inches) with fossiliferous BRUSH CREEK shale above. A fossil starfish was collected from this locality. Dip is 4° east.
69.60	104.30	AMES (MIDDLE CONEMAUGH) limestone and HARLEM coal below. One of the best exposures of Ames limestone and Harlem coal (16 inches) on the Turnpike occurs at the west end of this large cut. The Ames is black, calcareous, very fossiliferous shale 9 feet thick. Note that it is more shaly here than at mileage 15.50 to the west. It is best seen at the west end.
70.40	105.10	UPPER CONEMAUGH fresh-water limestone (7 to 8 feet), weathers buff. The limestone has been quarried north (left) of Turnpike.
71.15	105.85	Axis of JOHNSTOWN SYNCLINE.
71.60	106.30	Quemahoning cut. An abandoned tunnel which was excavated for a railroad that was never built is still open a few feet north of and below Turnpike grade. The rocks in the cut are UPPER CONEMAUGH shale and sandstone. Correlation in this part of the section is difficult because key beds such as persistent marine limestones and minable coals are lacking. From this cut to the Somerset Interchange, rocks are in UPPER CONEMAUGH.
73.70	108.40	Bridge over Turnpike.
75.15	109.85	LEAVE TURNPIKE, SOMERSET INTERCHANGE.
75.15	0.00	Ticket booth, Somerset Interchange. Re-set odometer at 0.00 here for trip mileage.
75.50	0.35	**Turn right** on Route 219 into Somerset, the county seat of Somerset County. Court house here is the highest one in Pennsylvania (elevation 2,190 feet).
75.85	0.70	**Turn left** on Route 53 toward Stoystown. For next 10 miles the route continues in the CONEMAUGH series along strike over rolling upland which contains few outcrops. The UPPER ALLEGHENY rocks are exposed only in valley bottoms.
81.15	6.00	Cross abandoned railroad grade at Friedens. An abandoned UPPER FREEPORT (TOP OF ALLEGHENY) coal mine visible on right. Continue on Route 53.
81.80	6.65	In distance to right, note strip mine in UPPER KITTANNING (MIDDLE ALLEGHENY) coal. Strata are rising to southeast (right) in this area toward the axis of NEGRO MOUNTAIN ANTICLINE.
84.45	9.30	UPPER FREEPORT coal mine on left.
84.80	9.65	Cross Beaverdam Creek. Note yellowish brown "sulphur water" derived from mine drainage.
85.05	9.90	MAHONING (BASAL CONEMAUGH) sandstone on left.
85.10	9.95	**Bear right** at traffic interchange on to Route 30. Outcrop of MAHONING sandstone at intersection. Continue eastward on Route 30.
85.40	10.25	Cross Stony Creek.
85.65	10.50	Small UPPER KITTANNING (MIDDLE ALLEGHENY) coal mine on left.
86.20 86.40	11.05– 11.25	On left, road bank exposes UPPER ALLEGHENY strata including two thin coal beds.
86.95	11.80	Mine in UPPER FREEPORT (36 inches) coal on right.
87.20	12.05	LOWER(?) FREEPORT coal rather poorly exposed in cut on left. FREEPORT(?) sandstone overlies the coal. Note the discordance between the coal and sandstone. Beds are rising eastward toward crest of NEGRO MOUNTAIN ANTICLINE.
87.80	12.65	Cut in shale and sandstone lying above thin MIDDLE KITTANNING coal.

MILEAGES Total	Trip	
87.90	12.75	Active mine in LOWER KITTANNING coal on right.
88.30	13.15	Active mine in UPPER KITTANNING coal on right.
88.55	13.40	The Grove well drilled by Peoples Natural Gas Company in 1949 is located in field south of the highway. The well bottomed in the SHRIVER (LOWER DEVONIAN) chert member of the ORISKANY group at a depth of 9,369 feet. There was a show of gas in the Shriver but the Oriskany sandstone, 172 feet thick, was dry. Gas shows were also found about 400 feet above the TULLY (UPPER DEVONIAN) limestone.
88.70	13.55	Weathered exposure of LOWER KITTANNING (LOWER ALLEGHENY) coal on left. Highway crosses axis of NEGRO MOUNTAIN ANTICLINE at this point at elevation 2,360 feet. The highest elevation in Pennsylvania (3,213 feet) is on Negro Mountain 20 miles to the southwest.
89.55	14.40	**Long View.** Fine view of Allegheny Mountain from this point, looking up dip slope. This mountain defines the ALLEGHENY TOPOGRAPHIC FRONT. The structural front lies a few miles to the east.
91.30	16.15	Crossing axis of BERLIN SYNCLINE.
91.75	16.60	Strip mine in LOWER BAKERSTOWN (LOWER CONEMAUGH) coal on right. The coal is 20 inches thick and represents one of the few Conemaugh coals that can be mined profitably.
92.60	17.45	Reels Corners.
93.90	18.75	Strip mine in UPPER FREEPORT coal on left.
94.15	19.00	Dip slope on northwest flank of Allegheny Mountain shows up well in distance to left.
95.35	20.20	Bald Knob Summit of Allegheny Mountains. Elevation, 2,906 feet. Large boulders of HOMEWOOD (UPPER POTTSVILLE) sandstone on right. Towers are for fire lookout, and for telegraph and television relay.
95.60	20.45	POTTSVILLE (PENNSYLVANIAN) and MAUCH CHUNK (MISSISSIPPIAN) shale contact exposed on left. The Loyalhanna limestone, which underlies the MAUCH CHUNK, is not exposed. The shallow valley developed on the Loyalhanna and lower MAUCH CHUNK is a characteristic topographic expression for those units. After crossing small creek, the road ascends a dip slope on BURGOON sandstone (top of POCONO).
96.75	21.60	**STOP 2.**

Grand View Point Hotel, ALLEGHENY FRONT. This escarpment marks the boundary between ALLEGHENY PLATEAU PROVINCE with its relatively flat lying Carboniferous strata, and the RIDGE AND VALLEY PROVINCE of highly folded Paleozoics. Outcrop of BURGOON (UPPER POCONO) sandstone on northwest side of highway. This is the Big Injun sand of the western Pennsylvania oil and gas fields.

From Grand View Point is a fine view of the closely folded Appalachians to the east. If the day is clear, Evitts Mountain will be seen 17 miles in the distance, where the early Silurian TUSCARORA sandstone rises to the surface on the western flank of NITTANY ARCH. Upper Cambrian GATESBURG rocks form hills 2 miles farther east and may be visible through Bedford Gap in Evitts Mountain. Evitts Mountain is offset on the north to form Dunning Mountain. Nearer and to the southeast, Buffalo and Wills Mountains are also formed by the Tuscarora along the flanks of Wills Mountain anticline; the northern tip of Wills Mountain is 11 miles east of Grand View. The prominent water gap west of Cumberland, Maryland, crosses the same anticline to the south. Ten miles to the south, the Carboniferous POTTSVILLE and POCONO form the nose of synclinal Savage Mountain. The Deer Park anticline, representing the structural front between the Valley and Ridge and the Plateau provinces lies between Grand View and the syncline of Savage Mountain. The axis of the SCHELLSBURG DOME of DEER PARK ANTICLINE will be crossed 5½ miles due east of Grand View, almost exactly halfway to the top of Wills Mountain. The ORISKANY sandstone, encountered at 7,050 feet below sea level in the Grove well on NEGRO MOUNTAIN ANTICLINE 8½ miles to the west, drops to about 7,400 feet below

Total MILEAGES	Trip	
		sea level along the BERLIN SYNCLINE, then rises rapidly from beneath Grand View to 1,600 feet and more above sea level at the SCHELLSBURG DOME. This is a rise of about 9,000 feet in 11 miles, or an average westward dip of nearly 9°. Latest Silurian and earliest Devonian limestones flanked by ORISKANY chert and sandstone are exposed in small quarries along this dome. Silty sandstones of Middle Devonian HAMILTON shales form the first escarpment both east and west of the dome. Nearer to Grand View, irregularly knobbed escarpments are formed by sandstone members of the UPPER DEVONIAN PORTAGE, CHEMUNG and CATSKILL groups. The body of water at a distance of 7 miles is Shawnee Park Reservoir, a recreational and conservation project at Schellsburg. Red soil in the fields below the hotel marks the outcrop of the CATSKILL red beds. All of these features can be observed at closer range as the buses travel eastward.
97.35	22.20	CATSKILL red beds (UPPER DEVONIAN) on left.
98.65	23.50	Fine view of ALLEGHENY FRONT, looking back and to north.
100.10	24.95	CHEMUNG (UPPER DEVONIAN) shale below CATSKILL red beds on right.
101.35	26.20	Road left to New Paris. HAMILTON (MIDDLE DEVONIAN) shale and siltstone exposed to left. Dip is northwest. Hill appearing ahead is at axis of SCHELLSBURG DOME of the DEER PARK ANTICLINE. The southwest plunge of the anticlinal axis is indicated by profile of hill.
102.00	26.85	ORISKANY (LOWER DEVONIAN) sandstone exposures on both sides of road.
102.60	27.45	Good view of ALLEGHENY FRONT escarpment to rear.
102.90	27.75	Highway crosses axis of SCHELLSBURG DOME, a part of the structural front separating the gently folded strata of the Appalachian Plateau province and the highly folded beds of the Valley and Ridge province.
103.50	28.35	Contact of ORISKANY (LOWER DEVONIAN) and overlying ONONDAGA (MIDDLE DEVONIAN) shale exposed near east end of cut. All but the upper 5 to 10 feet of ORISKANY sandstone in the cut is weathered to yellowish brown, fine-grained sand. Quarries in the Schellsburg dome area show that unweathered Oriskany sandstone is highly calcareous. The uppermost Oriskany consists of medium- to coarse-grained, hard, light gray quartzose sandstone. It is overlain by about 100 feet of Onondaga shale (Needmore shale facies) with about 10 feet of chert at the base and some chert near the top. The dark-colored NEEDMORE shale is also exposed in an excavation on the left about 150 yards east of this cut. The Oriskany-Onondaga section here closely resembles that of the Summit gas field in Fayette County to the west where production is obtained from both the Onondaga chert and the Oriskany sandstone. Onondaga, however, contains more chert at Summit than at Schellsburg.
103.90	28.75	Crossroads, village of Schellsburg, Pennsylvania.
104.65	29.50	Cut through upper part of HAMILTON (MIDDLE DEVONIAN) shale.
105.10	29.95	HAMILTON shale, dipping eastward.
105.30	30.15	HARRELL (UPPER DEVONIAN) shale on left, dipping eastward. Top of Tully limestone and bottom of Burket shale exposed along side road to left, but cannot be seen from highway.
105.70	30.55	HARRELL shale, dipping eastward.
106.00	30.85	BRALLIER (UPPER DEVONIAN) shale, dipping eastward.
106.15	31.00	BASAL CHEMUNG (UPPER DEVONIAN) to left.
107.05	31.90	CHEMUNG at crossroads. View of Evitts Mountain to east.
107.35	32.20	Axis of minor syncline on left.

MILEAGES Total	Trip	
107.75	**32.60**	Note abrupt reversal of dip. Dip here is 70° northwest.
108.25	**33.10**	DEVONIAN-SILURIAN contact. KEYSER (UPPER SILURIAN) limestone exposed in west end of cut and in quarry at west end. TONOLOWAY (UPPER SILURIAN) forms most of outcrop. It is more shaly and laminated than KEYSER. The age of the Keyser is questionable; some think it is Upper Silurian, others place it in the Lower Devonian.
108.55	**33.40**	Intersection, U. S. Route 30 and Pennsylvania Route 31. Keep straight on Route 30.
108.65	**33.50**	WILLS CREEK (UPPER SILURIAN) shale.
108.95	**33.80**	BLOOMSBURG (UPPER SILURIAN) red beds on right at road level. Wills Creek shale can be seen to north along Turnpike.
109.25	**34.10**	Notice water gap ahead on south side of highway where Raystown Branch of Juniata River cuts through the plunging northeast end of Wills Mountain. Quarry in TUSCARORA (LOWER SILURIAN) sandstone can be seen in distance.
109.60	**34.45**	Railroad crossing.
110.05	**34.90**	CLINTON (MIDDLE SILURIAN) shale exposed in cut on road to right. *Tentaculites* is an abundant fossil here.
110.35	**35.20**	Cross Raystown Branch of Juniata River.
110.70	**35.55**	Cut in CLINTON shale.
110.80	**35.65**	Evitts Mountain appears ahead on south side of highway. Note water gap east of Bedford where Raystown Branch of Juniata River cuts through the mountain which is held up by the resistant TUSCARORA sandstone.
112.20	**37.05**	Entering Bedford, Pennsylvania, county seat of Bedford County. Bedford Village was settled about 1750. It was originally called Raystown. Fort Bedford, built in 1758, was used during the French and Indian War and was General Washington's headquarters during the Whiskey Rebellion. The famous Bedford Springs summer resort is 2 miles south of town.
113.10	**37.95**	Intersection of Routes 30 and 220 in Bedford. Continue straight on Route 30.
113.65	**38.50**	LUNCH STOP.
114.35	**39.20**	Entering Raystown Branch water gap through Evitts Mountain. A fine outcrop of TUSCARORA (LOWER SILURIAN) can be seen on north side of river at west end of gap. The strata are nearly vertical.
114.60	**39.45**	TUSCARORA sandstone crosses river.
114.70	**39.55**	**STOP 3.**

Buses will stop on right in front of motel.

Bedford Narrows where Raystown Branch of Juniata River cuts through Evitts Mountain. View of cut along Turnpike from south side of gap. The highway cut is 2,200 feet long and exposes upended Early Silurian and Late Ordovician sandstones in the western limb of the Friend's Cove anticline or southern component of the great Nittany Valley arch. Stratigraphically, the beds dip to the northwest, but range from vertical to overturned where objectively the dip is as low as 40 degrees southeast. The strata are cut by numerous faults of small throw. Some are subvertical faults with strikes nearly paralleling the Turnpike; the cut exposes large faces of one or two faults of this type. Overthrust faults dipping to the west and thinning the sequence are numerous; the movement on the individual fault is small but the total effect may amount to reduction in apparent thickness of between 50 and 100 feet. At the east end of the cut, fault duplication has placed out of stratigraphic order 60 feet of interbedded red and green shaly sandstones.

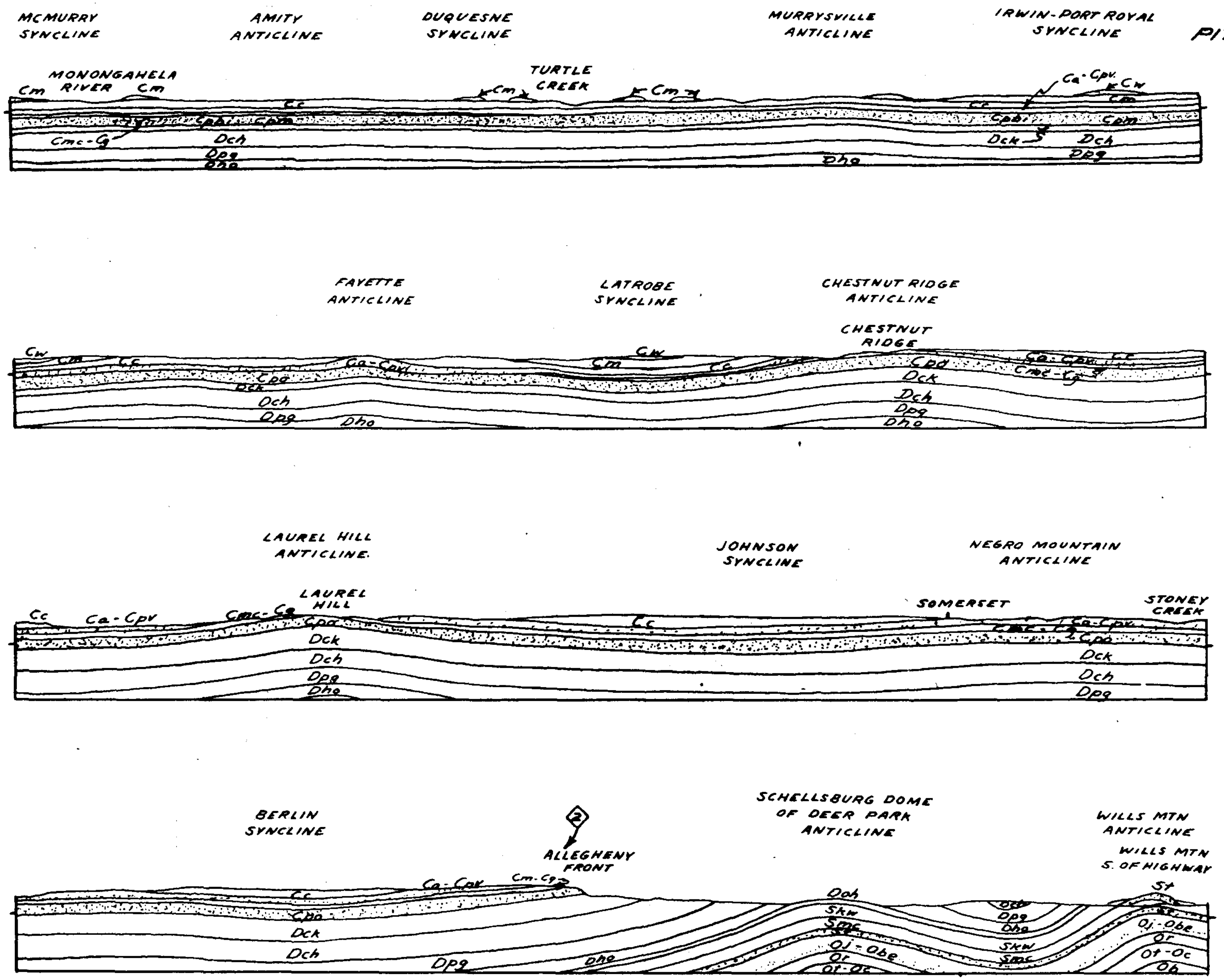
The section exposed, in descending order, according to measurements of F. M. Swartz (assisted by Doris Bye) is as follows:

	ft.
LOWER SILURIAN	
TUSCARORA SANDSTONE: thick bedded, resistant, white silica-cemented quartz sandstone or quartzite, making main ridge of Evitts Mountain. Used as ganister rock for silica brick in central Pennsylvania, the Tuscarora extends westward and northwestward into the gas.producing White Medina ("Clinton" Sand of Ohio), represented by the Whirlpool sandstone in the Niagara Gorge. Total thickness 400+ feet. Exposed in west end of cut....	165
UPPER ORDOVICIAN	
JUNIATA RED BEDS:	
Upper reddish quartzitic member: dark red quartzitic sandstone, with thin partings of red silty shale increasing below	60
Red siltstone member: red siltstone or mudstone and interbedded red sandstone	610
Lower sandstone member: thick bedded red medium-grained sandstone and some interbedded red mudstone; some minor interbeds of greenish sandstone in lower part	380
The Juniata correlates with the Queenston of Rochester and Niagara gorges.	
Thickness Juniata red beds	1,050
BALD EAGLE (OSWEGO) SANDSTONE: (intertonguing near top with Juniata facies) Ridge-making member: thick bedded, cross-bedded, greenish and much interbedded reddish sandstone or graywacke, with a few thin partings of gray or reddish shale; shale chips are common; a few ¼- to ½-inch pebbles of milky quartz occur in three thin lenses. These beds make subsidiary ridge of the mountain	215
Lower shaly member: interbedded greenish and reddish sandstone or graywacke and greenish and reddish silty mudstone that forms about a third of mass	320
Thickness of Bald Eagle (Oswego) sandstone	535
Reedsville shale:	
Upper sandy member containing *Orthorhyncula stevonsoni* fauna: carbonate-bearing greenish siltstone and some interbedded sandstone	47
(Bald Eagle red and green shaly sandstone duplicated by faulting at east end of cut; about 60 feet.)	

At Aliquippa Gap in Tussey Mountain, 5 miles to the east, the Bald Eagle sandstone formed by the lower shaly member and ridge-making member resting on the *Orthorhyncula* zone of the Reedsville, virtually lacks the red tongues so strikingly developed at Bedford Gap. The facies pattern of these strata is complex and unusual.

Total	Trip	
115.00	39.85	Turnpike crosses over Route 30. Beds exposed at bridge are REEDSVILLE shale.
116.25	41.10	Quarry in ORDOVICIAN limestone and dolomite on right.
116.35	41.20	ORDOVICIAN carbonates exposed in cut on both sides. The Lower Ordovician BELLEFONTE (BEEKMANTOWN) dolomite is overlain by Middle Ordovician LOYSBURG dolomitic limestone. Dip is northwest.
117.00	41.85	Small exposure, LOWER BEEKMANTOWN dolomite, nearly vertical.
117.20	42.05	Memorial Hospital of Bedford County. Approximate position of Friend's Cove fault. Here GATESBURG dolomite has been thrust over BEEKMANTOWN. The same fault along the Turnpike has thrust WARRIOR (CAMBRIAN) limestone against MARTINSBURG (UPPER ORDOVICIAN), directly east of the Narrows.

GENERALIZED STRUCTURE SECTIONS PITTSBURGH TO HARRISBURG, PENNSYLVANIA



0 1 2 3
MILES

ADAPTED 1955 FROM F.M. SWARTZ AND D.L. BYE, 1948

TRIASSIC
- ℞db DIABASE
- ℞n NEWARK SERIES

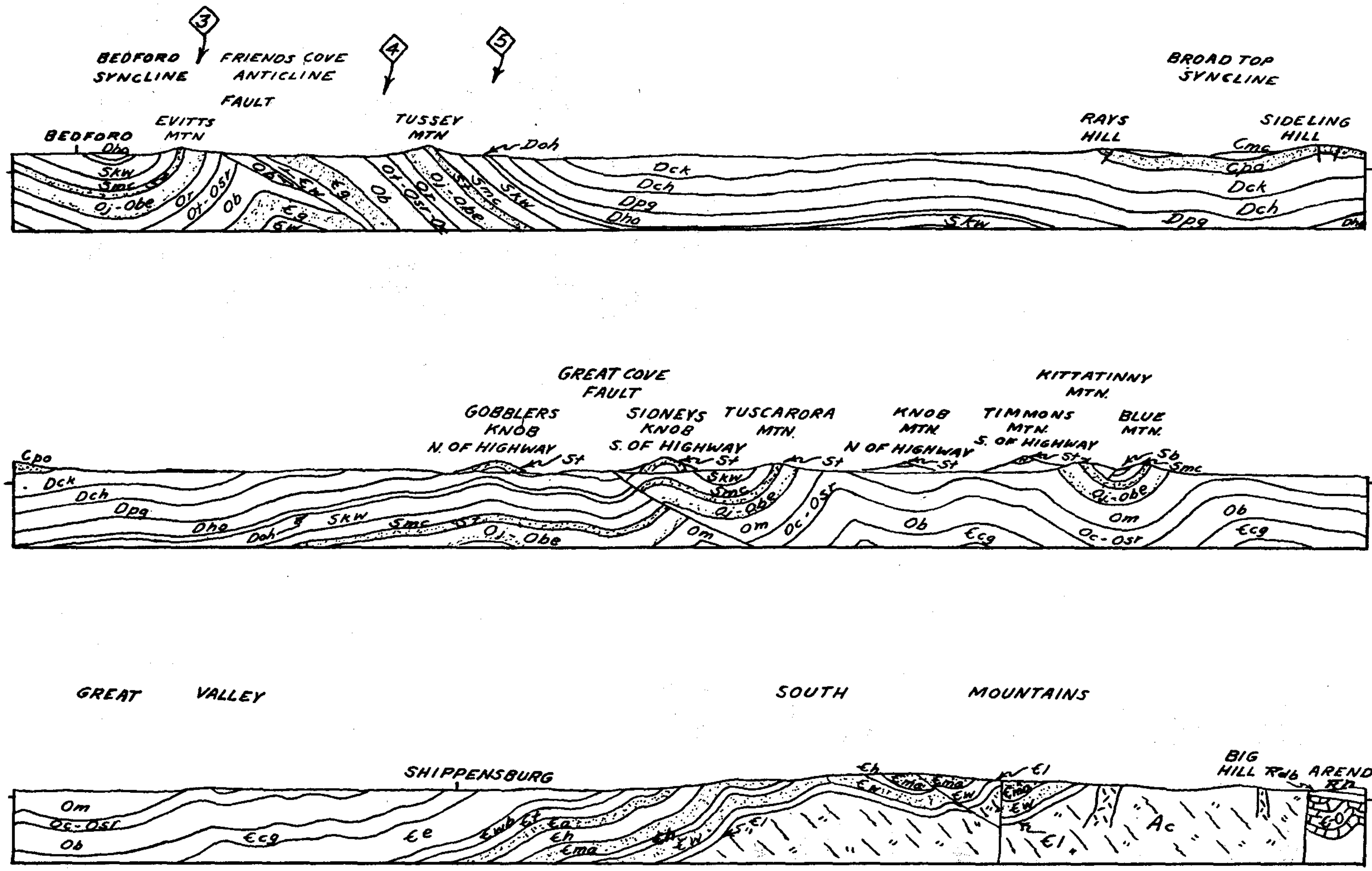
PERMIAN
- Cw WASHINGTON GROUP

PENNSYLVANIAN
- Cm MONONGAHELA GROUP
- Cc CONEMAUGH GROUP
- Ca-Cpv ALLEGHENY AND POTTSVILLE GROUPS

MISSISSIPIAN
- Cmc-Cg MAUCH CHUNK RED BEDS AND GREENBRIER LS
- Cpo POCONO Ss INCLUDING SUBSURFACE
  - Cpbi BIG INJUN SAND
  - Cpm MURRYSVILLE SAND

DEVONIAN
- Dck CATSKILL RED BEDS
- Dch CHEMUNG FM.
- Dpg PORTAGE AND GENESEE GPS.
- Dho HAMILTON, MARCELLUS, AND ONONDAGA FMS
- Doh ORISKANY AND HELDERBERG

SILURIAN
- Skw KEYSER TONOLOWAY, WILLS CREEK, AND BLOOMSBURG FMS.
- Smc McKENZIE SH. AND LS CLINTON GROUP
- St TUSCARORA SS



ORDOVICIAN

Oj - Obe JUNIATA AND BALD EAGLE FMS.
Or-Om REEDSVILLE AND MARTINSBURG SHS
Ot-Oc TRENTON AND CHAZY LSS
Oc-Osr CHAMBERSBURG AND STONES RIVER LSS
Ob BEEKMANTOWN LS AND DOL

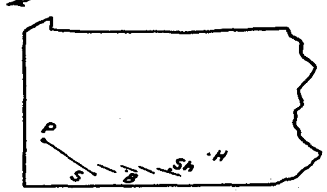
CAMBRIAN

Єg GATESBURG - SANDY DOLOMITE
Єcg CONOCOCHEAGUE LS
Єw WARRIOR LS
Єe ELBROOK LS
Єwb WAYNESBORO FM
Єt TOMSTOWN DOL
Єa ANTIETAM QTZITE
Єh HARPERS PHYLLITE
Єma MONT ALTO QTZITE
Єw WEVERTON SS
Єl LOUDOUN FM

PRE-CAMBRIAN

Ac CATOCTIN METAVOLCANICS

STOPS FOR GEOLOGY



OFFSETS IN LINE OF STRUCTURE SECTIONS

P = PITTSBURGH S = SOMERSET
B = BEDFORD Sh = SHIPPENSBURG
H = HARRISBURG

MILEAGES Total	Trip	
117.40	**42.25**	GATESBURG (UPPER CAMBRIAN) dolomite exposed in cut on overthrust side of Friend's Cove fault. The sandy phase, occurring in the Middle Gatesburg varies from sandy dolomite to sandstone with dolomite or silica cement. Here it is weathered to sandy soil and forms a topographic hill. This "sand" represents the lowest potential reservoir rock in this region and has been drilled in several deep wells in the valley, so far without success. It is believed to be present under most of the Allegheny Plateau area at considerable depth and has been reached by 3 wells, in Butler, Erie and Wyoming Counties. Interest is still held in this horizon for future deep drilling tests.
117.60	**42.45**	More sandy soil from weathered Gatesburg.
117.75	**42.60**	**Turn right** on road to Ashcom. Leave Route 30. Note water gap in Tussey Mountain to east.
117.95	**42.80**	New Enterprise Stone and Lime Company quarry may be seen to left in distance.
118.40	**43.25**	GATESBURG dolomite on left. Dip is southeast on southeast flank of Friend's Cove anticline. The dolomite gives a strong fetid odor when freshly broken.
118.75	**43.60**	BEEKMANTOWN dolomite exposed in bank of Raystown Branch, Juniata River to left.
118.95	**43.80**	STONEHENGE formation of BEEKMANTOWN exposed at north end of bridge over Raystown Branch. Dip is southeast.
119.15	**44.00**	Underpass beneath Turnpike. Approximate contact of STONEHENGE and NITTANY formations of the BEEKMANTOWN.
119.35	**44.20**	Road to right. Continue straight ahead on to overpass above Turnpike. NITTANY dolomite may be seen in Turnpike cut to right.
120.00	**44.85**	Bridge over Cove Creek. BELLEFONTE dolomite forms ledge across stream to left.
120.25	**45.10**	**Turn right** on quarry road, just west of quarry buildings.
120.35	**45.20**	**Keep right** through underpass and enter quarry.
120.65	**45.50**	**STOP 4.**

New Enterprise Stone and Lime Company quarry. A generalized section of the Middle Ordovician in the quarry and along the Turnpike is as follows:

ORDOVICIAN SYSTEM	ft.
Trenton group	
Salona formation. Limestone, dense, dark, cobbly to slabby, and then interbedded carbonaceous shales (top of quarry, total thickness not exposed).	
Nealmont formation. Limestone, dark gray, fine- to medium-grained, wavy impure partings, somewhat nodular in the upper portion	70
Black River (Bolarian) group	
Benner formation. Limestone, gray, fine-grained to dense (calcilutite), some creamy-weathering dolomitic ledges; a little limestone conglomerate near base	89
Hatter formation. Limestone, dark gray, fine-grained to coarsely crystalline (at base and top); argillaceous and silty, fossiliferous	60
Chazy group	
Loysburg formation. Limestone (calcilutite), light gray to dove, some striped beds ("tiger striped") representing alternations of argillaceous and dolomitic bands with limestone; thin massive dolomites, buff-weathering, transitional into Bellefonte dolomite below; ostracodes near base	183
Beckmantown group	
Bellefonte dolomite. Dolomite, massive ledged, alternating with dove calcilutites; exposed	36

Buses will turn around in quarry and retrace route to township road.

MILEAGES Total	Trip	
121.10	45.95	**Turn right,** proceed on township road under trestle.
121.60	46.45	Underpass beneath Turnpike. Note TUSCARORA sandstone float from west slope of Tussey Mountain in road cut.
122.10 122.85	46.95– 47.70	Beginning of water gap in Tussey Mountain cut by Raystown Branch of Juniata River. We proceed stratigraphically upward through greenish gray OSWEGO or BALD EAGLE (UPPER ORDOVICIAN) sandstone, JUNIATA (UPPER ORDOVICIAN) redbeds and TUSCARORA (LOWER SILURIAN) sandstone. The ORDOVICIAN-SILURIAN boundary occurs within this sequence. Retaining walls are constructed of TUSCARORA.
122.95	47.80	Sun Pipeline Company building.
123.15	48.00	Slag pile on left is from former Saxton Company Furnace which produced iron during World War I.
123.40	48.25	Everett Maintenance Building, Pennsylvania Turnpike.
123.50	48.35	**Bear left** at road intersection into Everett.
123.65	48.50	Underpass beneath Turnpike.
123.85	48.70	**Turn left** and cross bridge over Raystown Branch.
124.00	48.85	**Turn right** on to Route 30. Abandoned quarry across from intersection in HELDERBERG (LOWER DEVONIAN) limestones.
124.30	49.15	**Turn left** on to Route 26 toward Huntingdon. For next 3 miles the route follows a strike valley between Tussey Mountain (underlain by resistant TUSCARORA sandstone) on the left and Warrior Ridge (underlain by somewhat less resistant ORISKANY sandstone) on the right.
126.85	51.70	Note ORISKANY (LOWER DEVONIAN) sandstone outcrop along crest of Warrior Ridge to right.
127.55	52.40	**Turn right** toward Tatesville.
127.65	52.50	Crossroads. Keep straight.
127.70	52.55	**Turn left** into quarry.
127.90	52.75	**STOP 5.**

Pittsburgh Silica Company Quarry. ORISKANY sandstone is being quarried for glass, traction, grinding and molding sands. In this area the Oriskany Group is subdivided into an upper RIDGELEY sandstone member which is more than 100 feet thick and a lower SHRIVER chert member, about 150 feet thick. Above the Ridgeley lies the black, fissile NEEDMORE shale of Onondaga age. The quarry exposes only a part of the Ridgeley sandstone which is composed of medium-grained quartzose sand that is rather atypically limonite-stained. The sandstone is actually dipping southeastward but prominent joint planes inclined northwest may be mistaken for bedding. Fossils, although abundant in some other Oriskany exposures in the vicinity, are rather scarce here. An analysis of the sand after washing is:

	%
Alumina	0.13
Iron oxide	0.03
Titania	0.02
Lime	0.13
Magnesia	0.12
Alkalies	0.11
Loss on ignition	0.11
Silica	99.34
	99.99

MILEAGES Total	Trip	
		A section exposed 3 miles south of the quarry where the Turnpike cuts through the Oriskany in Warrior Ridge is as follows: (Measured by A. B. Cleaves)

	ft.	in.
LOWER DEVONIAN		
Onondaga Group		
Shale, NEEDMORE, black, fissile	—	—
Oriskany Group		
Sandstone, RIDGELEY, fossiliferous	114	0
Chert, SHRIVER, weathered, fragmentary	76	0
Helderberg Group		
Chert, NEW SCOTLAND, weathered, fragmentary	75	0
Keyser Formation		
Limestone, KEYSER, crystalline, very fossiliferous	15	0

Buses will turn around in quarry and retrace route to Route 30 at Everett (mileage, 124.30).

Total	Trip	
131.35	56.20	**Turn left** on to Route 30 toward Breezewood. Proceed through village of Everett.
131.70	56.55	HAMILTON (MIDDLE DEVONIAN) shale on left behind houses.
131.85	56.70	**Bear left.**
131.90 132.05	56.75– 56.90	Folded PORTAGE (UPPER DEVONIAN) shale in cut on left.
132.55	57.40	Interbedded shale and thin-bedded sandstone of PORTAGE on left.
133.85	58.70	CHEMUNG (UPPER DEVONIAN) shale and sandstone.
133.90 135.25	58.75– 60.10	Red soil in interfingering zone of UPPER CHEMUNG and LOWER CATSKILL (UPPER DEVONIAN) beds. The red continental Catskill (deltaic-alluvial plain) rocks westwardly overide, with interfingering, the grayish brown, marine Chemung. In this general area "*Spirifer disjunctus*" is found in Catskill-like lithology. Eastward the Catskill phase becomes more predominant so that in the Harrisburg region the beds are entirely continental. Clear Ridge Cut, along the strike from here on the Turnpike, exposes about 2,000 feet of Chemung and Catskill in a classic section illustrating the gradational nature of the two facies.
135.65	60.50	The folded CATSKILL redbeds crop out in rather abundant exposures for the next 5 miles.
137.15	62.00	Note small monoclinal flexure in CATSKILL on left.
137.95	62.80	Bridge over Raystown Branch, Juniata River.
138.00	62.85	Note thin green stringers interbedded with red layers in cut to left.
139.70	64.55	Keep straight. Hancock road (Route 126) to right.
140.10	64.95	**Turn right** on to approach to Turnpike.
140.25	65.10	Ticket Booth, Breezewood Interchange, Pennsylvania Turnpike.
140.60	162.90	Enter Turnpike. **Reset odometer** at Turnpike mileage 162.90 at east end of bridge over approach to Turnpike.
141.10	163.40	Note "Fishtail" structure of BROAD TOP SYNCLINE in distance to left. The Benedum-Trees Oil Company drilled an Oriskany test well in October, 1954, but abandoned at a depth of 11,743 feet in the Middle Devonian without reaching their goal.
142.45	164.75	West Portal of Rays Hill tunnel. CATSKILL redbeds. Soft, earthy, and arenaceous red shale.

MILEAGES Total	Trip	
		In this tunnel the POCONO sandstones rise sharply to the west. The CATSKILL redbeds are exposed at the west portal. The tunnel is driven mostly through POCONO and the overlying MAUCH CHUNK red shales are exposed at the east portal. Leaving tunnel, ridge in near distance is made by POCONO, raised in secondary anticline complicating the BROAD TOP synclinorium.
		The area between Rays Hill and Sideling Hill to the east is a gentle synclinorium, complicated by a minor anticline that brings the Pocono to the surface approximately midway between the tunnels. To the north, in this basin, progressively younger strata occur so that the productive coal measures of the Allegheny series are found in this, the Broad Top Coal Field.
143.15	165.45	East Portal, Rays Hill tunnel. MAUCH CHUNK red shale exposed at portal.
143.70	166.00	MAUCH CHUNK red shale.
145.40	167.70	POCONO sandstone, brought to the surface in a minor anticline. MAUCH CHUNK red shale crops out both to the east and west.
146.60	168.90	Excellent view of the rim of the Broad Top coal field may be seen in distance to north. The rim is upheld by resistant Pottsville sandstone. Sideling Hill, straight ahead, represents the eastern side of the Broad Top synclinorium, and is a topographic feature formed by outcropping Pocono sandstones.
147.00	169.30	West Portal Sideling Hill Tunnel. Approach to cut and tunnel is in the POCONO sandstone and shale. The entire tunnel is driven through the Pocono group. The strata, which dip west at a low angle into the Broad Top synclinorium, are complicated by faulting.
148.25	170.55	East Portal Sideling Hill Tunnel. This is the longest tunnel on the Turnpike (6,632 feet).
148.80	171.10	CATSKILL red shale and sandstone. Contact with overlying Pocono concealed to the west. In this cut the strata are strongly fractured and folded.
149.10	171.40	Cove Valley restaurant and service station. Note high terrace gravel on red shale near viaduct. Fine view of Sidneys Knob to right. A topographic feature formed by rapidly plunging anticlinal nose. Tuscarora quartzite.
151.50 151.80	173.80– 174.10	CATSKILL, soft red, arenaceous shales with interbedded sandstones.
153.00	175.30	Approximate contact of CATSKILL and CHEMUNG. Interbedded red and green shales and grayish green sandstones. A one foot conglomeratic bed is also present.
153.10	175.40	Bridge over the Turnpike. Cut in Chemung, interbedded red sandstone and greenish gray shale.
153.85	176.15	Base of Chemung—ALLEGRIPPIS(?) sandstone. 15 feet medium-bedded sandstone overlain by 5 feet of conglomerate.
153.90	176.20	PORTAGE (UPPER DEVONIAN) shale—Brallier. Olive-drab shale with occasional interbeds of grayish green sandstone. Much of the shale breaks down into pencil fragments. Fossiliferous.
154.45	176.75	PORTAGE shale—Brallier. Interbedded grayish green shales and siltstones.
154.70 155.10	177.00– 177.40	PORTAGE shale—Brallier. A few hundred yards north across the Hustontown road, the Helderberg limestones are quarried and Oriskany beds crop out. Faults occur in this area, but locally may decrease in magnitude so that the Portage is scarcely affected at this point on the Turnpike.
155.30	177.60	To north, knob at nose of plunging BLACK LOG ANTICLINE is in Tuscarora sandstone.

MILEAGES Total	Trip	
155.40	177.70	Bridge over Turnpike.
156.40 156.60	178.70– 178.90	Clay, buff and bluish gray. Section complicated by faulting. A calcareous shale and strongly slickensided limestone (both fossiliferous) are found. This limestone is believed to be Tully, the intervening shale Upper Hamilton (Moscow), with an underlying slightly conglomeratic Hamilton sandstone.
157.05 157.30	179.35– 179.60	Fort Littleton Interchange to U. S. Route 522. BURKET and HARRELL shales, dark gray to black, fissile, thin-bedded. Scrub Ridge to southeast forms west flank of anticlinal mountain which plunges rapidly toward Turnpike, north of Sidney's Knob.
157.80	180.10	Local anticline with residual soil bounding a strongly shattered limestone which is thought to be Tully. Occasional fragmentary fossils are found. The strong fracturing and development of clay suggests that this anticline of Tully(?) may be faulted into position.
158.10	180.40	BURKET, black thin-bedded shale.
158.60	180.90	PORTAGE (Brallier) sandstone, argillaceous, mottled red and green.
158.70	181.00	BRALLIER shale.
159.30	181.60	Gobblers Knob to the north. Point of rising anticline in Tuscarora quartzite.
159.60	181.90	BRALLIER shale with a little interbedded sandstone, grayish green.
159.80	182.10	BRALLIER shale, arenaceous, grayish green, fossiliferous.
160.70	183.00	GREAT COVE FAULT, sometimes called the Fulton County Fault. There is a concealed interval in this area, but the presence of a fault is inescapable. The first strata west are Upper Devonian, those adjacent to the east are Silurian. The magnitude of this fault increases to the south where Ordovician limestones rest against Upper Devonian shales.
161.30	183.60	BLOOMSBURG (UPPER SILURIAN) red and interbedded greenish gray shale, with ripple-marked surfaces.
161.40	183.70	KEEFER (MIDDLE SILURIAN) quartzite, cream-colored, and the ROSE HILL shale and sandstone. These strata are complexly folded and faulted.
161.90	184.20	KEEFER quartzite resting on ROSE HILL (CLINTON) and underlying the McKENZIE. This exposure is at the eastern end of the structure carrying the Turnpike over the Fannettsburg-Burnt Cabins Road. The Keefer is also exposed at the western end of this structure. The Rose Hill is best exposed in the cut beneath and northwest of the bridge, where it is fossiliferous. The weathered shales overlying the Keefer, probably represent the McKenzie; they are in part faulted out. They are fossiliferous. Strike N 55° E, Dip 57° SE.
162.40	184.70	Bridge over Turnpike.
162.70 162.90	185.00– 185.20	WILLS CREEK interbedded red and greenish yellow, soft shales.
162.90	185.20	TONOLOWAY (UPPER SILURIAN) ribbon limestone, gray, thin-bedded.
163.00	185.30	Burnt Cabins Emergency Landing Strip (Pennsylvania Aeronautics Commission).
163.60	185.90	TONOLOWAY ribbon limestone, exposed under the footings of the bridge which carries a township road over the Turnpike.
163.70	186.00	Burnt Cabins Maintenance Building.
163.90	186.20	West Portal Tuscarora Tunnel. WILLS CREEK red and yellowish green, soft shales crop in the approach cut to the tunnel. Dip 78° W.
164.90	187.20	East Portal Tuscarora Tunnel. Black, siliceous, MARTINSBURG (UPPER ORDOVICIAN) shale, thin-bedded. Strike N 33°, Dip 64° SE.

MILEAGES Total	Trip	
165.40	187.70	MIDDLE ORDOVICIAN limestone poorly exposed in field to left.
165.60	187.90	Path Valley restaurant and service station.
166.30	188.60	Willow Hill Interchange. BELLEFONTE (UPPER BEEKMANTOWN) dolomite crops out in cut near ticket booth to the southeast. The dolomite contains numerous "rosebud" siliceous concretions varying from pebble to boulder size. This zone, though not so well developed elsewhere, has been traced as far southeast as Chambersburg and eastward nearly to Harrisburg. It is one of the few persistent marker horizons in the Beekmantown of this region, occurring generally from 300 to 400 feet below the top of the group. We travel close to the axis of an anticline, the dip being 27° SE at the ticket booth and 46° NW in the interchange underpass.
167.10	189.40	BELLEFONTE dolomite on both sides of the road for 1.4 miles. Strike N 55° E, Dip 26° SE.
167.60	189.90	"ROSEBUD" CONCRETIONS in open fields and burrow pits 50 feet north of the Turnpike. The UPPER BELLEFONTE contains several beds of the light gray, dense high-calcium limestone.
168.20	190.50	Note rolling karst-like topography developed in the dolomite.
168.40	190.70	Transitional contact between LOWER and MIDDLE ORDOVICIAN. Near the contact, alternating limestone and dolomite of the Upper Beekmantown grade conformably into interbedded dove-colored calcilutites and dolomites of the "Stones River" (Chazyan). The lower "STONES RIVER" here contains the diagnostic *Tetradium syringoporoides* and several species of gastropods belonging to genus *Lophospira.*
168.70	191.00	Contact of graptolite-bearing MARTINSBURG shale and "TRENTON" limestones on north side of road. Partly exposed in this section above the "Stones River" is about 20 feet of "Black River" (Shippensburg limestone) and 50 feet of "Trenton" limestones (Mercersburg and Oranda). The lower 60 feet or so of Martinsburg is black shaly limestone. Farther east these beds grade into upper Jacksonburg (Hershey) limestone. In eastern Pennsylvania the base of the Martinsburg is drawn above this and beneath non-calcareous Martinsburg shale, whereas here it is drawn faunally at the first occurrence of the gastropod *Sinuites.* Path Valley marks the approximate position of the southwest extension of the Adirondack axis, an important Ordovician structure. The structure is evidenced here by thinning and facies changes of the Trenton limestones on both sides of the axis.
169.30	191.60	MARTINSBURG (UPPER ORDOVICIAN) shale, in cut. Fissile, black, siliceous shale with interbedded sandstone units occurring near the base. The sandstone is cross-bedded. Strike N 25° E, Dip 42° SE.
169.50	191.80	MARTINSBURG shale, as above without sandstone interbeds.
169.80	192.10	Nose of synclinal Knob Mountain on north. The crest of the mountain is Tuscarora sandstone, the underlying Martinsburg shale forming the lower part of the nose of the syncline.
170.85	193.15	Gravel deposit, stream terrace. (West Branch Conococheague Creek).
171.50	193.80	Gravel deposit, stream terrace.
172.50	194.80	MARTINSBURG shale, strongly weathered with a veneering of stream gravel, along valley of West Branch of Conococheague Creek.
173.90	196.20	North end of Timmons Mountain, rising syncline, crest of Tuscarora and flanks of Martinsburg.
174.20	196.50	Note cove on south, minor plunging anticline.

CORRELATION TABLE OF MIDDLE ORDOVICIAN, CENTRAL PENNSYLVANIA TO NEW JERSEY

STANDARD			WEST OF ADIRONDACK AXIS	EAST OF ADIRONDACK AXIS	WEST OF HARRISBURG AXIS	EAST OF HARRISBURG AXIS	EASTERN PENNSYLVANIA	WESTERN NEW JERSEY
CINCINNATIAN			REEDSVILLE	MARTINSBURG SHALE	MARTINSBURG SHALE	MARTINSBURG SHALE	MARTINSBURG SHALE	MARTINSBURG SHALE
MOHAWKIAN	TRENTONIAN	GLOUCESTER	ANTES SH.					
		COLLINGSWOOD						
		COBOURG	COBURN LS.					
		SHERMAN FALL	SALONA LS.	ORANDA LS.	ORANDA LS.	HERSHEY LS.	Jacksonburg: "CEMENT ROCK"	UPPER JACKSONBURG LS.
		KIRKFIELD	NEALMONT LS.	MERCERSBURG LS.	MERCERSBURG LS.	MYERSTOWN LS.	Jacksonburg: "CEMENT LIMESTONE"	
		ROCKLAND						LOWER
	BOLARIAN	CHAUMONT	BENNER LS.					
		LOWVILLE		SHIPPENSBURG				
		PAMELIA	HATTER LS.		SHIPPENSBURG			
CHAZY			LOYSBURG LS.	"STONES RIVER"	"STONES RIVER"	ANNVILLE LS.	ANNVILLE LS.	
BEEKMANTOWN			BEEKMANTOWN	BEEKMANTOWN	BEEKMANTOWN	BEEKMANTOWN	BEEKMANTOWN	KITTATINNY

Provisional correlation, after C. E. Prouty

MILEAGES Total	Trip	
174.80	197.10	MARTINSBURG shale on the northeast end of Timmons Mountain, a synclinal spur of Kittatinny Mountain which noses out just south of the Turnpike. The shale is splintery, siliceous, black, and contains hard sandstone interbeds. Strike N 60° E, Dip 42° SE.
175.20	197.50	West Portal Kittatinny Tunnel. MARTINSBURG, black siliceous shale. Strike N 55° E, Dip 68° to 90° SE. Amberson Valley to the north.
176.10	198.40	East Portal Kittatinny Tunnel and Gunter Valley. At this portal the BLOOMSBURG red shale is faulted into position against the ROSE HILL formation. The structure through Blue and Kittatinny tunnels being synclinal, the development of the valley may be attributed in part to faulting and to the eroding by Trout Run parallel to the axis of the syncline.
176.20	198.50	West Portal Blue Mountain Tunnel. ROSE HILL (CLINTON) weathered shales, extremely fossiliferous in the cut above the portal building. Strike N 46° E, Dip 55° NW.
177.00	199.30	East Portal Blue Mountain Tunnel. MARTINSBURG, black, siliceous, "pencil" shale. Strike N 45° E, Dip 38° NW. Great Valley lies ahead, South Mountains in distance to right.
179.00	201.30	Blue Mountain Interchange connects with State Route 944. MARTINSBURG, black shale.
180.20	202.50	Blue Mountain restaurant and service station.
180.70 184.90	203.00– 207.20	Throughout these four miles numerous low cuts show outcroppings of weathered Martinsburg shale. At 205.2 miles, view to northeast, up Doubling Gap Valley; note winding crest of ridge.
185.05	207.35	MARTINSBURG shale in cut and in the banks of the underpass beneath and north of the Turnpike. Showing numerous minor folds, the shale is fissile and in part arenaceous. Strike N 65° E, Dip 73° NW.
186.25	208.55	MARTINSBURG (UPPER ORDOVICIAN) shale, siliceous with occasional sandy beds. Strike N 56° E, Dip 78° NW.
187.40	209.70	MARTINSBURG shale in long cut, black, siliceous. Strike N 53° E, Dip 70° SE.
188.70	211.00	View of Doubling Gap to north.
189.70	212.00	MARTINSBURG shale in long deep cut. Black siliceous shale, and hard, massive sandstone interbeds. Exposed surfaces on the sandstone show "mud-flows" contemporaneous with deposition, north side of road. Strike N 52° E, Dip 82° SE.
191.90	214.20	Newville Maintenance Building.
192.30	214.60	MARTINSBURG shale, black, siliceous, pencil fragments. Used extensively for shoulder material. Strike N 65° E, Dip 79° NW.
192.85	215.15	Conodoguinet Creek bridge crossing Martinsburg shale.
192.95	215.25	Bridge over the Turnpike. The contact between the Martinsburg and the "Trenton" limestones occurs just west of this bridge.
193.00	215.30	"BLACK RIVER" and "TRENTON" (MIDDLE ORDOVICIAN) limestones. A generalized section here is:

	ft.
MARTINSBURG FORMATION	—
ORANDA FORMATION:	
Limestone, black, fine-grained, slabby; containing *Leptaena, Receptaculites, Crytolithus*	16
MERCERSBURG FORMATION:	
Kaufman member: Limestone, dark gray, fine-grained, platy to slabby; containing *Nidulites, Diplotrypa*	77
Housum member: Limestone, dark gray, fine- to medium-grained	45
SHIPPENSBURG FORMATION:	
Fannettsburg member: Limestone, dark gray, fine-grained, slabby	7
Pinesburg member: Limestone, fine-grained, cobbly, containing *Nidulites and Lambeophyllum*	—

Several thin metabentonite beds occur throughout the section.

MILEAGES Total	Trip	
193.70	216.00	SHIPPENSBURG and MERCERSBURG (MIDDLE ORDOVICIAN) limestones.
194.10	216.40	Upper BEEKMANTOWN (probably BELLEFONTE) dolomite and magnesian limestones.
194.80	217.10	Bridge over Turnpike.
195.45	217.75	Contact of Upper BEEKMANTOWN dolomite and lower "STONES RIVER" limestones and dolomites. Basal "Stones River" here carries a persistent fossil zone consisting of *Lophospira bicincta, L. centralis* and *Salterella* cf. *S. billingsi.*
196.25	218.55	Basal, calcareous MARTINSBURG on right. This is grading eastward into the HERSHEY limestone (UPPER JACKSONBURG).
196.90	219.20	Plainfield restaurant and service station. J. S. Diller, Geologist of U. S. Geological Survey, 1883-1928, is buried in cemetery to south of highway.
197.00 197.20	219.30– 219.50	"STONES RIVER" dark blue, limestones with clay partings, alternating with thin, massive gray, creamy-weathering dolomites, and dove, high-calcium calcilutite. About N 28° E, 18° SE.
197.35	219.65	Cobbly SHIPPENSBURG limestone. We are traveling close to the "STONES RIVER"-SHIPPENSBURG contact.
197.80	220.10	"STONES RIVER" limestone and interbedded dolomite. Beds dipping 75° to 80° SE overturned.
198.15	220.45	Upper BEEKMANTOWN dolomite, massive to thin bedded, impure. Dip 80° S (overturned).
199.25	221.55	Argillaceous limestone of the Middle "STONES RIVER".
200.00	222.30	"STONES RIVER" limestone and dolomite. Dip 20° to 25° S.
200.80	223.10	SHIPPENSBURG limestone.
201.40 201.90	223.70– 224.20	Long cut in "STONES RIVER" and SHIPPENSBURG, the contact being near the east end of cut. The entire "STONES RIVER" is exposed here, the lower beds showing *Maclurites magnus* and *Leperditia* ostracodes.
202.80	225.10	HERSHEY limestone (Oranda and basal Martinsburg of the central belts), slaty cleavage is better developed eastward.
203.20	225.50	Exit to Route 11. HERSHEY limestone.
203.30	225.60	From this point a good view of the South Mountain area may be seen to the south.
204.00	226.30	Carlisle Interchange. Note HERSHEY limestone near ticket booth to left. Carlisle, county seat of Cumberland County, is famous in Colonial and Civil War History. It is the home of Dickinson College (founded in 1783), and was the site of "Public Works," a cavalry post for a century (founded in 1777), that later became the Carlisle Indian School, and which has since been enlarged and converted into Carlisle Barracks, a U. S. Army Medical Department Field Service School.
205.00	227.30	MERCERSBURG limestone.
205.70	228.00	"STONES RIVER", dove, high-calcium and darker, impure, nodular limestones.
206.70	229.00	BASIC DIKE. **Slow buses** but do not stop. Stony Ridge is the surface expression of a diabase dike that extends from the Triassic basin, southeast of South Mountain, across South Mountain and Cumberland Valley, northward to the Juniata River in Perry County near Amity Hall. The dike cuts "STONES RIVER" here, the limestone showing a slight "burned" effect and some mineralization (epidote) along the contact.
207.40	229.70	"STONES RIVER" limestone and interbedded dolomite.

MILEAGES Total	Trip	
207.70	230.00	FAULT. Overturned BEEKMANTOWN thrust over normal (SE) dipping "STONES RIVER".
208.35	230.65	BEEKMANTOWN limestone on right, dip 25° to 30° southeast, overturned. Several small *Maclurites* gastropods.
209.00	231.30	Quarry in BEEKMANTOWN limestone in distance to right.
209.15	231.45	BEEKMANTOWN, along strike of quarry.
209.30 209.50	231.60– 231.80	BEEKMANTOWN limestone.
209.90 210.30	232.20– 232.60	BEEKMANTOWN dolomite and limestone.
210.70	233.00	STONEHENGE limestone, white, pink, light-gray mottled to dark blue. This is the only formation of the Beekmantown group that is generally separable in this area. Edgewise intraformational breccias are the most regionally persistent lithologic characteristic of the formation, persisting throughout much of central and eastern Pennsylvania. Beds overturned southeast.
211.50	233.80	Bridge over Turnpike. The cut is developed in STONEHENGE and transitional beds into the CONOCOCHEAGUE (UPPER CAMBRIAN, largely equivalent to the Gatesburg dolomite of western belts). Oolites and sandstone beds occur in the Conochocheague directly south of the Turnpike. The limestones here illustrate not only the general tendency for upper Cambrian and lower Ordovican dolomites of the west belts to grade into limestones (predominantly) eastward, but also indicates the tendency for much of the limestone in the belts adjacent to the Triassic basin to assume a mottled white, pink, and light gray color. N 32° E, 29° SE.
211.90	234.20	Dark blue, impure CONOCOCHEAGUE limestone on left.
212.25	234.45	Mechanicsburg restaurant and service station on left.
212.50	234.80	Bridge over Turnpike.
212.60	234.90	BEEKMANTOWN limestones on left. Dip about 10° to 20° SE. We have passed over the axis of an overturned anticline which plunges northeastward near Mechanicsburg. We are now passing along the more gentle southeast, normal, limb of the flexure.
213.20	235.50	BEEKMANTOWN limestones and dolomites.
213.65	235.95	Exit to Route 15 (Gettysburg Pike). MERCERSBURG (upper "Chambersburg") limestone on right of exit road, near Turnpike.
214.30	236.60	Road cut exposes HERSHEY-MARTINSBURG contact on left a few feet above road level. Where the Hershey is not weathered and leached of its lime content, it can be distinguished from the overlying non-calcareous Martinsburg shales. In most places it is difficult to draw the contact closely. We are on the northwest flank of the Steelton syncline.
215.30	237.60	MARTINSBURG shale. Southeast-dipping slaty cleavage is characteristic of the structural belts from the Harrisburg region eastward.
215.50	237.80	HERSHEY impure carbonaceous limestone, showing slaty cleavage. We are traveling close to strike at this point.
215.70	238.00	Rairoad overpass.
215.80	238.10	BEEKMANTOWN limestone dipping southeast, overturned.
216.20	238.50	Approximate contact of BEEKMANTOWN and red TRIASSIC (Gettysburg shale and sandstone). We travel close to the border fault of the Triassic basin for several miles. There is some question as to whether the border of the Triassic Basin is always a fault contact as generally indicated in literature and geologic maps of this area. (Note this contact at mileage 240.80.)
217.15	239.45	Entering York County; leaving Cumberland County.
219.20	241.50	BEEKMANTOWN limestone, steeply overturned to the south.

MILEAGES Total	Trip	
219.65	241.95	Harrisburg West Interchange, Pennsylvania Turnpike.
223.05	245.35	GETTYSBURG (TRIASSIC) formation red sandstone and shale. The Triassic is thought to be in the order of 16,000 feet thick in this general area. In addition to the red shales and sandstones, other rock types include quartzose conglomerates and limestone conglomerates derived in part from Paleozoic rocks to the northwest and from diabase stocks, dikes and sills.
223.70	246.00	Bridge over the Susquehanna River.
224.50	246.80	Slag pile of Bethlehem Steel Company plant.
224.90	247.20	Harrisburg East Interchange. LEAVE TURNPIKE.
225.40	247.70	Ticketbooth.
225.45	247.75	Turn right on Route 230 by-pass. The TRIASSIC-BEEKMANTOWN contact may be observed a few hundred feet from here along side road entering from the west.
226.10	248.40	Bridge over Laurel Run. The MYERSTOWN (lower Jacksonburg)-HERSHEY contact is exposed along old road to right near house.
		We cross a wide belt of Martinsburg shale.
227.20	249.50	Junction of Route 441, keep straight.
227.50	249.80	MARTINSBURG-HERSHEY contact. The black argillaceous Hershey limestone on weathering assumes a buffish brown color similar to the Martinsburg. Reddish shale occurs locally here in the Martinsburg and in a number of other localities.
228.40	250.70	Junction of Routes 322 and 422. **Keep straight** on Route 230 by-pass.
		The HERSHEY-MYERSTOWN contact marked by limestone and dolomite boulders (largely angular) occurs near out-door theater a few hundred yards to the west. We have just passed over a thin belt of ANNVILLE (high-calcium) limestone and are now traveling over middle "STONES RIVER" limestones.
228.45	250.75	Underpass, Reading Railroad.
228.70	251.00	Keep straight at Paxtang cloverleaf.
228.85	251.15	The Upper BEEKMANTOWN has been placed against the HERSHEY limestone about here along the Paxtang thrust. The actual thrust contact may be observed in Paxtang one mile to the west.
229.10	251.40	MARTINSBURG shale, highly weathered.
230.30	252.60	MARTINSBURG shale. We are traveling along the Harrisburg peneplain level.
231.45	253.75	Junction Route 22. Turn **left** on to Route 22 west.
232.90	255.20	**Keep straight**; temporary Route 22 bears right.
233.25	255.55	Entering Penbrook.
233.80	256.10	Get into inside lane for left turn.
233.85	256.15	Bear **diagonally left** across traffic on to Walnut Street.
233.90	256.20	Turn **sharp left** into Reservoir Park.
234.05	256.35	Keep **straight.**
234.35	256.65	Keep right around hill.
234.55	256.85	**Right.**

MILEAGES Total	Trip	
234.70	257.00	**STOP 6.**

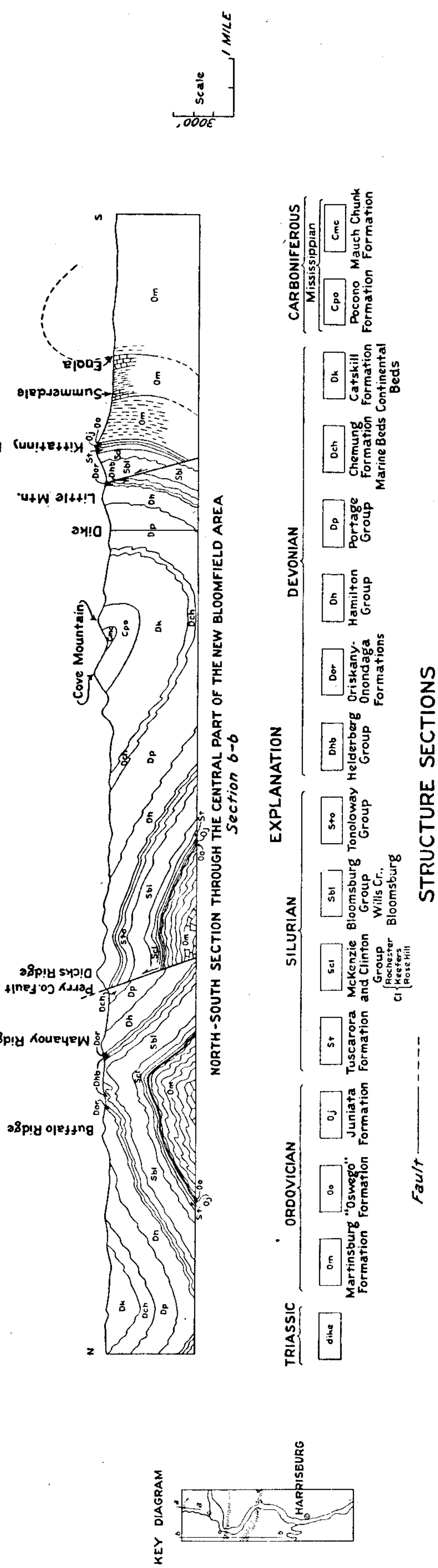
Buses will pull up to retaining wall.

This is a physiographic stop to view the Susquehanna Water Gap in Blue Mountain and the different erosion levels, commonly thought to be peneplain surfaces. The Schooley (Cretaceous) level is believed represented by the relatively even-crested tops of the mountains at 1,400 to 1,600 feet elevation. The Harrisburg (late Tertiary) level is developed in the Ordovician shales and limestones, largely the Martinsburg shale, at roughly 600 feet. The level near the present flood plain of the Susquehanna and Conodoguinet Rivers (about 320 to 350 feet) has been called the Somerville peneplain. Some have correlated the Harrisburg level with the Allegheny peneplain (1,250 feet) of western Pennsylvania and the Somerville level with the Worthington level (900 feet).

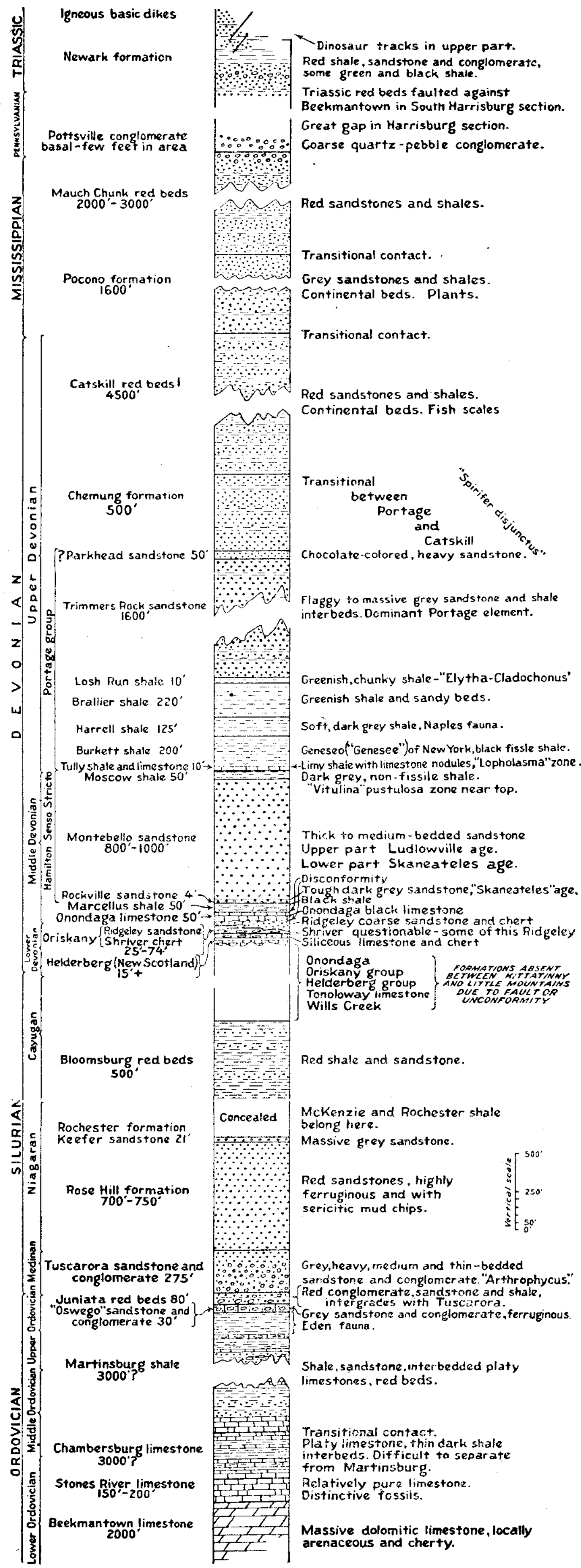
Reservoir Hill is supported by conglomeratic sandstone believed to be in the Martinsburg formation. This is an unusual occurrence although sandstones are quite common in the Martinsburg of this area.

Buses will turn around and retrace route to the Reservoir Hill entrance.

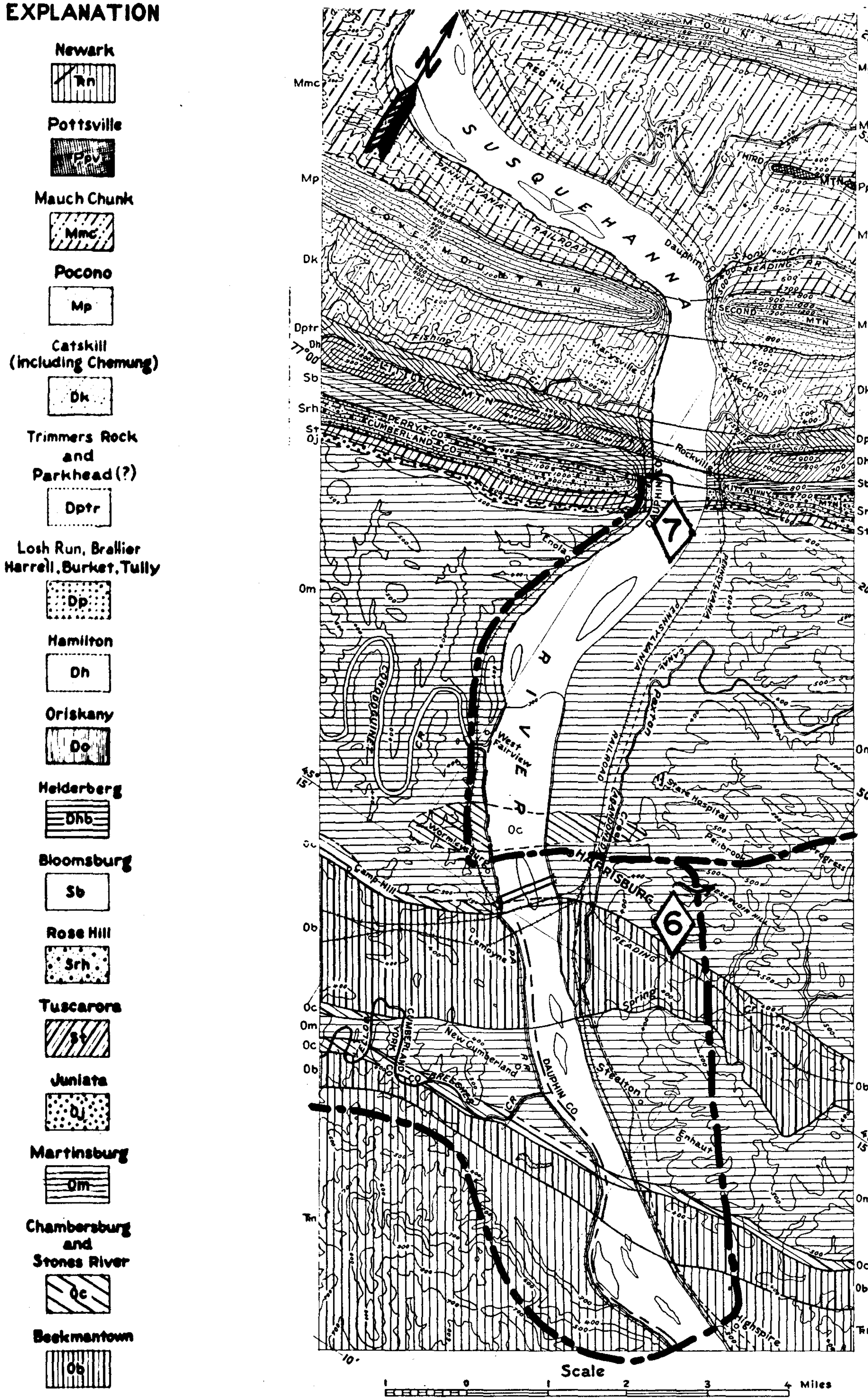
235.55	257.85	**Turn sharp left** on Walnut Street. **Do not cross into Route 22.**
235.80	258.10	Turn **right** on N. 18th Street.
235.85	258.15	**Left** on Route 22 (State Street).
236.35	258.65	Bridge. Capitol Building straight ahead.
236.80	259.10	Left at end of bridge.
237.15	259.45	Penn-Harris Hotel.



COLUMNAR SECTION ON SUSQUEHANNA–JUNIATA RIVERS BETWEEN HALF FALLS MOUNTAIN AND HIGHSPIRE



GEOLOGIC MAP OF THE HARRISBURG SECTION



SECOND DAY'S TRIP

MILEAGES Total	Trip	
237.15	0.00	Buses will load across from Penn-Harris Hotel on Walnut Street, heading west, in the same place passengers disembarked on Saturday. Proceed westward on Walnut Street. Reset odometer to 0.00. Departure time **7:30 a.m.**
237.25	0.10	Turn **right** on North Second Street and continue north around monument.
237.75	0.60	**Turn left** on to boulevard (Route 22) and continue straight across bridge over the Susquehanna River. Often dredges may be observed along the river working the bottom sediments for coal that has washed down from the anthracite fields.
238.65	1.50	**Turn right** at end of bridge on exit road to Routes 11 and 15.
238.75	1.60	Sharp right.
238.80	1.65	**Left** on to Routes 11 and 15 north. We travel in a broad belt of Martinsburg shale, approximately six miles wide in places. The thickness of the formation has been estimated by different workers at figures ranging from 2,000 up to 10,000 feet. Bedding is mostly obliterated and slaty cleavage dips southeastward throughout the entire belt.
239.65	2.50	Crossing the mouth of Conodoguinet Creek, noted for its entrenched meanders. Entering West Fairview.
240.10	2.95	**Keep right** on Routes 11 and 15.
240.95	3.80	Pennsylvania Railroad yards on right occupying an abandoned river channel. The prominent hill between the yards and the river is supported by sandstone in the Martinsburg. The cementing material in most of these sandstones is calcareous and usually is not sufficiently resistant to form sharp hills. Entering Enola community.
241.40	4.25	MARTINSBURG shale behind row of buildings on left. Note steep southeastward dipping, slaty cleavage.
241.75	4.60	One of the best exposures of limestones in the Martinsburg occurs beneath road level along bank facing railroad yards. This section does not show in the highway cut topographically higher and would appear to be cut off by faulting. Limestones within the Martinsburg in this area have in many cases been mapped as "Chambersburg" inliers. The limestones here, however, differ from other middle Ordovican limestones as shown in the following section from this station (beds overturned 70° SE, units described from youngest at the top to the oldest at the bottom):

Unit	Thickness (feet)
(7) Limestone, thin-bedded, gray, dense, alternating with thin beds and partings of gray, fissile shale; some beds containing coarse sand grains	40
(6) Limestone, gray, finely crystalline; thin wavy clayey partings, few "floating" quartz sand grains, cross-laminated	42
(5) Limestone, dolomitic, massive ledged, gray crystalline, very sandy; good edgewise dolomite breccia	18
(4) Limestone, gray, thin-bedded, fissile, dense; brownish weathering	24
(3) Limestone, dolomite, little edgewise dolomite breccia	4
(2) Limestone, dense to finely crystalline; weathers brownish gray, brownish gray shale partings	54
(1) Limestone, light gray, platy, silicified, highly metamorphosed, irregular bedding; red and olive shales beneath	38
Total	220

MILEAGES	
Total	Trip

This limestone sequence, together with the underlying redbeds, represents one of the few mappable units in the Martinsburg of this particular area that is useful in mapping the structure of the wide shale belt.

243.85 6.70 **STOP 7.**

Susquehanna Water Gap in Blue (Kittatinny) Mountain. Buses will unload at south end of gap and group will walk through gap and rejoin buses around curve.

Late Ordovician and Silurian strata are upended in the southern, slightly overturned limb of the major Cove Valley syncline, which within 5 miles north of Harrisburg brings down the Ordovician Martinsburg shale, possibly 2,000 to 3,000 feet thick with its structure complicated by minor folding, and then in the next four miles causes the rapid and relatively uncomplicated plunge below ground of the nearly 15,000 feet of strata of the Silurian, Devonian, and Mississippian systems, until the Pennsylvanian Pottsville conglomerate forms Third Mountain at the synclinal axis. The group will gather at about the Silurian-Ordovician junction, from which TUSCARORA-ribs can be seen crossing the river channel to the mountain as it continues east of the river, and views are given of the Harrisburg peneplain and, toward the north, of ridges formed by the Pocono sandstone.

The stop provides a visit to the southeastwardly coarsened, lithologically changed, and in part disconformably telescoped extensions of formations that were seen at Bedford Gap (80 air miles to the west).

At the southern end of the gap, the section begins with MARTINSBURG shale containing a *Cryptolithus* fauna of earliest Upper Ordovician Eden age. The highest Martinsburg, represented farther west by 500 feet or more of shales and sandstones carrying the *Orthorhyncula* zone at their summit, was here enough upwarped by Taconic movements so that it was worn away by Late Ordovician erosion. Lapping upon this erosion surface is the thinned, coarsely conglomeratic wedge-edge of the BALD EAGLE-JUNIATA sediments that are here 165 feet thick as compared to 1,500 or 1,600 feet at Bedford Narrows. Thus almost a half mile of strata are lost from the succession in a relatively few miles, in part by erosion and in part by lack of deposition. Since the Bald Eagle-Juniata sediments transgress from the west upon the surface of erosion, it is likely that the thinned and coarsened remnant at Susquehanna Gap represents a late rather than early part of the thick Bald Eagle-Juniata deposits farther west.

Northeastward from the Susquehanna to the Schuylkill and Delaware Water Gaps, the unconformity increases in discordance, so that the JUNIATA wholly disappears, and the TUSCARORA lies with marked angular unconformity on Taconic-folded Martinsburg. Still farther to the northeast, lower members of the Silurian progressively lap upon an ancient version of the Adirondack dome, until near Albany a mere 60 feet of Latest Silurian limestones rest directly on the Middle Ordovician.

The lower Juniata beds at Susquehanna Gap contain profuse 2- to 3- and 6-inch, chunky pebbles of milky quartz, vitreous quartzites, chloritic meta-argillites, and cherts, worn from the easterly uplands elevated by Taconic crustal movements.

The Juniata red beds are abruptly superseded by white, clean, TUSCARORA quartz sands, made quartzitic by overgrowths of silica; above the clean lower beds of the formation, the sands are dirty and graywackish, containing considerable amounts of chloritic materials, and colored dark gray, then red, then greenish, then a lighter green as the sands are again quartzose. Shale interlayers increase near the top of the 350 feet of TUSCARORA sandstones, which then are overlain by 650 feet of CLINTON formation here unfossiliferous and composed in half its thickness of dark purplish, iron-rich sandstones, some of which in thin section show crystal blades of hematite transecting silica overgrowths of the quartz sand grains. Above the exposed CLINTON strata 500 feet are concealed; there are then 1,000 to 1,100 feet of red BLOOMSBURG sandstone and shale; upon the Bloomsburg rests a few feet of Middle Devonian MARCELLUS beds, then the heavy-bedded, Middle Devonian, marine MONTEBELLO sandstone.

		Bedford Gap	Susquehanna Gap
Middle Devonian	Marcellus	black shale	black shale
Middle Devonian	Onondaga	125′ sh and ls	— — — —
Lower Devonian	Oriskany	250′ ss and sil. ls.	— — — —
Lower Devonian	Helderberg	75′ ls and sh	— — — —
Upper Silurian		250′ Keyser ls	— — — —
Upper Silurian		600′ Tonoloway ls 500′ Wills Creek sh 20′-50′ reddish Bloomsburg	1000′ to 1500′ red Bloomsburg sh and ss
Middle Silurian		350′ McKenzie sh and ls	(Basal red and uppermost gray ss and sh)
Middle Silurian	Clinton Group	40′ Rochester sh 10′ Keefer ss 600′ Rose Hill clayey sh	650-1000′ inter-bedded purplish iron rich ss, some gray ss, gray silty sh
Lower Silurian	Medina	400-500′ White quartzitic ss (Tuscarora)	350′ greenish and red ss and white quartzite in part conglomeratic (Tuscarora)
Upper Ordovician		1050′ Juniata red siltstone and ss 550′ Bald Eagle red and green ss and some sh	135′ Red ss and cgl, plus 30′ greenish cgl at base
Middle Ordovician including base of Upper Ordovician		1100′ Reedsville sh 300′ Trenton ls	2000-3000′ Martinsburg sh, including Trenton shales

MILEAGES Total	Trip	
		The marked contrasts here as compared with Bedford Gap are shown by the columnar sections on page 50. (Dashes indicate absence by unconformity.) It is clear from these comparisons that the Silurian sediments at Susquehanna Gap constitute a relatively near-source mass of land-derived detrital sediments. At their top, the earliest Middle Devonian, Lower Devonian, and highest Upper Silurian sediments are absent by non-deposition on the Auburn Promontory. Part of the Tonoloway, the Wills Creek, the thin red Bloomsburg tongue, and the higher McKenzie of the Bedford area have changed laterally into the thickening red, continental Bloomsburg shale and sandstone. The Middle and Lower McKenzie shales and limestones, the Clinton clay shales and the 10-foot Keefer sandstone are here transformed to somewhat hematitic purple sandstones and interbedded shales that locally crest Kittatinny Mountain. The Tuscarora includes some clean, white quartz sandstone or quartz like the characteristic Tuscarora farther west, but in part the formation is graywackish, gray or reddish. The Juniata-Bald Eagle sediments wedge out from 1,500-1,600 near Bedford to 165 feet at Susquehanna Gap and include coarse conglomerates, their lower beds are gone by unconformity, and below them the highest Reedsville-Martinsburg shales were cut away by erosion at the time of their Late Ordovician emergence.
244.15 244.45	7.00– 7.30	BLOOMSBURG red beds. Unconformity at top of Bloomsburg. Beds between Marcellus and Bloomsburg are missing (see page 50 for Susquehanna Gap section).
244.55	7.40	**Little Mountain.** This secondary ridge on the northwest side of Blue Mountain is formed by MONTEBELLO sandstone, which is a coarser, clastic eastward equivalent of the Hamilton siltstones near Bedford. The sandstone is very fossiliferous, numerous molds and casts of *Spirifer* predominating. A large quarry is developed in the Montebello sandstone on the left, a small expossure of MARCELLUS shale occurring on the south side. The ORISKANY sandstone is absent from this section and is part of a "no sand" (Oriskany) area extending linearly northeastward into Luzerne County and beyond. The "Harrisburg Axis" is inferred by this and other changes in the general Harrisburg area such as facies changes in the "Chambersburg", thinning and disappearance of part of the "Stones River", and perhaps the absence of the Maysville phase of the Martinsburg formation.
244.70	7.55	HARRELL shales on left.
244.95	7.80	**Buses turn around** in yard of first building on **left** (west) side of road. Retrace route to Harrisburg.
251.10	13.95	Keep straight under Route 22 bridge, slow for right turn.
251.20	14.05	**Right** at Harrisburg sign.
251.25	14.10	**Right,** follow Harrisburg signs.
251.35	14.20	**Right,** on to Route 22 bridge.
252.30	15.15	Keep straight at end of bridge.
252.60	15.45	Right, follow Route 22 East signs.
252.65	15.50	Turn **left** at Capitol, Route 22 East.
252.90	15.75	**Right.**
252.95	15.80	**Left** on to State Street Bridge, Route 22 East.
255.50	18.35	Traffic light, Paxtang Avenue. Keep straight on Route 22 East.
257.50	20.35	Outcrops of MARTINSBURG red shale on north side of road.
258.40	21.25	Roadcut in MARTINSBURG (UPPER ORDOVICIAN) formation showing a variety of lithology. Most of cut is in greenish gray fissile shale with interbedded olive-drab, dirty sandstone.

MILEAGES Total	Trip	
259.40	22.25	Intersection—Linglestown Road.
259.70	22.55	Buff-weathering MARTINSBURG sandstone and shale.
259.90	22.75	Outcrop of massive buff-weathering MARTINSBURG sandstone on north side of road.
260.50	23.35	Gray shale outcrops (MARTINSBURG).
261.00	23.85	Buff-weathering MARTINSBURG shale. Where fresh this shale is similar in appearance to the shale at the last exposure.
262.15	25.00	View of Manada Gap in Blue Mountain on the left. Blue Mountain is cut by a number of water gaps and wind gaps between Harrisburg and Easton. This is the first one east of Susquehenna Gap at Harrisburg. The highway here is on the level of the Harrisburg peneplain. The even crest of Blue Mountain represents the Schooley level.
263.75	26.60	Intersection of Route 39. Continue on Route 22.
264.15	27.00	MARTINSBURG gray shale in cut on left.
264.35	27.20	Massive MARTINSBURG sandstone on right.
267.35	30.20	Outcrops of red and green MARTINSBURG shale on left.
267.65	30.50	Intersection of Route 743.
268.35	31.20	Entering Lebanon County; leaving Dauphin County.
271.15	34.00	On left, at side road intersection, the MARTINSBURG is composed of fine-grained to silty sandstone, interbedded with thin layers of gray shale. The sandstone shows well-developed cross-bedding, which is lacking in the massive buff sandstones seen west of here.
271.35	34.20	Well-sheared MARTINSBURG shales on left. Local areas of shearing are common in the Martinsburg formation of this area.
271.75	34.60	View of Indiantown Gap on left. Site of Indiantown Gap Military Reservation and World War II Training Camp.
272.05	34.90	Overpass over Route 343.
272.35	35.20	Deep cut in MARTINSBURG shale with interbedded limestones. Platy, bluish gray limestones with thin shale interbeds or partings are a common feature in the Martinsburg formation of this area. More massive sandy limestones or dolomites and edgewise conglomerates are frequently associated with the platy limestone. The carbonates contain no recognizable fossils.
274.05	36.90	Outcrops of MARTINSBURG red shale with buff interbeds on left side of the road. This is near type locality of the Jonestown redbeds of Willard.
274.25	37.10	View of Swatara Water Gap on left.
276.45	39.30	Cloverleaf intersection, Route 72. Continue on Route 22. Four miles north on Route 72, at Swatara Gap, an exposure of Martinsburg shale is abundantly fossiliferous. The fossils include brachiopods, pelecypods, ostracodes, and trilobites. The beds there are believed to be of Eden age.
277.15	40.00	Crossing Swatara Creek.
277.45	40.30	Red and buff shale on right.
277.65	40.50	Red shale on left.
278.55	41.40	On right about two miles south of road, there is a MARTINSBURG sandstone quarry on top of hill. West of the quarry is Bunker Hill, underlain by lavas and diabase intrusives all of which are believed to be of Martinsburg age. The structure indicates that they are near the base of the formation. In the quarry the sandstone is relatively pure and coarse-grained, being nearly white where fresh. Sand of this type is rare in the Martinsburg.

MILEAGES Total	Trip	
280.75	43.50	Village of Fredericksburg on left.
281.15	44.00	On left, ridge between Route 22 and Blue Mountain is Little Mountain, capped by an outlier of Tuscarora sandstone. Structurally the ridge probably represents a tight syncline.
282.85	45.70	Entering Berks County; leaving Lebanon County.
285.95	48.80	On right, hills on skyline are at end of the Reading Prong of the New England Upland. They are formed by the basal Cambrian HARDYSTON quartzite and by PRE-CAMBRIAN gneisses.
287.25	50.10	Prominent knob on Blue Mountain is the topographic expression of a tight fold, probably related to syncline forming Little Mountain.
288.15	51.00	Intersection Route 501. Village of Bethel on right.
291.75	54.60	Intersection Route 83. Continue on Route 22.
294.55	57.40	Large outcrop of gray to dark gray, calcareous, silty shale. Disturbed bedding, probably caused by ancient slumping, is common in this exposure. Such bedding is usually present in the lower part of the Martinsburg formation.
295.05	57.90	**STOP 8.**

Large cut in weathered MARTINSBURG shale.

The shale, probably dark gray to black when fresh, here weathers light gray, reddish brown and white. One bed of light gray chert, or silicified shale, is present. Graptolites occur abundantly in at least one of the white-weathering beds. This is a new cut and the graptolites here have not yet been studied. Graptolites in similar occurrences have proved to be of Normanskill age. Near Harrisburg, graptolites of Deepkill age have been reported.

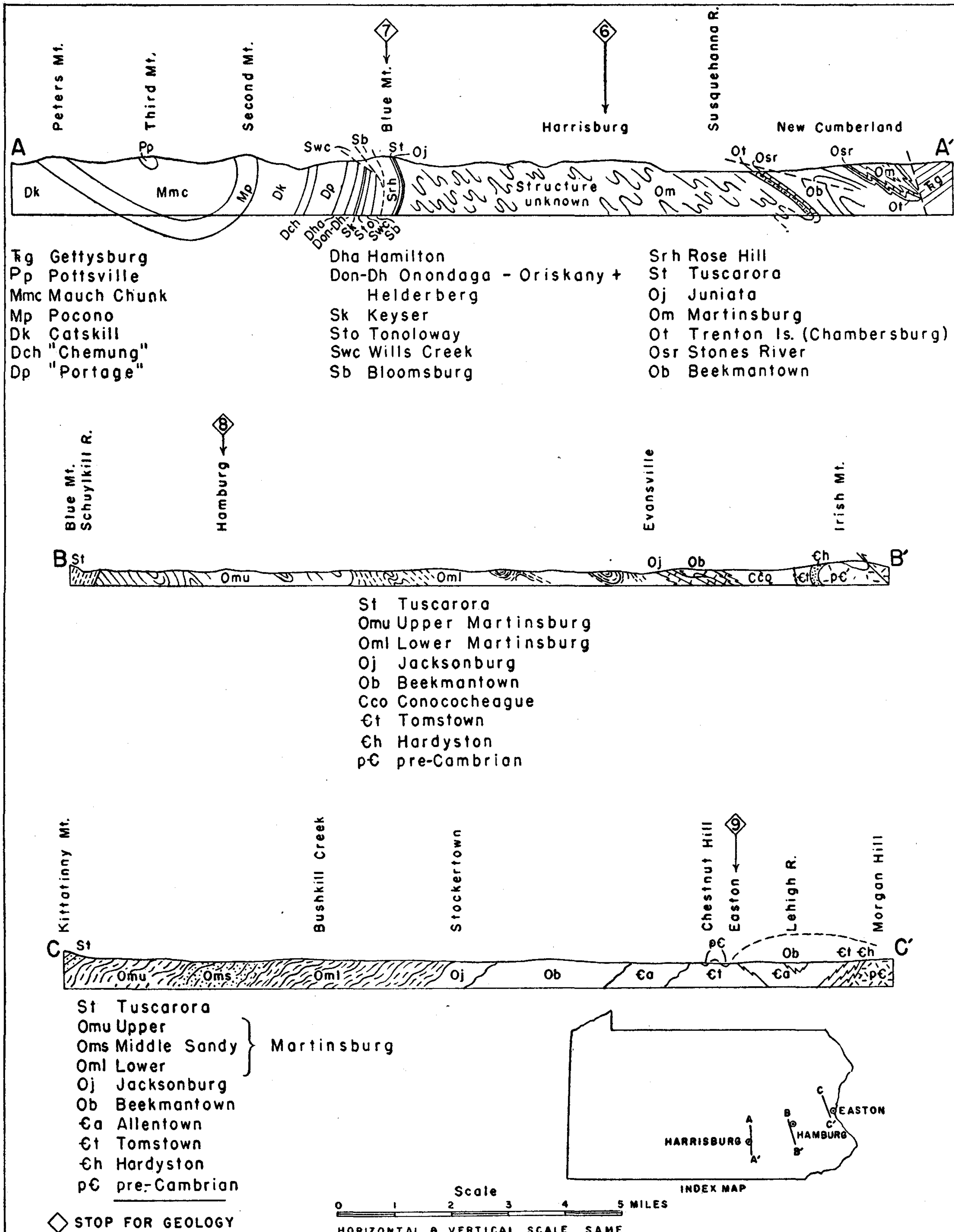
Stose proposes that much of the terrain mapped as "Martinsburg" between Harrisburg and western Lehigh County is different from, and probably in part older than the true Martinsburg formation, and that these rocks represent a klippe of a great overthrust. The hypothesis is based on three principal lines of evidence; (1) abnormal lithology, (2) age determinations from graptolite faunas, and (3) correlation of lithologic sequence with the "Taconic Sequence" of eastern New York and western New England.

Stose states that in the area between Harrisburg and Lehigh County, in contrast to the uniform gray argillaceous shale and sandstone of typical Martinsburg, the sequence consists of red and green shale; hard, green, cherty shale or chert; thick-bedded quartzite; thick-bedded quartzose limestone conglomerates containing pebbles of shale and limestone; and thin-bedded blue limestone with interbedded shale and limestone conglomerate.

He also states that the shales contain graptolites of Normanskill and Deepkill age. At the time of Stose's proposal, Normanskill was considered to be the equivalent of the Chazy ("Stones River") and Deepkill was considered Beekmantown in age.

Stose also established a tentative sequence of five units which are comparable with the units of the Taconic Sequence in eastern New York. His first line of reasoning is incontrovertible. The formation in this area is strikingly different from the rocks exposed in either direction along strike. The lithology of the Martinsburg of eastern Pennsylvania closely resembles that of the type area in West Virginia, but this intervening area has quite a different appearance. The problem is, therefore, either a question of facies change, or the juxtaposition of different facies (and possibly different ages) through faulting.

The fossil evidence for the age of these rocks of anomalous lithology is unfortunately not as clear-cut. Graptolites identified as Normanskill forms, which are now considered to be of Middle Trenton and older age, have been found in several places. The Martinsburg is underlain by limestones which, in general, range from early to mid-Trenton in age. It would require only a slight stretching of the range of the graptolites to include them in normal Martinsburg rocks. In fact some of the same graptolite forms have been found in rocks considered by everyone to be normal Martinsburg.



Assembled by Carlyle Gray 1955

MILEAGES Total	Trip	
		The Deepkill fauna was found at only a single locality near Harrisburg, and cannot be found any more. The Deepkill has now been extended to include the Chazy, but this still is considerably older than basal Martinsburg. Therefore, if the graptolites reported at Harrisburg are indeed Deepkill forms, then some sort of major structures must exist in that area at least.
		Stose's attempt to correlate the sequence of lithologies in the "Hamburg Klippe" with that of the Taconic Sequence is unconvincing. The minor structures of the area are so complex that, without extensive detailed mapping, it is impossible to determine the sequence accurately. Recent work in Lebanon County by J. R. Moseley has failed to resolve this problem, although much progress has been made. With a continuation of this work, it may be that in a few years the sequence will be known, but it appears that the validity of long-range correlation with the Taconic Sequence even then would be questionable.
		The problem is, therefore, still unsolved. The rocks of this area are certainly different in lithology from typical Martinsburg, and they may possibly have a different age, but it has not yet been conclusively shown that these rocks are part of a large overthrust.
296.25	59.10	Cut in massive, buff MARTINSBURG sandstone. This cut is deep enough to expose fresh, unweathered sandstone near road level. Here, it is gray, hard, with calcareous cement. The sandstone contains shale chips, mica flakes, etc., and can probably be considered a graywacke.
296.65	59.50	Another exposure of both weathered and fresh MARTINSBURG sandstone, similar to material in the last cut.
297.05	59.90	MARTINSBURG red shale, deeply weathered.
298.45 299.05	61.30– 61.90	Shartlesville, Pennsylvania.

GENERALIZED STRUCTURE SECTIONS—HARRISBURG TO EASTON, PENNSYLVANIA

Structure Section A-A′

Nearly north-south section from Peters Mountain through Harrisburg to edge of Triassic basin. Part north of Blue Mountain is after Willard & Cleaves. Remainder after C. E. Prouty (personal communication). Martinsburg structures are schematic. The line of section lies just east of the Susquehanna River. Stop 7 is just west of the River at Kittatinny Gap (Blue Mountain Gap).

Structure Section B-B′

Northwest-southeast section from Schuylkill Gap to Irish Mountain (Reading Hills). Martinsburg structure after Moseley. Remaining portion after Gray. Note that Moseley has used the two-fold subdivision of the Martinsburg, an upper sandy member and lower shaly member. Field work for this report was done before Stose proposed the Hamburg Klippe. The line of section lies about 10 miles east of Stop 8.

Structure Section C-C′

Northwest-southeast section from Kittatinny (Blue) Mountain west of Windgap through Easton to Morgan Hill. Martinsburg structures are after Behre, therefore, his interpretation of three members is shown. His middle, sandy member is approximately the same as Moseley's upper sandy and Willard's Shochary sandstone.

Southern part of section is after Miller, et al and Bayley. The overthrust interpretation of Chestnut Hill is after Bayley. Structural details of the Cambro-Ordovician limestones are omitted from all published maps. The line of section lies about 2 miles east of Stop 9.

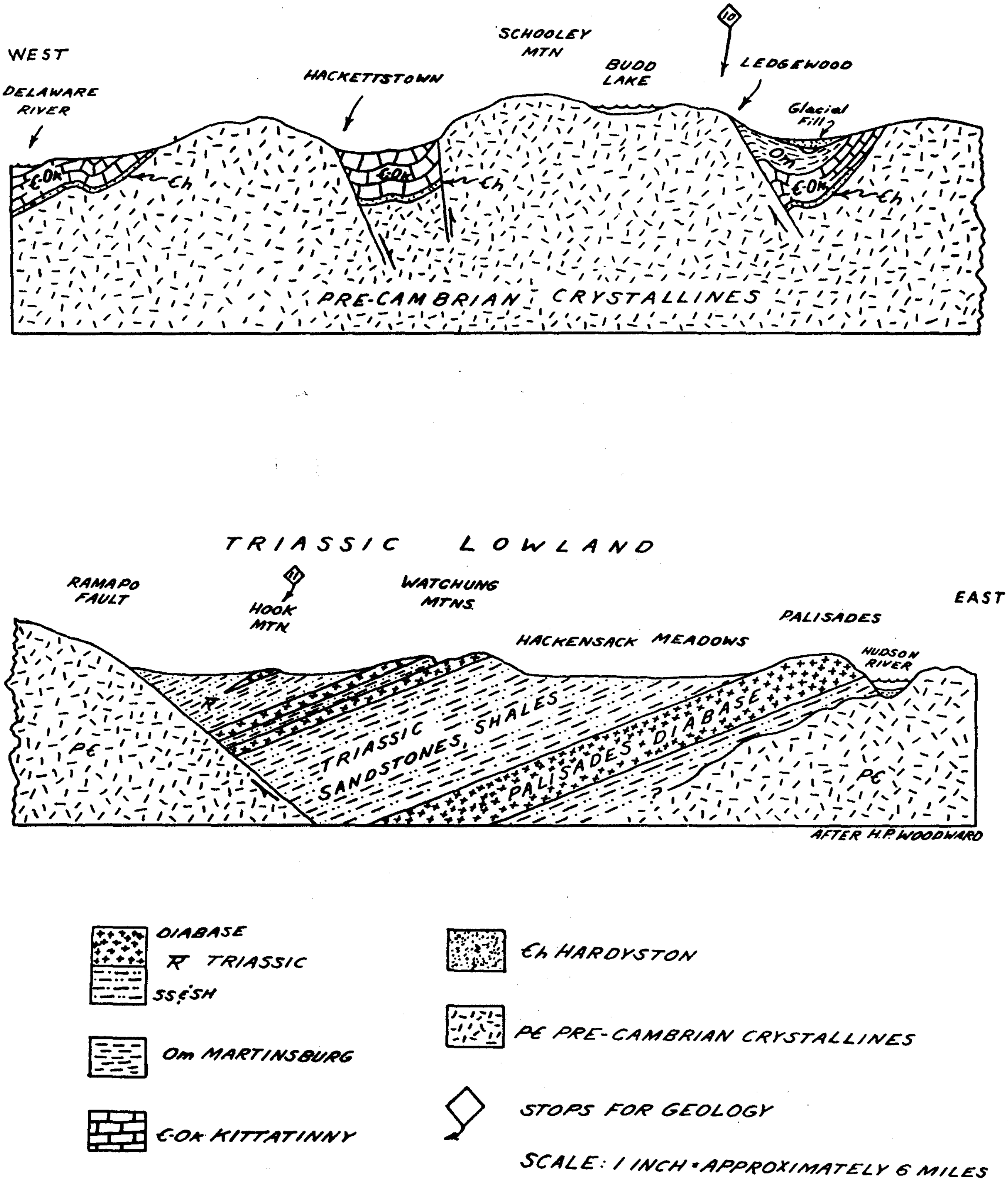
MILEAGES Total	Trip	
299.15	62.00	Distant view of Reading Hills ahead and on right.
301.35	64.20	Outcrops of MARTINSBURG red shale on left. Exposures from here to Hamburg are all in Martinsburg.
302.55	65.40	Road cut in red and green shale.
303.05	65.90	Buff shale on right.
303.25	66.10	View of Schuylkill Gap on left.
304.05	66.90	Red shale on left.
304.95	67.80	Crossing Schuylkill River.
306.05	68.90	Hamburg, Pennsylvania. Intersection U. S. Route 122.
306.75	69.60	On left, State Tuberculosis Sanitorium.
309.45	72.30	On left, at foot of Blue Mountain. "Blue Rocks", a large boulder field of talus blocks of Tuscarora quartzite. Boulder fields of this type are believed to have been formed by frost action during glacial times.
309.95	72.80	On left, The Pinnacle, a spur on Blue Mountain formed by a west-plunging syncline. Combined with a complimentary anticline, the structures offset Blue Mountain about three miles to the north. Ahead is an isolated hill known as the Spitzenberg. This hill is capped by a rock known as the Spitzenberg conglomerate, a unique sequence of cross-bedded, gray and red, arkosic sandstone and coarse conglomerate. The conglomerate consists principally of pebbles and cobbles of limestone, with sandstone, quartzite, shale, quartz, and jasper also being present. The matrix is arkosic sand. The general appearance is that of a fanglomerate. Structurally, the conglomerate occurs in a shallow synclinal basin resting unconformably on tightly folded Martinsburg. This syncline does not line up with the fold which forms The Pinnacle. Because no fossils have been found in either the matrix or the pebbles of the conglomerate, its age is questionable. It is probable, however, that it represents an outlier of Triassic.
311.25	74.10	Lenhartsville, Pennsylvania. Intersection Route 143.
311.75	74.60	On left, quarry in red MARTINSBURG slate. This quarry was originally worked for red roofing slate, but this operation was unsuccessful. From 1918 until the mid-thirties, the rock was crushed and ground and used as mineral pigment and filler.
312.05	74.90	Coarse arkosic MARTINSBURG sandstone on right.
312.25	75.10	Typical platy MARTINSBURG limestone, associated with red and green shales. A minor fault separates the limestone and shale here.
312.65	75.50	Red and green shales. Other exposures from here to Krumsville are all MARTINSBURG.
313.75	76.60	Green shales, with some red.
313.95	76.80	Red and gray shale.
314.65	77.50	Buff-weathering, sandy shale.
315.55	78.40	Buff-weathering sandstone.
316.25	79.10	Krumsville, Pennsylvania.
318.85	81.70	MARTINSBURG sandstone and shale.
319.05	81.90	Lehigh County line; leaving Berks County.
321.85	84.70	View ahead of hills underlain by pre-CAMBRIAN rocks. Route 22 here leaves the rocks included in the Hamburg klippe by Stose and enters the autochthonous Martinsburg belt.

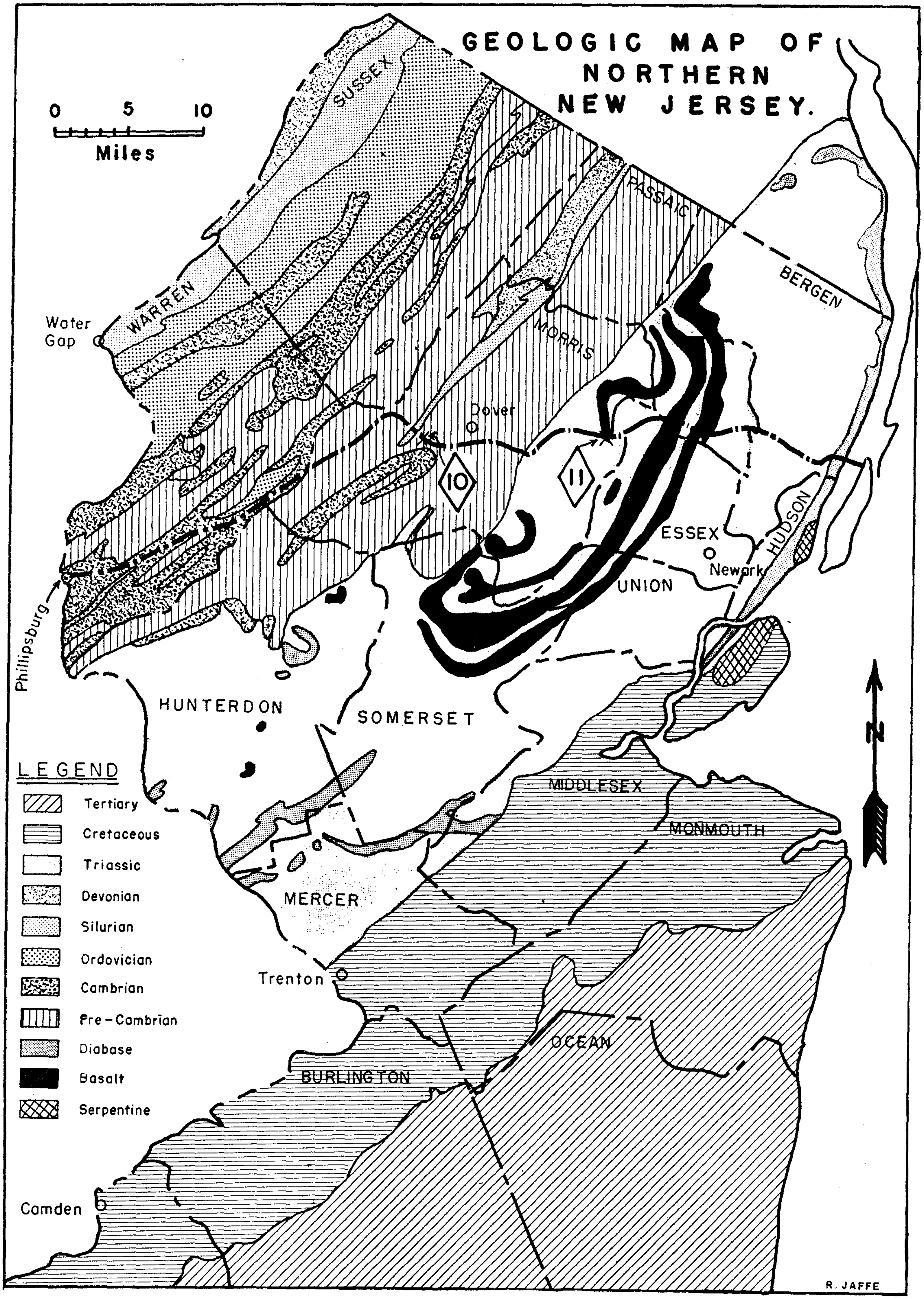
MILEAGES Total	Trip	
322.95	85.80	Buff-weathering slate on right.
323.25	86.10	Approximate location of contact between Upper Ordovician MARTINSBURG formation and Middle Ordovician JACKSONBURG. The Jacksonburg limestone is the source of raw material for the large Portland Cement industry of eastern Pennsylvania.
325.15	88.00	Fogelsville, Pennsylvania.
325.85	88.70	School on right, cut on left in JACKSONBURG (MIDDLE ORDOVICIAN) argillaceous limestones.
326.15	89.00	Half to three-fourths mile north, plant of Lehigh Portland Cement Company. Quarries in JACKSONBURG limestone at foot of MARTINSBURG escarpment.
327.15	90.00	Chapmans. Bridge over railroad. Limestone terrain with deep soil and glacial till.
327.95	90.80	Road east into Allentown; continue on Route 22.
328.25	91.10	Hills to right are morainal. Note small cut in glacial till. Bed rock is probably JACKSONBURG.
328.75 329.75	91.60– 92.60	Limestone terrain. One to two miles north, Huckleberry Ridge is a syncline of MARTINSBURG slate.
330.45	93.30	Cut in glacial till.
330.75	93.60	Small cut showing BEEKMANTOWN (LOWER ORDOVICIAN) limestone.
331.75	94.60	View to southeast of city of Allentown and tower of Pennsylvania Power and Light Building.
333.45	96.30	Cross Jordan Creek, tributary of Lehigh River. Intersection with Route 309.
334.75	97.60	Cross Lehigh River. Note old slag banks, relic of former iron works. In early days residual limonite was dug from pockets in the limestones. Among the early furnaces was that at Bethlehem, the progenitor of Bethlehem Steel works.
335.05	97.90	East bank Lehigh River. Road runs near the **transitional** contact between the CAMBRIAN (ALLENTOWN) and ORDOVICIAN (BEEKMANTOWN) limestones. Small cuts are probably all in CAMBRIAN limestone.
338.85	101.70	To right, the City of Bethlehem extends to the foot of South Mountain. Bethlehem is noted for the large plant of the Bethlehem Steel Company, for Lehigh University, and for the old buildings of the Moravian Community, an early setlement in the Lehigh Valley.
339.65 341.15	102.50– 104.00	The road passes over the Lower Ordovician BEEKMANTOWN limestone. The small hills on our right, Pine Top and Camels Hump, consist of pre-CAMBRIAN gneiss. On the opposite (south) side is a regular succession of CAMBRIAN formations, HARDYSTON, LEITHSVILLE, etc. The hills represent a block of pre-Cambrian and Cambrian rocks which have been thrust north upon the Ordovician strata.
341.55	104.40	Just visible over the high ground north of the road is the plant of the National Portland Cement Company, situated in a small syncline of JACKSONBURG (MIDDLE ORDOVICIAN) limestone.
342.45	105.30	Feeder on right, extensive cuts in BEEKMANTOWN.
342.65	105.50	Small cuts in BEEKMANTOWN limestone.
343.75	106.60	About 5 miles north, note string of cement plants along the main outcrop of the JACKSONBURG limestone.

MILEAGES Total	Trip	
344.25	107.10	We are here crossing the CAMBRIAN-ORDOVICIAN contact. Concealed now, it was uncovered when the road was being constructed. The CAMBRIAN (ALLENTOWN) is in fault contact with the ORDOVICIAN (BEEKMANTOWN).
347.25	110.10	On the left, large cut bank of south-dipping, typical LEITHSVILLE (MIDDLE? CAMBRIAN) dolomite. Note the shiny, sericitic surfaces and relatively massive beds. The hill behind the exposure consists of a pre-CAMBRIAN complex.
347.75	110.60	Entering the city of Easton, home of Lafayette College.
348.25	111.10	**STOP 9.**
		Park at right of highway where side road leads to Easton. Cut in UPPER CAMBRIAN limestone. Alternating color bands which are typical of Upper Cambrian limestones in this area are not well developed here as exposures are unweathered. Note such features as fairly even-bedding, stromatolites, and oolites. Turning to the east and looking along highway to next cut, the exposure on the right is the lower UPPER CAMBRIAN limestone, the LIMEPORT, which dips south and overlies the top of the MIDDLE(?) CAMBRIAN LEITHSVILLE on the north side of the highway. Here these formations are transitional with one another, the sericitic shale of the Leithsville continuing upward to mingle with the stromatolites of the Limeport.
348.65	111.50	Cut, noted above. On right, the base of the LIMEPORT; on left the top of the LEITHSVILLE.
349.05	111.90	Across the valley to north, large exposures in abandoned quarries of the massive LEITHSVILLE formation.
349.35	112.20	Curve right. Looking ahead (east) across valley of the Bushkill, see abandoned quarry showing exceptionally well the banded UPPER CAMBRIAN.
349.65	112.50	Across the creek on bluff, buildings of Lafayette College. Curving bridge crossing the Bushkill. Cuts, right and left, in the topmost CAMBRIAN (ALLENTOWN) formation.
349.85	112.70	As the road turns east, the cliff seen on right is cut in LOWER ORDOVICIAN (BEEKMANTOWN) limestone. The CAMBRIAN-ORDOVICIAN contact is underneath the highway at this point.
350.25	112.90	Easton. On left, Lafayette College occupies high ground. This elevation is supported by a core of pre-CAMBRIAN metamorphics and is structurally a horst.
350.35	113.20	Delaware River bridge and Pennsylvania-New Jersey state line. To the north (left), water gap in pre-Cambrian ridge. Note, this is not **the** Delaware Water Gap; it occurs about 20 air miles to the north-northeast. Washington's famous crossing of the Delaware was 35 air miles to the southeast. Flood flows of this river are now materially smaller than in Washington's day as a result of various reservoir projects along its upper reaches in New York.
		From Phillipsburg northeast to Washington, New Jersey, the road follows a folded synclinal belt of CAMBRO-ORDOVICIAN limestone comprising the KITTATINNY limestone, which is an eastern equivalent of the Tomstown, Allentown (Conococheague) and Beekmantown limestones of nearby Pennsylvania. In the middle of this syncline, south of Phillipsburg and extending from Alpha nearly to New Village, there is an infolded belt of JACKSONBURG (MIDDLE ORDOVICIAN) limestone which was formerly quarried, together with the overlying cement rock, at Alpha, Vulcanite and New Village.
350.55	113.40	Toll bridge, Phillipsburg. New Jersey end of Delaware River bridge. Proceed eastwardly following Route 24. Two miles north is an active quarry in highly metamorphosed FRANKLIN (PRE-CAMBRIAN) limestone. Serpentine is quarried, crushed and sold for use in terrazzo flooring. Steatite and molybdenite are also present.

MILEAGES Total	Trip	
350.65	113.50	KITTATINNY (CAMBRO-ORDOVICIAN) limestone outcrop.
		Outcrop of KITTATINNY limestone showing some internal folding and jointing. The structure of the rocks in Phillipsburg is quite complex and has not been worked out in detail. A small pre-CAMBRIAN remnant of the sole of a thrust block occurring just south of town is only half a mile west of a sliver of Ordovician JACKSONBURG limestone exposed in a cut of the D. L. & W. RR.
350.80	113.65	Main business district. City Natural Gas Company to right.
351.05	113.90	LUNCH STOP.
351.55	114.40	Buses will pull off road at Golden Valley Farms Milk Bar, Gateway Diner and adjoining gasoline service station.
351.85	114.70	Ingersoll-Rand plant at right. Manufacture gas compressors, drilling equipment, etc.
352.45	115.30	**Keep left** on Route 24.
353.95	116.80	Crossroads at Coopersville. About to enter synclinal valley with cement rock in center.
		The KITTATINNY limestone of this region is more than 3,000 feet thick. It overlies the HARDYSTON (LOWER CAMBRIAN) quartzite which has a narrow belt of outcrop at the edge of the pre-Cambrian rocks that form the hill country west and north (left) of the road.
354.55	117.40	Hills on left are underlain by pre-CAMBRIAN gneiss. Many years ago small deposits of mica were mined here. Some of the books were as large as a man's hand. Here the HARDYSTON quartzite, which is present at the southwest end of the anticlinal pre-CAMBRIAN mass about 1½ miles northwest, is either lacking, or is thin and inconspicuous.
357.05	119.90	Entering New Village. For many years the Edison Cement Corporation operated a plant about a mile to the south. Their quarry, between the plant and Pohatcong Creek, was abandoned not long after a blast broke into an open channel in the JACKSONBURG limestone, out of which gushed some 6,000 gallons a minute of beautifully clear but unwanted water.
357.75	120.60	Note the banks of the former Morris Canal on left. Started in the 1830's, and later deepened and widened, this canal was a hive of activity around 1850, carrying coal, iron ore and a variety of other goods and people across the northern part of the state.
359.35	122.20	Entering Broadway. This is near the middle of a broad synclinal valley with pre-CAMBRIAN walls.
360.15	123.00	Road swings across the center of the valley toward a gap in the right valley wall at Washington.
		The infolded limestone valley continues northeast, but the route leaves this syncline just beyond Washington and enters the parallel but larger valley of the Musconetcong River, skirting a hill on the left in which the pre-CAMBRIAN basement is exposed. These crystalline rocks are very complex, the predominant rock type in this area being BYRAM granite gneiss (see U.S.G.S. Bulletin 982-G, "Geology of the Dover Magnetite District, Morris County, N. J.", by Paul K. Sims, for a recent discussion of the pre-CAMBRIAN rocks). It is typically yellow-brown to brown-gray in color, but may have a pink tone because of the potash feldspar which distinguishes this rock type from the granitoid LOSEE gneiss.
362.45	125.30	Crossing Pohatcong Creek.
363.15	126.00	Entering Washington, New Jersey. Straight on Route 24.
363.90	126.75	Church on left made of greenstone serpentine quarried near Chester, Pennsylvania.
364.00	126.85	Traffic circle at junction with Route 69. Continue east on Route 24.

GENERALIZED CROSS SECTION ACROSS NORTHERN NEW JERSEY ALONG ROUTE OF FIELD TRIP




GEOLOGIC MAP OF NORTHERN NEW JERSEY.
0 5 10
Miles
SUSSEX
WARREN
PASSAIC
BERGEN
MORRIS
Water Gap
Dover
10
11
ESSEX
Newark
HUDSON
UNION
Phillipsburg
HUNTERDON
SOMERSET
MIDDLESEX
MONMOUTH
MERCER
Trenton
OCEAN
BURLINGTON
Camden
N
LEGEND
Tertiary
Cretaceous
Triassic
Devonian
Silurian
Ordovician
Cambrian
Pre-Cambrian
Diabase
Basalt
Serpentine
R. JAFFE

MILEAGES Total	Trip	
364.25	127.10	Underpass beneath main line of the D. L. & W. RR. Here we leave the valley of Pohatcong Creek and enter the valley of Musconetcong River. Note that the latter valley has been eroded in a down-folded mass of Paleozoic rock with known overthrusting of the pre-CAMBRIAN rocks on the southeast side, and a normal fault separating the MARTINSBURG shale from the pre-CAMBRIAN on the northwest side. The valley floor here is formed in part by the MARTINSBURG shale lying above the KITTATINNY limestone and showing here and there some evidence of the strong cleavage that once gave it much economic value as a source of slate in the Bangor-Penn Argyl region of Pennsylvania. The MARTINSBURG is at least 3,000 feet thick and is mainly UPPER ORDOVICIAN in age.
366.55	129.40	A mile to the north, at Port Murray, the National Fireproofing Company operates a brick plant where the raw materials used consist of weathered MARTINSBURG shale with some overlying glacial drift of Kansan age.
367.95	130.80	**Keep left** at road fork. Note Schooley Mountain to right. At several points on the way to Hackettstown, there is a good view of the level surface of this mountain east (right) of the road. The mountain marks the edge of the famous Schooley peneplain now believed to have been developed during the Tertiary.
368.45	131.30	Old lime kiln at quarry in KITTATINNY (CAMBRO-ORDOVICIAN) limestone. Note Musconetcong River on right. This is a famous trout stream which is annually stocked from the fish hatcheries at Hackettstown.
368.70	131.55	MARTINSBURG (UPPER ORDOVICIAN) shale forms low, smoothly rounded hills to left.
368.95	131.80	Note crumbling and shearing of MARTINSBURG.
371.15	134.00	More Martinsburg on left.
371.80	134.65	We have passed over the stratigraphic horizon of the JACKSONBURG (none outcropping). The limestone ledges on left belong to the KITTATINNY formation.
371.95	134.80	Note even-crested hills of MARTINSBURG shale to the left. Higher ridge beyond, called Upper Pohatcong Mountain, is composed of pre-CAMBRIAN gneiss.
372.75	135.60	Beattystown, New Jersey. Although limonitic iron ore was formerly mined half a mile to the northwest, the deposit, like most of those of similar type in the Great Valley, was relatively small, and the operation was short-lived.
374.65	137.50	Junction with Route 57. **Turn left.**
375.70	138.55	Junction with U. S. Route 46; Hackettstown, New Jersey. **Turn right.** At Hackettsown the route turns east (right) on U. S. Route 46 to ascend the west flank of Schooley Mountain, reaching the level summit of the Schooley peneplain at the mountain top, elevation about 1,200 feet. A last backward glance at the Musconetcong Valley will show that the KITTATINNY limestone belt continues northeast beyond Hackettstown. The low hill visible south of town is the northern end of the MARTINSBURG shale belt followed from Washington to Hackettstown.
375.90	138.75	Crossing Musconetcong River.
378.95	141.80	Top of Schooley Mountain and Schooley peneplain.
379.15	142.00	Pit in ILLINOIAN glacial drift to left. The composition and hardness of pebbles and cobbles in this drift differ considerably from those in the WISCONSIN drift.
380.75	143.60	Budd Lake to left. Formed as a result of the blocking of earlier drainage by the WISCONSIN terminal moraine. The lake outlet is to the southwest. From near the eastern end of the lake to a point well beyond Netcong, you will be traveling over the WISCONSIN terminal moraine. Its average thickness is probably close to 100 feet, although in places it is as much as 300 feet thick. It is economically important in that it is a source of both sand and gravel, and pure groundwater for private, industrial and municipal supply.

The majority of the morainal boulders are rounded fragments of the crystalline rocks of the New Jersey-New York "Highlands" belt, but one also sees here the purple "puddingstones" derived from the GREEN POND and SKUNNEMUNK formations of SILURIAN and DEVONIAN age, respectively. The "puddingstones" come from a synclinal inlier in the middle of the Highlands belt, across which we will soon be traveling. This syncline contains a Paleozoic section quite different in lithology from that of the more familiar Appalachian exposures, and it includes beds as young as ORISKANY (LOWER DEVONIAN) near the New York boundary line. Obviously, the different lithology is related to the fact that here we are in the eastern part of the Appalachian Trough, and the sediments, being nearer the source, are therefore coarser.

The enclosing belt of crystalline rocks continues northeast to form the New England Uplands and southwest as far as Reading, Pennsylvania, to form the Reading Hills. It forms the high hills, or mountains, through which the Hudson River cuts between West Point and Bear Mountain.

383.90 **146.75** Entering Netcong. Gravel pit on right. Just 1½ miles north is one of many bogs in the glaciated area of New Jersey. This one contains peat which is dug, dried and shipped for horticultural purposes. About 10 miles farther north is probably the largest peat operation in the country.

384.75 **147.60** Traffic circle. Junction with U. S. Route 206. Continue east on U. S. 46.

Between Netcong and Ledgewood, our route is over pre-CAMBRIAN rocks, although good exposures are few.

387.60 **150.45** **STOP 10.**

Cut in pre-CAMBRIAN gneiss. A typical granitoid gneiss of the New Jersey Highlands.

Just east of this cut the road crosses a gravity fault to enter the previously mentioned synclinal belt of SILURIAN and DEVONIAN rocks. Here they are mostly concealed beneath a thick cover of glacial outwash.

387.95 **150.80** Traffic circle at Ledgewood. Leave Route 46 and **keep right** for N. J. Route 10.

It was just north of this traffic circle that diatomite was found about 1872, and it is recorded that in 1874, fifty tons of it was used in making dynamite in the Kenvil plant of the Hercules Powder Company, one of the oldest powder plants in the country.

From Ledgewood past Succasunna the route crosses the flat valley floor of glacial outwash, and Black River, one of the headwaters of Raritan River. Note that it drains southward, whereas the stream which once drained the underlying pre-glacial rock valley flowed northward.

Leaving the valley the road again climbs the uplands formed by pre-CAMBRIAN rocks. Here the route is south of the WISCONSIN moraine, but patches of ILLINOIAN drift can be seen on both sides of the road. Only 2½ miles north of us as we reach the crest of the rise is the Scrub Oaks mine, the largest of a group of iron mines surrounding nearby Dover. Some of the mines in this area supplied the sinews of war to our revolutionary ancestors, and a succession of mines have been overlapping operation for more than 200 years. In 1953 shipments of New Jersey iron ore amounted to 815,905 long tons, with a value of $10,114,970. This does not appear large by comparison with national statistics; but the ore is high-grade, ranging from 61 to 65 percent iron, and with shipping charges to nearby furnaces much less than those for midwestern ore, it is hoped that we may continue to have an iron-mining industry in New Jersey for many years to come. All of the ore mined today is magnetite.

390.30 **153.15** Note weathered pre-CAMBRIAN granite gneiss on left.

MILEAGES Total	Trip	
392.20	155.05	Dover to left. Homes seen are part of new suburban development.
393.25	156.10	Road to left goes to Dover. Hills visible in distance to left contain iron mines.
395.80	158.65	Granite gneiss outcrops on right and left. Note joints.
397.40	160.25	Granite gneiss outcrops on right covered with moraine.
398.30	161.15	Starting downhill towards Ramapo fault. Granite gneiss outcrop on left.
398.75	161.60	Last outcrop of pre-CAMBRIAN granite gneiss.

Just before reaching Route 202 at Littleton, about 9.5 miles from Ledgewood, the route descends the steep face of the RAMAPO FAULT zone which is a major dislocation separating the TRIASSIC lowland (ahead) from the pre-CAMBRIAN upland (behind). It is a gravity-type fault in which the eastern block has dropped several thousand (perhaps 10,000) feet, truncating the pre-CAMBRIAN belt on the southeast. As the line of this fault can be traced from central New Jersey to Clove Creek, northeast of Peekskill, New York, on the east side of the Hudson River, it is a major element in the architecture of this region. Against it, or toward it, the red sandstones and shales of the TRIASSIC (NEWARK) series dip westward and northwestward at angles of 30° to 40°.

From Littleton to the Hudson River (30 miles), the route is entirely upon the TRIASSIC lowland belt and for the last 15 miles, it travels through the residential and industrial country of the Passaic and Hackensack valleys. The red TRIASSIC sandstones and shales have been extensively eroded to the level of the SOMERVILLE (TERTIARY) peneplain. We see only a few exposures of these relatively soft rocks. Only the more resistant basalts and intrusive diabase rise above the general lowland.

The major structure of this broad TRIASSIC lowland is fairly simple. It is a great half-graben in which the eastern TRIASSIC outcrop forms the west bank of the Hudson, off-lapping the crystalline rocks of New York. It includes 15,000 feet or more of red shale and sandstone, comprising the NEWARK series, out of which, either here in New Jersey, or farther east in Connecticut, the stone was obtained for the famous "Brownstone" epoch of New York architecture. Into these rocks, or upon their surfaces, were intruded at least one large sill of intrusive diabase and three flows of finer-grained basalt, both carrying the familiar name "trap" in the many quarries from which stone is taken for road building. The entire series, including the associated igneous rocks, dips westward or northwestward toward the Ramapo fault, a slight curvature of dip being responsible for the crescentic surface pattern of the several ridges of igneous rock. The latter rise 200 to 300 feet above the present level of the sediments, the greater resistance of these igneous rocks having prevented their erosion to the TERTIARY peneplain surface. Note that the level summit of the Palisades, elevation 350 to 400 feet, is the eastern expression of the Schooley peneplain that is 1,200 feet above sea level on Schooley Mountain, and more than 1,600 feet on Kittatinny Mountain at the extreme northwest edge of the state.

399.90	162.75	Junction with U. S. Route 202. **Turn left.**
		Road is roughly parallel and about 1 mile east of the RAMAPO FAULT. Traveling on thick deposits of WISCONSIN glacial drift above TRIASSIC rocks. Pre-Cambrian to the left.
402.95	165.80	Route 202 turns left. **Continue straight** ahead on unnumbered road to Route 46.
403.35	166.20	Sharp curve to the left.
403.50	166.35	Intersection with Route 46 at Jersey City Water Works.
		Turn right on Route 46.
404.40	167.25	Ridge in distance is the second or inner ridge of the Watchung or Orange Mountains.

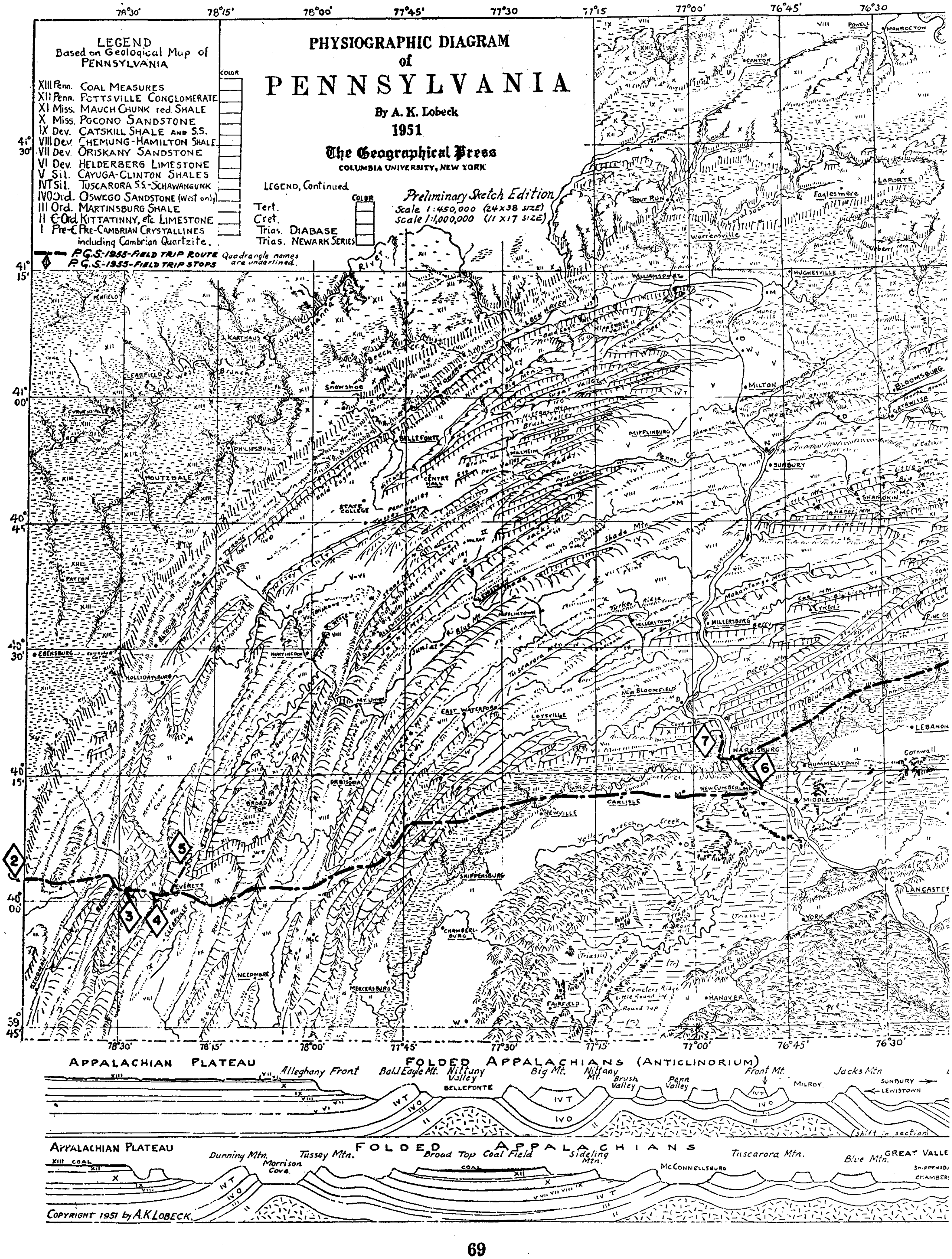
MILEAGES Total	Trip	
405.20	168.05	Intersection straight ahead, but **keep in LEFT LANE FOR LEFT TURN.**
406.05	168.90	**LEFT** off Route 46 to old blacktop road.
407.15	170.00	Crossing Rockaway River, a tributary of the Passaic River. Just ahead at Pine Brook the road cuts through the end of Hook Mountain, the youngest and stratigraphically the highest of the three extrusive basalt flows. This cut is an interesting place to examine the nature of a complex igneous flow.
407.65	170.50	**STOP 11.** Deep cut in TRIASSIC basalt. On the north side of the road, near the east end of the exposure, a lens-shaped zone in the basalt shows a slaggy, vesicular appearance unlike the massive or blocky aspect of the surrounding basalt. According to one opinion, this is the upper scoriaceous part of a lava flow, the denser basalt immediately above representing the next successive flow. Another has suggested that this is an olivine-segregation zone, more vulnerable to chemical weathering and hence possessing a crumbly appearance. Calcite and prehnite have been found in the amygdules, which are rather conspicuous in the vicinity. Westward, along the north side of the road cut, are several faults and shear zones. Some surfaces bear slickensides, visible about six feet above the ground and plunging at gentle angles, indicating an essentially lateral (strike-slip) movement. Some joint surfaces show green copper-staining. On the south side of the road the basalt is in part blocky due to the intersection of three sets of nearly perpendicular joints. Some of the joint-bounded blocky basalt is being spheroidally weathered in situ.
407.70	170.55	At east end of cut **turn right,** return to Route 46.
407.80	170.65	**Turn left** on U. S. 46. Be careful of traffic.
408.45	171.30	**Keep in left lane.**
408.65	171.50	Follow U. S. Route 46 **left** under overpass. Just beyond this point, the road crosses Passaic River which here flows north, draining the large inner lowland that was formerly the floor of glacial Lake Passaic. A few miles beyond, the road re-crosses the same river twice more, and 5 miles beyond the third bridge, it crosses the river a fourth time just below Paterson where the stream turns south to empty into Newark Bay.
409.00	171.85	Crossing Passaic River. Traveling on the bed of glacial Lake Passaic. The road is now north of the terminal moraine, last seen 9 miles back at Littleton, but deposits here of stratified glacial drift are a source of sand and gravel for local builders.
411.55	174.40	Entering Fairfield, home of the Propellor Division, Curtiss-Wright Corporation. Continue east on Route 46.
412.75	175.60	Crossing Passaic River a second time. Entering Passaic County; leaving Essex County.
413.45	176.30	Traffic circle—**bear left**—follow Route 46. Still on bed of glacial Lake Passaic.
414.45	177.30	**Stay in left lane** marked "Clifton—New York". Here the road heads eastward through the wide gap made through the Second Watchung Mountain by Passaic River, then it swings slightly south to pass through the narrow and much shallower gap in the First Watchung

Mountain at Great Notch (n.b. the city of Paterson fills the far, broader gap cut by the river). These crescentic ridges constitute a well-known topographic feature of northern New Jersey. They are upheld by two extrusive sheets of dark basalt, separated by 400 to 500 feet of red TRIASSIC shale that forms a subsequent valley between the two ridges, which can be followed for more than 40 miles. The basalts as well as the enclosing sediments dip northwestward toward the RAMAPO FAULT. In the old quarry near the railroad station in Paterson, a few miles north of this route, one could formerly collect an unusually excellent suite of minerals of the zeolite type. Quarrying of trap rock is one of the important mineral industries in New Jersey. In 1952, the latest year for which statistics are available, the state led all others in output of crushed basalt.

East of these ridges, the route again lies on the level floor of the TRIASSIC lowland, crossing first the Passaic River and its valley, and then the famous drowned valley of the Hackensack River (The Hackensack "Meadows") before reaching the back slope of the PALISADES.

MILEAGES Total	Trip	
415.05	177.90	Keep straight on U. S. Route 46.
415.25	178.10	Outcrop of basalt showing columnar jointing on right just before crossing the Passaic River again. Hill ahead is the First Orange or Watchung Mountain which the road crosses at Great Notch. The hill is formed by one of the extrusive flows of lava within the TRIASSIC series. Great Notch, a partial wind gap, may have been one of the spill points of glacial Lake Passaic.
416.65	179.50	Note the columnar jointing in the basalt.
417.35	180.20	TRIASSIC sandstones and shales, dipping northwest, can be seen behind the Esso station.
417.70	180.55	Junction Route 3—**Keep left** on U. S. Route 46. Ridge to left is the eastern edge of the First Watchung Mountain (basalt) through which the route just passed. (Note trap rock quarries.) The red shale we have just seen lies underneath it.
418.55	181.40	TRIASSIC red sandstone and shale on both sides of the road.
419.25	182.10	TRIASSIC red shale.
419.35	182.20	The road now descends on to the main flat floor of the TRIASSIC lowlands which from here nearly to the Hudson River are drained by the Passaic and Hackensack Rivers. Much of this country is an industrial suburb of the northern New Jersey metropolitan area, but the low eastern portion is still a salt-water marsh drained by the Hackensack River.
419.80	182.65	Continue on Route 46 **bearing left.**
420.15	183.00	Passing through Clifton, New Jersey.
420.75	183.60	Continue on Route 46 **bearing left** through underpass. Passaic River on the right.
421.05	183.90	Construction of highway overpass is for northern extension of Garden State Parkway.
421.65	184.50	**Keep right** on U. S. 46 over the Passaic River.
422.05	184.90	Overpass, Garden State Parkway.
422.55	185.40	TRIASSIC red shale and sandstone on both sides of the road.
423.95	186.80	Traffic circle. Continue east on Route 46. Road descending to Saddle River.
425.35	188.20	Junction Route 17—proceed on Route 46.
425.55	188.40	View of skyline of Manhattan. Empire State Building is tall structure on right. Extreme right is skyline of lower Manhattan. Ridge is formed of PALISADES diabase. Hackensack Meadows in foreground.

MILEAGES Total	Trip	
426.05	188.90	Entering Teterboro. Bendix Aviation plant on right; Ford plant on left. Teterboro Airport is where Arthur Godfrey "buzzes". It lies above the buried rock floor of Hackensack River which here was cut to 210 feet below present sea level. The varved clays in this valley have been used for nearly 100 years in the manufacture of brick.
427.10	189.95	**Keep left** on U. S. 46. Watch out for heavy traffic.
427.85	190.70	Traffic circle. Continue on Route 46 and cross Hackensack River.
429.15	192.00	Crossing under New Jersey Turnpike.
429.35	192.20	Crossing Overpeck Creek, a tributary of the Hackensack River.
429.60	192.45	Junction with U. S. Route 1. **Keep left** on U. S. 46. Beginning long climb up back slope of Palisades.
429.75	192.60	Stay on Route 46.
		The PALISADES is a long ridge forming an outer crescent with the same arc of curvature as the inner Watchung Mountains. It is an intrusive sill of fairly coarse diabase, 900 to 1,000 feet thick, dipping westward. The steep eastern face with its fine columnar joints, is a well-known feature of the lower Hudson Valley. The summit of the Palisades is an eastern remnant of the Schooley peneplain.
		The TRIASSIC series continues to the water's edge of the Hudson River; and the much older crystalline rocks of Manhattan Island emerge on the opposite bank. Possibly there is a fault here, but in any case there is a great unconformity, for most, and possibly all of the Paleozoic system is absent. Good outcrops of the PALISADES diabase can be seen at the toll gate to the George Washington Bridge as we leave New Jersey for New York.
431.00	193.85	At far left the range of the Watchung Mountains may be seen.
432.75	195.60	Toll gate, George Washington Bridge.


PHYSIOGRAPHIC DIAGRAM
of
PENNSYLVANIA
By A. K. Lobeck
1951
The Geographical Press
COLUMBIA UNIVERSITY, NEW YORK
Preliminary Sketch Edition
Scale 1:450,000 (24 X 38 SIZE)
Scale 1:1,000,000 (11 X 17 SIZE)
LEGEND
Based on Geological Map of PENNSYLVANIA
XIII Penn. COAL MEASURES
XII Penn. POTTSVILLE CONGLOMERATE
XI Miss. MAUCH CHUNK red SHALE
X Miss. POCONO SANDSTONE
IX Dev. CATSKILL SHALE AND S.S.
VIII Dev. CHEMUNG-HAMILTON SHALE
VII Dev. ORISKANY SANDSTONE
VI Dev. HELDERBERG LIMESTONE
V Sil. CAYUGA-CLINTON SHALES
IVT Sil. TUSCARORA S.S.-SCHAWANGUNK
IVO Ord. OSWEGO SANDSTONE (west only)
III Ord. MARTINSBURG SHALE
II Є-Ord. KITTATINNY, etc. LIMESTONE
I Pre-Є PRE-CAMBRIAN CRYSTALLINES including Cambrian Quartzite.
COLOR
LEGEND, Continued
Tert.
Cret.
Trias. DIABASE
Trias. NEWARK SERIES
P.G.S.-1955-FIELD TRIP ROUTE
P.G.S.-1955-FIELD TRIP STOPS
Quadrangle names are underlined.
WILLIAMSPORT
BELLEFONTE
STATE COLLEGE
MILTON
SUNBURY
BLOOMSBURG
MIFFLINBURG
HARRISBURG
CARLISLE
NEW CUMBERLAND
MIDDLETOWN
HUMMELSTOWN
LEBANON
LANCASTER
YORK
HANOVER
GETTYSBURG
CHAMBERSBURG
SHIPPENSBURG
MERCERSBURG
NEWVILLE
EVERETT
NEEDMORE
FAIRFIELD
LOYSVILLE
NEW BLOOMFIELD
MILLERSTOWN
MILLERSBURG
MIFFLINTOWN
HUNTINGDON
HOLLIDAYSBURG
EBENSBURG
PATTON
HOUTZDALE
PHILIPSBURG
CLEARFIELD
CURWENSVILLE
PENFIELD
KARTHAUS
SNOW SHOE
LOCK HAVEN
HUGHESVILLE
LAPORTE
CANTON
MONROETON
TROUT RUN
SHAMOKIN
ORBISONIA
BROAD TOP
Susquehanna
Juniata
APPALACHIAN PLATEAU
FOLDED APPALACHIANS (ANTICLINORIUM)
Allegheny Front
Bald Eagle Mt.
Nittany Valley
Big Mt.
Nittany Mt.
Brush Valley
Penn Valley
Front Mt.
MILROY
Jacks Mtn
SUNBURY
LEWISTOWN
APPALACHIAN PLATEAU
FOLDED APPALACHIANS
Dunning Mtn.
Morrison Cove.
Tussey Mtn.
Broad Top Coal Field
Sideling Mtn.
McCONNELLSBURG
Tuscarora Mtn.
Blue Mtn.
GREAT VALLEY
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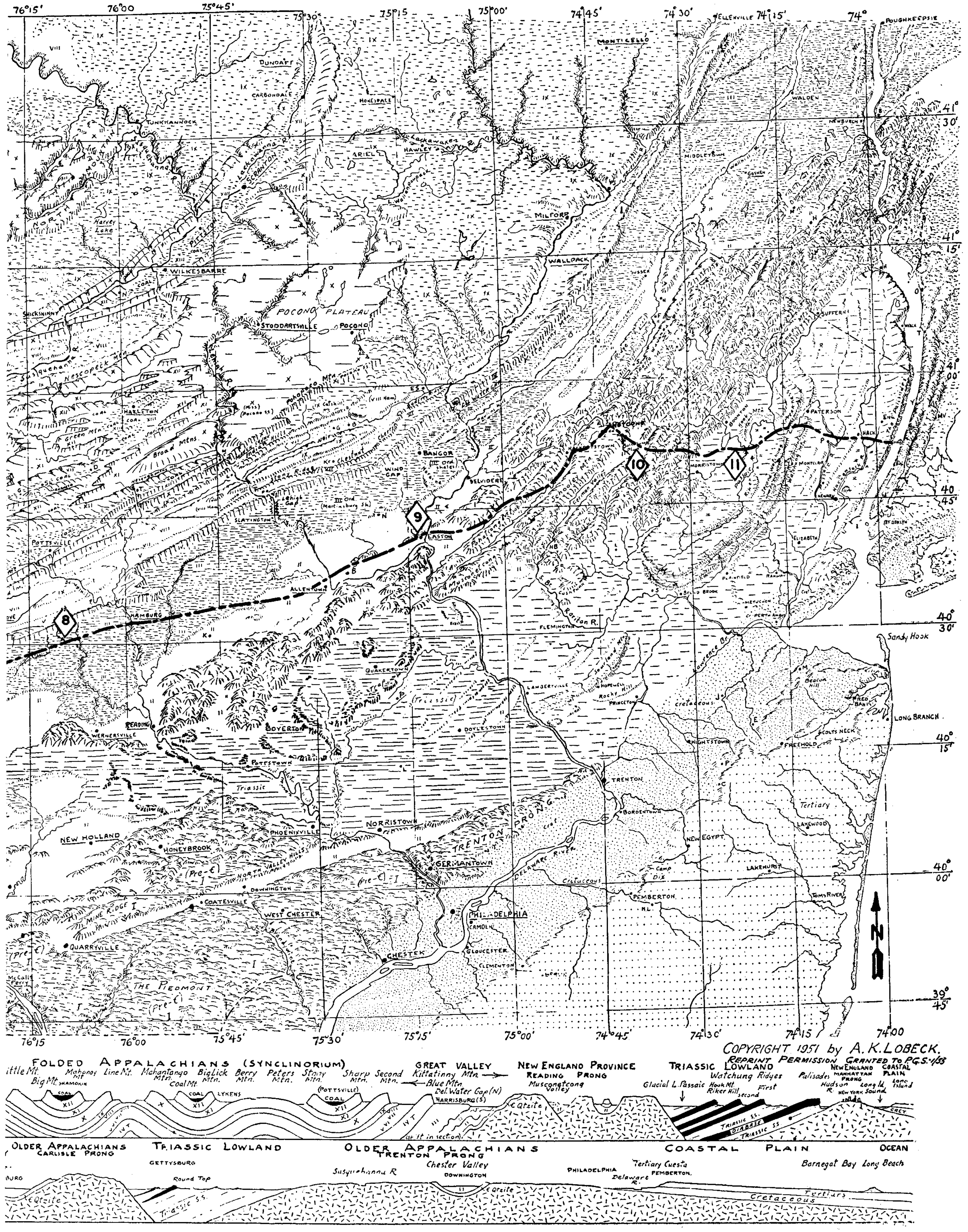
76°15'
76°00
75°45'
75°30'
75°15
75°00'
74°45'
74°30'
74°15'
74°
MONTICELLO
ELLENVILLE
POUGHKEEPSIE
DUNDAFF
CARBONDALE
HONESDALE
WALDEN
TUNKHANNOCK
NEWBURGH
ARIEL
HAWLEY
Lackawaxen R.
MIDDLETOWN
GOSHEN
SCRANTON
MILFORD
WILKESBARRE
WALLPACK
SHICKSHINNY
POCONO PLATEAU
STODDARTSVILLE
POCONO
SUFFERN
Nescopeck Mtn.
Pohopoco Mtn.
HAZLETON
Broad Mtns.
BANGOR
WIND GAP
BELVIDERE
PATERSON
MORRISTOWN
MONTCLAIR
NEWARK
SLATINGTON
Lehigh Gap
POTTSVILLE
EASTON
ELIZABETH
ALLENTOWN
HAMBURG
PLAINFIELD
RAHWAY
METUCHEN
PERTH AMBOY
FLEMINGTON
Raritan R.
Sandy Hook
QUAKERTOWN
LAMBERTVILLE
HOPEWELL
PRINCETON
Cretaceous
LONG BRANCH
READING
WERNERSVILLE
BOYERTOWN
DOYLESTOWN
HIGHTSTOWN
FREEHOLD
POTTSTOWN
Triassic
TRENTON
Tertiary
BORDENTOWN
LAKEWOOD
NEW HOLLAND
HONEYBROOK
PHOENIXVILLE
NORRISTOWN
TRENTON PRONG
NEW EGYPT
GERMANTOWN
DELAWARE RIVER
Camp Dix
LAKEHURST
NORTH VALLEY HILLS
DOWNINGTON
Cretaceous
PEMBERTON
TOMS RIVER
COATESVILLE
MINE RIDGE
WEST CHESTER
PHILADELPHIA
CAMDEN
QUARRYVILLE
CHESTER
GLOUCESTER
CLEMENTON
THE PIEDMONT
(Pre-Є)
8
9
10
11
N
41° 30'
41° 15'
41° 00'
40° 45'
40° 30'
40° 15'
40° 00'
39° 45'
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FOLDED APPALACHIANS (SYNCLINORIUM)
GREAT VALLEY
NEW ENGLAND PROVINCE
TRIASSIC LOWLAND
Mahanoy Mt.
Line Mt.
Mahantango Mtn.
Big Lick Mtn.
Berry Mtn.
Peters Mtn.
Stony Mtn.
Sharp Mtn.
Second Mtn.
Kittatinny Mtn.
Blue Mtn.
Del. Water Gap (N)
HARRISBURG (S)
READING PRONG
Musconetcong Valley
Glacial L. Passaic
Watchung Ridges
Hook Mt.
Riker Hill
First
Second
Palisades
Hudson R.
NEW ENGLAND PRONG
MANHATTAN PRONG
NEW YORK
Long Id. Sound
COASTAL PLAIN
LONG ISLAND
Big Mt.
SHAMOKIN
Coal Mt.
LYKENS
(POTTSVILLE)
COAL
TRIASSIC SS.
DIABASE
CRET
OLDER APPALACHIANS
CARLISLE PRONG
TRIASSIC LOWLAND
OLDER APPALACHIANS
TRENTON PRONG
COASTAL PLAIN
OCEAN
GETTYSBURG
Susquehanna R
Chester Valley
DOWNINGTON
PHILADELPHIA
Tertiary Cuesta
Delaware R.
PEMBERTON
Barnegat Bay
Long Beach
Round Top
Triassic SS.
Tertiary
Cretaceous

DESCRIPTION OF THE PALEOZOIC SEDIMENTS IN WESTERN AND CENTRAL PENNSYLVANIA

By F. M. SWARTZ*

The Paleozoic sediments of the regions in Pennsylvania crossed by the route of the 1955 field trip, total somewhere in the neighborhood of 25,000 feet in maximum thickness.

At their base in south-central Pennsylvania are several thousand feet of Lower Cambrian sands and clays that during the Appalachian deformation were metamorphosed to low-rank metaquartzites and phyllites. Higher Cambrian sediments, and Lower and Middle Ordovician deposits predominantly are limestones and dolomites. Sands intercalated in the Upper Cambrian of central Pennsylvania came from the north and northwest, and in their subsurface areas give promise for gas and oil. By Middle Ordovician time, lands bordering the eastern margin of the Appalachian region were enlarging and rising, shedding detritus to the Appalachian platform of deposition. Throughout the remainder of the Paleozoic Era, these easterly lands underwent recurrent uplift, each reinvigoration of their erosion reflected by a complex of detritals spreading westward across the Appalachian area. Carbonates accordingly decrease in proportion to clays and sands in the post-Middle Ordovician sediments. Shifting loci of the crustal movements of the easterly land areas probably from time to time brought differing regions into the belts of uplift and erosional attack.

Oftimes, the sedimentary rate of supply was rapid, and even in shallow reaches of the sea the detrital materials were poorly winnowed and graywackyish. During other intervals, clean quartz sands spread widely over the basin floor, the separation of sedimentary fractions probably aided by reworking of sedimentary detritus already partly sorted, by character of weathering in the regions of erosion, as well as by repeated shifting and reshifting of the land-derived debris in broad shallow regions of the sea, where cleansing was vigorous in ratio to influx.

The more significant upwarpings of the source-lands on the east slowed subsidence of nearer parts of the platform of deposition so that sedimentation or in some instances actual uplift raised the surface of accumulation, caused westward retreat of marine waters, and led to westward spreading of continental, poorly washed sands and clays, laid down across wide delta-coasts by sluggish river and lagoonal waters.

The keynote of this Appalachian Paleozoic deposition is flatness of the platform of deposition and wide spreading of the detrital sediments laid upon it. There is marked contrast, for example, with the narrow, rapidly sinking straits that set the scene for the Cretaceous and Tertiary sedimentation of California.

The platform was of course unstable. There was progressive though irregularly discontinuous subsidence that eventually carried the earliest Paleozoic surfaces as much as four to five miles below the level of the sea. Gentle warping ever shifted the details of the paleogeographic patterns. The Adirondack region of northeastern New York especially was a positive area, at least in terms of the earlier Paleozoic sediments that flank it and give some evidence of its history. Some of the large fold axes emphasized by Appalachian folding may have been gently active during Paleozoic sedimentation, but in general the effects are obscure and difficult to detect.

Aquatic plants and animals flourished through long periods and over wide areas of the marine and estaurine waters. The ratios of growth of organic debris, its oxidation and trend toward destruction, its entombment in the accumulating sediments, must have fluctuated widely both from place to place and from time to time. To the extent that the balances were favorable, organic substances became part of the sedimentary accumulations and thus potentially were the raw materials for oil and gas that then required proper reservoirs for preservation for human use.

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The Pennsylvanian and Permian sediments of the closing phases of Appalachian Paleozoic sedimentation were laid down over wide regions on surfaces exceptionally adjusted to the curvature of sea level. Slight fluctuating movements, with irregularities of subsidence and sedimentary fill, gave rise to cycles of sedimentation that began with low emergence and shallow fluviatile sculpturing, and then continued successively through alluvial aggradation, the spreading of ill-drained swamps nearly free of detrital influx, and the transgression of clay-depositing shallow estuarine-marine waters, until new shallowing or emergence began a new cycle. The swamp deposits of these cyclothems form the coal layers basic with man's ingenuity for industrialization of the Commonwealth of Pennsylvania.

Permian and Pennsylvanian Systems

Permian strata virtually are confined in Pennsylvania to a structurally deepened basin extending southwest of Pittsburgh. Pennsylvanian strata are preserved below present levels of erosion over a far larger region, the total area of outcrop forming a fourth or more of the surface of the state.

The trip route begins in upper parts of the Pennsylvanian; for the first 90 miles eastward to the Allegheny Front the surface is almost continuously veneered with the 1,400 or 1,500 feet thickness of the Pennsylvanian strata, that rise and fall in gentle anticlinal arches and synclinal troughs. East of the Allegheny Front the trip will skirt the southern margin of the Broad Top coal field, where Pennsylvanian strata are preserved in the deeper, gently flexed axial part of the Broad Top Synclinorium.

The older generation of geologists and miners realistically divided the Permian and Pennsylvanian or Coal Measures strata of western Pennsylvania into Upper Barren Measures, Upper Productive Measures, Lower Barren Measures, and Lower Productive Measures, based by the sandstones and conglomeratic sandstones now named Pottsville formation.

The Upper Barren Measures represent the Permian System. They reach thicknesses of 1,100 to 1,200 feet near the southwestern angle of Pennsylvania, where they are termed the Dunkard group or series. The sediments dominantly are shale with some thin interbeds of sandstone and limestones, and include several thin coals of which only one has much commercial value. The lower portion contains more limestone interbeds and is named Washington formation; higher beds are classed as Greene formation.

The Upper Productive Measures, 350 feet thick near Pittsburgh, are now termed Monongahela, and like the next lower Conemaugh and Allegheny were named from rivers that reach confluence in the Pittsburgh region and give rise to the Ohio. The Monongahela, Conemaugh, and Allegheny have been classed as formations since they commonly are mapping units; all are complex, and have variously been ranked as groups or series.

At the top and in the middle parts of the Monongahela are the Waynesburg, Uniontown, Sewickley, and Redstone coals. These are outweighed by the basal Pittsburgh coal, probably continuous in its original extent across at least 12,000 to 15,000 square miles. It is more than 13 feet thick near Pittsburgh, averages 7 feet through 2,000 square miles, is workable in some 6,000 square miles, and is said to be the most valuable continuous mineral deposit of the world.

Like the Monongahela, the Allegheny group contains coals of great value, including in descending order Upper and Lower Freeport, Upper, Middle and Lower Kittanning, and Brookville coals. Because of greater areal extent, the Allegheny coals probably total more in value in Pennsylvania than do those of the Monongahela. The Allegheny group is about 250 feet thick in western Pennsylvania. Between the Monongahela and Allegheny, the Conemaugh is 600 to 900 feet, its coals few and thin. Below the Allegheny, the Pottsville west of the Allegheny Front commonly measures about 200 feet; it has persistent upper and lower sandstone members, with the discontinuous, thin Mercer coal associated with the intervening shales.

The coals of The Pennsylvanian System constitute the greatest mineral resource of Pennsylvania. They furnish the major source of energy for transport and industrialization, and their byproducts are invaluable for chemicals and plastics. They draw to the State iron ores from Lake Superior and other regions of the world, and have led to growth of metallurgical and fabricating industries of first magnitude.

Sedimentation of the coal and associated strata of the Pennsylvanian presents features of much geologic interest. The continental surface stretched from Pennsylvania to and beyond Illinois as a platform of remarkable flatness. At times the platform stood high enough so that larger traversing streams sculptured valleys 20, 50, and less commonly 80 or 100 feet in depth, some of them nearly flat-floored for a mile or two in width. Sidewalls slumped into deeper channels. With gradual subsidence of the platform, sluggish streams clogged the channels with sands, silts, and clays swept in from hill-lands on the east, and in some degree eventually spread their debris over the flat-surfaced interfluves. Subsequently, perhaps by lateral shifts of the scenes of sedimentation, the influx of silt and clay was lessened, and widespread swamp lands were clothed by spreading growths of ancient, spore-reproducing ferns, giant horse-tails and scale-bark trees. Leaves, spores, branches, and tree-trunks fell into the swamp muck, were protected from complete oxidation, and grew into thick layers of peat that after burial were destined to become our present coals. Beneath the coals are underclays of disputed origin; some of these are fire-clays valuable for fire brick manufacture; some have been investigated as future ores of aluminum.

Upon this continental sequence, incoming seas and their marginal lagoonal-estaurine waters slowly deposited clays; where and when the waters cleared, marine limestones accumulated on the sea floor. The platform then again began to rise and the receding waters left behind them upper clayey and silty muck.

Continued rise carried the continental platform high enough so that it was again sculptured by its streams, which might locally cut to or through the buried, underlying layer of peat. After the interval of platform uplift, the cycle of movement would again revert to the predominant, progressive subsidence, and the scene again was set so that if the balance needed for swamp growth was long and delicately maintained, another sheet of peat would be formed and another bed of potential coal would be created.

The cyclic deposits or cyclothems produced by this combination of astounding flatness of platform, favorable relation to level of the sea, and tectonic fluctuation, were repeatedly spread upon areas stretching from eastern to central states, though the individual lithologic members had lesser geographic persistence. For some combination of reasons, fundamentally tectonic, swamps were most widespread and longest maintained during two stages of still larger rhythms, and the Allegheny and Monongahela productive measures were accumulated.

The coal measures of Pennsylvania reflect the closing stages of Appalachian Paleozoic sedimentation, just as the Late Cretaceous-Early Cenozoic coals of the western states were formed during the end period of the Rocky Mountain trough. Flatness of platform in part at least resulted from the grading effects of long continued sedimentation. Resurgent upward movements that time and again interrupted the progressive though slow subsidence may bear witness to activity of those earth movements that soon were to culminate in strong Appalachian folding; it might more properly be supposed that they reflect early stages of the Appalachian orogeny that were more strongly at work at or beyond the present eastern margin of the Appalachian Highlands.

Although the cyclothems have remarkable geographical extent, lateral changes within them are to be expected as in all sediments. Marine parts of the cyclothems, and limestone members of these marine portions, tend to be better developed toward the west, in the direction from which the marine invasions were derived. Relations to the geography of marine and fresh waters may have effected peat-swamp waters themselves and may be related to some of the variations in pyrite content of the coals. Some eastward coarsening of the clastic sediments can be expected. The sandstones and siltstones have of course intricate variations and patterns of thickness related to the sculpturing of the surface on which they were spread and the intricacies of the streams that deposited them. The upper marine hemicycle likewise is intricately transected by erosion that resulted from the post-cyclothem uplift.

The Pottsville in eastern Pennsylvania reaches thicknesses of 1,200 and 1,300 feet as compared to the 200 feet at the Allegheny Front. Many beds are conglomerates crowded with well worn pebbles of milky quartz and other rocks commonly an inch or so in diameter but ranging to six inches or even more. Neighboring lands on the east were active tectonically, undergoing rapid wear. At other times, however, little sediment reached the eastern Pennsylvania coal-field regions; the mammoth coal seam, 30 to as much as 50 feet and more in the anthracite fields, represents such a period of freedom from influx of clastic detritus.

Superimposed upon all these other geologic features of the Pennsylvanian is a change in character of the coals so that near the Ohio line the fixed-carbon content on the ash-free basis is about 55 to 57 per cent; compositions change progressively eastward so that at the Allegheny Front the fixed carbon has increased to 75 or 80 per cent; in the Broad Top field it is 80 to 85 per cent; in the eastern anthracite fields it rises from 90 per cent at the tip of the "Fish-Tail" north of Harrisburg to 97 per cent and more in some interior parts of the fields.

The overall rise in percentage of fixed carbon toward the east is complicated by various secondary modifications or anomalies of the general pattern.

General geologic opinion has long attributed the overall eastward increase in proportion of fixed carbon to physico-chemical alterations associated with the Appalachian deformation. Attention has also been called to secondary anomalies not immediately explained by relation to the region of deformation. Influence of varying thicknesses of overburden has been emphasized through its influence on building up of temperatures and pressures. One view has held that bacterial activities in the ancient swamps, continuing anaerobically under an accumulating overburden of sediments, has been an important factor affecting coal rank. Character of roof would affect rate of loss of gaseous hydrocarbons, and might modify the physicochemistry of change of peat to coal. Time is of course a kind of super-factor modifying the work of all of the above conditions and processes.

The problem of cause of change in coal rank has immediate interest to the petroleum geologist in view of the controversies that have continued to rage about the carbon-ratio theory of David White.

MISSISSIPPIAN SYSTEM

The Mississippian rocks of southwestern and central Pennsylvania consist of two major divisions: an upper body of red shale and sandstone, and a lower mass of graywackyish sandstone. The red shale is named Mauch Chunk from a town in eastern Pennsylvania now named Jim Thorpe, Pennsylvania, and the sandstone Pocono from a mountain area of the same general region. Thin sandy Loyalhanna limestone is widespread at the top of the Pocono west of the Allegheny Front in southwestern Pennsylvania, and thin Greenbrier limestone locally interfingers with the Mauch Chunk red beds.

As known in wells near and for some distance to the east of Pittsburgh, the Mauch Chunk red shale varies from zero to about 150 feet in thickness. Where it rises to the surface at the Chestnut Ridge and Laurel Hill anticlines along the course of the trip, it is about 150 feet thick and contains in its lower part thin tongues or lentils of highly fossiliferous, marine Greenbrier limestone, containing brachiopods and other fossils indicative of equivalence to the Maxville limestone of Ohio; the Greenbrier limestone thickens rapidly southwestwards across western Maryland to east-central West Virginia. Continuing eastward in Pennsylvania to the Allegheny Front, the Mauch Chunk red beds are 200 to 500 feet thick, and the Greenbrier limestone facies disappears, possibly replaced in part by greenish sandstones.

Eastward from the Allegheny Front, the Mauch Chunk shales thicken further in the Broad Top synclinorium, and still farther east in Cove Valley north of Harrisburg reach totals of 2,500 or possibly 3,000 and more feet, consisting of repetitions of red shale and weak red sandstone. Thicknesses of several thousands of feet are maintained along much of the margins of the southerly anthracite fields, giving rise to wide-floored valleys between the high ribs made of the Pocono and Pottsville conglomerates. Amphibian tracks have been reported in the Mauch Chunk of these easterly regions.

The Mauch Chunk sediments are deposits of a broad delta-coast region, the climate warm and humid. Much of the material probably was spread directly by sluggish rivers whose active upper waters were eroding hill lands on the east. Parts of the sediment probably spread, still red, into freshened waters of lagoons and estuaries. Shallow seas entering across western Maryland brought with them, when currents maintained normal saltiness, a profusion of brachiopods, together with bryozoa, mollusks, crinoids and blastoides, and rare trilobites.

The Pocono sandstone likewise was formed by a vast supply of detritus worn from easterly lands. Near Harrisburg the formation is about 1,200 to 1,500 feet in thickness, its middle and lower parts dominated by crossbedded, thick-bedded and resistant conglomerates in which the rounded pebbles consist of milky quartz, some cherts and quartzites, and commonly are an inch or so in diameter. Conglomerates are rarer in the upper parts, where some shale interbeds made their appearance, and the boundary with the overlying Mauch Chunk red shales appears to be transitional. Beneath the Pocono near Harrisburg are several hundred feet of red shaly Catskill sandstones, then the greenish Honesdale sandstones, then the bulk of the Catskill red beds.

In successive ridges north of Harrisburg, the Pocono undergoes marked diminution in numbers of the pebbles that are so prominent in Second Mountain. Similar diminution in numbers though not disappearance of pebbly beds occurs westward toward the Allegheny Front; minor pebbly members persist to the Laurel Hill and Chestnut Ridge anticlines.

At the Allegheny Front, the Pocono formation is about 1,000 feet thick. Here the coarser sandstones constitute the upper third or somewhat more of the formation and form the Burgoon sandstone member, in which shale interbeds are few. The lower two-thirds of the Pocono consist of interbedded greenish sandstone and shale, with some purplish to reddish shale interlayers; farther northwest, one of the shale interlayers has been named the Patton member of the Pocono.

Actually, the lower sandstone and shale member is composed of repetitive cyclothems, simpler than those of the Pennsylvanian. Where described by the writer near the Horseshoe Curve, a characteristic cyclothem of the lower or middle Pocono rests upon an erosion surface, in some instances clearly channeled even in a limited exposure; graywackyish sands were spread irregularly upon the eroded surface, tending to thicken in the channel depressions; the sands were followed by clays or silty clays; emergence was then sufficient to cause shallow erosion features. With renewal of sedimentation, another cyclothem was inaugurated.

Plant fossils are moderately common in many of the sandstone and shale members of these Pocono cyclothems; in the shales some of the preserved plant structures are very delicate and could not have survived other than quiet transport. The shale member of one of the cyclothems near the Horseshoe Curve contains thin-shelled pelecypods and fish plates; this may represent a shale member that farther south contains brachiopods and fossils of other definitely marine creatures.

Red deposits occur in several of the cyclothems. Most characteristically, it is the upper part of the sandstone member and more especially the lower part of the shale member that becomes red-colored.

In the Broad Top region, several thin streaks of coal have been reported in the Pocono. Relations to cyclothems are not known.

Westward from the Allegheny Front, the Pocono sandstones become sparingly calcareous, and marine fossils become more numerous. Pebbly lenses persist as a minor feature of the mass.

It is anomalous that at the Susquehanna north of Harrisburg it is the middle to lower part of the Pocono that is coarsest grained with few interbeds of shale, whereas at the Allegheny Front the upper beds of the formation as now understood form the thick and solid mass classed as Burgoon. It is possible that the main pebbly mass of the Pocono near Harrisburg will prove to be the equivalent of the Burgoon, and it may be that the strata at the Susquehanna now classed as highest Catskill, possibly including the Honesdale, will be found to represent the lower portion of the Pocono of the Allegheny Front. Further studies of the facies problems of these formational boundaries are much needed.

In general it appears that during Pocono time the eastern hill lands were elevated and were being actively carved by swift running streams that transported vast quantities of detritus to broad lowlands. In eastern Pennsylvania a delta coast with associated estuaries, lagoons, and beaches subsided below accumulating gravelly sands. Farther west the pebbles lessened in numbers; but sands and clays were carried onto floors of shallow marine waters. In parts of the region and for a time, at least, the progressive subsidence was recurrently interrupted; repeatedly, elevation with gentle erosion was followed by renewed sedimentation beginning with sands, that were followed by clays spread over the floors of shallow estuarine and lagoonal waters locally varying to more normal marine. Red sediments, that were to dominate the region in Mauch Chunk time, were formed from time to time, increased somewhat in quantity toward the east, and may be represented near Harrisburg by some of the red beds now classed as highest Catskill.

At the top of the Pocono sandstone along and to the west of the Allegheny Front, there is a well defined and widespread calcareous sandstone or sandy limestone termed Loyalhanna limestone. This formation is persistently characterized by strong cross-bedding suggestive of aeolian type. The sand grains are mostly quartz. More calcareous laminae in part are oolitic. Butts believes these strata are traceable southwestwards into the Fredonia-St. Genevieve division of the Mississippian. The rock has been quarried extensively for railroad ballast. For subsurface geology, it makes a sharply marked and excellently recognizable horizon. The Loyalhanna appears to be associated with renewal of sedimentary accumulation upon a widespread surface of emergence; the Burgoon sandstone beneath it is believed to trace into the Logan-Black Hand sandstone of Ohio, and if the Loyalhanna is St. Genevieve in age then the Meramec of the Mississippi Valley region is unrepresented in this region.

The Mississippian strata are well known to the well driller of western and southwestern Pennsylvania. The thin red Mauch Chunk shales are a marker at the summit of the persistent Big Injun sand or Burgoon sandstone. Lower beds of the subsurface Pocono include the important Murrysville sand.

DEVONIAN SYSTEM

The Devonian strata of Pennsylvania are composed of a great volume of sands and clays that were eroded from hill lands on the east and spread out upon the broad platform of the Appalachian trough, in part on delta-plains of rivers and in part on the floors of shallow estuarine and marine waters.

Eastwards from Pittsburgh to Harrisburg the Devonian sediments increase in thickness, coarseness of texture, and in proportion of continental red clay and sand rocks.

Throughout the region, limestones are thin and minor in proportion to the mass. There are, however, three limestone members that are widespread and important in correlation; these are the Tully limestone at the base of the Upper Devonian, the Onondaga limestone at the base of the Middle Devonian, and the Helderberg limestone at the base of the Lower Devonian. Several additional thin limestone layers occur more locally in the offshore phases of the Middle Devonian. Black shales tend to thicken somewhat westwards above the Tully and Onondaga limestones.

In tectonics of the time of deposition, the Devonian sediments of the region principally reflect resurgent uplifts of the Taconic disturbance.

In Early Devonian time, the hill lands of the east were relatively quiescent. Thin Helderberg lime deposits and some clays accumulated in seas that stretched southwestwards from western New York toward western Tennessee. The waters teemed with brachiopods and other marine life, and seem to have been connected with the oceans both to the northeast and southwest. On the southeastern margin of these shallow straits the Harrisburg region was emergent as was the Buffalo area to the northwest. Minor tongues of cleanly washed quartz sands were deposited locally along margins of the trough during Helderberg time, and later during the Oriskanian such sands spread far more widely over the sea floor to form the Oriskany sandstone beds.

Like the Helderberg strata, Oriskany deposits are missing near Harrisburg. The Lower Devonian Helderberg and Oriskany sediments rarely are as much as 300 feet thick along the course of the trip. The Oriskany sands nevertheless are significant where below ground for their pools of natural gas. In some regions of exposure they are valuable as a source of quartz sand pure enough to use in manufacturing glass. Over wide areas, the Oriskany sands contain considerable proportions of lime both as shells of the locally profuse brachiopods of the *Spirifer arenosus* fauna, and also as cement in interstices between the grains of quartz sand. Where the Oriskany sands are used for glass manufacture, the lime is low in percentage, perhaps in part due to leaching of the modern weathering cycle. In central Pennsylvania, and also probably in the subsurface areas of western and northern Pennsylvania and western New York, there is a surface of disconformity at the top of the Oriskany sands; lime-leaching at the time of post-Oriskany emergence may be significant in origin of porosity in at least some of the Oriskany reservoir areas, and may also have affected the Oriskany where most valuable for glass sand.

The Oriskany deposits are widely overlain by Onondaga sediments that inaugurate the Middle Devonian. In central Pennsylvania the Onondaga beds consist of limy clays and clayey limestones; but northeastward, northward, and westward, the limestones are less argillaceous but contain nodules of dark chert abrasive for drilling tools.

Following Onondaga time, upward surge of the hill-lands to the east led to rapid erosion, so that poorly washed graywackyish sands were carried to the Harrisburg region and there accumulated to form the thousand feet or more of Hamilton-age marine Montebello sandstone; clays swept farther west and north in the shallow marine waters to form the black Marcellus shales and the brachiopod-bearing, gray Hamilton or Mahantango shales with some thin, very subordinate limestone members such as the Menteth limestone of the shore of Lake Canandaigua in New York.

Following Hamilton sedimentation, the easterly hill-lands for a time were low; the seas of the Appalachian trough may have deepened somewhat; they at least cleared enough for widespread accumulation of the thin Tully limestone, highly valuable as a marker in subsurface studies. The Tully is characterized by *Hypothyridina venustula* that for a half-century was identified as *Hypothyris cuboides* and considered an intercontinental marker for the base of the Upper Devonian.

Renewed Acadian activity in the easterly lands again strengthened the forces of erosion and transportation, so that sands and clays again flooded westwards into the Appalachian basin. In some parts of northern New Jersey and eastern New York and Pennsylvania, the earliest of the Upper Devonian deposits and indeed at some places the later Middle Devonian as well, consist of continental red beds. At Harrisburg, however, the basal one to two thousand feet of the Upper Devonian consist of rapidly deposited, poorly cleansed, graywackyish marine or estuarine Trimmers Rock sands and some clays, that to the west and north become increasingly argillaceous and form the Naples or "Portage" shales and silty shales with decreasing sandstone interlayers. Black shales interfinger at the base of these deposits. The black shales in part contain a pelecypod fauna with distinctive *Buchiola retrostriata*. In the gray shales brachiopods rarely are abundant, perhaps due to unfavorably low salinity of the waters.

Progression of the Acadian diastrophism caused continued erosion of the hill lands on the east, westward retreat of the seas and westward advance of continental red bed sedimentation. Thus near Harrisburg the earlier Upper Devonian Trimmers Rock sandstone is overlain by 4,000 to 5,000 feet of red sandstone and shales of Catskill facies. Some interbeds near the base contain *Spirifer disjunctus* of the Chemung. High in the Catskill, there are about a hundred feet of hogback-forming gray Honesdale sandstone, thought to belong in the Devonian though relations to the Catskill-Pocono boundary farther west near the Allegheny Front are not well assured. The Catskill red beds consist in general of poorly washed, micaceous and graywackyish sand and clay strata, in which are found rare plates of bony-skinned Devonian fishes. Where the red beds interfinger westward into grayish sediments, they may contain brachiopods and other marine fossils, but such shells are lacking in the main parts of the red mass. The red sediments bear witness to the warm moist climates of their day and region.

Westward from Harrisburg to the Allegheny Front near Bedford, as well as northward to the Allegheny Front near Williamsport, the lower half of the red Catskill beds near Harrisburg grade laterally into grayish shales and sandstones that are characterized by *Spirifer disjunctus* and associated fossil species, and are classed as Chemung shale. The boundary between the Chemung and subjacent Naples is primarily faunal and based on the lowest appearances of *disjunctus* and certain other fossils; the junction of the Chemung and overlying Catskill is drawn where there is the major change from grayish Chemung with *disjunctus* faunas into red shales and sandstones in which marine shells are wanting. The Chemung-Catskill boundary clearly is transitional and is variable in time and stratigraphic level; the Chemung-Naples boundary as drawn may likewise shift somewhat in age. The Chemung-Catskill intergradation is accompanied by marked interfingering of red and grayish sediments, so that over wide areas a third or more of the Chemung deposits contain reddish and purplish interlayers, the purplish facies continuing farther into the marine masses of the rock.

At the Allegheny Front near Bedford, the Chemung beds are about 2,000 to 2,500 feet thick, the overlying Catskill facies having concomitantly thinned to about 2,000 feet from the approximately 4,500 feet near Harrisburg. The mass consists of numerous cyclothemic repetitions of shale with little sandstone and sandstone with little shale, the sandstones forming a fifth to a fourth or so of the mass. The sandstones in general are flaggy, poorly winnowed, graywackyish. Influx of the sediment evidently was relatively rapid. Marine shelly fossils are abundant at many horizons, so that the waters must have been salty and well oxygenated. Faunal changes are not very well marked from level to level, though the lower fourth is distinguished by *Dalmanella tioga*. Slump structures of "storm roller" type occur locally at some levels. There are several thin conglomeratic layers; an upper conglomeratic layer or series of lenses in southcentral Pennsylvania has been termed Saxton conglomerate, and lower lenses have been named Allegrippus sandstone and conglomerate.

Westward from the Allegheny Front there is thinning both of the Catskill red bed facies in proportion to total thickness of the Devonian, and also thinning of the Devonian sediments as a whole. In the Hockenberry well north of Pittsburgh the total thickness of the Devonian is only about 4,000 feet as compared to 7,000 to 8,000 feet in the region from the Allegheny Front to Harrisburg. "Pink rock" beds representing westerly tongues of the Catskill, but perhaps largely marine, are about 400 feet thick. The highest Catskill beds of the Front as well as the lower portions, have changed to non-red marine strata. The highest marine strata contain the Hundred Foot oil-gas sand. The Speechley and Bradford oil sands of western and northern Pennsylvania, and various other lenticular oil-gas sands as well, are believed to occur at stratigraphic levels represented at the Allegheny Front within the Catskill red bed facies.

SILURIAN SYSTEM

The Silurian sediments of Pennsylvania predominantly are formed of sands and clays, largely carried westwards from eroding, easterly hill-lands of Appalachia.

Reflecting tectonic movements and paleogeographic changes, the sediments form two great, subequal complexes. In each complex, the detritals coarsen eastwards; the detritals are coarser in the earlier, lower members, tend to become finer above, and tend to pass upward into carbonates that are better developed towards the west.

In contrast to these similarities, the complexes differ in that the lower, Early-Middle Silurian mass transforms eastwards into grayish sands and gravels, whereas the upper, Late Silurian complex grades eastwards into thickening red clays and sands. Interbedded toward the northwest in the upper complex are commercially important salt deposits that persist westward into the Michigan basin.

The lower complex where first encountered along the trip route near Bedford, includes at its base about 500 feet of Tuscarora quartz sandstone, the grains strongly cemented by silica overgrowths. Shaly interlayers form 10 to 15 per cent of the formation. The Tuscarora sandstones represent the Medina group of western New York. Their excellently winnowed character over large regions, the rather low amplitude of cross-bedding in most parts and presence in other parts of wave-rippled laminae paralleling the general bedding, suggest deposition in broad reaches of shallow water. The Tuscarora facies nowhere preserve shelly fossil faunas; it does contain *Arthrophycus* and *Scolithus* worm trails and burrows, and some of the shale interlayers bear eurypterid fragments. The faunas suggest that the shallow Tuscarora seas were relatively freshened, not salty enough to favor the shellfish that might otherwise have flourished in them.

The Tuscarora sediments are overlain by 600 feet of Clinton clay shales, containing near the top numerous 2- to 4-inch interbeds of limestone, as well as the 10-foot tongue of Keefer sandstone with which are associated thin Clinton iron ores. Above the Clinton strata are 300 feet of McKenzie interbedded shales and limestones. Both Clinton and McKenzie strata abound in marine fossil faunas, principally brachiopods and ostracodes; trilobites are common in the Clinton but not the McKenzie; the minute ostracodes are especially valuable as zonal markers traceable over wide regions.

The upper 40 feet of the Clinton sediments contain numerous fossil species of the Rochester shale of western New York, and are classed as Rochester Shale.

Above the McKenzie strata near Bedford are 1,300 to 1,400 feet of Upper Silurian sediments. These begin with about 40 feet of red, calcareous Bloomsburg shales, then 450 feet of calcareous, greenish-weathering Wills Creek shale, the latter overlain in turn by 600 feet of laminated Tonoloway limestone, then by 250 feet of thicker-bedded Keyser limestone that marks the top of the Silurian system.

Among these Late Silurian strata, the Keyser limestone contains shells of a profusion of marine brachiopods, bryozoa, and ostracodes, with some corals and trilobites. Fossils are rarer in the other formations, but ostracodes are found in parts of the Wills Creek and Tonoloway and brachiopods occur in some Tonoloway strata.

Traced eastward toward Harrisburg, profound changes occur in the lithologies and succession of the Silurian strata, and shelly faunas virtually are absent.

At Harrisburg the Tuscarora contains a hundred-foot tongue of gray-wackyish, in part reddish sandstones and conglomerates, and some other layers are less perfectly winnowed than the typical white Tuscarora sandstone beds. The Clinton strata are half sandstones, half silty shale;

most of the Clinton sandstones are purplish, and contain possibly five per cent of iron oxide so that they have long been named "iron sandstones." In some layers, thin sections show blades of hematite enclosed in overgrowths of the quartz sand grains. The McKenzie has disappeared as a distinguishable formation, though its lower part is represented in the highest Clinton beds.

Except for *Arthrophycus* and *Scolithus* worm burrows, no fossils have been recognized in the Tuscarora and Clinton strata where exposed along the Susquehanna River near Marysville, north of Harrisburg, although fossils are profuse in the Clinton and McKenzie within 20 miles to the northwest and several brachiopods and ostracodes have been discovered 25 miles to the northeast. Tuscarora sandstones have become increasingly conglomeratic with some dirty, graywackyish layers as they are traced across eastern Pennsylvania along their one narrow belt of outcrop; the Clinton beds become more sandy, but the iron sandstones so abundant near Harrisburg disappear; where the Tuscarora-Clinton strata cross into New Jersey they have as a result of these changes combined to form the Shawangunk conglomerate and sandstone, suggesting the essential paleogeographic-tectonic unity of the Tuscarora-Clinton deposits.

The higher Silurian, Bloomsburg-Wills Creek-Tonoloway-Keyser formations of the Bedford region are represented near Harrisburg only by Bloomsburg red shales and sandstones, thickened to at least 1,000 and possibly 1,200 or 1,300 feet. This change has largely occurred because of geographic variations in composition of the ancient sediments. At intervening localities, red-bed tongues appear in the Wills Creek and basal parts of the Tonoloway, as well as in the upper McKenzie strata below the main western Bloomsburg tongue. Not only the thin Bloomsburg formation near Bedford, but also the higher part of the marine McKenzie shale and limestone, the marine-estuarine Wills Creek shale, and the lower part of the marine Tonoloway limestone have all passed laterally, near Harrisburg, into the thickened, continental red Bloomsburg rocks.

There are good reasons to believe that the Keyser and the higher Tonoloway as well, are absent near Harrisburg by the same disconformity that there causes absence of the overlying Lower Devonian sediments.

The base of the Tuscarora sandstone, or base of the Silurian as here understood, is not marked by conspicuous disconformity near Harrisburg. There is on the other hand a well-defined disconformity 165 feet lower in the section, where basal conglomerates of the Juniata rest with sharp contact on the eroded surface of the Ordovician Martinsburg shale. Tectonically, this disconformity might be regarded as the Ordovician-Silurian boundary; but fossiliferous equivalents of the Juniata have been regarded as Late Ordovician in age by the majority of the men working with them.

ORDOVICIAN SYSTEM

The Ordovician sediments of Pennsylvania reach their maximum thickness of about one and a half miles in central Pennsylvania, and are at least a half mile in thickness through most other parts of the state. The Lower Ordovician strata consist predominantly of limestones and dolomites over most of the region, as does the earlier part of the Middle Ordovician. Beginning by Middle Ordovician time, however, Taconic activities were elevating easterly land areas so that great volumes of clay and attendant silts and sands spread farther and farther west over the sea floor, until they blanketed virtually the entire region. During the Late Ordovician, the Ordovician seas retreated westwards. In eastern Pennsylvania and eastermost New York, the Taconic movements culminated with folding and faulting; the disturbed region emerged and was planed by erosion. Several hundred feet of non-fossiliferous gravels and sands in central Pennsylvania reflect a stage during which the easterly lands were high, and the westwardly moving streams especially active. The gravel-rich beds were buried beneath as much as 1,500 feet of Latest Ordovician red beds, mostly sands below and giving place to silts and clays above; the sediments choked the delta-fluviatile plains and perhaps the freshened estuaries of a warm and humid region, and were supplied so rapidly in proportion to the rate of subsidence that marine waters were not able to invade the region. The red beds and the deposits at their base become finer textured toward the west, and grade laterally into fossiliferous marine sediments of Ohio and southwestern Ontario. In east-central Pennsylvania, on the other hand they transgress upon the surface of erosion produced by the Taconic movements, so that their thin, gravelly wedge-edge can be seen near Harrisburg.

Turning to the more factual characters of the Ordovician sediments of the area, the Lower Ordovician or Canadian strata reach their reported maximum of 4,000 feet in Nittany Valley near State College in central Pennsylvania, and there are about three-quarters dolomite, with 500-foot bodies of limestone at the base and near the middle of the mass. In Friend's Cove east of Bedford, Pennsylvania, the Beekmantown group is probably 2,000 to 2,500 fet thick, mostly dolomite. The upper beds have the dense, dove-weathering character of the Bellefonte dolomite division of the Beekmantown of Nittany Valley, where as lower beds in part at least have the darker color and somewhat coarser texture of the Nittany dolomite.

Eastward from Friend's Cove, the Beekmantown is about 2,000 feet thick where exposed along the Great Valley from Chambersburg to Harrisburg and eastwards toward New Jersey. Limestone tends to predominate over dolomite, instead of being subordinate as in Nittany Valley and Friend's Cove. Edgewise conglomerates are common in the lower limestones as in Nittany Valley, and are also present in higher beds. A few thin, very minor arenaceous zones suggest gentle tectonic movements.

The most southeasterly, definitely identified Beekmantown strata of Pennsylvania are argillaceous, moderately metamorphosed limestones, and more argillaceous Beekmantown sediments may be incorporated in the Wissahickon schists of disputed age. Beekmantown graptolites have been identified from some shales near Harrisburg that present a perplexing paleogeographic and structural problem.

In New York, the Beekmantown horizon is exposed only in the Hudson Valley and flanks of the Adirondacks. Beekmantown sediments are absent apparently by non-deposition along the western margin of the Adirondacks, but lap upon the southern margin as a thin sandy, dolomitic limestone wedge-edge from the thicker Beekmantown toward Pennsylvania to the south. Beekmantown sediments extend along the Hudson Valley and eastern flank of the Adirondacks as the limestones and dolomites deposited along the Beekmantown seaway east of the Adirondack dome; except that near Albany, shales deposited farther to the east have been overthrust upon the autochthonous strata.

In subsurface areas, Beekmantown limestones and dolomites extend westward, northwestward, and northward from their areas of thick development in central Pennsylvania. To the west, in the Hockenberry well north of Pittsburgh, about 200 feet of dolomite have been assigned to the Beekmantown by Fettke. To the north, the Beekmantown may be represented by 50 to 100 feet of silty dolomite in wells at Arcade and Rochester. In western, northwestern, and northern Pennsylvania there are thus at depth considerable thicknesses of Beekmantown limestones and dolomites, thinning out from their area of maximum thickness in central Pennsylvania, and extending as a thinning wedge up the regional dip into southern New York. These sediments may in some yet unknown areas have favorable reservoir porosities derived from fractures and vugcavities; their up-dip thinning in part at least must involve unconformities with which solution porosities may be associated.

The Middle Ordovician sediments are represented in Nittany Valley, central Pennsylvania, by about 1,000 feet of limestone plus several hundred feet of the overlying 1,100 feet of Reedsville shale. The limestone sequence includes in ascending order Chazyan, Black River or Bolarian, and Trenton deposits; the Black River beds include several high quality chemical limestone beds, including near Bellefonte a member that is worked in deep mines where the produced rock analyzes around 98 per cent calcium carbonate. The Trenton limestone is impure; many layers are dark, dense-textured though others are gray, crystalline, fossiliferous; shale interlayers appear on the higher part of the formation.

Well defined regional unconformities bound several members of the Middle Ordovician limestones.

Traced from central Pennsylvania to the Harrisburg region, the greater part of the Trenton limestone passes laterally into shales, that unite with the continuation of the overlying Reedsville shale to form the thick Martinsburg shale formation, sandy in its upper part. Chazy and Black River beds persist as limestones in the Harrisburg region, and are somewhat thicker than in Nittany Valley. East of Harrisburg these strata, and some thin limestones of early Trenton age, provide certain pure lentils workable for chemical lime, and other argillaceous limestones used for cement manufacture.

In New York, the Middle Ordovician like the lower portion crops out along the flanks of the Adirondacks and in the Hudson Valley. The type Black River limestone occurs along the western margin, the type Trenton a little farther south where its major portion originally was termed the "Blue Foetid limestone of Trenton Falls." For a considerable distance at the outcrop the Black River sediments rest directly on the eroded surface of a Pre-Cambrian granite-gneiss complex, with all the earlier Paleozoic sediments absent by unconformity. Minor unconformities occur within the limestone sequence.

The Black River-Trenton limestones are about 500 to 600 feet thick along the western flank of the Adirondacks, and with them several hundred feet of the overlying shales are Middle Ordovician in age. The shales immediately upon the limestones are very fine textured, black, "Utica" in facies, and pass upwards into gray shales.

Traced southeastwards along the flanks of the Adirondacks, the Black River-Trenton sediments first thin somewhat, then thicken, with much of the Trenton limestone first becoming shaly, then being transformed to black shale, the black shale in turn grading eastward into grayish shales that tend to become silty and then somewhat sandy. Traced to the eastern margin of the Adirondacks, there are still a few feet of early Trenton limestone; Black River sediments are generally absent; the Chazy group missing along the western and southern margins, is represented by about 900 feet of limestone. Near Albany, Normanskill shale of Chazy-Black River age has been thrust westward from their more easterly locale of original deposition.

In their subsurface regions in western and northern Pennsylvania and western New York, there are relatively minor changes in the overall characters of the Middle Ordovician sediments as compared to their equivalents along the outcrop belts in Nittany Valley in central Pennsylvania and along the western margin of the Adirondacks. So far as known, Middle Ordovician limestones are persistent with thicknesses of 500 to 1,000 feet. They are overlain by fine-textured dark shales, the boundary between the Middle and Upper Ordovician as currently defined being obscure.

East of a line extending from the southwestern Adirondacks into east-central Pennsylvania, much of the Trenton limestone probably grades laterally into shales.

It is improbable that any significant sandstones are interbedded in the subsurface portions of the Middle Ordovician shales in New York and Pennsylvania west of the Catskill and Pocono Mountain regions.

Trenton limestones have been a source of gas for many years in west-central New York as well as in Ohio and Indiana. In the latter area, the occurrences are according to some geologists thought to be related to areas of dolomitization, though others have thought that the reservoirs primarily are associated with surfaces of unconformity. In New York, shale breaks commonly act as caps to gas occurrences in the limestone, and additional quantities of gas are obtained by deepening wells to cut through the successive shale layers. Some reservoirs have been explained as representing dolomitized shelly masses in the limestone.

Through the subsurface areas in general in western and northern Pennsylvania and western New York, it is unlikely that extensive dolomitized lenses will be found in the Middle Ordovician limestones. Shale breaks that may trap gas in any available openings of the subjacent limestones can be expected, even though the boundary between the limestones and overlying shales probably undergoes some regional changes in age. The dark dense limestones of the Trenton of central Pennsylvania, like the "Blue Foetid limestones of Trenton Falls," appear to have accumulated under conditions that did not favor as extensive a degree of oxidation and destruction of organic matter as may have occurred in the sedimentation of some other limestones. Judging from conditions both in central Pennsylvania and along the western Adirondack margin, the Middle Ordovician limestones of the subsurface areas farther west probably are interrupted by several surfaces of unconformity, and these may at places be associated with solution phenomena favorable for potential reservoir porosities.

The base of the Upper Ordovician of North America commonly is drawn at horizons correlated with the base of the Eden shale of the Cincinnatian of Ohio. This horizon is represented in Pennsylvania and New York within the body of grayish shale that overlies Trenton limestones in the westerly two-thirds or so of the two states, and so has little objective meaning within the area.

In Friend's Cove near Bedford, Pennsylvania, where the Middle and Upper Ordovician sediments are first encountered along the route of the trip, and elsewhere along the Nittany Arch upon which the Cove is located, the Middle-Upper Ordovician boundary occurs near the middle of the 1,100-foot Reedsville shale. The higher, Upper Ordovician portion of the Reedsville consist of brownish-weathering clay shales, with thin calcareous silty and finely arenaceous and some limestone interlayers appearing near the top.

Fossils are common at many horizons, and include strophomenid and other brachiopods, bryozoa, crinoid fragments, some trilobites. In the uppermost 50 feet of the Reedsville are calcareous siltstones and some shale and sandstone, characterized by the stout, coarse-ribbed brachiopod. *Orthorhyncula stevensoni,* lingulas, gastropods and pelecypods, with few of the strophomenids and bryozoa of the subjacent strata. The *Orthorhyncula* fauna persistently in central Pennsylvania marks the latest fossiliferous marine sediments of the Ordovician; to some degree it is a facies fauna, and yet it continues eastwards into medium to thick-bedded graywackyish sandstones, and appears from all evidence so far available to persistently mark a horizon of relatively constant age. The fauna is found southwards from Pennsylvania along the Ridge and Valley region of the Virginias. The *Orthorhyncula* in the past has been widely identified with *Orthorhyncula linneyi* of Fairview beds of the Maysville group of Ohio but this identification is not satisfactory.

The Reedsville shale as a whole gives witness to the Taconic tectonic activities that were raising easterly lands so that their clays spread farther and farther westwards across the Appalachian platform. Progress of these crustal activities is further evidenced along the Nittany arch by the increase of silt and sand in the upper Reedsville, and then by the influx of Bald Eagle or Oswego sands that blanketed the Reedsville along the Friend's Cove-Nittany Valley region.

In its crops along the Nittany Arch the Bald Eagle deposits commonly are 600 to 700 feet thick, consist of graywackyish sandstone, and subdivide into lower sandstone with shale interbeds, middle resistant sandstones that crest subsidiary hogbacks of the double, Tuscarora-Bald Eagle ridges, and upper weak graywackyish sands. Eastward from the more northerly part of the Nittany Arch, the middle, resistant member becomes conglomeratic and transforms into the Lost Run conglomerate, which attains thicknesses of more than 350 feet, and contains a profusion of pebbles, commonly ranging to two and three inches and consisting of milky quartz, quartz-veined vitreous metaquartzites, whitish cherts, reddish jaspers, and some quartz veined, chloritic metaquartzites. These pebbles derived from parent rocks of the easterly, eroding source lands must not be confused with the 2- to 6-inch shale chips that tend to be common throughout the extent of the

Bald Eagle sediments and that evidently were formed by fragmentation of clay layers deposited on the platform of Bald Eagle sedimentation.

The Bald Eagle-Lost Run sandstones and conglomerates are overlain in the region of the Nittany Arch by 1,000 to 1,500 feet of Juniata red sediments, sandy below, silty above, with the thin, more quartzitic red Run Gap member at the very summit. The silty member passes eastward into sandstones. The Bald Eagle-Lost Run sediments present a peculiar color pattern in the Nittany Arch region. Commonly they are grayish beds, and tend to be so distinguished from the overlying Juniata red beds. Toward the east and northeast, the Lost Run conglomerates tend largely to become red and Juniata-like, a change not unexpected in the nearer-source portion of these sediments. A special change takes place, however, in Friend's Cove in the southern part of the Nittany Arch. Here the Bald Eagle deposits consist of 500 to 600 feet of gray graywacke at Aliquippa Gap on the eastern flank of the Cove; but five miles to the west at Bedford Gap on the west flank of the Cove the Bald Eagle sediments contain numerous red tongues that form nearly 50 per cent of the rock so that the Bald Eagle is a hybrid of Bald Eagle and Juniata facies. Still farther southwest in Wills Mountain the green tongues of Bald Eagle facies virtually have disappeared. The paleographic causes of this southwesterly change of gray beds to red beds are not yet well understood.

Marked changes in the Upper Ordovician sediments occur from the Nittany Arch to Susquehanna Gap north of Harrisburg that will be visited at Stop No. 7. The Juniata-Bald Eagle sediments that are about 1,600 feet thick at Friend's Cove and 2,200 feet farther northeast near Lewistown and Mifflintown, have here thinned down to 165 feet and rest disconformably upon the eroded surface of Martinsburg shale beds that correspond to middle if not earlier parts of the Reedsville shale. The lower half of the 165 feet consists of coarse puddingstone conglomerates, 2- and 3-inch pebbles numerous, some reaching six inches and more. The basal 30 feet of the conglomerates are gray; most of the higher beds are red. Half or more of the pebbles are chlorite-splotched quartz; but other rock types are numerous, and include vitreous, quartz-veined metaquartzites; many pebbles of quartz-veined chloritic metaquartzites or meta-argillites; gray and red jaspers, dark slaty-appearing highly siliceous rocks.

The 165 feet of red and grayish conglomeratic sandstones and conglomerates at Susquehanna Gap represent the thinned wedge-edge of Bald Eagle-Lost Run-Juniata sediments that are about 2,200 feet thick near Mifflinsburg and Lewistown 30 to 50 miles toward the northwest, and that rapidly disappear along their belt of outcrop east of the Susquehanna River. They are transgressive upon the eroded surface of the Martinsburg shale and hence are younger than the main emergence caused by the Taconic crustal movements. In view of these transgressive relationships, and lack of well marked evidence of disconformity within and at the top of the Juniata deposits, it appears likely that the 165-foot wedge-remnant at Susquehanna Gap represents the eastwardly coarsened later rather than earlier portion of the Bald Eagle-Lost Run-Juniata sediments of the Mifflintown-Lewistown-Nittany Arch region.

Northward in western New York, the Bald Eagle-Lost Run-Juniata deposits are represented by the Queenston red shale, about 1,100 feet thick where named from Queenston at the north end of Niagara Gorge, and the subjacent, graywackyish Oswego sandstone, possibly 150 feet thick near Oswego on the shores of Lake Ontario east of Rochester. All evidence supports the conclusion that the Queenston is, without much change in limits, the northerly, less sandy extension of the Juniata red beds of central Pennsylvania. The Oswego sandstone is comparable in facies to the Bald Eagle sandstone and lies at essentially the same stratigraphic horizon; it is thinner than the type Bald Eagle and does not certainly fall within the actual time limits of that formation; it is not itself fossiliferous and is not underlain by beds carrying the *Orthorhyncula* fauna that is so helpful in Pennsylvania. The areal, surface geologist thus is attracted by use in their respective areas of the terms Bald Eagle and Oswego; the subsurface geologist who almost certainly will find the gray sandstones continuous belowsurface probably will throughout these sediments prefer the name, Oswego sandstone, that has precedence in time.

No shelly fossils have ever been discovered in the Juniata-Queenston red bed sediments of Pennsylvania and New York, nor in the Bald Eagle sandstone and Lost Run conglomerate of Pennsylvania; fossiliferous sandstones and shales have been incorporated in the lower part of the Oswego sandstone in New York but do not show at the surface at Oswego. In general, the Juniata-Queenston-Bald Eagle-Lost Run-Oswego are continental and may in part be alluvial, in part the sediments of shallow sheets of water too freshened for the shelly faunas of the age. Westward from Niagara Falls in southwestern Quebec, however, the Queenston red beds develop grayish bands with fossils of the marine Richmond group, and Richmond fossils likewise appear in tongues within Juniata sediments of southwestern Virginia.

CAMBRIAN SYSTEM

Crops of Cambrian sediments will be crossed along the trip route only in Friends Cove, east of Bedford. If the day is clear, glimpses of South Mountain ridges crested by Lower Cambrian quartzites may be had from the Great Valley before reaching Harrisburg.

The Cambrian sediments surfacing in Friends Cove are Upper Cambrian in age and are as follows in descending order:

	Feet
Mines dolomite with nodular layers of siliceous oolite	250-300
Gatesburg dolomite with interlayers of dolomitic quartz sandstone; Ore Hill limestone 50-100 feet thick near middle	1,600
Warrior limestone	1,200

The Mines dolomite is overlain by Lower Ordovician Beekmantown strata. In Morrison Cove north of Friends Cove, the Warrior limestone is underlain by Middle Cambrian Pleasant Hill limestone, 600 feet; below this the oldest strata exposed in the two coves are 200 feet of Waynesboro shales and sandstone containing the Lower Cambrian *Olenellus* fauna.

The Gatesburg dolomite crops out extensively in Friends Cove, and with weathering of its carbonates mantles the surface with sandy soil, so that at first sight it appears that the bulk of the formation is sandstone. Actually the sandstones form only 10 to 15 per cent of the mass of the formation, and are interbedded in cyclical fashion with dolomite layers, that include some cryptozoon beds; there are several thin limestones in addition to the Ore Hill limestone member. The Mines dolomite above the Gatesburg contains little sand, and much oolitic chert that is rare in the Gatesburg. The Warrior limestone below the Gatesburg includes dark, medium textured, in part oolitic limestones bearing diagnostic Upper Cambrian trilobites. Thin cryptozoon reef beds and argillaceous limsetones also are present.

The Gatesburg sandy dolomites of central Pennsylvania are lithologically comparable to the Upper Cambrian Theresa sandy dolomites of the northwestern and southern margins of the Adirondacks, and apparently are essentially continuous with the Theresa and Potsdam sediments of those regions. Sandy Gatesburg-Theresa-Potsdam sediments are represented at the bottom of the Hockenberry well north of Pittsburgh; the bottom of the Childs well in northwesternmost Pennsylvania; the Wilson well at Arcade in Wyoming County, New York. In the Wilson well about 950 feet of dolomites, sandy dolomites, and sandstones have been classed as Upper Cambrian Little Falls, Theresa, and Potsdam formations by Fettke; the rocks upon which they rest unknown. In a well 50 miles farther northwest at Rochester, however, there reportedly are not more than a few feet of Upper Cambrian sediments resting directly on the Pre-Cambrian complex. The reported Pre-Cambrian materials penetrated in the bottom three feet of the well, are said to consist of powdered quartz and quartzite, so that their Pre-Cambrian age is not wholly assured.

So far as can be judged from the data now available, sandy dolomites of Gatesburg type can be expected throughout subsurface regions in western, northwestern, and northcentral Pennsylvania, and likewise in western New York where they may thin decidedly as they approach the shore regions of

Lake Ontario and Lake Erie. Salt waters have been reported at a number of places in these sandy rocks so that porosity conditions are reasonably promising; locally, porosities may have been further improved wherever any Late Cambrian or Early Ordovician weathering was associated with surfaces of unconformity and produced sandy soil like that mantling the Gatesburg crop in Friends Cove. Where the Gatesburg-Theresa-Potsdam sediments are thick and underlain by earlier Cambrian marine sediments such as the Warrior, Pleasant Hill, and Waynesboro of central Pennsylvania, relations to possible source horizons are further improved and oil and gas possibilities tend to be enhanced.

Westward, northwestward, and northward from the Allegheny Front region of central Pennsylvania, the Gatesburg strata rise in accordance with regional convergence of the overlying Paleozoic sediments. This regional condition must have developed by Middle Paleozoic time, and may have significantly affected the history of the Early Paleozoic oil and gas of the region.

The Gatesburg sands, unlike the clays and sands of most other parts of the Paleozoic detrital sediments of the Appalachians, evidently were carried in from regions on the northwest or west, rather than from the Appalachia oldlands on the east. The trilobites of the Ore Hill member of the Gatesburg occur in the Great Valley on the east in the middle part of the somewhat silty Conococheague limestone, and some Warrior trilobites are found in the basal Conococheague. The stratigraphic-paleontologic evidence thus shows with considerable clarity that the Gatesburg of the Nittany Arch grades laterally southeastward into the Conococheague both with loss of its sandy interlayers and change from dolomite to limestone with some dolomite. Contrariwise, the expected persistence of sands and dolomites in the Gatesburg northwestward from the Nittany Arch favor Gatesburg oil and gas possibilities in its regions of subsurface occurrence.

The fullest development of Cambrian strata in Pennsylvania occurs 50 miles east of Friends Cove along the Great Valley-South Mountains region southwest of Harrisburg near Shippensburg and Chambersburg. In this area the Conococheague limestone of Gatesburg and late Warrior age is underlain successively by 3,000 feet of Elbrook argillaceous limestone and calcareous shales; 1,000 feet of Waynesboro limestone and shaly sandstone; 1,000 feet of Tomstown dolomite; 3,000 to 4,000 feet of Antietam quartzite, Harpers phyllite, Weverton quartzite, and Loudoun conglomerate and slate. The Elbrook probably is Upper Cambrian above; Middle Cambrian below. The Waynesboro beds have not yielded fossils in the Chambersburg region, but probably are late Lower Cambrian. The Lower Cambrian *Olenellus* fauna has been discovered in the Tomstown dolomite and upper part of the Antietam. The Harpers, Weverton, and Loudoun strata represent the beginning phases of a stage of sedimentation that continued through Antietam and Tomstown time, and their depositional history favors their classification as Lower Cambrian along with the Antietam and Tomstown formations.

Thus in the Chambersburg-Harrisburg region the Conococheague limestone of Gatesburg age is underlain by 8,000 to 9,000 feet of Upper, Middle, and Lower Cambrian sediments that include thick sandy formations in their lower half and that have been subjected to appreciable metamorphism.

The 3,000 feet of Elbrook shaly limestones and calcareous shales of the Chambersburg region are represented in central Pennsylvania along the Nittany Arch by the 600 feet of Pleasant Hill limestone plus part of the 1,200 feet of Warrior limestone. The thickness of these strata accordingly is reduced northwestward. The Warrior limestone contains silty and shaly layers, together with two local, thin layers of quartz sandstone; the lower part of the Pleasant Hill limestone is shaly. The direction from which these detritals were derived remains uncertain; the quartz sand lenses of the Warrior could have been reworked from unparched, emergent portions of the Lower Cambrian sandstones.

Cambrian sediments extend onto the southern flank of the Adirondacks as a 300- to 400-foot wedge-edge that rests directly on the Pre-Cambrian granite-gneiss complex. Not only are Middle and Lower Cambrian strata absent along the belt, but even the Upper Cambrian sediments fail along the western border of the Adirondack area. Farther west, however, Upper Cambrian sandy dolomites reappear down the dip of the Paleozoic, Pre-Cambrian boundary, and have thickness of 50 to 100 feet in wells east of Syracuse.

The Lower and Middle Cambrian sediments thickly developed southwest of Harrisburg in Pennsylvania, thus disappear northeastwards toward the Adirondack and westwards toward northwestern Ohio. The rate of thinning and locale of disappearance remain unknown.

Improved grounds for speculation about changes of the Lower Cambrian sediments in the subsurface areas would be obtained if better information were available about source and direction of transport of the exposed detrital sands and clays. There is some evidence in the Chambersburg region that the Lower Cambrian sands and clays came from the east. The geographic pattern of textural changes, however, is too imperfect to allow confident use of this supposition. If the sands were derived chiefly from easterly source-areas they probably thin out westward and northward from their thick development in the South Mountain area.

Whatever the exact distribution, the Middle and Lower Cambrian sediments must in some fashion thin across western and northern Pennsylvania, and must rise in accordance with the convergence of overlying strata as well as with the regional rise of surface formations from northern Pennsylvania into New York. Such conditions are favorable for stratigraphic traps; the beds are, however, very deep and any exploration would be very costly. In the area of the folded Appalachians of central Pennsylvania, Lower Cambrian sandstones should everywhere be present, and should be thrown into great folds related to structures transected by the present surface of erosion. Possibilities for oil and gas will be conditioned by rate of waning of the metamorphism exhibited in the South Mountains.

STRATIGRAPHY AND STRUCTURE OF LOWER PALEOZOIC ROCKS IN EASTERN PENNSYLVANIA*

by CARLYLE GRAY and BRADFORD WILLARD**

CAMBRIAN

Lower Cambrian—The Lower Cambrian strata consist of the Hardyston quartzite formation which ranges in thickness from 25 to 800 feet. Although dominantly quartzite, its lithology includes conglomerate, shale, and jasper. In southern Lebanon County the thickness of the Hardyston is estimated at 800 feet, but the formation is only 25 to 350 feet thick in eastern Pennsylvania. No exposure of the Hardyston will be seen in Pennsylvania.

Middle Cambrian—The Leithville dolomitic limestone, formerly called "Tomstown", overlies the Hardyston quartzite. The Leithville limestone is highly dolomitic and in places contains sericitic shale. Because it is non-fossiliferous its age is somewhat uncertain but it is now assigned to the Middle Cambrian. In extensive exposures, the formation shows a characteristic alternation of thick-, medium-, and thin-bedded strata.

Upper Cambrian—In eastern Pennsylvania, the Limeport dolomitic limestone lies at the base of the Upper Cambrian. It is 800 to 900 feet thick and is separated from the overlying Allentown formation of similar lithology by a disconformity. The Limeport is characterized by weathering into light and dark gray layers, by occasional abundant oolites and stromatolites, and locally by its content of Trempeleanian (lower Upper Cambrian) invertebrates.

The Allentown, which overlies the Limeport, is 400 to 500 feet thick and is also a dolomitic limestone, which on the weathered surface shows alternate light and dark gray layers of rather uniform thickness. This color banding is, however, less conspicuous in the Allentown than in the Limeport. The latter contains many stromatolites and is somewhat oolitic. It locally contains a Dresbachian (uppermost Cambrian) invertebrate fauna.

The terms Elbrook and Conococheague are also used as names for Upper Cambrian carbonate rocks in southeastern Pennsylvania. The Conocheague is recognizable as far east as Lebanon County where it can be subdivided into five mappable units.

ORDOVICIAN

Beekmantown group—Detailed studies of the Beekmantown in Lebanon and Berks Counties have not as yet been completed. A tentative sequence of lithology can be presented here, but it has as yet to be tested by mapping. Certain similarities to the lithology of the Central Pennsylvania sequence can be observed. Fossils are scarce, but are much more common than in the Cambrian rocks of the area.

The lower part of the Beekmantown group is composed of primarily blue, finely crystalline limestone which is commonly fucoidal. Gray dolomite beds apparently make up less than 20 percent of the rock. Edgewise conglomerates and calcarenites are fairly common. A few beds of white or pink crystalline limestone are present. The dolomite interbeds increase in frequency upward and at the top of the unit make up about 50 percent of the rocks. The total thickness of this unit is about 500 to 700 feet. The edgewise conglomerates and pink crystalline limestone beds suggest a correlation with the Stonehenge formation of Central Pennsylvania.

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*A considerable portion of the geology on which the following discussion is based was done by J. R. Moseley, C. E. Prouty, and by G. W. Stose and A. M. Jonas as well as by the authors.

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Above this basal unit is a distinct dolomite unit, consisting of dolomite beds with blue limestone interbeds that make up less than 10 percent of the whole. The dolomite is light gray in color, crystalline, and thick-bedded. Gray to light gray chert is common. A few sandy beds are present. The limestone interbeds are gray to blue, frequently crystalline, with varying amounts of shaly laminae. Chert occurs in the limestone interbeds, also. This unit which ranges from 200 to 350 feet thick, is overlain by another 100 feet in which limestone and dolomite are interbedded in approximately equal amounts. This upper dolomitic unit lies above a predominately limestone unit, just as the Nittany dolomite lies above the Stonehenge limestone.

Above the interbedded zone lies 200 to 300 feet of massive, blue limestone with thin dolomite interbeds, less than 10 percent of this body being dolomite. It grades up into 300 to 500 feet more of limestone and dolomite interbedded in equal amounts. The limestone is generally bluish gray, and is commonly fucoidal. Some beds of white crystalline limestone apparently occur in this unit. The dolomite beds are gray, finely crystalline to dense, and typically weather creamy to gray in color. This relatively limy unit may be the equivalent of the Axemann limestone. Its thickness is probably more than 500 feet.

The uppermost part of the Beekmantown in Lebanon County consists chiefly of light gray to black, dense dolomite. Thick shaly partings are common. This unit is probably 200 or more feet thick. It may correspond to the Bellefonte dolomite of Central Pennsylvania. Further east this unit contains more limestone beds and loses its identity.

Annville limestone—The Annville limestone directly overlies the Beekmantown group in most of Lebanon County. Prouty, on the basis of stratigraphic position and lithology, tentatively correlated the Annville limestone with the upper part of the "Stones River" group. In the Harrisburg area, the Annville is separated from the Beekmantown group by Middle Stones River limestone. The Stones River beds wedge out west of the Lebanon-Dauphin County line, and are almost entirely absent in Lebanon County. One bed of vaughnitic limestone containing fossils of possible Stones River age is present in a quarry 5 miles east of Lebanon. With this one exception, the Annville lies disconformably on the Beekmantown group.

The Annville limestone has a normal stratigraphic thickness of about 240 feet. Structural complexities locally reduce the actual thickness to 130 feet and possibly less. In western Berks County the formation wedges out, and is not recognized east of the Schuylkill River.

The Annville is dominantly a thick-bedded to massive, crystalline, high-calcium limestone, weathering to smooth or fluted surfaces.

Myerstown limestone—The Myerstown limestone overlies the Annville limestone everywhere in Lebanon County. Prouty has classified the Myerstown limestone as Black River to lowest Trenton in age on the basis of fragmentary fossils, stratigraphic position, and lithologic correlation with more fossiliferous areas. Its thickness ranges from less than 50 feet to possibly more than 200 feet without an apparent regular pattern of variation. Much of the variation in thickness may be due to structural complications, but this is difficult to determine because of a scarcity of exposures in Lebanon County.

The Myerstown limestone is typically dark blue to black, dense, thin-bedded graphitic limestone with occasional beds of calcarenite.

Hershey limestone—The Hershey limestone is poorly exposed generally and its relations are therefore not too clear. On the basis of lithology, stratigraphic position, and limited faunal evidence, Prouty has correlated the Hershey limestone with the upper part of the Jacksonburg formation (lower Trenton) of Eastern Pennsylvania and New Jersey. No accurate measurements of thickness are possible in Lebanon County, but the width of the belt of outcrop indicates that the Hershey limestone varies from less than 50 feet to several hundred feet in thickness. The maximum thickness is north of Womelsdorf in Berks County.

The Hershey is dark gray, graphitic, shaly or silty limestone. It is less pure and darker in color than the typical Myerstown limestone.

Locally the base of the Hershey limestone contains beds of limestone conglomerate. In Berks County, the zone containing the conglomerate beds may be more than 100 feet thick and is mapped as a separate member. The conglomerate beds consist of angular to sub-rounded fragments of dolomite and magnesian limestone in a matrix of dark gray, graphitic shaly limestone. The beds vary from one to several feet in thickness and are interbedded with normal Hershey limestone. Where the conglomerate is absent, it is often difficult to locate accurately the contact between the Hershey and Myerstown limestone.

Annville, Hershey, and Myerstown limestones, together with some younger limestone occurring in the Martinsburg shale, are included in the Leesport formation on the Geologic Map of Pennsylvania.

East of the Schuylkill River the Beekmantown is overlain by the Jacksonburg formation roughly equivalent to the Hershey and Myerstown limestones. The Jacksonburg limestone is about 400 feet thick. It consists of limestone, argillaceous above, crystalline below, of middle Trenton age. This formation is the important "cement limestone" of the Lehigh Valley.

Martinsburg formation—Although the group of sedimentary rocks identified by the United State Geological Survey as the "Martinsburg shale" has been divided into a number of formations, thereby raising the name "Martinsburg" to a group designation, it is feasible for the purposes of this Guidebook to consider these rocks as the "Martinsburg formation" following the terminology of the Ordovician Subcommittee of the National Research Council. Several geologists (Stose, Willard, Cleaves, and Moseley) have divided the formation into two, three or four members. From the type locality at Martinsburg, West Virginia, through Maryland into south-central Pennsylvania, the Martinsburg formation consists essentially of a lower shale member with thin limestones near the base, and an upper sandy member. Behre subdivided the formation of the slate belt in Northampton County into three members: an upper shaly, a middle sandy and a lower shaly member. Willard separated the upper fossiliferous sandstones of eastern Berks County and western Lehigh County from the Martinsburg and proposed the name "Shochary" for them. All geologists who have made field studies of the Martinsburg formation in Dauphin, Lebanon, Berks or Lehigh Counties have recognized that there are lithologic phases of the formation which are unlike the normal rocks of the Martinsburg to the southwest. Stose proposed that these anomalous rocks be separated from the Martinsburg formation as the "Taconic Sequence" forming the "Hamburg Klippe", an overthrust sheet brought from the southeast into contact with normal Martinsburg between the Susquehanna and Lehigh Rivers. He divided the rocks into five formations ranging in age from Lower Cambrian to early Trenton and assigned numbers rather than names to the subdivisions. Detailed areal mapping in Lebanon County has failed to reveal incontrovertible evidence to either substantiate or to negate the hypothesis of an overthrust position for these rocks. Severe deformation has destroyed evidence of bedding, particularly in the southern portion of the shale belt. Shear zones with broken fragments of sandy beds oriented more or less parallel to their longer dimensions are common.

Lithology—The outstanding characteristic of the "Martinsburg formation" is the wide range of lithologic types represented. Key beds which can be traced for relatively short distances along the strike are present in several localities, but none of these occur with sufficient extent that rocks of a similar type can be bound together as a unit over wide areas. Environments of deposition varied widely and included both sedimentary and igneous rock-forming conditions.

Sedimentary rocks make up the bedrock of all but a few percent of the area of the Martinsburg formation in Lebanon County. The formation is commonly spoken of as a shale, but sandstone, conglomerate, and limestone are also present. Each of the classes of sedimentary rock includes several varieties, some of which can be traced and mapped separately on the scale of 1:20,000.

Shale is the most abundant rock type, varying considerably in color and composition. Light to dark gray is the most common color, but red, black, green, brown and yellow occur in about that order of abundance. Much of the shale has been metamorphosed to clay shale, or phyllite. Interbedded sandstone, or argillaceous sandstone, is commonly found with the gray shale, but it rarely occurs in the red shale. Black shale occurring interbedded with limestone in certain areas makes up a considerable thickness of rock. Red shale showing little or no evidence of bedding, but with well-developed cleavage, occurs in several areas of considerable extent. Scattered stringers of red shale, not connected with the main bodies of the rock, are indicated by narrow red streaks in the soil. Green shale is associated with red shale as interbeds and also as stringers along joint planes. Brown and yellow shale are primarily the result of weathering of red or gray shales.

Sandstones of four varieties are found within the formation: (1) pure, white to buff quartzose sandstone making up as much as 100 to 150 feet of rock; (2) massively bedded, argillaceous sandstone, commonly called "arkose", which contains chips of gray shale; (3) medium- to coarse-grained arkosic sandstone containing pink feldspar grains; and (4) medium- to coarse-grained sandstone showing current cross-bedding.

The quartzose sandstone, massively bedded and containing thin lenses of waxy, bluish green shale, makes up the southern crest of Bunker Hills, south of Jonestown. A similar sandstone, weathering rusty brown and possessing small conglomerate lenses, occurs at Sand Hill, north of Lebanon, and extends southwestward to the contact of the shale formation with the underlying Cambro-Ordovician limestones. The thick-bedded argillaceous sandstone extends as a belt from the eastern edge of the Indiantown Gap Military Reservation southwestward to the border of the county. It is repeated by folding to the south, and the thickest beds, twelve or more feet thick, occur along Swatara Creek north of Brindnagles Church. The western part of Little Mountain, north of Jonestown, also contains massive, coarse-grained, argillaceous sandstone in a sharply folded anticline. Coarse-grained sandstones occur sporadically as narrow belts in areas which are predominantly shale. Although called "arkose" by Stose, feldspar was not observed in any of the outcrops of this rock type. Shale chips are locally abundant and weathering has softened them until they have the appearance of kaolinized feldspar. It is suggested that "graywacke" is a better descriptive term to apply to the argillaceous sandstones which do not contain feldspar. True arkosic sandstone with pink feldspar in irregular grains occurs adjacent to intrusive masses of diabase south of Jonestown. The presence of feldspar only at places close to the intrusions raises the question whether it may be secondary as a result of contact metamorphism of the graywacke type of sandstone. The cross-bedded sandstone had only a small amount of clay in the original sediment. Cross-bedding is of the current type and is found in beds which range from half-inch to two or three inches thick. This phase occurs in connection with the massively bedded graywacke and also interbedded in thin series of beds with the gray shale.

Conglomerate occurs sporadically and is seen primarily as boulders of float although several outcrops show conglomerate in place. The east-west ridge of Little Mountain consists of a coarse-grained graywacke whose basal beds are a quartz-pebble conglomerate. Maximum thickness exposed is a few feet, but conspicuous float covering the flat top of a portion of the ridge suggests as much as several tens of feet being locally present. Pebble conglomerate with a matrix mud appears at several localities, but the rock type cannot be traced from one outcrop to another. These occurrences are interpreted as lenses of conglomerate at different horizons.

Limestones in the Martinsburg formation consist of four varieties according to Moseley: (1) argillaceous limestone interbedded with shale; (2) massively bedded, dense, dark gray to black limestone; (3) arenaceous limestone with rounded grains of quartz; and (4) intraformational conglomerate. None of the limestone has high-calcium content; insoluble residues range from 11.5% to 46.3% with an average of 26 samples being 23.9%. The residues are estimated to be about 60% sand and silt, and 40% clay.

Igneous rocks in the belt of the Martinsburg formation of Lebanon County were first described by Gordon in 1921 as consisting of several dikes of intrusive diabase and two basaltic flows. Stose and Jonas explained the disjointed nature of the dikes or intrusive sheets on the basis of numerous dip-faults which offset the broken parts. They believed that a single lava flow, repeated by a strike fault, accounts for the main part of Bunker Hills and the outcrops of lava to the south.

The northern crest of Bunker Hills, south of Little Swatara Creek, is composed of a series of amygdaloidal lava flows separated by pyroclastics. Outcrops along the north slope of the ridge, in the cut of the Reading Railroad south of Jonestown, and in fields and roadcuts south of Bunker Hills, expose the rocks. Pillow lava is indicated in several places by ellipsoidal masses which possess concentrically arranged amygdules of calcite, or vesicles from which the calcite has been dissolved. The rock in natural outcrops is greatly weathered, but an abandoned quarry on the south bank of Little Swatara Creek, west of the Jonestown-Lebanon road, shows massive dark gray to almost black basaltic lava. Fracturing and adjustment of the blocks have produced many slickensided surfaces. The base of the lava series is exposed in the railroad cut along Little Swatara Creek to the east, and again to the south of Jonestown. In these locations the lava contains inclusions of limestone which range in size from a fraction of an inch to two or three inches.

South of the quartzose sandstone ridge of Bunker Hills, the lava is primarily a flow breccia with masses of red and green rock ranging in size from a few inches to a few feet. Float of a porphyritic rock is conspicuous in the southwestern portion of the area of lava rock. On the basis of the megascopic differences of the lava in the two areas, they are believed to represent two distinctive episodes of extrusive volcanic activity.

The intrusive igneous rock occurs as masses which are in part concordant, and in part, discordant. The rock is medium- to coarse-grained, light to dark gray quartz diabase, containing pyrite as a common accessory mineral. Much of the labradorite has been zoisitized and the augite chloritized, producing a dull greenish color in several areas. The degree of alteration varies and in some exposures the rocks have a relatively fresh, glassy luster. Exposures of the diabase along the bank of Swatara Creek southwest of Jonestown indicate a concordant relationship with the enclosing arkosic sandstone, which here dips to the southeast. Measured thickness of the exposed sill is 105 feet, but the top contact is covered. Farther southwest, distribution of outcrops of the diabase and arkose suggest a thickness of almost 180 feet.

A similar diabase is exposed in the cut along Route 343, three and three-fourths miles south of Fredericksburg, overlying an arkosic sandstone which dips north. There the computed thickness is 210 feet. Those two exposures are believed to delineate a general synclinal structure of the area of the intrusive rocks. Few exposures of the adjacent rock occur in the area occupied by the plutons, but the parallel belts of diabase, argillaceous sandstone, and shale float strongly suggest concordant relationships of most of the diabasic masses with the enclosing rocks. Within the limbs of the syncline there are about twenty block-like masses of diabase which are interpreted as sills at a higher stratigraphic level. The blocks have been broken and shifted along approximately north-south trending cross faults. Outcrops are rare, but belts of float of large and small diabase boulders along ridge crests indicate the presence of the plutons. Some of the plutons show a distinctly discordant relationship with the enclosing sedimentary rocks, indicating that they are dikes.

The geologic age of the intrusive masses is in doubt. Urry reports ages of $375 \pm 15x10^6$ and $335 \pm 15x10^6$ years as the age of intrusives associated with the Martinsburg. These figures suggest late Ordovician as the time of intrusion. Stose suggests that the "basalt flow and associated diabase sills and thick-bedded limestones which occur south of Jonestown . . . may be an uplifted block in which Lower Cambrian rocks are exposed." It hardly seems possible that the intrusives could represent Cambrian rocks if their age is as low as $335 — 15x10^6$ years. They have been cut by cross faults which affect the enclosing sedimentary rocks. $335x10^6$ years would suggest Silurian or early Devonian age. If these rocks are post-Ordovician in age, the cross-faults must also be post-Ordovician and could not have been produced during Taconic orogeny.

Structural Geology

The Great Valley can be considered as the southern limb of a great synclinorium. The regional dip is to the north, that is, younger and younger beds crop out to the north. The beds, however, are intensively crumpled into folds, overturned to the north and west, so that south dips are the rule in individual outcrops throughout much of the region. The impure limestones and shales commonly have well-developed cleavage and extreme flowage is common. The folds vary in size from drag folds that can be collected as hand specimens, to recumbent folds almost a mile long.

The folding was accompanied by both thrust faulting and tear faulting. In the Martinsburg formation, a great many cross-faults have been mapped. Wherever detailed mapping is possible, minor thrusts and tears are common features.

Structures in the Martinsburg Formation

Any attempt to delineate the structural features of the Martinsburg formation is handicapped by the paucity of outcrops, the mangled character of the rocks and the weathered condition of the exposures. The region is one of rolling topography without abundant deep highway cuts with the exception of those along U. S. Highway 22, which extends approximately parallel to the general strike of the rocks. Key beds, which can be traced successfully by float to tie into outcrops, give a reliable picture of the structural conditions in some areas, but over an appreciable portion of the shale terrain neither diagnostic float nor outcrops are found. Most of the key beds can be traced along the strike for a distance of a mile or two, but with few exceptions they do not extend across structural axes.

On the basis of available information, a number of anticlines and synclines may be plotted, giving a general pattern to the folded character of the rocks. The folds are, for the most part, overturned to the northwest. More than three-fourths of the dip measurements registered angles steeper than 45 degrees. The most extensive folds can be traced with a reliable degree of certainty for distances of less than ten miles. In large areas axial traces cannot be plotted because of the lack of diagnostic data. The high-angle dips, scattered though they be, indicate tightly compressed folding as the rule for the formation.

Key beds traced by float are abruptly offset by distances of as much as 600 to 700 yards. These are interpreted as dip faults. At no place is there an exposure of a fault plane along which such movement has taken place. There is no direct evidence as to the nature of the actual movement. There may be either normal faults or tear faults. A nearly vertical, normal fault trending about north-south cuts the younger Paleozoic rocks at the northern end of Swatara Gap, but there is no evidence that it is associated with any of the faults cutting the Martinsburg rocks. Willard reports normal faults cutting folds of Paleozoic rock and passing into Triassic sediments in Bucks County. He suggests that such faults in Bucks County are Triassic in age. So far no evidence has been found to indicate a Triassic age for the faults in the Martinsburg formation.

The area of lava flows and intrusives south of Jonestown and to the east contains at least a dozen faults which are nearly perpendicular to the general strike of the rocks. The faults are indicated by offset ridges whose crests are literally paved with large and small boulders of the diabase, and by offset belts of sandstone and lava. North of Harper's Tavern (Indiantown Gap quadrangle) three nearly parallel belts of limestone, traced by float from outcrop to outcrop, likewise have been offset by three parallel faults. Four parallel belts of limestone which can be traced by float as well as outcrops and abandoned quarries, end abruptly with no decrease in the width of the belts along a line about one-fourth of a mile east of Bellegrove (Palmyra quadrangle). Southeast of Steelstown a prominent hill is held up by a syncline composed of red shale, greenish gray quartzite, and interbedded shale and argillaceous sandstone. The syncline ends abruptly to the north along the westward-flowing tributary of the Quittapahilla Creek. This is interpreted as a fault with a strike almost east-west. There is no evidence to indicate the nature of the fault.

THE LITHOLOGY, STRATIGRAPHIC RELATIONS AND STRUCTURE OF PRE-CAMBRIAN ROCKS IN EASTERN PENNSYLVANIA

by T. V. BUCKWALTER*

The pre-Cambrian rocks of Pennsylvania may be divided into two major groups, those of the Piedmont Province near and west of Philadelphia, and those of the Reading Highlands. The latter structural and physiographic unit extends from southeastern New York through the Highlands of northern New Jersey into Northampton, Lehigh, Berks, Lebanon and Lancaster Counties of southeastern Pennsylvania. It is bordered on the north by lower Paleozoic formations of the Great Valley and on the south by the Triassic Lowland which separates it from the crystalline rocks of the Piedmont. Its full length is visible to the south from the route of the field trip, and it is entered in the extreme western part of New Jersey across the Delaware River from Easton, Pennsylvania. The stratigraphy of the pre-Cambrian rocks of the highlands is briefly summarized below.

Most of the pre-Cambrian formations of the New Jersey Highlands are recognized also in the Reading Hills, but some distinct lithologic types occur in Pennsylvania. Exposures in most places in the hills are quite poor, and some of the field relations are therefore obscure. The formations recognized in Reading Highlands are tabulated below in approximate order of age, with the oldest at the bottom:

Metadiabase
Pegmatite
Furnace Creek quartz diorite gneiss
Byram granite gneiss
Pochuck gneiss
Moravian Heights formation
Franklin formation

Franklin formation—The oldest of the pre-Cambrian formations is the Franklin formation, correlated with the type locality at Franklin Furnace, New Jersey. The most easily identified member of this formation is a white, medium-grained saccharoidal marble. The marble is not common in Pennsylvania, however, and by far the bulk of the formation is a group of graphitic gneisses and graphite-quartz schists. The most abundant of these in the southwest part of the Pennsylvania highlands is a fine-grained, light gray to buff, quartz-feldspar gneiss which in some localities carries abundant graphite and biotite. The feldspar is orthoclase and microcline. The gneissic structure is ill-defined in many places, and that which exists is due to parallelism of biotite and graphite and to a slight elongation of quartz and feldspar. Other types related to this gneiss vary in grain size and in content of graphite and ferromagnesian minerals. Some Franklin marble, especially that near Easton, has been intruded by pegmatite and altered by hydrothermal solutions to form masses of serpentine and lime-silicate rock. In places Byram granite and pegmatite have thoroughly injected the graphitic gneisses, forming migmatites that are difficult to distinguish from Byram gneiss.

The graphitic gneisses associated with the Franklin limestone have been correlated by some workers with the Pickering gneiss of the Piedmont area, but others have included them in the Franklin formation because they are interbedded and consistently associated in the field. Because of the interbedding with the Franklin marble and the common occurrence of graphite, these gneisses are considered also to be metasediments.

Moravian Heights formation—This formation, which is chiefly a quartz-sericite-sillimanite schist, has been found locally in Lehigh and Northampton Counties. In most places it has been strongly injected by Byram granite. The original material is thought to have been a shaly sandstone which was metamorphosed to a quartz-sillimanite schist and later hydrothermally altered to a quartz-sericite-sillimanite schist. It is believed to be a part of the same former sedimentary section to which the Franklin formation belongs.

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Pochuck gneiss—The Pochuck gneiss comprises two chief members, gabbro gneiss and hornblende gneiss, as well as several minor types of basic gneisses. The gabbro gneiss and hornblende gneiss are mineralogically much alike, but differ considerably in texture. Gabbro gneiss is a dark gray to black, medium-grained rock with little or almost no gneissic structure. It contains about 50 per cent labradorite and 50 per cent ferromagnesian minerals, which include hornblende, augite, hypersthene, and minor biotite. Hornblende gneiss typically has a "salt and pepper" appearance and is composed primarily of labradorite and hornblende with locally a little garnet. Its prominent gneissic structure is formed by parallel lineation of hornblende in discontinuous bands and lenses which are usually 1 to 2 millimeters apart and a millimeter or so thick. The grain size is medium to coarse and the overall color a dark gray. All gradations exist between typical gabbro and hornblende gneiss.

The origin of Pochuck gneiss has not yet been satisfactorily determined. No evidence at present conclusively shows that the gabbroic gneiss is of other than igneous origin. However, hornblende gneiss appears to be in part at least of sedimentary origin. This conclusion rests mainly on its local gradation and interbedding with graphitic gneiss of sedimentary origin and with gneisses of intermediate composition between hornblende gneiss and graphitic gneiss. Such interbedding may also suggest metamorphosed sills or flows or perhaps diabase or basalt, but this appears unlikely in view of the gradational transitional zone between hornblende gneiss and the metasediments. The intermediate gneisses may well represent sediments of composition between the carbonaceous sediments and the impure calcareous sediments which resulted respectively in graphitic gneiss and hornblende gneiss. The original sediment which presumably gave rise to hornblende gneiss must have been relatively high in lime, iron oxides and magnesia. Some sediments with roughly such a composition include glauconitic greensands, calcareous chloritic shale, and dolomitic shale. In existing stratigraphic sections, the first two are rather restricted to be likely source beds, but dolomitic shale is not uncommon.

The term Pochuck gneiss is confined by some workers to the basic gneisses of solely igneous origin, but differentiation of the meta-igneous from metasedimentary varieties is virtually impossible in the field in most places.

Byram granite gneiss—Byram granite gneiss, including all of its varieties, is by far the most abundant of the pre-Cambrian formations. It underlies perhaps three-fourths of the pre-Cambrian area of the Reading Prong, and injects many of the other pre-Cambrian rocks. It forms most of the higher hills in the northeastern part of the Prong, though in the southwestern part, near Reading, the overlying Hardyston formation supports the highest hills.

Typical Byram granite gneiss is light buff to light pink, and fine- to medium-grained. Most of the grains are about one millimeter in diameter. The gneissic structure is in most places ill-defined or almost absent, and is caused by an imperfect parallel orientation of biotite. Some outcrops weather into large slabs which break parallel to the weak gneissic structure. Locally some granite weathers into spheroidal boulders.

The essential minerals composing it are quartz, microcline, and about 5 to 10 per cent of biotite and hornblende gneiss combined. In some localities the ferromagnesian minerals are very sparing and the rock may be called a leucogranite. Orthoclase and albite usually occur in minor quantities and the accessories include magnetite and zircon. Hornblende is commonest where hornblende gneiss or gabbro has been invaded. It is commonly strongly chloritized as is biotite. Sericitization of the feldspars is common. A moderate degree of dynamic metamorphism is indicated by many sutured contacts of the grains, by mortar structure, by slight parallelism of biotite, and by a few microscopic crushed zones which have been partly recrystallized.

A variety common in the southwest part of the highlands near Wernersville is a coarse-grained gneissic pegmatitic granite. Like most of the pegmatites the major minerals are quartz and alkali feldspar. Biotite and hornblende comprise in most places less than 5 per cent of the rock.

In a few places Byram granite gneiss is so intensely sheared that a schistose foliate structure is developed. The resulting rock closely resembles the upper Hardyston arkoses which are similarly converted to quartz-feldspar schists.

Much of the gneiss which has been mapped as Byram consists of migmatites formed by partial assimilation of Pochuck hornblende gneiss and gabbro. All migmatitic gradations exist from typical granite gneiss to hornblende gneiss and gabbro. In some localities hornblende gneiss occurs as sharply defined xenoliths in the granite, whereas elsewhere it has been partly assimilated and drawn out into prominent schlieren, or has nearly disappeared as vague diffused patches of hornblende crystals. In places the usual leucogranite has incorporated about 30 per cent of its volume as hornblende from the mechanical assimilation of the Pochuck gneisses.

The most common of these migmatites is a medium gray granite gneiss which is distinctly darker than typical Byram granite. Pink or light brownish colors are nearly absent unlike the typical Byram. The grain size is 1 to 2 millimeters in most places, although locally in areas of pegmatite it is one centimeter. The minerals comprising it are almost the same as in ordinary Byram, but the proportions are different in that hornblende is much more abundant. The gneissic structure is also much more prominent than in typical Byram granite. It is caused by alternate discontinuous bands and lenses of hornblende and minor biotite separated by bands of sodic plagioclase, potash feldspar and quartz. Some of these bands are poorly defined because of chloritization of hornblende and biotite. Byram granite also forms less abundant migmatites by injection of the Franklin formation.

Furnace Creek quartz-diorite gneiss—In a few places in the southwestern part of the Pennsylvania highlands, assimilation of Pochuck basic material by Byram granitic magma had been complete, and a new igneous rock of intermediate composition has crystallized. This new, usually homogeneous, recrystallized migmatite is in some places readily distinguished from the much more common mechanical mixtures. Several minor varieties of such migmatites exist, but one, a quartz-diorite gneiss, is so distinctive and locally abundant that it has been mapped separately, even though it is related genetically to the Byram and Pochuck. This gneiss is a dark greenish-gray, medium-grained rock, with a less obvious gneissic structure than typical hornblende gneiss. It looks somewhat like some gray anorthosites of the Adirondacks. It contains about 25 per cent quartz and 50 per cent andesine, the remainder being chiefly augite, hypersthene, hornblende, and biotite. Augite is usually fresh and relatively uncorroded, but hypersthene is almost invariably altered to a confused aggregate, in part sericitic. Assimilation of hornblende gneiss is not everywhere complete in this rock for in places it contains diffuse bands and clots of hornblende. The few outcrops and areas of float are small, and everywhere the gneiss grades into either Byram gneiss, Pochuck gneiss, or into the more common mechanical migmatites of these two rocks.

Pegmatites—Pegmatite and associated aplite are fairly widely distributed throughout the Pennsylvania highlands, but quantitatively are relatively unimportant. Most pegmatites occur as dikes a few inches to a few feet in width. Only a very few are as wide as eight feet and carry biotite and commercial quantities of muscovite. Although outcrops are so uncommon that exact structural relations are difficult to determine, pegmatites appear to cut all the pre-Cambrian gneiss into which they grade imperceptibly in many places. At one locality near Easton, Fraser (1941) has described pegmatite of Paleozoic age which cuts the Hardyston quartzite.

All the pegmatites observed, including the commercial ones, have a fairly simple mineralogy; all can be put in the "simple" class defined by Landes (1933). The color of most of them ranges from white to brown, depending on the quantity of weathered ferromagnesians that are present. The grain size ranges from 1 millimeter in the aplites to several inches in the thicker pegmatite dikes. The common minerals are quartz, orthoclase, microcline, albite, biotite and muscovite. Some of the pegmatites, particularly those occurring as thin lenses in the Byram, show a distinct gneissic structure due to a very pronounced elongation of quartz and feldspar grains. The source of the pegmatite appears to be the Byram granite magma, and much of the pegmatite juices has injected other pre-Cambrian formations, in many places in lit-par-lit fashion.

Metadiabase—Dikes of metamorphosed diabase, ranging from a few inches to about 50 feet in thickness, occur in many places in the highlands, especially to the southwest in Berks County. Most of them are profoundly hydrothermally altered, consisting chiefly of sericite, epidote, chlorite, magnetite, saussurite, and introduced quartz. The age of these dikes is in doubt. A pre-Cambrian age is suggested by their intense alteration and by the fact that most of them cut the pre-Cambrian formations and not the lower Cambrian Hardyston formation. In a very few localities, however, the Hardyston is cut by them. (Fraser, 1939) has suggested that the dikes are Ordovician in age because of the lithologic similarity to known Ordovician diabases elsewhere in Pennsylvania and New Jersey, and because of the intrusion of the Hardyston. It is very unlikely they are Triassic in age, for they are much more altered, even macroscopically, than diabases of known Triassic age.

Structure—The gneissic structure of the pre-Cambrian rocks in general strikes northeast-southwest, approximately parallel to the Appalachian structural trends. It appears likely that pre-Cambrian structure has in part controlled the Appalachian structure. Most dips are to the southeast, varying from about 20 degrees to vertical. Maps based largely on float show clearly the northeast trends, particularly of some rudely defined bands of hornblende gneiss and graphitic gneiss. Intrusion by Byram granite has largely broken up the continuity of the meta-sediments. The trend is also illustrated by many pre-Cambrian diabase dikes, which probably filled earlier faults and fissures to some extent. In a few places, however, the trend of the crystallines is east-west or to the norhtwest, as in the area about Shanesville in the southern part of the highlands. In other than local areas, little more than this broad picture of the regional structure can be obtained due to the scarcity of outcrops.

The most evident structural features in and near the highlands, are Appalachian in age, but they partly involve pre-Cambrian rocks. For about twenty years a controversy has centered around the structural relations of the crystalline highlands to the Paleozoic limestones of the Great Valley and also to the limestones exposed in flat low valleys within the highlands. The hypothesis originated by Stose and Jonas states that the crystallines of the entire Reading Highlands have been thrust perhaps 25 miles north and west over the underlying limestones of the Great Valley and that the intermontane valleys are windows in the overthrust crystalline sheet. In contrast to this Miller and others believe the highlands to be an uplifted mass into which the valley inliers of limestone have been down-faulted or steeply infolded. Much of the controversy has centered about the interpretation of these "windows", about the structural discordances in places along the northern and western fronts of the highlands, the mylonite zones and their presumed relations to the overthrust, the stratigraphy of the limestones and the lowest Cambrian Hardyston formation, and finally the significance of some deep drill holes. The various aspects of these points, too long to discuss here, are stated in several papers by Stose, Jonas and Miller.

Of these points, perhaps the most important is the interpretation of the flat intermontane valleys, for if they are truly windows, the overthrust hypothesis is essentially confirmed. Stose and Jonas indicate that several of them are floored with Elbrook limestone which is in fault contact with the walls of crystallines or Hardyston quartzite. Miller and others have questioned the accuracy of mapping in the windows, particularly the identification of the Elbrook limestone. If the limestone were Tomstown, which conformably overlies the Hardyston, the valleys could as readily be interpreted as infolds or local down-dropped blocks. It is noteworthy that in a few of these windows mapped as Elbrook no limestone whatsoever crops out.

In several places in the highlands, test borings or wells beginning in crystalline rocks have penetrated well below the depths at which limestone would be expected according to the overthrust theory, but failed to encounter it. While some of the records of the holes are incomplete, the failure to encounter lime in others suggests either that the thrust is non-existent or that its sole is unexpectedly deeply folded.

More recent work has still not resolved the problem, but has shown that large thrusts are present in a number of places, not only along the north side of the highlands, but in the Great Valley as well. Further mapping in a few of the intermontane valleys tends to support the infolded-local faulting hypothesis.

GENERALIZED COLUMNAR SECTION FOR PENNSYLVANIA

System	Series	Group	FORMATION	THICKNESS IN FEET	MINOR DIVISIONS	LITHOLOGY
CARBONIFEROUS	Permian		Dunkard	1000+	Washington coal Waynesburg "A" coal Waynesburg sandstone	Coarse, friable sandstone and sandy shale; many thin beds of blue or buff limestone; and several beds of coal, mostly thin and only locally workable. The formation is about 1000 feet thick in Green County, but only the lower 25 feet are seen on this trip.
			Monongahela	330	Waynesburg coal Uniontown coal Benwood limestone Sewickley coal Redstone coal Pittsburgh coal	Dominantly calcareous. Massive limestone 140 to 160 feet thick near middle of formation and thin beds of limestone both above and below. Shale interbedded with limestones. Coarse sandstone near the top and bottom of formation. Waynesburg coal at top and Pittsburgh coal at base.
	Pennsylvanian		Conemaugh	600	Connellsville sandstone Morgantown sandstone Ames limestone Saltsburg sandstone Mahoning sandstone	Shale and coarse sandstone with occasionally thin beds of limestone and coal. Most of shale is sandy, but some red and green clay shale. Lower half is sandy with several beds of coarse sandstone and conglomerate.
			Allegheny	280	Upper Freeport coal Bolivar fireclay Lower Freeport coal Upper Kittanning coal Middle Kittanning coal Lower Kittanning coal Brookville-Clarion coal	Shale, sandstone, fireclay and coal beds. Shale predominates. Sandstone is thin bedded and shaly, occasionally coarse and massive. Fireclay usually present and of value. Coal beds are actively operated.
			Pottsville	150	Homewood sandstone Mercer coal group Connoquenessing sandstone	Coarse, quartzose sandstone or conglomerate, sometimes massive, with intermediate shale carrying coal beds locally.
	Mississippian		Mauch Chunk	150	Greenbrier limestone	Red and green shale with green, flaggy sandstone. Blue, fossiliferous limestone near the base.
			Loyalhanna	40-70	Loyalhanna limestone	Blue sandy limestone.
			Pocono	700	Burgoon sandstone (Big Injun sand)	Coarse gray sandstone at the base interbedded with sandy shale.
DEVONIAN	Upper Devonian		Catskill	2000-2500		Bright red shale, alternating with red and brown sandstone. Bright green layers and mottling in red shale. Beds of gray shale and sandstone throughout with some marine fauna. This interval contains many oil and gas producing zones.
			Chemung	2400-3350		Shale and sandstone. Upper 1000 feet chocolate colored shale and sandstone. Lower part gray and green shale with sandstone. Sands in this interval are gas producing. Fossils plentiful.
		Portage	Brallier	1350-1800		Sandy and micaceous greenish-gray shale, highly laminated with manganese oxide staining, weathered surfaces black. Thin green sandstone layers near top. Fossils scarce.
			Harrell	250 (80)	Burket black shale Tully limestone	Interbedded black and gray soft, fissile clay shale. Small fossils throughout.
	Middle Devonian		Hamilton	750-1200		Shale and siltstone in western area. Few feet gray shale with thin limestone layers near top with many fossils.
			Marcellus	150		Black fissile shale. Few fossils.
			Onondaga	50		Dark and drab shale. Thin limestone at top. Fossiliferous.
	Lower Devonian	Oriskany	Ridgeley	100		Calcareous sandstone and fine conglomerate. Highly fossiliferous.
			Shriver	200		Thin bedded siliceous limestone. Black calcareous shale with fossils at bottom.
			Helderberg	150+	New Scotland Coeymans Keyser	Thick and thin bedded blue-gray limestone. Keyser member nodular argillaceous. Cherty near bottom. Main quarry bed at bottom.

GENERALIZED COLUMNAR SECTION FOR PENNSYLVANIA

System	Series	Group	FORMATION	THICKNESS IN FEET	MINOR DIVISIONS	LITHOLOGY
SILURIAN		Cayugan	Tonoloway	450		Thick bedded dark to black limestone at top. Few fossils.
			Wills Creek	400+		Drab fissile clay shale. Thin limestone at bottom. Few fossils.
			Bloomsburg	50+		Red shale and sandstone.
			McKenzie	400		Highly fossiliferous thin bedded blue limestone.
		Niagaran	Clinton	775±	Keefer sandstone Marklesburg ore Frankstown ore Block or Levant ore and "Iron sandstone"	Predominantly shale; chocolate at top, green-gray in middle with red layers in lower part and pink fissile shale at bottom. Limy ore beds near top and workable ore near middle. Fossiliferous, particularly at top.
			Tuscarora	400-600		Gray sandstone and quartzite. Source of ganister for refractory brick.
ORDOVICIAN	Upper Ordovician		Juniata	850		Predominantly red shale and sandstone with cross-laminations.
			Oswego (Bald Eagle)	800		Almost all gray thick bedded sandstone. Few layers gray, red and green sandy shale.
			Reedsville	1000		Olive-green clay shale, except 20′ at bottom which is black. Top 30′ calcareous sandstone and thin shell limestone bands. Fossils in upper part.
	Middle Ordovician	Trenton	Antes Coburn	400± 300±		Dark brownish weathering shale. Dark gray coquinal and calcarenitic limestone.
			Salona	20-160±		Black argillaceous buff-weathering limestone with prominent shaly partings.
			Nealmont	30-235±	Rodman Centre Hall Oak Hall	Blue-gray weathering limestone at top and a lower gray to tan argillaceous buff-weathering limestone.
		Bolarian	Benner	0-100	Stover Snyder	Dark to dove, thin to heavy-ledged limestone. Limestone conglomerate at base.
			Hatter	60-420±	Hostler Grazier Eyer	Five distinct limestone types ranging from dark gray and cobbly, dark gray and even bedded, medium to coarse calcarenite, interbedded dark gray type and calcilutite pellet conglomerate, and dove calcilutite. (Black River Group of some reports.)
		Chazy	Loysburg	1000±		Three fold division, with lower section a dove calcilutite, middle dark gray cherty limestone, and a upper dark gray to dove limestone.
	Lower Ordovician	Beekmantown	Bellefonte Axemann Nittany Stonehenge	1000 150 1000 500		Thick bedded cherty dolomite. Thin bedded blue limestone. Thick bedded gray cherty dolomite. Thick bedded dolomite with some chert and fossils.
CAMBRIAN	Upper Cambrian		Mines	250		Blue gray dolomite like Gatesburg, containing considerable chert, siliceous oolites, very little sandstone.
			Gatesburg	1750	Ore Hill limestone Stacy dolomite	Thick bedded blue dolomite with argillaceous bandings giving striped appearance. Many interbedded layers of quartzite which make ridges covered with quartz boulders and sand. Sand has economic value.
			Warrior	1250		Blue to dark blue gray limestone which is probably magnesian with few quartzite bands and layers of rounded quartz grains.
	Middle Cambrian		Pleasant Hill	600		Upper 200′ thick bedded dark gray pure limestone with oolitic and conglomeratic layers containing trilobites and other fossils. Lower 400′ thin bedded and argillaceous.
	Lower Cambrian		Waynesboro	250+		Green and red shale above, sandstone, quartzite and conglomerate below. Not all exposed and thickness unknown.

PHYSIOGRAPHIC SUMMARY FOR NEW JERSEY*

By MEREDITH E. JOHNSON**

New Jersey is readily divided into four physiographic provinces: (1) Ridge and Valley; (2) Highlands; (3) Piedmont, or Triassic Lowlands; and (4) Coastal Plain. Our field trip takes us into all these provinces except the Coastal Plain.

Ridge and Valley Province. This is a belt of ridges and valleys, its New Jersey portion only about 12 miles wide, lying between the Appalachian Plateau on the west, and the New Jersey Highlands on the east. In general, its surface is much lower than that of the adjacent provinces, its trend being northeast, the same as the regional strike of the rocks into which the topography has been carved by erosion. It includes much of Warren and Sussex Counties, amounting to a little more than one-twelfth the area of the state. Its eastern part includes the Kittatinny Valley which extends throughout the northwestern corner of the state. Delaware River follows another but much narrower valley along the extreme northwestern boundary. The intervening Kittatinny Mountain, rising to a height of 1,800 feet, is the highest in the state, and the most striking feature of this province.

Highlands Province. The New Jersey Highlands are part of a chain of mountains extending southwest to Reading, and northeast through New York state into New England. To physiographers the chain is known as the Reading Prong of the New England Upland, and the entire belt is characterized by crystalline rocks of pre-Cambrian age. The Highlands are relatively narrow where they cross the Delaware, but broaden to the northeast. At their widest point they are about 25 miles across. They have an area of approximately 900 square miles—about one-eighth of the state—and are found in the southeastern parts of Sussex and Warren Counties, and in northern Hunterdon, Morris and Passaic Counties. Their maximum elevation is 1,496 feet near Vernon, Sussex County, and the most easterly ridge, Ramapo Mountain, is less than 25 miles from New York.

In general, the Highlands consist of broad, rounded or flat-topped ridges, rising 400 to 600 feet above the lowlands on either side and are separated from each other by deep and relatively narrow valleys. The soil on top of the ridges is usually good, the broader ridges having been cleared generations ago and farmed continuously ever since. The steep slopes are generally wooded, as are the narrower ridges. The larger topographic features have the regional northeast trend, although some of the minor features are irregular. In prominent contrast to the regional trend are the courses of some of the larger rivers such as the Pequannock, Rockaway and Delaware (between Phillipsburg and Riegelsville), which trend southeast through the ridges. The only logical explanation for this type of drainage appears to be that offered by William M. Davis, an explanation later expanded by Douglas Johnson. It assumes that these streams were consequent upon an assumed cover of coastal plain sediments on the Fall Zone peneplain. As uplift occurred, the streams had sufficient cutting power to maintain the general direction of their courses, although each has probably suffered some vicissitudes as the result of stream piracy by subsequent streams acting on soft rock, and by glacial action.

Piedmont, or Triassic Lowlands. In New Jersey the Piedmont is characterized by a belt of relatively soft red rocks having the same general northeast trend as the older rocks which they border, but which also includes some cross-cutting and curving ridges of much harder rock. Ranging in width from 30 miles where it crosses the Delaware to less than 16 miles where it crosses the New York state line, the belt has an area of about one-fifth that of the entire state of New Jersey. The Piedmont occupies the southeastern portions of Hunterdon, Morris and Passaic Counties, large areas of Mercer, Somerset and Middlesex, and the whole of Union, Essex, Hudson and Bergen Counties. It is chiefly a lowland of gently rounded hills separated by wide valleys, with some ridges and isolated hills rising conspicuously above the general surface.

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*Summarized from Bulletin 50, N. J. Geol. Survey.

**Director, New Jersey Geological Survey.

The lowlands range in elevation from about 400 feet above sea level at the northwestern border of the province to sea level at Newark and Elizabeth, with elevations of 50 to 100 feet along the southeastern border. Borings have shown that the Hackensack and Passaic Rivers, prior to the Wisconsin glaciation, had eroded the lower portions of their courses to elevations 250 feet below present sea level. The evidence is indisputable that this could only have been done when the sea was at much lower elevation, and it seems reasonable to believe that this was during the Pleistocene glacial epochs. Today these deeply buried rock valleys are tidal marshes. There is a good view of these to the south (right) as we cross under the north end of the New Jersey Turnpike.

All of the higher ridges and hills in this province are composed of diabase or basalt, their elevations above sea level today giving mute testimony to their superior resistance to erosion. The Watchung Mountains are a conspicuous and well-known feature of the landscape bordering the metropolitan area of northeastern New Jersey. The First and Second Watchung Mountains are compound flows whose curving edges form concentric, ellipsoidal ridges nearly 40 miles long. A third compound flow, Hook Mountain, roughly parallels the others, but exhibits a reverse curve east of Montville which can only be explained by assuming a slight upward flexure along an axis bisecting the curve and trending southeast. Another interesting structural variation occurs about 14 miles farther to the southwest where the same compound basaltic flow rises in what is almost a quaquaversal fold. The highest point on any of these ridges is on High Mountain, a peak north of Paterson, which reaches an elevation of 879 feet above sea level. Between Paterson and Summit, First Mountain ranges from 550 to 691 feet, and Second Mountain attains a comparable elevation just north of Verona.

Were the trip across New Jersey to be made from east to west, everyone taking it would agree that one of the most impressive topographic features to be seen is the Palisades. This is the eastward-facing cliff of diabase whose crest near Closter is 547 feet above sea level, and which extends as a continuous sill from Haverstraw, N. Y., south and southwest for a distance of 86 miles; although it sinks below tide level just east of Carteret and reappears only between Deans and Hopewell. Much has been written about the Palisades; suffice to say here that it exhibits interesting differentiation; and that it derives its name from its appearance.

Sourland Mountain is probably a faulted extension of the Palisades sill which rises to an elevation of 563 feet near its northeast end. Cushetunk Mountain, almost surrounding Round Valley in northern Hunterdon County, is another prominent diabase ridge, its highest point being 839 feet above sea level.

Coastal Plain Province. Between the Piedmont and the shore lies the Coastal Plain. It includes three-fifths of the state in area. Geologically and physiographically it is completely different from other parts of New Jersey. Consisting essentially of easily eroded, unconsolidated sediments, much of the area is relatively low, with sluggish, swampy streams and gentle slopes. The vegetation reflects these differences, particularly in the more sandy parts, by a preponderance of yellow pines in comparison to the hardwoods of central and northern New Jersey.

Not all of the sediments in the Coastal Plain are easily eroded. Sand and gravel deposits have been cemented by deposition of limonite from groundwaters carrying iron in solution, and with the passage of time these consolidated beds have become conspicuous hilltops because of the erosion and removal of the surrounding unconsolidated material. Rising 50 or 100 feet above the surrounding lowlands, some of these hills have been given such fanciful names as Forked River Mountains, Apple Pie Hill and Arney Mount.

Half of the Coastal Plain is less than 100 feet above sea level. Also the divide between the headwaters of Rancocas Creek, draining westward, and the Mullica River, draining eastward, has an elevation of less than 100 feet.

The divide between east and west drainage rises northward, so that at Crawfords Hill, Monmouth County, an elevation of 391 feet is attained. Hills between Clarksburg and Perrineville reach an elevation of 354 feet, and the Navesink Highlands, directly overlooking Sandy Hook and the lower New York Harbor, attain an elevation of 276 feet. Though not a "dizzying" altitude, this is the highest point adjoining salt water between New York and Key West.

Conspicuous features of the Coastal Plain are the marshes bordering stream courses and the numerous estuaries which are due to the submergence of valleys carved when sea level was lower (i.e. the Pleistocene epochs). Delaware and Raritan Bays are conspicuous examples. The present width of the Coastal Plain is 30 to 60 miles, but it is obvious that this width has varied greatly in geologic time and doubtless will continue to vary in the future.

STRATIGRAPHIC SUMMARY FOR NEW JERSEY*

PRE-CAMBRIAN ROCKS

By MEREDITH E. JOHNSON**

In pre-Cambrian time in New Jersey a sequence of sediments probably totaling thousands of feet was deposited. The best known of these deposits is the crystalline, graphitic Franklin limestone, although a variety of associated slates, sandstones, and conglomerates is present in Marble Mountain, just north of Phillipsburg, and elsewhere. These oldest sediments have been folded and strongly metamorphosed, and intruded by molten rock which formed the several types of gneiss now constituting so large a part of the New Jersey Highlands. A stop will be made to examine a good exposure of one of these typical granitoid gneisses.

PALEOZOIC ROCKS

Cambrian System

In New Jersey, Cambrian rocks are represented by a relatively thin formation of quartzite or sandstone, the Hardyston, and by a great thickness of limestone, the lower part of the Kittatinny formation. The upper part of the Kittatinny limestone is considered Ordovician in age.

Just how far east Cambrian sediments once extended is unknown. The Hardyston formation can now be traced as far east as Gladstone and Peapack (north central), and it seems likely that before the Appalachian Revolution at the close of Paleozoic, the Cambrian sediments extended many miles farther east than that.

Following the deposition of the Hardyston formation there was long-continued limestone deposition which resulted in the gray, finely crystalline limestone now represented on the state geologic map as the Kittatinny formation. The maximum thickness of this unit is 3,500 feet. One of the problems of New Jersey stratigraphy is to establish sufficient criteria for subdividing this great thickness of limestone into smaller units. Based on certain general characteristics, a rough subdivision may be made into Tomstown (lower), Allentown or Conococheague (middle), and Beekmantown (upper). Paleontologists tell us, however, that on a faunal basis, there is no Middle Cambrian in New Jersey. Fossils which have been found (they are relatively few) point to a Lower Cambrian age for the Tomstown, to an Upper Cambrian age for the Allentown (Conococheague), and to an Ordovician age for the Beekmantown. Although paleontology suggests the absence of Middle Cambrian in New Jersey, there is no mappable unconformity between Lower and Upper Cambrian strata. Neither is there one between the Upper Cambrian and Lower Ordovician.

Ordovician System

It has already been stated that deposition of limestone (Kittatinny) continued without any apparent break from Upper Cambrian into Lower Ordovician time. Following the Kittatinny deposition, however, the sea withdrew and erosion removed some of these beds before another advance of the sea permitted deposition of the relatively pure and fossiliferous Jacksonburg limestone of Trenton age. Volcanic activity, evidenced by bentonite in the Jacksonburg, perhaps caused some differential elevation of the land, for today we find a thick series of calcareous shales above the Jacksonburg limestone in the Phillipsburg area, whereas farther to the north and northeast we find an unconformity with much or all of the Jacksonburg removed in large areas.

The Jacksonburg is overlain by the Martinsburg formation, the latter being predominantly shale with some sandstone. Typically, these Martinsburg beds are gray, and weather brown. There is, however, in the region west of Clinton, a considerable thickness of red shale with some sandstone and thin-bedded limestone which stratigraphically appears to occupy the position of the Martinsburg, although the contained graptolites suggest an older age. Possibly they represent the erosion interval which followed Jacksonburg deposition, and the true Martinsburg may be absent in this area.

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*Summarized from "The Geology of New Jersey", Bulletin 50, N. J. Geol. Survey.

**Director, New Jersey Geological Survey.

The Ordovician period was terminated by widespread earth movements of the Taconic Revolution which uplifted and tilted the previously deposited sediments. The rising land was immediately subjected to erosion. In the Green Pond region all of the Ordovician sediments, and in places, all of the Cambrian, were removed. In the upper Delaware River region where the sediments were thicker and the erosion interval probably shorter, only the uppermost Ordovician strata were eroded.

Silurian System

Formations of Silurian age now occur in two distinct regions:

(1) In Kittatinny Mountain and Wallpack Ridge in the northwestern corner of the state.

(2) In the narrow, down-folded and faulted mass of Paleozoic rocks in the Flanders-Green Pond-Greenwood Lake region in the midst of the Highlands. In the upper Delaware Valley these formations aggregate 4,200 feet or more of sediments, whereas in the Green Pond region they do not exceed 1,800 feet. There can be little doubt that originally the strata of these two areas were continuous, and that erosion since Silurian time has removed all traces of them from the intervening areas.

We will not see any Silurian strata on the field trip, nor will space permit a detailed description of them. Suffice it to say that in the Green Pond region, 1,200 to 1,500 feet of sandstone (now quartzite) and conglomerate, are overlain by 200 feet of shale and a little limestone (Decker). How much of the Rondout and Manlius were deposited, only to be later eroded, will probably never be known. We do know that in the Delaware Valley area the Rondout and Manlius are 39 and 35 feet thick, respectively. The Decker in the Delaware Valley area is underlain by at least 100 feet of Bossardville limestone which is not represented in the Green Pond area.

Devonian System

Whether a brief erosion interval followed deposition of the Manlius limestone (uppermost Keyser) is debatable. Some believe there is a slight disconformity between it and the overlying Coeymans limestone. In any case, deposition of the fine-grained, dark gray Manlius was followed by deposition of the coarsely crystalline, light gray and highly fossiliferous Coeymans with very little evidence of a withdrawal of the sea between Silurian and Devonian times. The original extent of Devonian rocks is unknown, but beds of Oriskany age can be traced eastward as far as the Green Pond area. There, all the Devonian beds are composed of either sandstone, shale or conglomerate. In the Delaware Valley area the basal Devonian Coeymans formation is overlain by a series of relatively thin limestones and shales which terminate at the river with the black Marcellus shale.

Later Paleozoic history of New Jersey cannot be read from the sedimentary record now preserved within its borders. The region became a land area in late Devonian time and possibly no part of it was again submerged during the Carboniferous and Permian periods. Certainly, if sediments of either age were deposited in New Jersey, they have since been removed by erosion. It seems probable that uplift of the New Jersey area began in Carboniferous time and that it was dry land during the long eons of time during which the Appalachian Mountains were brought into being and partially eroded.

MESOZOIC ROCKS

Triassic System

Long after the Appalachian Mountains were formed, a series of northeast-trending faults on the southeastern side of pre-Cambrian area permitted the development of a broad, intermontane valley which extended both northeast and southwest of New Jersey. Into it sediments were washed from mountain ranges to the southeast and northwest. With an ever-increasing load of sediment the valley floor dropped lower and lower (or is the boundary fault a reverse fault, indicating rejuvenation of the mountainous belt to the northwest?). Occasional heavy rains brought down the debris from higher ground and spread it in broad coalescing alluvial fans upon the valley floor. The prevailing red color of these sediments and the general absence of organic material is evidence that the climate was warm. At many places along the northwestern border of the basin, coarse conglomerate composed of quartzite, limestone or gneiss was deposited. Nearer the center of the valley the Triassic beds show reptilian footprints, some of which are almost perfectly preserved. Small crustaceans and fresh-water fish are other evidences of life that has been preserved in these strata.

Near the center of the basin the Triassic rocks may be subdivided into three units. The lowest unit is the Stockton formation, composed of feldspathic conglomerate and sandstone totaling 3,000 to 3,100 feet in thickness. The Stockton is overlain by the Lockatong formation, a 3,500-foot sequence of gray and dull red argillite. Above the Stockton lies the upper of the three units, the Brunswick formation. This is composed of red argillite having a total thickness probably in excess of 10,000 feet. Towards the northeast, where the Triassic strata are typically composed of red argillaceous sandstone and conglomerate, this three-fold subdivision cannot be made.

Vulcanism: In the Physiographic Summary, the writer has already mentioned the conspicuous ridges of basalt and diabase which mark the New Jersey Piedmont. These represent four major periods of igneous activity, the first one coming about midway in late Triassic time. The initial flow (actually, it is compound) is 580 to 600 feet thick; the second is even thicker, being 800 to 900 feet; and the third is 280 feet thick. The composition of all these flows is almost identical and probably no one who has studied them doubts that they came from the same deep-seated magma. Still later, a tremendous sill of lava, 900 to 1,000 feet thick, was intruded into the Triassic sediments where it slowly congealed far below the surface.

The extrusive flows are conformable to the surface of the sediment over which each flowed, and the overlying shales fit into all the minor irregularities of the upper surfaces of the flows. These upper surfaces are porous and spongy as a result of gases being trapped beneath the congealed surface layer during the cooling process. The basalt or diabase in the lower part of the flows is, however, dense and fine-grained. In some places the basal part of the flow rock is a black, vesicular glass which probably resulted from quick cooling as the lava flowed over marshy ground, or perhaps over a small pond. Elsewhere the base of the lava is dense, and the underlying shale is bleached to a depth ranging from 6 inches or less to a maximum of 18 inches. In contrast, the thick Palisades diabase which cooled slowly far below the surface, altered the adjoining beds for distances of several hundred feet. Moreover, it broke across the bedding, and incorporated tilted slabs of metamorphosed sandstone and shale in both its upper and lower parts. These features are well shown in the cliffs adjoining the George Washington bridge.

The New Jersey Triassic rocks show a series of strike faults which divide them into a succession of long and narrow blocks, tilted to the northwest. Some of these faults have displacements of thousands of feet, indicating that the diastrophism occurring at the close of Triassic time would no doubt have made the San Francisco earthquake seem tame by comparison.

Jurassic Period

All of New Jersey was apparently above sea level during the Jurassic, for no sediments of that age occur here. Presumably it was at the close of the Triassic that the land mass of Appalachia, which had contributed a tremendous volume of clastic sediment to the Triassic basin, sank beneath the waters of the Atlantic, never to reappear.

Initially the Jurassic landscape must have been marked by many ridges, but the vigorous erosion to which these were subjected ultimately beveled the tilted strata, uncovered the margins of the buried basalt flows and even exposed the deep-seated intrusive sill of diabase. Ultimately the land was worn down to a region of relatively low relief.

Cretaceous System

Erosion continued in most of New Jersey during the early Cretaceous. However, a deep well drilled in southern New Jersey at Salem has disclosed the presence of sediments of Lower Cretaceous age there. As yet no wells east or southeast of Salem have been drilled to bedrock; but it seems probable that the indicated thickness of more than 5,000 feet of sediments beneath Cape May County may well include several hundred feet of Lower Cretaceous.

Remnants of Cretaceous sand on top of Rocky Hill, between Trenton and New Brunswick, show conclusively that at one time the Cretaceous deposits reached as far as the Highlands and indeed may have spread many miles to the northwest as suggested by Douglas Johnson. Regardless of their former extent, however, we do know from the character of the basal sediments, and their limited faunas, that they were deposited in relatively shallow waters. As the sea deepened, the character of the deposits changed and dark clays, fine-grained sands and greensands, all containing abundant marine life, were deposited.

Deep wells and geophysical investigations have shown that the rock floor—the Fall Zone peneplain—upon which the Cretaceous seas advanced, slopes to the southeast at rates which range from a minimum of 65 feet per mile to a maximum of more than 100 feet per mile. Superimposed deposits dip more gently and the top Upper Cretaceous bed, the Tinton marl, slopes seaward at a rate of only 30 feet per mile.

At the close of Cretaceous the land was differentially warped. The center of a mild uplift at the close of Cretaceous time is indicated near the southwestern border of the state, for in that area all of the Cretaceous sediments above the Navesink, and much of the Navesink also, are eroded, a loss of approximately 180 feet as compared with the section in eastern Monmouth County.

CENOZOIC ROCKS

Tertiary System

Tertiary rocks, like the Cretaceous, are confined to the Coastal Plain Province and will not be seen on our field trip. The Tertiary strata, totaling about 700 feet in thickness, are mostly marine and are composed of unconsolidated sands, gravels, marls, and greensands. Although marine conditions prevailed during most of the Tertiary, continental deposition towards its close is indicated by the Cohansey sand, with only an occasional clay lens, in which so far only a restricted flora of land plants has been found.

Oil and Gas Possibilities

For members of the American Association of Petroleum Geologists, the foregoing brief summary of the stratigraphy would not be complete without some discussion of the oil and gas possibilities in New Jersey.

A glance at the geologic map and geologic cross-sections of the state is enough to show that northwestern New Jersey is a region of closely folded and faulted rocks. The discovery of commercial amounts of either oil or gas in such rocks seems unlikely, to say the least.

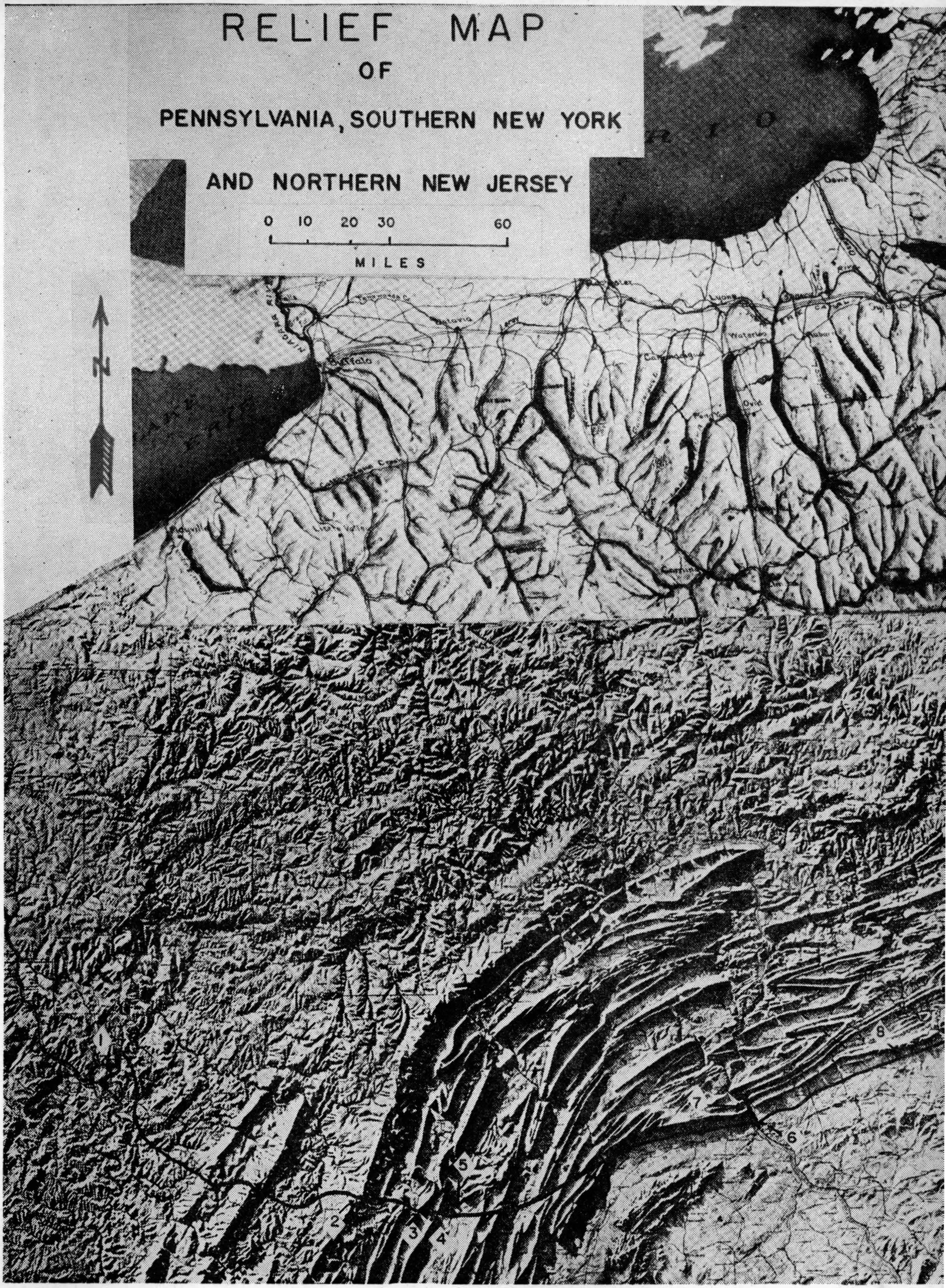
The Piedmont area of Triassic rocks does not seem to offer much more hope. These strata too have been folded and faulted to a considerable degree; moreover, their prevailing red color is an indication that most of the organic matter contained within the original deposits was oxidized and destroyed immediately following deposition. Without any known source material, therefore, even the structural trap at New Vernon, with closure of about 400 feet, offers little attraction to the geologist seeking oil or gas.

There remains for consideration the wedge of unconsolidated sediments constituting the Coastal Plain. At Jacksons Mills, in northern Ocean County, a well was drilled into the crystalline rock and revealed a 1,326-foot thickness of sediments. Another well was drilled to crystalline rock at a depth of 1,376 feet at Salem in southern New Jersey. In neither well was any oil or gas noted. That part of the Coastal Plain northwest of a line connecting these two points would appear to be as barren of possibilities as are the Mesozoic and Paleozoic deposits. Whether the area to the southeast offers better possibilities remains to be proven. We do know that there is an abundance of marine life preserved in some of the Cretaceous and Tertiary formations. We also know that none of the deep water wells or test holes sunk in the area encountered any trace of oil, or more than a puff of gas. Since the deepest of these wells (at Atlantic City) was only 2,306 feet, and the depth to bedrock beneath the southern tip of the state is 5,000 to 6,000 feet, it is also obvious that as yet the drill has not fully tested the possibilities. Knowledge gained through geophysical investigations of the structure of the sediments between Bridgeport, on the Delaware River, and Avalon, Cape May County, indicates that, with minor variations, the formations dip rather uniformly to the southeast. On the favorable side, however, is the fact that the older sediments are all overlapped to the northwest, and therefore there is the possibility of stratigraphic traps in the southeastern part of the state.

Finally, attention should be called here to the deep tests drilled in Delaware and Maryland. These found basement at depths ranging up to 8,000 feet, yet none of them found either oil or gas.

GENERALIZED COLUMNAR SECTION FOR NEW JERSEY

SYSTEM	Series	FORMATION	THICKNESS IN FEET	LITHOLOGY
CENOZOIC	Pleistocene	Cape May	0-30	Sand and gravel
		Pensauken	0-60	Sand and gravel
		Bridgeton	0-30	Sand and gravel
	Tertiary	Beacon Hill	0-20	Sand and gravel
		Cohansey	100-250	Sand
		Kirkwood	100-200	Sand and clay
		Shark River	11	Glauconitic clay and sand
		Manasquan	25	Greensand (chiefly glauconite)
		Vincentown	25-100	Sand and limestone, some glauconite
		Hornerstown	20-30	Greensand
MESOZOIC	Upper Cretaceous	Tinton	0-21	Indurated glauconite and clayey sand
		Red Bank	0-145	Glauconitic sand and clay
		Navesink	3-40	Greensand
		Mount Laurel	5-60	Glauconitic sand
		Wenonah	35-60	Sand
		Marshalltown	30-50	Glauconite, clay and sand
		Englishtown	20-140	Lignitic sand
		Woodbury	50	Clay
		Merchantville	50-60	Glauconitic and partly sandy clay
		Magothy	25-130	Lignitic sand and clay
		Raritan	150-300	Sand and clay
TRIASSIC	Upper (Newark Series)	Brunswick	8000+	Red shale and sandstone
		Lockatong	3500	Black shale
		Stockton	3100	Conglomerate
DEVONIAN	Upper	Skunnemunk	1500	Conglomerate
		Bellvale	1800	Sandstone
	Middle	Cornwall	1000	Shale
		Onondaga (Kanouse)	215 to 250	Sandstone
		Esopus	375	Grit
	Lower	Oriskany	170	Sandstone
		Port Ewen	80	Shaly limestone
		Becraft	20	Limestone
		New Scotland	160	Limestone
		Stormville	0-10	Sandstone
		Coeymans	40-80	Limestone
SILURIAN	Upper	Manlius	35	Limestone
		Rondout	39	Limestone
		Decker Ferry	52	Limestone
		Bossardville	100	Limestone
		Poxino Island	300+	Shale
	Middle	High Falls	2300	Shale
	Lower	Shawangunk Green Pond	1500	Conglomerate
Ordovician		Martinsburg	3000	Shale
		Jacksonburg	0-300	Limestone
Cambro-Ord.		Kittatinny	2500 to 3000+	Limestone
Cambrian		Hardyston	0-250	Quartzite
Pre-Cambrian		Franklin		Limestone, including Losee, Pochuck and Byram injection and granite gneisses


RELIEF MAP
OF
PENNSYLVANIA, SOUTHERN NEW YORK
AND NORTHERN NEW JERSEY
0 10 20 30 60
MILES
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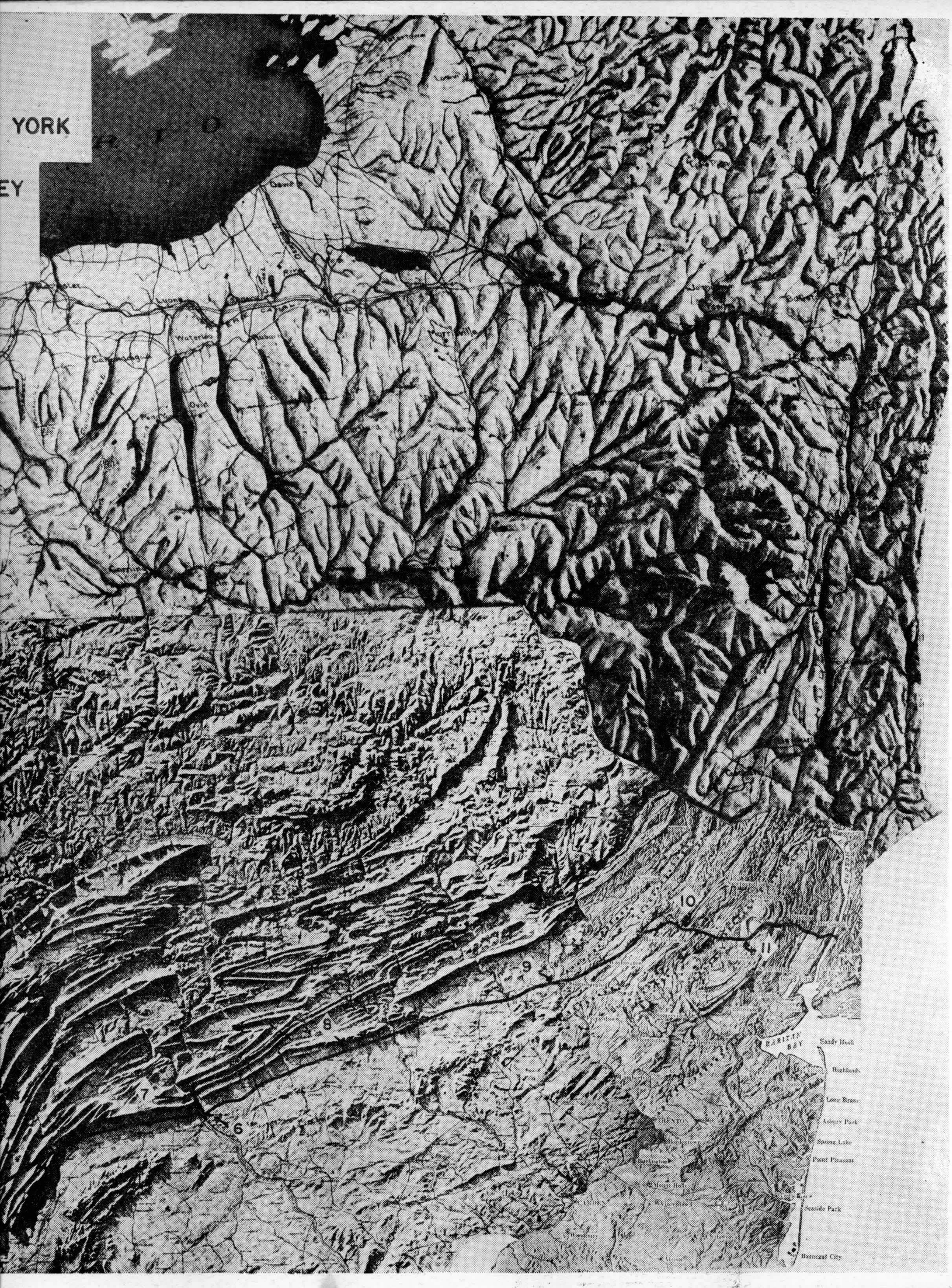

YORK
EY
10
11
9
8
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6
Sandy Hook
Spring Lake
Point Pleasant
Seaside Park
Barnegat City