

GUIDEBOOK

26th FIELD
CONFERENCE
OF PENNSYLVANIA
GEOLOGISTS
OCTOBER 20, 21, 1961
BETHLEHEM, PA.



HOST
LEHIGH UNIVERSITY
DEPARTMENT OF GEOLOGY

STRUCTURE AND STRATIGRAPHY OF THE
READING HILLS AND LEHIGH VALLEY IN
NORTHAMPTON AND LEHIGH COUNTIES,
PENNSYLVANIA

Guidebook for the 26th Meeting
Field Conference of Pennsylvania Geologists

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CHESLEIGH ARTHUR BONINE
E.M., Lehigh University, 1912
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by
Lawrence Whitcomb

The Department of Geology, Lehigh University, is proud to dedicate this guidebook to the 1961 meetings of the Field Conference of Pennsylvania Geologists to a Lehigh alumnus.

In the spring of 1931, C. A. Bonine, who was then Professor of Geology at the Pennsylvania State College, sent out a number of letters to geologists of his acquaintance in Pennsylvania, to geology departments, both academic and commercial, and to a few geologists from the adjacent states. He stated that he had recently read a paper listing the number of geologists in the various states and at that time realized how few of those in Pennsylvania he knew. Feeling that this might be true of many others, he invited all of us to come to State College for the Memorial Day week-end. The plans called for some field trips, but the major objective was that we might become better acquainted with the other geologists located in or working in Pennsylvania.

On Friday, May 29, we arrived for the start of a memorable week-end, (no one who on Saturday walked the Horseshoe Curve in temperatures over ninety will ever forget it) to find a program with the title "Field Conference of Pennsylvania Geologists". That evening at a Smoker, it was decided that Bonine had

started something that must be continued. B. L. Miller of Lehigh and Freeman Ward of Lafayette invited the group to visit the Lehigh Valley in 1932 and George H. Ashley stated that the Pennsylvania Geological Survey would be the host at Harrisburg in 1933. A sound start was assured and the name which Bonine had placed on his first program became the accepted designation of the group.

Now thirty years later, it is appropriate for us at Lehigh to recognize Chesleigh Arthur Bonine, E.M., Lehigh, 1912, as founder of the Field Conference of Pennsylvania Geologists.

MEETINGS OF THE FIELD CONFERENCE OF
PENNSYLVANIA GEOLOGISTS

<u>Year</u>	<u>Area</u>	<u>Host</u>
1. 1931	State College	Pennsylvania State College
2. 1932	Forks of the Delaware	Lehigh University and Lafayette College
3. 1933	Harrisburg	Pennsylvania Geological Survey
4. 1934	Pittsburgh	University of Pittsburgh, Carnegie Inst. of Tech., Gulf Companies
5. 1935	Philadelphia	Academy of Natural Science and cooperating colleges and companies
6. 1936	Anthracite Region	Lehigh University and cooperating anthracite companies
7. 1937	Bradford	Pennsylvania Geological Survey
8. 1938	Virginia	Virginia Geological Survey
9. 1939	West Virginia	West Virginia Geological Survey
10. 1940	New Jersey	New Jersey Geological Survey
11. 1941	Johnstown	Pennsylvania Geological Survey
12. 1946	State College	Pennsylvania State College
13. 1947	Lehigh Valley	Lehigh University
14. 1948	Harrisburg	Pennsylvania Geological Survey
15. 1949	Lancaster	Franklin & Marshall College
16. 1950	Pittsburgh	University of Pittsburgh
17. 1951	Bryn Mawr	Bryn Mawr College
18. 1952	New Jersey	New Jersey Geological Survey
19. 1953	Easton	Lafayette College
20. 1954	Hershey	Pennsylvania Geological Survey
21. 1955	State College	The Pennsylvania State University
22. 1956	New Jersey	New Jersey Geological Survey
23. 1958	Hagerstown, Md.	The Johns Hopkins University
24. 1959	NW Pennsylvania	Pennsylvania Geological Survey

<u>Year</u>	<u>Area</u>	<u>Host</u>
25. 1960	SE Pennsylvania, Lancaster County	Franklin & Marshall College
26. 1961	Northampton and Lehigh Counties	Lehigh University

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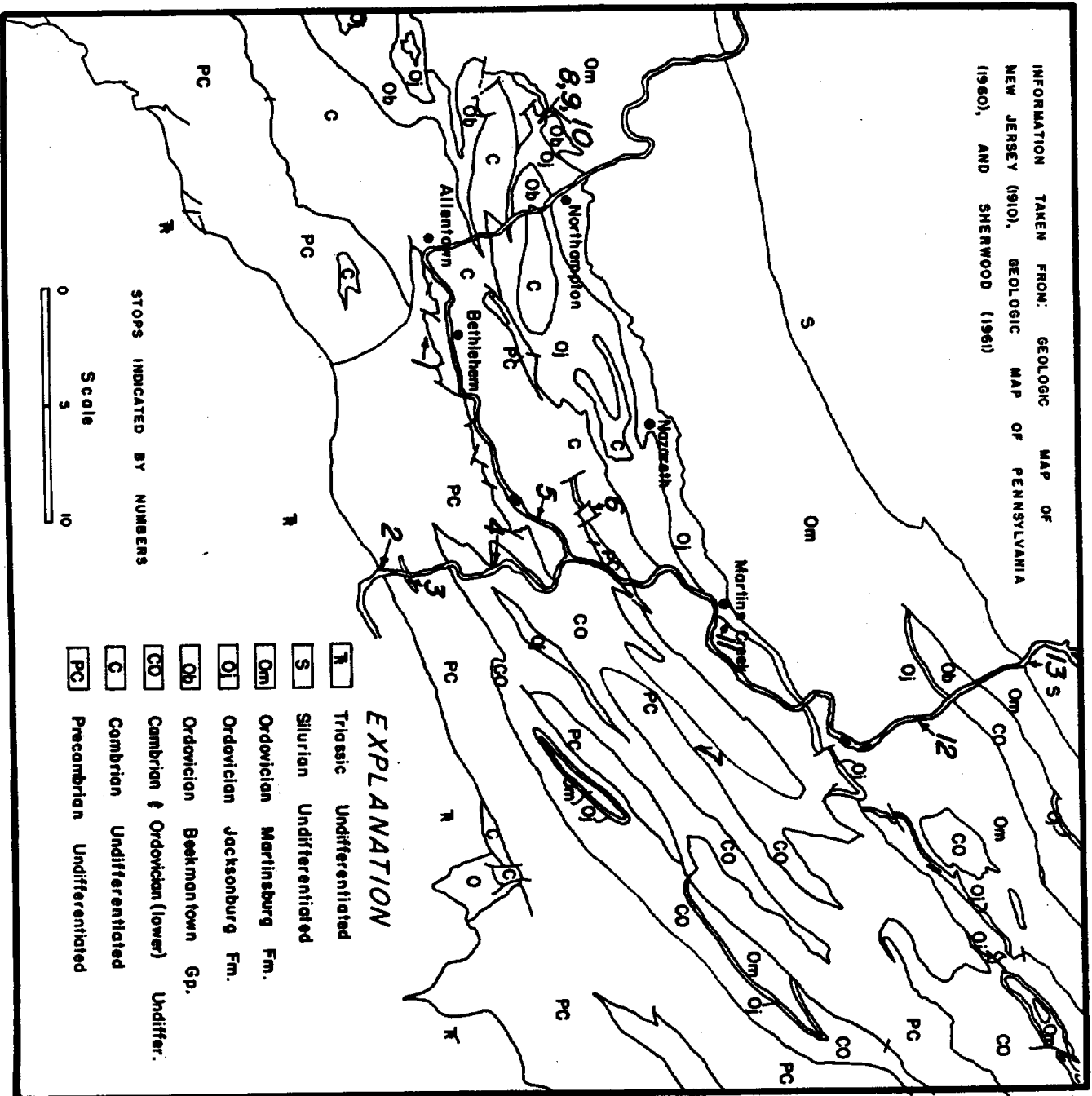
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INFORMATION TAKEN FROM: GEOLOGIC MAP OF
NEW JERSEY (1910), GEOLOGIC MAP OF PENNSYLVANIA
(1960), AND SHERWOOD (1961)



EXPLANATION

- R Triassic Undifferentiated
- S Silurian Undifferentiated
- Om Ordovician Martinsburg Fm.
- Ob Ordovician Jacksonburg Fm.
- C Ordovician Beekmantown Gp.
- CO Cambrian & Ordovician (lower) Undiffer.
- C Cambrian Undifferentiated
- PC Precambrian Undifferentiated

STOPS INDICATED BY NUMBERS

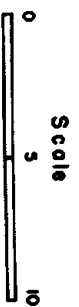


FIGURE 1

MAP OF FIELD TRIP AREA

INTRODUCTION

by

J. Donald Ryan
Lehigh University

This guidebook has been prepared for a two-day field trip through the Reading Hills and Lehigh Valley in Northampton and Lehigh Counties, Pennsylvania, and adjacent parts of New Jersey. The objectives of the trip are 1) to examine and compare the structural features of the rocks in these two provinces, and 2) to examine the relationship between Early Paleozoic tectonism and sedimentation.

The routes followed are shown on figure 1. The first day of the trip is devoted to the Reading Hills and immediately adjacent areas. Seven stops are spaced along an irregular traverse from the crest of South Mountain overlooking Bethlehem, Pennsylvania, to Musconetcong Mountain near Asbury, New Jersey. Most of the stops are in areas of overturning or thrust-faulting.

The second day of the trip includes six stops in the Lehigh Valley between Ormrod, Pennsylvania, and the Delaware Water Gap. Three of the stops are located to demonstrate the existence of a recently discovered nappe structure in the Ordovician Jacksonburg formation.

Acknowledgments

The field trip is based largely on work recently completed or in progress.

Members of the United States Geological Survey presently are engaged in mapping a number of quadrangles in the Delaware River Valley between Frenchtown, New Jersey, and Delaware Water Gap. This work is under the supervision of Avery A. Drake, Jr. who will lead the trip on the first day.

W. Cullen Sherwood, Virginia Council of Highway Investigation and Research, has recently completed a study of the "Structure of the Jacksonburg Formation in Northampton and Lehigh Counties, Pennsylvania, as a Ph.D. dissertation at Lehigh University. Dr. Sherwood will be the senior trip leader on the second day of the tour.

John A. Ames, Alpha Portland Cement Company, has kindly furnished us with notes on the development of the cement industry in the Lehigh district and will lead the group at the Alpha Portland Cement Company quarry.

The United States Geological Survey in cooperation with the Pennsylvania Topographic and Geological Survey recently published a series of aeromagnetic maps of parts of eastern Pennsylvania. Permission has been granted to reprint in the Guidebook an article by W. Randolph Bromery on "Preliminary Interpretation of Aeromagnetic Data in the Allentown Quadrangle, Pennsylvania" which appeared previously in the United States Geological Survey Professional Paper 400-B (1960). Mr. Bromery will make further comments on this significant new work during the course of the field trip.

The Pennsylvania Topographic and Geologic Survey distributed advance notices of the Field Conference, offered encouragement and advice, and helped in many other ways.

The Alpha Portland Cement Company, the Giant Portland Cement Company, the Lehigh Crushed Stone Company, and the Whitehall Cement Manufacturing Company all gave permission for the trip participants to visit their quarries.

Lehigh University is grateful to these individuals and organizations for their help.

GEOMORPHIC ENVIRONMENT

by

Lawrence Whitcomb

Lehigh University

The area covered by the trips of this year's Field Conference of Pennsylvania Geologists lies in and adjacent to the Lehigh Valley section of eastern Pennsylvania. To many, it will be a familiar region as it is the fourth time that the Conference has been in the valleys of the Lehigh and the Delaware.

For those who are not familiar with the area, the following brief description of its subdivision into physiographic provinces and a discussion of the geomorphic features is offered as a setting for the excursions.

Parts of three provinces of the Appalachian Highlands, the Triassic Lowlands of the Piedmont, the Reading Prong of the New England Uplands, and the Valley and Ridge will be traversed by the caravan.

Lehigh University is on the north flank of "Old South Mountain" and on a clear day affords a magnificent view of the valley of the Lehigh. Kittatinny Mountain with its several wind and water gaps forms a backdrop to the northwest. People who like to ponder the problems of Appalachian drainage and peneplains, or try to explain them to students, can, on a clear day, see enough from a vantage point, such as The Lookout on the upper campus, to raise some interesting speculations and questions. At other times natural haze and industrial smoke

cut the distant views and even obscure nearby parts of the valley.

Only the northwestern edge of the Triassic Lowlands will be seen on these trips. At Monroe on the Pennsylvania side of the Delaware, the river leaves the Precambrian and included Lower Paleozoic rocks, crosses the north border fault and flows upon Triassic rocks to the vicinity of Trenton. As Monroe is the southernmost point on the itinerary, the discussion of the Triassic will be limited to the first few miles downstream from that point.

As the river crosses from Precambrian rocks into the less resistant Brunswick lithofacies of the Newark group its valley widens and a noticeable flood plain, a quarter to a half mile in width, becomes characteristic of the valley. Steep cliffs in the gently dipping red sediments bound the river or the flood plain in many places, and have sometimes been called locally the "Palisades of the Delaware".

Southwest of the border fault, there are four pronounced hills; Buckwampum and Chestnut (Bucks County) in Pennsylvania and two unnamed ones in New Jersey, which are due to the presence of resistant Triassic fan-shaped concentrations of conglomerate. The best exposure of these fanglomerates is at "Pebble Bluffs" on the New Jersey shore upstream from Milford. The fanglomerate seen at Monroe is a portion of the Chestnut Hill fan. Coffman Hill, three miles southeast of Monroe, is the high point on a diabase sheet which caps the "Palisades", and which also

produced the "Ringing Rocks", a felsenmeer, over two acres in extent, in which the diabase boulders ring like bells when struck with a hammer.

The Reading Prong, lying northwest of the border fault, is an area of hills and valleys with up to eight hundred feet of relief. The major structural and topographic trend is northeast-southwest, Precambrian rocks supporting the hills and Cambrian and Ordovician sediments underlying the valleys.

In the Bethlehem area, the northern flank of South Mountain, and in the Easton area, the northern side of Chestnut Hill (Northampton County) constitute the boundary with the adjacent Valley and Ridge province.

Where the Delaware has cut Precambrian rocks, steep cliffs bound the river; where the bed rock has been the included Lower Paleozoics, the slopes are more gradual and the secondary streams have opened up valleys which produce the variations in relief.

From New York to Alabama, the easternmost portion of the Valley and Ridge province is a major valley. The Lehigh Valley is the local section. Across the Delaware to the northeast, it becomes the Kittatinny Valley of New Jersey and to the southwest it grades into the Lebanon, Cumberland, and Shenandoah Valleys of Pennsylvania, Maryland, West Virginia, and Virginia.

The first ridge of the province also changes names from northeast to southwest. It starts out as Shawangunk Mountain in New York, becomes Kittatinny Mountain in New Jersey, and

according to the United States Geological Survey topographic maps becomes Blue Mountain at "The Big Offset" north of Bangor, Pennsylvania. Southwest of Lehigh Gap, the name Blue Mountain seems to be unchallenged, but between Delaware Gap and Lehigh Gap there is a variance in usage. B. L. Miller (1939), one of our "charter members" used the name Kittatinny for this entire stretch of the mountain in the Northampton County report, and we at Lehigh prefer this designation. We have found that Blue Mountain is apt to be switched by the uninitiated to Blue Ridge. The next step is obvious, a miscorrelation with the Blue Ridge Mountains of Virginia, which, of course, in this area would correlate with the Reading Prong.

Cherry Valley and Godfrey Ridge, which are just north of the Delaware Water Gap, are at the northern end of our trips. They are quite typical of the major portion of the province and need no further discussion.

The Lehigh Valley, Kittatinny Mountain area has been the subject of many papers and thoughts regarding Appalachian drainage and peneplanation. The origin and history of wind and water gaps is no longer a major problem, but the peneplains still cause discussion.

The fundamental question is whether there are one, two or three peneplains in the region. George H. Ashley (1935), State Geologist at the time of the start of this organization and a "charter member", believed that there was but one peneplain in the Valley and Ridge province and that all other apparent

penепlains were produced by differential weathering on the various rock strata. Freeman Ward (1930) of Lafayette, another "charter member" and co-leader with B. L. Miller on the 1932 trip, believed in two penепlains, the Kittatinny and the Harrisburg, but thought that the lower level was the result of differential erosion. B. L. Miller (1939) of Lehigh believed in three penепlains, the Kittatinny, Harrisburg, and the Somerville.

Ashley's single penепlain hypothesis has never had many strong adherents, but the two and three penепlain hypotheses still find supporters. All three hypotheses regard the relatively uniform crest of Kittatinny Mountain and the other ridges of the Valley and Ridge province as indication of an old erosion surface, the Kittatinny (Schooley) penепlain.

Supporters of the two penепlain hypothesis believe that rejuvenation started a second cycle which has produced the lowlands of the Valley and Ridge region. It is their contention that the two noticeable levels in the Lehigh Valley are due to differences in lithology and rates of erosion and that they are not due to a second uplift. If one compares the areas of the Harrisburg and Somerville erosion surfaces in the Lehigh Valley with a geologic map, one cannot help but be struck by the fact, that the Harrisburg is on the Martinsburg Formation and the Somerville on the Cambrian and Ordovician limestones.

The three penепlain school of thought would require a second uplift or period of rejuvenation in post-Harrisburg time

to allow for the development of the Somerville surface. As present-day streams, such as the Lehigh, Monocacy, Bushkill, and Martins Creek, are all entrenched in this lower Somerville level, there is need for still another final uplift.

If one compares the Lehigh Valley district with the area of the Susquehanna Valley at and above Harrisburg, one finds a distinct difference. The Kittatinny peneplain is well shown by the tops of Blue, Second, Cove and Peters Mountains, the second or Harrisburg level is seen at the City of Harrisburg and in the floors of the valleys between the ridges where it is developed on rocks of different lithologies and different geologic ages. There is no third level, but the various streams have entrenched themselves in the second or Harrisburg surface. This area could therefore be interpreted as having had one cycle, complete to peneplanation, the Kittatinny; uplift and a partial cycle leading to what might better be called the Harrisburg base-level, rather than peneplain, as the area covered by the mountains is too great to call them monadnocks; and a third uplift to start the present cycle which has produced the entrenchment of the streams in the Harrisburg base-level.

In some portions of the Shenandoah Valley in Virginia, there are three levels which people have correlated with the Kittatinny (Schooley), Harrisburg, and Somerville. As in the Lehigh Valley, there is a remarkable correlation between bed rock and erosion surface. Frank J. Wright (1934) attributes this difference in levels to differences in lithology and

solubility of the underlying rocks.

There is an interesting similarity between the valleys of the Lehigh and the Shenandoah which does not apply to the Valley of the Susquehanna. In the first two cases the major streams are flowing on and roughly parallel to the strike of the soluble formations which have wide outcrop belts, while in the case of the Susquehanna, it flows roughly perpendicular to the strike and the outcrop belts are much narrower. This may be a significant fact, for when a stream is flowing across the strike the more resistant or less soluble formations downstream produce local base-levels which control the depth of erosion upstream.

In closing this discussion of the peneplain controversy, it should be pointed out that there are those who are not satisfied with the explanations that have been given to account for the Kittatinny (Schooley) peneplain. Objections range from the improbability of crustal stability for a long enough time for the peneplain to be developed, to its location on the western side of the height of land of the original post-Paleozoic Appalachians. Such a position would seem to necessitate westward flowing streams and the development of a pediplain. One thing that is certain is that the final word has not been written on this subject.

Regardless of which hypothesis one believes is the most acceptable, there are certain recognizable topographic differences between the limestone terrain (Somerville) and the

slate terrain (Harrisburg).

Disregarding the valleys of the major streams which cross it, the surface of the limestone floored valley is remarkably uniform and might be called gently rolling. Differences in relief as great as one hundred feet per mile are few and far between. Local streams are practically non-existent, due to the porous character of the limestones. An area around Hecktown and Newburg on the Bethlehem-Nazareth Pike has for years been known locally as "Drylands". Before the introduction of municipal water and before deep drilled wells were so common, the majority of the farms and houses in this area depended upon cistern water.

In contrast, the slate area of the Martinsburg has considerable relief and many permanent local streams which are the headwaters of the few streams which cross the lower limestone region. Two hundred or more feet of relief in a half mile is common and areas of as much as a square mile of relatively level land are essentially non-existent.

The topographic scarp which separates these two areas corresponds almost perfectly with the outcrop belt of the Jacksonburg limestone, an impure, shaly limestone, and many of the cement plants are to be found adjacent to the scarp with the quarry actually in the scarp.

There are some smaller scale features within the Lehigh Valley that should be mentioned. Pine Top-Camelhump, two hills of Precambrian rock rise above the limestones of the valley

three miles north of the center of Bethlehem. Their relief is explained by their lithology. Though isolated, these hills are in line with the structural trend of Chestnut Hill, Easton. The possible structures involved are discussed in another portion of this guidebook.

The northeastern portion of the Lehigh Valley in the vicinity of Portland and the Delaware Water Gap shows the effect of Wisconsin glaciation. The terminal moraine crosses from New Jersey to Pennsylvania in the vicinity of Belvidere and extends roughly northwest to Fox Gap. North and east of this moraine, glacial topography is noticeable. Although there is indication of an older period of glaciation which extended as far south as Bethlehem and the Saucon Valley, it has not left any geomorphic evidence.

While of human origin, it seems wise to mention the huge accumulations of waste that rise as distinct hills adjacent to the quarries in the slate belt. In many cases eighty to eighty-five per cent of the material that comes from the quarries ends up on the dump.

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STRATIGRAPHY

by

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The Stratigraphic Column

The stratigraphic units herein described are those used by the trip leaders in the area of the excursion.

TRIASSIC

Newark Group

Diabase

Dark gray, fine- to coarse-grained igneous sheets and dikes.

Brunswick lithofacies

Red sandstones, mudstones, and shales; interbedded limestone and quartzite conglomerates (or fanglomerates) near the border fault.

Lockatong lithofacies

Gray to black argillites and shales.

Stockton lithofacies

Red, gray, and brown shales; interbedded arkosic sandstones and conglomerates.

SILURIAN

Middle Silurian

Bloomsburg Formation (600 feet)

Red shales, siltstones, and sandstones; locally some green shales.

Middle and Lower Silurian

Shawangunk Formation (1550 feet)

Upper unit - gray to tan to white protoquartzite; cross beds and ripple marks; eurypterids.

Middle unit - interbedded black argillite and protoquartzite.

Basal unit - conglomerate protoquartzite; cross beds and ripple marks, Arthropycus.

ORDOVICIAN

Upper Ordovician

Martinsburg Formation (3000 feet??)

Dark gray to black slate, shale, and lithic sandstone, grading upward into interbedded slate and lenticular graywackes (Shochary sandstone).

Middle Ordovician

Jacksonburg Formation (1000 feet)

Cement rock facies - dark gray to black argillaceous limestone, locally interbedded with an upper and a lower crystalline limestone unit; thin bentonite beds; Prasopora orientalis.

Cement limestone facies - medium to dark gray, bedded calcarenite, dolomite pebble conglomerate at base; thin bentonite beds.

Lower Ordovician

Beekmantown Group (Coplay of Willard, 1958) (1400 feet)

West of Churchville, Northampton County, Pa.--bedded dolomite with rare interbeds of limestone. East of Churchville--bedded dolomite with abundant interbeds of limestone (especially in upper part) and chert, and in places, lenses of rounded quartz sand. (Mapped as the Epler Formation [overlying] and the Rickenbach Formation [underlying] by the USGS along the Delaware River.)

CAMBRIAN

Upper Cambrian

Allentown Formation (1700 feet)

Massive to flaggy limestone and dolomite; gray, weathers to cyclic light and dark gray layers. Oolites, stromatolites. (As used in the current mapping program of the United States Geological Survey, this unit includes the Allentown Formation [overlying] and the Limeport Formation [underlying] as defined by Howell, Roberts, and Willard, 1958).

Middle Cambrian (?)

Leithsville Formation (800-900 feet)

Thin- to thick-bedded high magnesia limestone, in places cherty, interbedded with sericitic shales. No recognizable fossils.

Lower Cambrian

Hardyston quartzite (-250 feet)

Gray, brown-weathering quartzite with a few lenticular shales, conglomerates; arkosic at base.

PRECAMBRIAN

The United States Geological Survey applies compositional and textural or structural terms to the Precambrian rock units in the Lehigh and Delaware River Valleys. The following lithologic units are recognized:

Granite pegmatite	)	
Microperthite alaskite	)	
Microantiperthite alaskite and granite	)	formerly
Hornblende granite	)	Byram
Potassic feldspar gneiss	)	gneiss
Migmatite (microperthite alaskite in amphibolite)	)	
Biotite granite	)	
Albite - oligoclase granite	)	
Quartz - oligoclase gneiss	)	
Quartz diorite (charnockitic)	)	formerly
Albite pegmatite	)	Losee
Veined gneiss (oligoclase - quartz gneiss in amphibolite)	)	gneiss

Amphibolite (3 types recognized)	)	
Pseudodiorite	)	
Pyroxene gneiss	)	
Hornblende - clinopyroxene -	)	formerly
quartz - plagioclase gneiss and	)	Pochuck
granofels	)	gneiss
Epidote - clinopyroxene - hornblende -	)	
plagioclase gneiss	)	
Clinopyroxene - garnet - quartz	)	
granofels	)	
Sillimanite - bearing gneiss	)	formerly Moravian
Biotite - quartz - plagioclase	)	Heights and part of
gneiss	)	Pickering Formations
Carbonates with associated meta- sedimentary and metavolcanic rocks		

Tectonics and Sedimentation

The tectonic control of sediment properties and the relationship of sedimentary facies to tectonic stages has attracted much attention in recent years. Krynine (1941, 1942, 1945), Pettijohn (1943, 1957), Dapples, et al. (1948), and others have emphasized the tectonic control of sedimentation. The apparent cyclic nature of the Paleozoic sediments in the Appalachians has been correlated by some students with the tectofacies of the source land-depositional basin couple.

The Paleozoic sediments which will be studied by the members of this field conference are recognized as the lower of two Paleozoic geosynclinal cycles in the Appalachians (Pettijohn, 1957, Figure 165, p. 641). The sedimentary facies are believed to be related to the tectonic cycle (figure 2).

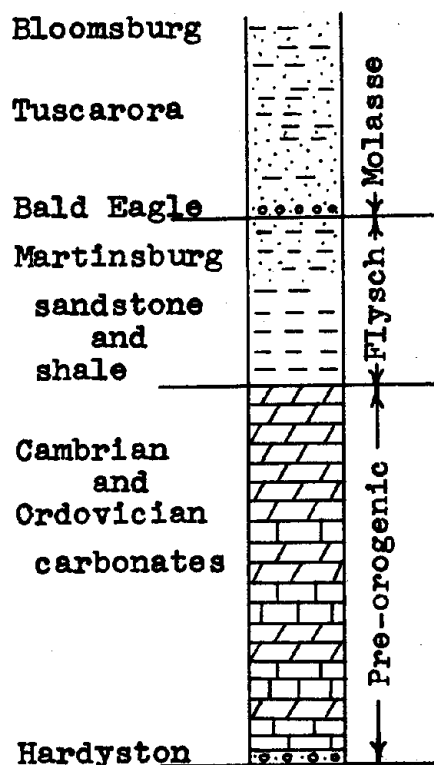


Figure 2. Lower Geosynclinal Cycle of the Paleozoic.
(Modified from Pettijohn, 1957)

Recent stratigraphic, petrographic, and paleocurrent syntheses (Pelletier, 1958; Yeakel, 1958; McBride, 1960; McIver, 1960) appear to support the concept of the geosynclinal cycle. McBride (1960) mapped graywacke sole markings in the Martinsburg and Reedsville Formations from Staunton, Virginia, to Kingston, New York. He observed two paleocurrent trends; "one parallel (longitudinal) and one subperpendicular to oblique (transverse) to the present strike". The transverse currents

flowed northwest. The longitudinal currents flowed northeast as far north as New Jersey, farther north the longitudinal currents flowed southwest. McBride interpreted this twofold pattern to be the result of basin filling by turbidity currents which flowed northwest down the subsea slope of a landmass to the southeast. The currents which reached the axis of the basin changed course and flowed down the regional plunge of the basin.

Yeakel (1958) concluded that the Bald Eagle, Juniata, and Tuscarora sediments in Pennsylvania and adjacent states were derived from the southeast. The main sediment transport direction, as inferred from the cross-stratification and quartz-pebble diameters, was toward the northwest. The sediments were considered to be predominantly of fluvial origin. It appears as if the west to northwest paleoslope of the Upper Devonian (McIver, 1960), Mississippian, and Lower Pennsylvanian (Pelletier, 1958) developed in Late Ordovician time.

The inferred change in sediment transport direction between the Martinsburg and the Bald Eagle may be interpreted as being the result of decreased negativity in the depositional basin because of increased sedimentation or decreased subsidence, either of which is a function of tectonism. It is also possible that the observed shift in paleocurrent direction is only apparent and that processes related to currents and tides in the depositional basin of the Martinsburg modified the basic northwest sediment transport pattern.

Several students (for example, Engel and Engel, 1953) have criticized the concept of sedimentary facies related to particular tectofacies. Folk (1954, 1956) and Van Andel (1958, 1960) have questioned the validity of the assumption that tectonics are the prime controller of sediment properties. Most of the conclusions concerning the relationship between tectonics and sedimentation have been drawn from observations on ancient rocks. For example, the assumption that the regional slope of deposition is reflected in the directional features of sediments is perhaps questionable. The influence of the water mass on the sediment properties is as yet almost unknown.

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STRUCTURAL PROBLEMS IN THE
AREA OF THE FIELD TRIP

by

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"Unfinished business"

Although the geology of this region has been studied for over a century, many structure problems remain unsolved. This is not an unfamiliar situation. The work of the geologist is always "unfinished business".

Two major items of unfinished business will be considered in this and the following two articles. These are: (1) the contact relations of the crystalline rocks of the Reading Hills and the younger sedimentary rocks adjacent to them, and (2) the nature of the folds and related structures in the Lower Paleozoic sedimentary rocks of the Lehigh Valley. The two problems are related, and both have great significance in regard to the regional plan of orogenic movement.

This article will deal primarily with the problem of the Reading Hills, discussing only briefly the structure of rocks in the Lehigh Valley. Comparison articles which follow are by R. W. Bromery on "Preliminary interpretation of aeromagnetic data in the Allentown quadrangle, Pennsylvania" (reprinted from U. S. Geological Survey Professional Paper 400-B) and W. C. Sherwood on "Structural Geology of the Jacksonburg Formation in the Lehigh Valley".

The Reading Hills

Early geologists in Pennsylvania (Rogers, 1858, Prime, 1883, and others) regarded the ridges of Precambrian gneiss and Hardyston quartzite in the Reading Hills as anticlinal structures. This view generally was accepted by Wherry (1916) and later B. L. Miller (1925) who added that the anticlinal ridges were in part overturned or, locally, thrust-faulted. Both of these authors explained the limestone-floored valleys as synclinal folds and/or blocks down-dropped by normal faulting. The maps of Miller and his colleagues (Miller, 1925, Miller, et al., 1939, 1941) show numerous normal faults, especially along the southern flanks of many of the ridges, throughout the area of the Hills. The southern boundary of the Hills was also a normal fault, the famous Triassic border fault (or north border fault).

At a meeting of the Geological Society of America on December 29, 1934, George W. Stose and Anna Jonas proposed that "most of the mountain area is a great overthrust sheet, composed of pre-Cambrian rocks and Hardyston quartzite, dissected and cut through by the deeper drainage, exposing the overridden Paleozoic limestones" (Stose and Jonas, 1935, p. 762). This claim was based mainly on the following:

1. The authors cited numerous localities where Precambrian gneiss was believed to overlie Lower Paleozoic limestone or the Ordovician Martinsburg

slates. Further, at some localities, the Precambrian gneiss was said to abut discordantly and successively against several Lower Paleozoic formations. In other places, the gneiss was in contact with the Elbrook Formation.

2. Mylonites in the Hardyston quartzite and Precambrian gneiss were believed to indicate and be located along the thrust plane.

3. Relatively small, isolated hills of gneiss in the limestone valley were considered to be "detached areas of the main overthrust sheet" (*ibid.*, p. 769).

4. Intermontane valleys such as Oley Valley and Saucon Valley were presumed to be fensters. Fragments of chert and jasper frequently found scattered on valley floors were thought to have formed by silicification of the limestone along the thrust plane.

5. In a later paper (1940), Stose and Jonas reported that gravity determinations in the vicinity of Bethlehem indicated that the crystalline rocks of South Mountain rest on Paleozoic limestones.

The overthrust hypothesis was vigorously denied by a number of geologists who had worked in this area. Chief among these were B. L. Miller and D. M. Fraser. In a paper written just before his death, Miller (1944) summarized the evidence against the view of Stose and Jonas:

1. Deep drill-holes at several points on the overthrust plate (a 700-foot well at Emaus, Pennsylvania, for example) should have encountered limestone underneath the gneiss--but did not.

2. During the years 1940-41, three holes were drilled in Saucon Valley near the contact of the Precambrian gneiss of South Mountain and the Paleozoic limestones of the valley floor. Two of the holes collared in the Beekmantown passed through the limestones and encountered gneiss--one at a depth of 500 feet, the second at a depth over 1,000 feet (measured vertically from the valley floor). A normal fault, dipping steeply south was clearly indicated.

3. Miller denied the existence in the valleys of "discordancies" such as contacts of the gneiss with formations younger than the Hardyston quartzite.

4. Miller believed that jasper fragments found on the valley floors were derived from the Hardyston formation. Several outcrops of Hardyston containing large quantities of jasper were described.

5. It was pointed out that gravimetric data would be of value only if the densities of the Precambrian gneiss and the Paleozoic carbonate rocks were significantly different. Density measurements furnished by J. B. Hersey indicated a density contrast for the Byram gneiss and dolomitic limestone of such low magnitude (0.0 - 0.19)

that gravimetric measurements would be of no value in solving the problem.

Miller's evidence seemed so overwhelming that until recently his interpretation was neither seriously contested nor significantly modified.

The latest series of studies of this area have been carried out by members of the United States Geological Survey under the direction of Avery A. Drake, Jr. Drake and his associates are in the process of mapping a series of quadrangles in the Delaware River Valley. These studies suggest that low-angle thrust faults and overturned folds are more of a factor in the distribution of the Precambrian crystalline rocks than supposed by Miller. According to Drake (oral communication), field relations and interpretations of aeromagnetic data indicate that several of the major crystalline ridges in the Reading Hills (for example, Pohatcong Mountain in New Jersey) are indeed klippen. A number of other ridges, such as Chestnut Hill-Marble Mountain and Morgan Hill, are bounded on the north side by thrust faults carrying the Precambrian gneiss over Lower Paleozoic limestones. Thrust faults and overturned folds also have been recognized in the limestone valleys. Wrench faults which generally strike northeast or northwest are associated with the thrusts. Normal faults, except for the border fault, are conspicuously absent from Drake's field sheets. The border fault is considered to be an old fault reactivated during Brunswick time. It is suggested that this fault originally was

formed by thrusting or wrenching (Drake, et al., 1961).

Drake's interpretation does not necessarily imply a return to the concept of a "Reading Overthrust". (In fact, this author would strenuously oppose any hypothesis which requires thrust movements of the magnitude suggested by Stose and Jonas.) However, Drake's interpretation does suggest a movement pattern quite different from that implied by Miller, a movement pattern which, on the basis of studies by Gray (1959), Sherwood (1961), and others, seems more consistent with the movement pattern of rocks in the Great Valley (including the Lehigh Valley). This would suggest a Taconic age for structures in the Reading Hills. If the older interpretation of Miller is correct, the structures of the Reading Hills probably are of later (possibly post-Paleozoic) origin.

Structures in the Lehigh Valley

On a gross scale, the structure of the Lower Paleozoic rocks between the Reading Hills and Kittatinny Ridge is simple. The Lehigh Valley section is located on the southeast limb of a synclinorium, the axis of which follows a northeast trend through the Pennsylvania anthracite basins. Thus, in general, belts of successively younger rocks, following a northeast trend appear in the valley as one travels north from the Reading Hills. In detail, the structure is extremely complex.

The carbonate belt

Structures in the Lower Paleozoic limestones and dolomites of the Lehigh Valley include (1) bedding, (2) flow cleavage, fracture cleavage, and slip cleavage, (3) folds of several orders of magnitude and probably of more than one generation, (4) thrust and wrench faults, (5) lineations including intersection of cleavages and cleavage and bedding, crenulation, boudinage, mineral streaking, deformed ovoids, and slickensides, (6) joints of various kinds, (7) normal faults.

As early as 1858, Rogers observed that folds in this region are asymmetric or overturned to the northwest. In many places overturned folds pass into recumbent folds or thrusts. Drake (oral communication) has mapped several such thrusts in the Easton Quadrangle. Sherwood (1961 and later paper in this Guidebook) recently described overturning in the Jacksonburg Formation and a recumbent isoclinal fold or nappe of considerable magnitude.

Flow cleavage has not been studied in detail except by Sherwood (1961). Throughout the Jacksonburg belt, the flow cleavage dips gently southeast.

The Martinsburg belt

Structures in the slates and shales of the Martinsburg Formation include (1) bedding (graded in some of the lithic sandstones and graywackes), (2) flow cleavage (the dominant structure throughout the slate belt), slip cleavage, and fracture cleavage, (3) folds of several orders of magnitude

and of more than one generation, (4) thrusts and probably wrench faults, (5) lineations including intersections of cleavage and cleavage and bedding, crenulations, and slickensides, (6) joints of various kinds, (7) small normal faults.

Behre (1924, 1925, 1926, 1927, 1933) has published extensively on the Martinsburg Formation and its structures. He considered the over-all structure to be monoclinal but described many local folds, asymmetric or overturned to the north and some small thrusts. Two of the larger folds in the region were said to be synclines; the axis of one syncline passed through Shochary Ridge, the axis of the second passed through the next sandstone ridge to the south. Later, Willard (1943) described the Martinsburg belt as a synclinorium, the axis of which passed through Shochary Ridge. This judgment was based on a study of fossil suites which showed that the slates on either side of Shochary Ridge were of Eden age, while the sandstones forming the ridge were of Maysville (Pulaski) age. This interpretation would require a Martinsburg section of considerably less stratigraphic thickness than that proposed by Behre.

Flow or slaty cleavage dominates all structures in the Martinsburg. The flow cleavage, like that of the Jacksonburg, dips gently south or southeast throughout the entire belt.

Age Relations

Numerous geologists have attempted to classify chronologically structures in the Lehigh Valley and Reading Hills.

A few ideas pertinent to the area of the field trip are presented below.

Long ago, Behre (1925) called attention to an unconformity at the top of the Martinsburg and folded flow cleavage in the Martinsburg. It was suggested that the cleavage was formed during the Taconic orogeny and deformed by later Appalachian movements.

Woodward (1957) recently assigned Appalachian structure in central and east-central Pennsylvania to three epochs of folding--Taconic, Acadian, and "terminal Paleozoic". Woodward based his interpretation largely on what he considers to be threefold patterns, each with a characteristic trend. Major folds in the Cambro-Ordovician rocks of the Lehigh Valley follow the Taconic trend, and thus are of Taconic age. The trend of Kittatinny Ridge from Delaware Water Gap northwestward is believed to be Acadian.

Drake (1960) compared structures in pre-Silurian and younger rocks and concluded that pre-Silurian structures are considerably more complex. He refers only to "Taconic and post-Taconic orogenies". Taconic folding is considered to be more intense than post-Taconic folding. Pre-Silurian rocks contain structural elements assigned to both orogenies.

Sherwood (1961, and later in this Guidebook) described fold and associated structures of two generations in the Jacksonburg Formation. Sherwood (1961, p. 99) admits the possibility that these structures are respectively Taconic and

post-Taconic in age. However, he believes there is little evidence on which to base a positive correlation.

According to McLaughlin and Willard (1949), movement on the border fault began in early Newark time and probably ended late in the Triassic.

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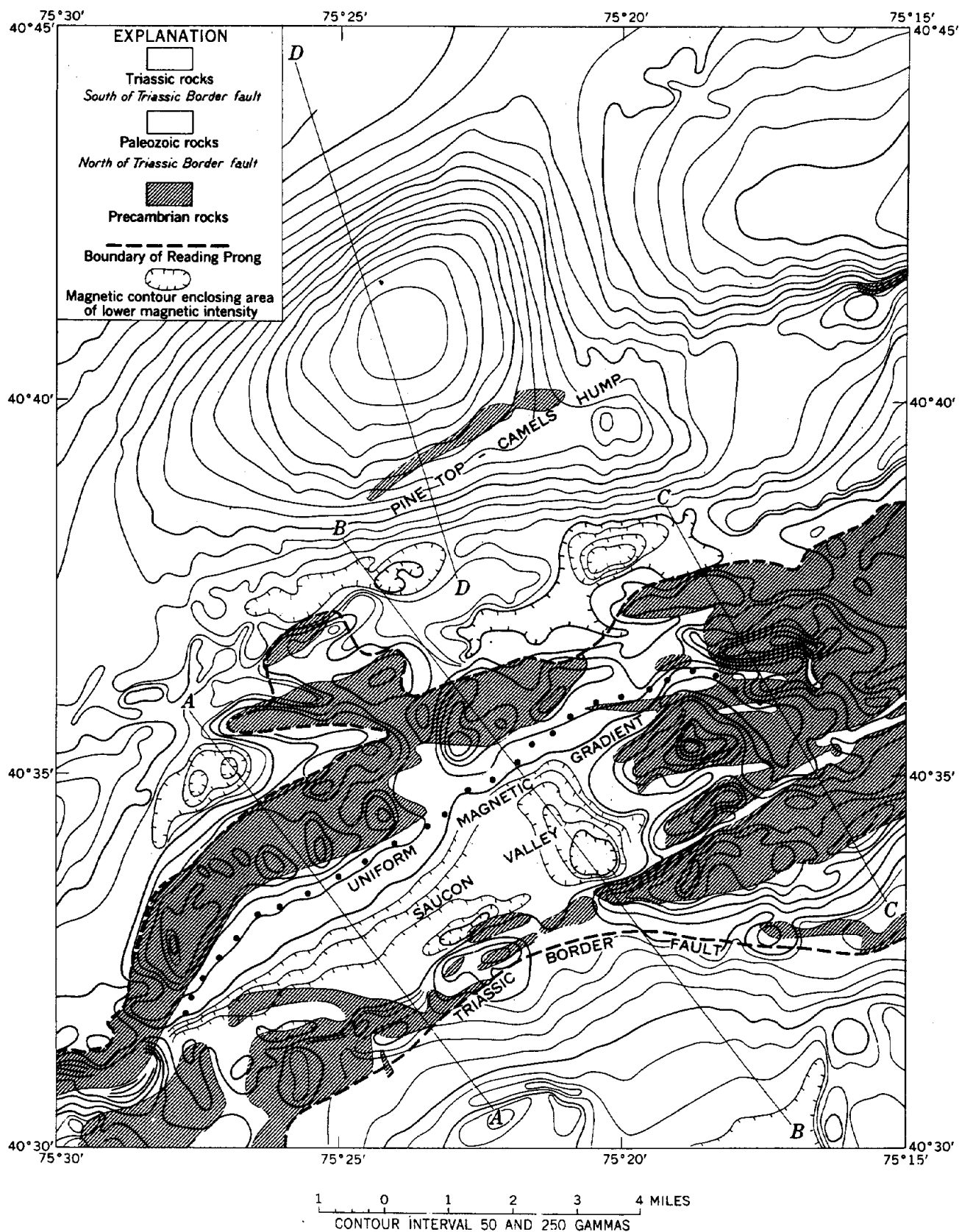


Figure 3. Aeromagnetic and generalized geologic map of the Allentown quadrangle, Northampton, Lehigh, and Bucks Counties, Pa. Magnetic data from Bromery and others (1959).

PRELIMINARY INTERPRETATION OF AEROMAGNETIC DATA
IN THE ALLENTOWN QUADRANGLE, PENNSYLVANIA*

by
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[Prepared in cooperation with the Bureau of Topographic and Geologic Survey, Commonwealth of Pennsylvania]

The Allentown quadrangle was surveyed with the airborne magnetometer in 1956 as part of a detailed survey in southeastern Pennsylvania, to obtain geophysical data useful in areal geologic mapping and in searching for magnetic iron deposits. The flying was done at 500 feet above the ground surface, on traverses a quarter of a mile apart.

Precambrian metamorphic and igneous rocks of complex geologic structure form a continuous belt that trends northeast across the south-central part of the quadrangle, separating the Paleozoic sedimentary rocks in the northern half of the quadrangle from the Triassic sedimentary and igneous rocks in the southeastern part of the quadrangle (figure 3).

The exposed Precambrian rocks are delineated in detail by a "bird's-eye maple" magnetic pattern. Some of this detail has been sacrificed in preparing figure 3, but the original magnetic contours (Bromery and others, 1959) have proved useful in mapping the areal extent of the underlying Precambrian rocks. The magnetic data indicate that some previously mapped faults are longer

*Reprinted from U. S. Geological Survey Professional Paper 400-B, p. B178-B180, 1960.

than was supposed, and that faulting may have occurred in some areas where it had not hitherto been recognized.

The Paleozoic sedimentary rocks in Saucon Valley are characterized by a uniform magnetic gradient leading to a magnetic low. This gradient extends northeastward along the northern edge of the valley beyond the head of the valley.

To show the possible configuration and depth of burial of magnetic rocks, three theoretical structure sections A, B, and C, were graphically computed from the magnetic profiles across the Reading Prong. This analysis was performed by using a modified Pirson Polar Chart (Pirson, 1940). The calculations indicate that the Precambrian rock surface along the northern edge of Saucon Valley and its apparent northeast extension is nearly vertical. The buried surface of the magnetic rocks underlying Saucon Valley is approximately a mile deep. Low-amplitude magnetic anomalies observed along the southern edge of Saucon Valley are underlain by Precambrian rocks, and if a uniform magnetic susceptibility is assumed for these rocks the magnetic data along section A show that they are less than 1,000 feet thick. Magnetic anomalies of higher amplitude are observed along sections B and C, on strike with the low-amplitude anomalies, and calculations indicate that here the thickness of the underlying Precambrian rocks is far greater--4,000 feet. The Precambrian rock surface at the Triassic Border fault along sections A and B is nearly vertical, and there is no magnetic expression of buried Precambrian rocks over the Triassic Basin. Possibly this is

because Precambrian rocks are deeply buried, so that any weak magnetic expression is masked by anomalies associated with Triassic diabase rocks, as for example at the southeast end of section A.

Along the northern edge of the Reading Prong, the magnetic profiles indicate that the Precambrian rocks were dropped 1,000 feet on the north side of a nearly vertical fault; and that the Precambrian surface north of the fault slopes northward beneath Paleozoic sedimentary rocks.

Along section D, magnetic computations indicate that an arching surface of Precambrian rocks four miles wide is buried a mile below the surface. An anticline in the overlying Paleozoic sedimentary rocks, shown on the new Pennsylvania State Geologic Map, is centered over this buried arch; the exposure of apparently non-magnetic Precambrian rocks on Pine Top and Camels Hump (figure 3) extends along its southern edge. The magnetic anomaly associated with this buried structural feature extends to the northeast and increased in amplitude in the adjacent Easton quadrangle (Bromery and others, 1960), where it is underlain by exposed Precambrian rocks at Chestnut Hill. The exposed Precambrian rocks on Pine Top and Camels Hump are probably related to those at Chestnut Hill and to the buried magnetic mass along section D, but these relationships are not yet clear. Analysis of the magnetic data in the Allentown quadrangle and in the adjoining quadrangles indicates areas where Precambrian rocks may be relatively thin.

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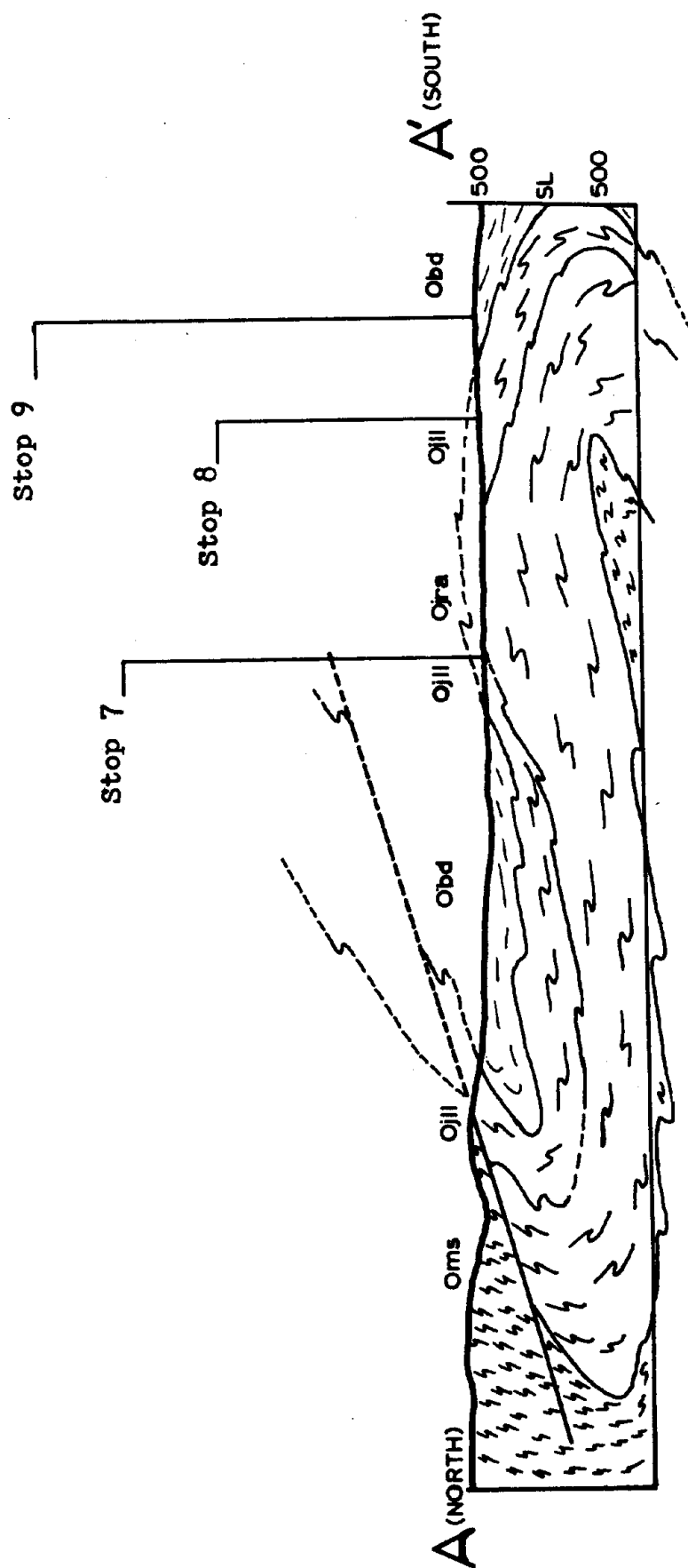


Figure 4. Generalized cross section through the Jacksonburg belt at Ormrod, Penna.

STRUCTURE OF THE JACKSONBURG FORMATION
IN THE LEHIGH VALLEY

by

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and Research

The Jacksonburg Formation of Ordovician (Trenton) age crops out in the Appalachian Valley Section of the Valley and Ridge province in eastern Pennsylvania and western New Jersey (see figure 1). The formation is composed of limestones and argillaceous limestones, which, in Northampton and Lehigh Counties, have a maximum thickness of 1,150 feet. A conglomerate at the base of the formation contains dolomite and chert pebbles, probably derived from the underlying Beekmantown Group. The upper part of the formation grades into the overlying Martinsburg slate.

Structural relations in the Jacksonburg indicate two distinct phases of deformation. Recumbent, isoclinal folds of the first generation are the dominant structural elements in the area mapped. One such fold which extends from Weaversville, Pennsylvania, to Ironton, Pennsylvania, is of sufficient magnitude to be designated the "Northampton nappe". An axial plane flow cleavage appears to be genetically associated with folds of the first generation. Stops 7, 8, and 9 on the field trip are designed to demonstrate the Northampton nappe. These stops are located on the nappe as shown in figure 4.

Second generation folds are of two types: 1) large open folds, and 2) small scale crinkle folds. The second generation folds are superimposed homoaxially on those of the first generation, deforming pre-existing bedding and flow cleavage. Slip cleavage is genetically associated with folds of the second generation.

Major faults in the area are high- and low-angle thrusts which strike roughly parallel to the trend of the formation. Cross faults of undetermined attitude offset by beds and contacts at a number of localities. Normal faults were mapped in one small area in the overturned limb of the Northampton nappe. Joints in the Jacksonburg are smooth, planar and uniformly steeply dipping. The dominant joint set strikes northeast-southwest.

Lineations are of two types. These are: 1) lineations in the b or fold axis direction, and 2) lineations subparallel or parallel to a, the direction of transport. The b lineation is the most common and includes the following: 1) intersections of cleavage and bedding, 2) intersections of flow and slip cleavage, 3) axes of minor folds, 4) boudinage, mullion and rodding, and 5) pyrite grain elongation in bentonites. Slickensides and mineral streaking occur roughly parallel to a.

It is possible that the recumbent folds in the Jacksonburg were caused by gravity gliding. Two types of evidence are

presented to substantiate this theory. These are: 1) configuration of the folds observed within the Jacksonburg Formation, and 2) structural relation in related areas.

While two phases of folding usually can be recognized, sufficient evidence does not exist at the present time to allow correlation of these phases with specific orogenies.

NOTES ON THE HISTORY OF
LEHIGH DISTRICT CEMENT INDUSTRY

by

John A. Ames

Alpha Portland Cement Company

Among a number of early contributions and inventions, the 1824 patent of Joseph Aspdin, an English brickmason, now generally is credited as having marked the origin of consistently good hydraulic cement which he called "Portland cement". The resemblance of concrete made with his cement to the popular dimension stone from the limestone formations of the Isle of Portland prompted Aspdin to select the name "Portland" cement. Portland cement from England and other countries found a ready market in some East Coast cities of the United States prior to its manufacture in this country.

Records indicate that as early as 1830 natural cement was produced in the vicinity of the present village of Northampton. Demand for cement was created by the construction of canals. A number of natural cement plants were located in the Lehigh Valley, proper, where transportation routes and facilities crossed the outcropping usable limestone. Plants called Siegfrieds, Atlas and Hercules (presently properties of Dragon, Universal-Atlas and Whitehall) were among the more successful of the natural cement producers. In 1850 the partners, Saylor, Woolever and Rehrig, started their natural cement plant at Coplay with some degree of success.

David O. Saylor experimented with the raw materials available at his plant with the express goal of producing portland cement. In 1871 Saylor patented and began producing portland cement at Coplay. Informed historians identify Saylor as being the first to manufacture portland cement in the United States, although the record is not entirely clear, and there seems little doubt that other very early United States producers independently also arrived at methods of making portland cement.

The success of domestic portland cement producers seemed to start slowly in terms of years, but in terms of decades was spectacular enough to encourage a great deal of "promotional" activity--both legitimate and the sort fabricated only to sell stock.

The natural cement plants concentrated in the original "Lehigh Valley" complex were located on the "cement rock" formation. In the 1870's the Pennsylvania Geological Survey made a multiple-purpose study of limestones and dolomites of the area, primarily directed toward a better understanding of materials available for fluxing. Robert W. Lesley, an outstanding figure in the early years of the portland cement industry, praised the work of the Survey in developing information useful to the cement industry of the area.

Rapid expansion of the portland cement plants in the area soon made use of the "Lehigh Valley" geographical designation erroneous since the plants were located on favorable deposits of the "cement rock" wherever workable extensions were found.

The Lehigh District extended from its Lehigh River nucleus through Lehigh County into Berks County and through Northampton County into Warren County, New Jersey. The unifying fact was that the cement plants were located on the same--or apparently the same--"cement rock" formation. This mappable unit has come to be called the "Jacksonburg". Proper description, identity and stratigraphy of the Jacksonburg Formation will continue to require work and attention of interested geologists; it presents complex problems.

Depending to some extent upon one's definition of a plant, the Lehigh District reached its maximum expansion in numbers of plants with about 26 contemporaneously active plants. At present there are 16 nominally active plants--and for some years none has been active in New Jersey.

Examination of Saylor's patent indicates that he had confidence that the cement rock from his quarry would make relatively uniform cement of portland cement chemistry; but, perhaps even more importantly, his patent stressed that he would "burn his raw materials harder" so that the resulting cement density would be from 20% to 40% greater than that of competitive natural cements. Quality control was a problem and within the manufacturing techniques lay the opportunity to overtake and excel the European producers.

England's Frederick Ransome invented the rotary kilns and it soon was brought to the United States by A. de Navarro in 1886. After making the kiln work at their Rondout, New York,

plant, the de Navarros installed a "sister" kiln at their Keystone Portland Cement plant in the Lehigh Valley. Rotary kiln developments came rapidly in the United States with perhaps the greatest breakthrough made by Thomas A. Edison at his New Village, New Jersey, plant (Lehigh District) in 1909. Mr. Edison virtually eliminated then existing limitations on lengths and volumes of rotary kilns. He also was an early important innovator in shovel and drill design.

Another important early development was the successful burning of powdered coal instead of liquid or gas (producer) in rotary kilns.

Near the turn of the century, Edwin C. Eckle with other "Survey" and local geologists provided important information to the cement industry. Over the years geology staff personnel from Lehigh, Lafayette, and some other schools have provided formal and informal advice to the Valley cement industry. Some consulting geologists other than academicians have contributed. Professor B. L. Miller's pertinent publications probably have as high a use factor as any comparable reference volumes in the literature.

Probably beginning with the employment of Dr. Carl Warmkessel, by Lehigh Portland Cement Company, a number of cement companies now have full-time geologists, although their work generally is not limited to the Lehigh District.

Miller's division of the Jacksonburg into two members with the names Cement Limestone and Cement Rock seemed clear enough,

although new complexities continue to unfold as local detailed work proceeds. However, the wide application of similar "use terms" to limestones recovered for cement raw material has added a dimension of confusion to the terminology. The concept of a "cement rock" is understandable and useful. It is a naturally occurring limestone which contains essentially the correct proportions of all chemical components necessary for cement raw material. Since "perfection" in cement rock is not possible, the hope of the operator is to have rock just a bit high in calcium carbonate so that he can correct it with sand or shale. This is a better circumstance than having "low stone" which has to be upgraded with more expensive high calcium limestone.

The work indices of cement rock is relatively low so that it is more cheaply quarried and processed than many of the purer, harder rocks used for cement. Blending always is a problem (especially in a dry plant) and the naturally blended cement rock is preferred.

While the economics of modern transportation of bulk materials tends to further restrict volume of cement production in the Lehigh District, it still contains the greatest concentration of plants, capacity and production in the country. The Jacksonburg has supplied in the order of one-half billion tons of limestone and its reserves available to quarrying are a number of times as great.

ROAD LOG - FIRST DAY

Quadrangles

15' series

Allentown, 1939
Easton, 1929

7 1/2' series

Easton, 1956
Bloomsbury, 1955
Riegelsville, 1956

Geologic Maps

Bayley, W. S., "Geologic Map of the Pre-Cambrian and Lower Cambrian (Hardyston) Areas in the Delaware Water Gap and Easton Quadrangles, Pennsylvania," in U. S. Geol. Surv. Bull. 920, 1941.

Drake, A. A., et al., "Geologic Map of the Frenchtown Quadrangle, New Jersey-Pennsylvania," U. S. Geol. Surv., Map GQ-133, 1961.

Miller, B. L., et al., "Geologic Map of Northampton County, Pennsylvania," in Penna. Geol. Survey, 4th series, Bull. C48, 1939.

Willard, Bradford, et al., "Geologic Map of Bucks County, Pennsylvania," in Penna. Geol. Survey, 4th series, Bull. C9, 1959.

Assemble at 10:15 a.m., Broughal parking lot, Packer and Brodhead Avenues, Bethlehem, Pennsylvania.

- 0.0 Leave Broughal parking lot, drive south on Brodhead Ave.
- 0.1 Turn right on Summit Street.
- 0.3 Turn left (south) on Wyandotte Street, Route 191.
- 1.2 Turn left at traffic light on crest of South Mountain.
- 2.4 Stop sign; park just beyond this sign.

STOP 1. SOUTH MOUNTAIN OVERLOOK

Panoramic view of the Reading Hills, the Great Valley, and Kittatinny Ridge; discussion of the problems to be considered on this trip. Remarks by Lawrence Whitcomb, Lehigh University, Avery Drake, United States Geological Survey, and Randolph W. Bromery, United States Geological Survey.

(No detailed description of this stop in the guide-book.)

Following stop, continue straight ahead.

- 2.6 Fork in road; bear right and begin descent into Saucon Valley.
- 3.6 Intersection; continue straight.
- 4.5 Complex intersection; turn left.
- 4.8 Fork in road; follow main road to left.
- 5.7 Enter Hellertown, Pennsylvania.
- 5.8 Traffic signal; turn right on Main Street, Route 412.
- 6.8 Follow main highway.
- 7.8 Entering Leithsville, Pennsylvania; continue straight and leave Saucon Valley.
- 9.6 Fork in road; bear left, follow Route 412 toward Springtown.
- 10.2 Stop sign at junction Route 412 and 212; turn left, follow 212 toward Springtown.
- 10.8 Enter Springtown, Pennsylvania; continue on Route 212.
- 11.5 Leave Springtown.
- 12.1 Continue straight on Route 212 toward Durham Furnace; Route 412 turns right.
- 16.1 Enter Durham Furnace, Pennsylvania, site of one of the earliest iron furnaces in Pennsylvania. The hematite ore used in these furnaces was obtained from two groups of ore bodies located in the Precambrian gneiss of nearby Rattlesnake Hill and Mine Hill.

- 16.7 Stop sign; junction Routes 212 and 611. Guides will indicate parking areas.

STOP 2. RATTLESNAKE HILL

Following stop, drive north on Route 611 toward Riegelsville.

- 17.3 Enter Riegelsville, Pennsylvania, continue on Route 611.
- 17.7 Turn right on Cedar Road. DANGER--residential area, drive slowly.
- 17.8 Turn right on Durham Road. Park here--10 minute walk across bridge and into New Jersey for:

STOP 3. RIEGELSVILLE, NEW JERSEY

Following stop, continue south on Durham Road.

- 17.9 Turn right on Sycamore Avenue, first cross-road south of Cedar Road.
- 18.0 Stop sign; turn right (north) on Route 611.
- 19.2 Good view of last stop (look east across the river).
- 19.5 Road cuts through Bougher Hill; outcrops of Precambrian gneiss.
- 21.8 Enter Raubsville, Pennsylvania.
- 22.4 DANGER. Park along shoulder on left side of Route 611 for:

STOP 4. NORTH EDGE OF RAUBSVILLE, PENNSYLVANIA

Following stop, continue north on Route 611.

DANGER--follow instructions of road guards.

- 24.6 Outcrops of Precambrian gneiss on south flank Morgan Hill.
- 26.2 Outcrops of limestone (Allentown Formation) on bluff across the rims.

- 26.6 Check point; Terry's Drive-In Restaurant. Prepare for left turn (across traffic).
- 26.9 Turn left on light-duty road just south of sewage disposal plant; follow road up north flank of Morgan Hill.
- DANGER--follow instructions of road guards.
- 27.8 Check point; St. Anthony's Cemetery on right.
- 28.4 End of paved road and intersection; turn left (uphill) on Old Philadelphia Road.
- 29.4 Turn right on Morgan Valley Road, begin long descent from Morgan Hill.
- 30.9 Fork in road; bear left.
- 31.2 Stop sign; bear right toward Glendon, Pennsylvania.
- 31.3 Outcrops of limestone (Allentown Formation) on right.
- 31.6 Turn left across narrow bridges, crossing abandoned canal and the Lehigh River.
- 31.9 Turn left at end of second bridge.
- 32.2 Enter parking lot, Lehigh Valley Sand and Gravel Company at South 25th Street and park automobiles.

STOP 5. GLENDON LIMESTONE QUARRY

Following stop, drive northwest on South 25th Street.

- 32.6 Small limestone quarry on right in the Allentown Formation.
- 32.9 Fork in road; bear right.
- 33.1 Stop light, intersection South 25th Street and Alternate 22; continue straight on South 25th Street.
- 33.6 Traffic signal; continue straight but prepare for left turn.
- 33.9 Turn left, enter Route 22 Thruway (eastbound).
- DANGER--heavy traffic on Thruway and at Thruway entrance.

- 34.7 Limestone (Leithsville Formation) outcrops on left (north) side of Thruway.
- 35.4 Leave Thruway at Tatamy exit (bear right); limestone (Allentown Formation) outcrops along exit ramp.
- 35.6 Stop sign; turn left (north) on North 13th Street.
- 35.9 Turn left on Bushkill Drive.
- 36.4 Park automobiles in Life Lumber Company parking lot.

STOP 6. NORTH FLANK CHESTNUT HILL

Following stop, head back toward Thruway on Bushkill Drive.

- 36.8 Stop sign; turn right on North 13th Street.
- 37.2 Turn right, enter Route 22 Thruway. Keep right for eastbound lane.
- 37.4 Limestone (Allentown Formation) outcrops on right.
- 37.8 Limestone (Leithsville Formation) outcrops on left.
- 38.1 Lafayette College on bluffs north of Thruway.
- 39.1 Entrance Delaware River Toll Bridge.
- 39.5 Leave bridge; pay toll; continue east in New Jersey on Route 22.
- 39.9 Route 22 bends left.
- 40.3 Bear right, follow Route 22 east.
- 42.7 Bear left, follow Route 22 east.
- 43.0 Bear left, follow Route 22 east.
- 44.4 Limestone (Beekmantown Group) outcrops along Thruway.
- 45.9 Leave Thruway (bear right) at Asbury exit.
- 46.2 Stop sign; turn left toward Asbury. Road follows Musconetcong River.

- 50.9 Stop sign; turn right into Asbury, New Jersey.
- 51.3 Bear left across bridge.
- 51.5 Turn left on gravel road following brook.
- 51.7 Fork in road; bear right.
- 52.0 Park at fork in road.

STOP 7. MUSCONETCONG MOUNTAIN

This is the final stop of the day. Caravan will break up and automobiles will proceed back to Bethlehem singly. For your convenience, the following route to Bethlehem is suggested:

Turn around and drive back toward Asbury.

- 52.3 Turn left.
- 52.5 Follow blacktop into Asbury.
- 53.1 Turn left toward Bloomsbury.
- 57.2 Entrance to Route 22 Thruway (westbound), turn right.

Follow Route 22 Thruway west through Phillipsburg and Easton to Bath Pike (Route 512) Interchange. Drive south on Bath Pike into Bethlehem.

ROAD LOG - SECOND DAY

Quadrangles

15' series

Allentown, 1939
Alburtis, 1957
Easton, 1929
Delaware Water Gap, 1942

7 1/2' series

Bangor, 1956
Belvidere, 1955
Easton, 1956
Portland, 1955
Stroudsburg, 1955

Geologic Maps

Miller, B. L., et al., "Geologic Map of Northampton County, Pennsylvania," in Penna. Geol. Survey, 4th series, Bull. C48, 1939.

Sherwood, W. Cullen, "Geologic Map of the Jacksonburg Formation in Lehigh and Northampton Counties, Pennsylvania," in "Structure of the Jacksonburg Formation in Northampton and Lehigh Counties, Pennsylvania," Ph.D. Dissertation, Lehigh University, 1961.

Assemble at 8:15 a.m., Broughal parking lot, Packer and Brodhead Avenues, Bethlehem, Pennsylvania.

- 0.0 Leave Broughal parking lot, drive north on Brodhead Ave.
- 0.1 Traffic signal; continue straight on Brodhead Ave.
- 0.2 Stop sign; turn left on Third Street and onto Hill-to-Hill Bridge. Stay in right-hand lane.
- 0.8 Turn right on Route 191 at monument. Move to center lane.
- 0.9 Leave bridge; turn left on Main Street (Route 191). Remain in center lane.
- 1.0 Traffic signal; continue straight on Main Street. Remain in center lane.

- 1.2 Traffic signal; continue straight on Main Street.
Move to right lane.
- 1.8 Traffic signal; Moravian College on left; turn
right on W. Elizabeth Avenue (Route 191).
Move to center lane.
- 2.2 Junction Route 191 and 512, turn left on Center
Street and follow 512 north.
- 4.3 Brief stop to reform caravan.
- 4.4 Roadcut in "Pinetop", a low monadnock of Precambrian
gneiss and Hardyston quartzite projecting above
the limestone plain of the Great Valley. Pinetop
and Camel Hump, a similar and adjacent monadnock,
follow the trend of Chestnut Hill (Stop 6 of first
day). Outcrop of Hardyston quartzite in roadcut.
- 4.7 Turn right; enter Route 22 Thruway, westbound.
Continue west on Thruway.
- 10.9 Turn right and leave Thruway at Allentown 7th Street
(Route 145) exit. Continue north on Route 145.
- 12.9 Check point; cemetery on right. Continue north on
Route 145, prepare for left turn.
- 13.8 Turn left on blacktop toward Egypt, Pennsylvania.
- 15.1 Outcrops of argillaceous limestone (cement rock
facies, Jacksonburg Formation) in roadcut.
- 15.6 Turn left and enter Giant Portland Cement Company
property.
- 15.9 Intersection; continue straight.
- 16.0 Bear left into plant.
- 16.3 Park automobiles.

STOP 8. GIANT PORTLAND CEMENT COMPANY QUARRY,
EGYPT, PENNSYLVANIA

Following stop, turn around and drive back toward
plant entrance.

- 16.6 Plant entrance; bear left at fork, follow blacktop across small bridge.
- 17.1 Stop sign; turn left on Main Street (Route 329).
- 17.7 Turn left next to Mary's Cafe.
- 18.3 Turn left next to Ormrod Hotel.
- 18.35 Turn right.
- 18.4 Turn left and enter Ormrod Quarry, Whitehall Cement Manufacturing Company.
- 18.5 Continue straight.
- 18.7 Turn right, descend into quarry.
- 19.0 Park along road.

STOP 9. ORMROD, PENNSYLVANIA, QUARRY, WHITEHALL
CEMENT MANUFACTURING COMPANY

Following stop, turn around and drive back toward quarry entrance.

- 19.3 Turn left.
- 19.5 Turn right, leave quarry property.
- 19.6 Turn right, follow blacktop.
- 19.75 Turn left.
- 19.8 Bear right across small bridge.
- 19.85 Turn right.
- 20.0 Park along road.

STOP 10. LEHIGH CRUSHED STONE COMPANY QUARRY,
ORMROD, PENNSYLVANIA

Following stop, continue ahead to turn-around area, then back toward Egypt, Pennsylvania.

- 20.4 Continue straight.
- 21.3 Stop sign; turn right on Route 329.
- 21.9 Bear left, follow Route 329.
- 22.1 Fork in road; bear right, follow Route 329.
- 22.5 Traffic signal; continue straight. Good view just ahead of Martinsburg escarpment.
- 23.6 Cross Lehigh River into Northampton, Pennsylvania. Continue on Route 329.
- 24.9 Pass Universal Atlas Cement Company plant and quarry.
- 28.5 Traffic signal; continue straight on Route 329.
- 29.0 Bear left, follow Route 329.
- 29.9 Pass Keystone Portland Cement Company plant and quarry.
- 30.8 Intersection Routes 329 and 45. Turn right, follow Route 45 into Bath, Pennsylvania.
- 30.85 Turn left, follow Route 45.
- 30.9 Traffic signal; turn right on West Northampton Street (Route 45).
- 31.0 Traffic signal; continue straight.
- 31.3 Outcrop of slate (Martinsburg Formation) on left.
- 31.6 Drive downhill over Martinsburg escarpment.
- 32.6 Pass Penn-Dixie Cement Company plant and quarry.
- 34.7 Pass another Penn-Dixie Cement Company plant and quarry.
- 35.5 Junction Routes 45 and 191. Continue straight, follow Route 191 north. Enter Nazareth, Pennsylvania.

(NOTE: Route 191 until recently was designated Route 12.)

- 35.7 Turn left on South Broad Street (Route 191).
- 36.2 Turn right on East Walnut Street.
- 36.4 Stop sign; continue straight on East Walnut Street.
- 39.0 Flashing traffic signal; continue straight toward Martins Creek.
- 39.5 Fork in road, bear left across bridge toward Martins Creek.
- 40.0 Traffic signal and intersection with Route 115; continue straight toward Martins Creek.
- 42.5 Stop sign; bear left down hill.
- 42.9 Outcrop of argillaceous limestone (cement rock facies, Jacksonburg Formation) on right.
- 44.1 Enter Martins Creek, Pennsylvania.
- 44.3 Traffic signal and junction Route 611; continue straight on Route 611.
- 44.5 Outcrop of argillaceous limestone (cement rock facies, Jacksonburg Formation) in roadcut.
- 45.4 Continue straight toward Belvidere (Route 611 turns left).
- 45.5 Turn right on dirt road into barnyard.
- 45.8 Bear right.
- 45.85 Bear left.
- 45.9 Turn left, drive toward quarries.
- 46.4 Park along road.

STOP 11. MARTINS CREEK QUARRY, ALPHA PORTLAND
CEMENT COMPANY

Following stop, pull ahead into quarry, turn around and drive back toward barnyard.

- 46.9 Turn right into barnyard.
- 47.0 Keep left.
- 47.2 Leave barnyard; turn right on concrete highway toward Belvidere.
- 52.8 Cross Delaware River into New Jersey.
- 53.0 Enter Belvidere, New Jersey; continue straight.
- 53.3 Traffic signal; continue straight.
- 55.0 Fork in road, bear left.
- 55.2 Stop sign; turn left and follow Route 46 west toward Columbia and Delaware Water Gap.
- 55.6 Outcrop of slate (Martinsburg Formation) on right.
- 60.1 Park along shoulder of road. DANGER--heavy traffic.

STOP 12. ROAD CUT NEAR COLUMBIA, NEW JERSEY

Following stop, continue north on Route 46.

- 61.9 Route 46 ends. Continue north on Route 611.
- 63.7 From this point on, note younger gravels on either side of Delaware River.
- 65.5 Contact Martinsburg Formation and Shawangunk Formation at Kittatinny Mountain.
- 65.9 Turn right into parking lot.

STOP 13. THE DELAWARE WATER GAP

End of Trip

STOP 2

RATTLESNAKE HILL

Speaker: Avery A. Drake, Jr.
U. S. Geological Survey

- I. Location: Rattlesnake Hill near intersection of Highways 611 and 212, Riegelsville quadrangle, Pennsylvania.
- II. Geologic setting: Block of Precambrian rock in SW extension of Musconetcong Mountain bounded on the south by the Triassic border fault and on the north by a thrust. At this locality, relations are further complicated by a northwesterly trending tear fault.
- III. Geologic features to note:
 - A. Satellitic folds in Leithsville Formation associated with the Riegelsville petit nappe. Note fold style, flow cleavage, and sheared-out fold axes.
 - B. Precambrian-Hardyston Quartzite contact--overturned and dipping to SE.
 - C. Strongly deformed Precambrian migmatite, veined gneiss, and amphibolite. Shear planes are essentially parallel to cleavage in the Paleozoic rocks and transect compositional layering. In places, the Precambrian is refoliated parallel to these shear zones. Two "b" lineations are present, parallel to both Precambrian and Paleozoic fold axes. These features are thought to have resulted from the sliding of the sedimentary cover over the Precambrian basement in a decollement.
 - D. Probable fenster of Leithsville Formation. Contact of Precambrian with limestone fanglomerate of the Brunswick Formation with caught-up slice of Leithsville Formation. Note shearing of dolomite.

STOP 3

RIEGELSVILLE, NEW JERSEY

Speaker: Avery A. Drake, Jr.
U. S. Geological Survey

- I. Location: Cut and quarry exposures starting back of Pennsylvania Railroad Station in Riegelsville, New Jersey, Riegelsville quadrangle.
- II. Geologic setting: Generally on overturned limb of an overturned syncline that underlies the Musconetcong Valley. The Riegelsville petit nappe drapes out onto this fold.
- III. Geologic features to note:
 - A. Complex small folds and cleavage and bedding relations in the petit nappe.
 - B. Lithology of upper Leithsville Formation.
 - C. Overturned beds of the Allentown dolomite, lithology of the Allentown dolomite, NW dipping beds in the keel of the syncline.

STOP 4

NORTH EDGE OF RAUBSVILLE, PENNSYLVANIA

Speaker: Avery A. Drake, Jr.
U. S. Geological Survey

- I. Location: Roadcut just north of Raubsville, Pennsylvania, Easton quadrangle.
- II. Geologic setting: Small inlying valley of Leithsville Formation bounded on the south by a thrust block of Precambrian rock and on the north by a major fault that is not well understood. Extreme shearing in the Precambrian and stratigraphic relations suggest a decollement, although wrench faulting is also possible.
- III. Geologic features to note: Stop is primarily made to show the lithology of the lower Leithsville Formation which is infrequently exposed.

STOP 5

GLENDON LIMESTONE QUARRY

Speaker: Avery A. Drake
U. S. Geological Survey

- I. Location: Abandoned quarry on NW side of Lehigh River across from Glendon, Pennsylvania, Easton quadrangle.
- II. Geologic setting: Probable nappe that brings rocks of the Allentown dolomite out onto an overturned syncline which is keeled by Jacksonburg limestone. This prominent zone of thrusting apparently continues up the Lehigh River to the SW.
- III. Geologic features to note: Folds and thrust in the Allentown dolomite are particularly well exposed here. Note fractures associated with thrust.

STOP 6

NORTH EDGE OF CHESTNUT HILL

Speaker: Avery A. Drake, Jr.
U. S. Geological Survey

- I. Location: North edge of Chestnut Hill along Bushkill Drive, Palmer Township, Easton quadrangle.
- II. Geologic setting: Block of Precambrian rock forming Chestnut Hill is thrust out onto NW dipping Leithsville Formation. This is the northernmost Precambrian in this area, and this locality is at the contact of the Reading Prong with the Great Valley. This hill may well be a klippe in one sense, in that it appears to be a wedge within the Paleozoics; perhaps a crystalline core within a nappe.
- III. Geologic features to note: Precambrian-Hardyston Quartzite contact. Bedding in the Hardyston and the contact itself dips SE back under the Precambrian.

STOP 7

MUSCONETCONG MOUNTAIN

Speaker: Avery A. Drake, Jr.
U. S. Geological Survey

- I. Locations: Cut along Central Railroad of New Jersey about 1/2 mile SE of Asbury, New Jersey, Bloomsbury quadrangle.
- II. Geologic setting: Precambrian rocks of the major mountain, Musconetcong, are in thrust contact with the Paleozoics of the major Musconetcong Valley overturned syncline.
- III. Geologic features to note: Geometric relation of the Precambrian gneiss to the Leithsville Formation--the gneiss overlies the limestone.

STOP 8

GIANT PORTLAND CEMENT COMPANY QUARRY

Speaker: W. Cullen Sherwood
Virginia Council of
Highway Investigation
and Research

I. Location:

- A. Giant Portland Cement Company plant, Ormrod, Pennsylvania (1 mile SW of Egypt, Penna.).

II. Geologic setting (see figure 4):

- A. Stop located on lower limb of a large recumbent fold--the Northampton nappe.
- B. Low area to north underlain by outlier of Beekmantown; drill records show Jacksonburg underlying the Beekmantown.
- C. Exposed contact shows Jacksonburg dipping under the Beekmantown.

III. Reasons for stop:

- A. To illustrate the fold types and cleavage in the Jacksonburg.
- B. To point out complexities of Jacksonburg structure near the Beekmantown contact.
- C. To show the Jacksonburg dipping under the Beekmantown.

IV. Folds and cleavage:

- A. Folds are recumbent and similar.
- B. Nearly horizontal axial plane flow cleavage.
 - 1. This general attitude of the flow cleavage prevails in the Jacksonburg throughout Northampton and Lehigh Counties. The contoured stereo diagram (figure 5, next page) shows concentrations representing 12-8-4%.

B. (continued)

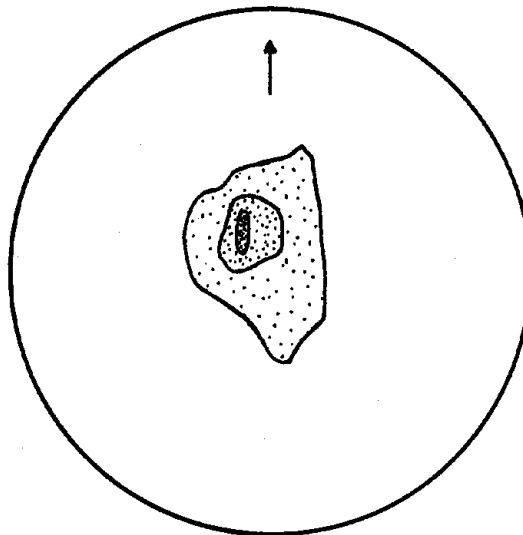


Figure 5. Contour diagram of 1090 poles of flow cleavage in the Jacksonville Formation.

2. Flow cleavage is dominant S-surface.

C. Fold at top of quarry face is interpreted as a "topping fold" in the inverted sequence.

D. The partly exposed lower fold would then be a "bottoming fold".

E. These folds might be referred to as cascade folds which plunge under the Beekmantown to the left.

V. Structure at the Beekmantown contact:

A. Intense deformation possibly caused by tectonic dragging of the Jacksonville against the more competent dolomites.

B. Boudinage in crystalline bed.

STOP 9

WHITEHALL CEMENT MANUFACTURING COMPANY QUARRY

Speaker: W. Cullen Sherwood
Virginia Council of
Highway Investigation
and Research

I. Location:

A. One-quarter mile south of Ormrod, Pennsylvania.

II. Geologic setting (see figure 4):

A. Near the west end of the proposed nappe structure;
on lower limb of nappe.

B. Jacksonburg outcrop narrows to approximately 3,000
feet in width.

a. Beekmantown exposed both north and south
of the belt.

b. A cross fault immediately west of the quarry
has terminated the belt against the
Beekmantown.

III. Reasons for stop:

A. To show the nature of the Jacksonburg-Beekmantown
contact.

B. To study joints.

C. To look at some bentonites.

IV. The Jacksonburg-Beekmantown contact (SW face of quarry)

A. Large exposure allows more detailed study.

B. Contact is conformable.

C. Jacksonburg shows evidence of flow around dolomite blocks.

D. Weathering of Beekmantown is typical for this area.

E. Below the contact thin bentonites accentuate otherwise
obscure bedding.

E. (continued)

1. Indicate the presence of tight, high amplitude folds.

a. Evidence:

- (1) repetition of bentonite beds,
- (2) slight divergence of bedding,
- (3) one closure at fold crest is exposed.

V. Joints:

A. Joints are abundant throughout the Jacksonburg.

B. Joints are almost uniformly steeply dipping.

1. Average dip of 1093 joints measured in Northampton and Lehigh Counties = 74° .

C. A set which strikes approximately N 60° E dominates throughout Northampton and Lehigh Counties.

1. The contoured stereo diagram shows the orientation of 1093 joints measured in the Jacksonburg. Concentrations represent 2-4-6-8%.

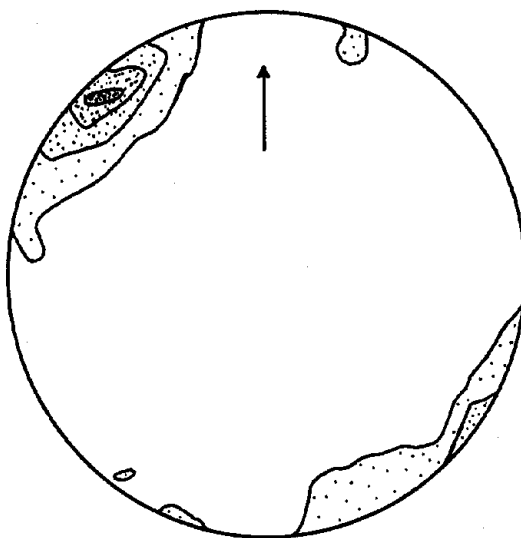


Figure 6. Contour diagram of 1093 poles of joints in the Jacksonburg Formation.

C. (continued)

2. This joint set apparently predominate in other portions of the Appalachians.

D. Joints most closely spaced in zones of intense deformation and in rocks containing a high percentage of non-carbonate material.

1. These two conditions exist in the passageway near the middle of the quarry.

- a. Here the joints are often less than 1 inch apart; generally at high angles to the flow cleavage causing rocks to break into long pencil-like fragments.

VI. Bentonites:

- A. At least 4 separate bentonite beds occur in the Jacksonburg in eastern Pennsylvania.

1. These are of approximately the same stratigraphic position as those described by Whitcomb and others in central Pennsylvania and western Virginia.

- a. Bed by bed correlation has not been established.

- B. Two (possibly three) bentonites are exposed near the base of the quarry face directly below the Beekmantown-Jacksonburg contact.

- C. A bentonite containing euhedral pyrite crystals is exposed in the southeast face of the quarry.

1. This bed can be traced over a large part of Northampton and Lehigh Counties.

2. No other bentonite bed in this area contains more than a trace of pyrite.

3. Individual pyrite crystals are elongate in the tectonic b direction.

STOP 10

LEHIGH CRUSHED STONE COMPANY QUARRY

Speaker: W. Cullen Sherwood
Virginia Council of
Highway Investigation
and Research

I. Location:

A. One-half mile south of Ormrod, Pennsylvania.

1. 500 yards east of STOP 9.

II. Geologic setting (see figure 4):

1. Approaching the "root zone" of the nappe.
2. Quarry mainly in the Beekmantown.
3. Jacksonburg-Beekmantown contact at southwest end of quarry.
 - a. Jacksonburg underlies the Beekmantown.
 - b. Contact dips south.

III. Reason for stop:

A. To observe complex folds in the Beekmantown.

IV. Northeast wall of the quarry:

- A. Complex folds limited to the zone near the Jacksonburg contact.
- B. Folds are generally concentric with the following characteristics:
 1. Little or no thickening in crests.
 2. Axial plane cleavage weak or absent.
 3. Slickensides on bedding planes.
 4. Evidence for flowage of material into the zones of low pressure between the beds in the fold crests.

C. Fold in lower center of the face is an example of a pinch fold.

1. Appears that through the mechanism of flexural slip, the uppermost beds in the fold crest have pulled away from the lower beds.

- a. This would tend to create a low pressure zone in the crest and cause a pinching together of the limbs of the unattached beds.

V. South wall of small abandoned quarry northeast of and adjacent to the main quarry of the Lehigh Crushed Stone Company:

- A. Tight recumbent folds in the Beekmantown.

- B. The largest, best exposed fold shows:

1. Thickening in the upper limb.

2. Thinning in the lower limb with what appears to be an early stage in the formation of boudinage.

STOP 11

ALPHA PORTLAND CEMENT COMPANY QUARRIES,
MARTINS CREEK, PENNSYLVANIA

Speaker: John A. Ames
Alpha Portland Cement Company

- I. Location: Alpha Cement Company quarries #2 and #3 about 10,000 feet east of Martins Creek village--see map.
- II. Geologic setting: Alpha's Martins Creek quarries are located peripheral to a Delaware River terrace of considerable size (about 350 acres). Rock surfaces beneath unconsolidated materials in the area between Route 611 and the Delaware River, and bounded on the east by the significant tear fault "M", are virtually all Jacksonburg.

The Jacksonburg-Martinsburg contact is difficult to locate, but all near contact Martinsburg is badly deformed. The somewhat less obscure Beekmantown-Jacksonburg contact is one along which faulting seems to have been the rule and the Beekmantown beds dip at lower angles than the Jacksonburg on respective sides of the contact because of the faulting. Nevertheless, the known rapid thinning of the Jacksonburg northeast of the Martins Creek deposit may be due, in part, to angular unconformity of the Beekmantown-Jacksonburg contact.

- III. Notable geologic features: Although numerous structural complications exist and much of the Jacksonburg exhibits cleavage, the Martins Creek deposits are thought to be among the least altered (perhaps also the least disturbed) of known Jacksonburg sections. Roughly 765 feet true thickness of the Cement Limestone Member and more than 300 feet (could be 600 feet +) for the Cement Rock Member are known on the property.

In the quarry #2 area, the alternation of crystalline fossiliferous beds with muddier interbeds of rock exhibiting cleavage can be observed very well on the weathered stripped rock surface. Differences in lithology between this rock (mostly Submember 5, the top of the Cement Limestone) and the massively bedded rock of Submember 1 in quarry #3 are accentuated by weathering.

The calcite and mud-filled break in the face of quarry #3 is one of the largest and most persistent yet encountered.

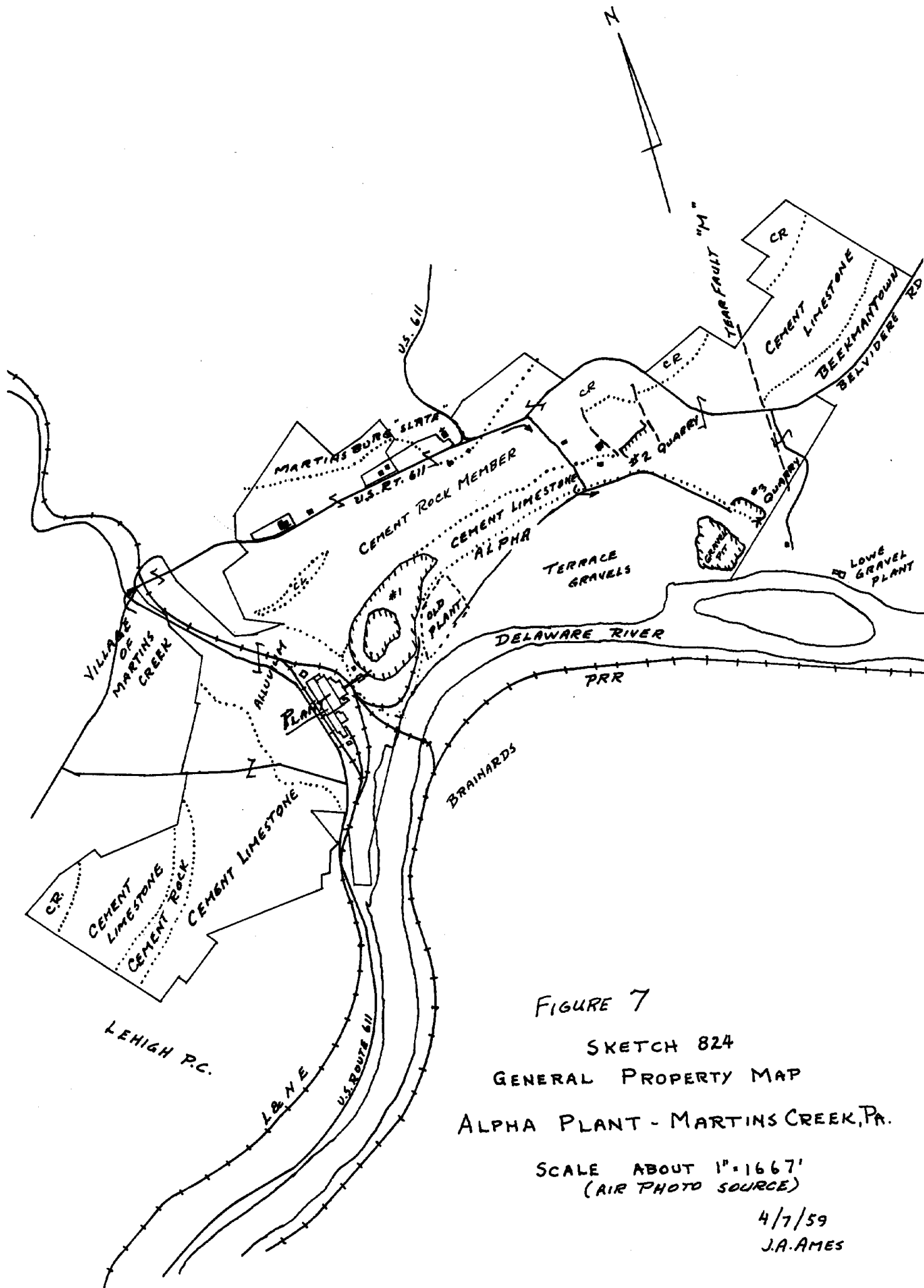


FIGURE 7

SKETCH 824
GENERAL PROPERTY MAP

ALPHA PLANT - MARTINS CREEK, PA.

SCALE ABOUT 1" = 1667'
(AIR PHOTO SOURCE)

4/7/59
J.A. AMES

STOP 12

ROADCUT SOUTH OF COLUMBIA, NEW JERSEY

Speaker: J. D. Ryan
Lehigh University

I. Location: Roadcut along Highway 46, beginning about 1 1/2 miles south of Columbia, New Jersey.

II. Lithology:

A. Unusually fine exposure of the Martinsburg Formation.

1. At this locality, dark gray slate with interbedded gray, medium- to fine-grained lithic sandstones. Sandstone beds from 1/4 inch to 12 inches thick. Also, look for quartz veins.
2. Farther south, the slate grades upward into a sandier member, the Shochary sandstone, containing fragments of fossils tentatively identified by Bradford Willard (oral communication) as being of Pulaski age.
3. Still farther south, the basal slates reappear at the surface.

B. The Martinsburg Formation is a Lower Paleozoic flysch deposit.

III. Structure:

A. Bedding

1. Look for the thin sandstone layers.
2. Throughout most of the cut, bedding dips gently south. At the parking site, bedding strikes about N 70°E, dips about 12°SE.
3. At north end of cut, bedding turns over and is nearly vertical.

B. Flow cleavage

1. The dominant planar structure in the cut.
2. The dip of the cleavage is steeper than that of the bedding. At the parking site, measured in the slates, cleavage strikes about N 80°E, dips about 35°SE.
3. Note refraction of cleavage along contacts of sandstone and slate.

C. Slip cleavage

1. Less obvious than flow cleavage.
2. As measured near the parking site, slip cleavage strikes about N 70°E, dips about 40°NW.

D. Intersections

1. Intersection of flow cleavage and bedding (strike N 85°E, plunge 0-3°E).
2. Intersection of flow cleavage and fracture cleavage (strike N 75°E, generally horizontal).
3. Intersection of fracture cleavage and bedding (strike N 70°E, generally horizontal).
4. The two intersecting cleavages in places give rise to "pencil structure".

E. Conclusion--general structure

1. Stop 12 is located on the north limb of a broad syncline, on the south limb of an anticline, asymmetric or overturned to the north. The fold axis is horizontal or plunging slightly to the east and follows a trend of about N 85°E.

STOP 13

THE DELAWARE WATER GAP

Speaker: J. D. Ryan
Lehigh University

I. Location: Paved parking area just off of Highway 611 and below the crest of Kittatinny Ridge; New Jersey side of the Delaware River. Good outcrops all along the highway from 1/2 mile south of parking area to 1/2 mile north of parking area.

II. Formations exposed:

- A. Martinsburg Formation (Ordovician) poorly exposed 1/2 mile south of parking area.
- B. Shawangunk Formation (Silurian) exposed from 1/2 mile south of parking area to a few hundred yards north of parking area.
- C. Bloomsbury Formation (Silurian) exposed beginning a few hundred yards north of parking area.

III. Stratigraphic notes:

- A. The Shawangunk and Bloomsbury Formations are part of a Lower Paleozoic post-orogenic molasse deposit.
- B. The Martinsburg Formation rests beneath an unconformity which generally is best exposed at the various water gaps in Kittatinny Ridge. At Delaware Water Gap, the unconformity is between the Martinsburg and the Shawangunk Formation. Farther west, the Bald Eagle conglomerate and the Juniata red beds of Late Ordovician age appear above the unconformity but below equivalents of the Shawangunk (Willard, 1943). Thus, the Taconic orogeny deformed pre-Bald Eagle rocks. Post-orogenic deposition of coarse clastics as a consequence of the Taconic orogeny began in Late Ordovician times.

IV. Structure:

- A. The Shawangunk Formation here dips north under the red beds of the Bloomsbury Formation. Thus, the parking lot is located on the south limb of a syncline.
 - 1. Note congruent drag folds in the Shawangunk.

B. North of the parking lot, a number of small folds (including the Kemmerville anticline) can be seen in the Bloomsbury Formation.

1. Note fracture cleavage dipping steeply south in the Bloomsbury.

C. The Shawangunk crops out again on the north side of the ridge (first demonstrated to the author by J. Epstein, U. S. Geological Survey) forming the north limb of the syncline.

ADDENDA

I. Geologic maps:

Geologic maps not listed on the road logs but pertinent to the field trip are found in the following reports:

Behre, Charles H., Jr., 1933, Slate in Pennsylvania: Pennsylvania Geological Survey, Bulletin M16, 4th series, 400 p.

Miller, B. L., 1925, Allentown Quadrangle: Penna. Topog. and Geol. Surv., Atlas no. 206, 28 p.

II. Stratigraphy:

Glacial deposits and other forms of unconsolidated alluvium are not shown on the stratigraphic column.

A brief discussion of glaciated areas is found in the article on "Geomorphic Environment" by Lawrence Whitcomb.

FIELD NOTES

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FIELD NOTES

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