

MAY 27 1953 ³

GUIDEBOOK

FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

NINETEENTH ANNUAL MEETING

Easton, Pa.

29, 30, 31 May 1953

HCST

DEPARTMENT OF GEOLOGY AND GEOGRAPHY

Lafayette College

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FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

Nineteenth Annual Meeting

Department of Geology and Geography
Lafayette College, Easton, Pa.

May 29, 30, 31, 1953

PROGRAM

FRIDAY, MAY 29

9:30 a.m. - 1:00 p.m.	Registration John Markle Hall
1:00 p.m.	Trip A. Slate and Cement Trip B. Mineral Collecting
8:00 p.m.	Smoker Gold Room, Hotel Easton Co-sponsors: Ingersoll-Rand and Hotel Easton

SATURDAY, MAY 30

8:30 a.m.	Trip C. Northern Trip (all day) Travel by bus; lunch in field
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SUNDAY, MAY 31

9:00 a.m. - 3:00 p.m.	Trip D. Southern Trip Travel by bus; lunch in field
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ACKNOWLEDGEMENTS

The field trips and guidebook were prepared by members of the staff of the Department of Geology and Geography, Lafayette College. The summary of the regional geology and the section on Paleozoic rocks were prepared by James L. Dyson. The section on pre-Cambrian geology was prepared by Arthur Montgomery.

Dean McLaughlin, of the University of Michigan, generously furnished the information on the Triassic stratigraphy. He will be one of the leaders on Trip D.

Bradford Willard has supplied new information on the Paleozoic stratigraphy; he will serve as one of the leaders on Trip C.

B. Franklin Shepherd, Chief Metallurgist of Ingersoll-Rand Company, arranged the smoker. Mr. Shepherd has an exceptional collection of mineral and rock spheres which he has cut and polished. These, including spheres of local rocks and minerals which he has prepared especially for the conference, he has agreed to exhibit at the smoker.

Willis Schlaseman, Superintendent of Strippings, Lehigh Navigation Coal Company, has made possible the Conference visit to the Greenwood Stripping and has furnished information for use in the guidebook.

Carl Warmkessel, Geologist for Lehigh Portland Cement Company, who will lead the trip at the Sandt's Eddy quarry, has generously contributed information and time.

John Bertrand, Science Department at Easton High School, has assisted in planning the mineral trip and will help lead it.

Sincere appreciation is extended to the Ingersoll-Rand Company for its generosity in co-sponsoring the smoker.

John J. Meyers, Manager of Hotel Easton, has been most helpful and cooperative. Thanks go to him and Hotel Easton for many favors, and for co-sponsoring the smoker.

Michael L. Kidda, of the Murphy Corporation, generously furnished extensive data and information on the Panther Valley coal region.

We are grateful for the cooperation of Doney Brothers, Stoddard Brothers, and the Lehigh Portland Cement Company for enabling us to visit their quarries and operations.

Publications by others who have done geologic work in the area of the Conference have been freely used in preparing the guidebook.

Marchant N. Shaffner, Pennsylvania Topographic and Geologic Survey, Harrisburg, is the permanent secretary of the Conference.

STAFF OF THE DEPARTMENT OF GEOLOGY AND GEOGRAPHY

Charles K. Cabeen
James L. Dyson, Chairman
Robert F. Gantnier
Arthur Montgomery

SUMMARY OF THE REGIONAL GEOLOGY

The area of the field trips is situated within four major physiographic provinces, the Triassic Lowland (Newark Basin) of the Piedmont Province, the Reading Prong of the New England Province, the Folded Appalachians, and the Appalachian Plateau (Pocono Section). The geologic structure and rock types vary greatly among these provinces, although in places the boundaries between them are indistinct and can be drawn only with difficulty.

The most complex geologic structures and the oldest rocks within the region are present in the Reading Prong. The rocks are pre-Cambrian in age and consist largely of amphibolitic orthogneiss, granite gneiss, and pegmatite. Topographically the Prong is a narrow zone of low mountains extending southwestward from the Taconic Mountains across northern New Jersey to a point about eight miles west of Reading, Pennsylvania (See Fig. 1, Physiographic diagram on following page). Because of the relatively great resistance of the crystalline rocks, the hills formed by them rise from three to six hundred feet above the general level of the adjacent physiographic provinces to maximum summit elevations of 1000 to 1200 feet in New Jersey, and to somewhat lower heights in Pennsylvania. The Prong attains its maximum width, about 25 miles, in northern New Jersey. Its extension in Pennsylvania is broken in two places, south of Allentown and Bethlehem and at Reading (Fig. 1), by infolded and faulted Cambrian and Ordovician limestones. Elsewhere, especially from the Delaware River eastward, other infolded limestone zones, because of their parallelism to the Prong and to the trend of the Appalachian folds, create parallel ridges and valleys bearing a marked similarity to the topography of the Ridge and Valley Province. This feature is especially well shown on the north half of the Easton topographic quadrangle, and to a lesser extent on the southern half of the Allentown quadrangle. Drainage for the most part is structurally controlled, the major streams paralleling the axis of the Prong.

The Ridge and Valley Province (Folded Appalachians) borders the Reading Prong on the northwest. Its width at the New York-New Jersey boundary is about 14 miles, at Easton nearly 25 miles, and in central Pennsylvania it attains a maximum of 80 miles. More than half the width of the province in the Delaware and Lehigh Valleys is contributed by the Great Valley, one of the major physiographic units in the entire Appalachian region.

The Great Valley is underlain by Cambrian and Ordovician limestone and dolomitic limestones and Martinsburg shale (slate, in the Delaware and Lehigh Valleys). The limestones are confined largely to the southeastern half of the valley and the

PHYSIOGRAPHIC DIAGRAM
of
PENNSYLVANIA

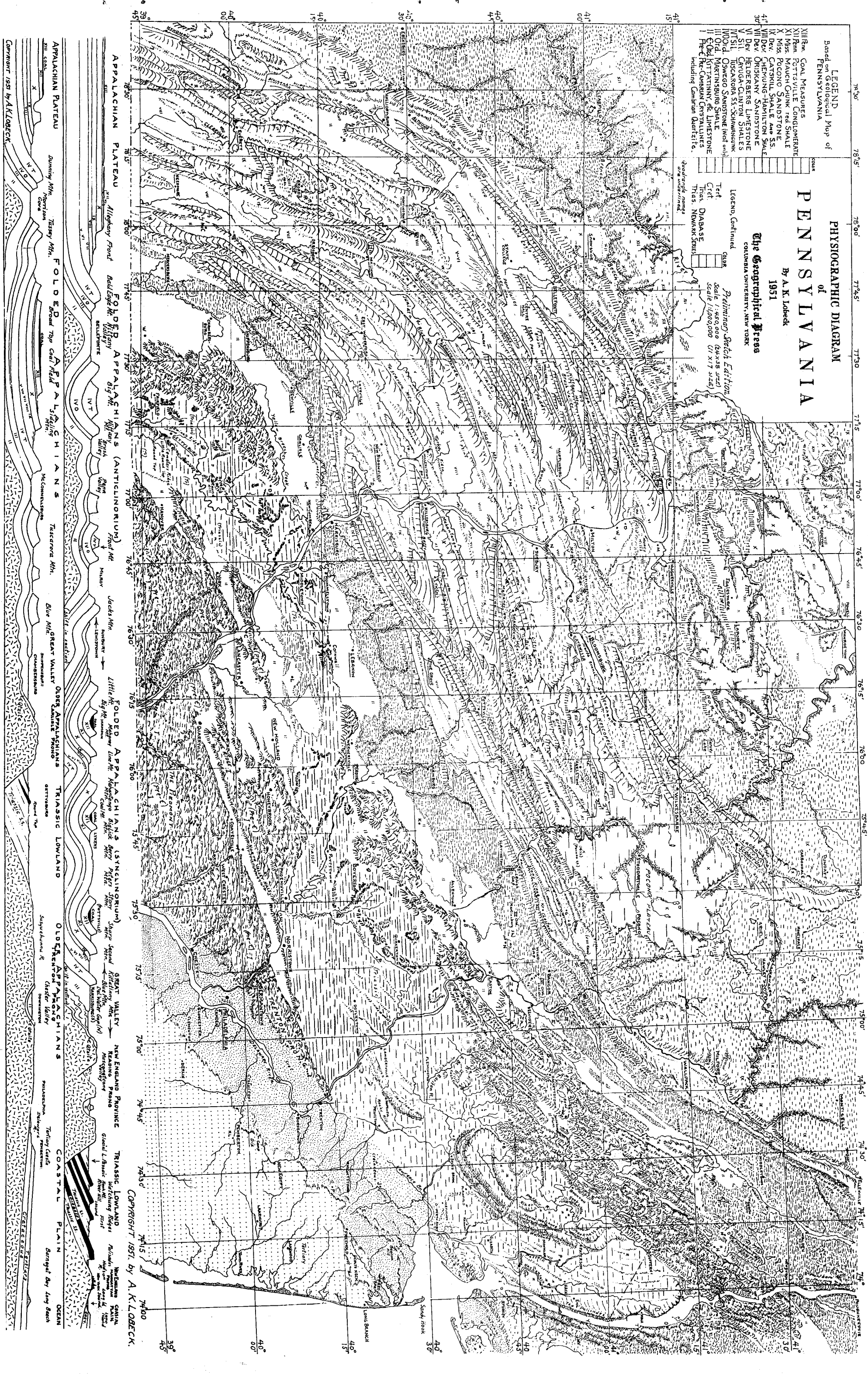
By A. K. LOBECK
1951

Geographical Features

COLUMBIA UNIVERSITY, NEW YORK

- LEGEND
Based on Geological Map of
PENNSYLVANIA
- XIII Ben. COAL MEASURES
 - XII Penn. POTTSVILLE CONGLOMERATE
 - XI Miss. MOUCH CHOUP red SHALE
 - X Miss. POCONO SANDSTONE
 - IX Dev. CATSKILL SHALE and SS.
 - VIII Dev. CHEMUNG-HAMILTON SHALE
 - VII Dev. ORISKANY SANDSTONE
 - VI Dev. HELDERBERG LIMESTONE
 - V Sil. CAUGA-CLINTON SHALES
 - IV Sil. OSWEGO SANDSTONE (incl. on)
 - III Old. MARTINSBURG SHALE
 - II Old. KITTANNY or LIMESTONE
 - I Pre-C. Pre-Cambrian Crystallines
including Cambrian Quartzite.

- LEGEND Continued
- Preliminary Sketch Edition*
Scale 1:450,000 (64x38 in.)
Scale 1:1,000,000 (17x17 in.)
- Color
- Tert. Cret.
 - Trias. Diabase
 - Trias. Newark Schist
- Shaded relief ranges
as indicated



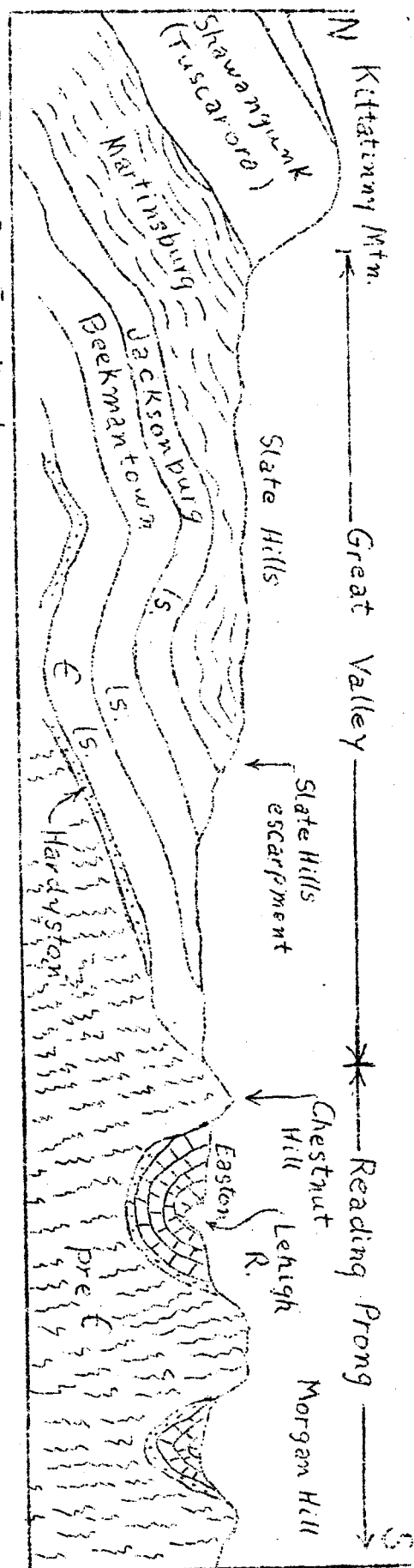
COPYRIGHT 1951, by A. K. LOBECK.

Martinsburg to the northwestern half. The limestone part of the valley is about 300 feet lower than the part underlain by the slate, and is separated from it by a conspicuous escarpment which is well shown on Figure 1 and on the Allentown quadrangle between Nazareth and Northampton. The higher part of the valley, in the Martinsburg, is known locally as the "slate hills".

Although some of the streams in the slate hills parallel the strike of the rocks, the drainage pattern, because of the uniform resistance of the slate to erosion, is largely dendritic. Streams are deeply incised near the southern margin because the floor of the adjacent limestone valley is several hundred feet below the Martinsburg belt. In the main part of the limestone belt, streams other than those originating in another section, are scarce because there is a considerable amount of underground drainage. The pattern here is also largely dendritic.

The boundary between the Great Valley and the Reading Prong is extremely irregular (Fig. 1) because of the unevenness of the basement complex surface upon which the limestones of the Great Valley rest. Actually the crystalline rocks were folded during the Appalachian Revolution as well as earlier, and many of the ridges comprising the Reading Prong are the cores of doubly plunging anticlines, most of them associated with faults and from which the lower Paleozoic sedimentary rocks have been stripped by erosion. The intervening synclines of Paleozoic limestones, which are inliers completely surrounded by pre-Cambrian crystalline rocks, normally are regarded as part

Figure 2. Idealized



of the Reading Prong. Actually the topography and underlying rock of these synclinal valleys are the same as in the Great Valley.

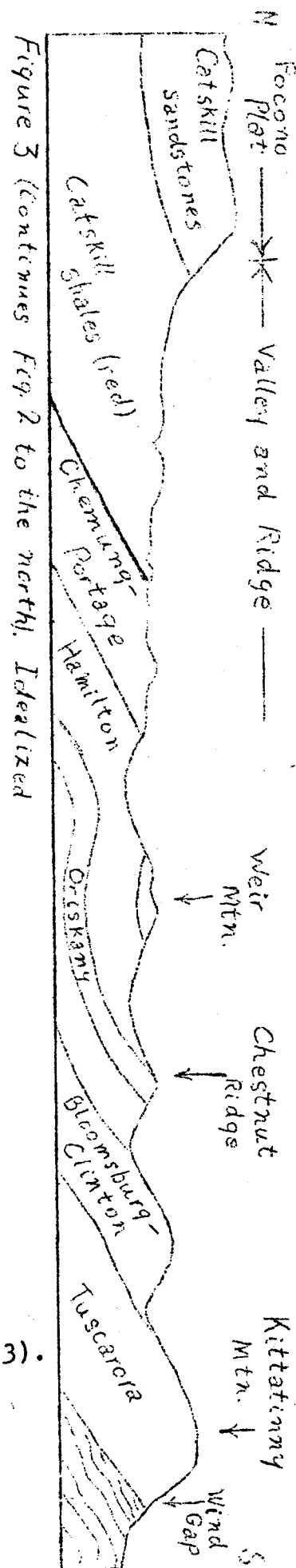
Although the rocks of the Great Valley are folded, they have a general northward dip and pass under the basal Silurian rocks of Kittatinny Mountain at the northwest edge of the Valley (See Fig. 2 for the topographic-geologic relationships in the Great Valley and Reading Prong).

Slate and cement are two important economic products of the Great Valley in this region. The cement is obtained from the Jacksonburg limestone, which underlies the slate and crops out in a narrow band at the base of the escarpment between the limestone valley and the slate hills.

The formations underlying the Great Valley in the vicinity of Easton listed in order of decreasing age and in order of outcrop from south to north are: Hardyston, Leithsville, Limeport, Allentown, Beekmantown, Jacksonburg, and Martinsburg (for descriptions see list of formations).

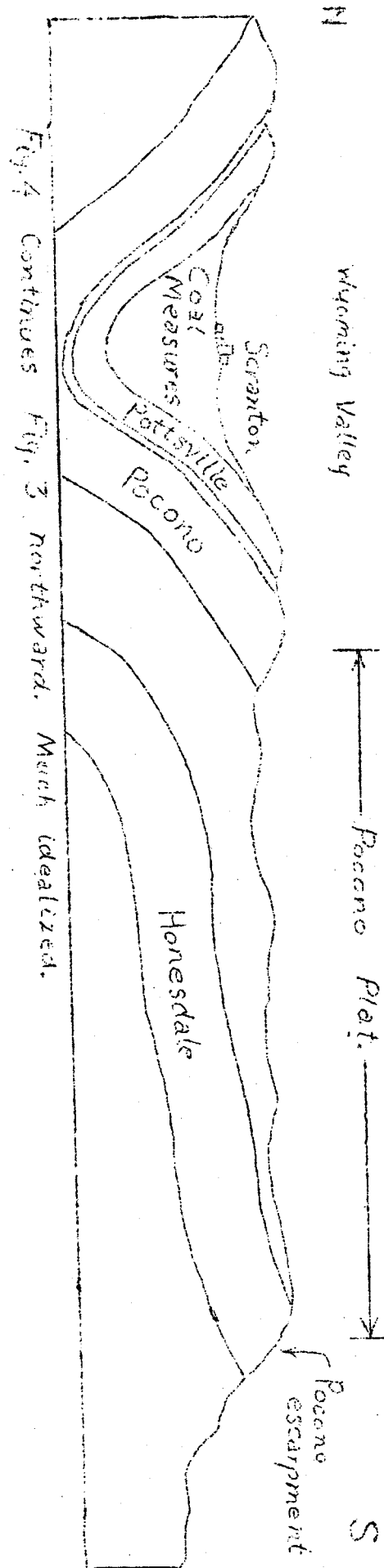
Northwest of the Great Valley and sharply separated from it by Kittatinny Mountain (known as Blue Mountain west of the Lehigh River) is the northwestern section of the Folded Appalachians. For this part of the province the term "Ridge and Valley" is far more appropriate than for the Great Valley.

Along the west edge of the Pocono Plateau the width of this section of the province is 40 or more miles, whereas between the Delaware and Lehigh Rivers the average width is only 9 miles. Here the only major ridge is Kittatinny Mountain which is formed by the very resistant Shawangunk (Tuscarora) sandstone and quartzite (Figs 1 & 2) of early Silurian age. Between this mountain and the Pocono Plateau there are several minor ridges made by formations of lesser resistance (Fig. 3).



In that part of the Folded Appalachians north of Blue Mountain and immediately west of the Lehigh River three additional formations are important ridge-makers. They are the uppermost sandstones in the Catskill (Honesdale principally), the Pocono sandstone, and the Pottsville conglomerate. (See formation list). The Pocono and upper Catskill sandstones are intergradational and of approximately equal resistance, hence they jointly form a single broad ridge which in places may be double-crested. An example is Mauch Chunk Ridge extending southwest from the town of that name (see Nesquehoning topo, sheet). Because the relatively weak Mauch Chunk shale lies between two of the principal ridge-making formations (Pocono and Pottsville), its outcrop is marked by a conspicuous valley. The valley of Mauch Chunk Creek between Mauch Chunk Ridge and Pisgah Mountain and the valley north of Nesquehoning Mountain (both shown on Nesquehoning quadrangle) are typical examples. These are also shown on Figure 1.

The Pocono section of the Appalachian Plateau is bordered on the south-east, west, and northwest sides by the Folded Appalachians, and on the east and northeast by a lower section of the Appalachian Plateau which rises northeastward into the Catskill Mountains (Fig. 1). The boundary of the Pocono Plateau, especially its southeast edge, is a prominent escarpment 500 to 800 feet high, formed by the Honesdale sandstone (Figs. 3 & 4). Most of the plateau is underlain by red sandstones and shales belonging to the Catskill facies. Only along its west border where it merges more or less imperceptibly with the Folded Appalachians

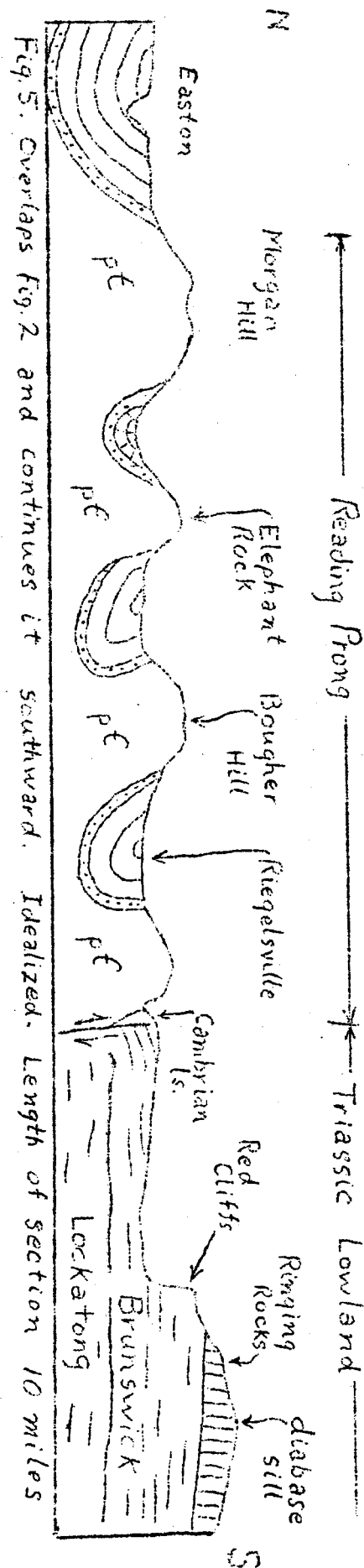


(Anthracite Region) does the Pocono sandstone occur on the plateau. Here the Pocono crops out on several narrow westward extensions of the plateau, conspicuous among which is Broad Mountain just north of Mauch Chunk (Fig. 1 and Tamaqua topo. sheet). Elevations of the plateau range mainly between 1600 and 2000 feet; a number of summits rise to 2100 and 2200 feet.

South of the Reading Prong lies the Newark Basin, a great structural trough filled with Triassic sediments known collectively as the Newark Group (Series). In the Delaware Valley the maximum thickness of sediments is 12,000 to 13,000 feet. They are mainly red shales, siltstones, arkosic sandstones, and coarse conglomerates (fanglomerates). Three units, usually regarded as separate formations, Brunswick, Lockatong, and Stockton, intergrade and interfinger, and are thus facies representing partly-contemporaneous deposition. Dips are mainly under 20 degrees and the few folds present are very gentle.

A conspicuous feature of the group in this region is the Coffman Hill diabase sill (Fig. 5), the outcrop of which at Ringing Rocks has been converted by weathering into a prominent field of blocks, many of which ring when struck with a hammer.

Several conspicuous erosion levels are present in the region traversed by the Conference trips (Fig. 6). The oldest and highest is the Schooley peneplane (No. 1 on Fig. 6), remnants of which are the summits of Kittatinny Mountain and the ridges of Honesdale, Pocono and Pottsville sandstones. Elevations range from 1400 to 1600 feet on the ridges and to more than 2000 feet



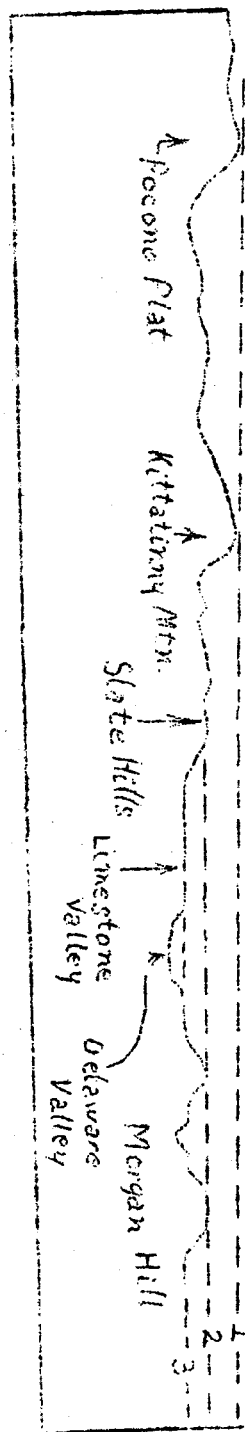
on the Pocono Plateau.

The Harrisburg erosion surface (No. 2 on Fig. 6) corresponds to the general level of the slate hills and the summits of several of the crystalline ridges in the vicinity of Easton. Its average elevation is about 700 feet.

Approximately 300 feet below the Harrisburg level is the Somerville level (No. 3), best developed upon the limestones of the Great Valley and less noticeably so on the Triassic shales. Although this level represents a widespread erosion surface, it can hardly be regarded as a peneplane (ultimate level to which a region can be reduced by subaerial erosion).

The Delaware River and its principal tributaries have entrenched themselves about 200 feet below the Somerville level in the Easton area.

Figure 6



THE GEOLOGIC COLUMN

Although many of the stratigraphic units listed will not be seen, all those in the vicinity of the routes followed are described below in order of youngest to oldest. Thicknesses in all cases are those along or close to the routes.

PLEISTOCENE

Wisconsin: Till and various types of stratified drift cover the region north of the outermost Wisconsin moraine which passes approximately through Belvidere, Bangor, thence northward across Kittatinny Mountain, westward to Wind Gap, then north onto the Pocono Plateau (Fig. 1). It forms a conspicuous mantle on the Martinsburg at Bangor (Trip A).

Terrace sand and gravel occur in the valleys of all streams and are very conspicuous along the Delaware south of Easton.

Another feature probably formed in late Wisconsin time is the block (boulder) field, of which there are several on the unglaciated parts of the Pocono Plateau, on Kittatinny Mountain, and on the Triassic diabase. A very large one is located along State highway 29 on the south side of Kittatinny Mountain (Trip C).

Pre-Wisconsin (Illinoian): Scattered patches of deeply weathered till as far south as Riegelsville.

Stratified drift of pre-Wisconsin age forms the high terrace at Riegelsville. (Trip D).

TRIASSIC

Parts of the great thickness of Triassic rocks in the Delaware Valley have been designated as Brunswick, Lockatong, and Stockton, according to the conventional idea of three conformable formations. These, however, can not be considered formations in a temporal sense. Rather, they are lithofacies. The Lockatong and Brunswick especially interfinger on a large scale. The interbedded red and gray shales along the Delaware River south of Milford are a section across the region of extensive interfingering. In this section, the

Stockton is the oldest, the main body of the Lockatong next youngest, the extensive interfingering of Lockatong and Brunswick still younger, and the almost pure Brunswick red shale the youngest of all. In another section farther west, however, the passage from dominant gray to dominant red shale would occur stratigraphically lower by hundreds, or thousands, of feet. The Lockatong disappears completely in Chester County, after having gradually decreased in thickness by interfingering with Brunswick red shale and sandstone.

Interfingering of Stockton and Lockatong is certainly much less extensive, and has not been clearly demonstrated in the Bucks County area. In northern Lancaster County, however, the New Oxford (equivalent of Stockton) and the lower 1000 feet or so of the Gettysburg (equivalent of Brunswick) do apparently interfinger.

In the higher part of the section some conspicuous gray shale members, as well as some thinner ones, occur separated by large thicknesses of Brunswick red shale. These gray members have no observed connection with the main body of the Lockatong, and it is considered practically certain that no such connection ever existed. They are believed to represent a recurrence of Lockatong conditions of sedimentation. These higher members have been traced for a great distance along the strike, in several cases for as much as 40 miles. Northeastward in New Jersey they pass along the strike into quartz fanglomerate.

Brunswick lithofacies: Terrestrial red shales, siltstones, sandstones, and coarse conglomerates (both quartzite and limestone) derived chiefly from Paleozoic sediments to the north. Several thin beds of limestone occur locally. Dinosaur tracks are abundant at places. A diabase sill (Coffman Hill) has altered the adjacent sediments to a hard gray or black hornfels in which cordierite is a common contact metamorphic mineral. The diabase is of normal character, consisting predominantly of augite and labradorite in an ophitic texture. A small percentage of olivine is present.

Lockatong lithofacies: Gray to black shales and argillites which grade laterally into the Brunswick. Adjacent to diabase they have been altered to hard gray or black hornfels. The Lockatong represents a lacustrine and paludal facies deposited after the southern highland had been considerably lowered by erosion and before the influx of sediments from the

north could overwhelm the lakes and swamps with a thick blanket of sediments. It reaches its greatest development where the basin was widest, and hence where the quiet conditions could persist while neighboring areas were being buried under muds from the north.

Stockton lithofacies: Red, gray and brown shales and arkoses with local arkosic conglomerates which represent detritus from a southern highland of igneous and metamorphic rocks, not many miles south of the border of the Triassic belt.

Triassic total thickness: 12,000-13,000 feet

PENNSYLVANIAN

Monongahela formation (group): Consists of several hundred feet of shales, sandstones, and siltstones, all of terrestrial origin (as are all other Pennsylvanian rocks in this area) with the Sandrock coal (1-10 feet thick) at the base.

Estimated thickness: 400 feet

Conemaugh formation (group): Shales, siltstones, micaceous sandstones, and coals between the base of the Sandrock coal and the top of the Mammoth coal. Because of similarity of floras in the upper Conemaugh and the Monongahela it is difficult to separate the two. There are 10 to 12 coal beds in the group with ranges of thickness from one foot to 30 feet. The Primrose (average thickness 12 feet) and Orchard (5 to 25 feet) are the most important coals. Only one other, the Diamond, is worked in the Panther Creek Valley.

Thickness: 800 feet

Allegheny formation (group): Sandstone, shale, conglomerate, and coals. Ironstone concretions are abundant. The Mammoth coal forms the top of the group and the Buck Mountain coal is at the base. The U.S. Geological Survey puts the top of the Allegheny at the bottom of the Holmes coal (Rothrock et al, 1951). Inasmuch as the Holmes is not continuous in the Panther Valley, it is not a satisfactory marker for the boundary between the Allegheny and Conemaugh formations. C.B. Read (1941, pp. 65-66) on the basis of flora has correlated the Buck Mountain coal with the lower Kittanning coal of western Pennsylvania. The

Allegheny beds underlie the entire Panther Creek Synclitorium. Thickness varies greatly but averages about 230 feet. Sandstones are commonest in the lower part of the formation.

About 80 per cent of the coal mined in the Panther Valley has come from the Allegheny. The Buck Mountain is the lowest workable coal, thus its outcrop is marked by the outermost stripping in the zone between Nesquehoning and Pisgah Mountains (Nesquehoning and Tamaqua topo. sheets), in places reaching nearly to the crests of those ridges.

The Mammoth bed, the most important anthracite coal in the Panther Valley, consists of from one to three beds (splits) and varies greatly in thickness. It has been strip-mined along practically its entire outcrop. In the workings of the Coaldale Colliery the average thickness of good coal in the bed is 39 feet. In places the Mammoth coal has been squeezed into overlying beds of less competent shale. Because of this the structure of the Mammoth bed in the Greenwood Stripping of the Lehigh Navigation Coal Company is fantastically complex. (Fig. 14. Trip C)

The Allegheny is conformable with both the overlying Conemaugh and underlying Pottsville.

Average thickness: 230 feet.

Pottsville formation (group, series): This formation, composed largely of coarse conglomerate and lying stratigraphically between the top of the Mauch Chunk red shale and the base of the Buck Mountain coal, is one of the principal ridge-makers of the Folded Appalachians. All coal basins in the Anthracite Region are encircled by it. Nesquehoning and Pisgah Mountains, on the north and south sides respectively of Panther Valley, are Pottsville ridges. The crests of these ridges are formed by the conglomerates in the uppermost part of the formation.

The pebbles in this formation are mostly white quartz, but a number of other materials also occur, and at several horizons in the lower part of the formation large pebbles of red shale are present.

Although there are one or two very thin coal beds in the upper part of the Pottsville in the Panther Valley, none has ever been worked east of Tamaqua.

The Pottsville grades downward into the red Mauch Chunk in the area east of Tamaqua, and the boundary between the two formations is indefinite. In the gap north of Tamaqua (Tamaqua topo. sheet) the zone in which red shale intergrades with conglomerate and sandstone beds is at least 690 feet thick. If the base of the Pottsville is placed at the bottom of the lowermost conglomerate there is an aggregate thickness of 140 feet of red shale in the lower part of the Pottsville. At Nesquehoning Gap (Nesquehoning topo. sheet) the transitional zone is about 360 feet thick. At Mauch Chunk, four miles to the east, the lowermost conglomerate member is overlain by a zone, 280 feet thick, in which red shale is the dominant rock. A short distance north of the town of Mauch Chunk this conglomerate contains a considerable amount of uranium, mainly in the form of several carnotite-type minerals. This is the only potential commercial deposit of uranium so far known in the eastern states.

Approximate thickness at Lansford: 870 feet.
At Tamaqua: 1150 feet

MISSISSIPPIAN

Mauch Chunk formation: Mainly terrestrial red shales, but the upper part intergrades with Pottsville as described above. Fossils, except for rare footprints and plants, are lacking. Mud cracks and ripple marks are common. The topographic expression of this formation is everywhere a conspicuous valley.
Thickness at Mauch Chunk: 2200 feet.

Pocono formation (group): Consists mainly of gray quartzitic sandstones and conglomerates of terrestrial origin. Plants are the only fossils found. The largest area of outcrop is along the western margin of the Pocono Plateau where it forms the resistant capping rock. Several westward extensions of the plateau, the most conspicuous of which is Broad Mountain (Tamaqua topo. sheet), are also capped by this formation. Farther west the Pocono is a prominent ridge-maker. It grades upward into the Mauch Chunk and downward into terrestrial sandstones of Upper Devonian age.

Thickness: 750 feet.

DEVONIAN

Catskill terrestrial facies: Predominantly non-marine red shales, siltstones, and sandstones, although a considerable thickness of non-red sandstones with minor amounts of conglomerate occur near the top. In the Lehigh Valley these rocks are mainly of Portage age. In the gap south of Mauch Chunk, according to Willard (Guidebook, 13th An. Field Conf. Pa. Geol., 1947), the following units are present in order of increasing age (north to south on the ground):

1. Upper red sandstone, shale and some conglomerate. Probably Cherry Ridge. In the ridge southeast of Mauch Chunk there is a zone in which uranium occurs in fractures and disseminated crystals (autunite) in sandstone, apparently associated with carbonaceous plant remains.

Thickness: 500 feet.

2. Honesdale sandstone. Contains thin conglomerates. This unit forms the escarpment of the Pocono Plateau.

Thickness: 500 feet.

3. Lower red beds (mainly shales).

Thickness: 1000 feet.

4. Delaware River flags. Greenish and gray sandstones.

Thickness: 700 feet.

Portage Group:

Trimmers Rock formation: Comprises the bulk of the marine Portage in the Lehigh Valley, and consists largely of fine-grained sandstones and siltstones which grade upward into the Delaware River flags. Concretionary structures, some of large size, are fairly common.

Thickness: 800 feet.

Burket black shale: This formation is readily distinguishable from the overlying and underlying formations, and probably is the correlative of the Genesee of New York. It crops out just north of Bowmanstown and also north and south of Lehigh (Trip C), and is normally unfossiliferous although Buchiola and Styliolina occur in places.

Thickness: 50 feet.

Tully limestone: This limestone is quite shaly in the Lehigh Valley and apparently grades into sandstone farther east.

Thickness: 20 feet.

Hamilton Group:

Mahantango formation: A great thickness of shales, siltstones, and sandstones probably equivalent to the Moscow, Ludlowville, and Skaneateles of New York. It is usually very fossiliferous at the top (Moscow) and near the middle where the Centerfield biostrome (Ludlowville) occurs, a rock characterized by an abundance of cup corals, crinoids, bryozoa, and other invertebrates.

Thickness: 1200 feet.

Marcellus formation: Black laminated shale with sideritic concretions. For the most part it is unfossiliferous, but at Stroudsburg is replete with the remains of planktonic organisms.

Thickness: 650 feet.

Onondaga Group:

In the Lehigh Valley there is very little limestone in this group. The principal units are the Palmer-ton sandstone and the Bowmanstown chert.

Palmerton sandstone: This unit, plus several feet of limestone which overlies it, comprises the upper part of the group. It consists of massive, coarse-grained sandstone, which in most places is conspicuously iron-stained, and which has the lithologic appearance of the Oriskany sandstone. Although this formation is more than 100 feet thick at Palmerton, where it forms the prominent ridge north of the town, it is confined to a zone between the Schuylkill and Delaware Rivers.

Thickness: 130 feet.

Bowmanstown chert: Mainly a sandy and silty white chert interbedded with sandstones and siltstones. Its upper part is very fossiliferous and affords excellent collecting in the quarry of the Alliance Sand Company in the ridge north of Palmerton. Among the diagnostic forms are Spirifer macrus, Eodevonia arcuata, Leptocoelia

acutiplicata, and Schuchertella pandora.

Between the Bowmanstown and the underlying Ridgeley there is a 4-foot bed of silty hematite.

Thickness: 65 feet.

Oriskany Group:

Ridgeley sandstone: This, the only representative of the group in the Lehigh Valley, is a massive, coarse, gray sandstone which weathers brownish.

Thickness: 25 feet.

Helderberg Group:

There are practically no exposures of the members of this group in the Lehigh Valley but the New Scotland chert (white chert and interbedded clays) and probably also the Coeymans formation (sandstone and clay) are present. They are concealed by talus rubble along the south flank of the ridge north of Palmerton.

Probable thickness: 90 feet.

SILURIAN

Keyser formation: This formation is not now exposed in the Lehigh Valley (Mauch Chunk topo. sheet), but earlier field studies prove its presence. It consists of sandy limestone, shale, and sandstone. Farther east, beginning in the vicinity of Stormville (south side of Godfrey Ridge on Delaware Water Gap sheet), the Keyser has been given group status and subdivided into the Manlius and Rondout limestones and the Decker sandstone (Swartz and Swartz, 1941).

Probable thickness: 90 feet.

Bossardville limestone: Finely laminated gray-blue limestone with pronounced columnar structure. Except for a few Leperditia it is unfossiliferous. It probably is the correlative of the Tonoloway which it resembles in all respects.

Along Chestnut and Cherry ridges (Wind Gap topo sheet) and Godfrey Ridge (Delaware Water Gap sheet) it has been extensively quarried. Along the route of Trip C (Mauch Chunk sheet) it is not exposed.

Approximate thickness: 75 feet.

Poxono Island shale: Unfossiliferous greenish and variegated shale, parts of which may be calcareous or sandy; minor amounts of limestone and red shale. The name, Poxono Island, is applied only in the Lehigh and Delaware Valleys. To the west the better known term Wills Creek is used for rocks of this age. Exposures of the Poxono Island are scarce. It grades downward into the Bloomsburg.

Approximate thickness: 200 feet.

Bloomsburg redbeds: A terrestrial facies which represents different geological ages at different places, in the Lehigh Valley probably extending from early Niagaran (Clinton) well into Cayugan (Salina) time. It is composed almost entirely of red sandstones and shales.

Approximate thickness: 2000 feet.

Clinton formation: At Lehigh Gap between the Bloomsburg and Tuscarora there is a thick series of sandstones and shales assigned to the Clinton. It intergrades with both the Bloomsburg and Tuscarora, and except for some worm burrows in the exposure on the highway immediately north of Aquashicola Creek (Mauch Chunk sheet), is unfossiliferous. At Delaware Water Gap, contemporaneously deposited sediments are included in the Shawangunk.

Thickness: 1100 feet.

Tuscarora formation: Massive sandstones and quartzites with minor amounts of conglomerate. A few thin beds of black shale are also present. This is the formation responsible for Kittatinny Mountain and many other major ridges in the Folded Appalachians farther west. Large accumulations of rubble, especially on the south side of Kittatinny Mountain, characterize the weathering of the Tuscarora. These features probably date from an earlier, colder and wetter part of post-Wisconsin or earlier time.

Thickness: 460 feet.

ORDOVICIAN

Bald Eagle conglomerate: At the base of the Tuscarora are 3 to 4 feet of coarse, iron-stained, poorly sorted conglomerate which, because of its dissimilarity to the conglomerates of the Tuscarora, may be Bald Eagle (Willard and Cleaves, 1939). It is

present in a number of sections between Lehigh and Susquehanna Gaps, and at the latter place has a thickness of 30 feet. There it is regarded as a member of the Juniata formation. At Lehigh Gap most of the pebbles are a brownish quartzite and range in diameter between one and three inches. They may possibly have been derived from Cambrian quartzites in the Reading Prong to the south.

Thickness: 3-4 feet.

Martinsburg formation (group): There is a sharp break between the conglomerates, whether they be Tuscarora or Bald Eagle, and the underlying Martinsburg. At Lehigh Gap the youngest Martinsburg beds are sandy shales and sandstones, whereas at Delaware Gap they are black slates.

The Martinsburg in this region represents a relatively nearshore black shale and sandy facies which extends in time from Trenton into Pulaski.

Those who have studied the Martinsburg in detail have subdivided it into either two or three main divisions. Behre (1933) has been the chief proponent of the three-fold division. Stose, Moseley, Willard and others hold to the two-fold division. According to the two-fold school there is an upper sandy member best exposed in the high hills (Shochary Ridge) 8-10 miles southwest of Lehigh Gap, and a lower shaly member much of which has been metamorphosed to slate. Much of the slate has a dark gray color and is cut by a well developed cleavage, on the surfaces of which the bedding appears as bands. (For excellent descriptions and information on the structure and lithology of the slate see Behre's report, the most detailed and comprehensive work yet done on the Martinsburg slate).

There is considerable disagreement about the thickness of the Martinsburg in this region, estimates varying from 3500 to 11,800 feet. Determination of thickness is difficult, if not impossible, because of tight folding and the absence of key beds.

Fossils are essentially absent in the slate but not uncommon locally in the sandy beds.

Thickness estimates

(Willard): 3500-4000 feet

(Moseley): 3400-7800 feet

(Behre): 11,800 feet

Jacksonburg formation: The Jacksonburg is a dark-colored non-magnesian limestone composed of two distinct lithofacies; the lower, a high-calcium (partly crystalline) limestone, is known as the "cement limestone" facies and the upper, an argillaceous black limestone with slaty cleavage, the "cement rock" facies. Both facies are cement-producing. The upper facies in the field can easily be confused with the overlying Martinsburg, into which it appears to grade. The Jacksonburg, however, effervesces readily with dilute hydrochloric acid and does not possess the banding so characteristic of the Martinsburg. The age of the formation is middle Trenton, as indicated by fossils which are common in the lower member, scarce and local in the upper. Prasopora is one of the most common genera.

Thickness: 1000-1500 feet.

Beekmantown formation: For the most part massive dolomitic limestone. Fossils are rare, but those found establish the age of the formation. Although the Beekmantown in the main is more massively bedded and lighter colored than the Jacksonburg, in several of the cement quarries the two formations are somewhat similar in appearance close to their contact, but the cement companies readily distinguish between them by chemical analyses.

The Beekmantown occupies the northern part of the limestone belt in the Great Valley.

Approximate thickness: 1000 feet.

CAMBRIAN

In the Lehigh Valley there is a thick series (2000-2700 feet) of Cambrian unfossiliferous dolomitic limestones which, together with the Beekmantown, are sometimes referred to collectively as the Kittatinny limestone. Some of the more recently used names for various subdivisions of the Cambrian part of the sequence include Allentown, Limeport, Leithsville, and Tomstown. The names Allentown and Leithsville were proposed by Wherry in 1909. The latest attempt at subdivision (Howell, Roberts, and Willard, 1950) uses Allentown, Limeport and Leithsville.

Allentown limestone (formation): The contact with the Beekmantown is not easily recognizable. The formation is composed of dense, blue to dark-gray dolomitic limestone, which on weathered surfaces shows conspicuous alternation of light and dark banding. Cross-bedded sandy lenses, oolites, ripple marks, and edgewise conglomerate are common. Stromatolites, especially Anomalophycus compactus, are common, often in biostromes. The age of the formation is late Cambrian (Trempealeauian).

Approximate thickness: 400-500 feet.

Limeport limestone (formation): Similar to the Allentown but contains a considerable number of shaly beds and is very sandy. Diagnostic stromatolites are Cryptozoon fieldii and Archaeozoon undulatum. Like the Allentown, weathered surfaces usually show light and dark bands. Conglomerates and oolites are very abundant, and biostromes are present. Shales are less abundant than in the underlying Leithsville. The age of the formation is late Cambrian (Dresbachian).

Thickness: 400-500 feet.

Leithsville limestone (formation): A dolomitic limestone which differs from the two overlying formations in the absence of biostromes and sandy beds. Oolites and conglomerates are very scarce, but some doubtful stromatolites are present in the upper part. The formation intergrades with the underlying Hardyston. Its age is doubtful, and may be anywhere from Early to Late Cambrian.

Thickness: 800-900 feet.

Hardyston quartzite (formation): This is the oldest Cambrian formation in the area under consideration. Although unfossiliferous, except for Scolithus (worm burrows), it has been definitely correlated with rocks containing the Lower Cambrian trilobite, Olenellus, in New Jersey.

The lithology of the Hardyston varies so considerably that no single rock term, such as quartzite, can adequately describe it. The lower part is mainly a fine- to coarse-grained arkosic sandstone. The proportion of feldspar decreases upward. Much of the upper part is quite quartzitic. At the base there is, in places, a thin residual basal arkose which has much the appearance of the crystalline pre-Cambrian rock upon which it rests, and from which it was directly derived.

Thickness: 0-300 feet.

PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks of the Guidebook area, because of their complexity and vast difference from the younger rocks, will be treated as a separate entity and described lithologically from oldest to youngest. A summary will then be given of their structural evolution and metamorphic history.

The stratigraphy of these rocks is not at all certain, but the stratigraphic sequence here used is the generally accepted one based on mapping by Wherry (1918), Bayley (1937), Fraser (1939), and others. Some slight changes have been made.

Franklin limestone

This formation, tentatively correlated by Fraser (1939, p. 164) with the Franklin limestone of northern New Jersey, is not widely exposed in the area. It occurs in a zone several hundred feet wide along the south slope of Chestnut Hill in the north part of Easton, which continues eastward along the strike across the Delaware as sporadic outcrops in Marble Mountain. There is another small area of it 8 miles westward in the Allentown quadrangle, perhaps still on the strike, at the northwest edge of Camel's Hump Ridge, north of Bethlehem (Allentown quadrangle).

The least altered rock, of very limited occurrence, consists of a medium- to coarse-grained white to gray marble, showing scattered small flakes of graphite that in part tend to lie in parallel orientation and give some of the rock a crude semblance of foliation. Some streaky dark banding is present also, and appears to parallel graphitic foliation. This rock is best exposed in the west wall of the serpentine quarry of the Royal Green Marble Co. on the east side of the Delaware River. The same type of rock is found at Camel's Hump. A somewhat similar graphitic marble, but much sheared and partly altered to serpentine and talc, occurs over a small area above the northwest wall of the Williams serpentine quarry on the west bank of the Delaware. The major part of the formation is no longer marble, but has been altered to three distinctive rock types, consisting chiefly of tremolite, of serpentine, or of talc.

The tremolite rock is abundant in the northern part of the Williams quarry. It is white, glistening, and medium- to coarsely-crystalline. Broad-bladed, stubby tremolite crystals, haphazardly oriented in densely packed aggregates, make up most of the rock. Some coarsely-crystalline calcite may be

present; greenish serpentine occurs as small masses interstitial to the tremolite or as gray-green material intimately associated with and apparently altering from the tremolite.

The serpentine rock is largely pure serpentine, commonly of pale-green to deep apple-green color. It is well exposed in the Williams and Royal Green Marble Co. quarries. The serpentine is in part massive and dense, in part micaceous and crudely schistose. Shearing and hydrothermal alteration have been responsible for the conversion of the serpentine in the latter case to a micaceous vermiculite-type of mineral. Some of this material is talcose also. Much of the dense green serpentine is veined by white fibrous calcite; these seams, up to several inches wide and many feet long, represent fracture fillings. Small lenticular masses of quartz are found in certain parts of the serpentine rock.

The talc rock occurs widely along the southwest side of Chestnut Hill, where it may be observed in several old quarries. It is a crudely-schistose rock consisting of gray micaceous talc mixed with minor pale greenish-gray serpentine. It seems a product of further shearing and hydrothermal alteration effective upon serpentine rock.

Moravian Heights formation

This rock, very poorly exposed in the Easton area, has been described in the Allentown quadrangle by Wherry (1918, pp. 379-385) and Miller (1925, p. 144); Fraser (1939, pp. 170-175) has treated its occurrences in the Easton area.

At Weygadt Gap at the east end of Chestnut Hill a grayish thinly-banded gneiss contains gray-green streaky layers interlaminated with granite. The gray-green rock is a micaceous quartzite, and Fraser (1939, p. 173) has mapped it as part of the Moravian Heights formation.

More typical material is found as loose blocks along part of the summit of Morgan Hill (south side of Easton). This rock is a massive, banded, greenish-gray gneiss. Gray-green quartzitic layers alternate with layers of gneissic granite. The quartzite is typified by elongate quartz grains, scattered parallel-oriented muscovite flakes, and streaks and coatings of a pale-greenish chloritic mineral. Some of this rock reportedly contains abundant needles of sillimanite (Fraser, 1939, p. 173).

Pochuck gneiss

This dark-colored hornblende-rich rock occurs very widely in the Easton area, occupying an especially large zone southeast of Morgan Hill.

It is a medium- to fine-grained, greenish-black rock, consisting chiefly of hornblende and andesine. Commonly it is more or less banded; since it is not always gneissic, however, it more properly should be called amphibolite. It has a very distinctive equigranular, pepper-and-salt appearance due to an even-textured spotting of the dark hornblende and light andesine grains. Well developed gneissic banding is due chiefly to alternation of bands of granitic material with hornblende-rich bands. Where granitic material is not present, much of the amphibolite still shows an inherent poorly developed gneissic banding caused by a lengthening of hornblende grains and a stringing out of andesine grains in the plane of foliation.

Some amphibolite contains abundant small flakes of greenish-black biotite; these are arranged in parallelism throughout the groundmass or on certain foliation surfaces. Pod-shaped lenses of pure hornblende occur, and large-size irregular layers and lenticular patches of grayish pegmatite are not uncommon. These last contain very coarse uralitic hornblende, biotite crystals, and greenish sausseritized plagioclase. Some masses of gray-white granite pegmatite or pegmatitic granite in the Pochuck crosscut the gneissic foliation, and here partial assimilation of amphibolite by granite and pegmatite is evident. Small masses of amphibolite have been surrounded and engulfed by granite, so that in some cases shreds of hornblende are strewn about through the intruding rock. Fenner (1914) has described similar assimilation relations between related rocks in the New Jersey Highlands.

Thin sections of typical Pochuck gneiss reveal a granoblastic intergrowth of stubby grains of hornblende and andesine. The hornblende grains show rounded clean-cut edges and are of fresh appearance. Surrounding them are murky pale-green patches with fuzzy outlines; these consist chiefly of chlorite associated with epidote granules. The plagioclase is partly in fresh-looking, clear, clean-cut grains of oligoclase-andesine composition, partly in indistinct patchy aggregates, murky with dark specks of alteration products. Some rounded, clear grains of microcline are present in these aggregates, as are micropegmatitic intergrowths of microcline with murky plagioclase. Stubby apatite prisms are fairly abundant; ilmenite in coarse grains surrounded by leucoxene may be common, also small sphene crystals.

Evidence suggests that the Pochuck gneiss was originally an igneous rock of gabbroic composition, and became transformed through regional metamorphism to a hornblende-andesine amphibolite. Whether it was originally in the form of basaltic flows, diabase sills, or intrusive gabbro, is not known. Considerable variability of structure and texture in different exposures may indicate that there were originally several kinds of basic igneous rocks, all becoming similarly metamorphosed to the same general type of hornblende-andesine rock.

Byram granite and pegmatite

South of Easton considerable areas of pre-Cambrian igneous rock have been mapped as Byram granite gneiss and pegmatite (Bayley, 1941, pp. 50-53; Fraser, 1939, pp. 187-194). Unfortunately, there is no single rock type in this region that can be diagnostically identified as Byram. The name, Byram, has been assigned to any pre-Cambrian igneous rock containing quartz and potash feldspar and of granitic or pegmatitic appearance.

Most typically Byram perhaps is any granite or pegmatite containing flesh-colored microcline together with quartz. A large amount of such granite pegmatite may be observed on the Pennsylvania side of the Delaware, south of Easton along Route 611, almost always in association with dark Pochuck gneiss.

Many other kinds of granitic rock are exposed in road cuts along both sides of the Delaware. Most of these are of a gray color, and where biotite is present in some quantity, the scattered flakes are lined up crudely in parallelism, imparting a gneissic foliation. The gray rock consists predominantly of quartz and orthoclase, with or without minor pale-gray or colorless microcline.

Some pegmatites, especially the type containing pink microcline, occur as narrow, irregular, vein-like bodies, in part with crosscutting relations to the gneissic foliation and in part conformable with the foliation. Other pegmatites are simply layers, usually quite thin, of coarse-grained quartz and gray or colorless potash feldspar, interlaminated with dark gneissic rock. Still other pegmatites consist of very large masses of exceptionally coarse-grained rock, predominantly grayish microcline with, or without, quartz. Some such pegmatite contains streaky inclusions of dark minerals, as actinolite or fibrous uralitic hornblende. Most pegmatites are largely lacking in any minerals other than potash feldspar and quartz; the absence of muscovite is especially noteworthy. Coarse-grained crosscutting pegmatites at Weygadt Gap contain coarse prisms of black tourmaline in great abundance.

It is clear that Byram granite and pegmatite have infiltrated, intruded by lit-par-lit injection, and assimilated on a very widespread scale dark Pochuck gneisses in the Easton area. Such assimilation appears to have affected the granite and pegmatite by giving it an over-all darker shade of gray or else darkening it through an abundance of hornblende-biotite inclusions. As a result, there are many varieties of granite and pegmatite, most of them grayish or of washed-out appearance. The pink microcline-bearing pegmatites do not appear to have assimilated Pochuck gneiss; they also commonly show crosscutting relations with the Pochuck, and therefore are interpreted as being a late stage differentiate of the Byram.

Minor basic meta-igneous rocks

Along the south side of Chestnut Hill there are some limited outcrops of small bodies of much-sheared and altered, basic meta-igneous rocks. These are of meta-diorite character and probably of late pre-Cambrian age, but age relations with other pre-Cambrian rocks are unknown.

PRE-CAMBRIAN GEOLOGIC HISTORY

All of these rocks, except for a minor part of the granite and perhaps all granite pegmatites, were subjected to strong compressional forces along northwest-southeast lines. They must have been deep in the crust where high temperatures prevailed. They thus became folded along northeast-southwest axes and marked indelibly by the effects of a regionally-widespread metamorphism of dynamothermal character. The gneissic banding and foliation present in these rocks are those indelible effects. These structures strike parallel to fold axes but do not parallel axial planes of the folds; therefore, they are presumed to represent bedding foliation.

Widespread granitic intrusion must have followed immediately while compressional forces still were being exerted, for most of the older rocks became infiltrated and partially assimilated by, and interlayered in lit-par-lit fashion with, gneissic granite. The new migmatitic structures served to accentuate the earlier gneissic foliation. Large bodies of granite are themselves generally of gneissic character.

During this regional metamorphism the rocks became recrystallized. Purer limestone became graphitic marble, while dolomitic types were converted to tremolite-diopside assemblages; argillaceous sandstone became micaceous sillimanite-bearing quartzite; gabbroic or basaltic rocks became amphibolite.

With cessation of compressional forces there came a period of intensive pegmatitic intrusion and hydrothermal mineralization. At first pegmatites tended to follow planes of regional foliation but later on they became more penetrating and cross-cut old structures. Some late-stage pegmatites were charged with volatiles, as attested by the tourmaline-bearing pegmatites of Weygadt Gap, and hydrothermal solutions associated with these became locally effective. Much of the tremolite-marble rock of Chestnut Hill became profoundly altered to massive serpentine and talc. Episodes of intense shearing and fracturing appear to have alternated here with long-continued hydrothermal mineralization and undoubtedly helped in providing pathways for the solutions. The serpentine rock itself was fractured, the openings becoming filled with chrysotile and fibrous calcite. A great variety of minerals was deposited in the serpentine late in this period, including rare-element minerals such as thorianite. This thorianite has been dated (Wells, 1933, p. 52) at 800,000,000 years, and thus is of late pre-Cambrian age and serves to fix almost certainly in pre-Cambrian time all of the above-mentioned events of geologic history.

Structural and metamorphic relations make clear the relative ages of the Moravian Heights formation, the Pochuck gneiss, and Byram granite and pegmatites, for at Weygadt Gap the former of these underlies the Pochuck and both it and Pochuck have been everywhere intruded by Byram. The age of the Franklin limestone relative to that of Pochuck and of Moravian Heights, however, is unknown. The stratigraphic sequence of Fraser (1939, p. 165) and others, fixing Franklin limestone as the oldest of these rocks, has been followed here, but there is some evidence to show that the limestone may be younger than, or at least overlies, Pochuck and Moravian Heights. At Weygadt Gap these latter rocks dip steeply south; across the Delaware Pochuck layers dip north. Between the two exposures there must lie a synclinal axis; it is along this axis, on both sides of the river, that exposures of Franklin lie. The limited extent of Franklin in this region may find its explanation in this possibility, if the supposition prove true.

LIST OF FORMATIONS

CENOZOIC

Pleistocene

Wisconsin till and outwash
Pre-Wisconsin till and outwash

MESOZOIC

Triassic

Brunswick lithofacies
Lockatong lithofacies
Stockton lithofacies

PALEOZOIC

Pennsylvanian

Monongahela formation
Sandrock coal
Conemaugh formation
Diamond coal
Orchard coal
Primrose coal
Holmes coal
Allegheny formation
Mammoth coal
Skidmore coal
Seven-foot coal
Buck Mountain coal
Pottsville formation

Mississippian

Mauch Chunk shale
Pocono sandstone

Devonian

Catskill terrestrial facies	}	Upper
Upper red beds (Cherry Ridge)		
Honesdale sandstone		
Lower red beds		
Delaware River flags		
Portage group		
Trimmers Rock formation		
Burket black shale		
Tully limestone		

Hamilton group	}	Middle
Mahantango formation		
Centerfield biostrome		
Marcellus formation		
Onondaga group	}	Lower
Palmerton sandstone		
Bowmanstown chert		
Oriskany group	}	Lower
Ridgeley sandstone		
Helderberg group		
New Scotland formation		
Coeymans formation		

Silurian

Keyser formation
Bossardville limestone
Poxono Island shale
Bloomsburg redbeds
Clinton formation
Tuscarora formation

Ordovician

Bald Eagle conglomerate ?
Martinsburg formation
Jacksonburg formation
Beekmantown formation

Cambrian

Allentown limestone
Limeport limestone
Leithsville limestone
Hardyston formation

Pre-Cambrian

Minor basic meta-igneous rocks (age unknown)
Byram granite and pegmatite
Pochuck gneiss (amphibolite)
Moravian Heights formation
Franklin limestone

FIELD TRIP A

Friday, May 29

North from Easton to slate and cement areas.

Departure: 1:00 p.m.: by car (as few as possible)
From John Markle Mining Engineering Hall.
Park cars facing east in front of building.

Topographic maps: Easton quadrangle (1:62,500)
Wind Gap quadrangle (1:62,500)
Delaware Water Gap quadrangle (1:62,500)

ITINERARY

Miles

- 0.0 Leave Markle Hall, Lafayette College, which is on the Allentown limestone of Cambrian age. Go two blocks east to Cattell Street, turn north (left) on route 115.
- 1.0 Top of Chestnut Hill. This ridge is the northernmost part of the Reading Prong in Pennsylvania, and is held up mainly by pre-Cambrian gneiss. Directly ahead and about 100 feet lower is the limestone lowland of the Great Valley. Its surface is the Somerville erosion level, and the underlying rocks are mostly Allentown and Beekmantown limestones. From here, when visibility is good, the "slate hills" escarpment, four to five miles distant, can be seen rising 200 to 300 feet above the limestone valley.
- 4.5 Pass from Easton quadrangle to Wind Gap quadrangle.
- 5.0 Cemetery; contact between Beekmantown and Jacksonburg limestones.
- 5.5 Entering Stockertown. Here the route enters the slate hills (underlain by Martinsburg formation) via the deeply incised valley of Bushkill Creek. At the north end of the town the Jacksonburg-Martinsburg contact crosses the highway.

TRIP A

- 7.6 Belfast. The route is approaching the Harrisburg erosion level developed on the Martinsburg slate.
- 10.0 In this vicinity there are several good views of Kittatinny Ridge (Shawangunk formation) and the great piles of discarded slate near Pen Argyl.
- 12.6 Town of Wind Gap. Turn right (east) at stop light; signs point to Pen Argyl.
- 13.8 Turn right 200 feet beyond railroad crossing (no sign at road side); continue to Diamond Slate Quarry and Doney Slate Cutting Works.
- 14.2 STOP I - 45 minutes.
Here can be seen the technique of cutting, splitting, polishing and fabricating slate into many useful and decorative forms such as billiard table tops, blackboards, surfaces used in photogrammetry, and so on.
- 14.4 Return to highway; turn right.
- 15.3 Turn right at street beyond "Esso" sign and proceed 0.7 mile to Stoddard Quarry.
- 16.0 STOP II STODDARD QUARRY - 45 minutes.
This quarry produces slate for all purposes- roofing and structural. The stone is in the "Albion" run, whereas the Diamond quarry is in the "Diamond" run, or bed, of the Martinsburg formation.

At the top of the east face of the quarry can be seen a weathered zone about 75 feet thick which must be removed before good slate can be secured.

The bedding is very well shown. A complete overturned fold is visible in the darker beds. The cleavage has a dip of 15 degrees to the southeast and strikes northeast. The present quarry is nearly 400 feet deep, but another part now filled with water is 700 feet deep. The near-by Parsons quarry, now abandoned and water-filled, was over 800 feet deep.

Leave Stoddard Quarry, return to main road and turn right. This becomes Market Street in Bangor. We have now entered the Delaware Water Gap quadrangle, and the area covered by Wisconsin till. The terminal moraine crosses the route in the eastern part of Pen Argyl.

20.0 Bangor; intersection of Main and Market Streets.
Turn right one short block; turn left on road
marked Portland.

20.9 STOP III - Capitol Slate Company (20 minutes)
Operation of the wire saw.

Two holes are drilled with a calyx drill about 20 feet apart and 10 feet deep. Standards with a pulley at each end are mounted in each hole. A three-strand 3/16 to 1/4-inch cable travels as an endless belt, with sand as an abrasive, over a block of slate. Electric power moves the cable, and water is added with the sand. This device has greatly reduced the wastage in getting the slate out of the quarry.

22.2 Return to Bangor, turn left at first intersection onto Route 90. This section of the route follows the valley of Martins Creek which is deeply incised in the Martinsburg slate below the Harrisburg surface.

25.2 Nazareth Junction; cross Wisconsin terminal moraine (not conspicuous here) and leave area of Wisconsin glaciation. South of Nazareth Junction several bedrock exposures in road cuts are Martinsburg slate.

28.4 Enter town of Martins Creek and cross boundary between Martinsburg and Jacksonburg.

28.5 Turn right at traffic light. Route parallels the strike; Martinsburg escarpment on immediate right; Jacksonburg underlies bench on left; Beekmantown and the Cambrian limestones in valley beyond. In the distance (4 miles) across the Delaware River is Scotts Mountain, underlain by pre-Cambrian rocks.

29.8 Descend steep hill (slow); Upper Jacksonburg (cement rock) exposed in cut on left side of road; contact between Jacksonburg and Martinsburg is in gully on right.

30.0 STOP IV - 10 minutes
Martinsburg-Jacksonburg relations.
Park cars along road in valley of Mud Run. Examine

TRIP A

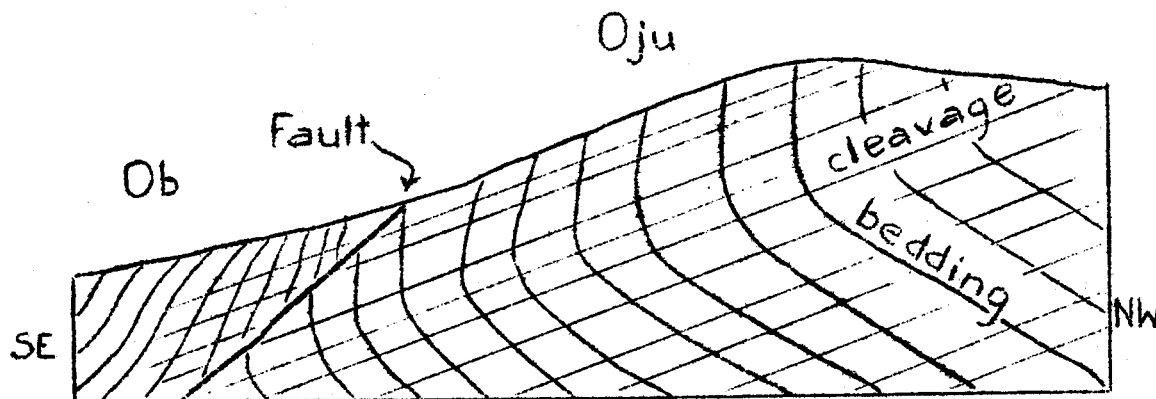
upper Jacksonburg, then walk northwest along side road to exposures of Martinsburg. Note differences.

30.1 Turn left and follow road down Mud Run Valley to intersection with U.S. Route 611. Turn left on 611 for $\frac{1}{2}$ mile to Sandt's Eddy quarry of Lehigh Portland Cement Company.

31.5 STOP V - 50 minutes.
Sandt's Eddy Quarry: Leader for this part of trip is Carl Warmkessel, geologist of Lehigh Portland Cement Company.

Quarry No. 4

At quarry entrance Beekmantown dolomitic limestone is in fault contact with upper Jacksonburg (cement rock). The relations are shown on the figure below.



Between quarries 1 and 2, and between 2 and 3, the blocks of unquarried rock are low grade (low in lime and high in alumina). The more suitable rock between these blocks is quarried along the strike. About $\frac{1}{4}$ mile northwest (in direction of the dip) of quarry No. 3, the top of the Beekmantown is 800 feet below the surface.

TRIP A

The Jacksonburg cement rock contains 30 to 80% CaCO_3 , the average being 65 to 70%. The cement limestone (lower member of the formation) runs 80 to 93%. The desired amount of CaCO_3 for a cement "mix" is 78%. Annville limestone (98% CaCO_3) is mixed with the Jacksonburg when it is too low in lime to make a satisfactory mix.

Fossils are uncommon in quarries 1, 2, 3, and 4, but R.L. Miller (1937 p. 1705) has reported the following:

Prasopora orientalis
Sowerbyella sp.
Dalmanella rogata
Dinorthis pectenella
Zygospira sp.

Conularia sp.
Calymene sp.
Callops sp.
Trilobite-indeterminable

37.5

Return to college on Route 611.

FIELD TRIP B

Friday, May 29

Mineral collecting trip to serpentine quarries north of Easton.

Departure: 1:00 p.m.; by car (as few as possible).
From John Markle Mining Engineering Hall. Park cars facing east in front of building.

Leaders: Arthur Montgomery, John Bertrand.

ITINERARY

Miles

- 0.0 Leave Markle Hall, Lafayette College, which is on the Allentown limestone of Cambrian age, descend College Hill eastward to Route 611 via McCartney and Lafayette Streets.
- 1.1 Turn north on 611 following west bank of Delaware River.
- 1.4 Passing quarry of the C.K. Williams Co. on left. This serpentine quarry was opened nearly 100 years ago and is the largest of its kind in the area. Ornamental serpentine rock was produced, but the main product was ground serpentine-talc rock for use as paper filler. An ornamental pink dolomite-green serpentine rock, called verdolite, was also produced in quantity at one time. A more recent use for the crushed serpentine was in terrazo floor tile. Quarry operations were discontinued in 1947.
- 2.3 Weygadt Gap - 15-minute stop. A water gap cut through Chestnut Hill by the Delaware. High cliffs on the west side of road consist of pre-Cambrian gneisses in core of hill. Slickensided surface shows steeply pitching fault striations. From north to south, are Byram granite gneiss and pegmatite, gray-green thinly-banded migmatitic gneisses of the Moravian Heights formation (south-central part of outcrop), more pegmatitic Byram, and still farther south past cliffs a zone of Pochuck gneiss intensely altered in part to a spotted epidote-orthoclase

rock. Crosscutting tourmaline-bearing pegmatites are common in the cliff exposures, and fair tourmaline prisms, as well as graphic intergrowths of quartz and tourmaline can be collected. Attitude of foliation and bedding here is N60E, 60SE.

From here the regional position of the main zone of serpentized Franklin limestone may be observed, close to river on west side farther downstream, then crossing river and continuing northward across the Delaware through quarry of the Royal Green Marble Co., now in operation and the plant of which is clearly visible from the Gap.

- 3.3 Turn around, retrace route, and drive into main part of Williams Quarry; 2-hour stop. Mineral collecting in quarry and on old dumps by river.

This quarry used to be one of the finest mineral localities in Pennsylvania. Since 1947, good specimens have been increasingly hard to find, but the old dumps by the river, recently turned over for a pipe-line installation, now offer the best collecting opportunities in 4 or 5 years.

For a discussion of the background geology and mineralogy of this serpentine deposit, see Franklin limestone, under Pre-Cambrian Rocks, in this Guidebook. Excellent descriptions of this and related deposits are given in Peck (1905), and Fraser (1939, pp. 165-169). The mineralogy of the Williams deposit was covered by Miller (1939, pp. 435-463). The main face of the northern part of the quarry is largely in tremolite rock, mixed with pale-green serpentine. High above the central wall, are outcrops of dark-green serpentine, veined by fibrous calcite and associated with some tremolite. Granite pegmatite crops out just above the quarry wall here, and is reported to have extended nearly to the present highway. Recent slides have piled up huge blocks in the south part of the quarry; the west wall here is a poor grade of serpentine-talc rock, while the south wall is largely in much-sheared pegmatite. Another great mass of pegmatite borders the quarry on the north.

Good specimens of the following minerals can be collected here: Calcite (ordinary and fibrous), diopside (broad greenish-gray prisms partly altered to pale-green serpentine), dolomite (flesh-colored),

muscovite-phlogopite (large crystals in serpentine), pyrite (small cubes), pyrolusite (dendritic coatings), quartz (small prisms in cavities with dolomite), serpentine (fibrous chrysotile and massive serpentine of many shades), talc (gray-white foliated and massive), tremolite (small square-stubby and long flattened blades), uranophane (yellow coatings), vermiculite (olive-green micaceous alteration product of serpentine).

Other minerals formerly found in good specimens, but now rarely obtainable: autunite (minute yellow-green plates as coatings), carnotite (bright-yellow coatings), sphene (small wedge-shaped brownish crystals with actinolite), thorianite (small rounded resinous-black grains in serpentine, surrounded by brown-yellow-orange thorium-uranium alteration products, among which thorogummite may be a new species), zircon (excellent brownish prisms up to an inch long in serpentine-diopside rock).

- 4.3 Continue south on 611; steeply southward-dipping beds of Allentown Cambrian limestone on right
- 4.6 Turn left at intersection with Route 22; bear left, take underpass beneath bridge.
- 4.9 Delaware River bridge
- 5.3 In Phillipsburg; turn sharp left, follow paved road along east bank of river.
- 6.2 Good view of Williams Quarry across river.
- 6.6 Steeply northward-dipping layers of Pochuck gneiss on right for next one-half mile. Here a fine-grained amphibolite, in part biotite-rich. Attitude of foliation is N50E, 70NW.
- 7.4 Plant and quarry of Royal Green Marble Co.; 2-hour stop. Mineral collecting in dumps along road and inside quarry. Quarry is dangerous, and every precaution must be taken.

This quarry is also quite old, and has produced some excellent ornamental serpentine. It is now actively producing crushed serpentine for terrazo flooring.

This serpentine deposit is on the regional strike (N50E) of the same zone of altered Franklin limestone seen at Williams Quarry. Inside the quarry tremendous shearing is evident. In the north part, the northeast wall is in a complex of dark, banded, contorted and brecciated rocks of apparently impure-calcareous character. Masses of a bright-pink brecciated dolomite are of note here. Granite pegmatite (tourmaline-bearing) crops out near the top of this wall. Across this part of the quarry, the west wall consists mainly of much-sheared pale-green serpentine-talc rock.

In the deep central part of the quarry, a zone of magnificent deep-green serpentine is exposed, much veined by white calcite and showing inclusions of large rhombohedrons of flesh-pink dolomite. Much of the west wall here consists of gray, banded, graphitic marble. Banding and foliation apparently represent compositional banding and bedding; here the strike is the usual regional one of N50E, with nearly vertical dip. A short distance farther north, still in the bottom part of the quarry and along the west wall, the banding veers around to N20E. Complex folding and tremendous crushing of the Franklin limestone are well shown in this quarry, and are definitely related to the profound mineralogical changes that have transformed dolomitic limestone into serpentine and talc.

Good specimens of the following minerals can be collected here: dolomite (large flesh-pink rhombohedrons, also pinkish-red masses), graphite (small scales in gray marble), molybdenite (excellent, large, scaly masses in serpentine and dolomite), pyrite (small cubes), serpentine (various types and colors), talc (gray, foliated).

11.5 Return to Markle Hall

FIELD TRIP C

Saturday, May 30

North from Easton to Panther Valley Anthracite Region

Departure: 8:30 a.m. promptly; by bus.
From John Markle Mining Engineering Hall.

Topographic Maps:	Easton quadrangle	(1:62,500)
	Allentown quadrangle	(1:62,500)
	Mauch Chunk quadrangle	(1:62,500)
	Nesquehoning quadrangle	(1:24,000)
	Tamaqua quadrangle	(1:24,000)
	Hamburg quadrangle	(1:62,500)
	Allentown West quadrangle	(1:62,500)

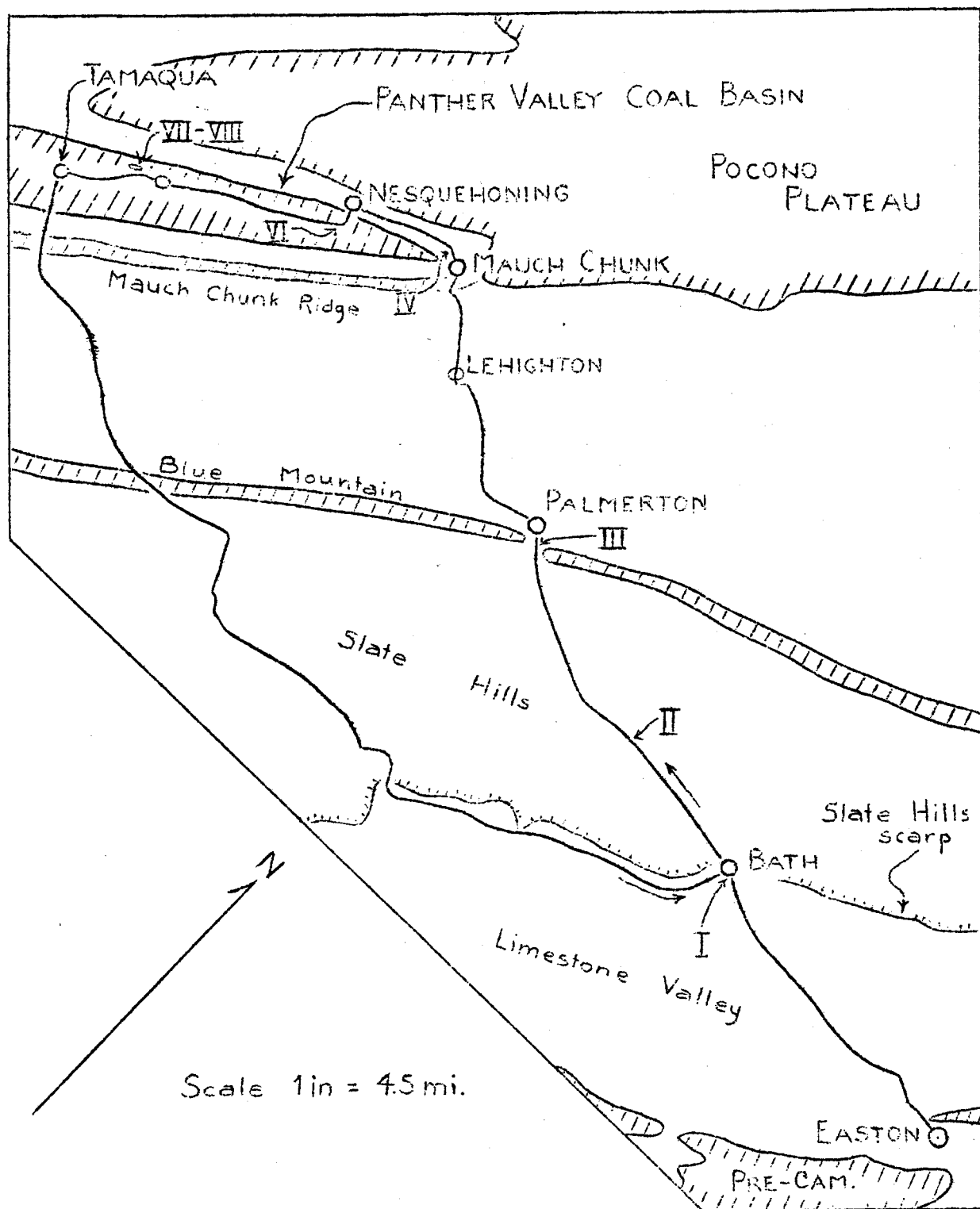
Important stops will be made only on the Allentown, Mauch Chunk, Nesquehoning and Tamaqua quadrangles.

General Information: Box lunches will be delivered to the busses. Purchase box lunches at the registration desk.

At all stops a long whistle blast is the signal to return to the bus immediately.

Much of the trip is over heavily travelled highways. It is vital that you pay strict attention to warnings and obey the guards.

ROUTE MAP - TRIP C

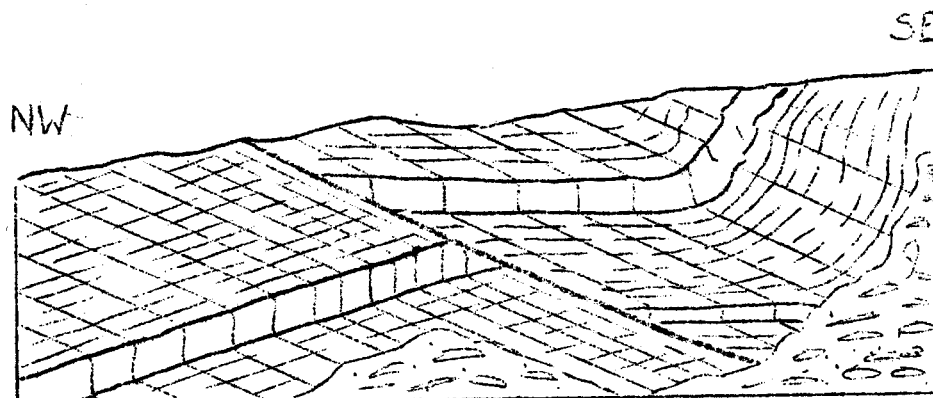


ITINERARY

Miles

- 0.0 Start from John Markle Hall (Easton quadrangle), turn north (left) on McCartney Street, then west on Lafayette Street which lies approximately on the contact between pre-Cambrian (in Chestnut Hill) and Leithsville limestone.
- 1.7 Exposure of pre-Cambrian gneisses, mainly Byram granite gneiss, in gap where Bushkill Creek has cut through Chestnut Hill. Franklin limestone, largely altered to serpentine and talc, occupies a zone along the south edge of the hill.
- 2.6 Bear left on black-top road along Bushkill Creek and at railroad crossing pass from Easton to Allentown quadrangle.
- 3.2 Cross bridge over Bushkill Creek.
- 3.4 Exposure of pre-Cambrian Byram granite and pegmatite in old overpass on right side of road. Route immediately turns west.
- 4.1 Seipsville; intersection with State Route 45. Pre-Cambrian crops out in low hill just beyond houses to north (extension of gneiss seen at 3.4) and also on ridge immediately to south (western extension of Chestnut Hill). For the last mile, route has followed a very narrow synclinal limestone valley.
- 4.8 Turn west from route 45 onto Bath Road. From here to Bath, route lies on the Somerville erosion surface and is underlain by Cambro-Ordovician limestones. Sinkholes of various sizes are visible along the way. From several high points it is possible to see all the way from the Reading Prong on the south to Kittatinny Mountain on the north, (pre-Cambrian to Silurian). The "slate hills" (Martinsburg) escarpment between the Somerville and Harrisburg surfaces is visible several miles to the north.
- 5.5 Vicinity of Lomero Acres farm. Route crosses boundary between Allentown (Cambrian) and Beekmantown (Ordovician) formations.

- 8.1 Entering Newburg. Outcrop of Beekmantown on right; silty dolomitic limestone shows low dip to south.
- 8.2 Cross State Route 12 in Newburg.
- 8.6 After leaving Newburg there is a good view of the slate hills escarpment ahead and to north.
- 9.6 Outcrop of Beekmantown in cut on left. N35E, with low dip to northwest. Red clay soil above outcrop.
- 11.0 Good view of Penn Dixie Cement Company plant north of road.
- 11.3 Railroad crossing at edge of Bath. Contact between Beekmantown and Jacksonburg just beyond railroad.
- 11.5 STOP I - 2 minutes. Do not get out of bus.
Excellent view of series of cement quarries southwest of town in Jacksonburg limestone; they occupy bench at foot of Martinsburg slate escarpment.
- 11.8 Stoplight in Bath; cross State Route 512 and rejoin Route 45. Immediately after passing through center of Bath and across railroad, route ascends Jacksonburg bench at foot of Martinsburg escarpment.
- 12.4 Ascend Martinsburg escarpment via short stream valley.
- 13.9 On top of the escarpment on the Harrisburg surface; a striking difference in topography is evident, a rolling hilly upland on Martinsburg shale and slate. From here to Lehigh Gap route will be on this surface.
- 15.5 In this vicinity from several high points there are very good views of the Harrisburg surface and Kittatinny Mountain. Soil shows abundance of slate fragments.
- 15.8 Good views of Little Gap, a wind gap, and Lehigh Gap.
- 16.7 STOP II - 10 minutes.
On south side of valley of Hokendaugua Creek; large slate outcrop in cut on right shows folding, faulting, and two kinds (?) of cleavage; complex structural relations. Plunge is toward west. See figure on next page.



20.7 Crossroads in Cherryville.

20.8 Leave Allentown quadrangle; enter Wind Gap quadrangle. Route crosses only the southwest corner (distance of about 1 mile) of this quadrangle, then enters Allentown West quadrangle (1 mile across north-east corner), and finally Mauch Chunk quadrangle.

22.3 Descending hill into Berlinsville; dumps of several slate quarries on left.

24.8 STOP III - 30 minutes.
Ordovician-Silurian relations at Lehigh Gap.

CAUTION: Do not cross highway until signalled to do so by road guards. Walk several hundred yards along railway to gap. Rapidly repeated blasts of the whistle indicate an approaching train.

Unconformity between Martinsburg (Ordovician) and Tuscarora (Silurian). Several hundred feet south of contact beds of Martinsburg show strong slaty cleavage dipping steeply southward; bedding planes are weakly developed as widely-spaced jointing; as contact is approached cleavage dies out, bedding surfaces become more pronounced, and several sets of joints appear in the Martinsburg; bedding shows attitude of N60E, 41 NW. Graptolites have been found in these beds.

At the contact, three to four feet of coarse basal conglomerate (Bald Eagle?) rests upon the slate with iron oxide staining along the contact.

Pebbles are mainly quartzite. The conglomerate passes upward into medium-grained dark gray sandstone or graywacke. Beds strike N60E and dip 32 NW; a 9-degree difference in dip between the two formations. Some black shale interbeds and small faults are present in the Tuscarora here.

From the north end of the Gap one can obtain an excellent view of the Clinton, the red Bloomsburg facies, and the ridge (with sand quarry) made by the lower Devonian sandstones (Palmerton and Oriskany).

- 25.1 Junction with U.S. Route 309 at Weiders Crossing.
- 25.7 Crossing Aquashicola Creek.
- 25.8 Road cut on right in Clinton sandstone, siltstones, and shales.
- 26.0 Conspicuous outcrop of red Bloomsburg shale, siltstone, and sandstones; beds are vertical.
- 26.2 Entering Palmerton.
- 27.1 Palmerton smelter and treatment plant of New Jersey Zinc Company on left.

The ridge north of Palmerton is held up by Palmerton sandstone (Onondaga) and to a lesser extent by the Oriskany. Heavy Palmerton rubble, probably covering upper Silurian limestone, is present along the route in the western part of the town.

- 28.4 After leaving Palmerton and where the route begins to turn northward, two conspicuous ridges can be seen across the Lehigh River. Both are held up by the Palmerton sandstone. In the southernmost ridge the rock sequence, from south to north, is: Oriskany sandstone (20 feet), chert (20 feet), hematite (4 feet), Bowmanstown chert (20 feet), sandstone (4 feet), all with a south dip of 80 degrees. These beds are in fault contact with gently northward-dipping Palmerton beds (see sketch). The same sequence is exposed on this side of the river along the highway.

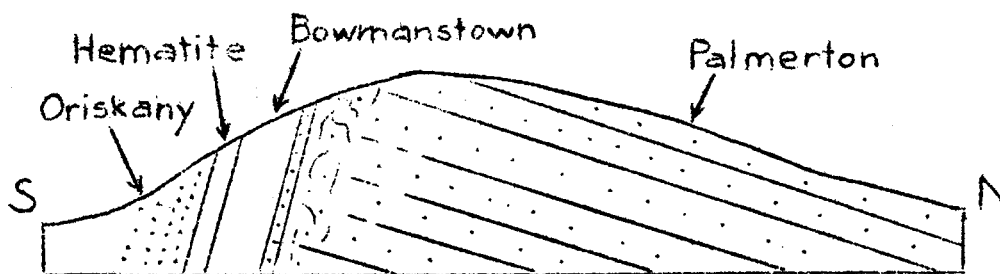


Fig. 9

In Stony Ridge (with conspicuous pinnacles) immediately north of Lizard Creek, Palmerton beds dip 40 degrees south; they are overturned because at the north edge of the ridge they overlie, apparently conformably, Marcellus shale. From here northward for about one mile (to Nis Hollow), the dip is south. (See fig. below.)

29.3 Road junction in Bowmanstown.

29.6 Route crosses a fault here; south of it Hamilton beds dip south (overturned); north of it Tully, Burket, and younger beds dip northward. Across river the fault follows Nis Hollow.

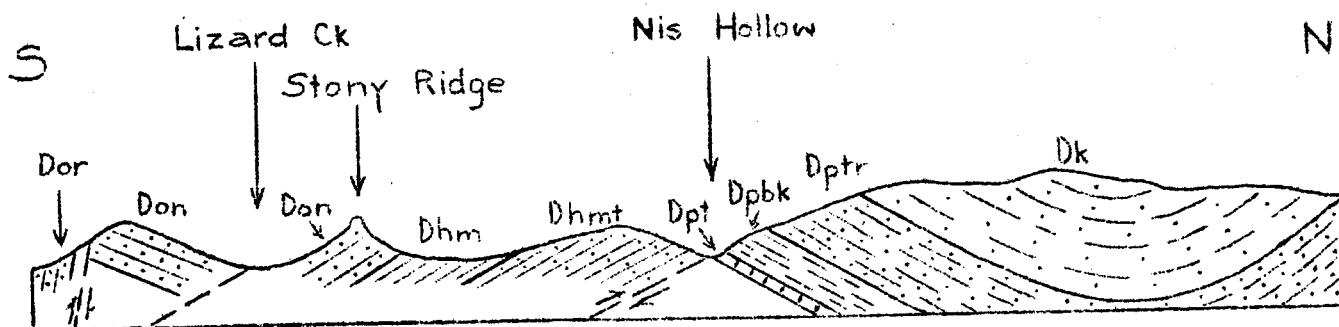


Fig. 10

- 30.1 Road cut on right; Catskill red beds exposed in a syncline; north dip changes to south.
- 30.9 Top of terrace north of Parryville; terrace gravel 70 feet above river; mostly boulders of Catskill, Pocono, and Pottsville conglomerates, sandstones and quartzites.
- 32.0 Hill leading down to Lehighon bridge; road cut exposes sandy shales of Portage age dipping southward.
- 32.3 East end of bridge over Lehigh River to Lehighon. Junction with U.S. Route 209. High wooded ridge visible to north of Lehighon is Honesdale sandstone in upper Catskill.
- 32.7 Just north of west end of river bridge Centerfield coral reef (Hamilton) exposed in high cut.
- 33.8 North edge of Lehighon; passing nearly vertical beds of Trimmers Rock (Portage) and then Delaware River flags (in Catskill facies).
- 34.4 Interfingering of red and non-red Catskill beds.
- 34.6 Entirely red Catskill; entering Packerton.
- 35.2 Massive beds of upper Honesdale visible in road cut and in Bear Mountain across river, which is held up by the Honesdale.
- 35.6 Route curves to west and parallels strike of Honesdale and Cherry Ridge beds in the Catskill. Ridge immediately north of bend in river (to our right front) is held up by Pocono sandstone. Next ridge to north, now coming into view, is Mt. Pisgah which is formed by Pottsville conglomerate. The narrow valley between the two ridges is underlain by Mauch Chunk red shale.
- 36.1 About 100 yards short of the curve near the top of the Catskill there is an occurrence of uranium minerals, mainly autunite crystals, as coatings on fracture surfaces and as replacements of carbonized plants. A scintillometer carried in a car past this point (especially on the inside lane of the highway) will give a reading slightly higher than the background count. A few feet

stratigraphically above these beds the uppermost red beds of the Catskill can be seen; they continue to the town of Mauch Chunk.

- 36.4 Foot of hill; entering Mauch Chunk. In vicinity of Anthony's Garage Catskill intergrades with Pocono. The town is situated mainly on Pocono, nearly vertical beds of which can be seen across the river.
- 36.7 Railroad depot in Mauch Chunk.
- 36.8 Pocono intergrades with Mauch Chunk formation; to the north along the highway and railroad there is an almost complete section of the Mauch Chunk.
- 37.2 At road junction and Esso Service Station route crosses a 70-foot bed of dark gray sandstone and conglomerate (not visible along highway) which dips north. It lies at the base of the Pottsville formation.
- 37.4 Axis of syncline which plunges west and forms the Panther Valley coal basin. The red shale in the road cut is above the basal conglomerate and is Pottsville. The axis of the syncline can be seen in the red Mauch Chunk beds across the river (at creek mouth). The ridge of Pocono sandstone can be seen beyond East Mauch Chunk, making a loop where it crosses the synclinal axis.

Immediately after crossing the axis, the route comes again (at the curve) to the conglomerate (dipping south) and the principal zone of uranium mineralization, which extends westward along the highway for nearly one half mile.

- 37.5 STOP IV - 45 minutes.
Uranium in Pottsville conglomerate and sandstone.

CAUTION: Traffic is heavy (and fast) and there is only a very narrow shoulder on which to walk. Follow directions given and cross the highway only on signal. Do not get on the concrete surface at any other time.

After leaving the bus, follow the group leader westward along the outcrop for about one-half mile

to the point where busses are parked. Along the way you will pass from the Mauch Chunk to the Nesquehoning quadrangle.

Because the road follows the strike here, the entire outcrop is in the 70-foot basal conglomerate and sandstone member of the Pottsville which has an average dip of 40 degrees south. Its contact with the Mauch Chunk shale is covered by the highway.

Several uranium minerals, the most conspicuous of which is carnotite, occur in the sandstone and conglomerate. The beds are very lenticular and few of them can be traced more than a few yards. In the conglomerate lenses carnotite occurs in fractures, in the spaces between pebbles, and possibly as a replacement of the cementing material. In the sandstone it is limited to fractures. Along the outcrop there is a number of lenses with rather high concentrations of uranium, and samples collected anywhere in the member contain uranium. The uranium extends for an undetermined distance down the dip. Some of the highest values have been obtained from rock, usually sandstone, in which there are no carnotite or carnotite-type minerals.

Thin sections of high-grade ore of this latter type show a strongly brecciated arkose containing quartz as a major constituent and abundant grains of feldspar (both albite-oligoclase and orthoclase as well as much sericitized and sausseritized calcic plagioclase). Subangular grains of siltstone, carbonaceous shale, muscovite and calcite are present. A few of the calcite grains appear to be residual, but most surround other grains as tongue-like shapes, some of which extinguish in unison, even though far apart, and these represent late-stage calcite as a fracture-filling or cementing medium or else late calcite of hydrothermal origin. Heavy minerals, such as zircon, rutile, and magnetite, are conspicuously absent, as are hydrothermal minerals like sulfides. This rock has been derived from two chief sources, from granitic rocks and from carbonaceous siltstones and shales.

Quartz grains are much fractured. Where these are clustered together, without intervening softer grains to absorb the pressure by yielding, they are reduced to a fine-grained crush mortar. More isolated grains are fractured and broken apart so that calcite and chloritic and shaly material have been squeezed around them plastically. All quartz grains show pronounced undulatory extinction.

Much of the carnotite, first determined by Wherry (1909, 1912, 1914) is of recent secondary origin, as seen by the fact that it is especially abundant as surface coatings or near-surface fracture fillings. At the present time ground water is depositing on exposed surfaces or in near-surface fractures a number of secondary uranium minerals whose identity is not yet known. Several of these were checked by x-ray powder photograph, and at least two could not be identified with any known species. They occur as coatings or clusters of minute tabular or platy crystals, range in color from palest green to pale apple-green to bright greenish-yellow, fluoresce a brilliant green, and are all apparently carbonates.

The Lehigh Coal and Navigation Company is currently doing development work on this deposit.

37.8 From here (the point where busses are reboarded) to Nesquehoning, the route lies in a Mauch Chunk Valley; several outcrops of red shale occur in road cuts.

Broad Mountain, a westward extension of the Pocono Plateau, is on the north. Nesquehoning Mountain, the Pottsville ridge on the north edge of the Panther Valley coal basin, is to the south (see Fig. 11).

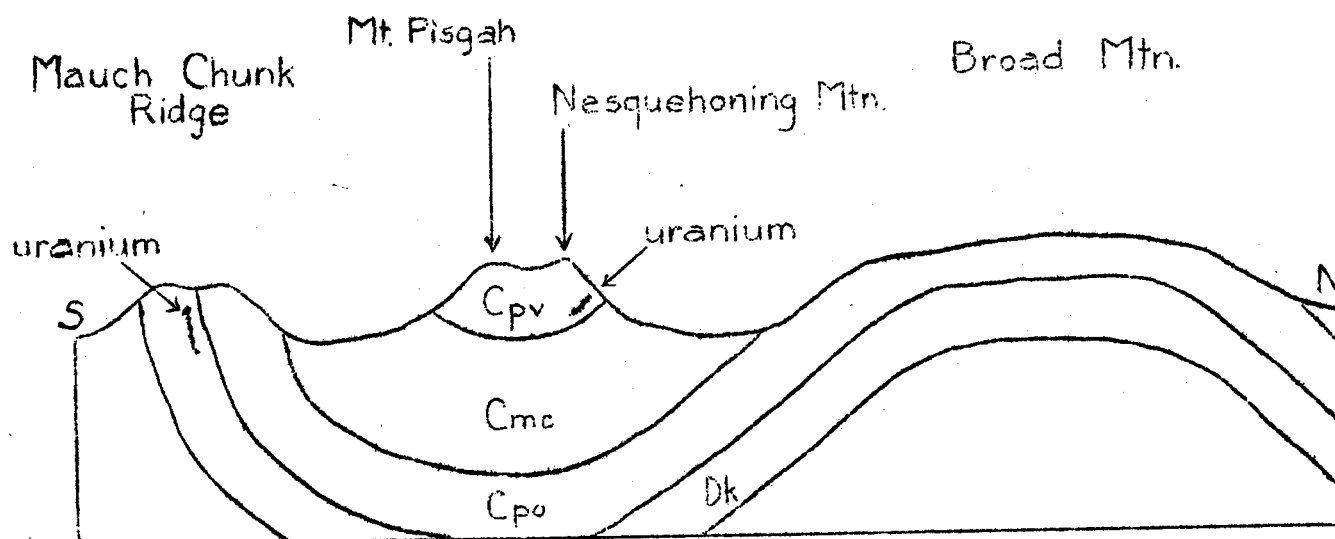


Fig. 11

Legend

- Cpv - Pottsville
- Cmc - Mauch Chunk
- Cpo - Pocono
- Dk -- Honesdale and Cherry Ridge

40.3 STOP V - 45 minutes.
Roadside rest (Pa. Dept. of Highways); LUNCH.

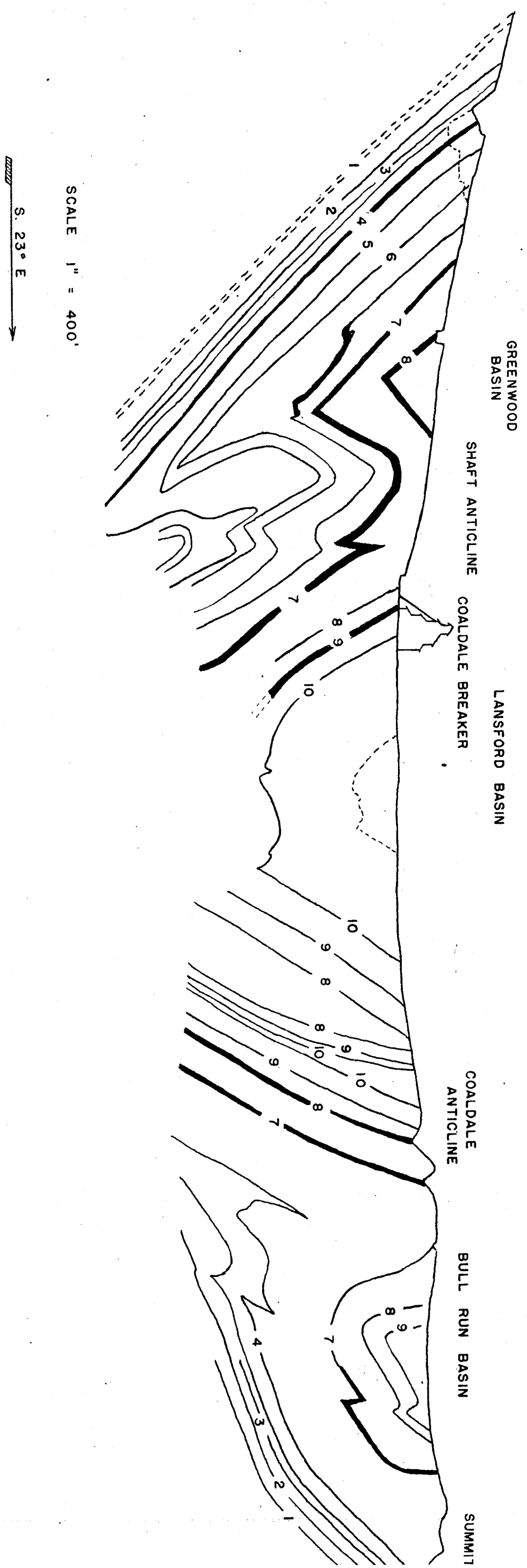
41.6 West edge of Nesquehoning; turn south following U.S. Route 209 and pass through Nesquehoning Mountain (in Nesquehoning Gap) into the Panther Valley coal basin, the easternmost extension of the Southern Anthracite Field.

Material in the large culm piles has come from the Nesquehoning Mine of the Lehigh Navigation Coal Company located at the head of the gap.

Ascending the gap one can see the intertonguing Pottsville and red Mauch Chunk shale in road cut on left. This transitional zone is about 360 feet thick. Farther on, conspicuous outcrops of massive conglomerates in the upper part of the Pottsville, which form the crest of the ridge, are visible. The Buck Mountain coal (at the base of the overlying Allegheny formation) and the Mammoth coal cross under the highway just short of the curve.

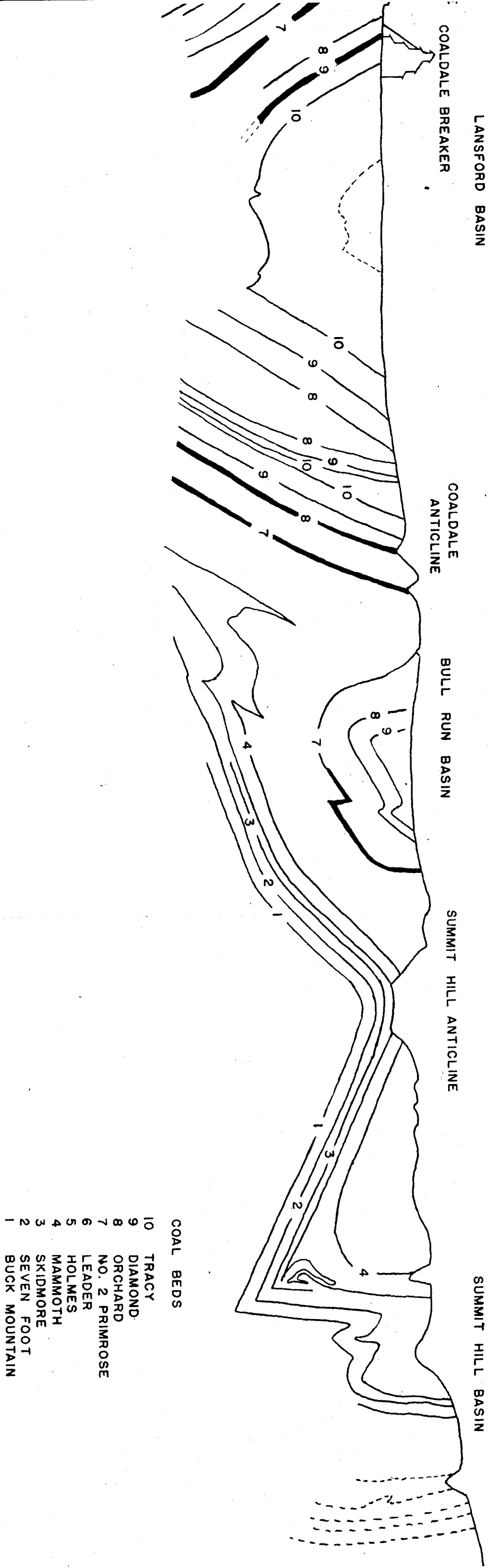
- 42.1 Head frames for the shafts of the Nesquehoning Mine, (Lehigh Navigation Coal Co.) on right. Four- to five-foot bed of coal in road cut on left. Five beds of coal are mined here, the Buck Mountain, Mammoth, lower and upper Primrose and the Orchard (see columnar section, Fig. 13). Strip-pings visible on both sides of road.
- 42.4 STOP VI - 15 minutes.
Coal stripping in Primrose and Holmes coals.
- Three coal beds are visible on the west face of the pit, the Primrose appears twice, on the foot wall and in the center; and the Holmes in the south end of the pit. The structure is very complex.
- This stripping was started in June, 1950 at the north edge where the Primrose is 19 feet thick. The Mammoth stripping can be seen to the north beyond the mine buildings.
- Plant fossils, mainly fragments which have come from the shales underneath the several coal beds can be found around the edges of the pit.
- From this point to Coaldale, the route lies essentially along the axis of Panther Valley synclinorium (see cross section of Panther Valley following this page).
- 45.1 Dodson Colliery and huge culm piles on right. Many strippings visible.
- 45.4 Entering Lansford. At 3rd cross street pass from Nesquehoning to Tamaqua quadrangle.
- 47.3 Passing Coaldale Colliery of Lehigh Navigation Coal Company.
- 47.5 Beyond second traffic light on right notice an entire block of houses tilting and subsiding because of mining activities underneath.
- 48.0 West end of Coaldale; huge piles of waste brought up from mines. Notice attempts at reforestation on culm banks.
- 48.6 Bear right at fork (Methodist Church on right).

CROSS SECTION OF PANTHER VALLEY



FROM SECTION BY LEHIGH NAVIGATION COAL CO.

CROSS SECTION OF PANTHER VALLEY



FROM SECTION BY LEHIGH NAVIGATION COAL CO.

48.9 Right turn onto secondary road across creek and railroad to Greenwood Stripping of Lehigh Navigation Coal Company.

50.2 STOP VII - 2 hours.
Greenwood Stripping

At this stop, made possible through the courtesy of the Lehigh Navigation Coal Company, we will be conducted on a tour of the stripping and surroundings by company representatives.

The Greenwood stripping is one of the most spectacular in the entire anthracite region, not only in size but also in the structure of the coal beds. The stripping is in a minor syncline known as the Greenwood basin. The Mammoth and Primrose are the only coal beds in the stripping, but the Mammoth has been folded in an extraordinary manner and has been "injected" into overlying beds where it is referred to as another bed known as the Forty-foot bed (see figure following this page).

The present depth of the stripping is 350 feet; maximum depth at completion of the operation will be 700 feet. To date 24,000,000 cubic yards of material have been removed. An additional 21,000,000 cubic yards remain. Total production has been $2\frac{1}{2}$ million tons of rough coal; 7 million tons will be removed in the future. Each day 15,000 cubic yards of material, including 3,000 to 3,500 tons of unprepared coal, are removed. The stripping was started in June, 1945.

To do this job the stripping contractor has about \$2,000,000 worth of equipment in the pit. It includes:

- 45 30-Ton Euclid trucks
- 11 9-inch blast-hole drills
- 1 Ingersoll-Rand Quarrymaster drill
- 2 $6\frac{1}{2}$ -yard shovels
- 1 5-yard shovel
- 1 4-yard shovel
- 1 $2\frac{1}{2}$ -yard shovel
- 4 bulldozers

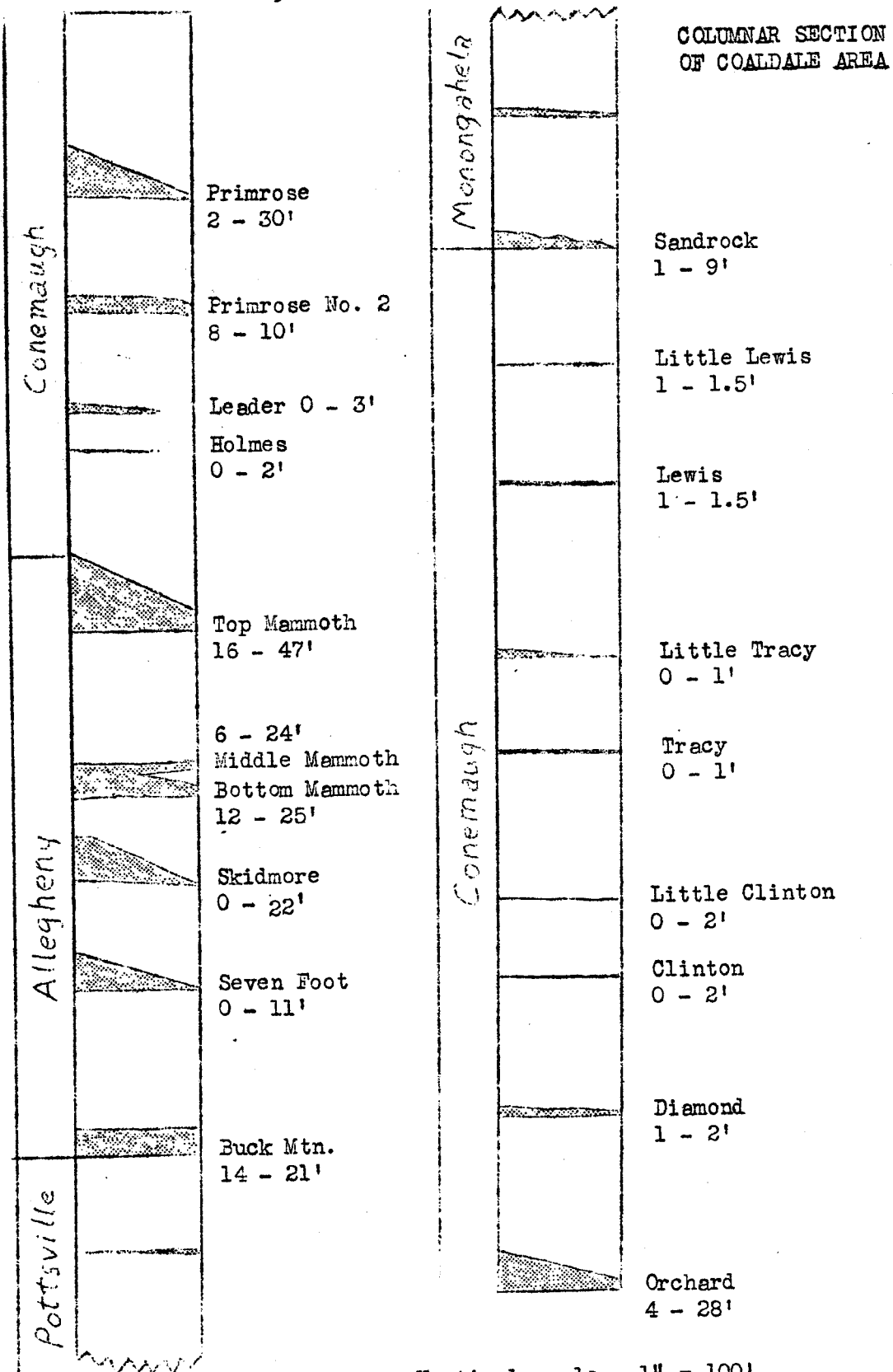


Fig. 13

50.9

STOP VIII - 20 minutes.

Fossil plant collecting along coal haulage road to Tamaqua Colliery.

Some of the best collecting in the valley may be done on the dumps of stripping refuse. In such cases determination of the stratigraphic horizon is usually impossible. Some of the plants yielded by certain horizons are the following (Kidda, 1952):

Upper part of the Pottsville

Mariopteris lobata
Neuropteris aculeata
N. ravinervis
Alethopteris grandini
Lepidodendron sp.
Sphenophyllum sp.
Stigmaria ficoides

Roof and shale partings of Buck Mountain coal

Alethopteris serli
Asterophyllites equisetiformis
Asterotheca herdi
Validopteris serrata

Mammoth coal (shales on roof and floor)

The flora is abundant but poorly preserved.

Asterotheca cf. miltoni
Neuropteris tenuifolia
N. scheuchzeri
Odontopteris sp.
Pecopteris sp.
Ptychopteris unitus

Orchard coal (shales on roof)

Annularia sphenophylloides
A. stellata
Neuropteris scheuchzeri
Pecopteris

Diamond coal (from the underlying shales)

Asterotheca sp.
Neuropteris heterophylla
N. scheuchzeri
Pecopteris vestita
Sphenopteris cf. obtusiloba

Sandrock coal (from underlying shale)

Neuropteris aculeata

N. gigantea

N. ovata

This constitutes the last stop on the trip. From here on, as along the route thus far, the stratigraphy is clearly reflected in the topography. Brief notes are for use in aiding you to keep oriented for the remainder of the trip.

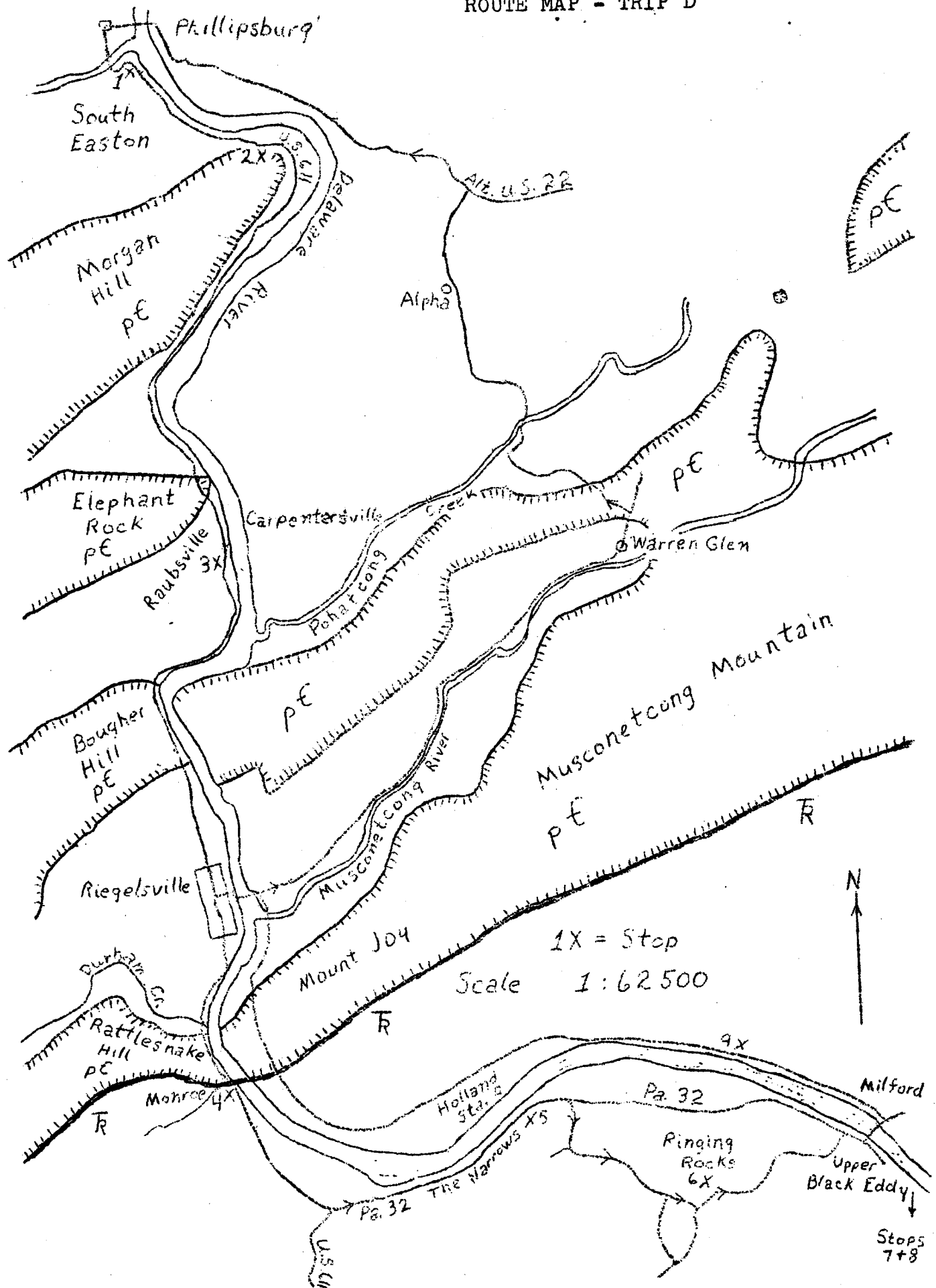
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- 51.8 Intersection with U.S. Route 209. Lelite plant on right.
 - 52.2 Entering Tamaqua.
 - 53.0 Intersection with state route 29. Route turns south from the main synclinal axis and crosses all the coal beds, in reverse order, that were crossed where the route entered the syncline at Nesquehoning.
 - 53.5 In the gap of the Little Schuylkill through Pisgah Mountain beds are nearly vertical. The Buck Mountain stripping is conspicuous.
 - 53.7 Pottsville and Mauch Chunk intertonguing. Very good section of Pottsville and Mauch Chunk. Beds nearly vertical.
 - 54.2 Gap through Mauch Chunk Ridge. Pocono and upper Catskill sandstones (Honesdale).
- For the next 8 miles, to Lizard Creek, the route lies on Upper and Middle Devonian sandstones and shales. A synclinal axis along which Catskill lower red beds crop out is crossed at about 59.4 miles.
- 58.6 Pass from Tamaqua to Hamburg quadrangle.
 - 62.1 Junction with state route 895 at Snyders; bridge over Lizard Creek. Soon after crossing the creek the Palmerton and Oriskany are crossed. Only scattered boulders show along the road.
 - 62.6 Crossing Keyser limestone. There is a small abandoned quarry to the right of the road.

- 63.3 After starting up the north side of Blue Mountain, red color in fields is Bloomsburg.
- 63.7 Road cut shows nearly vertical beds of Bloomsburg.
- 64.4 Near top of mountain; Clinton beds on right.
- 64.9 Top of Blue (Kittatinny) Mountain; elevation 1,360 feet; blocks of white Tuscarora sandstone visible.
- Magnificent view of Great Valley; spectacular difference in resistance to erosion between Tuscarora and Martinsburg. Three or four miles to the south Shochary Ridge, held up by sandstones of the upper member of the Martinsburg, rises about 200 feet above the general level of the Harrisburg surface.
- 66.9 Large block (boulder) field of Tuscarora sandstone much of which has moved down the mountain over Martinsburg shale.
- 68.1 From crest of hill a big "offset" in Blue Mountain (9-10 miles toward the west) can be seen. It is formed by two plunging folds in the Tuscarora sandstone. The sharp cone-shaped hill is Spitzenberg which, according to Lawrence Whitcomb, is capped by Triassic conglomerate.
- 69.9 Intersection with route 143.
- 72.5 Intersection with route 100 at Jordan Creek.
- 81.6 Descending Martinsburg escarpment; view of limestone valley (Cambrian and Ordovician) to south. Several cement plants in sight along base of escarpment.
- 83.1 Entering Egypt. Here we cross an arm of the Martinsburg bordered on the east and west by limestones.
- 84.5 Descend from the Martinsburg onto the Jacksonburg at Cementon. Cement quarry on right.
- 85.0 Lehigh River between Cementon and Northampton. Leave Allentown West quadrangle and enter Allentown quadrangle.

TRIP C

- 86.2 Very large quarry of Universal Atlas Cement Company.
 Route lies on Jacksonburg bench and follows the
 strike to Bath.
- 89.8 Cement plant on left.
- 91.1 Plant and quarries of Keystone Portland Cement Com-
 pany. These are the quarries seen from Stop I.
- 91.9 Intersection with route 45 in Bath. From here to
 Easton same route as followed on first part of
 trip.
- 93.3 Notice slate fence posts on right.
- 103.9 Markle Hall; end of trip.

ROUTE MAP - TRIP D



FIELD TRIP D

Sunday, May 31

Southern Trip

Departure: 9:00 a.m.; by bus
From John Markle Mining Engineering Hall.

ITINERARY

Miles

- 0.0 Markle Hall. Proceed east on High Street to McCartney Street. Turn right three blocks to right turn down hill on College Avenue.
- 0.4 Dip slope of Allentown limestone on right. Attitude of beds: N50E, 55SE. Follow U.S. Route 611 through Center Square and turn left immediately after crossing Lehigh River.
- 1.3 STOP I - 20 minutes.
Allentown limestone.
- Climb bank to Lehigh Valley Railroad tracks.
- Exposure of Allentown formation of Cambrian age. Close to contact with Limeport. It is a massive, sandy, dolomitic limestone containing interbedded chert, bedding faults, sedimentary breccias, prominent diastems and biostromes (Cryptozoon fieldii). Attitude of beds: N65W, 18SW.
- 2.0 Approximate location of a synclinal axis here.
- Across Delaware River, in railroad yards, Mount Parnassus is visible. It is composed to two blocks of pre-Cambrian granite gneiss thrust upward into the Cambrian limestone. The softer limestone was partly removed by the railroad company to allow building of a spur track through the hill.
- 2.2 Beds of Allentown limestone in quarry on right show a change of dip to north. South wall is in a fault zone.
- 2.3 Easton Sewage Disposal Plant on right.

- 2.6 Outcrops of Leithsville formation on right and then on left. Dark gray-blue, rather massive, high-magnesian limestone. Attitude of beds: N55E, 60NW.

2.7 STOP II - 20 minutes.

Pre-Cambrian-Cambrian contact in old trolley cut.

This is on nose of Morgan Hill, an anticline plunging northeastward. The plunge carries the pre-Cambrian surface under the river into New Jersey where it is buried beneath Cambrian limestones.

Hardyston beds lie unconformably on pre-Cambrian gneiss, largely Byram granite with minor dark layers of Pochuck gneiss. Contact is irregular and in places almost obliterated by strong shearing and invasion by quartz veins, but dips gently northeast (about 20 degrees) apparently conformable with plunge of fold. It was here that Fraser (1939, pp. 198-200) found evidence of pegmatite veinlets intrusive into Hardyston.

Some irregular, thin, discontinuous lenses of grayish arkosic basal conglomerate are at base of Hardyston, with fine-grained, thinly-laminated arkosic sandstone above. Rocks above and below contact much sheared and mylonitized to a schistose rock in part. Thin sections of sheared arkosic sandstone show subangular to angular quartz grains together with abundant grains of microcline embedded in a matrix of sericitic-chloritic impurities. Small grains of zircon are numerous.

- 3.1 Across river Somerville erosion surface truncates southward dipping Allentown or Limeport beds.
- 3.3 For about two miles the road here follows base of Morgan Hill, approximately on contact between pre-Cambrian and Cambrian rocks.
- 3.8 Pre-Cambrian gneisses exposed on right. Mostly Byram granite gneiss and pegmatite, with minor dark layers of Pochuck amphibolitic gneiss. Gneissic foliation here: N80E, 70SE.
- 4.6 Mylonite zone begins here. Granite becomes slabby and almost schistose, with gray-green layering due to streaking out of chloritic or sericitic material around porphyroclasts of feldspar and quartz. Some of the slabby rock shows films of white sericite interlayered with quartzose bands;

this may be part of the Moravian Heights formation. Mylonitic structure strikes N60E and dips steeply to south.

Tremendous shearing, apparently along a great thrust, operated here. Such a fault, in part at least, lies wholly within the pre-Cambrian. Whether of late pre-Cambrian or younger age is unknown. Fraser (1939, pp. 301-303) has described this mylonitic zone.

- 5.3 Houses on right are built on Pleistocene high-level sand and gravel terrace.
- 5.8 Shaly Allentown limestone with south dip on right. Raubsville is located in a synclinal limestone valley between anticlinal ridges of Morgan Hill and Elephant Rock Hill.
- 5.9 Outskirts of Raubsville. Carpentersville gravel pit across river. Musk-ox vertebra now on display in Markle Hall, was found in this pit in 1951.
- 6.1 Leithsville limestone on right, dipping north off flank of Elephant Rock Hill.
- 6.2 On left, partly mylonitized Leithsville beds grading southward into schistose Hardyston. Pre-Cambrian granite gneiss lies 50 yards to south along right side of road. Contact of pre-Cambrian and Cambrian rocks is probably located in draw just behind house.
- 6.3 Byram gneiss on right, exposed in core of eastward plunging anticlinal nose of Elephant Rock Hill. Entering Raubsville.
- 6.5 Intersection with Hellertown road.
- 6.8 Across river, beds of Allentown limestone dip steeply to the south.
- 7.2 STOP III - 20 minutes.
Ripple-marked Allentown limestone in quarry.

Casts of unusually large oscillation ripple marks preserved in a sandy bed of Allentown limestone. These measure up to 1 foot or more in wave length, and are up to 4 inches in height. Beds dip steeply to south and are overturned.

- 8.3 Prominent wooded ridge to south is Bougher Hill, another anticlinal ridge held up by pre-Cambrian gneiss.
- 8.7 Entering north end of water gap through Bougher Hill. Pre-Cambrian exposed throughout its length, largely Byram granite gneiss and pegmatite showing blocky jointing. Strongest joints parallel gneissic foliation and simulate bedding surfaces. Small zone of Pochuck gneiss occurs at south end of pre-Cambrian exposures.
- 8.9 Outcrop on right at end of water gap strikingly shows age relations between Byram granite and Pochuck gneiss. The outcrop is along a contact between the two rocks. Dark Pochuck has been invaded by and interlayered with granite and granitic pegmatite; some pegmatitic granite has crosscut gneissic foliation of Pochuck and partly assimilated small masses of the amphibolite. See Pochuck gneiss and Byram granite and pegmatite under Pre-Cambrian Rocks in this Guidebook.
- 9.1 Crossing Bucks County line and entering Riegelsville.
- 10.8 Just south of Riegelsville highway is situated on a Wisconsin gravel terrace. Pits about 200 yards to the west are in a higher Wisconsin terrace. Behind these is a high-level terrace of pre-Wisconsin age.
- Ridge ahead is Rattlesnake Hill with a core of pre-Cambrian gneiss. Magnetite ore for the old Durham Furnace was obtained from Pochuck gneiss on this ridge.
- 11.2 On right, complexly folded beds of Allentown limestone on north side of Durham Creek. Durham Furnace was located near mouth of creek.
- 11.3 Byram granite gneiss exposed on the right from here to Monroe as anticlinal core of Rattlesnake Hill is passed.
- 11.8 Road junction in Monroe.

11.9 STOP IV - 35 minutes.
Triassic border fault.

For the safety of the group, please follow guides and cross highway only at places and times indicated.

Directly across the highway is the first view of the Newark red beds of the Upper Triassic. They are predominantly shales, fine sandstones and lime-pebble conglomerates (fanglomerate) of the Brunswick lithofacies. Here beds dip northward about 20 degrees.

Cross highway and walk up path past spring outlet and house. The spring is probably the result of concentration of groundwater in the fracture zone of the fault. About 75 yards up this path are exposures of silicified Cambrian limestone. The limestone is so sheared and deformed that its attitude is impossible to determine. It appears to be a section about 200 feet thick, which may be in place rather than being a fault splinter. The contact between the limestone and sheared pre-Cambrian granite is at, or very near, the top of the stream bank a few feet north of the dirt road. Evidence places the Triassic border fault somewhere near the spring and between the limestone and the redbeds. Contact here between limestone and pre-Cambrian may be either an unconformity or a fault contact.

A hundred yards or so farther south on highway than bus stop, a three-foot thickness of gray limestone is exposed just above road level on west side. This becomes increasingly red towards the top, and appears to grade into overlying limestone conglomerate. This is probably a limestone bed in the Brunswick formation, but the rarity of such beds in the Brunswick and the adjacency of this bed to the zone of gray Cambrian limestone not far distant at Monroe suggests the possibility that it might be Cambrian, and thus the floor on which the Triassic sediments rest. It is not a dolomitic limestone, however, as is much of the Cambrian in this area.

From here to Kintnersville Triassic beds are nearly horizontal, except for very gentle folds.

- 13.1 Turn left from 611 onto State Route 32 along the Narrows. Road follows base of high cliff in gently dipping Brunswick red shales.

- 14.2 STOP V - 10 minutes.
Exposure of Brunswick red shale and siltstone.

High cliff of Brunswick redbeds here directly opposite Holland Station of N.J. Power and Light Co.

The following lithologic description of strata in this cliff has been kindly furnished by Dean B. McLaughlin:

"At the large exposure at the foot of the cliff, Brunswick red shale can be examined. Most of this exposure is quite typical. The lowest two feet is a red mudstone with rather wavy bedding. Above it are four feet of a slightly atypical shale, in that a number of very even laminae of one inch or less in thickness can be traced for the entire width of the exposure (about 200 feet). These are believed to have been deposited in a quiet pond or lake. They are distinctly calcareous. Above these beds is more typical Brunswick shale and siltstone. About forty feet above road level, a 3-foot bed shows an interesting joint pattern. Joints strike east-west and dip about 70° north, but more gently at top of bed (i.e. joint surfaces concave to south).

One hundred yards east of exposure at base of cliff, a deep ravine exposes a monotonous succession of red shales and siltstone to top of cliff. The gray hornfels that caps the cliff is not visible from the road."

The gray hornfels referred to by Prof. McLaughlin marks approximate bottom of metamorphic zone below the Coffman Hill diabase sill.

- 15.2 Turn off Route 32 up steep hill on side road to Ringing Rocks. Soon after turning off, boulders of diabase show up and become more common as hill is ascended.
- 15.7 Turn left at top of hill. Stone fences here made of diabase.

- 15.8 Crossing approximate contact of diabase with underlying Brunswick.
- 16.5 Several huge boulders of diabase here with jointing well shown.
- 16.6 STOP VI - 1 hour.
Ringing Rocks boulder field and contact metamorphism of redbeds by Coffman Hill diabase sill.

Follow path to Ringing Rocks. Extensive gently-sloping field of slabby diabase boulders. Field due in part to pronounced square-set jointing of diabase, in part to strong frost-wedging and weathering favored by cold and wet climate of Pleistocene. Diabase jointing has controlled the shaping of the rounded, square-rectangular, and slabby boulders. High, metallic, ringing tones may be obtained from many of them by striking with a hammer.

The diabase is medium- to coarse-grained, brownish-gray on freshly broken surfaces, and weathers easily to a rough, knobby, reddish-brown or dark-gray crust on exposed surfaces. Megascopically, the texture is sub-ophitic, with larger-sized brownish pyroxene grains seeming to stand out idiomorphically against surrounding dark-grayish areas of densely-aggregated small-size plagioclase laths. Thin sections, however, show a normal ophitic texture, with the large, irregular augite grains molding around and enclosing the small labradorite laths. The two minerals are present in nearly equal proportions. A small percentage of rounded, much-fractured olivine grains is present. Some scattered, large magnetite grains occur also. The augite, more resistant than the labradorite, is responsible for the dark knobs on the weathered surfaces.

No explanation for the ringing qualities of this diabase can be given, other than the dense homogeneous texture and the unusual slabby character of many boulders, as well as their tendency to well-balanced positions. It is also true that there is no soil to dampen vibrations. Perhaps those boulders that do not ring are internally cracked or jointed, or else too massive.

The metamorphism of the Brunswick redbeds by intrusion of the diabase sill, is well shown in outcrops in the ravine directly below and east of Ringing Rocks along the banks and bed of a small stream. The zone of metamorphism apparently extends vertically below the sill for nearly 200 feet. The base of the sill lies very near the top of the high bank overlooking the waterfall near head of ravine; beds of hornfels outcrop here and some very large blocks of diabase, nearly in place, are not far distant up the slope towards the boulder field.

Outcrops from the top of the bank down to the stream, a 100-foot drop or more, are very scarce, but downstream from the waterfall there is an almost uninterrupted series of exposures of the hornfels zone. After another 50 feet or more of vertical drop, the hornfels zone changes fairly abruptly to massive redbeds which in turn grade quickly into shaly redbeds of normal character.

The general nature of the metamorphic changes may be determined by megascopic examination of outcrops and by thin-section study. The unmetamorphosed beds close to the contact consist of four main lithologic types: shale, calcareous sandstone, siltstone, and calcareous siltstone. These rocks have been metamorphosed to different hornfels types, but near the edge of the contact zone it is difficult to differentiate between them. Red shale, at the contact, loses much of its brown-red color, turning to a gray-brown, and becomes somewhat more massive. Farther inside the contact zone, the gray-brown changes to dark gray or gray-black. Dense, hard hornfels comes in a few yards farther upstream. From here to the top of the bank above the waterfall and quite close to the base of the sill, dense, tough, flinty, gray-white to gray-black types of hornfels occur. Siltstone in general has changed to light-colored hornfels, shale to gray-black types, and calcareous mudstone to dark-gray hornfels. Near the top of the bank a dark gray layer, several inches thick, contains numerous rounded black spots up to 3 mm. in diameter; these are cordierite crystals. Lewis (1908, pp. 143-145) has described similar cordierite hornfels from New

Jersey. A light gray thinly-banded hornfels close to the cordierite zone shows a few small scattered grains of a silvery-white sulfide.

Thin sections of unmetamorphosed and metamorphosed redbeds reveal the nature of the principal mineralogical changes that have occurred. Calcareous siltstone, apparently most sensitive to metamorphic change, loses its brown-red color more readily than any other type. An opaque film of ferric oxide vanishes, to be replaced by scattered clots and streaks of dark ferrous oxide through which abundant tiny grains of quartz, feldspar, muscovite and calcite stand out clearly. Calcite grains make up nearly 50% of some of this rock. Inside the metamorphic zone this type of rock becomes a gray hornfels, with calcite missing and granules of pale-green hornblende taking its place. The matrix shows abundant, minute scales of sericite. One type of similar rock shows very small whitish, curving, branching, lenticular shapes that may represent worm burrows or cavities left by rootlets. These are filled with coarsely-crystalline calcite and a scaly chlorite mineral in the unmetamorphosed rock, but in the hornfels the calcite changes to coarse, patchy grains of green hornblende.

The calcareous mudstone apparently goes to a dense, flinty, gray-black hornfels showing crude prisms of pale-green hornblende scattered through a dense mat of minutely crystalline sericite. Shale goes to dark cordierite hornfels, at least in part. The cordierite crystals are crudely formed, though some show good pseudo-hexagonal cross-section and twinning and are much altered along outer rims to muscovite and chlorite. Specks of magnetite occur as abundant inclusions in these, and sharp magnetite octahedra completely surround some cordierite crystals. The groundmass is a dense mat of finely-crystalline sericite.

The metamorphism of these redbeds has been a thermal one of not very high intensity, without metasomatic additions from the diabase. Ferric oxide has been changed to ferrous, removing all traces of reddish-brown color. Calcite, plus chloritic and iron-oxide impurities, has gone to green hornblende. Argillaceous (and sericitic) impurities have gone to make abundant minute scales of

sericite. Iron oxides have been changed to magnetite octahedra, and chloritic and argillaceous impurities together have yielded cordierite crystals.

Leave Ringing Rocks. Intersection with macadam road after 1/3 mile; turn left, descend hill towards river.

18.7 Intersection with Route 32 at Upper Black Eddy; turn right.

18.9 Bridge crosses Delaware River to Milford, N.J.

From here to Point Pleasant not many outcrops, but alternation of red Brunswick and gray Lockatong shales may be seen at a number of places.

23.0 STOP VII - 30 minutes - LUNCH.
Lippay's Restaurant in Uhlarstown, short distance beyond bridge to Frenchtown.

28.0 STOP VIII - 15 minutes.
Delaware Stone Quarry.

Typical interbedding of red and gray shale. Quarry is opened in the "Double Red" member, designated by McLaughlin as near top of Lockatong. McLaughlin's description follows:

"The beds now visible in the quarry are: most of the upper red member, the 29-foot gray member below it, the lower 22-foot red member, and about 20 feet of the underlying gray. Features of interest: sun-cracked gray shale; red shale filling cracks in gray shale (the reverse has never been noted, to the best of my knowledge); bluish gray calcareous argillite; plant fragments in gray shale; fine and even lamination of some of the gray shale; a shear zone several feet wide is exposed in the quarry, but it causes no appreciable displacement of the interbedded red and gray shales."

37.0 Take bridge across Delaware; entering Milford, N.J.

37.2 Sharp left turn at first street going north; follow road along river.

- 37.6 Road follows base of cliffs with outcrops of gently-dipping, typical Brunswick shale, siltstone and sandstone.
- 39.0 STOP IX - 10 minutes. (tentative)
Fanglomerate.
- Pebble Bluffs begin; excellent exposures of very coarse fanglomerates for more than a mile. The rock is conglomerate, containing large quartzite cobbles and occasional limestone pebbles, interbedded with reddish-brown siltstones. Lensing of conglomerate in sandstone may be observed near here. Several faults are present in this section, and have been traced across river by McLaughlin where north edge of Coffman Hill diabase sill has been offset by them.
- 40.6 Holland Power Plant on left. Across river gently arched anticline in Brunswick formation is visible.
- 42.6 Intersection with Spring Mills road. Pre-Cambrian and Triassic contact is approximately here.
- 42.8 On right, north of brick house, highly sheared Byram granite.
- 43.5 Junction with Riegelsville road. Turn right towards Phillipsburg, N.J., and follow Musconetcong River. Limestone in valley is in a southwestward plunging syncline hemmed in by pre-Cambrian hills ahead.
- 47.4 Junction with N.J. Route 519.
- 47.8 Ascending hill which is an anticline held up by pre-Cambrian gneiss and Hardyston sandstone.
- 52.3 At brick school, junction with U.S. Alternate Route 22. Turn left on 22. Entering Phillipsburg.
- 53.5 On left. Allentown limestone truncated by Somerville erosion surface.
- 55.3 Crossing Delaware River into Easton.
- 55.8 Back to Route 611; turn right, ascend College Hill to Lafayette College campus and starting point at Markle Hall.

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