

GUIDEBOOK
20TH ANNUAL FIELD CONFERENCE
OF
PENNSYLVANIA GEOLOGISTS



HOST: PENNSYLVANIA GEOLOGICAL SURVEY

HERSHEY, PENNSYLVANIA

May 28, 29, 30, 1954

FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

Twentieth Annual Meeting

Topographic & Geologic Survey
Harrisburg, Pa.

May 28, 29, and 30, 1954

PROGRAM

FRIDAY, MAY 28

9:30 A.M. to 1:00 P.M. EDT

Registration
Mezzanine Floor, Community Inn, Hershey, Pa.

1:00 P.M.

Cornwall Magnetite Deposit
Travel by automobile -- fill them!

8:00 P.M.

Smoker
2nd Floor, Community Inn
Sponsored by:
H. E. Millard Lime and Stone Company
Bethlehem Steel Company
Calcite Quarry Corporation
Drinks and eats!

SATURDAY, MAY 29

8:30 A.M.

Cambro-Ordovician Limestones
Bus Travel; box lunch in the field.

SUNDAY, MAY 30

8:45 A.M.

Martinsburg Formation Trip.
Bus Travel; box lunch in the field.

ACKNOWLEDGEMENTS

The field trips and guidebook for the Conference were prepared by members of the staff of the Pennsylvania Geologic Survey. The introductory material was written by Carlyle Gray, John R. Moseley, and D. B. McLaughlin. The Geologic Map of Lebanon County (Plate 1) is taken from manuscript maps prepared for the Pennsylvania Geologic Survey by Gray, Geyer, McLaughlin, and Moseley. Much of this work is preliminary and incomplete, subject to later revision, but is presented for the convenience of the Conference.

The Cornwall trip description was written by Carlyle Gray, from work by Gray and Alan R. Geyer.

The Cambro-Ordovician limestone trip was written by Carlyle Gray and C. E. Prouty, based on mapping by Gray, Prouty, and Geyer.

The Martinsburg formation trip was prepared by John R. Moseley.

We wish to thank, on behalf of the Conference, the Bethlehem Steel Co., the H. E. Millard Co., and the Calcite Quarry Corporation for sponsoring the smoker.

Thanks are also due to the Community Inn, Hershey, for cooperation in planning the Conference.

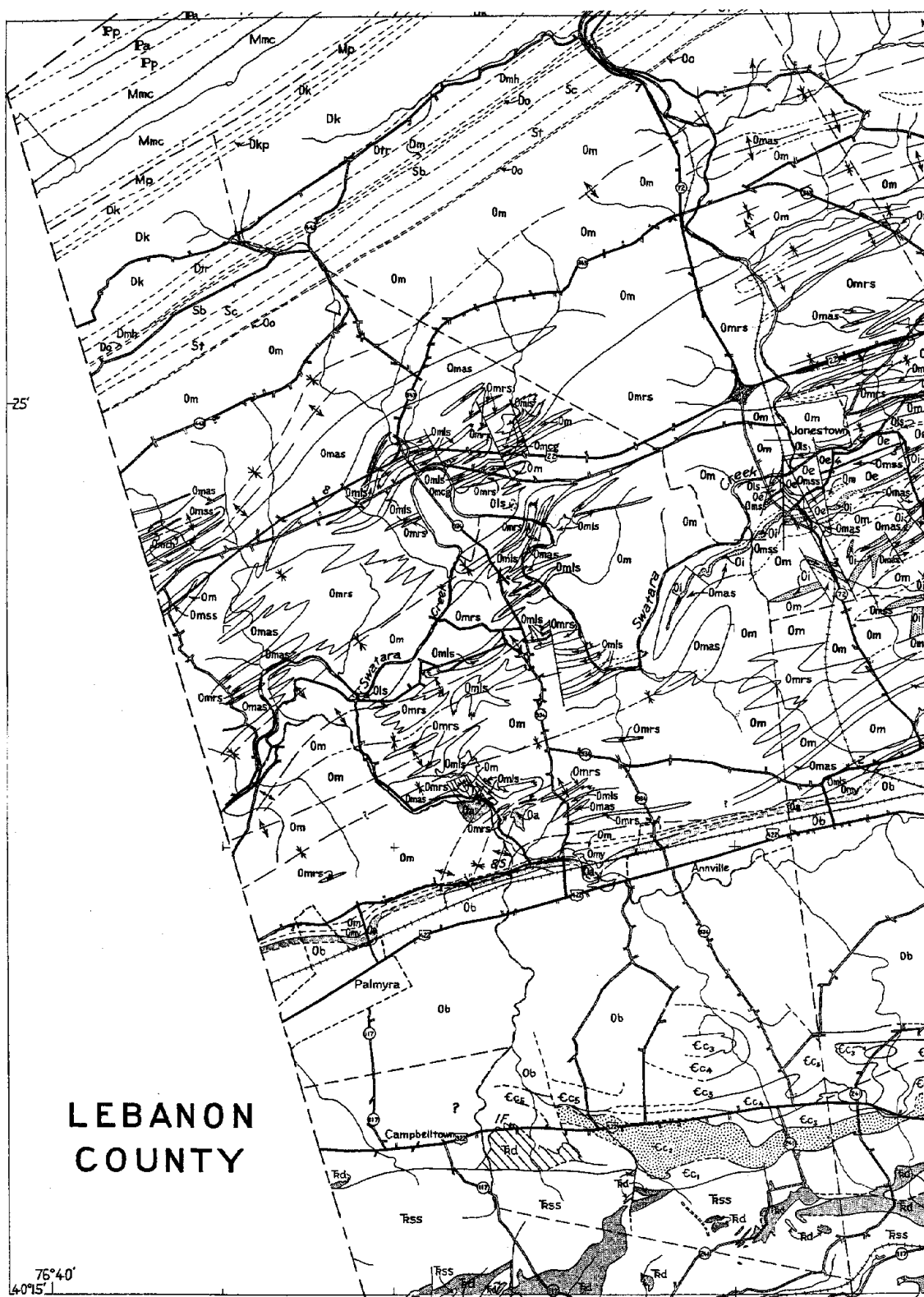
Grateful acknowledgements are given to the following companies for their cooperation in granting access to various quarries, mines, and cuts:

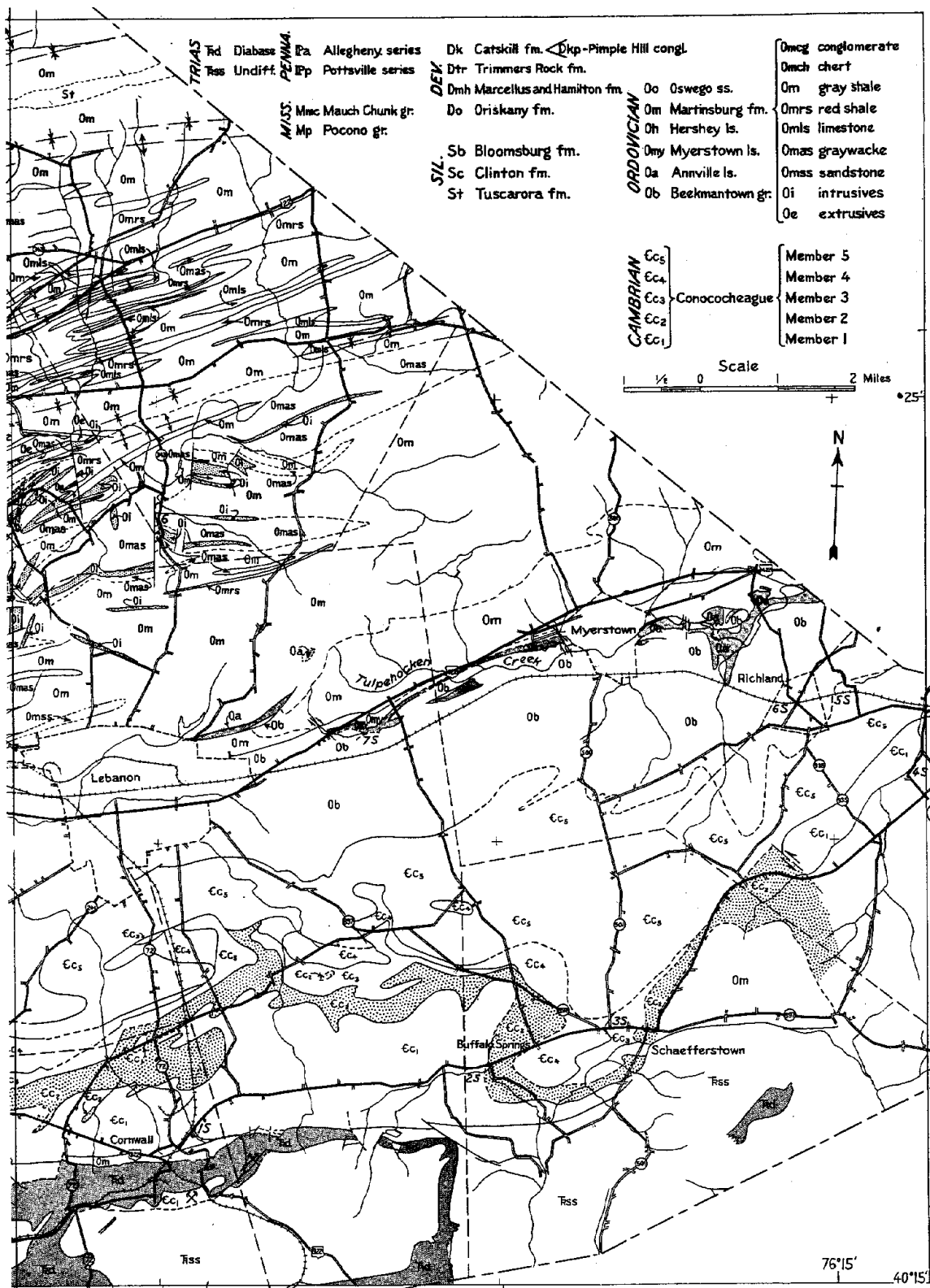
The Bethlehem Steel Company
 The H. E. Millard Lime and Stone Company
 The Calcite Quarry Corporation
 The Reading Railroad Company
 The Reber Sand and Coal Company

The Department of Internal Affairs and the Pennsylvania State Police cooperated wholeheartedly in the planning and execution of the Conference.

STAFF OF THE PENNSYLVANIA GEOLOGIC SURVEY

Carlyle Gray
 R. C. Bolger
 William S. Lytle
 M. N. Shaffner
 Harry V. Gouse





SUMMARY OF THE REGIONAL GEOLOGY

The trips of the 1954 Field Conference of Pennsylvania Geologists lie almost entirely within Lebanon County; an outline map of the geology of the county is included in the guidebook. For the most part, the routes are in the Great Valley section of the Ridge and Valley province. On the south the valley is bounded by the rolling hills of the Triassic lowland, which here has considerably greater than normal relief. At the eastern edge of the county, the tip of the Reading Prong rises to separate the Great Valley from the Triassic. On the north the valley is bounded by Blue Mountain, a linear ridge continuous with Kittatinny Mountain in Eastern Pennsylvania and New Jersey.

The southern half of the valley is underlain by limestone and dolomites of Cambrian to Middle Ordovician age and has an average elevation 100-200 feet lower than the northern half of the valley. The limestone valley is fertile farm land with a gently undulating surface, pock-marked by hundreds of sink holes. Surface drainage is inconspicuous and there is no major stream paralleling the valley here.

The northern part of the valley is underlain by a complex group of rocks which have been lumped under the name of Martinsburg formation. The hilltops of this higher ground are interpreted as remnants of the Harrisburg peneplane. The land is also largely under cultivation although the steeper slopes and poorer soil make the land less desirable than the limestone terrain to the south.

The structure and stratigraphy of the rocks underlying the Great Valley are exceedingly complex. Until recently no attempts have been made to map the geology of this part of the Great Valley in detail. However, in 1951 the Pennsylvania Geological Survey started a program of detailed mapping of Lebanon County. This work is still in progress, but Plate 1 is a preliminary version of the map. The scarcity of outcrops and the lack of any continuous sections have made it necessary to build up the stratigraphic section piecemeal. Minor structural details must be studied with care, and the succession of lithologies in many separate areas compared, before piecing together the section. It is therefore impossible on a trip like this to show the complete evidence for the subdivision of the stratigraphy. Only a few localities can be visited, only partial sections of each of the units are exposed, and only a few of the structural complexities can be seen.

STRATIGRAPHIC COLUMN

Pre-Cambrian

Pre-Cambrian rocks are exposed only in the southeastern corner of the county and will not be visited on this trip. Buckwalter (1953) has described and mapped the following formations, or rock types:

Diabase
 Pegmatites
 Byrom granite and granite gneiss
 Furnace Creek quartz diorite gneiss
 Pochuck gabbro and hornblende gneiss
 Franklin graphitic gneiss

Lower Cambrian

The Lower Cambrian consists of the Hardyston quartzite and the Tomstown dolomite. Both are exposed only in the southeastern part of the county and will not be seen on this trip. The Hardyston is a fairly pure quartzite, conglomeratic at the base. It is quarried for ganister rock in a large quarry near Newmanstown. The thickness in Lebanon County is estimated to be 800 feet.

The Tomstown dolomite is believed to be present at the foot of South Mountain, but outcrops are practically non-existent. It is supposed to be a massive dolomite several hundred feet thick.

Upper Cambrian

Conococheague formation

As the result of detailed mapping and the piecing together of incomplete sections it has been possible to divide the Conococheague formation into five members. These members are lithologic units and no key fossils have been found as yet. For this reason no names have been applied and they are simply given numbers for local identification. It is not even certain that all the members belong within the Conococheague formation as defined by Stose (1908).

Member #1 is the oldest Cambrian limestone seen on this trip. It consists of white to pinkish-white crystalline limestone, (usually with thin shaly laminae) alternating with buff-weathering, light-gray, dense dolomite and magnesian limestone. The white limestones often grade laterally into light-blue, fine crystalline limestone; both types are locally oolitic. Blue limestone is most common near the top of the formation. Cryptozoans are the only fossils which have been found. They are also most common near the top of the formation. Thin sandy limestone to silty limestone beds occur and can be traced for short distances. Buff-weathering, shaly limestone interbeds also are present in many outcrops. Cleavage is commonly well-developed in the limestone and shaly limestone beds, often to the point of obliteration of the bedding. Extreme drag folding and flowage is common. Large pyrite crystals were found in the soil at one locality.

Member #2 consists of massive, gray crystalline dolomite, commonly oolitic, with some blue limestone or dark-blue shaly limestone interbeds. The dolomite varies from dense to coarse crystalline. Where coarse-grained, it is also vuggy. Shaly partings, commonly stylolitic, occur in the dolomite. A number of sandstone beds are present. The sandstone generally has a dolomitic

cement, is gray on fresh surface, but weathers brown and porous. Sand grains locally grade into silt. In some places the sandstone beds are represented by dolomite with abundant floating sand grains. Dark-gray to gray chert is locally abundant.

This member has the stratigraphic position of, and is lithologically similar to, the Big Spring Station member (Wilson, 1952) of the Conococheague formation. It is estimated to be 250 to 300 feet thick.

Member #2 consists of blue limestone with distinct shaly bands. Fresh exposures appear thick-bedded, but when weathered the rock appears shaly. Patches and thin beds of dark-blue calcarenite are characteristic. Dolomitic beds are rare. Near the base, some pink beds occur. The shaly bands and laminae are carbonaceous and make the member particularly susceptible to flowage, so well-preserved cryptozoans are not common. The thickness is unknown for the same reason. It may be in the order of 200 to 500 feet.

The base of member #3 is placed at the top of the last massive dolomite bed of #2. The top is drawn at the first appearance of the white or pink crystalline limestone of member #4.

Member #4 is distinguished from member #3 by presence of pink or white crystalline interbeds, and less distinct shaly partings and bands in the blue limestone beds. This member is lithologically very similar to member #1 and is distinguished principally by stratigraphic position, although apparently member #4 has larger proportions of blue limestone beds than member #1. A few thin sandstones and sandy limestones or dolomites are present. Cryptozoans are rare, but this may in part be due to rather poor exposures of this formation.

Member #4 is poorly exposed, underlying low, flat lands. The soil generally contains abundant white quartz float. The beds are frequently well cleaved, to the point of obliteration of bedding. No measurement of thickness is possible, therefore, in this area. The width of outcrop suggests that it has about the same thickness as member #3.

Member #5 at its base consists of massive, gray, cherty dolomites which frequently are oolitic. The oolites are large and are present both in the chert and the dolomite. In the eastern part of the County, this member is quite thick; it contains limestones in its middle section, and is dolomitic at top and bottom. The cherts may or may not be oolitic. They are usually gray to light-gray in color, but some non-oolitic chert that is almost white occurs.

In the excellent exposure east of Richland on the Reading Railroad, the upper part of the member appears to reflect cyclic sedimentation. Gray, siliceous dolomites are repeated at least twelve times. These beds are usually overlain by limy dolomite, magnesian limestones, or banded limestone and dolomite. The bands are often broken into conglomerate. Above this are typically gray to light-gray dolomites with shaly partings or bands. The cycle then begins again with siliceous dolomite.

Ordovician

Beekmantown group

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

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

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

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

The uppermost part of the Beekmantown in Lebanon County consists chiefly of light-gray to black, dense dolomite. Thick shaly partings are common. This unit is probably 200 or more feet thick. It may correspond to the Bellefonte dolomite of Central Pennsylvania.

Annville limestone

The Annville limestone (new name, Prouty, 1951) directly overlies the Beekmantown group in most of Lebanon County. Prouty (1951) has tentatively correlated the Annville limestone with the lower part of the Black River group. This correlation is based on the stratigraphic position and lithology. In the

Harrisburg area, the Annville is separated from the Beekmantown group by Middle Stones River limestone. The Stones River beds wedge out west of the Lebanon-Dauphin County line, and are almost entirely absent in Lebanon County. One bed of vaughnitic limestone containing fossils of possible Stone River age is present in the Calcite Quarry Corporation quarry, 5 miles east of Lebanon. With this one exception, the Annville lies disconformably on the Beekmantown group in the area covered by this report.

The Annville limestone has a normal stratigraphic thickness of about 240 feet. Structural complexities locally reduce the actual thickness to 130 feet and possibly less. East of Myerstown the limestone thins abruptly, and is only 20 feet thick at Womelsdorf.

The Annville is predominantly a thick-bedded to massive, crystalline, high-calcium limestone, weathering to smooth or fluted surfaces. In the eastern part of the area the beds are blue, with some light-gray and pinkish-gray interbeds. Light-gray and pinkish-gray colors are dominant in the west. The fluting of weathered surfaces, one of the most characteristic features of the lithology, is formed by differential weathering of bedding laminae and where present, cleavage planes. Another persistent feature is the light and dark-gray mottling or banding of the basal beds of the limestone.

The normal appearance of the limestone is sometimes altered in areas of structural complexity. The rock is bleached and is soft and friable, but does not lose its high purity.

Myerstown limestone

The Myerstown limestone (new name, Prouty, 1951) overlies the Annville limestone everywhere in Lebanon County. Prouty (1951) has classified the Myerstown limestone as Black River to lowest Trenton in age on the basis of fragmentary fossils, stratigraphic position, and lithologic correlation with more fossiliferous areas. Its thickness varies from less than 50 feet to possibly more than 200 feet without an apparent regular pattern of variation. The limestone is not well exposed in Lebanon County, and much of the variation in thickness may be due to structural complications.

The Myerstown limestone is typically dark-blue to black, dense, thin-bedded graphitic limestone with occasional beds of calcarenite. Calcite grains are commonly scattered through the dense limestone in varying abundance. Three or four metabentonite beds are present in the formation. Weathered outcrops frequently show fluted edges similar to the fluting of the Annville limestone. Float in the soil above the limestone consists chiefly of rounded, platy fragments that ring when struck with a hammer. Dense, white-vein quartz with a columnar or striated texture is commonly associated with float from the Myerstown limestone. The contact with the Annville limestone is marked by one or more beds of black, very graphitic, shaly limestone, which are succeeded by a varying thickness of impure, gray, crystalline limestone in beds six inches to one foot thick. These beds grade upward into the typical lithology of the Myerstown limestone.

Hershey limestone

The Hershey limestone (new name, Prouty, 1951) is poorly exposed in Lebanon County and its relations are not too clear. On the basis of lithology, stratigraphic position, and limited faunal evidence, Prouty has correlated the Hershey limestone with the upper part of the Jacksonburg formation (lower Trenton) of Eastern Pennsylvania and New Jersey. No accurate measurements of thickness are possible in Lebanon County, but the width of the belt of outcrop indicates that the Hershey limestone varies from less than 50 feet to several hundred feet thick. The maximum development is north of Womelsdorf in Berks County.

The Hershey is a dark-gray, graphitic, shaly or silty limestone. It is less pure and darker in color than the typical Myerstown limestone. Weathered exposures are typically brownish-gray and show well-developed cleavage. Bedding is marked by shaly laminations. Float derived from the Hershey limestone usually consists of fine chips of light-brown porous shale, leached of all calcite. Angular plates of light-gray limestone appear locally in the float. These plates are similar in color to the float of the Myerstown formation, but are more angular and do not ring when struck with a hammer.

The base of the Hershey limestone contains beds of conglomerate in the eastern part of the mapped area. In Berks County, the zone containing the conglomerate beds may be more than 100 feet thick and is mapped as a separate member (Gray, 1951). The conglomerate beds consist of angular to sub-rounded fragments of dolomite and magnesian limestone in a matrix of dark-gray, graphitic shaly limestone. The beds vary from one to several feet in thickness and are interbedded with normal Hershey limestone. Where the conglomerate is absent, it is often difficult to locate accurately the contact between the Hershey and Myerstown limestones.

The Annville, Hershey, and Myerstown limestones, together with some younger limestones occurring in the Martinsburg shale, are included in the Leesport formation on the Geologic Map of Pennsylvania (Stose and Ljungstedt, 1932).

Martinsburg formation

Although the group of sedimentary rocks identified by the United States Geological Survey as the "Martinsburg shale" (Wilmarth, 1938) has been divided into a number of formations, thereby raising the name "Martinsburg" to a group designation (Willard, 1939), it is feasible for the purposes of this Guidebook to consider these rocks as the "Martinsburg formation", following the terminology of the Ordovician Subcommittee of the National Research Council (Dunbar, et al., 1954). Several geologists (Stose, 1909 and 1930; Willard and Cleaves, 1939; Willard, 1939 and 1943; and Moseley, 1950) have divided the formation into two, three or four members. From the type locality at Martinsburg, West Virginia, through Maryland into south-central Pennsylvania, the Martinsburg formation consists essentially of a lower shale member with thin limestones near the base, and an upper sandy member. Behre (1925, 1927, and 1933) subdivided the formation of the slate belt in Northampton County, into three members: an upper shaly,

a middle sandy and a lower shaly member. Willard (1939 and 1943) separated the upper fossiliferous sandstones of eastern Berks County and western Lehigh County from the Martinsburg and proposed the name "Shochary" for them. All geologists who have made field studies of the Martinsburg formation in Dauphin, Lebanon, Berks or Lehigh Counties, have recognized that there are lithologic phases of the formation which are unlike the normal rocks of the Martinsburg to the southwest. Stose (1946) proposed that these anomalous rocks be separated from the Martinsburg formation as the "Taconic sequence" forming the "Hamburg klippe", an overthrust sheet brought from the southeast into contact with normal Martinsburg between the Susquehanna and Lehigh rivers. He divided the rocks into five formations ranging in age from Lower Cambrian to early Trenton and assigned numbers rather than names to the subdivisions. Detailed areal mapping in Lebanon County has failed to reveal incontrovertible evidence to substantiate or to negate the hypothesis of an overthrust position for these rocks. Severe deformation has destroyed evidence of bedding, particularly in the southern portion of the shale belt. Shear zones with broken fragments of sandy beds oriented more or less parallel to their longer dimensions are common.

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

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

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

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

The quartzose sandstone, massively-bedded and containing thin lenses of a waxy, bluish-green shale, makes up the southern crest of Bunker Hills, south of Jonestown. A similar sandstone, weathering rusty-brown and possessing small conglomerate lenses, occurs at Sand Hill, north of Lebanon and extends southwestward to the contact of the shale formation with the underlying Cambro-Ordovician limestones. The heavily-bedded argillaceous sandstone extends as a belt from the eastern edge of the Indiantown Gap Military Reservation southwestward to the border of the county. It is repeated by folding to the south, and the heaviest beds, twelve or more feet thick, occur along Swatara Creek north of Brindnagles Church. The western part of Little Mountain, north of Jonestown, also contains a massive, coarse-grained, argillaceous sandstone in a sharply folded anticline. Coarse-grained sandstones occur sporadically as narrow belts in areas which are predominantly shale. Although called "arkose" by Stose (1930 and 1946), feldspar was not observed in any of the outcrops of this rock type. Shale chips are locally abundant and weathering has softened them until they have the appearance of kaolinized feldspar. It is suggested that "graywacke" is a better descriptive term to apply to the argillaceous sandstones which do not contain feldspar. True arkosic sandstone with pink feldspar in irregular grains occurs adjacent to intrusive masses of diabase south of Jonestown. The presence of feldspar only close to the intrusions raises the question whether it may be secondary as a result of contact metamorphism of the graywacke type of sandstone. The cross-bedded sandstone had only a small amount of clay in the original sediment. The cross-bedding is of the current type and is found in beds which range from half an inch to two or three inches thick. This phase occurs in connection with the massively bedded graywacke and also interbedded in thin series of beds with the gray shale.

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

Limestones in the Martinsburg formation consist of four varieties (Moseley, 1952): (1) argillaceous limestone interbedded with shale; (2) massively bedded, dense, dark-gray to black limestone; (3) arenaceous limestone with rounded grains of quartz; and (4) intraformational conglomerate. None of the limestone has a high-calcium content; insoluble residues range from 11.5% to 46.3% with an average of 26 samples being 23.9%. The residues are estimated to be about 60% sand and silt and 40% clay.

The limestones occur in five separate localities with no reliable evidence of correlation from one area to another: (1) the railroad cut of the Tremont Branch of the Reading Railroad west of Lebanon; (2) from southwest of Fredericksburg eastward to Greble (Lebanon quadrangle); (3) east and west of Harpers Tavern (Indiantown Gap quadrangle); (4) along Swatara Creek southeast of Harpers Tavern; and (5) westward from Union Water Works through Bellegrove

hence southward to the Quittapahilla Creek (Palmyra quadrangle). The four types are closely associated in all the localities. Thickness varies from place to place with the maximum exposure of about 250 feet near the Quittapahilla Creek northwest of Annville. Abandoned quarries dot the belts which can be traced by float for various distances ranging from half a mile to two and one-half miles. In four of the five areas, dip faults cut the limestones with offsets as much as 1200-1500 feet.

Igneous rocks in the belt of the Martinsburg formation were first described by Gordon (1921) as consisting of several dikes of intrusive diabase and two basaltic flows. Stose and Jonas (1927) explained the disjointed nature of the dikes or intrusive sheets on the basis of numerous dip-faults which offset the broken parts. They believed that a single lava flow, repeated by a strike fault, accounts for the main part of Bunker Hills and the outcrops of lava to the south.

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

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

The intrusive igneous rock occurs as masses which are, in part, concordant and, in part, discordant. The rock is a medium- to coarse-grained, light to dark-gray quartz diabase (Stose and Jonas, 1927), containing pyrite as a common accessory mineral. Much of the labradorite has been zoisitized and the augite chloritized, producing a dull greenish color in several areas. The degree of alteration varies and in some exposures the rocks have a relatively fresh, glassy luster. Exposures of the diabase along the bank of Swatara Creek southwest of Jonestown indicate a concordant relationship with the enclosing arkosic sandstone, which here dips to the southeast. Measured thickness of the exposed sill is 105 feet, but the top contact is covered. Farther southwest, distribution of outcrops of the diabase and arkose suggest a thickness of almost 180 feet.

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

The geologic age of the intrusive masses is in doubt. Urry (1936) reports ages of $375 \pm 15 \times 10^6$ and $335 \pm 15 \times 10^6$ years as the age of intrusives associated with the Martinsburg. These figures suggest late Ordovician as the time of intrusion. Stose (1946) suggests that the "basalt flow and associated diabase sills and thick-bedded limestones which occur south of Jonestown ... may be an uplifted block in which Lower Cambrian rocks are exposed". It hardly seems possible that the intrusives could represent Cambrian rocks if their age is as low as $335 \pm 15 \times 10^6$ years. They have been cut by cross faults which affect the enclosing sedimentary rocks. 335×10^6 years would suggest Silurian or early Devonian age. If these rocks are post-Ordovician in age, the cross-faults must also be post-Ordovician and could not have been produced during Taconic orogeny.

STRUCTURAL GEOLOGY

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

The folding is accompanied by both thrust faulting and tear faulting. In the Martinsburg formation, a great many cross faults have been mapped. A number of thrust faults with considerable displacement are shown on the map. Apparently the largest is the fault southeast of Richland which brings the beds of member #1 of the Conococheague formation in contact with member #5 of the same formation, a stratigraphic throw of at least several hundred feet. This fault ends abruptly in a tear fault between Richland and Schaefferstown. It may be a continuation of a fault mapped a few miles to the east in Berks County which apparently brings the Conococheague in contact with the Myerstown formation, cutting out the entire lower Ordovician, or about 2000 feet of beds. A number

of smaller thrusts have also been mapped. Most of these appear to be due to shearing out of beds on the overturned limbs of folds. Wherever detailed mapping is possible, minor thrusts and tears are common features. A number of these are described in "The High Calcium Limestones of the Annville Belt" (Gray, 1951). Extensive quarrying and exploratory drilling of the Annville high-calcium limestone in the area made more accurate structural interpretation possible. Some of these features will be seen on this trip.

A particularly interesting example of recumbent folding was found near Buffalo Springs, five miles east of Cornwall. Here a recumbent fold more than a mile across has been mapped. It is described more fully in the itinerary.

Structures in the Martinsburg Formation

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

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

The exposure of Pre-Martinsburg limestones along Swatara and Little Swatara creeks suggests the presence of a structural high. The sequence of rocks to the north of the high indicates considerable thicknesses of red shale, gray shale, and graywacke in a syncline bordered on the north near Blue Mountain by an anticline in the Eden shale. To the south of the arch is a similar sequence of the same types of rock, but also including the lava flows and intrusives south of Jonestown. How far to the east and to the west of Jonestown the structural high extends cannot be determined with certainty since the underlying limestone is exposed for a relatively short distance along the strike and the exposures do not lend themselves to working out a detailed stratigraphic sequence.

Key beds traced by float are found to be abruptly offset by distances of as much as 600-700 yards. These are interpreted as dip faults. At no place

is a fault plane exposed, along which such movement has taken place. There is no direct evidence as to the nature of the actual movement. They may be either normal faults or tear faults. A nearly vertical, normal fault trending about north-south cuts the younger Paleozoic rocks at the northern end of Swatara Gap, but there is no evidence that it is associated with any of the faults cutting the Martinsburg rocks. Willard (personal communication) reports normal faults cutting folds of Paleozoic rock and passing into Triassic sediments in Bucks County. He suggests that such faults in Bucks County are Triassic in age. So far no evidence has been found to indicate a Triassic age for the faults in the Martinsburg formation.

Although faults are indicated on the map involving only the lava flows, the diabase sills and associated sedimentary rocks, and limestones, they are believed to be much more common and more widespread. Many scores of fault planes have been recognized in outcrops, but their extent cannot be delineated because of the highly complex lithology and the close folding which has destroyed evidence of bedding.

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

If the picture presented by the presence of the cross-faults is the pattern for the whole of the Martinsburg belt, the group of rocks here considered becomes a mosaic whose central theme still eludes the author.

Triassic Structures

The structure of the Triassic rocks in the Lebanon district can be described as a monocline, broadly warped and block faulted. The beds, in general, dip toward the northern border of the Triassic basin. With local exceptions, the straight east-west contact between the Triassic rocks and the Paleozoic limestone to the north is interpreted as a profound fault. For most of the distance from the western Lebanon County line near Campbelltown to the prominent hill south of Fontana, the boundary truncates the northwesterly-dipping sediments and a diabase sill. No local masses of conglomerate, such as might form against a precipitous bordering escarpment, have been found. The conglomerates that do

occur appear to be large lenses that are related to a much more extensive sedimentary pattern.

East of Fontana, the border is marked for about 7 miles by a dike of diabase with an average width of about one-fourth mile. Locally, some metamorphosed sandstone occurs between the diabase and the limestone of the valley, but along most of the distance, diabase is directly in contact with limestone. At a number of places, vein quartz float occurs along the contact.

At Cornwall, Paleozoic rocks crop out north and south of the diabase intrusive. On the south, where the Paleozoics are in direct contact with the Triassic, there is no evidence for faulting. Drilling in connection with exploration for ore has shown that the contact surface dips about 22 degrees to the south, but is a rather irregular surface. The relatively low dip and absence of any brecciation indicate that this is an unconformity rather than a normal fault.

East of the reservoir, east of Cornwall, the sharp contact between Triassic sandstone and Paleozoic limestone is resumed, but about three-fourths mile east of Hammer Creek the contact bends northeastward. At once the character of the rock changes. For a mile or more, limestone conglomerate is interbedded with shale and sandstone, and this conglomerate becomes particularly coarse at the southern edge of Schaefferstown, within less than 100 yards of the outcropping limestone. This part of the border, though perhaps not entirely free of faulting, is believed to again represent overlap of the Triassic on the Paleozoic. The limestone conglomerate is interpreted as a "plaster conglomerate", that is, a local deposit plastered against the shelving floor from which it was derived.

At Schaefferstown the contact again turns eastward. The rock north of the Triassic here is Martinsburg shale, and the boundary is marked by a depression that truncates the strike of the Triassic rocks. Limestone conglomerate occurs along the border here, but the limestone is mainly in the form of small flakes, and was probably transported some distance. This east-west contact is believed to be a fault. Farther east, it continues in a nearly straight line along the southern foot of South Mountain.

PLATE 2

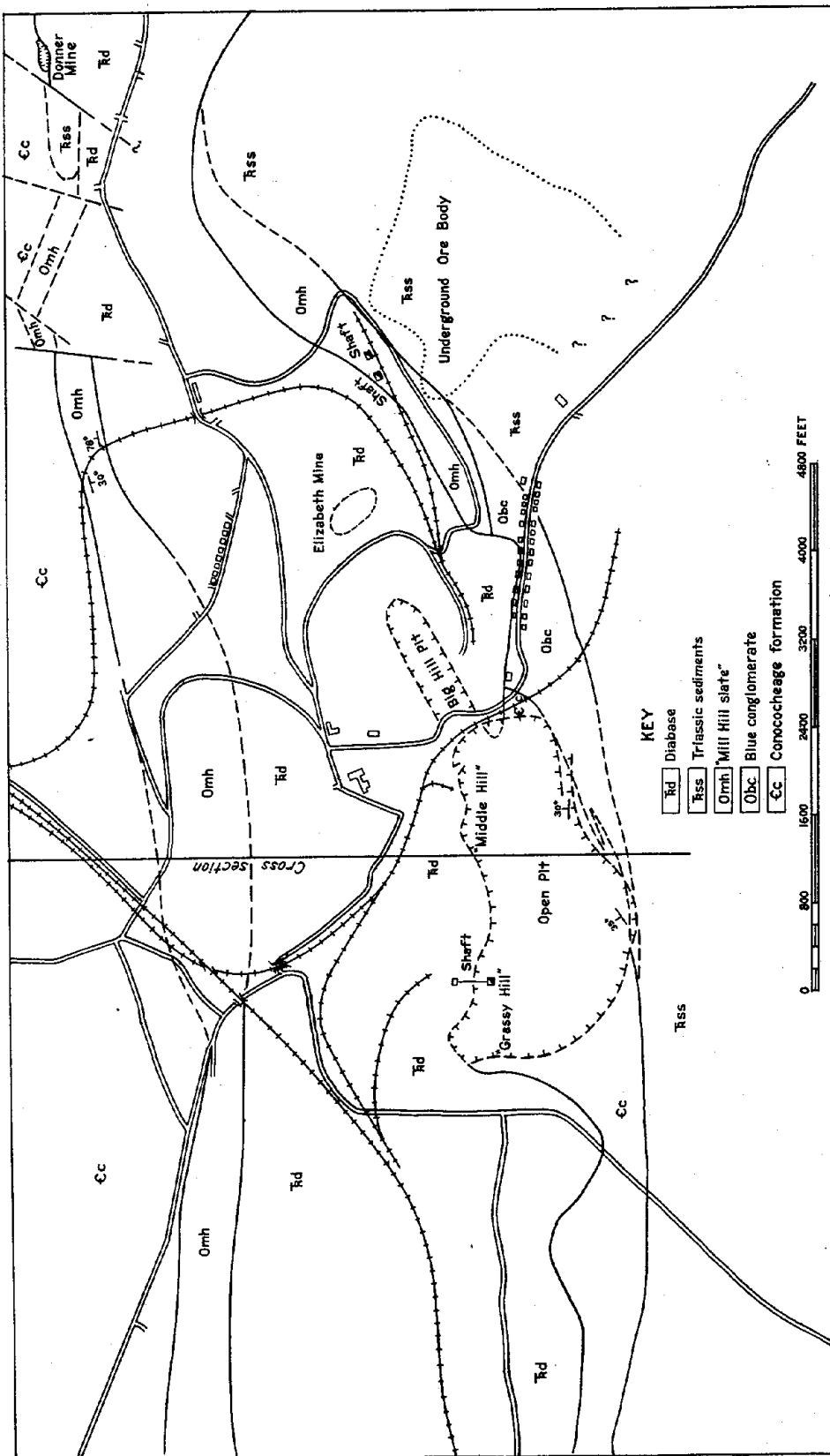
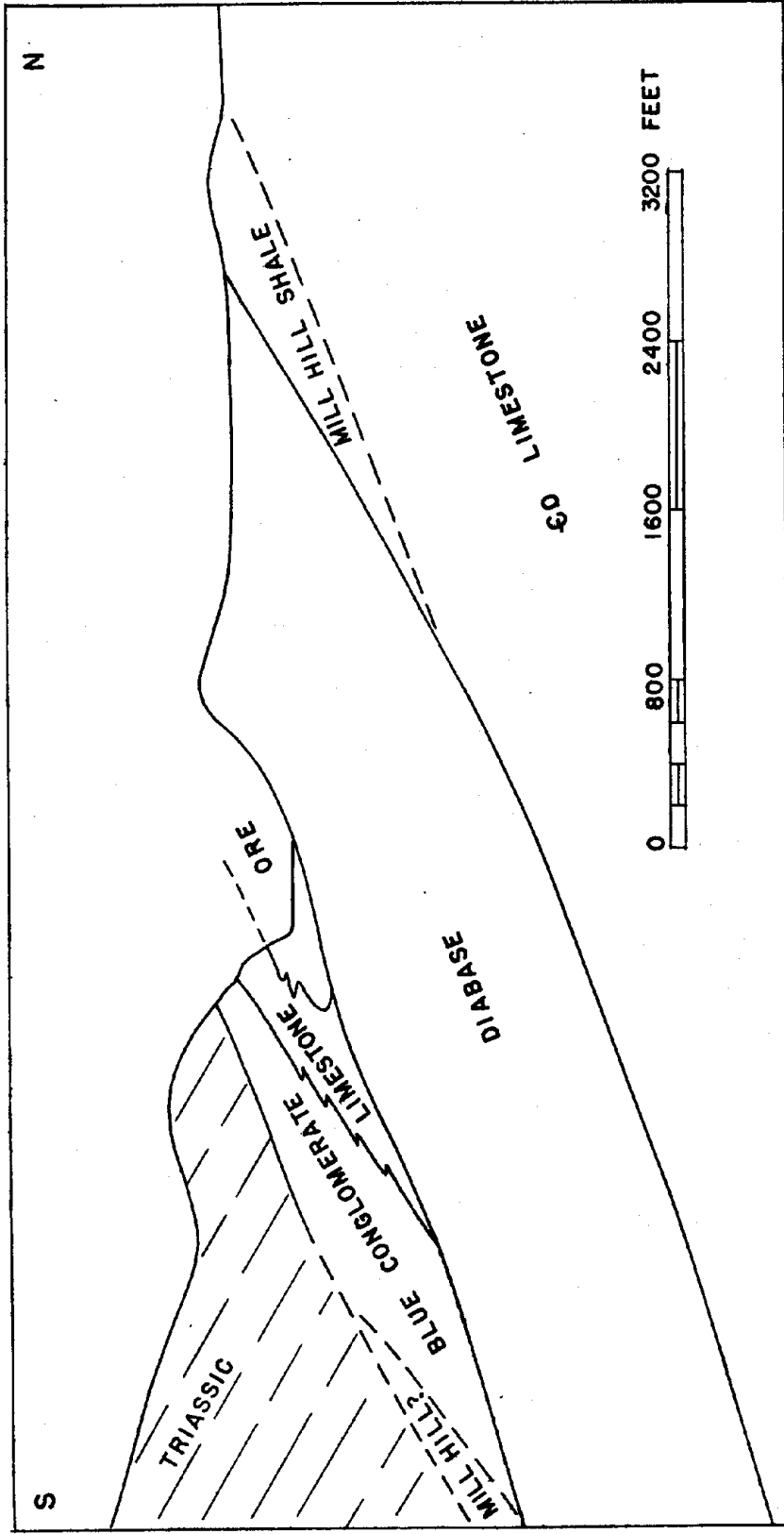


PLATE 3



TRIP 1

Friday, May 28, 1954

Cornwall Iron Deposits

Departure 1:00 P.M. Private cars, from Community Inn.
Line up on Cocoa Avenue, heading south.

Topographic maps: Hummelstown and Lebanon quadrangles.

 ITINERARY
Miles

0.0 Go south on Cocoa Avenue from the Community Inn.

0.7 Turn left on route U.S. 322.

The route of the trip lies entirely in the Great Valley, underlain by Cambro-Ordovician limestone. The hills on the south are underlain mostly by Triassic sandstones and conglomerates. To the north occasional glimpses can be had of the slightly higher Harrisburg peneplane underlain by the Martinsburg shales. On clear days, Blue Mountain, supported by Tuscarora quartzite, can be seen on the northern side of the valley. Its even crest is a remnant of the Schooley peneplane.

3.3 Lebanon County line.

4.6 Entering Campbelltown.

5.0 Straight ahead, cross route 117. Leaving Campbelltown.

5.7 STOP 1 -- 15 minutes.

Roadcut exposing diabase dikes cutting Conococheague limestone.

In this low cut at least four thin diabase dikes are exposed. The rocks are somewhat weathered so that the relationships are not too clear. To the south the dikes are expressed only by float in the fields, mixed with limestone float and the individual dikes could not be traced. They are shown, therefore, as a cross-hatched pattern and can be thought of as a dike swarm.

It is important to note here how little the limestone shows contact metamorphic effect. The only megascopic change is slight bleaching and increased crystallinity. This is in marked contrast to the total replacement at Cornwall.

- 7.4 Village of Mt. Pleasant, on low hill underlain by member #2 of Conococheague formation. Excellent view of valley to the north.
- 8.6 Village of Fontana. Entering Lebanon Quadrangle.
- 9.5 Straight ahead on route U.S. 322.
- 10.3 Straight ahead on route U.S. 322.
- 11.8 Entering Quentin.
- 13.0 Entering Cornwall, bear right, at intersection.
- 13.2 Straight ahead through underpass.
- 13.4 Turn left through another underpass.
- 13.6 Cars stop in line. Conference will be divided into three or four groups here. Stay with your guide, you will have plenty of time to see everything.

THE CORNWALL IRON DEPOSITS

The Cornwall iron deposits have had a long and interesting history of exploitation, and are equally interesting scientifically. Mining of iron was begun in 1740, and has continued uninterruptedly to the present day. The larger western ore body outcropped in three low hills, Grassy Hill, Middle Hill, and Big Hill. Early operations were small scale and after a hundred years ore was still being brought down from the mine to the furnace. Originally the property was divided among several owners and there were actually several pits operating in the same ore body, and the ore was shipped to several local furnaces. In 1916, however, the Bethlehem Steel Company acquired most of the property and began unified operation. Shortly after the first World War, Bethlehem became the sole owner. Since that time none of the ore has been smelted locally. The second ore body, which does not crop out, was discovered by Bethlehem in the early 1920's by a dip needle survey.

With the exception of veins of supergene enriched copper recovered from the oxidized zone by selective mining in the early days, iron was the only metal recovered until shortly after 1920. At this time a combination magnetic separation, froth flotation plant was built in Lebanon to remove the sulphides from the ore to reduce its sulphur content. Differential froth flotation makes it possible to separate the chalcopyrite from the pyrite so that copper is now an important by-product. The pyrite concentrates contain about 1 percent of cobalt, and until recently Cornwall was the leading domestic producers of cobalt. Sulphur (sulphuric acid) is recovered in the roasting of the pyrite. Gold and silver in appreciable quantities (1700 oz. of Au in 1953) are derived from the refining of the copper. At present the mine is producing five metals and one non-metal. In addition, the limestone overburden removed from the pit is being

crushed and sold for aggregate. The present production is around one million tons of ore per year. The grade of the ore averages 40-42% Fe. The magnetic concentrates contain about 62% Fe.

Geologically the deposit is a contact metasomatic deposit at the contact of a Triassic diabase sheet and Cambrian limestones. The intrusive is a dike, here about 1000 feet thick and dipping 40-45° S. at the surface. The dike is part of a basin-shaped sheet, in part cross cutting and in part concordant, having an elliptical outcrop pattern. On its northern edge the sheet follows approximately the contact between the Triassic sediments and the Paleozoic sediments of the Great Valley. At Cornwall a wedge of the Paleozoic sediments lies above the dike and this wedge contains the major ore bodies.

The Paleozoic sediments of the wedge include three mappable units. The limestone, now partly replaced by ore, apparently belongs to the oldest member of the Conococheague formation, (see above.) On the mine map, this is shown as 6c. The limestone is overlain by either of two units which have been given the local names of "Mill Hill slate" and "Blue Conglomerate".

The "Mill Hill slate" is recognized as such only where it has been considerably altered by thermal metamorphism. It is a hard, dense, light-brown to black, banded hornstone. Locally it contains a small amount of calcium carbonate. Bedding is shown by the color banding. It is believed to be an outlier of Martinsburg shale which has been altered by the diabase intrusive. The Martinsburg normally lies on Middle Ordovician limestones, but apparently overlapped older rocks south of its main belt of outcrop. Near Schaefferstown, an outlier of Martinsburg lies on member #2 of the Conococheague formation.

The "Blue Conglomerate" is of even more problematical age and origin. Where least metamorphosed, it appears to consist of pebbles, cobbles, and boulders of vein quartz in a carbonaceous shale matrix; the pebbles are mostly subangular.

In some places the Blue conglomerate definitely overlies the Mill Hill slate. Elsewhere the Mill Hill grades laterally into Blue conglomerate and the Blue conglomerate directly overlies the limestone. In many drill holes and a few outcrops, the Blue conglomerate appears to be interbedded with both Mill Hill and the limestone. In some areas of closely spaced drilling, cores containing alternating Blue conglomerate and limestone cannot be correlated. This is interpreted as meaning that the conglomerate actually contains large blocks of limestone. Over the open pit, however, a tongue of Blue conglomerate is clearly interbedded with limestone. To add to the confusion, however, this tongue grades laterally into Mill Hill lithology.

These features, combined with the fact that no similar conglomerate has been observed associated with other outliers of the Martinsburg formation, suggest that the "Blue Conglomerate" may be in part, at least, a tectonic breccia related in some way to peculiar structural features that led to the deposition of ore at Cornwall.

The limestone at Cornwall apparently belongs to member #1 of the Conococheague formation. Recrystallization and replacement have so altered the

appearance of these beds that correlation, which must be based on lithology, is difficult.

The beds vary from massive to finely-laminated or banded with shaly and silty bands. The texture varies from dense to coarsely crystalline. In chemical composition, the beds are divided almost evenly between impure limestones and impure magnesian limestones. Dolomites are rare, and even the magnesian limestones are nearer the limestone field than the dolomite field when plotted on a triangular (CaCO_3 - MgCO_3 -insol) diagram. These figures are from 49 analyses of limestones in the hanging wall of the open pit ore body. In general the laminated or shaly banded beds are more magnesian. The three true dolomite analyses are very siliceous, all over 20 percent SiO_2 . Many of the beds sampled can be traced visually into the ore and it is thought that the analyses are fairly typical of the replaced beds.

The intrusive underlying the ore bodies at Cornwall is a typical diabase, quite similar to the intrusives found elsewhere in the Triassic basin. It is composed essentially of plagioclase and pyroxene showing typical ophitic to sub-ophitic texture, with accessory magnetite and biotite, and with quartz and orthoclase present in interstitial micropegmatite. The plagioclase is mostly labradorite occurring in well formed laths. Some zoned crystals have been observed. Orthoclase is present in a few crystals as well as in the micropegmatite. In the upper part of the dike, pyroxenes are about evenly divided between pigeonite and hypersthene, with augite also present. Lower in the dike the orthopyroxene becomes dominant. The large grains of hypersthene show peculiar "exsolution" type textures that may represent mixture of ortho and clino pyroxenes. Much petrographic work must yet be done on these minerals.

Hickok (1933, p. 200) divides the normal diabase into four facies, "glassy contact facies, crystalline contact facies, intermediate facies, and coarse facies". These are based on grain size variations and all show similar composition. In addition, he describes the following abnormal facies that show considerable differences in mineralogy, diabase pegmatite, aplite, and altered diabase.

The diabase pegmatite is most common in the upper third and lower third of the dike. It consists of long crystals of pyroxene, mostly augite, in a ground mass of coarse-grained feldspar and micropegmatite. Titaniferous magnetite is abundant. The pegmatite occurs both as dikes with definite boundaries and irregular schlieren. This is also true of the fine-grained pink aplite. The aplite consists of pink feldspar, probably orthoclase, quartz, pyroxene and mica, with locally abundant titaniferous magnetite or ilmenite.

Cornwall

The western of the two ore bodies at/cropped out and has been worked both from the open pit and underground. The ore body had an outcrop length of 4400 feet and a dip length of about 1000 feet. The plunge is to the west so that the deepest part is near the western end where the #3 shaft is located. The open pit has been worked to the maximum economic depth and is now about 500 feet deep. The ore has a thickness of about 150 feet.

The hanging wall of this ore body is entirely limestone. The limestone is well exposed in the southern face of the open pit. The limestone is considerably contorted and is apparently isoclinally folded. The beds in general dip north and northwest. The contact between the ore and limestone is quite sharp, but irregular. Some of the beds were apparently more favorable to replacement and tongues of ore can be seen penetrating the limestone. The ore consists principally of magnetite and actinolite. Chalcopyrite, pyrite, diopside, phlogopite, chlorite, and serpentine are also present in considerable quantity. A great many other minerals have been found here, and a partial list of the more common minerals is appended.

The ore shows a variety of textures, most of which are inherited from the limestones. Most commonly it is banded, black magnetite-rich bands alternating with green actinolite-rich bands. Near the footwall diopside largely takes the place of the actinolite. In some places the banding is broken up, giving the ore a brecciated texture. Elsewhere the ore is massive, with magnetite crystals scattered more or less evenly through the silicate gangue. The pyrite and chalcopyrite are scattered irregularly through the ore as disseminations, as bands paralleling the magnetite bands, and as cross-cutting veinlets.

Hickok gives the following paragenetic sequence of the ore minerals:

Feldspars

Diopside (Garnite, Feldspar, and Epidote)

Actinolite

Phlogopite

Chlorite

Hematite

Magnetite

Pyrite

Chalcopyrite

Calcite and Dolomite

Chlorite

Quartz

Serpentine

Talc

Brucite

Zeolites

The eastern, underground ore body has roughly the shape of a lima bean. The upper end is about 150 feet below the surface, while the lowest part is about 1,150 feet below the surface. It is about 2,500 feet wide at its widest part and reaches a maximum thickness of over 200 feet. The average thickness is probably less than 100 feet.

The ore body differs from the other in that the hanging wall is formed by the Mill Hill slate and the "Blue Conglomerate". The upper contact is therefore more regular than that seen in the open pit. The western end of the underground ore-body tongues cut into limestone, however.

TRIP 2

Saturday, May 29

Cambro-Ordovician Limestones of Lebanon County

Departure: 8:30 A.M., by bus, from Community Inn, Hershey, Pa.

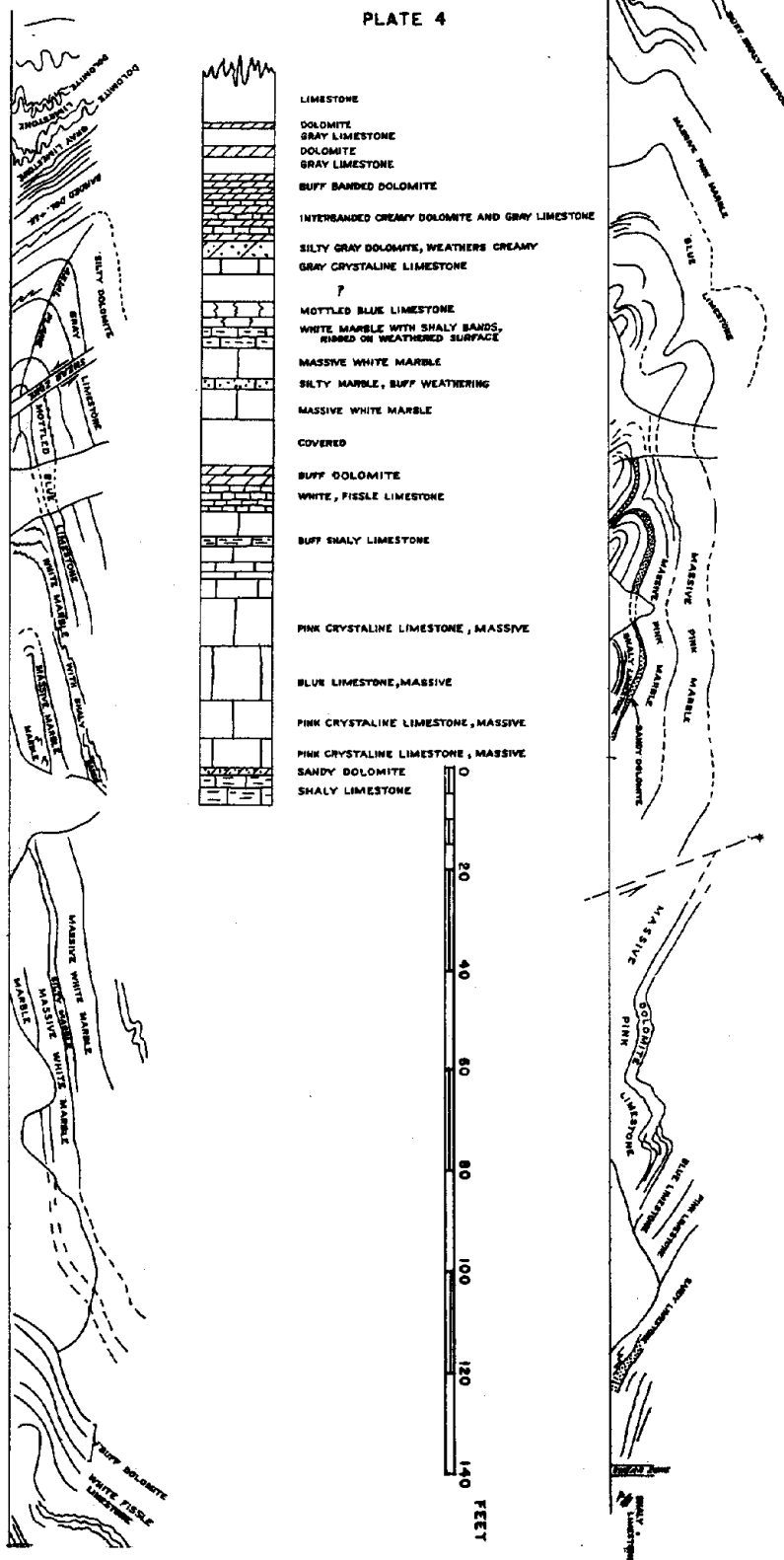
Topographic maps: Hummelstown, Lebanon, and Wernersville quadrangles.

ITINERARY

Miles

- 0.0 Go south on Cocoa Avenue from the Community Inn.
- 0.7 Turn left on route U.S. 322.
The route of the trip lies entirely in the Great Valley, underlain by Cambro-Ordovician limestone. The hills on the south are underlain mostly by Triassic sandstones and conglomerates. To the north occasional glimpses can be had of the Harrisburg peneplane underlain by the Martinsburg shales. On clear days, Blue Mountain, supported by Tuscarora quartzite, can be seen on the northern side of the valley. Its even crest is a remnant of the Schooley peneplane.
- 3.3 Lebanon County line.
- 4.6 Entering Campbelltown.
- 5.0 Straight ahead, cross route 117. Leaving Campbelltown.
- 5.7 Low road cut. Four Triassic diabase dikes cutting Conococheague limestone are exposed in this cut. Dikes continue south to edge of Triassic basin.
- 7.4 Village of Mt. Pleasant, on low hill underlain by member #2 of Conococheague formation. Excellent view of valley to the north.
- 8.6 Village of Fontana. Entering Lebanon Quadrangle.
- 9.5 Straight ahead on route U.S. 322.
- 10.3 Straight ahead on route U.S. 322.
- 11.8 Entering Quentin.
- 13.0 Entering Cornwall, bear right, at intersection.

PLATE 4



- 13.2 Turn left, do not go through underpass.
- 13.4 Turn right at STOP SIGN, cross railroad tracks, then
- 13.45 Turn left toward Schaefferstown, leave route U.S. 322.

13.7 STOP 1 -- 30 minutes.

Railroad cut in member #1 of Conococheague formation.

Cut is 5-minute walk north of road. The beds here are exposed in a complex anticline with a double crest. The cross section shows most of the larger structures as seen in the eastern side of the cut, but is probably not the only possible interpretation. The beds exposed are typical of this member. Note the abundance of white and pink crystalline limestones with buff-weathering dolomitic and shaly interbeds. Near the center of the cut a few sandy beds are exposed.

Drag folding of the beds is spectacular at the northern end of the cut. Here several dolomite beds have been thrown into a series of small isoclinal folds. The limestone has acted in a completely plastic fashion and shows no effects of the folds a few feet away from the folds.

- 15.2 Straight ahead, at crossroad.
- 16.2 On right, outcrops of sandy limestone in member #1.
- 16.5 On left, white crystalline limestone of member #1.
- 16.8 Straight ahead, at crossroad.
- 17.7 On left, outcrops of dolomite beds of member #2.
- 17.8 Buffalo Springs.
- 18.0 STOP 2 -- 25 minutes.

Buffalo Springs. Outcrops of member #2 in recumbent syncline.

Walk along road leading south from the intersection. Beds exposed in roadcut belong to member #2 of the Conococheague formation. Note the massive dolomite beds, dark-blue, impure limestone interbeds, and sandy dolomite.

The beds here are on the overturned limb of a recumbent syncline. It will be noted on the map, plate 5, that the outcrop of member #2 has an S-shaped pattern near here. This is due to the presence of a recumbent syncline whose axial plane has been gently warped. The fold plunges gently west at Buffalo Springs, but at Schaefferstown has no plunge and therefore the outcrop of member #2 is confined entirely to the upper, overturned limb of the syncline.

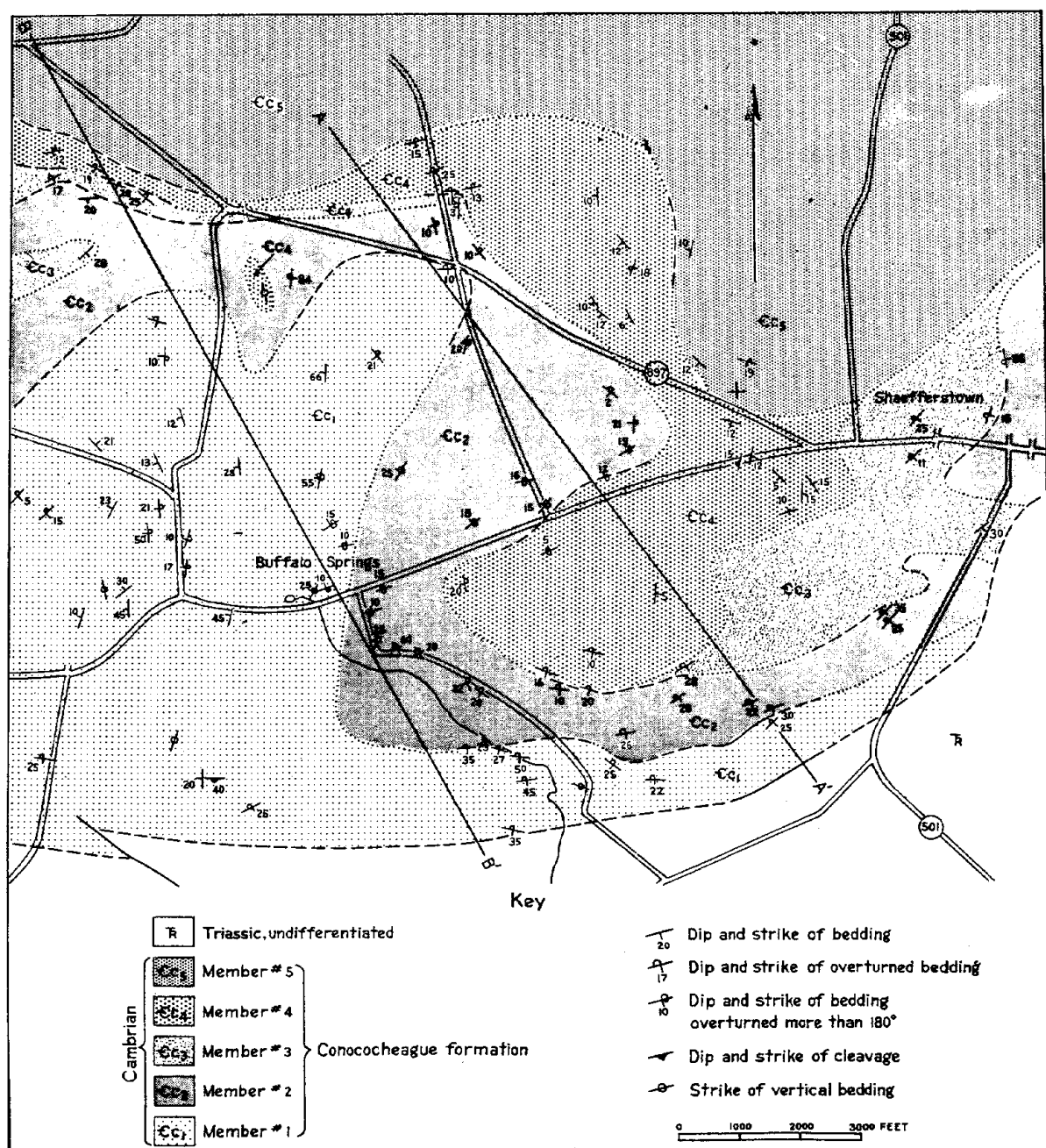


Plate 5. Map of area between Buffalo Springs and Shafterstown.

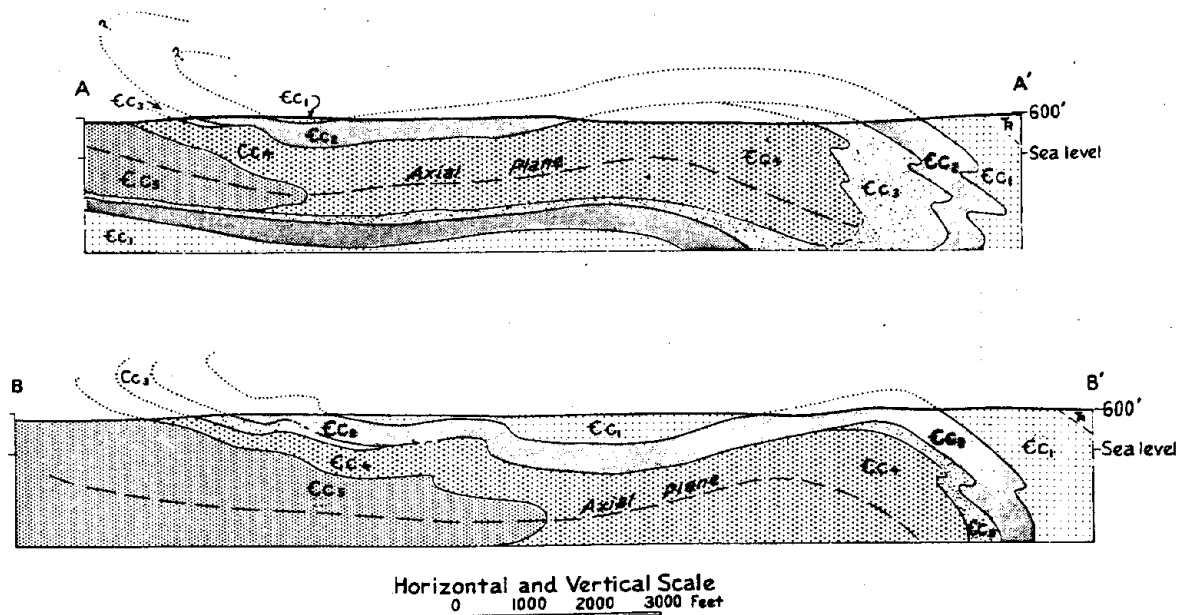


Plate 6. Cross sections, Buffalo Springs Area.

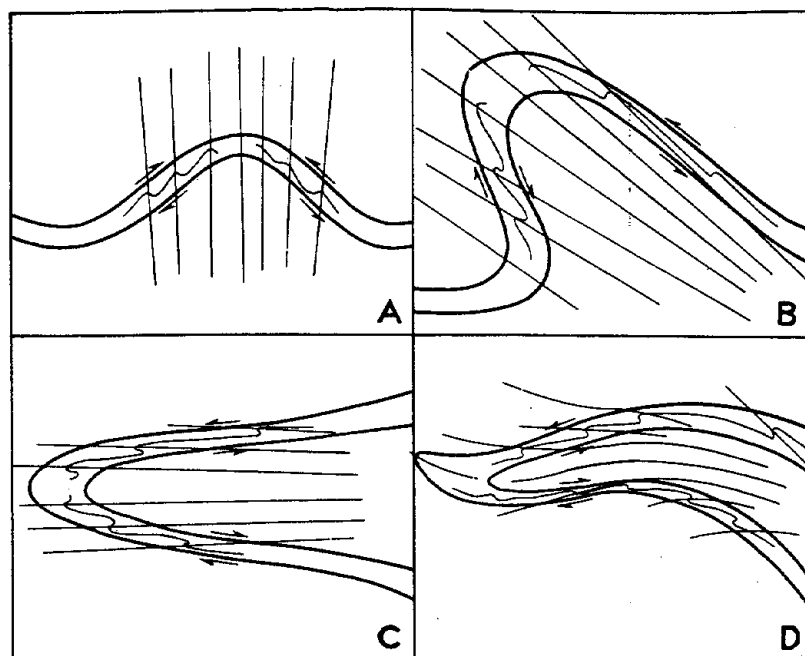


Plate 7. Diagrams illustrating bedding-cleavage relations in various types of folds.

Because of the lack of uniformity of plunge, the map pattern alone does not lead to the interpretation of the recumbent fold. The key to the interpretation is in the structural details of the scattered outcrops. If the dips were ignored, the area underlain by member #4 between Buffalo Springs and Schaefferstown would probably be interpreted as a syncline plunging to the northeast, with member #4 lying unconformably on member #2 on the north limb of the syncline. Examination of the dips, however, show that this area is anticlinal, and that the plunge is to the southeast, in other words, the younger beds of member #4 are overlain by the older beds of members #3 and #2 on the flanks of a gentle anticline. The sequence here has been completely inverted, and later gently folded. Examination of the area north of Buffalo Springs shows that here member #1 lies on top of the younger member #2 in a syncline. The local rotation of beds beyond the horizontal leads to an interesting relationship of bedding and cleavage. Here the beds dip N to NW about 15 degrees. The cleavage, and axial planes of the drag folds dip north more steeply. According to the usual rule of thumb, this would indicate that the beds were right side up. Yet in the same outcrop are cryptozoan reefs and some sandy beds which present independent evidence that the beds are overturned. Cryptozoans are laminated algal structures, in which the laminae are typically curved convex upward when in normal position. Where well developed, these structures are reliable guides to tops of beds. Here they clearly show that the beds are overturned. The evidence of the cross-bedded sandstones is not so conclusive, as the cross-beds are poorly developed, but they also appear to be overturned.

The explanation of the apparently anomalous relationship of the cleavage and axial planes of the drag folds lies in the careful study of the geometry of folds. The relationships are illustrated in Plate 7. The flow cleavage is in the form of a fan opening toward the apex of the anticline, and the axial planes of the drag folds are essentially parallel to the flow cleavage. In the overturned fold, B, the dip of the cleavage on the normal limb is in the same direction as the dip of the bedding, and steeper. On the overturned limb, the cleavage dips in the same direction, but less steeply than the bedding. Near the crest of the fold, the cleavage and bedding dip in opposite directions. The shear arrows show the direction of relative movement on the bedding planes. In the recumbent fold, C, the axial plane is horizontal. Because of the fan, the cleavage in the overturned limb dips in the opposite direction from that in the normal limb. In Plate 6 it can be seen that the axial plane of the fold is gently undulating, apparently a common feature of recumbent folds. The result is that the overturned limb is locally rotated more than 180 degrees, as in Plate 7, D. Here the bedding and cleavage dip in the same direction, the cleavage having the steeper dip, as in the normal limb of B. In limited outcrops, and in the absence of

primary features indicating top and bottom, this can lead to confusion. However, it should be kept in mind that in regions of intense deformation the folds are usually overturned all in one direction. In the Great Valley, for example, the folds are almost all overturned to the northwest, i.e., the axial planes dip to the southeast. Where the overturning is extreme and cleavage has low dips, local reversals of dip are much more likely to represent rotation beyond the horizontal than overturning opposite to the regional deformation:

18.7 On left, outcrops of dolomite beds of member #2 dipping north. Member #4 dips north, under member #2 here.

19.1 Roadcut exposes pink and blue limestones of member #4.

19.2 On right, quarry in member #4.

19.4 Straight ahead, at STOP SIGN. Route 897 comes in from left.

19.5 Straight ahead, route 501 comes in from the left.

19.7 STOP 3 -- 20 minutes.

Horst Quarry. Member #3 of the Conococheague formation.

Excellent exposure of member #3. The lithology of this unit is more uniform than that of the other units. It consists chiefly of blue to dark-blue limestone with dark-gray silty or clayey bands and laminae. Thin beds and patches of calcarenite are present. A few thin dolomite interbeds are present. The characteristic features of this unit are the generally dark-blue color (light-blue and pink beds are rare), the scarcity of dolomite, the presence of patches of calcarenite.

The carbonaceous laminations apparently provided excellent lubrication and extreme flowage is common in this member. The map indicates rapid changes in thickness, most of these being due to flowage. In this quarry drag folding of the shaly bands is well developed. Note that the axial planes of the drag folds are nearly horizontal, while the beds dip 10 to 15 degrees to the southeast. The beds are, therefore, overturned.

20.2 Schaefferstown. Straight ahead (route 501 to the right).

20.25 Turn left at Square toward Newmanstown, leave route 897 here.

20.4 On right, outcrop of Martinsburg formation. An outlier of Martinsburg shale here lies on member #2 of the Conococheague formation. The Martinsburg formation in Berks County overlaps successively older formations in similar outliers, and is believed to lie unconformably on rocks as old as Upper Cambrian. Here, however,

some faulting may have occurred as the shale apparently lies on overturned beds of Cambrian age. As the contact is nowhere exposed, the relationships are problematical. Road travels along this contact for about one and one-half miles.

- 20.8 To left, view across valley. Main belt of Martinsburg formation underlies low hills in the middle distance.
- 21.7 Road crosses diabase dike, probably Triassic, about here.
- 22.5 Straight ahead at intersection. Large quarry visible on mountain side is in Hardyston quartzite. Supplies ganister to silica brick factory at Womelsdorf.
- 23.3 Crossing Mill Creek.
- 23.9 Entering Wernersville Quadrangle.
- 24.4 Straight ahead, route 935 comes in from the left.
- 24.45 Straight ahead, at STOP SIGN.
- 24.8 On left, outcrops of member #1.
- 25.2 Turn left at intersection.
- 25.8 STOP 4 -- 20 minutes.
Quarry in Member #1, Conococheague formation.

Excellent examples of Cryptozoan reefs in white to pink crystalline limestones of member #1 are found near the northern end of this quarry. No attempt has been made to classify the Cryptozoans found here, but several types seem to occur. The Cryptozoans indicate that all the beds are overturned.

At the top of the hill, on the opposite side of Mill Creek, similar beds are in contact with member #5. This is believed to be a thrust fault of considerable extent. Its throw apparently increased eastward.
- 25.9 Straight ahead, at intersection.
- 26.4 E. J. Lavino Company ferro-manganese blast furnaces on the right.
- 26.6 Turn left, toward Richland, at STOP SIGN.
- 26.67 Roadcut in member #5, Conococheague formation.
- 27.4 Turn right, on narrow, black-top road at Richland Borough line.

27.7

STOP 5 --

Railroad cut in member #5, Conococheague formation. Beware of trains.

As one goes west through the cut, progressively younger beds are exposed. The first exposures are of dark-blue impure limestones and interbedded gray dolomite. These belong to the middle, limy part of member #5, which occurs only in the eastern part of the County.

Above a covered interval are exposed about 525 feet of dolomite beds with some limestone interbedding. A few faults are visible so this is only an approximation of the stratigraphic thickness. The dolomite beds show quite a variety of lithology and near the western end of the cut, there is some indication of cyclic repetition of the lithologies. The most common lithologies are gray-weathering, dense dolomite with silty laminae, massive, creamy-weathering crystalline dolomite, sandy dolomite grading into dolomite sandstone, gray magnesian limestone. Chert and intraformational conglomerate are frequently associated with sandy beds. The exposure is not typical of member #5 in that sandy beds here have not been found in this member elsewhere in the County. Also, the large oolites, frequently cherty, are absent here.

At the western end of the cut, the dolomite beds are in contact with laminated, banded blue-gray limestone believed to be Beekmantown. This is based on the presence of crinoid fragments and fucoids, both very rare in the known Cambrian of the area. The contact shows evidence of some movement, but it is not known whether an important fault occurs here.

28.4 Leaving Wernersville Quadrangle, returning to Lebanon Quadrangle.

28.5 Turn left, at intersection.

28.7 Bear left, entering Richland.

29.2 Cross railroad, park in parking lot on the right.

STOP 6 -- 30 minutes.

Railroad cut in Beekmantown dolomite.

Exposures of approximately 350 feet of dolomite, with a few limestone interbeds. In a quarry on the eastern edge of town, blue limestones of the lower Beekmantown (Stonehenge?) are exposed. These beds overlie the limestone and apparently represent a mappable unit of dolomite, since a similar sequence has been found in the western part of the County. The dolomite grades upward into a more limy unit. At the western end of the cut, the beds consist of blue limestone with some dolomite interbeds. The transition takes place in an interbedded zone about 100 feet thick.

The beds in the dolomite zone dip steeply to the southwest and are overturned. Near the top of the dolomite, they become vertical. Farther west the beds dip to the northwest and right-side up. Tops of the beds of the limestone interbeds have undergone a considerable amount of flowage.

Tops of beds are indicated by graded bedding in the sandy zones and fracture cleavage. The limestone interbeds have undergone considerable amounts of flowage. In some places, this flowage gives rise to drag folds whose axial planes have anomalous relations to the bedding, that is, they indicate tops to the west. The predominance of evidence is, however, that the tops are to the east.

LUNCH STOP

- 29.2 Go back across railroad and turn left, toward Millardsville.
- 29.5 Straight ahead, at intersection.
- 30.2 Bear left, on main road.
- 30.5 Abandoned quarry in Annville limestone.
- 30.7 Straight ahead at crossroad in Millardsville.
- 31.1 Roadcut in Myerstown formation. This is one of the best exposures of this formation in this area, and is considered a standard section for this formation.
- 31.2 Double intersection, cross first concrete highway, and turn left on route U.S. 422.
- 33.2 Straight ahead, at STOP LIGHT.
- 34.5 Straight ahead, at intersection.
- 36.4 Turn left, on black-top road, toward Prescott.
- 36.5 Turn right, on gravel road along quarry rim.
- 36.7 STOP 7 -- 25 minutes.
Calcite Quarry Corporation Quarry.

This is the second largest, high-calcium limestone operation in this area. The quarry is in the Annville limestone. Dolomite from the Beekmantown formation, removed in stripping operations, is sold as low-silica dolomite. The sequence is overturned, so that in the southern wall the Annville limestone is overlain by massive dolomite of the Beekmantown formation. The road down into the quarry follows the "footwall" contact of the massive,

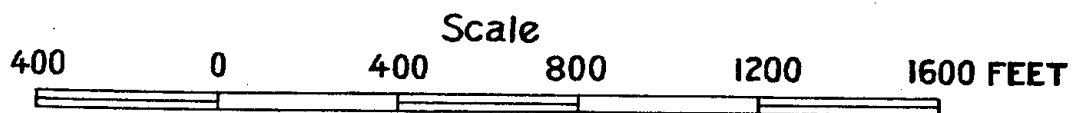
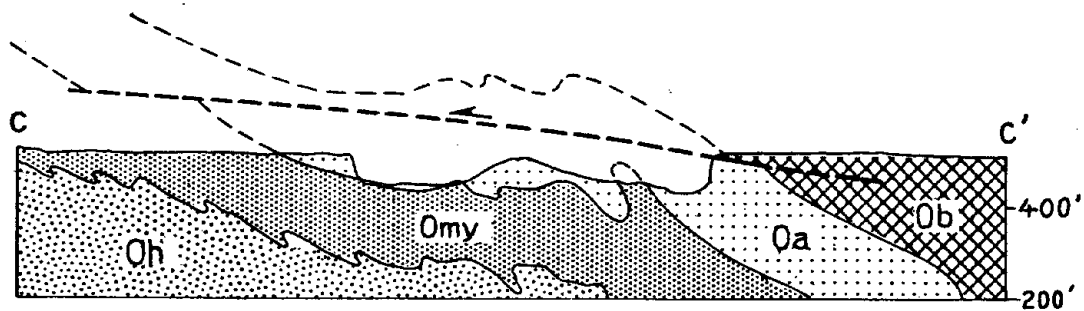


Plate 8. Cross section near west end of Calcite Quarry.

blue, Annville limestone with the younger, but underlying gray, impure, Myerstown limestone.

In the quarry a large drag fold in the upper beds of the Annville is exposed. This fold is an overturned anticline. When it is remembered that these beds are in the overturned limb of a large fold, it becomes evident that the beds in the overturned limb of the drag fold have been rotated more than 270 degrees. It is believed that the drag fold is the result of movement on a thrust fault which can be seen in the opposite side of the quarry. The relationships are shown on Plate 8, a cross section of this part of the quarry.

Turn around and return to black-top road.

- 37.0 Turn left at black-top, and return to U.S. 422. Turn left on U.S. 422.
- 38.5 Road crosses old bed of the Union Canal, which formerly linked the Susquehanna and Schuylkill Rivers.
- 39.5 Entering Lebanon. Continue straight through the City.
- 42.3 On right, large slag pile. Blast furnaces to treat the Cornwall ores and valley brown ores were formerly located here. Slag is now being used as road material.
- 43.5 Cleona.
- 44.7 Entering Annville, and Hummelstown quadrangle.
- 45.8 Straight ahead, at STOP LIGHT.
- 46.3 Leaving Annville, crossing Quittapahilla Creek.
- 47.2 Turn right at H. E. Millard Lime & Stone Company.
- 47.6 Quarries in Annville limestone on both sides of road. Quarry on the right is being filled with tailings from the washing plant.
- 47.7 Turn left, stay on black-top road.
- 48.4 STOP 8 — 60 minutes.
H. E. Millard Lime & Stone Company Quarries and Plant.

The H. E. Millard Lime & Stone Company is the largest producer of high-calcium limestone in this area. This stop is at the main plant and quarries. The active and inactive quarries passed between Annville and here all belong to this company.

The high-calcium stone is all from the Annville formation, and the entire formation is of high-calcium grade. The stone averages

about 97% CaCO_3 and less than 2% SiO_2 . The Annville has a stratigraphic thickness here of about 240 feet. Near the plant the structure is relatively simple, the beds strike a fairly regular N 75°E and dip about 45° South, overturned. To the east the dip lessens and a true recumbent fold is exposed. Here the only complications are a few minor cross faults. Some of these are visible in the south wall of the quarry. The south wall of the quarry is mostly dolomite, belonging to the upper part of the Beekmantown. This fractures more readily than the pure Annville limestone and none of the faults can be traced across the quarry. The largest fault, near the present working face, offsets the dolomite-limestone contact about 50 feet. On the opposite side of the quarry, there is no break, only a gentle cross fold in the footwall beds.

The footwall is the contact between the Annville limestone and the younger Myerstown limestone. The Myerstown is somewhat graphitic and the contact was a plane of considerable slippage. Slickensides and minor brecciation are common. The basal beds of the Myerstown formation are more massive than the main body of the formation, but are easily distinguished by their darker color and graphitic nature. More typical beds, including fossiliferous calcarenites are exposed in a cut just east of the crushing plant.

Continue west on same road.

- 50.5 Turn left at intersection, toward Palmyra.
- 51.2 Turn right on U.S. 422, entering Palmyra.
- 52.7 Leaving Lebanon County, entering Dauphin County.
- 54.5 Entering Hershey, continue straight through town on U.S. route 422.
- 55.8 Bear left on route U.S. 422.
- 59.9 Crossing Swatara Creek. Road climbs hill underlain by Martinsburg shale on west side of the creek.
- 60.8 Turn left, at top of hill, leave route U.S. 422.
- 61.1 Turn left, on black-top road.
- 62.5 STOP 9 -- 30 minutes.
Covered bridge across the Swatara Creek. There will be a discussion of the "Leesport" problem at this stop.

Though partly covered along the road and field, this is probably the best exposed section of the Beekmantown-Martinsburg interval in

this general area. The beds are overturned to the southeast, the upper Beekmantown appearing high in the wall of the quarry. The Annville-Beekmantown contact usually appears conformable, though the Annville in the Harrisburg area apparently overlies middle "Stones River" limestones. In this quarry the Annville shows locally a discordant relationship to the Beekmantown but may be involved in minor faulting. However, basal Annville, marked by bluish striped marble beds, are present in this section.

The high-calcium Annville is readily contrasted to the generally darker, slabby limestone of the overlying Myerstown. This contact is complicated locally, owing perhaps to the less competent behavior of the thin-bedded Myerstown. The upper contact is drawn at a dolomite conglomerate and breccia zone, persistent regionally from Harrisburg to eastern Pennsylvania.

In places the fragments of dolomite in the conglomerate reach boulder proportions, as in the Womelsdorf area. The upper and lower contacts of the Myerstown are better delimited in this section than elsewhere and therefore is considered the typical section. The slabby weathering so typical of the Myerstown is better shown in other sections, as at Millardsville, which is considered a standard section for the Myerstown formation. This latter section is quite complex, however. Fossils are rare, consisting largely of crinoid stems and fragmented brachiopod shells. Echinospaerites aurantium, Prasopora simulatrix, Diplotrypa appalachia, and Rhinodictya sp. have been collected from the Myerstown at Millardsville.

The Hershey-Myerstown contact is not readily placed in the absence of the basal Hershey conglomerate. The Hershey is uniformly black, thin-bedded, impure carbonaceous limestone, essentially the "cement rock" of eastern Pennsylvania. The limestone seems to be invariably slaty-cleaved in Pennsylvania, the bedding largely obliterated in most exposures. In this section a few silty limestone beds may be followed through the outcrop. The upper contact is questionable in most sections due to the difficulty in distinguishing leached Hershey from the weathered, non-calcareous Martinsburg shale. Also, drift from the topographically higher Martinsburg usually conceals the contact. To distinguish fresh Martinsburg shale from the Hershey, it usually becomes a matter of testing for the calcareous content of the latter. In this section the lower Hershey beds are highly weathered and have the appearance of Martinsburg shale. Higher beds along the undercut bank of the Swatara are less weathered, showing the black, calcareous nature of these beds. Though the upper contact was determined by acid testing, this section has as definite boundaries as any section observed and is therefore considered the type for the Hershey limestone. The measured section is as follows:

<u>Unit</u>	<u>Thickness in feet</u>
<u>Martinsburg shale</u>	
<u>Hershey limestone</u>	
Limestone, black, carbonaceous, impure; slaty cleaved, few silty limestone beds, (rough estimate) ...	300
Covered interval, containing some exposures of limestone, buffish-brown, highly weathered and leached; black on fresh surface	135
Conglomerate zone, mostly angular dolomite pebbles in a dark shaly limestone matrix	0-3
<u>Myerstown limestone</u>	
Limestone, shaly; alternating with black fissile, carbonaceous shale	18
Limestone, thin-bedded, slabby, dark smoky-gray; showing "fluting" on weathered surface	12
Limestone, thin-bedded, slabby, dark-gray	13
Limestone, shaly, carbonaceous; some white, columnar quartz along bedding (where found abundantly, this is highly characteristic of the Myerstown and is helpful in mapping where found as residual in the soil)	3.0
Limestone, dark-gray, thinly laminated, weathering into the rock along some laminae to give distinctive type of "fluting"; some columnar quartz	6.0
<u>Annyville limestone</u>	
Limestone, dark-gray, few thin carbonaceous layers; smoky-gray weathering	7.5
Limestone, gray, showing lighter gray "frosted" appearance on fresh fracture; high calcium	7.0
Limestone, bluish-white and bluish-gray striped	2.0
Limestone, gray and bluish-gray, mottled; high calcium	3.0
Limestone, dark-blue; smoky-blue weathering	6.0

<u>Unit</u>	<u>Thickness in feet</u>
Limestone, dark-blue with irregular, gray impure bands	12.5
Limestone, bluish-gray, finely crystalline	11.1
Limestone, light-gray with blue bands	2.8
Limestone, dark-blue, finely crystalline	2.5
Limestone, bluish-white and blue striped, occasionally mottled; highly fluted on weathering	5.0
Limestone, dark-blue, finely crystalline	3.2
Limestone, bluish-gray and gray mottled; finely crystalline, high-calcium	5.0
Limestone, white and blue striped, dense; high-calcium	6.0
Limestone, dense, high-calcium, light-gray	0.5
Limestone, creamy white with bluish streaks (a good marker for basal Annville); dense, weathered surface shows "fluting" with few thin laminae weathering into rock rather than standing out in relief as is commonly the case	3.5

Beekmantown dolomite

Turn around and return to Hershey by same route.

- 63.9 Turn right.
- 64.2 Turn right on U.S. route 422.
- 65.1 Crossing Swatara Creek. Outcrops in east bank are Upper Beekmantown dolomite, lying on Annville limestone, which is exposed under the bridge.
- 69.2 Entering Hershey.
- 70.5 Community Inn.

PLATE 9

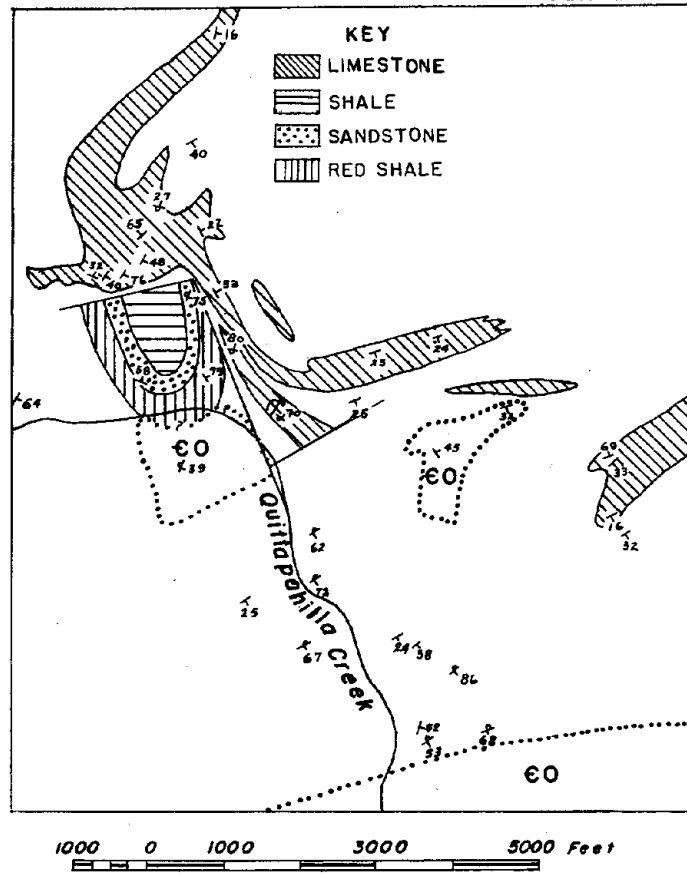
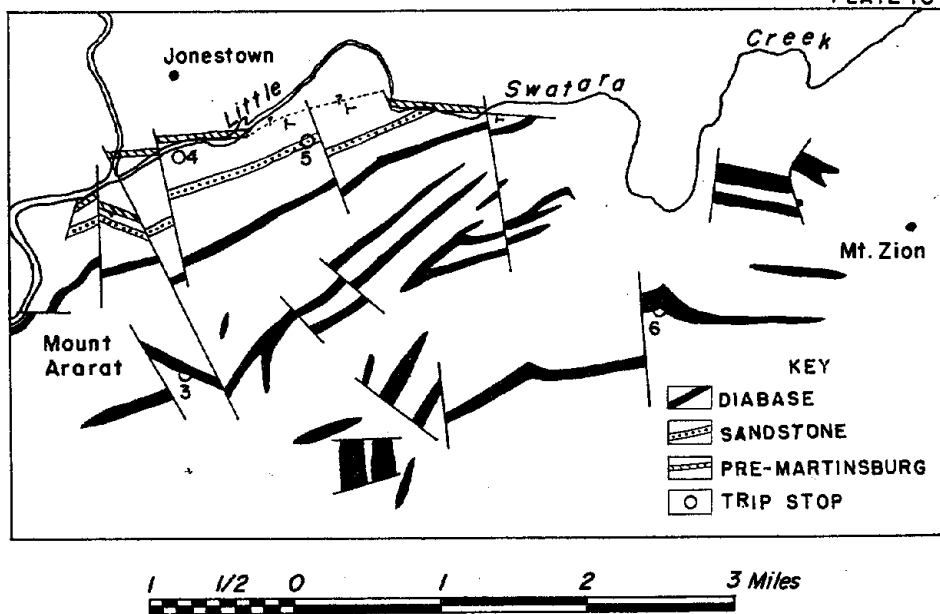


PLATE 10



TRIP 3

Sunday, May 30

Martinsburg Formation and Associated Eruptive Rocks of the Jonestown Area.

Departure: 8:45 A.M., by bus, from Community Inn, Hershey, Pa.

Topographic maps: Hummelstown and Lebanon quadrangles.

ITINERARY

Miles

- 0.0 Go east on E. Chocolate Avenue (route U.S. 422).
- 2.4 Lebanon County line. Entering Palmyra.
- 3.2 Straight ahead.
- 3.7 Straight ahead, leaving Palmyra.
- 4.7 On left, waste piles of H. E. Millard Lime & Stone Company Quarries.
- 5.6 Outcrops of Beekmantown dolomite in creek bank.
- 6.4 Turn left, just beyond Millard Lime & Stone Company office.
- 6.9 Turn left.
- 7.4 Turn right.
- 7.5 Crossing Quittapahilla Creek.
- 7.6 Outcrops of typical Martinsburg shale. Note slumping.
- 8.2 On right, red shale float. On left, outcrops of Annville limestone on far side of creek.
- 8.4 STOP 1 — 20 minutes.
Quarry in Martinsburg Limestone.

The rocks exposed in this quarry and along the road to the northeast display the greatest continued thickness of limestone in the Martinsburg formation. They were classified as Leesport Cement Rock by Stose and Jonas (1927) and by Stose (1937). R. L. Miller (1937) described a roadcut at this place with 50 feet of Martinsburg limestone exposed. Stose (1946)

included these rocks with others exposed on both banks of the Susquehanna River as Formation No. 2 of the Taconic Sequence. The quarry was opened after Miller had seen the exposure, and the following sequence exists:

Lithologic types	Thickness
Thin-bedded black shale with interbedded calcareous sandstone and a few thin layers of argillaceous limestone; beds 1/2"-5"	---
Dark-gray limestone in beds 1"-2" with shale partings	40'
Black limestone in beds ranging from 1/2"-3" with shale partings; many veins of intergrown quartz and calcite	51'
Massive, dark-gray to black limestone with intra-formational conglomerate in lower part	81'
Interbedded platy limestone 1/2"-5" and shale 1" with one thick layer of intra-formational conglomerate whose matrix contains rounded quartz grains	75'
Gray shale	---
Total	247'

The rocks are overturned to the southwest and dip about 70 degrees to the northeast. They grade downward into soft, gray shale and are overlain by interbedded black shale and calcareous sandstone which has been greatly sheared in a fault zone. The quarry is located near the southeast end of a wedge which is cut by a dip fault about 200 yards southeast of the road corner. Southeast of the fault is gray shale interbedded with sandstone and overlain by red shale.

Across the Quittapahilla Creek to the southwest is a knob of Annville limestone. This is overturned to the northwest, and it must, therefore, be separated from the quarry limestone by a fault. A second area of Annville limestone occurs to the southeast beyond the ridge.

Along the road paralleling Quittapahilla Creek to the west is gray shale interbedded with sandstone and that, in turn, is overlain by red shale exposed at the next road corner to the west.

9.5 Turn left.

10.0 Turn right.

10.4 Turn left on route U.S. 422.

10.9 On both sides of road, quarries in Annville limestone,

11.2 Crossing Quittapahilla Creek, entering Annville.

11.8 Straight ahead

13.5 Entering Cleona.

14.0 Turn left.

14.1 Railroad overpass.

14.5 Turn right. Road climbs hill to Harrisburg peneplane level; underlain by Martinsburg shale.

15.2 STOP 2 -- 25 minutes. Stop east of overpass and walk across.
Enter cut north of bridge.
Railroad cut in Martinsburg shale and limestone.

The rocks in the cut, like those at STOP 1, have been assigned to various stratigraphic horizons. They are represented on the Geologic Map of Pennsylvania as an inlier of the Leesport Cement Rock and are so described by Stose and Jonas (1927). R. L. Miller (1937) recognized them as possibly Martinsburg limestone and gave an estimated thickness of 105-270 feet. Stose (1946) cites this exposure as part of the lower limestone of the Taconic Sequence. He gives the following section:

Lithologic types	Thickness
Gray shale	---
Platy limestone (1" beds) and irregular bedded limestone (2"-4") with shale partings	45'
Massive limestone with round, glassy quartz grains	
Shale and thin-bedded limestone (may be the overlying beds repeated by folding)	
Thick-bedded, dark-gray, granular, siliceous limestone (2"-3" beds) with shale partings	30'

Total	75'

The outcrop consists essentially of interbedded limestone and shale with two or more sequences of shale measuring about 20 feet thick. To the north of the overpass are some 80 feet of limestone separated into two units by 20 feet of dark-gray sericitic shale. Immediately under the bridge is a unit composed of dark-gray-to-black sericitic shale which shows shearing and drag folds. South of the bridge is an overturned anticline composed of about 80 feet of platy limestone, and this sequence also is divided into two units by about 20 feet of shale. In addition, the southern exposure contains a six-foot layer of dense, dark-gray limestone which has no counterpart in the northern part of the exposure. The shale in the southern part of the exposure is dark-gray-to-black which weathers to a reddish-brown whereas that of the northern part is dark-gray sericitic shale which weathers to a light-gray. The northern sequence contains more limestone and less shale than does the southern. Megascopically, the two sequences seem not to be repetitions of each other. Structurally, it is difficult to fit them into a plausible scheme. Tentatively, the following is suggested as the sections here exposed:

Lithologic types	Thickness
Interbedded limestone 1/2" to 4" and shale 1/8" to 1/4"; in part evenly bedded but mostly lenticular	50'
Dark-gray sericitic shale	22'
Interbedded limestone and shale	10+'
Dark-gray-to-black sericitic shale showing drag folds and considerable shearing (under bridge)	---
Platy, dark-gray limestone 1/4" to 4" interbedded with hard, calcareous sandy shale 1/16" to 1/4"; limestone equals 80-90 percent of the thickness	35'
Dark-gray-to-black brittle shale; weathers reddish-brown	22'
Massive limestone with thin interbeds of hard shale	6'
Dark-gray-to-black sericitic shale	16'
Interbedded dark-gray limestone and shale forming core of anticline	10+'

Total	171+'

15.5 Road crosses over the line of the Union Canal Tunnel. This tunnel cuts approximately the same beds as the railroad cut at STOP 2. It is the oldest transportation tunnel in the United States. It was built between 1823 and 1827. Although it has been abandoned since 1884, the tunnel has not caved in.

15.9 Turn left.

16.1 Intersection with route Pa. 72. Continue north on route Pa. 72.

18.5 STOP 3 -- 30 minutes.

Roadcut and quarry in intrusive diabase.

a. Roadcut. Medium-to-coarse-grained dark-gray diabase and massively bedded graywacke type of sandstone occur in the roadcut. The plane of contact between the two is obscure due to weathering,

but it appears to be dipping gently to the south. A diabase sill in contact with a similar coarse-grained quartzitic sandstone occurs on the valley wall of Swatara Creek to the southwest, and a similar occurrence is strongly suggested in a roadcut to the southeast (STOP 6). This, and other evidence, indicates that this also is probably a sill. The diabase extends across the hilltop east of the road for a distance of 150-200 yards where it ends in graywacke and shale.

Mt. Ararat, to the southwest of this exposure, also is made up of diabase intrusive bordered on the north and south by arkosic or graywacke sandstone. Between the railroad and the abandoned route 72, the diabase gives way to clastic sedimentary rock as float. It is believed that the roadcut is located in a block of the same intrusive as that on Mt. Ararat which has been cut by cross faults and twisted to a position which is about 45 degrees to the trend of the western portion of the sill. In this block is a quarry which was opened several years ago as a source of crushed stone and which is the next stop.

- b. Quarry. The quarry is just west of the railroad, about two miles south of Jonestown. It is roughly triangular in outline, and the southwest wall is about 90 feet high. The rock is a medium-grained diabase which has been sheared and faulted along many surfaces with varied orientation. Chloritization of the diabase is prominent, especially in the northwest corner of the quarry. Near the entrance to the quarry is a knob which seems to be composed of finer grains and to be less disturbed. This is believed to be near the contact with the underlying graywacke.

These two exposures are interpreted as part of a block of a sill which has been cut by cross faults and then turned into its present position. Although contacts are not exposed, there is a parallelism between the belts of float of diabase and graywacke or arkose which is characteristic of the area.

- 18.9 Buses park here for STOP 3.
- 19.0 Bear right on black-top road. Leave route Pa. 72.
- 19.8 Outcrops of Beekmantown (?) dolomite.
- 20.0 Straight ahead.
- 20.35 Top of Bunker Hill, underlain by quartzose sandstone at crest, with lavas on both sides.
- 20.5 Take right fork and park.

STOP 4 -- 30 minutes.

Quarry in amygdaloidal lava, south of Little Swatara Creek.

The quarry is located near the base of a series of lava flows which make up the bulk of Bunker Hills. Seven types of extrusive igneous rock are recognized megascopically in the area: (1) massive dark-gray-to-black basalt; (2) flow breccia with blocks showing few small amydules and a matrix showing a granular nature; (3) coarse amygdaloidal lava; (4) pillow lava with concentric rows of small amydules around the periphery of the pillows; (5) flow breccia of red and green blocks with much vein calcite; (6) porphyritic lava with phenocrysts of feldspar; and (7) pyroclastics, some of which suggest water deposition. Stose and Jonas (1927) describe a lave flow, three hundred feet thick, repeated by a strike fault in the southern portion of the Bunker Hills area. The presence of pyroclastic rock, as well as the megascopically different characteristics of the lava, strongly suggests several thin rather than one thick flow in the area.

The least weathered lava of the area is exposed in this quarry. Three varieties are shown: (1) dense, bluish-gray lava which becomes dark-gray to almost black with slight weathering; (2) vesicular patches or zones which can be traced along the quarry face for a few feet; and (3) pyroclastics. The dense, bluish-gray lava shows a varied character where weathering has progressed beyond the initial stage: (a) dense, reddish-purple rock which is either massive or amygdaloidal; (b) blocks of gray, amygdaloidal lava which contains calcite or calcite and quartz; and (c) dense, brittle, light-gray lava which is jointed into sharp-angled fragments. The pyroclastic rock is exposed above the top of the quarry, on the north slope of Bunker Hills and consists of three types of material: (a) dense, brittle, light-gray fragments 2"-4"; (b) somewhat rounded masses 4"-8", some of them dense, some amygdaloidal; and (c) angular to rounded granular masses in the matrix which weathers to a brown, punky material.

Small "bun-like" pillows have been described from this exposure, but the author was unable to locate them. Slightly weathered surfaces offer the best opportunity of studying the internal structures of the lava.

Faults without uniform orientation occur at many places on the quarry wall. Many of the surfaces are slickensided, and the pitch of the striations has no uniform orientation. The faults are believed to be the result of minor adjustment between the blocks during the time of major deformation. The lava ridge to the west of the quarry is broken by a cross fault which can be traced for a distance of about one mile

with the rock on the east having been shifted to the north.

- 20.55 Turn right.
- 20.8 On right, outcrops and large float blocks of lava.
- 20.9 STOP 4a -- Pillow lavas.
- 21.5 Turn right, entrance to Reber Sand Quarry.
- 21.7 STOP 5 -- 20 minutes.
Reber Sand Quarry

The quarry is located in the end of the higher of two ridges which make up Bunker Hills. The ridge is traceable on aerial photographs westward beyond the Tremont Branch of the Reading Railroad. In this distance it is broken by three cross faults and offset by as much as 300 yards. To the east the ridge also is offset to the south a comparable distance, and the offset portion can be traced to the south bank of Little Swatara Creek. No sandstone of comparable type has been observed north of the Little Swatara Creek. Apparently, it is bounded by a fault there, also. A similar sandstone occurs at Sand Hill north of Lebanon, where it has been quarried. A belt of float can be traced from the quarry southwestward almost to the railroad cut (STOP 2). These two occurrences of sandstone are believed to be the north and south limbs, respectively, of a syncline which is the principal structural feature of the belt of Martinsburg formation between Jonestown and Lebanon.

The rock is a relatively pure, coarse-grained massive quartzose sandstone. It is nearly white where freshly exposed, but it becomes stained a light-brown upon weathering. Discarded blocks show greenish and bluish waxy clay in stringers ranging from an eighth to half an inch thick. In the summer of 1952, the quarry face showed a thin lens of the waxy clay, about eight inches thick and fifteen to twenty feet long. This was interpreted as bedding and showed a strike of N 47° E and a dip of 42° S. The sandstone is underlain by a thin red shale which can be traced intermittently westward to highway 72. It is overlain by lava which megascopically is different from the lava of the last stop, containing a great deal of reddish rock rather than the gray-to-black basalt.

Turn around and return to paved road.

- 21.9 Turn right on paved road.
- 22.0 Straight ahead. Sandstone on left is the same as in the Reber Quarry. Note how ridge is offset here.

- 22.4 Road crosses valley underlain by shale, hill ahead is supported by a diabase intrusive.
- 22.7 Straight ahead.
- 22.9 Top of diabase ridge.
- 23.8 Turn sharp left.
- 24.5 Turn left.
- 24.6 Bear right
- 25.8 Turn right on route Pa. 343.
- 25.9 Straight ahead on Pa. 343.
- 26.4 STOP 6 -- 25 minutes.
Roadcut. Contact metamorphism of argillaceous sandstone.

The south end of the outcrop is composed of medium- to coarse-grained hard, brittle arkose containing euhedral and anhedral crystals of feldspar which show glassy luster on fresh surfaces. The beds dip about 20° N. Overlying the arkose is a medium- to coarse-grained diabase which can be traced, as float, from the western edge of the hill just west of the highway, eastward for one and one-half miles. Contact of the diabase and arkose is not exposed, but the pattern of the outcrop with a "V" pointing down stream seems to indicate that the diabase is a concordant intrusive. The computed thickness of the sill is 210 feet. The floor of the small valley, west of the highway, is a veritable "felsenmeer" of diabase boulders.

Overlying the sill is a second arkose which shows less feldspar and is apparently devoid of bedding. The contact between the diabase and the upper arkose is obscured, but the evidence of parallelism of the belts of float of the upper and lower arkose and the diabase bears out the suggestion of a concordant relationship between the intrusive and the arkose.

The diabase ends at the western edge of the hill on the west side of the highway where it has been cut by a cross fault. This portion has apparently been moved northward about 300 yards with respect to the western portion.

Turn around.

- 27.1 Continue north on Pa. 343.
- 28.7 Straight ahead.

- 29.2 Roadcut in buff shales and arkosic sandstone.
- 30.1 Turn left on route U.S. 22. (LUNCH STOP).
- 32.1 Reber Sand Quarry visible on the left.
- 32.9 Outcrop of red shale on right.
- 33.1 Outcrops of red and tan shale on left.
- 33.5 Crossing Swatara Creek.
- 33.7 Turn right, leave U.S. 22, continue north on route Pa. 72.
- 34.9 More interbedded red and tan shales.
- 35.2 View of Swatara Gap straight ahead.
- 36.0 Lickdale. Straight ahead.
- 36.5 On right, Little Mountain, formed by an anticline of argillaceous sandstone in the Martinsburg.
- 37.5 Approaching Swatara Gap in Blue Mountain. Blue Mountain is supported by the Tuscarora sandstone.
- 38.2 STOP 7 -- 25 minutes.
Shale quarry at south end of Swatara Gap through Blue Mountain;
in shale at top of Martinsburg; Eden fossils.

This quarry has been known for a long time. The rock is a soft, gray shale with thin silty sandstone layers. The shale breaks up into small chips $1/4"$ to $1"$. About 85 feet are exposed here, but shale chips, containing fragments of Cryptolithus are found for 150-175 feet south of the quarry, suggesting a thickness of at least 235 feet, or more. The formation is fossiliferous, and especially well-preserved specimens of Cryptolithus have been found. Stose (1909) gives the following list of fossils from this locality:

Graptolites

Diplograptus sp.

Bryozoan

Spatiopora lineata

Crinoids

Ectenocrinus simplex

Heterocrinus sp.

Brachiopods

Pholidops cincinnatiensis

Dalmanella emacerata

Dalmanella multisecta

Sowerbyella aff. sericea

Sowerbyella aff. plicatella

Rafinesquina ulrichi

Leptaena gibbosa

Pelecypods

Otenodonta filistriata

Clidophorus planulatus

Rhytmya producta

Colpomya faba

Cuneamya cf. neglecta (Eden form)

Gastropods

Archinacella patelliformis

Simulites cancellatus

Liospira micula (Eden var.)

Liospira ohioensis

Cephalopods

Orthoceras aff. transversum

Worms

Cornulites aff. flexuosus

Ostracods

Jonesella crepidiformis

Geratopsis chambersi

Primitia cf. bivertex

Primiticella unicornis

Elpe radiata

Trilobites

Cryptolithus bellulus

Cryptolithus tessellatus (Eden var.)

Calymene granulosa

Triarthrus beeki (Eden var.)

Tornquistia sp.

He quotes Ulrich as saying: "Most of these species are confined to the Southgate (middle) member of the Eden in the Cincinnati section. Others in the list occur there also in the Economy (lower) member of the Eden... The available faunal evidence thus seems to establish that the top of the Ordovician section in the Swatara Gap is a bed of shale not younger than middle Eden."

Buses turn around.

- 40.2 Lickdale. Turn right on route Pa. 343.
- 42.1 Entering Indiantown Gap Military Reservation.
- 43.7 Turn left on route Pa. 343.
- 44.5 Leaving Military Reservation.

45.6 Turn right, go west on route U.S. 22.

46.8 STOP 8 -- 15 minutes.

Roadcut in graywacke, shale, etc., of Martinsburg formation.

North of highway 22, the cut on the side road exposes a thickness of about 250 feet of graywacke, shale, and interbedded cross-bedded sandstone and shale. The graywacke ranges in thickness from a few inches to ten feet with interbedded shale layers from 2 to 10 inches. The shale is soft and gray, and weathers into small irregular chips. At the road corner, the youngest rock exposed in this section is about 30 feet of medium- to fine-grained sandstone with some silt which shows current cross-bedding. The cross-bedded sandstone ranges in thickness between one-half inch and twelve inches and is interbedded with light-gray shale.

Each of the two lithologic types shown here is quite characteristic of the elastic sedimentary rock of much of the Martinsburg formation.

Continue west on route U.S. 22.

50.2 Turn left on route 743.

50.5 Red and tan shale in roadcut.

50.7 Red and gray shale in roadcut.

51.7 More red shale

53.2 Buff shales.

54.0 Crossing Swatara Creek.

54.1 Turn right.

54.4 Road crosses Martinsburg shale -- Hershey limestone contact. On left, waste piles from quarries in Annville limestone.

55.5 Bear left.

55.7 Turn right.

56.1 Turn left.

56.4 Turn right on Chocolate Avenue, entering Hershey.

57.0 Community Inn.

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