XVI INTERNATIONAL GEOLOGICAL CONGRESS

Guidebook 10 - Excursions B-1, B-2, B-3

SOUTHERN PENNSYLVANIA AND MARYLAND

International Geological Congress
XVI session
United States, 1933

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SOUTHERN PENNSYLVANIA AND MARYLAND

By

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1932

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 15 cents

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SOUTHERN PENNSYLVANIA AND MARYLAND

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By G. W. Stose, A. I. Jonas, and G. H. Ashley

Excursions B–1 and B–2 cross the Atlantic Coastal Plain and the Appalachian region. Their purpose is to see the Paleozoic rocks and typical structural features of the Appalachians, the Triassic sediments and intrusive diabase, and the magnetite deposits associated with the diabase.

APPALACHIAN REGION

The Appalachian region is a highland tract about 350 miles (563 kilometers) wide, nearly parallel to the Atlantic coast and extending from eastern Quebec to central Alabama. Southwest of New England it is characterized topographically by linear mountain ridges that trend northeast, some of which are many miles in length, narrow valleys parallel to the ridges, and dissected plateaus. From north to south the region exhibits similar geologic features and has had a similar geologic history. Pre-Cambrian crystalline rocks form the floor on which a thick sequence of Paleozoic sediments was deposited, beginning with the Lower Cambrian and including the Pennsylvanian and a small representation of the Permian. These sediments were laid down in a shallow epicontinental sea, forming the gradually sinking Appalachian geosynclinal basin. The sediments were later compressed and compacted into hard rocks and were folded by compressive forces in late Paleozoic time into elongated arches and troughs trending northeast, at right angles to the direction of the compression. Erosion of these folded rocks removed the softer beds more rapidly than the resistant beds and produced valleys underlain by the soft beds and mountains composed of the hard beds.

The physical divisions of the Appalachian region comprise, from east to west, the Piedmont province, the Blue Ridge province, the Valley and Ridge province, and the Appalachian Plateaus. The Coastal Plain province borders the Appalachian region on the southeast and is underlain by Cretaceous, Tertiary, and Quaternary sediments, which overlap on the crystalline rocks of the Piedmont Upland to the west and whose submerged eastern part forms the Continental Shelf.

The easternmost or Piedmont province is divided into two parts—the Piedmont Upland and the Piedmont Lowland. The upland is underlain by pre-Cambrian crystalline rocks of sedimentary, intrusive, and extrusive origin. In the northern part of the upland there are some valleys of lower Paleozoic rocks. The Piedmont Lowland, northwest of the upland, contains lower Paleozoic rocks, mostly limestones, and an area of younger Triassic sediments.

The Blue Ridge province is underlain in part by pre-Cambrian rocks and includes infolded synclines of hard Lower Cambrian conglomerates, quartzites, and slates, which in Pennsylvania and Maryland generally form the tops of the mountains that rise above the moderate relief of the Piedmont province, to the southeast.

The Valley and Ridge province in Pennsylvania and Maryland is divided into two parts—the southeastern part a wide flat valley underlain by Cambrian and Ordovician limestones and slates, and the northwestern part a belt of alternate high ridges and valleys. The narrow ridges are composed of resistant sandstone of Silurian, Devonian, and Mississippian age, the beds of which are generally steeply dipping and truncated, and are separated by parallel valleys underlain by softer shales, limestones, and less resistant sandstones. The ridges of this region are distinctly level-crested as the result of peneplanation.

The westernmost province, the Appalachian Plateaus, is underlain by slightly folded shales and sandstones of the Carboniferous coal measures. The eastern margin of the plateau is called the Allegheny Escarpment or Allegheny Front in Pennsylvania and Maryland. The western part of this province is a lower and younger plateau, which grades imperceptibly into the Mississippi Valley region to the west.

Pre-Cambrian crystalline rocks are exposed in the Piedmont and Blue Ridge provinces. They comprise sedimentary schists, gneisses, quartzites, and marbles; intrusive igneous rocks, both granite and gabbro; and metamorphosed basalt and rhyolite lava flows. They occur in two belts. The southern belt of the crystalline rocks, which is included in the Piedmont Upland, extends from the western border of the Coastal Plain to the Lower Cambrian rocks on the northern edge of the Piedmont Upland. The northern edge of these pre-Cambrian rocks is the trace of an overthrust fault, the Martic overthrust. The northern belt of crystalline rocks occurs for the most part within the

Blue Ridge province, which comprises the Highlands of New York and New Jersey, the Reading Hills, and the Catoctin-Blue Ridge anticlinorium of Pennsylvania. The Hellam Hills anticline and other upfolds that lie in the Piedmont Province are parts of this anticlinorium.

The Lower Cambrian sediments were deposited on these old rocks, but because of deep erosion they occur only as remnants on the pre-Cambrian rocks of the Martic thrust block, and their former eastward extent is not known. To the northwest, in the Appalachian Mountains, the Lower Cambrian beds, including quartzites, slates, and conglomerates, are 4,000 feet (1,219 meters) thick and form some of the high ridges. These first sediments were followed by about 13,000 feet (3,962 meters) of fine silts, mostly calcareous, which formed limestones, dolomites, and fine shales. The deposition of these beds continued through the rest of Cambrian and all of Ordovician time, though during this long period there were minor intervals in which deposition ceased, owing to local uplift and erosion followed by overlap. The most marked unconformity thus produced is in the southeastern part of the region, where Ordovician argillaceous limestone (Conestoga) overlaps the eroded edges of the older Paleozoic limestones and rests on the Lower Cambrian quartzite.

Northeast of Harrisburg, Pennsylvania, the Ordovician period was ended by uplift, folding of the rocks, and erosion, of increasing intensity in the northern Appalachians and New England, but southwest of Harrisburg no break is observable. The Silurian sedimentation was marked throughout by deposition of thick beds of sand and argillaceous silt, which became massive sandstone and shale. The heavy sandstone near the base of the Silurian (Tuscarora) forms some of the highest mountains of the Valley and Ridge province. In the Devonian period the deposition of argillaceous silt predominated, with some fine sand, and great thicknesses of shale and sandstone, amounting to 10,000 feet (3,048 meters) in eastern Pennsylvania, are credited to this period. In lower Carboniferous (Mississippian) time hard sandstone and red and green shales, with some coarse conglomerate, were deposited, and these were followed in upper Carboniferous (Pennsylvanian) time by a great thickness of coal measures, largely nonmarine deposits including many beds of coal, some over 10 feet (3 meters) thick. These younger beds crop out in the western part of the region, in the Allegheny Plateau. A heavy conglomerate at the base of the coal measures forms the Allegheny Front, which is the east edge of the Allegheny Plateau in Pennsylvania, and the Cumberland Escarpment, farther south.

In Permian time, after a small deposit of sediments, mountain-making forces, acting from the southeast, compressed the rocks and folded them into great anticlines and synclines many miles long. This orogenic movement was accompanied by thrust faulting toward the northwest and metamorphism in the inner or southeastern part of the Permian folded mountains. The region was at the same time uplifted above the sea and subjected to erosion.

In Triassic time great elongated basins paralleling the coast were formed by down warping, probably accompanied by down faulting, and during Upper Triassic time nonmarine red shales and sandstones accumulated to a thickness of 25,000 feet (7,620 meters). These beds were later tilted but not folded, broken by normal faults, which displaced the blocks and further tilted them, intruded by diabase sheets and dikes, and in places covered by surface lava flows. In pre-Cretaceous time the block-fault mountains formed after Triassic time were reduced by long continued erosion to a peneplain. In Cretaceous and Tertiary time the Appalachian region was gently bowed up and subjected to erosion, and the mountains and valleys were carved out of its peneplaned surface. From early Cretaceous time to the end of the Miocene marine sediments derived from the erosion of the uptilted land were deposited on the submerged eastern border of this peneplaned surface. Renewed uplift in Pliocene and Quaternary time raised these beds above the sea, and they are now exposed on the Coastal Plain, on the east border of the Appalachian Highland region.

During the Pleistocene epoch ice sheets invaded the northern part of the region several times and left evidence of their presence in glacial features. Along the Atlantic coast the sea level is considered to have oscillated up and down, going down with the withdrawal of water from the ocean through evaporation and precipitation as snow on the land during glacial stages, when the ice sheets were built up, and going up with the melting of the ice in interglacial stages, and the resultant spasmodic retreat of the sea is recorded in nearly level, steplike gravel-covered benches and terraces along the coast and bordering the larger streams.

THE ROCKS

The oldest rock of the area, the Baltimore gneiss, is exposed in several anticlines from the western edge of the Coastal Plain sediments at Baltimore to a point 3 miles (4.8 kilometers) south of Bluemont, Maryland, a distance of about 15 miles (24 kilometers) across the strike. It is a recrystallized rock of sedimentary origin, which is in some places a thick-bedded gneiss of granitic aspect and in others a thin-banded ribbon gneiss. It contains layers of hornblende gneiss and is intruded by the Hartley augen gneiss.

The Baltimore gneiss is overlain unconformably by a series of later pre-Cambrian rocks termed the Glenarm series, which consists, from the bottom up, of the Setters formation, 1,000 feet (305 meters) thick, composed of mica schist, mica gneiss, and prominent quartzite beds; the Cockeysville marble, 400 feet (122 meters) thick; and the Wissahickon formation, of unknown thickness, composed of oligoclase mica schist, gneiss, and quartzite. The oligoclase-mica schist is a crystalloblastic rock containing biotite, staurolite, kyanite, and garnet and was formed in the mesozone. The Glenarm series is intruded by granite, granodiorite, diorite, gabbro, and ultrabasic rocks, also of pre-Cambrian age. (See table of formations.) In the base of the Wissahickon formation and interlayered with the underlying Cockeysville marble there are flows of metabasalt. Basal Cambrian rocks unconformably overlie this series in southern Pennsylvania and Maryland.

Half a mile (0.8 kilometer) northwest of the Phoenix anticline the oligoclase-mica schist passes into the albite-chlorite schist facies of the Wissahickon formation. This facies includes both coarse and fine grained schist with quartzose beds which are prominent in the zone of the so-called Peters Creek formation, now considered to be a part of the Wissahickon and not a separate formation. The coarse-grained albite-chlorite schist is in part biotitic and garnetiferous and exhibits retrogressive metamorphism [1] in the chloritization of these mesozone minerals. It extends northwestward across the strike for about 12 miles to a point near Shrewsbury, Pennsylvania. The albite-chlorite schist becomes fine grained with a marked younger foliation to the northwest of Shrewsbury, where it forms the northwestern edge of the Martic overthrust. This overthrust is a low-angle fault of wide extent on which the Wissahickon formation has been carried over Lower Cambrian phyllite and schist and over Lower Cambrian and Ordovician limestones in Pennsylvania near the western edge of the Piedmont Upland.

The Martic overthrust was folded during and after overthrusting into a great foliation anticline called the Tucquan arch, which extends for 65 miles (105 kilometers) along the strike from the southwest edge of Mine Ridge, Pennsylvania, to a point south of the Patapsco River, Maryland. In this arch both the older and

[1] Retrogressive metamorphism is the alteration that takes place when a schist that has been crystallized under deep-seated conditions is later carried into an upper tectonic zone, and new minerals that are characteristic of the upper zone of metamorphism are formed at the expense of the heavier minerals of the deep-seated zone.

the younger foliations dip northwest and southeast, away from the axis.

Northwest of the Martic overthrust, in the northern part of the Piedmont province, are anticlines exposing Lower Cambrian and pre-Cambrian rocks with intervening synclines containing Cambrian and Ordovician limestones. The rocks are closely folded and overturned to the northwest, and many of the northwestern limbs of the anticlines are broken and thrust northwestward over the adjoining synclines. This folding and faulting occurred during late Paleozoic time.

The Hellam anticline, lying north of York Valley, belongs to the folds of the Catoctin-Blue Ridge anticlinorium, to the west, from which it is separated by the belt of Triassic sediments. The Mount Joy limestone valley, north of the Hellam anticline, would be continuous with the Lebanon Valley, also underlain by Paleozoic limestones, were it not for the presence of the younger unconformable Triassic sediments, and the two would together form one great limestone valley.

Northeast of York the Hellam anticline exposes pre-Cambrian altered rhyolite and basalt lava flows like those of the Appalachian Mountains to the southwest. They are overlain unconformably by the basal unit of the Cambrian, here 600 feet (183 meters) thick, called the Hellam conglomerate member of the Chickies quartzite and composed of slate and beds of both fine and coarse quartzose conglomerate. Above the Hellam member is 350 feet (107 meters) of quartzite bearing *Scolithus*, which constitutes the upper part of the Chickies formation. Still higher rocks of the Lower Cambrian arenaceous series are the Harpers phyllite and Antietam quartzite, together about 1,200 feet (366 meters) thick. The upper beds of the Antietam quartzite contain Lower Cambrian fossils.

The Antietam is overlain by Lower Cambrian carbonate rocks—the Vintage dolomite, 650 feet (198 meters) thick; the Kinzers formation 130 feet (40 meters), and the Ledger dolomite, 1,000 feet (305 meters). This series occurs on the south side of the Hellam anticlinorium in the York and Lancaster Valleys and is equivalent to the Tomstown dolomite of the Appalachian Valley. The limestones carry Lower Cambrian fossils, and the Kinzers formation contains a rich trilobite fauna.

In the York-Lancaster area uplift and erosion followed Beekmantown deposition, and in Chazy or Black River time the Conestoga limestone, with a basal limestone conglomerate, was laid down on the beveled edges of the eroded Lower Cambrian rocks.

North of the Hellam anticline in the Mount Joy and Lebanon Valleys the Vintage and Ledger dolomites overlie the Antietam quartzite, and the Kinzers shale is absent.

The Elbrook limestone, 1,000 feet (305 meters) thick, of Middle Cambrian age, overlies Lower Cambrian dolomite and is followed by the Conococheague limestone, which is 1,000 feet thick and carries cryptozoan reefs. The Conococheague is of Upper Cambrian age (Ozarkian of Ulrich).

The Beekmantown limestone, 2,000 feet (610 meters) thick, of Lower Ordovician age, overlies the Conococheague limestone. North of Lancaster it is overlain by the Cocalico shale, which may be lower Trenton or younger and is probably about equivalent to the Martinsburg shale in the Appalachian Valley north of Lebanon. In the Lebanon Valley the Stones River limestone, of Chazy age, is present under the Martinsburg shale, and west of Harrisburg the Chambersburg limestone lies between the Stones River and Martinsburg. At this time there was minor uplift and erosion also in the Appalachian Valley and an outpouring of basalt lava north of Lebanon.

Above the Martinsburg shale of Lebanon Valley is the Tuscarora sandstone, basal Silurian, which is 400 feet (122 meters) thick and forms Blue Mountain. North of Harrisburg and westward red shale and sandstone of the Juniata intervene between the Martinsburg and Tuscarora. The Juniata is classed as Ordovician by the United States Geological Survey but is believed by the writers to be basal Silurian. There is a marked unconformity in places between the Martinsburg and Tuscarora east of Harrisburg, where the Juniata is absent.

The Clinton formation, largely shale and some sandstone with beds of fossiliferous iron ore (hematite), succeeds the Tuscarora. It is about 800 to 1,000 feet (244 to 305 meters) thick. The Cayuga formation overlies the Clinton and is about 1,000 to 1,500 feet (305 to 457 meters) thick. This formation, which contains salt deposits in New York State, is in this region largely thin-bedded limestone and shale with some red mudrock called Bloomsburg shale. The next formation is the basal Devonian Helderberg limestone, 150 to 700 feet (46 to 213 meters) thick. It contains many beds of chert and is generally very fossiliferous. The Oriskany sandstone, next above, is 300 to 400 feet (91 to 122 meters) thick and is in places a very pure sandstone quarried for glass sand. This sandstone makes ridges and is characterized by hollow molds of large fossil shells that have been dissolved out. The Devonian black shale above is called Marcellus and Hamilton and is 1,000 to 1,200 feet (305 to 366 meters) thick. Black calcareous beds at the base in places represent the Onondaga limestone. This black shale is followed by the Genesee and Portage shales, thin fissile black shale and olive-green platy shale and fine sandstone, almost barren of fossils, 1,500 to 2,000 feet (457 to 610 meters) thick. The Chemung formation, next above, is a buff to pink shale with rusty fossiliferous sandstones containing characteristic brachiopods and ostracodes. It is 1,000 to 3,500 feet (305 to 1,067 meters) thick. It merges upward into red sandstone and shale, unfossiliferous except for fragments of wood and probably of estuarine or nonmarine origin, called the Catskill, which is 2,000 to 4,000 feet (610 to 1,220 meters) thick. In this area the Catskill is largely of Chemung age. This is the last of the Devonian rocks.

The Carboniferous begins with a heavy sandstone with pebbly beds, called Pocono, 800 to 1,000 feet (244 to 305 meters) thick. The overlying Mauch Chunk shale, 3,000 feet (914 meters) thick, consists largely of red shale with some limestones which thicken to the southwest and are named the Greenbrier. The Mauch Chunk and Pocono belong to the Mississippian series of the Carboniferous. The Pottsville conglomerate, 1,200 feet (366 meters) thick, is the basal formation of the Pennsylvanian part of the Carboniferous. It is a ridge maker and forms the top of the escarpment of the Allegheny Plateau. It is succeeded by "Coal Measures" rocks, named the Allegheny, Conemaugh, and Monongahela formations, but these rocks will not be seen in the section visited.

At the end of the Paleozoic era came the Appalachian deformation in response to compressive stress. The pre-Cambrian rocks of the Piedmont Upland were thrust northwestward over Cambrian and Ordovician rocks along a low-angle thrust fault called the Martic overthrust. There also occurred close folding, thrust faulting, production of cleavage, and retrogressive metamorphism in the pre-Cambrian rocks of the northwestern part of the overthrust block; close folding, production of cleavage, thrust faulting, and metamorphism in the Paleozoic rocks of the York and Lancaster Valleys west of the overthrust; and close folding in the Paleozoic rocks of the Cumberland Valley north of Harrisburg and of the Lebanon Valley. Since the post-Paleozoic mountain making the region has not been again subjected to intense compression and folding.

After prolonged erosion of the mountains formed by the Appalachian revolution an elongated basin was formed in the Piedmont by down warping and faulting, and in the late part of the Triassic period red sand and mud derived from the uplifted area on the east side were laid down unconformably on the older rocks in the basin, largely Paleozoic limestone and shale. Two Triassic formations are recognized—the New Oxford formation (arkosic sandstone and red shale) below and the Gettysburg shale (red shale and sandstone) above. These beds are tilted uniformly northwest at an average dip of 20° and aggregate

25,000 feet (7,620 meters). They are nonmarine and contain a few fresh-water shells, fossil wood, and dinosaur tracks. They are of Upper Triassic age. Normal faulting, which occurred during and at the end of the Triassic deposition, tilted the beds gently northwestward. The intrusion of diabase sills and dikes accompanied the faulting, and at the same time hot solutions brought up the magnetite mined at Cornwall. Since Triassic time this area has been above sea level and erosion has prevailed, but along the Atlantic coast sand, clay, and marl have been deposited on the submerged part of the continental shelf. These sediments have since been raised above sea level, so that on the Atlantic Coastal Plain are now exposed deposits of Cretaceous and Tertiary age dipping gently seaward. In Quaternary time terraces were cut by the sea and streams on the rising land surface at definite levels that mark temporary positions of sea level. These terraces were covered by gravel and sand along the coast, scattered remnants of which are now found on the upland far inland.

Formations encountered on excursions B–1 and B–2

Age		Name	General character
Triassic	Upper.	Gettysburg shale	Red shale and sandstone.
		New Oxford formation	Arkosic sandstone and red shale.
		Unconformity	
Carboniferous	Pennsylvanian.	Monongahela formation	Coal-bearing shale and sandstone.
		Conemaugh formation	Do.
		Allegheny formation	Do.
		Pottsville conglomerate	Hard sandstone and conglomerate.
	Mississippian.	Mauch Chunk shale	Red sandstone and shale.
		Pocono sandstone	Thick sandstone.
Devonian	Upper.	Catskill formation	Red sandstone and shale.
		Chemung formation	Shale and sandstone.
		Portage shale	Gray shale and platy sandstone.
		Genesee shale	Black fissile shale.
	Middle.	Hamilton shale	Black, highly fossiliferous shale and sandstone.
		Marcellus shale (with representative of Onondaga limestone at base).	Black fossiliferous shale.
	Lower.	Oriskany sandstone	Coarse sandstone.
		Helderberg limestone	Blue limestone and chert.

Formations encountered on excursions B-1 and B-2—Continued

Age		Name	General character
Silurian		Cayuga formation	Shaly limestone, shale, and Bloomsburg red shale.
		Clinton formation	Shale, sandstone, and fossiliferous red hematite.
		Tuscarora sandstone	Hard ridge-making sandstone.
Ordovician		Juniata shale [a]	Red shale and sandstone (absent east of Harrisburg).
		—Unconformity in east—	
		Martinsburg shale	Gray shale.
		—Unconformity in east—	
		Chambersburg limestone	Fossiliferous limestone (absent east of Harrisburg).
		Stones River limestone	Very pure limestone (absent south of Harrisburg).
		Beekmantown limestone	Thick-bedded limestone and dolomite.
Cambrian	Upper.	Conococheague limestone	Limestone and dolomite (Ozarkian of Ulrich).
	Middle.	Elbrook limestone	Thin earthy limestone.
		Waynesboro shale (absent in this area).	Red shale, sandstone, and limestone.
	Lower.	Ledger dolomite	Pure dolomite and limestone.
		Kinzers formation	Shale and mottled limestone.
		Vintage dolomite	Blue knotty dolomite.
		Antietam quartzite	Rusty-weathering quartzite.
		Harpers phyllite	Phyllite and schist.
		Chickies quartzite	Thick white quartzite containing *Scolithus* tubes.
		Hellam conglomerate member.	Coarse conglomerate and slate.
		—Unconformity—	
Pre-Cambrian [b]		Greenstone	Metabasalt.
		Aporhyolite	Acidic lava.

[a] Believed to be Silurian by the authors.
[b] In the Hellam Hills.

Crystalline rocks in the Martic overthrust block encountered on excursion B–3

<table>
<tr><th colspan="2">Age</th><th>Name</th><th>General character</th></tr>
<tr><td colspan="2">Late Paleozoic?</td><td>Woodstock allanite granite and associated pegmatite.</td><td>Intrusive. Shows little cataclastic deformation.</td></tr>
<tr><td rowspan="6">Pre-Cambrian</td><td></td><td>Aplite
Port Deposit granite (granodiorite)
Relay quartz diorite
Gunpowder granite
Serpentine, peridotite, pyroxenite
Hypersthene gabbro</td><td>Intrusives of post-Glenarm age. Show cataclastic deformation accompanied by partial or complete recrystallization.</td></tr>
<tr><td rowspan="4">Glenarm series (late pre-Cambrian).</td><td>Wissahickon formation</td><td>Oligoclase-mica schist and albite-chlorite schist facies, both containing quartzite beds.</td></tr>
<tr><td>Metabasalt</td><td>Lava flows.</td></tr>
<tr><td>Cockeysville marble</td><td>Coarse phlogopitic dolomitic and calcic marble.</td></tr>
<tr><td>Setters formation</td><td>Mica gneiss, quartzite, and mica schist.</td></tr>
<tr><td>Early pre-Cambrian.</td><td>–Unconformity –
Hartley augen gneiss (intrusive)
Baltimore gneiss</td><td>Sedimentary gneiss of granitic aspect, intruded by gabbro.</td></tr>
</table>

ITINERARY

WASHINGTON TO YORK, PENNSYLVANIA

From Washington the train runs first on the Talbot terrace and then for several miles on the Wicomico terrace, 40 and 100 feet (12 and 30 meters) in altitude respectively. For most of the way to Baltimore the route passes over the unconsolidated rocks of Lower Cretaceous age (Potomac group), and in the railroad cuts the variegated clay of the Patapsco formation (uppermost formation of the Potomac group) may be seen. At the Patuxent River large rounded masses of pre-Cambrian gabbro are exposed in the stream bed beneath the Cretaceous. In the higher lands around Odenton the overlying Raritan formation (basal formation of the Upper Cretaceous), consisting of interbedded sand and clay, is crossed. Near Baltimore the railroad leaves the Coastal Plain and the pre-Cambrian Baltimore gneiss is exposed.

Beyond Baltimore on the right of the railroad is a large quarry in the Baltimore gneiss. Farther on many coarse pegmatite dikes make prominent ledges across Jones Falls,[2] conspicuous from the railroad, and beyond gabbro extends to a point north of Mount Washington. From Mount Washington to Rider the railroad skirts the west side of the Glenarm-Towson anticline, which has been thrust westward along a north-south fault over the Cockeysville marble. (See pl. 1.) The route then follows the broad valley of Cockeysville marble through Cockeysville, the type locality. There are many quarries in this coarse white marble, from which the rock used in the lower part of the Washington Monument at Washington was obtained. The hills west of the valley are composed of mica schist and mica gneiss of the Wissahickon formation.

From a point 2 miles north of Cockeysville to and beyond Monkton the railroad crosses the Phoenix anticline in the gorge of Gunpowder Falls (river), which exposes the Baltimore gneiss and overlying Setters quartzite. Thence northward can be seen the Wissahickon formation, consisting of foliated biotite-muscovite-oligoclase schist, gneiss, and quartzite. A mile north of Monkton this formation exhibits retrogressive metamorphism in chloritization of garnet and biotite and to the north passes into the albite-chlorite-muscovite schist facies of the Wissahickon formation. It contains a younger foliation that cuts the older. The dip of both foliations is south to Bentley, where it changes to northwest as the Tucquan foliation anticline is crossed. The albite-chlorite schist is well exposed in the gorges of Little Gunpowder Falls, Maryland, and of Codorus Creek north of New Freedom, Pennsylvania. The schist is a fine chlorite-muscovite schist, and the younger cleavage is very prominent all the way to Smyser, where the route crosses the north edge of the Martic overthrust and turns east in a limestone valley. (See pl. 1.)

This narrow valley of infolded Ordovician (Conestoga) limestone lies south of folded Lower Cambrian rocks of the Harpers schist and Chickies formation. Two miles (3.2 kilometers) south of York in a meadow on the left can be seen a conspicuous rock pinnacle rising out of the meadow, a residual core of an anticline of Chickies quartzite left by erosion in the valley of Codorus Creek. (See pl. 2, *A*.) South of York Cambrian schist and quartzite (the Chickies formation and Harpers schist) are thrust on a flat fault plane northwestward over Conestoga limestone.

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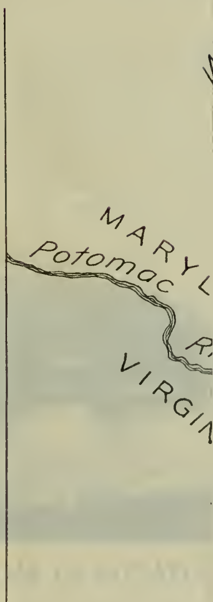
[2] This part of the stream is called "falls" because of its steep gradient and many rapids.



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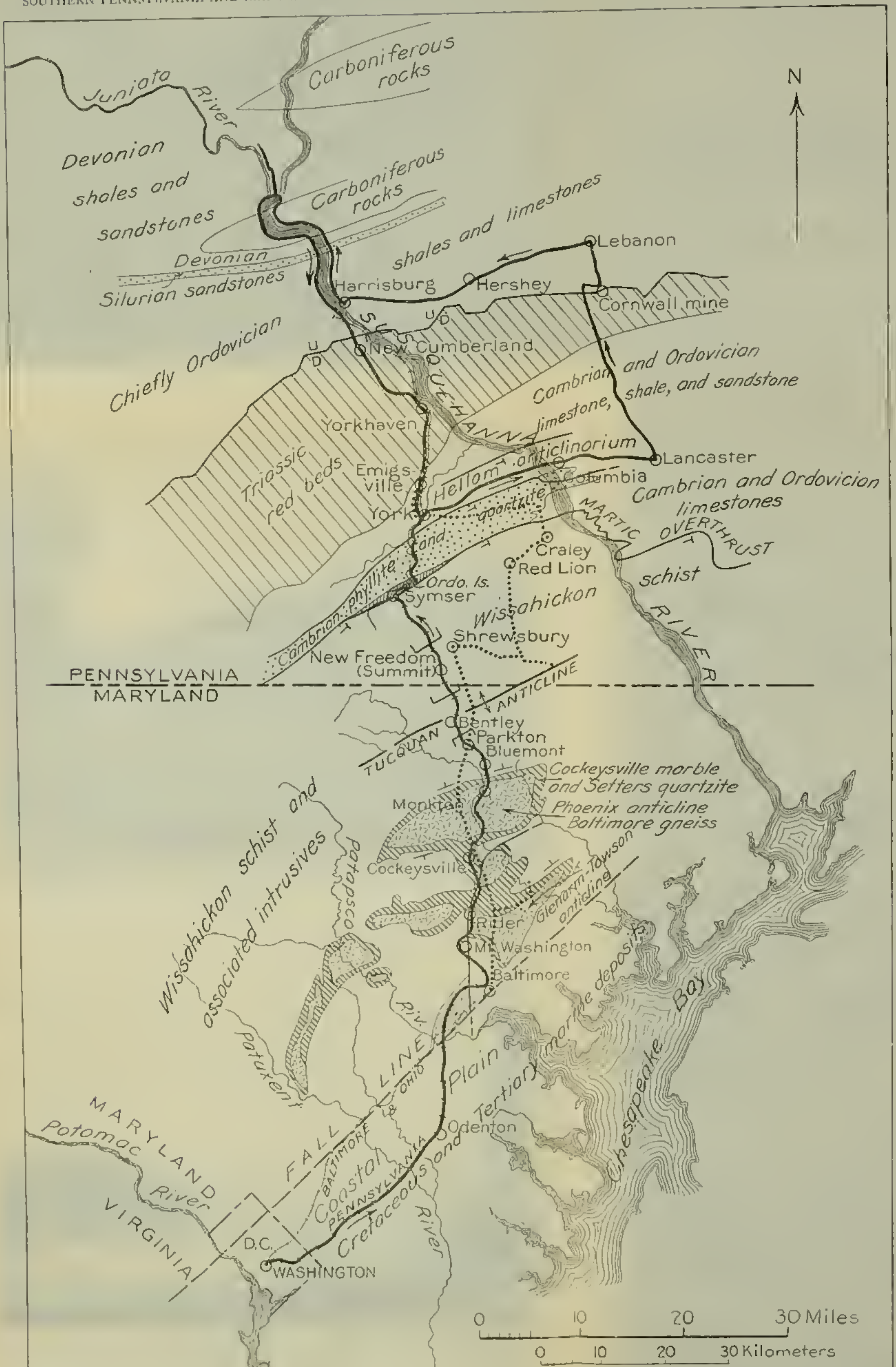


GEOLOGIC MAP OF PARTS OF MARYLAND AND PENNSYLVANIA SHOWING ROUTE OF EXCURSIONS B-1, B-2, AND B-3

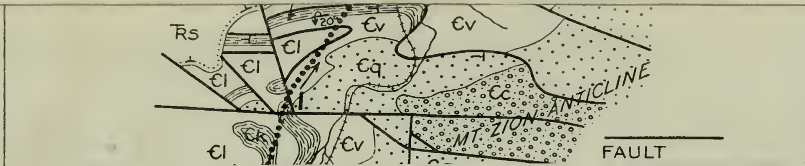
Heavy line shows route of excursions B-1 and B-2; dotted line, B-3. U, D, Upthrown and downthrown sides of normal fault; **T**, overthrust side of thrust fault; ⊥, strike and dip of bedding; ⊔, strike and dip of schistosity.

A. PINNACLE OF CAMBRIAN QUARTZITE NEAR BRILLHART, PENNSYLVANIA

Rising out of meadow of Codorus Creek. The pinnacle is the remnant of the crest of an anticline. Photograph by George W. Stose.

B. GAP IN KITTATINNY MOUNTAIN AS SEEN FROM HARRISBURG, PENNSYLVANIA

Level tops of mountains are remnants of the Kittatinny peneplain. Photograph by George W. Stose.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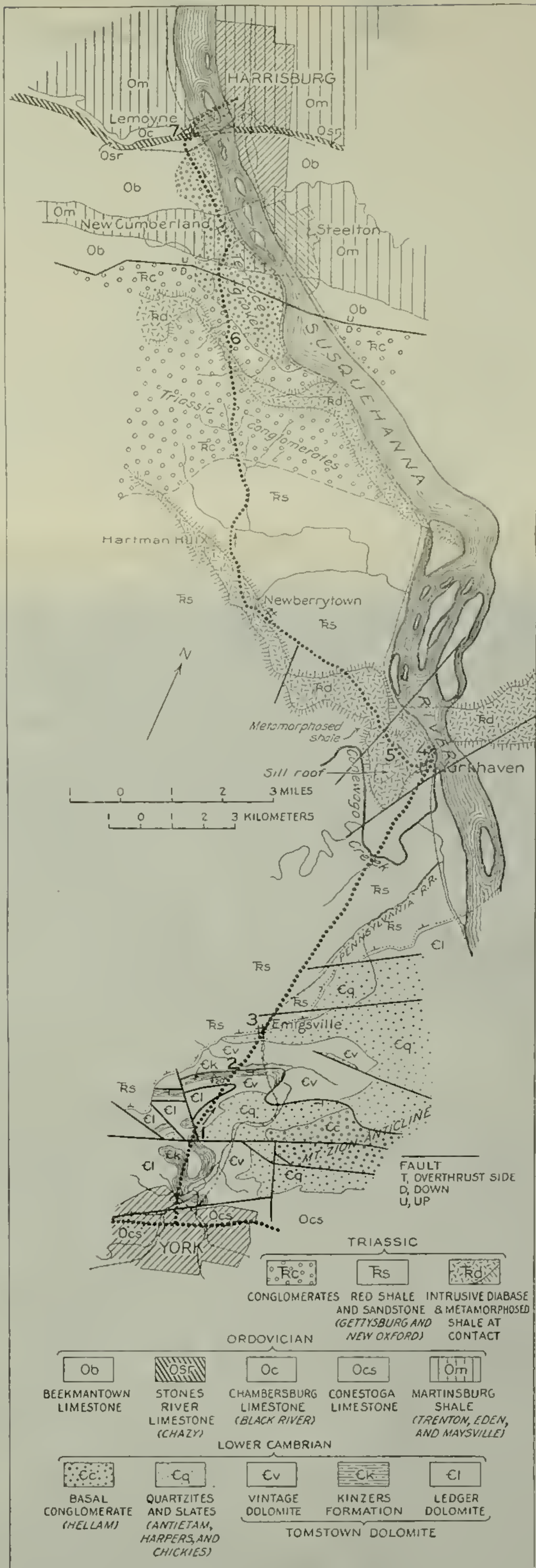
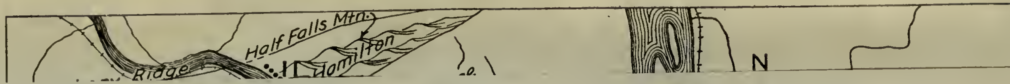


ROUTE MAP, YORK TO HARRISBURG, PENNSYLVANIA

Dotted line shows route; numbers indicate stopping places. ⊥, Strike and dip of bedding.


Half Falls Mtn.
Hamilton
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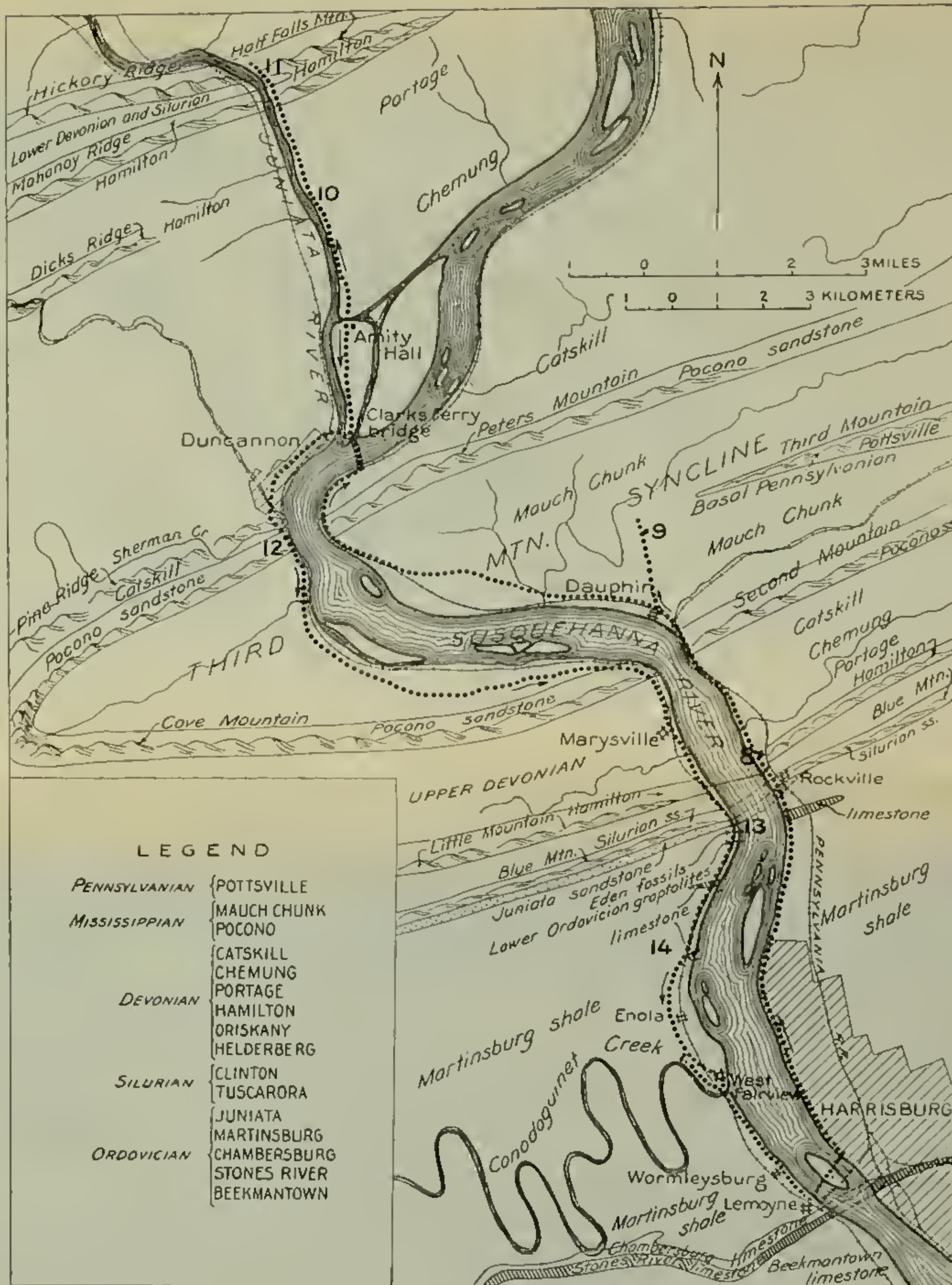
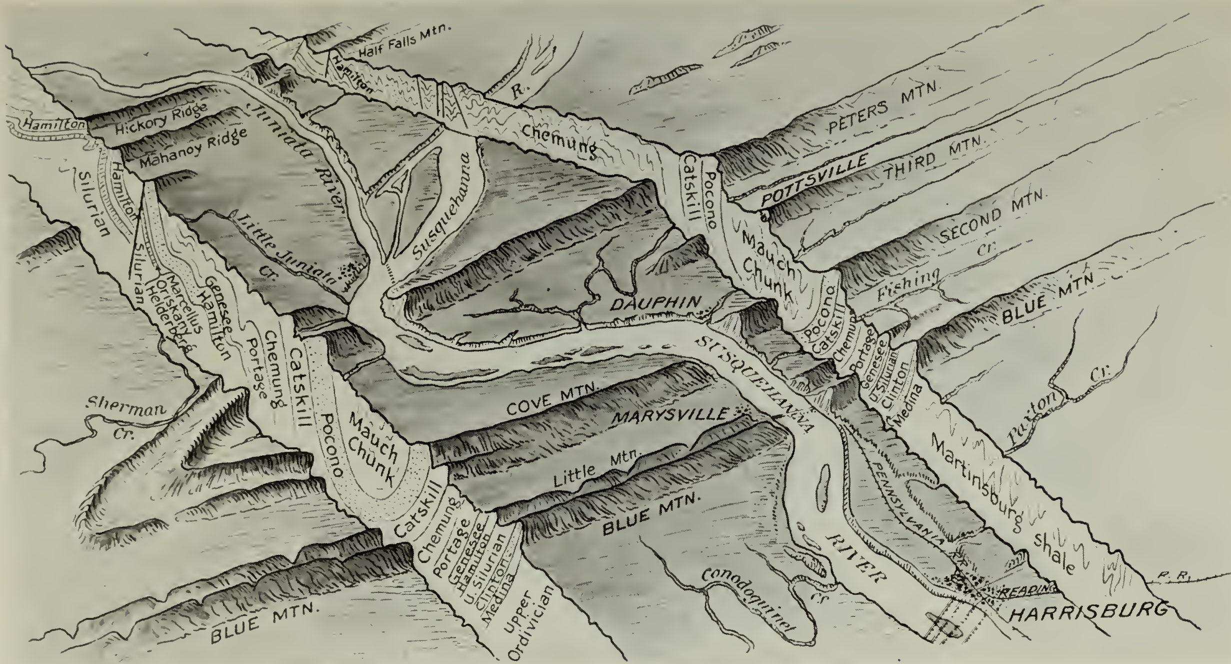


ROUTE MAP, HARRISBURG TO JUNIATA RIVER, PENNSYLVANIA

Dotted line shows route; numbers indicate stopping places. Hamilton includes Marcellus and Onondaga below and Genesee above; Clinton includes Cayuga above.



BLOCK DIAGRAM, HARRISBURG TO HALF FALLS MOUNTAIN, PENNSYLVANIA

YORK TO HARRISBURG, PENNSYLVANIA

The city of York lies in a limestone valley at the nose of the southwestward-plunging Hellam anticlinorium, which forms low hills to the northeast. (See pl. 3.) North of York the highway crosses Lower Cambrian limestones that overlie older arenaceous Cambrian rocks (Chickies and Harpers), exposed to the northeast in the Hellam Hills. These strata are broken by many normal faults that offset and repeat the beds. In the northern part of the city the road crosses a shale hill of the Kinzers formation, which locally carries a rich trilobite fauna. The shale is well shown in a cut on the left. A mile (1.6 kilometers) to the north, on the next hill [1],[3] is another outcrop of the shale of the Kinzers formation, at the plunging end of the Mount Zion anticline. The shale is cut off by a normal cross fault from the Antietam quartzite in the plunging nose of the anticline, which makes the hill to the east, and the narrow valley east of the road at this point contains the intervening Vintage dolomite, which is normally about 1,000 feet (305 meters) thick but is largely cut out by the faulting.

Northward the route passes over a valley underlain in part by Ledger dolomite to another low hill [2] composed of Kinzers formation. The beds here are overturned and dip 15° SE., so that the fossiliferous limestones of the upper part of the Kinzers formation on the north side of the shale hill dip under the shale and are thrust northwestward over Vintage dolomite on a low-angle fault of considerable throw. The Vintage dolomite extends to Emigsville, where the rise of the strata brings up the Antietam quartzite.

[3] At Emigsville, in the railroad cut just south of the highway bridge, the Triassic red sandstone unconformably overlies the Antietam quartzite, with a small mass of Cambrian limestone infolded or infaulted at the contact. There is a notable discordance in dips (Triassic, 58° NW.; Antietam, 30° SE.). The Antietam contains rust-covered molds of Lower Cambrian trilobites and shells.

Between Emigsville and Yorkhaven the road passes diagonally over the northwestward-dipping yellowish arkosic sandstone and interbedded red sandstone of the Upper Triassic New Oxford formation, the lowest formation of the Triassic.

At 5.8 miles (9.3 kilometers) from York the road is on a remnant of the Harrisburg peneplain, here 520 feet (158 meters) above sea level, probably Pliocene. At 8 miles (12.9 kilometers) the road crosses Conewago Creek, 290 feet (88 meters) below the

[3] Locality numbers in brackets are shown on the route maps.

peneplain level. The intricate meanders of this stream, as well as those of Conodoguinet Creek (see pl. 4) and other large streams of this region, are believed to have been acquired on the Harrisburg peneplain. Most of the hilltops at about 520 feet (158 meters) above sea level close to the Susquehanna River have scattered waterworn pebbles or cobbles in the soil. Scattered pebbles or gravel deposits also occur on flat-topped hills or benches at several levels below this plane. Such deposits may be seen along the route half a mile (0.8 kilometer) north of Conewago Creek, 100 feet (30 meters) above the river and on near-by hilltops at altitudes of 410 to 480 feet (125 to 146 meters). They are remnants of deposits left by the river in deepening its valley.

At Yorkhaven (10 miles, or 16 kilometers) the road turns northwestward more directly across the strike of the beds. For 2 miles (3.2 kilometers) the road passes over a thick sheet of Triassic diabase.

[4] The Triassic diabase is well exposed in a large quarry in the river bluff, and the shales at the contact are baked to hard black porcelanite banded with white. Large round residual boulders of diabase abound in the fields.

[5] On the hill southwest of Yorkhaven there are interesting basic and acidic differentiates of the diabase, as well as altered and mineralized shale, in the thin roof remnant of the sheet.

Farther on, the road crosses hard gray sandstone and some coarse conglomerate beds interbedded with red shale, the lower part of the Gettysburg formation. This conglomerate forms the Conewago Hills to the southwest. The dip of the beds is uniformly northwest, 15° to 35°. The Triassic in this area has a calculated aggregate thickness of 25,000 feet (7,620 meters).

At Newberrytown (14.5 miles, or 23.3 kilometers) the sandstone and conglomerate are intruded by a thick crosscutting body of diabase. The high hills near by are formed by the baked shale bordering this diabase. Just southeast of Kartman Hill (16.2 miles, or 26 kilometers) a small diabase sill shows in the road cut, with black metamorphosed shale at the lower contact.

In the lower ground to the north the red shale and soft red sandstone of the Gettysburg shale are exposed. Harder gray sandstone and coarse conglomerate interbedded with red shale dip northwest above the softer red shale and form the upper part of the Gettysburg shale. A diabase mass, which intrudes these upper beds, has altered them into hard baked sandstone.

The upper conglomerate beds extend to the north edge of the Triassic belt, where they are terminated by a normal fault (see pl. 3) by which the Triassic block has been depressed along its north edge and the beds tilted northward. Although the block north of the fault was uplifted, the limestone exposed by the uplift has been dissected into a lowland, as may be seen from the edge of the escarpment [6]. The fault, which crosses the road 0.7 mile (1.1 kilometers) beyond the foot of the hill, is deeply covered with terrace gravel.

New Cumberland lies in an abandoned bed of the Susquehanna River floored with river gravel deposited in late glacial time (Illinoian or Wisconsin). The present river channel is 60 feet (18 meters) lower. There is here a belt of Martinsburg shale, of Trenton and younger age, which forms the line of hills west of New Cumberland. (See pl. 3.)

From New Cumberland to Harrisburg the road crosses a broad valley underlain mainly by Beekmantown limestone.

[7] At Lemoyne (Riverton) pure Stones River limestones of Chazy (Lower Ordovician) age and a thin representative of the fossiliferous Chambersburg limestone, of Black River (Middle Ordovician) age, crop out between the Beekmantown limestone and the Martinsburg shale that forms the hills at the bridge entrance and in the city of Harrisburg. These fossiliferous limestones (Stones River and Chambersburg) are absent at the Martinsburg shale contact at the south side of the Beekmantown area, near New Cumberland.

At Harrisburg the Susquehanna River runs in a rock-cut channel 10 to 15 feet (3 to 4.5 meters) deep. Local "deeps" or rock-cut channels are filled with gravel to a depth of 45 feet (13.7 meters). The business part of Harrisburg lies on a gravel terrace 340 feet (104 meters) above sea level, the gravel, 20 feet (6 meters) or more deep, lying on an irregular rock floor 10 to 15 feet (3 to 4.5 meters) above the river. The capitol buildings stand on a gravel-capped rock hill, 60 feet (18 meters) above the lower river terrace, or 360 feet (110 meters) above sea level. The eastern part of the city lies on a gravel and silt covered terrace at 120 feet (37 meters) above the river, or 420 feet (128 meters) above sea level, which is correlated with glacial deposits of Illinoian (?) age. The railroads run in an old channel of the river, still flooded at very high water.

HARRISBURG TO HALF FALLS MOUNTAIN AND RETURN

From Harrisburg to Rockville the route follows the river road on the east side of the Susquehanna. (See pl. 4.) Highly folded Middle and Upper Ordovician Martinsburg shale containing some limestone and sandstone is exposed in ledges in the river and in a quarry across the river. The islands in the river are at present washing away, and at low water roots of former islands are visible. The uniform width and shallowness of the river are noteworthy.

At Rockville the river flows in a gap through Blue Mountain (see pl. 2, *B*), which is composed of lower Silurian rocks (Tuscarora quartzite and lower sandstones of the Clinton formation) overturned so that they dip steeply south on the south limb of the Third Mountain syncline. Some minor faulting has occurred. The relation of these beds to the Martinsburg here is not determined because of poor exposures. The upper part of the Martinsburg is lacking at this contact and is believed to have been removed by erosion before the Tuscarora was deposited. Farther east there is a marked unconformity between the Tuscarora and Martinsburg.

The river gaps here and on the Delaware, Potomac, and other major streams in this region are the result of downcutting by the streams after the uplift of the Kittatinny peneplain, on which they formerly flowed. The exact position of the gaps is probably determined by zones of weakness due to minor faulting or local folding. Second Mountain is offset by minor faulting a quarter of a mile (0.4 kilometer) north of the axis of its counterpart, Cove Mountain, across the river.

[8] A view east from the rear of the schoolhouse at Rockville shows that the mountain east of the village is double. Blue Mountain, on the south, is composed of lower Silurian resistant rocks; the valley between shows red Bloomsburg shale (upper Silurian) and black Marcellus shale (Middle Devonian); Little Mountain, on the north, contains Middle Devonian (Hamilton) sandstone. The Lower Devonian and uppermost Silurian have probably been squeezed out. Upper Devonian rocks form the north slope of Little Mountain and continue across the valley of Fishing Creek to Second Mountain. They are exposed in an old quarry at Hecks, where they consist of red, brown, and green beds carrying plant fragments (Catskill).

Second Mountain is formed by basal Mississippian (Pocono) massive conglomeratic sandstone, dipping north into the Third Mountain syncline.

At Dauphin the excursion leaves the main route and follows the road to the right (uphill) to a point a quarter of a mile (0.4 kilometer) past a brick school. This locality [9] is almost in the center of the great syncline spooning out to the west. Third Mountain is upheld by massive conglomerate with a very little shale and coal at the base of the "Coal Measures" (Pottsville) in the axis of the syncline. Second and Peters Mountains are corresponding ridges composed of basal Mississippian rocks on opposite limbs of the syncline, uniting at the west in Cove Mountain as the syncline rises. The flat mountain tops are relics of the Kittatinny peneplain (lowered by erosion several hundred feet). The school stands on the partly reduced Harrisburg peneplain, cut in much folded upper Mississippian (Mauch Chunk) red shale and sandstone. Waterworn pebbles and cobbles on this surface have come from three sources—the basal conglomerate of the Pottsville on Third Mountain, underlying conglomerates in the Mauch Chunk, and remnants of river gravel common at this level all along the river and in part derived from the Pottsville and Mauch Chunk. The excursion returns to Dauphin and continues north.

From Dauphin to the highway underpass at 15.8 miles (25.4 kilometers) the road cuts are in Mauch Chunk red beds, nearly along their strike.

At Peters Mountain (16 miles, or 25.7 kilometers) the southward-dipping Pocono sandstone, in the north limb of the Third Mountain syncline, appears in the mountain face, in river reefs, and on the face of Cove Mountain across the river. High-ash coal beds as much as 4 feet (1.2 meters) thick occur in the Pocono sandstone.

At Clarks Ferry Bridge the route crosses the river. By looking back the shoulder on the north side of Peters and Cove Mountains, formed by Upper Devonian (Catskill) sandstone, can be seen. The road runs across flood-plain and deltaic material dropped at the confluence of the Juniata River with the Susquehanna. Upper Devonian rocks crop out along the railroad on the west side of the Juniata.

At Amity Hall the road turns left and then up the Juniata Valley, passing Upper Devonian (Chemung and Catskill) red beds. One mile (1.6 kilometers) above Amity Hall a Triassic diabase dike, weathering rusty yellow-brown, cuts the red beds, which exhibit contact metamorphism.

[10] Highway cuts show Upper Devonian rocks, folded, crenulated, and cut by minor faults. The color changes from red to chocolate-brown as lower formations are crossed. The formations are distinguished largely by their faunas.

Just beyond locality 10 the road reaches the Upper Devonian (Genesee) black shale, 200 feet (61 meters) thick. The total thickness of the Upper Devonian in this section is about 7,500 feet (2,286 meters).

Mahanoy Ridge, across the Juniata River, shows a talus slope of coarse, massive light-gray sandstone, up-faulted Middle Devonian (Hamilton).

[11] Half Falls Mountain is a faulted anticlinal mountain composed of the Hamilton formation and exposing at the center, where cut by the river, Middle Devonian black shale (Marcellus) and black limestone (Onondaga) and Lower Devonian chert and sandstone (Oriskany) and limestone (Helderberg). The Onondaga limestone at the base of the Marcellus has been

quarried. An old quarry shows Oriskany faulted against Helderberg in the axis of the mountain.

Returning to the west end of Clarks Ferry Bridge, the excursion turns south, crosses the Juniata River, and goes through Duncannon, just beyond which Upper Devonian red beds form Pine Ridge.

[12] Cove Mountain is made up of lower Mississippian (Pocono sandstone, seen in road cuts, river reefs, and the end of Peters Mountain, across the river. A plant-bearing slaty coal bed is passed. The contact of the Pocono and Mauch Chunk is crossed on the road on the south side of the mountain. Road cuts show Mauch Chunk red beds. Both here and farther on there are good views of the flat intermontane upland (Harrisburg peneplain) east of the river. The route passes the east end of the south arm of Cove Mountain, opposite Second Mountain, and goes through Marysville and the gaps of Little Mountain and Blue Mountain. The quarry in Little Mountain is in Hamilton (Middle Devonian) sandstone, which is here capped by Oriskany (Lower Devonian), locally overthrust as a result of close folding and tight squeezing. Small-scale nearly horizontal faulting can be seen in the lower Silurian rocks of Blue Mountain.

[13] About 40 feet (12 meters) of Juniata red beds (lacking farther east) are exposed here below the Tuscarora. About 200 feet (61 meters) to the south are fossiliferous shales of the lower part of the Martinsburg, and about 1,000 feet (305 meters) farther south graptolites of Normanskill (Chazy) and Deepkill (Beekmantown) age occur. These relations have been interpreted, in the light of evidence to the east, as an unconformity due to erosion of upper beds of the Martinsburg in pre-Juniata time.[4] It is possible, however, that the Ordovician, normally in this region 3,500 feet (1,067 meters) or more thick, is compressed into 1,200 feet (336) meters), soft beds having been faulted or squeezed out.

[14] A road cut exposes thin red shales near the base of the Martinsburg. Below the road, in a railroad cut, are exposed thin limestones interbedded with shale and sandy limestone conglomerate, which do not rise to the road. These are interpreted as basal beds of the Martinsburg in a tightly squeezed anticline.[5]

The Enola classification yards of the Pennsylvania Railroad occupy an abandoned channel of Conodoguinet Creek lying between the highway and the hill to the east. The road passes

[4] Stose, G. W., Unconformity at the base of the Silurian in southeastern Pennsylvania: Geol. Soc. America Bull., vol. 41, p. 639, 1930.

[5] Idem, p. 637.

over highly folded Middle and Upper Ordovician shales and sandstone (Martinsburg). A side road to the right is taken to the concrete road. The intrenched meanders of Conodoguinet Creek, acquired on the Harrisburg peneplain, are noteworthy. The creek is crossed at West Fairview, and the route leads through Wormleysburg and across the Susquehanna River to Harrisburg.

The view at Reservoir Park (altitude 620 feet, or 189 meters) shows to the north, in the middle foreground, the type locality of the Harrisburg peneplain (hilltop altitude 520 to 560 feet (158 to 171 meters) above sea level). Beyond is the level-crested Blue Mountain, composed of upturned lower Silurian rocks. To the northwest are the water gaps of the Susquehanna River through both Blue and Second Mountains (the latter composed of basal Mississippian (Pocono) rocks). (See pl. 2, *B*.) Through the gaps is seen Peters Mountain, composed of the Pocono sandstone rising on the north side of the syncline. To the west lies Harrisburg, the Susquehanna River, and the winding valley of Conodoguinet Creek. To the southwest rise conical hills composed of diabase in dikes and sills that cut the Triassic red beds.

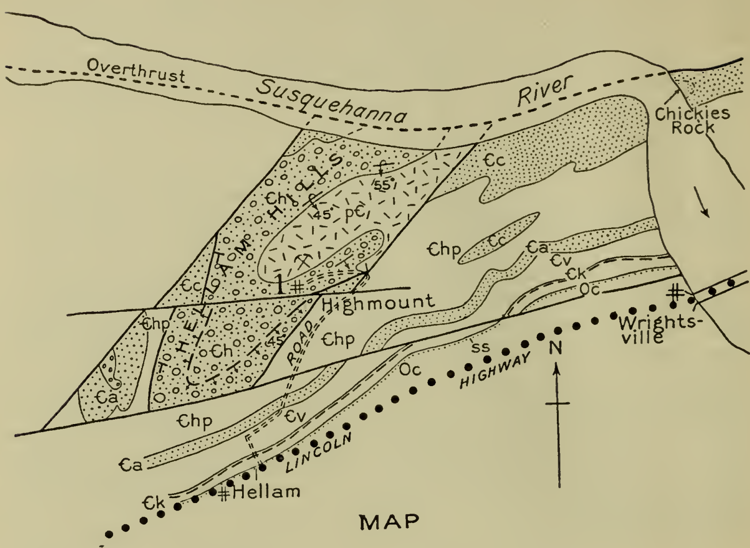
From Reservoir Hill State Street is followed to the capitol building. From Eighteenth Street to the bridge the street is on a terrace 100 feet (30 meters) above the river, or 400 feet (122 meters) above sea level, covered with silt and gravel (Illinoian?). The Memorial Bridge crosses an old river channel, now occupied by the railroad, separated from the main channel by a gravel-topped shale and sandstone ridge, on which the capitol building stands, 360 feet (110 meters) above sea level. The present river channel is cut 10 to 15 feet (3 to 4.5 meters) deep in rock below the level of the rock under the city.

YORK TO CORNWALL MINES AND HARRISBURG

York to Lancaster.—On excursion B–2 the road follows the York Valley to the Susquehanna River at Wrightsville. (See pl. 6.) The valley is underlain by Ordovician (Conestoga) limestone in a syncline between hills of older rocks, chiefly Cambrian. On the south side of the valley Cambrian slate and quartzite are thrust over the Ordovician limestone, concealing the intervening beds.

At Stonybrook the road crosses a Triassic diabase dike which makes a low ridge covered with characteristic rounded diabase boulders. The dike rock is exposed in the adjacent Pennsylvania Railroad cut.

[15] About 1½ miles (2.4 kilometers) east of Stonybrook a quarry shows the impure argillaceous character of much of the



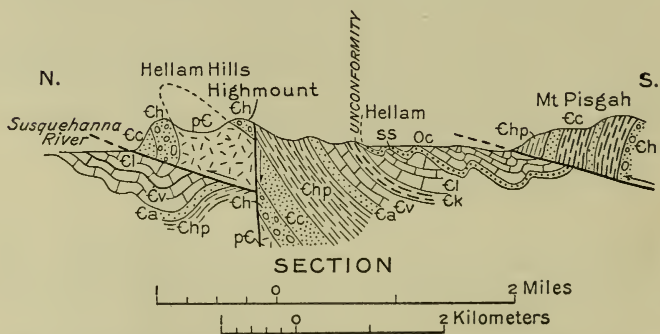
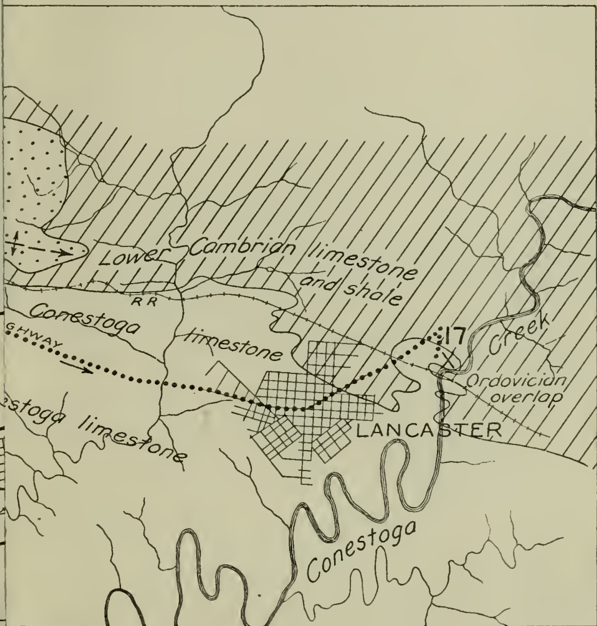
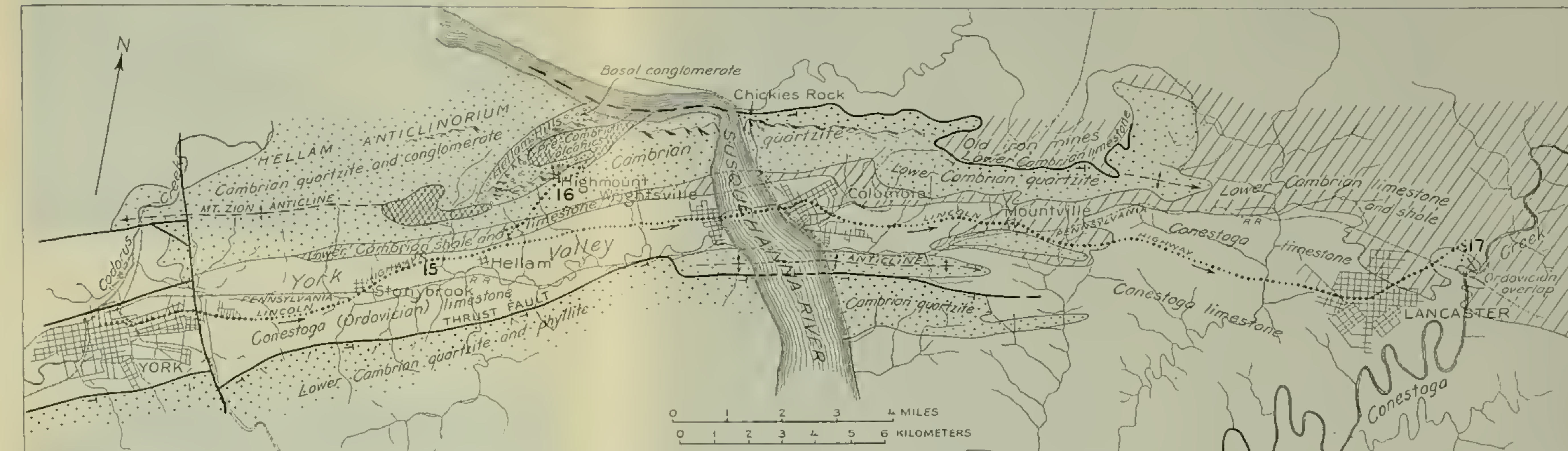


Figure 1.—Detailed map of the Hellam Hills, north of Hellam, Pennsylvania, and sketch section across the valley, showing general structure, overthrusts, and normal faults. Oc, Conestoga limestone, with sandstone (ss) at base; Ꞓl, Ledger dolomite; Ꞓk, Kinzers formation; Ꞓv, Vintage dolomite; Ꞓa, Antietam quartzite; Ꞓhp, Harpers phyllite; Ꞓc, Chickies quartzite; Ꞓh, Hellam conglomerate member; pꞒ, pre-Cambrian volcanic rocks; T, thrust side of overthrust fault; 1, stopping place


Lower Cambrian limestone
and shale
RR
Conestoga
limestone
GHWAY
stoga limestone
17
Creek
Ordovician
overlap
LANCASTER
Conestoga

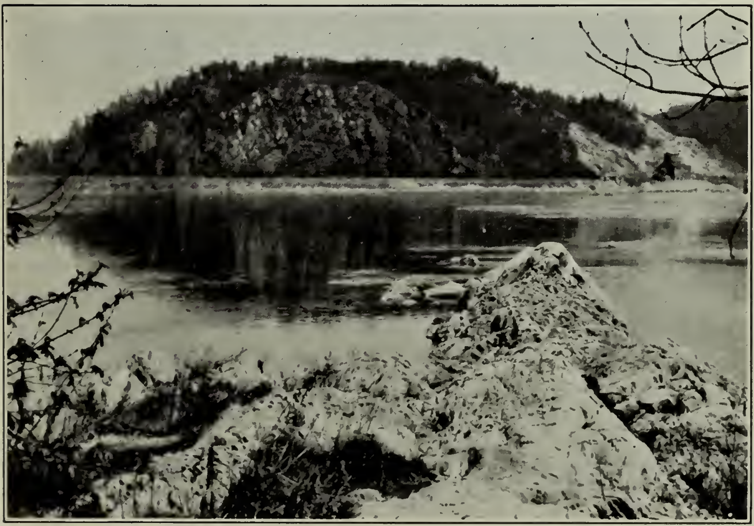


ROUTE MAP, YORK TO LANCASTER, PENNSYLVANIA

Dotted line shows route; numbers indicate stopping places. T, Overthrust side of thrust fault.

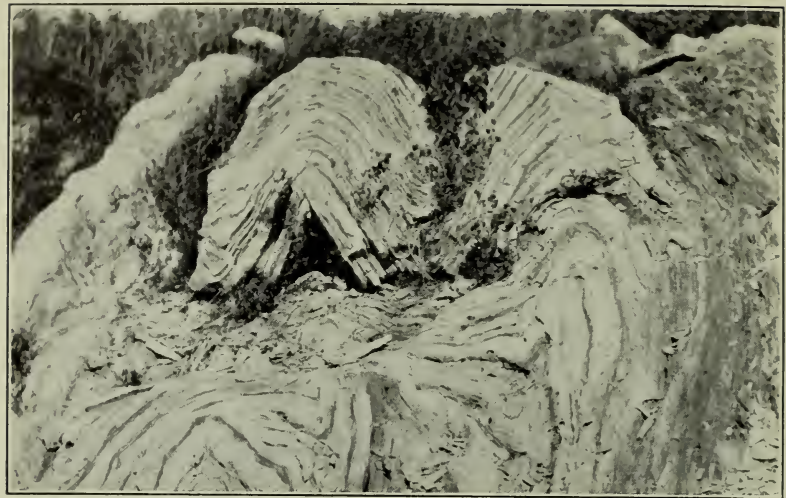
A. RIVER TERRACE CUT ON HARPERS PHYLLITE SOUTH OF CHICKIES ROCK, PENNSYLVANIA

Altitude 500 feet (152 meters). Looking south from top of Chickies Rock. Photograph by George W. Stose.



B. CHICKIES ROCK AS SEEN FROM HELLAM POINT

Anticline of Lower Cambrian quartzite. Photograph by George W. Stose.

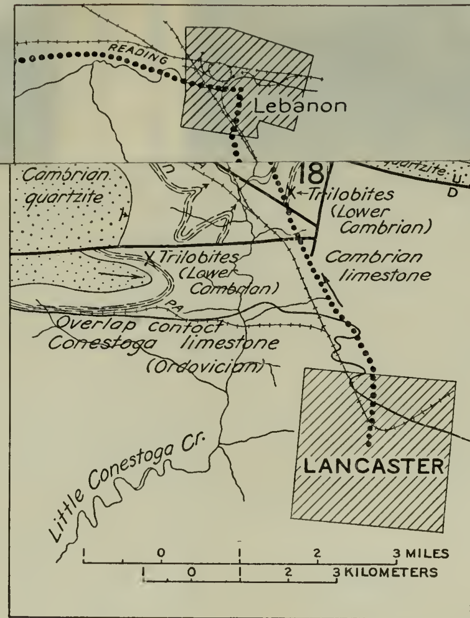


A. CLOSELY FOLDED THIN-BEDDED CONESTOGA LIMESTONE, LANCASTER, PENNSYLVANIA

Photograph by George W. Stose.

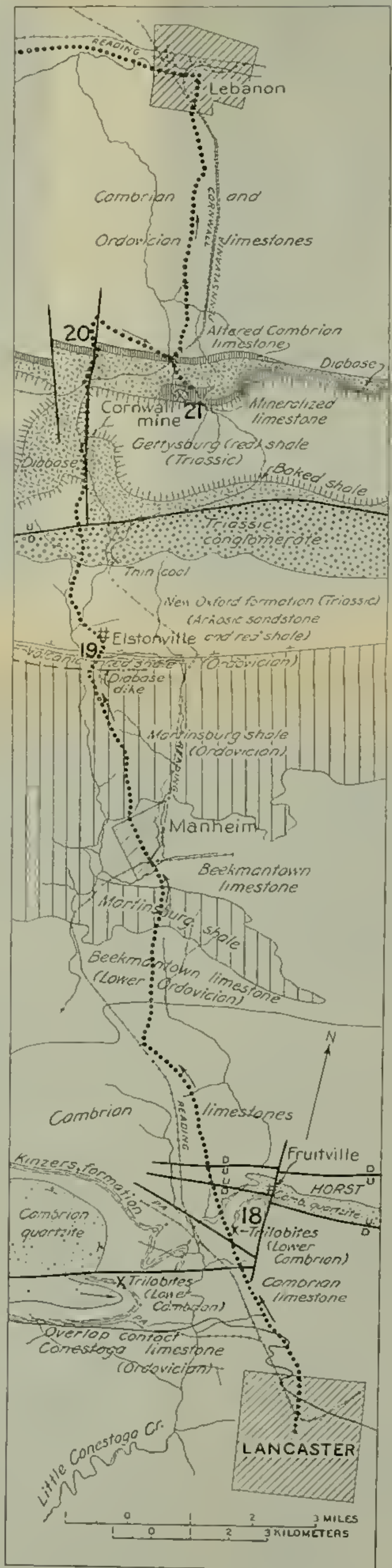
B. UNCONFORMABLE CONTACT OF LIMESTONE CONGLOMERATE IN THE CONESTOGA (ORDOVICIAN) LIMESTONE ON LEDGER (LOWER CAMBRIAN) DOLOMITE

Near Lancaster, Pennsylvania. Photograph by George W. Stose.



ROUTE MAP, LANCASTER TO LEBANON, PENNSYLVANIA

Dotted line shows route; numbers indicate stopping places. D, U, Downthrown and upthrown sides of fault.



ROUTE MAP, LANCASTER TO LEBANON, PENNSYLVANIA

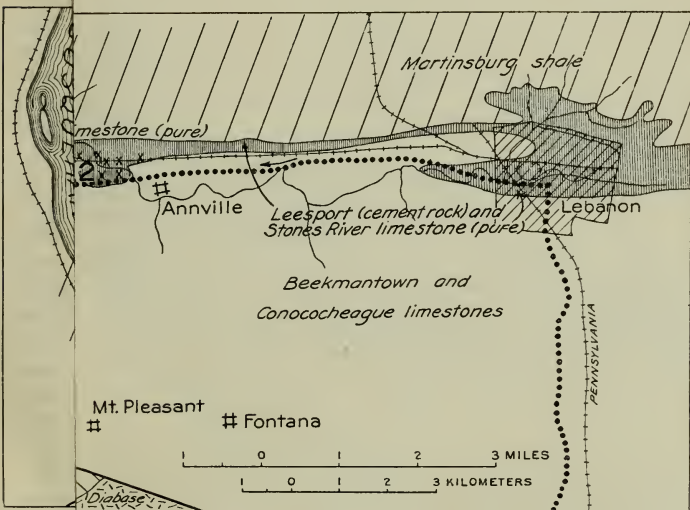
Dotted line shows route; numbers indicate stopping places. D, U, Downthrown and upthrown sides of fault.

A. MARBLE WITH RHYTHMIC WAVY IMPURITIES OF ORGANIC ORIGIN IN KINZERS FORMATION

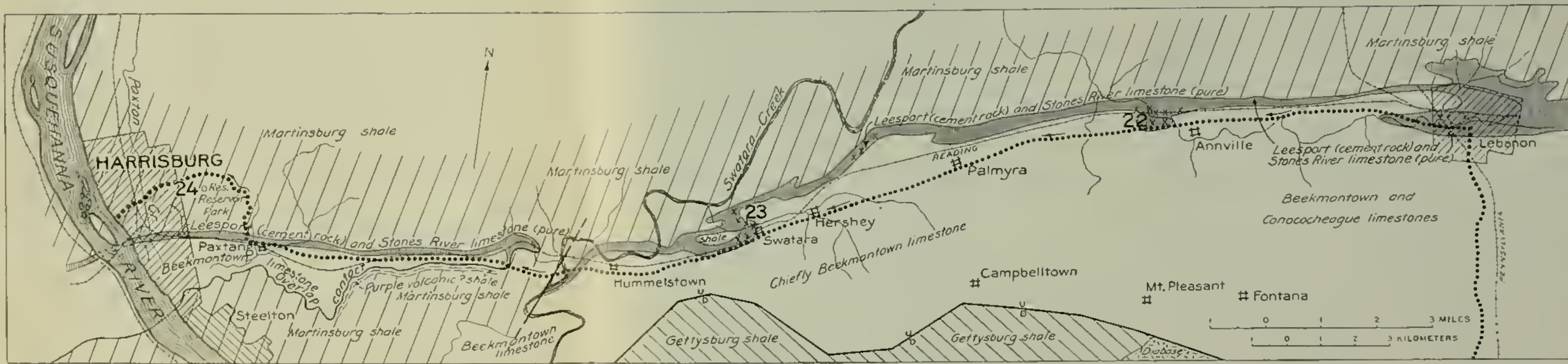
Railroad cut at Kinzers, Pennsylvania. Photograph by George W. Stose.

LOWER CAMBRIAN TRILOBITES FROM KINZERS SHALE NEAR FRUITVILLE, PENNSYLVANIA

b, *Olenellus thompsoni; c*, *Paedumias transitans*. Specimens collected by George W. Stose.


Martinsburg shale
mestone (pure)
2
Annville
Leesport (cement rock) and
Stones River limestone (pure)
Lebanon
Beekmantown and
Conococheague limestones
PENNSYLVANIA
Mt. Pleasant
Fontana
1 0 1 2 3 MILES
1 0 1 2 3 KILOMETERS
Diabase

fault.



ROUTE MAP, LEBANON TO HARRISBURG, PENNSYLVANIA

Dotted line shows route; numbers indicate stopping places. U, D, Upthrown and downthrown sides of normal fault.

Ordovician limestone, some beds of which carry a few brachiopods and cystid plates of Stones River or Black River (Middle Ordovician) age.

At Hellam the excursion leaves the highway for a side trip north into the Hellam Hills to see the basal Cambrian sequence and pre-Cambrian basement rocks in the Hellam anticline. (See fig. 1.) The Ordovician (Conestoga) limestone rests unconformably on the Lower Cambrian (Ledger) dolomite. It has at its base dark argillaceous banded sandstone and earthy black slate, which make a low ridge and are exposed in road cuts in Hellam. The Ledger is a very pure dolomite or in places a very pure limestone and was formerly extensively quarried for lime burning at Wrightsville. The Lower Cambrian Kinzers formation, beneath the Ledger, makes another low shale hill. Beyond this hill the route passes over, in descending order, Vintage dolomite, Antietam quartzite, Harpers phyllite, and Chickies quartzite with its coarse basal Hellam conglomerate member. These beds all stand nearly vertical and are thinned by compression and cut out in places by faulting.

[16] The basal Cambrian conglomerate (Hellam) here is exceptionally heavy and coarse and was named from these hills. The pre-Cambrian greenstone (altered basalt flow) and red rhyolite porphyry (also a lava flow) are well shown in a quarry and in outcrops at the axis of the uplift. East of Highmount the flat ridge top is at an altitude of 520 feet (158 meters), the level of the Harrisburg peneplain. Other hilltops at this altitude are seen just south of Wrightsville and in the same position east of the river. (See pl. 7, *A*.) Traces of river gravel have been found on all these flat-topped hills.

Returning to the Lincoln Highway, the trip proceeds to the Susquehanna River, the longest river of the eastern United States. From the new highway bridge crossing from Wrightsville to Columbia can be seen to the north one of the water gaps that are conspicuous features of the superimposed streams of the eastern Atlantic slope. The river has cut through a ridge of Cambrian quartzite, whose anticlinal character is shown in the cliff on the east side of the gap, the well-known Chickies Rock. (See pl. 7, *B*.) This is the eastern continuation of the Hellam anticline. It is thrust northward on a low-angle fault over the Paleozoic limestones in the valley beyond.

Eastward to Lancaster the road crosses the Conestoga limestone with shale hills of the underlying Kinzers formation near Mountville. South of Mountville, clay derived from disintegrated ferruginous beds of the upper part of the Antietam quartzite brought up in an anticline, which makes the hill to the south, is used to make brick of beautiful rich red colors, seen in many of the houses in York and Lancaster.

Near Lancaster closely folded thin-bedded argillaceous Conestoga limestone (Ordovician) is well exposed. (See pl. 8, *A*.) It generally contains a coarse limestone conglomerate at or near the base. This conglomerate is made up of angular blocks of white limestone as much as 10 feet (3 meters) thick, with a limy argillaceous matrix, and it rests unconformably with irregular contact on Lower Cambrian dolomite. This will be seen northeast of Lancaster, near the waterworks, at locality 17. (See pl. 8, *B*.) In places a thin earthy black shale forms the basal layer below the conglomerate.

Lancaster to Lebanon.—The road to Lebanon turns north at Lancaster. (See pl. 9.) The hills to the left are composed of Lower Cambrian quartzite in the eastward-plunging end of the Hellam-Chickies anticlinorium, whose pre-Cambrian core was seen north of Hellam.

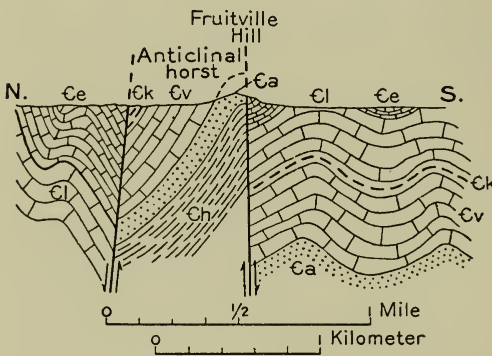


FIGURE 2.—Section across horst of Antietam quartzite and associated beds in Ledger dolomite and Elbrook limestone at Fruitville, Pennsylvania. Ꞓe, Elbrook limestone; Ꞓl, Ledger dolomite; Ꞓk, Kinzers formation; Ꞓv, Vintage dolomite; Ꞓa, Antietam quartzite; Ꞓh, Harpers phyllite. The quartzite and associated formations are apparently punched up through younger limestones

The Kinzers formation, which makes a broken line of low shale hills around the end of the plunging fold, carries in places a trilobite fauna which was made famous by the late Charles D. Walcott, Secretary of the Smithsonian Institution, who obtained the finest specimens from the Goetz quarry, 3 miles (4.8 kilometers) northwest of Lancaster. Some good trilobites (*Olenellus thompsoni* and *Paedumias transitans*) have been obtained from the shale hill 3 miles (4.8 kilometers) north of Lancaster (locality 18). Associated with the shale is a mottled white marble, called leopard rock, composed of alternations of pure limestone and wavy argillaceous layers that apparently were deposited by organisms. (See pl. 10, *A*.)

The low hills at Fruitville, just east of the road, are composed of Cambrian (Antietam) quartzite brought up in a narrow anticlinal fault block or horst. (See fig. 2.) The faulting is believed to have occurred in late Triassic time, because of the character of the displacement and because associated grabens to the east affect Triassic strata.

Northward the route passes onto higher rocks—Elbrook limestone (Middle and Upper Cambrian), Conococheague limestone (Upper Cambrian; lower Ozarkian of Ulrich), and Cocalico shale (Ordovician), which is nearly equivalent to the Martinsburg shale. Thin purple and green shales near the base of the Cocalico shale, seen south of Elstonville [19], are believed to represent a layer of volcanic ash.

At Elstonville the Cocalico shale, which dips 40° S., is overlain unconformably by gently northward-dipping Triassic rocks, first yellow arkosic sandstone and red shales (New Oxford for-

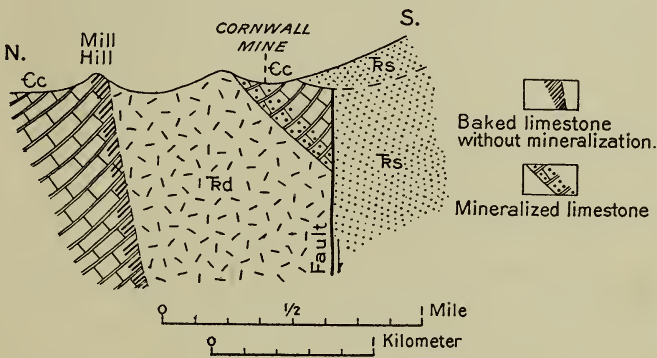


FIGURE 3.—Ideal section across the Cornwall mine area, Pennsylvania, showing the hypothetical fault along which the diabase ascended, baked limestone at north contact forming "Mill Hill slate," and the mineralized wedge of limestone at the Cornwall mine overlain by thin Triassic beds. Ꞓs, Triassic red beds; Ꞓd, diabase; Ꞓc, Conococheague limestone

mation), then thick conglomerate, and then red shale and sandstone (Gettysburg shale). These are intruded along the bedding by a thick diabase sill which has baked the adjacent shale to a hard purplish-black porcelanite, also indicated by the bluish-gray color of the soil. Large residual masses of diabase strew the fields in places. The diabase in places crosscuts the bedding and is broken by faults which displace it a mile or more.

A steeply crosscutting mass of diabase at the north edge of the Triassic belt is believed to be directly over the vent in the floor of the Triassic basin through which the magma came, for the magnetite deposits of the Cornwall mine, 3 miles (4.8 kilometers) to the east, are associated with this intrusion. Paleozoic limestone at the north contact of the diabase (locality 20) is altered to a hard dark siliceous slaty rock, which makes a low ridge along this contact. This ridge is sharply broken and offset by two cross faults, at and just west of the road. (See pl. 9.) It is believed that the limestone forms the north wall of the fault along which the block of Triassic rocks was dropped and tilted northward, and it was along this break that the intrusion of diabase is supposed to have occurred. (See fig. 3.)

[21] The Cornwall mine is the only large iron-ore mine at present operating in Pennsylvania. For many years Pennsylvania produced about half of the iron ore mined in the United States, mostly limonite or brown ores, but mining of brown ore declined with the development of the Lake Superior hematite ores in the later part of the nineteenth century. Mining began at Cornwall in 1740 and has been continuous ever since, making this probably the oldest continuously producing mine in the United States. The ore is chiefly magnetite but carries at least 25 associated minerals, of which the most common are hematite, iron pyrite (pyritohedrons), chalcopyrite, calcite, and serpentine.

The ore body was formed by the replacement of Upper Cambrian limestone adjacent to an intrusive diabase mass. The shapes and relations of the ore bodies are shown by glass models in the office of the Bethlehem Mines Corporation at Cornwall. It is mined partly by open-cut methods and partly by underground stoping. The part of the ore body most recently developed does not crop out and was located by magnetic surveys. It is mined by shaft and underground workings.

The ore carries 40 to 65 per cent of metallic iron and 0.005 to 1.76 per cent of metallic copper. Minute quantities of gold and silver occur in the sulphide ore and are recovered as a by-product.

The ores from the Cornwall mine vary considerably as shown by the following analyses:

	High-grade ore	Low-grade ore
Iron	64.900	41.900
Manganese	.158	.194
Copper	.005	.319
Sulphur	.071	.428
Phosphorus	.014	.019
Alumina	.324	4.970
Lime	1.010	2.810
Magnesia	1.131	7.457
Silica	3.980	20.910

In recent years the annual production of magnetite has been over 1,000,000 tons (1,016,050 metric tons); of copper, from 500,000 to 5,000,000 pounds (226,796 to 2,267,960 kilograms); of gold, 300 to 1,000 ounces (9,330 to 31,103 grams); and of silver, from 2,000 to nearly 8,000 ounces (62,206 to 248,824 grams). Up to the present time about 40,000,000 tons (40,642,000 metric tons) of magnetite has been taken from this mine, and there appears to be enough ore in reserve to last many more years.

The diabase mass at the mine cuts through Paleozoic limestone at the north edge of the Triassic deposits and is believed to have come up along a fault of Triassic age at the edge of the Triassic basin. (See fig. 3.) At the south contact of the diabase, which dips about 45° S., impure argillaceous layers in the Conococheague limestone are altered to hard slaty bands, and the purer beds to white marble. The purer limestone has been altered to marble for half a mile (0.8 kilometer) westward and for 2½ miles (4 kilometers) eastward. At the mine the limestone has been highly mineralized and replaced near the diabase by solutions that accompanied or followed the intrusion. The alteration to marble and replacement by ore apparently occurred only in the narrow limestone wedge between the diabase and the fault, which is partly covered at the surface by Triassic beds. (See fig. 3.)

In the open pit the marble farther away from the diabase changes into less altered dark banded limestone and light magnesian limestone of the Conococheague type. This is overlain in the upper two or three levels of the pit on the south side by nearly horizontal black baked shale and sandstone containing quartz pebbles and quartz grains and somewhat epidotized by the diabase. These beds are Triassic and were apparently the last sediments to be deposited before the intrusion of the diabase. In the pit they are cut by a thin diabase sheet and a dike and contain a thin bed of basaltic amygdaloid.

The limestone at the north contact of the diabase has been baked into an unrecognizable hard dark slaty rock and is little mineralized.

From Cornwall to Lebanon the route crosses gently dipping Ordovician and Cambrian limestone (chiefly Beekmantown and some Conococheague). Lebanon stands in a very fertile limestone valley, but the great piles of slag in and around the city bear evidence of the past activity of the furnaces and iron industry.

Lebanon to Harrisburg (26 miles, or 42 kilometers).—The road from Lebanon to Harrisburg follows the Paleozoic limestone valley, mostly on Beekmantown limestone, with Martinsburg shale hills to the north. (See pl. 11.) Close to the road in most places is a band of very pure Stones River limestone, of Chazy age, which with the Leesport limestone (cement rock) lies between the Beekmantown of the valley and the shale hills to the north. The pure limestone has been extensively quarried at Annville, Swatara, and other points along the valley and was used for flux at the smelters, but it is now used largely for mixing with low-calcium cement rock in the cement industry in the Lehigh district, to the east.

[22] West of Annville a body of this high-calcium limestone is so crumbly that it can be crushed in the hand to a flour.

[23] The local rock structure is well displayed at a quarry at Swatara.

Most of the limestone part of the valley is below the level of the Harrisburg peneplain, which is represented by large areas of flat hilltops at an altitude of about 520 feet (158 meters) near Fontana, Mount Pleasant, and Campbellstown. The high hills just south of these villages are underlain by Triassic sandstone and shale and stand above the peneplain.

North of the highway followed by the excursion is a line of hills underlain by shale and hard sandstone of the Martinsburg. The general surface of this upland is mainly at about the level of the Harrisburg peneplain—500 to 600 feet (152 to 183 meters). The highway passes through Hershey, one of the most modern of manufacturing towns, with public parks, swimming pools, clubhouses, civic centers, and other city attractions.

Just south of Hummelstown in the limestone of the valley is one of the many attractive caves in the State. West of Hershey the limestone valley narrows, and west of Hummelstown a tongue of Martinsburg shale crosses the valley from the shale hills on the north, and the limestone valley is cut off for a few miles. At the base of the shale here is a thin purple bed similar to that seen at Elstonville. Purple shale is widespread at this horizon and is believed to be of volcanic origin. The high-calcium limestone of Stones River age and the cement rock of the Leesport limestone are largely absent here, probably owing to overlap of the Martinsburg shale.

The Philadelphia & Reading Railroad yards at Rutherford, 2½ miles (4 kilometers) long, and the highway from the railroad underpass at Rutherford to Paxtang are again on limestone and at the same altitude as at Hummelstown and Hershey. At Paxtang the route turns to the right, following the parkway to Reservoir Park and traversing hills composed of Martinsburg shale with a hard bed of conglomeratic sandstone, which can be seen in the wall at the top of Reservoir Hill (locality 24).

WASHINGTON TO BALTIMORE, MARYLAND, AND YORK, PENNSYLVANIA

By A. I. Jonas and E. B. Knopf

Excursion B–3 crosses the Atlantic Coastal Plain and the Piedmont province. Its purpose is to see the overthrust pre-Cambrian rocks of northeastern Maryland and southern Pennsylvania and Paleozoic rocks over which the thrust block rode.

The Baltimore gneiss, the oldest rock of the Appalachians south of New England, will be visited in a quarry in the city of Baltimore, the type locality. (See pl. 12.) The quarry (Schwind's) is on the east side of Jones Falls and the Pennsylvania Railroad. It has been cut for 400 to 500 feet (122 to 152 meters) across the direction of the strike, which is N. 60° E. The prevailing dip is 30°–50° NW. The rock of Schwind's quarry is a thick-bedded quartzose biotite gneiss of light color and granitic aspect interlayered with biotitic and hornblendic beds. Intrusions of pink pegmatite and coarse white granite cut across the schistosity of the gneiss. These pegmatites cross Jones Falls in marked ledges north of the quarry. The biotite gneiss is made up of sodic oligoclase, microcline, quartz, greenish-brown biotite, garnet, hornblende, and magnetite. Myrmekite is developed on the border of the microcline. Accessory constituents are zircon, apatite, allanite, and titanite. The gneiss is considered to be of sedimentary origin, because of the distinct, persistent, and even layering and because the various beds show a distinct difference in composition. It is now a granoblastic gneiss formed in the katazone in pre-Cambrian time. The Baltimore gneiss that underlies the city of Baltimore has been brought to the surface in an anticline which is covered on the east and south by Coastal Plain deposits.

The route of the excursion (see pls. 1 and 12) runs 6 miles (9.6 kilometers) northward from Baltimore to Towson through a thickly settled suburban section in which rock outcrops are not visible. Towson is on the north flank of the Towson-Glenarm anticline, where the Setters formation unconformably overlies the Baltimore gneiss in Setters Ridge and is the base of the younger pre-Cambrian Glenarm series. The series comprises from the base up the Setters formation, 1,000 feet (305 meters) thick; the Cockeysville marble, 400 feet (122 meters) thick, and the Wissahickon formation, composed of schist, mica gneiss, and quartzite, of unknown thickness.

The Setters formation is well exposed on Setters Ridge, northeast of Towson, but there are no outcrops showing the unconformity at the base. This unconformity will be seen later on Piney Creek, 12 miles (19 kilometers) north of Towson.

From Towson the excursion proceeds eastward along the edge of Setters Ridge to Loch Raven, which is the storage reservoir for the water supply of Baltimore. The Setters quartzite in the ridge is seen in a ravine south of Loch Raven, where it dips 50° N. on the north side of the Towson-Glenarm anticline. The section from the base up comprises mica schist, quartzite, mica schist, and mica gneiss. In this vicinity the base of the Setters formation up to the level of the quartzite is injected by granite, probably associated with the intrusion of the Gunpowder granite.

The mica schist of the Setters is a fine-grained aggregate of biotite, quartz, and feldspar, usually garnetiferous. The quartzite is a coarse-grained vitreous rock speckled with pale-pink microcline feldspar, with silvery flakes of muscovite developed on bedding planes. Tourmaline is abundant in both the mica schist and the quartzite.

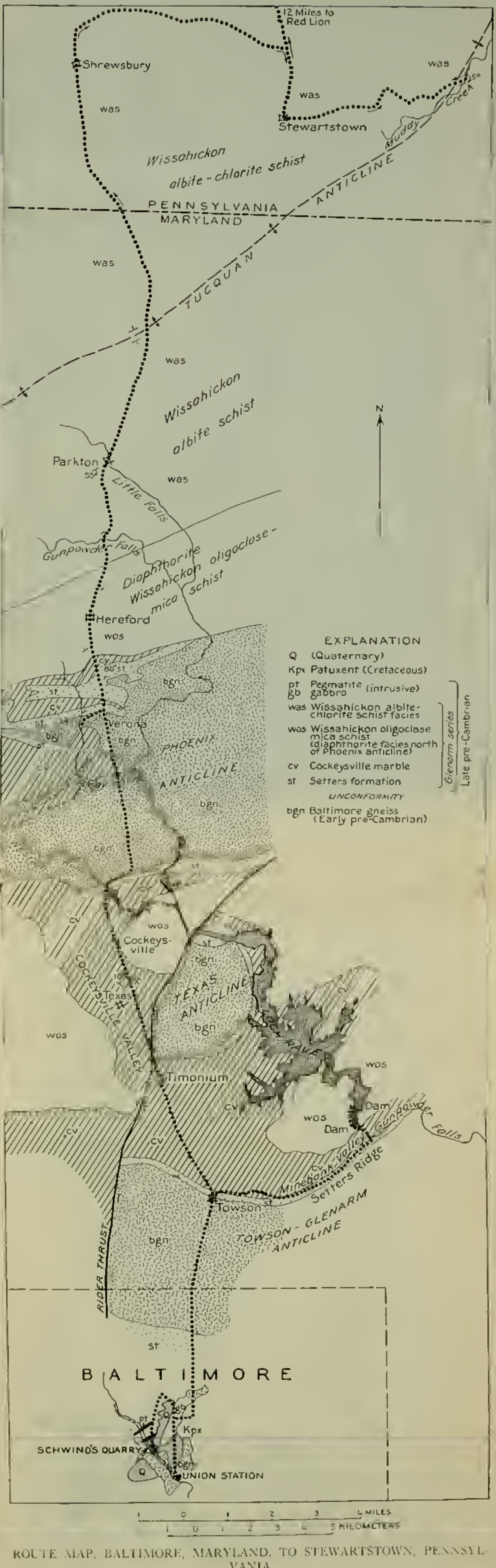
The route continues across Minebank Valley, northwest of Setters Ridge. This valley is underlain by the Cockeysville marble, which overlies the northwestward-dipping Setters formation of the ridge. The marble is here cut by pegmatites similar to the granite pegmatites that intrude the lower beds of the Setters formation in the neighboring ridge. The marble is white and coarsely crystalline and contains some impure beds. It is not well exposed in this valley but will be seen later in a quarry near the highway 5 miles (8 kilometers) north of Towson.

At Loch Raven there are excellent exposures of the Wissahickon formation along the road that borders the south edge of the lake. The cuts expose a succession of garnetiferous mica schist, feldspathic quartzite, and oligoclase-biotite gneiss. The gneiss is a crystalloblastic rock consisting chiefly of quartz, biotite, and oligoclase, with some orthoclase. Accessory minerals are garnet, apatite, zircon, and magnetite. The quartzite is composed chiefly of quartz and microcline, and the schist is a medium to coarse grained rock composed of biotite, muscovite, and quartz with a variable content of feldspar and accessory garnet. The formation elsewhere contains staurolite and kyanite. The individual beds resemble those in the Setters section, but individual members in the Wissahickon formation are thin and lack the persistence of the beds of the Setters formation along the strike.

The oligoclase-mica schist shows, by its complete recrystallization and by its content of such minerals as garnet, staurolite, and kyanite, that its present condition has been developed by metamorphic agencies characteristic of a deep-seated zone. That the original material was a sediment may be inferred from the heterogeneous character of the formation and the presence of abundant rounded grains of zircon, suggestive of waterworn

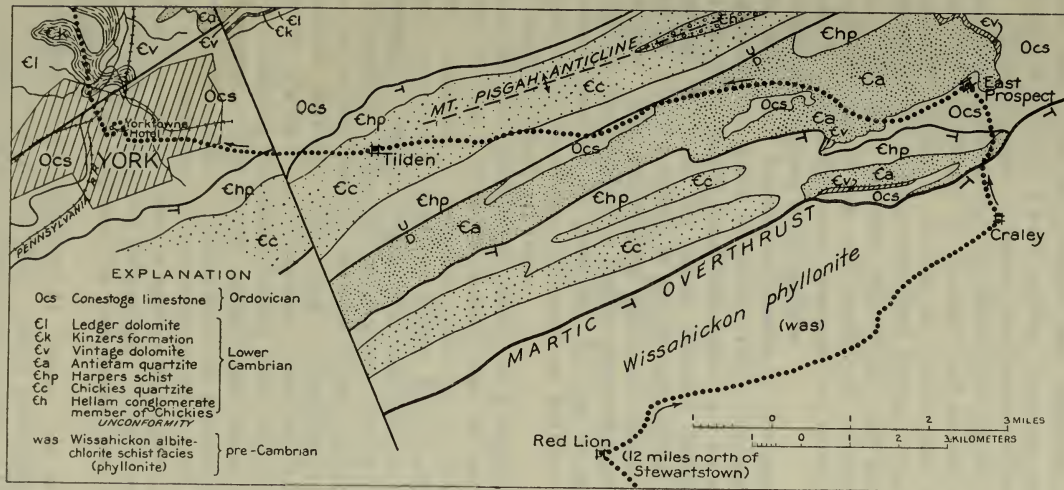
ROUTE MAP, BALTIMORE, MARYLAND, TO STEWARTSTOWN, PENNSYLVANIA

Dotted line shows route. ⊥, Strike and dip of bedding; T, overthrust side of thrust fault.



ROUTE MAP, BALTIMORE, MARYLAND, TO STEWARTSTOWN, PENNSYLVANIA

Dotted line shows route. ⊥, Strike and dip of bedding; T, overthrust side of thrust fault.



ROUTE MAP, RED LION TO YORK, PENNSYLVANIA

Dotted line shows route. U, D, Upthrown and downthrown sides of normal fault; T, overthrust side of thrust fault.

grains; from the occurrence of minerals high in alumina, such as staurolite and kyanite; and from the lack of correspondence between the chemical composition of the rock and any known igneous type. In the gneissic and schistose members of the Wissahickon there is a well-marked cleavage parallel to the bedding. The formation overlies the Cockeysville marble between the anticlines that bring the Baltimore gneiss to the surface.

The trip will return to Towson and go northward along the Cockeysville Valley. North of Timonium an anticline of Baltimore gneiss (Texas anticline) forms a low hill on the east. North of Texas on the east side of the road there is a quarry in Cockeysville marble that will be visited. Formerly many active quarries in the marble were operated in this vicinity for building and ornamental stone and for lime.

Two miles (3.2 kilometers) north of the quarry and 1½ miles (2.4 kilometers) north of Cockeysville the road climbs up the south side of a wide upland belt made up of a succession of long flat-topped hills cut by steep wooded ravines. The Setters formation, dipping south, is poorly exposed at the beginning of the ascent. The underlying Baltimore gneiss crops out along the road to the north as a highly contorted banded gneiss with lit-par-lit injection of granite. In the central part of the anticline Cockeysville marble rests on Baltimore gneiss with no intervening Setters formation.

Six miles (9.6 kilometers) north of Cockeysville, at Verona, the trip will turn west on a side road to see the base of the Setters formation in contact with the underlying Baltimore gneiss. At an old dam on Piney Run rock ledges 50 feet (15 meters) in height border the creek for an eighth of a mile (0.2 kilometer). The Baltimore gneiss at this place is a banded gneiss in which heavily biotitic layers alternate with pink feldspathic bands. The rock immediately overlying the Baltimore gneiss is a feldspathic mica schist, followed by a closely crumpled quartzose mica gneiss that carries tourmaline. The micaceous beds grade upward into thick beds of massive muscovite quartzite. Evidence of the unconformable nature of the contact between the two formations is seen in the character of the deformation, which is more pronounced in the Baltimore gneiss than in the Setters formation. There is also a divergence in average strike between the two formations that amounts to about 20°.

Returning to the highway at Verona the trip will continue northward across two narrow valleys underlain by marble and an intervening ridge of Setters quartzite. The repetition of marble and quartzite is caused by a fluting on the north limb of the Phoenix anticline.

North of the second limestone valley the road continues through Hereford on the Wissahickon formation, which is here a coarse-grained muscovite-biotite schist and gneiss. North of Hereford the schist is a fine-grained gray quartzose biotite gneiss interbedded with a lustrous phyllitic muscovite schist that contains a small amount of quartz and is characterized by the presence of large garnets altered on the rim to chlorite. The biotite typical of the Wissahickon schist in Baltimore County has been partly replaced by chlorite. The chlorite fibers are intimately intertwined and show in places remnants of the original brown color and polarization of biotite. Associated with the chlorite is a large amount of iron oxide liberated from the original biotite during the formation of chlorite. The characteristics of this rock indicate a reversal in metamorphism. This diaphthoritic zone lies on the northwest side of the uplifted area in which the Baltimore gneiss occurs at the surface. The same belt of retrogressive metamorphism extends northeastward into Pennsylvania and southwestward across Maryland.

Two miles (3.2 kilometers) north of Hereford the retrogressive facies of the Wissahickon becomes albitic, and this facies extends 20 miles (32 kilometers) northwestward to the edge of the Martic thrust fault. (See pl. 13.) This overthrust began as a great recumbent fold during the late Paleozoic deformation and carried the pre-Cambrian Glenarm rocks northwestward over Lower Cambrian rocks and Ordovician limestones. The northern edge of the thrust lies several miles south of York.

At Parkton (see pl. 12), 4 miles (6.4 kilometers) north of Hereford, the coarse-grained albite schist facies of the Wissahickon formation is well exposed. The albite occurs in metacrysts which contain inclusions of quartz, garnet, muscovite, biotite, epidote, and calcite. These albites lie in a fine schistose matrix of quartz, chlorite, muscovite, and biotite. The chlorite is derived from biotite and garnet. Both biotite and chlorite contain inclusions of zircon with pleochroic halos. Similar albite schist underlies the area northward into Pennsylvania.

From Shrewsbury, Pennsylvania, 10 miles (16 kilometers) north of Parkton, the trip will go east through Stewartstown to the valley of the South Branch of Muddy Creek, where the Wissahickon schist is exposed in the crest of the Tucquan arch, a foliation anticline developed in the Wissahickon chlorite-albite schist of the Martic overthrust block after overthrusting. This folding involved both the overthrust rocks and those of the underlying block.

In the Tucquan arch the minor folds are overturned to the northwest on the south side and to the southeast on the north side. The foliation developed during the folding cuts the older foliation and dips away from the crest of the anticline on both sides. At Muddy Creek the older foliation in the crest of the arch is flat to gently rolling, and the younger foliation is poorly developed. The rock is a ferruginous chlorite-muscovite schist with garnets. The thin section shows fine dust parallel to the older foliation and crossing feldspar crystals. The rock contains also fine quartz, much chlorite, and muscovite. Pleochroic halos about the black dust and zircons are developed in chlorite.

Returning to Shrewsbury the trip will cross the Wissahickon albite-chlorite schist on the northwest side of the Tucquan arch. Exposures are few because the road follows the upland. From Red Lion (see pl. 13), 12 miles (19 kilometers) north of Stewartstown,[6] the trip goes northeast to the edge of the Martic thrust fault north of Craley. New road cuts expose fine-grained chlorite schist in which the younger foliation is dominant and has dips ranging from vertical to northwest. This rock is composed of albite, quartz, chlorite, and muscovite. The younger foliation cuts across the older, which is preserved in arches of the close folds. The rock is a phyllonite derived from the coarser-grained albite schist. In the area to the west the albite-chlorite schist is thrust over the Lower Cambrian Harpers schist. North of Craley the pre-Cambrian albite-chlorite schist overlies the Antietam quartzite, which is the upper member of the Lower Cambrian arenaceous rocks and is well exposed at the northern edge of the thrust. Here it is composed of quartz, microline, and albite, with fine muscovite and coarse brown biotite porphyroblasts containing zircons surrounded by pleochroic halos. It is a rock of progressive metamorphism formed in the lower epizone and is part of the Lower Cambrian succession of the Mount Pisgah anticline, which will be crossed in going northwest to York.

North of the Martic thrust and Antietam quartzite the road crosses the Ordovician Conestoga limestone, which overlaps Vintage dolomite and Antietam quartzite on the eastern edge of the plunging folds of the Mount Pisgah anticline. From East Prospect westward the road crosses Antietam quartzite, Harpers schist, and Chickies slate in descending sequence to Tilden and Harpers schist on the north side of the anticline to the York Valley. This valley is underlain by the Conestoga limestone, over which the Pisgah anticline is thrust northwestward on a fault parallel to the Martic overthrust.

(For the remainder of the trip, York to Emigsville, see p. 13.)

[6] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 74–77, 1929.