XVI INTERNATIONAL GEOLOGICAL CONGRESS

GUIDEBOOK 3 - - - EXCURSION A-3

SOUTHERN APPALACHIAN REGION

International Geological Congress
XVI session
United States, 1933

Guidebook 3: Excursion A–3

SOUTHERN APPALACHIAN REGION

By

CHARLES BUTTS, G. W. STOSE
AND ANNA I. JONAS
UNITED STATES GEOLOGICAL SURVEY

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1932

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 35 cents

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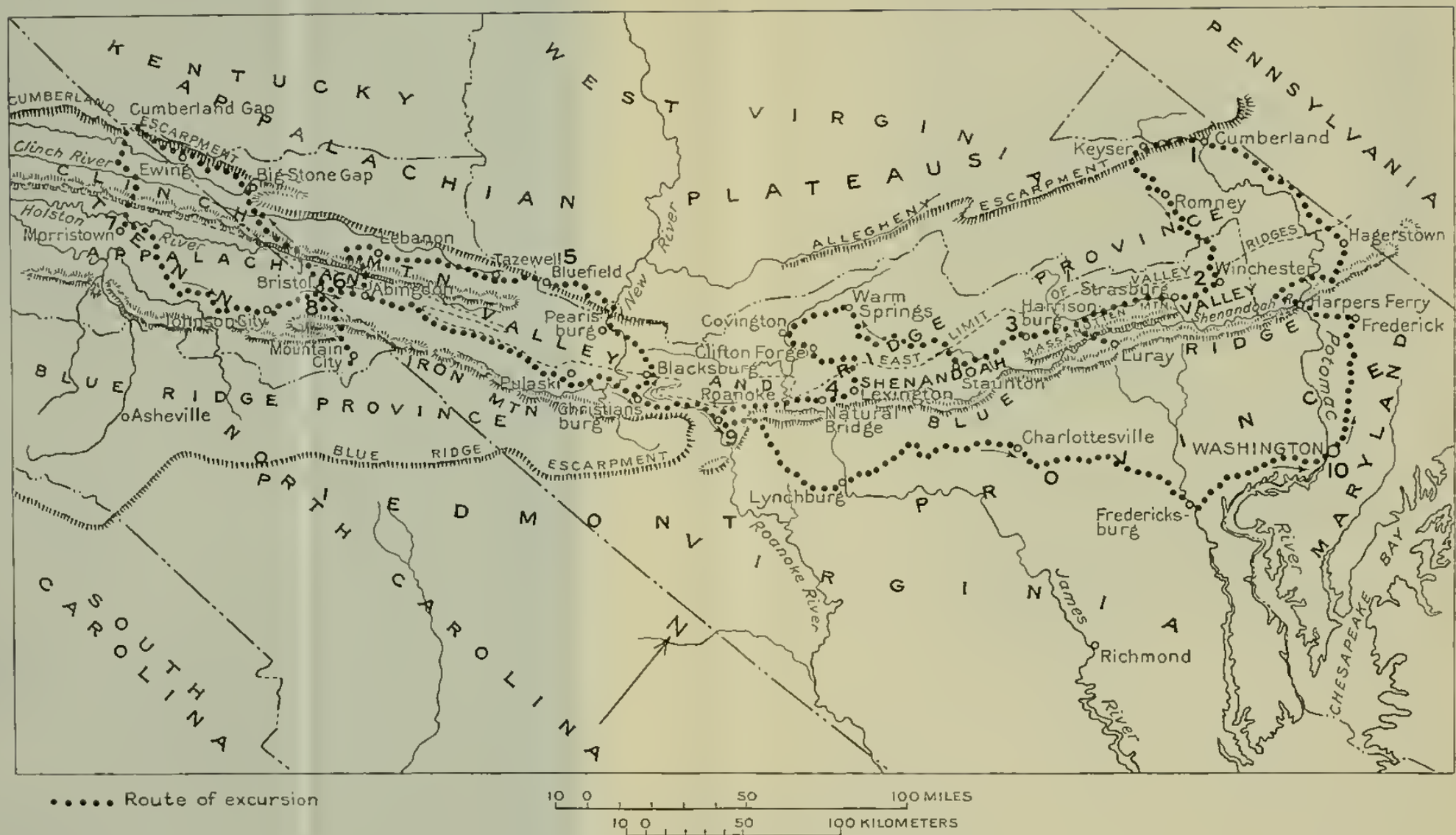
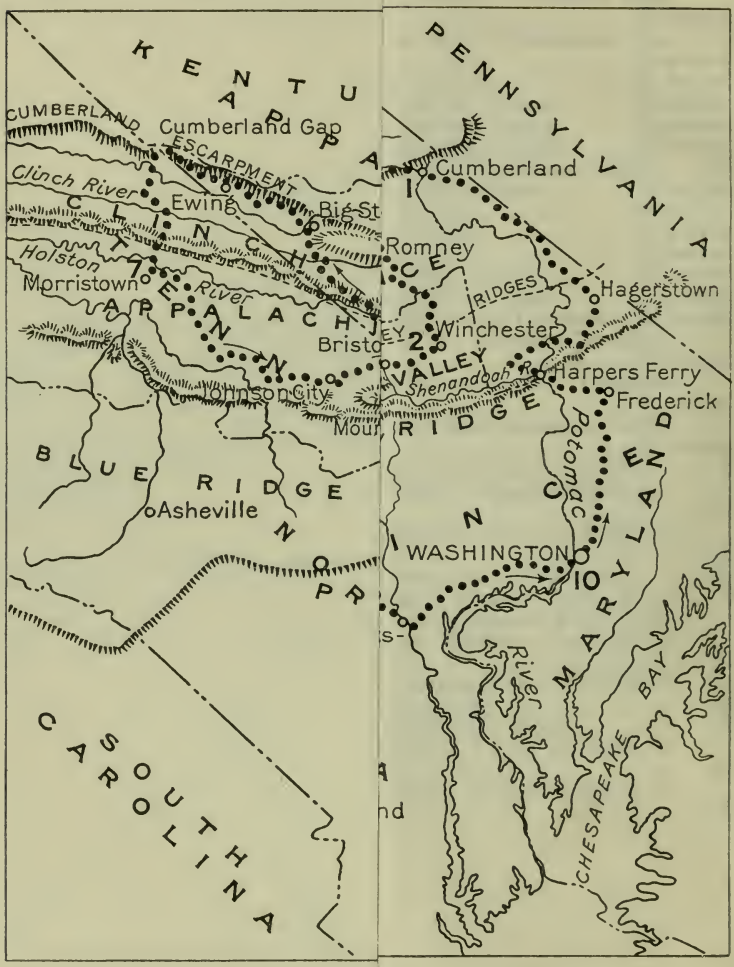


SKETCH MAP OF THE APPALACHIAN REGION

Showing route of excursion and geomorphic divisions. Nos. 1 to 10 indicate probable places of stopping at night.



••••• Route of excursio

SOUTHERN APPALACHIAN REGION

By Charles Butts, G. W. Stose, and Anna I. Jonas

The purpose of excursion A–3 is to study Paleozoic stratigraphy, Appalachian structure, and geomorphology in the Appalachian Valley and Ridges in Virginia and portions of bordering States. (See pl. 1.)

GENERAL FEATURES OF THE REGION

Appalachian Highlands.—The broad term Appalachian Highlands comprises several geologic and geomorphic divisions, named from southeast to northwest the Piedmont province, a dissected upland composed mainly of pre-Cambrian crystalline rocks with tracts of lowland underlain in part by Paleozoic limestone and in part by Triassic shale and sandstone; the Blue Ridge province, consisting of one or more parallel ridges (chiefly a single ridge, the Blue Ridge, in northern Virginia, expanding into a broad area of high mountains in Tennessee and North Carolina), composed of Cambrian quartzites and pre-Cambrian rocks; the Valley and Ridge province, a series of parallel ridges and valleys composed of folded Paleozoic rocks, more fully described beyond; and the Appalachian Plateaus, a series of more or less dissected plateaus composed of nearly flat-lying Carboniferous rocks and bounded on the southeast by an abrupt escarpment called the Allegheny Front or Allegheny Escarpment in Pennsylvania, Maryland, and northern Virginia and the Cumberland Escarpment in southwestern Virginia and Tennessee.

As the excursion will be largely in the Valley and Ridge province, a more detailed description of that province follows.

Appalachian Valley and Ridge province.—An area 50 to 60 miles (80 to 96 kilometers) wide between the Blue Ridge on the southeast and the Allegheny-Cumberland escarpment on the northwest is included in the Valley and Ridge province. Because its general level is lower than that of the bordering mountains and plateaus it has been generally referred to as the Appalachian Valley, or simply the Great Valley, or the Valley, but inasmuch as high mountains and ridges many miles long and as high as the bordering mountains are an integral part of the belt, it is more appropriately called the Appalachian Valley and Ridge province.

For most of its length this province is bounded on each side by an abrupt scarp rising 1,000 to 2,000 feet (305 to 610 meters) above the general valley level. For 50 miles (80 kilometers) northeast and southwest of Bluefield, West Virginia, however, there is no distinct scarp on the northwest, and the Valley and Ridge province merges topographically with the Appalachian Plateaus. This absence of a scarp is probably due to deep dissection in the vicinity of the New River, which crosses the scarp line here, and in the valleys of the Clinch and Greenbrier Rivers, which run close to the scarp line for considerable distances.

The southeastern part of the Valley and Ridge province is in most places a wide, flat valley. The wide, comparatively level valley between Winchester and Lexington drained by the Shenandoah River is the Shenandoah Valley, which from Strasburg to Harrisonburg is divided lengthwise into two parts by Massanutten Mountain. From Christiansburg and Blacksburg southwest to Tennessee is another relatively level valley, which may be referred to as the Valley in southwest Virginia. It comprises the Abingdon and Dublin Valleys, and to the north of the Dublin are the smaller Salem and Fincastle Valleys, also part of the Great Valley.

The northwestern part of the province has many high linear ridges parallel to the valley trend, which are called the Valley Ridges. Southwest of Natural Bridge in the vicinity of Buchanan the Valley Ridges and the Blue Ridge approach so closely that they end the Shenandoah Valley and separate it from the Fincastle Valley, to the south.

The Valley Ridges division of the Valley and Ridge province is marked by many monoclinal and some synclinal ridges rising to heights of 2,000 to 4,000 feet (610 to 1,219 meters) above the sea and 1,000 to 1,500 feet (305 to 457 meters) above the general valley level. These high ridges are almost invariably controlled by the Clinch or Tuscarora sandstone (basal Silurian). Where the sandstone is steeply inclined, it forms the resistant core of the monoclinal ridges; where it is flat, it makes the narrow summits of synclinal ridges, of which those along and near the route between Tazewell and Lebanon are the best examples.

Geomorphic forms.—The Shenandoah Valley and the Valley in southwest Virginia have gently sloping floors, into which the streams are trenched 100 feet (30 meters) or more and above which the bordering mountains rise abruptly. Many of the mountains and ridges throughout the region have even crests, which stand at an upland level and above which few summits rise. These two geomorphic features are generally well marked and represent two stages of erosion—a widespread upland pene-

plain and the valley-floor partial peneplain. (See fig. 3.) The best preserved example of the upland peneplain is on the plateau of the Blue Ridge province, 12 miles (19 kilometers) southeast of Roanoke, where a remnant of the old flat surface is preserved at an altitude of about 3,000 feet (914 meters), with the drainage flowing gently southward, away from the abrupt scarp of the plateau.

Valley-floor partial peneplains were formed only on soft or soluble rocks, and the altitude of such a local flat surface is dependent on the distance to the sea along its drainage course. The flat floor of the Shenandoah rises from an altitude of 600 feet (183 meters) at the Potomac River to about 1,800 feet (549 meters) at the head of the valley, near Natural Bridge, and most of its surface is strewn with large cobbles, gravel, and sand brought from the adjacent mountains by steep-gradient tributaries and spread over the old flat valley floor before it was elevated to its present height. The floor of the Valley in southwest Virginia is about 2,100 to 2,200 feet (640 to 670 meters) above sea level, rising to 2,700 feet (823 meters) at the divide between the Dublin and Abingdon Valleys. The high level of this valley floor is due to the fact that the New and Holston Rivers, which drain the valley, are tributary to the Ohio and Tennessee Rivers, and the area is a long distance from the ocean base level along these streams. In the vicinity of the Narrows of the New River, near Pearisburg, coarse gravel occurs at an altitude of 2,100 feet (640 meters), deposited by the river on a preexisting valley floor which now stands 500 feet (152 meters) above the present stream level.

Other partial peneplains occur at intermediate levels in the mountains, but these are not everywhere present nor readily recognized. Along the trunk streams there are also gravel-covered terraces below the valley-floor level. The valley-floor peneplain and the lower gravel-covered terraces are well displayed at many places along the route of travel, especially in the Potomac Valley from Washington to Cumberland.

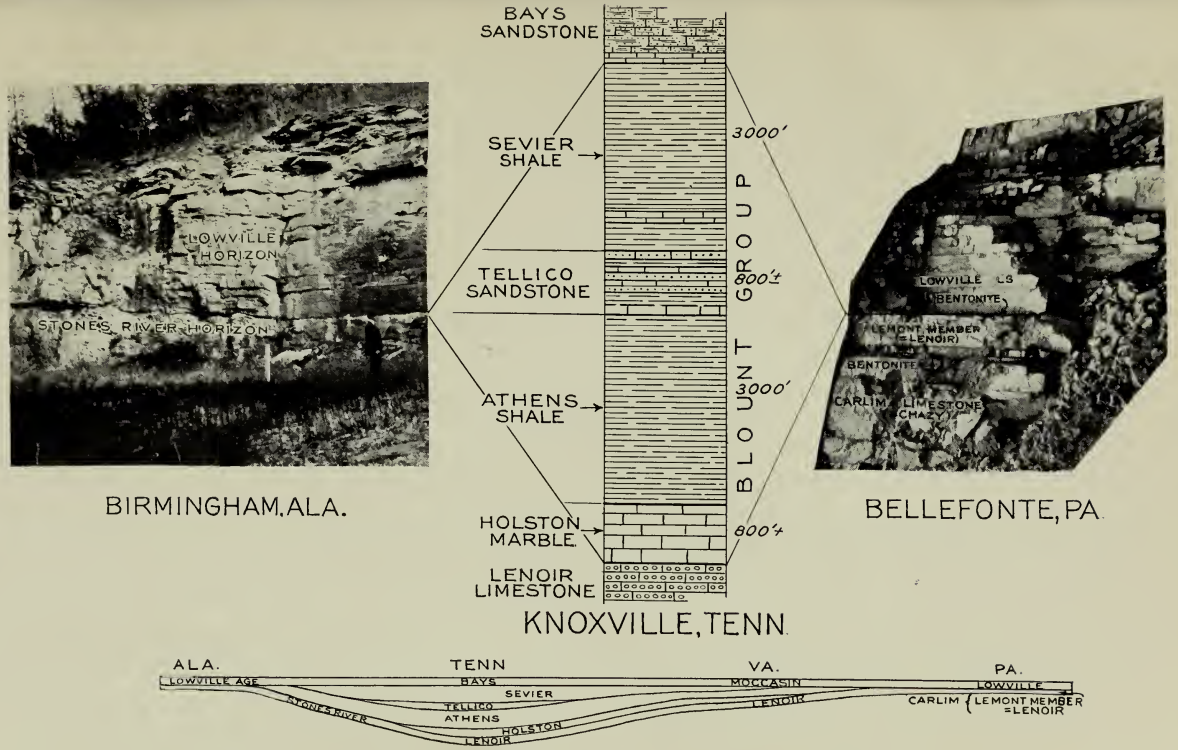
Drainage.—After the land surface was reduced in post-Triassic time to a gently rolling peneplain, which is now the upland peneplain, it was apparently uplifted into a broad, flat arch, the drainage from which went in part eastward into the Atlantic Ocean and in part westward into the Mississippi lowland. The eastward-flowing streams had a steeper gradient than the westward-flowing streams and were nearer their base level, the ocean, so that they cut back their headwater divides, encroached on the drainage areas of the westward-flowing streams, and diverted many of these streams by capture. The result is that much of the drainage of the northern and middle

parts of the Appalachian region now flows eastward across the Valley and Ridge province, through narrow gaps in the Blue Ridge, across the Piedmont upland in deep valleys, and over the Coastal Plain into the Atlantic. In places the deeply intrenched streams preserve strongly incised meanders, such as those of the Potomac River above Hancock, Maryland, which were acquired on one of the younger partial peneplains developed on the softer rocks. The New River is an exception in that it has maintained its original westward course. It rises within the Blue Ridge province, flows westward through a gap in the front ridge of the Blue Ridge, across the Appalachian Valley and Ridge province, through the Appalachian Plateaus in a deep meandering gorge, and is still tributary to the Mississippi. The gorge of the New River at the Narrows, on the route of the excursion, is an example of a water gap through a ridge of hard rock.

Geology.—The Paleozoic rocks of the Appalachian Valley and Ridge province accumulated in a sinking trough—the Appalachian geosyncline. At the beginning of the Paleozoic era this trough was probably a relatively narrow depression extending from Newfoundland to the Gulf of Mexico. In Virginia and Tennessee it probably coincided in location approximately with the present Appalachian Valley and Blue Ridge. This conclusion is reached from the fact that the oldest Paleozoic strata, although extending the whole length of the valley along and for considerable distances both southeast and northwest of the Blue Ridge and its southern extension through Tennessee, do not occur in northwestern Ohio, the nearest point on the northwest at which the ancient crystalline rocks of the basement have been reached by boring. At that point the oldest sedimentary rocks are regarded as of Upper Cambrian age, corresponding about to the Nolichucky shale of the Appalachian Valley. That northwestern region was probably land during all of Lower and Middle Cambrian time.

Although subsidence of the geosyncline was the general rule through the Paleozoic, there was in the last half, say, of Chazy time, an interruption of deposition (emergence) in the interior region (Ohio and Mississippi Valleys) and in Alabama and Pennsylvania, and during that interval the Blount group of the Ordovician, comprising the Holston, Athens, Tellico, and Ottosee formations, was deposited in the intervening regions. This group aggregates 6,000 to 8,000 feet (183 to 244 meters) in thickness in Tennessee. The facts and hypotheses above set forth are illustrated in Figure 1. (See also pl. 2.)

Such oscillations of the sea bottom as this, though common, did not perceptibly affect the general stratigraphic parallelism in the geosyncline, and discordance of bedding of more than a



VIEWS AND SECTIONS SHOWING DISTRIBUTION AND STRATIGRAPHIC RELATIONS OF THE BLOUNT GROUP

Note the parallelism of the bedding shown in the photographs. (After Butts, Charles, Washington Acad. Sci. Jour., vol. 18, No. 13, fig. 2, 1928.)

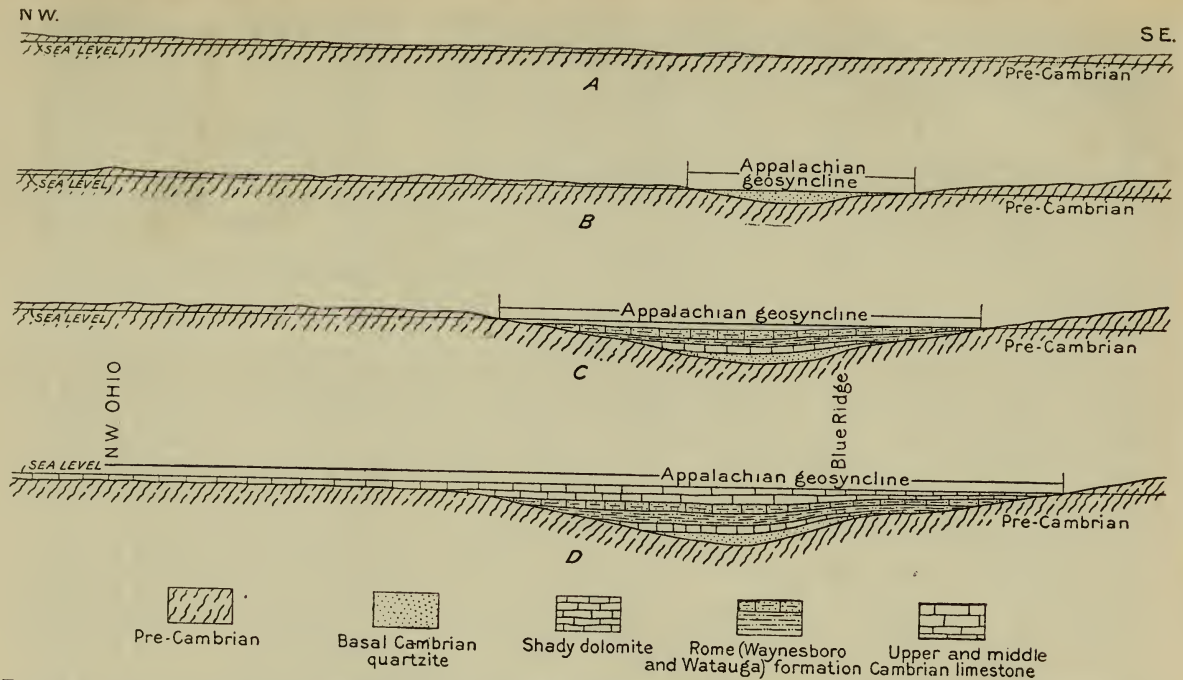


FIGURE 1.—Hypothetical sections across the Appalachian geosyncline to show its progressive subsidence, the probable location of the axis of subsidence, and the transgression and overlap of the younger deposits outward from the axis. *A*, At beginning of Cambrian time; *B*, at end of Antietam time; *C*, at end of Rome (Waynesboro) time; *D*, at end of Upper Cambrian time

few degrees has not been observed in this region. In late Mississippian time the sea covered the entire area from the middle of the Great Valley near Bristol, Virginia, to the Mississippi Valley, as indicated by the unbroken extent of Ste. Genevieve limestone, of uniformly pure oolitic character, over the whole area. Probably the Mississippian sea reached the site of the Blue Ridge, for the greatest known thickness of Mississippian in America, 6,000 feet (1,829 meters) or more, is in the great syncline next southeast of the North Fork of the Holston River, only 24 miles (39 kilometers) northwest of the pre-Cambrian at the Blue Ridge line. At the end of Mississippian time downwarping of the geosynclinal area not far northwest of the Blue Ridge was accelerated while the great interior region emerged, so that the greatest thickness of the oldest coal-bearing (Pennsylvanian) rocks, amounting to as much as 10,000 feet (3,048 meters) in Alabama, accumulated in this southeastern trough, whereas only much later Pennsylvanian rocks transgressed northwestward over the denuded edges of the slightly tilted Mississippian rocks of the Appalachian Plateau, resulting in one of the greatest stratigraphic gaps in the eastern United States.

The depositional history of the geosyncline ended in the Permian, which is represented by 1,500 feet (457 meters) or so of rocks along the Ohio River in Ohio and West Virginia. The entire thickness of Paleozoic strata that accumulated in the geosyncline is not less than 40,000 feet (12,192 meters). It is probable that, even after allowing for nondeposition in places, strata of this total thickness were actually in superposition in some parts of the Valley, involving a depression of the geosyncline in such places of over 7 miles (11 kilometers).

In later Permian and possibly early Triassic time occurred the Appalachian revolution, when the geosyncline was compressed and elevated, with the production of folds and overthrusts, briefly described beyond. During all the time subsequent to the Appalachian revolution the area of the geosyncline has been subjected to erosion and periodic differential uplifts, through which the existing surface features have been produced.

Structure.—The strata of the Appalachian Valley and Ridges were strongly folded and faulted during the Appalachian revolution. The folds and faults trend parallel to the sides of the Valley and extend for many miles. The folds are commonly unsymmetrical, the northwest limbs of the anticlines being steeper than the southeast limbs. The northwest limbs of some of the anticlines are even overturned, as in the Iron Gate anti-

cline, near Clifton Forge, Virginia. (See pl. 17.) A good example will also be seen in Panther Gap. (See pl. 15.)

Many of the folds are broken and overthrust, chiefly toward the northwest. The stratigraphic throw on some of the faults is very great; for example, the Saltville overthrust is stratigraphically as much as 14,000 feet (4,267 meters) at Greendale, Virginia, and probably 16,000 feet (4,877 meters) in some other places. Some of the faults are great low-angle overthrusts having several miles of horizontal displacement; for example, the Pulaski overthrust in the middle of the Valley and the Pine Mountain overthrust at Cumberland Gap in southwestern Virginia. (See pls. 19 and 23.) The existence of these faults is demonstrated by fensters or windows through the overthrust plate, one of the most notable examples of which is that on the Pulaski overthrust between Christiansburg and Blacksburg, Virginia. (See pl. 19.) Here the lower Mississippian (Price formation) is overridden by the Rome formation (Lower or Middle Cambrian) on the Pulaski fault. Another fenster on the Pulaski overthrust is crossed by the Lee Highway 2 miles (3.2 kilometers) east of Wytheville, and others on the Pine Mountain overthrust block occur in Lee County southeast of Rose Hill and Ewing. (See pl. 23.) All these overthrusts have moved on clean-cut low-angle thrust planes, and none seem to be nappes of the recumbent-fold type so characteristic of the high calcareous Alps. Possibly these overthrusts originated as recumbent folds, as suggested by the overturning of the beds southeast of the great Massanutten syncline, shown in the profile section in the guidebook for northern Virginia (excursion B–5).

There are striking examples of klippen, most of them along the northwest margin of the Blue Ridge, but the one northwest of Burketown, Virginia (see pl. 14), lies out in the valley. A notable klippe is Cherokee Mountain, 5 miles (8 kilometers) south of Johnson City, Tennessee. (See pl. 25.) Holston and Iron Mountains, southeast of Bristol, are on another great klippe. (See pl. 26.)

PALEOZOIC FORMATIONS

The entire Paleozoic sequence, possibly the most nearly complete known in the world, is well developed in the Appalachian Valley and Ridge province, and most of it is in the part of the Valley to be traversed by this excursion. A brief description of the formational units follows, beginning at the bottom.

CAMBRIAN

The oldest Cambrian rocks (Lower Cambrian) crop out along the Blue Ridge in northern Virginia and along the same line southwestward into Tennessee. Their divisions are named and correlated as indicated below:

Maryland and Virginia north of Roanoke	Southern Virginia and Tennessee
Antietam quartzite.	Erwin quartzite.
Harpers shale.	Hampton shale.
Weverton quartzite. Loudoun formation.	Unicoi sandstone.

Loudoun formation, Weverton quartzite, Unicoi sandstone.—The Loudoun is a heterogeneous formation composed of conglomerate, quartzite, and slate, 100 to 800 feet (30 to 244 meters) thick. Some of the shale is dark purplish in places. The Weverton is largely a pure quartzite, locally containing many feldspar grains, 200 to 1,000 feet (61 to 305 meters) thick. The Unicoi sandstone, the equivalent of the Weverton and Loudoun south of Roanoke, Virginia, is a thick-bedded sandstone 1,000 feet (305 meters) or more thick. Good exposures of the Unicoi are present on the Mountain City road on the northwest side of Holston Mountain in southern Virginia, 15 miles (24 kilometers) east of Bristol, Virginia.

Harpers shale, Hampton shale.—The Harpers and Hampton consist essentially of gray siliceous and argillaceous shale and thin-layered quartzite, probably 1,200 to 2,000 feet (366 to 610 meters) thick. The name Hampton is applied south of Roanoke, Virginia. A complete exposure of the Hampton in sequence above the Unicoi sandstone is seen on the Mountain City road referred to above.

Antietam quartzite, Erwin quartzite.—The Antietam quartzite in northern Virginia and Maryland and the equivalent Erwin quartzite in southern Virginia and Tennessee consist of thick-bedded hard gray to white quartzite 500 to 1,000 feet (152 to 305 meters) thick.

Owing to their hard and resistant character, all the clastic formations described above enter largely into the composition of the Blue Ridge and the escarpment bounding the Valley on the southeast in continuance of the Blue Ridge line southwestward from Roanoke, Virginia, into Tennessee.

Tomstown dolomite, Shady dolomite.—The Tomstown dolomite in Pennsylvania, Maryland, and Virginia north of Roanoke and the equivalent Shady dolomite in southern Virginia and Tennessee succeed respectively the Antietam and Erwin quartzites. This unit is a coarse crystalline white to gray dolomite, the first carbonate deposit of the Appalachian geosyncline. Locally in Virginia there is near the bottom a persistent bed of limestone 200 feet (61 meters) or more thick. The total maximum thickness is apparently 2,000 feet (610 meters). It contains large bodies of zinc ore, mostly sphalerite, at Austinville, south of Wytheville, Virginia. At this place *Olenellus*, *Dorypyge*, *Zacanthoides*, and *Nisusia* occur in limestone in the Shady and prove its equivalence, at least in part, with limestone and shale in the vicinity of York and Lancaster, Pennsylvania, that are correlated with the typical Tomstown dolomite.

Waynesboro formation, Rome (Watauga) formation.—The Waynesboro formation in Pennsylvania, Maryland, and northern Virginia and the equivalent Rome formation farther south consist of a heterogeneous aggregation of red shale, red sandstone, green shale, fine-grained calcareous ferruginous sandstone, coarse bluish dolomite in beds perhaps as much as 100 feet (30 meters) thick, and here and there a bed of pure blue banded limestone as much as 50 feet (15 meters) thick. From Pennsylvania to Roanoke, Virginia, the name Waynesboro is applied to the formation; south of Roanoke the eastern belt is called Rome (Watauga) and the western belts Rome.

Olenellus sp. and a few ptychoparian trilobites have been found in the Rome in Virginia, and other olenelloids and brachiopods occur elsewhere in the formation. *Olenellus* has in some areas been found near the top of the Rome. According to current and nearly universal usage the occurrence of *Olenellus* places the beds containing them in the Lower Cambrian. Walcott reported Middle Cambrian fossils from the Rome in some areas, and Ulrich would assign the whole formation to the Middle Cambrian.

Rutledge limestone (Middle Cambrian).—The Rutledge is a thick-bedded banded limestone 250 to 500 feet (76 to 152 meters) thick. In the base of this unit *Dolichometopus productus* occurs, and *Zacanthoides* and other trilobites of ptychoparian affinities are common in what is certainly Rutledge.

Rogersville shale (probably Middle Cambrian).—A yellowish-gray to bluish-gray, rather soft, fissile shale with a few thin sandy layers, 20 to 100 feet (6 to 30 meters) thick is known as the Rogersville shale. It occurs only on the northwest side of the Valley and Ridge province south of latitude 37°.

Maryville limestone (Upper Cambrian).—The Maryville is a thick-bedded blue limestone much like the Rutledge but rather more profusely and finely banded. It is perhaps 500 feet (152 meters) thick. Trilobites, such as *Maryvillia*, *Blountia*, and *Kingstonia*, referred to the Upper Cambrian, are supposed to have been obtained from this formation.

Honaker limestone (Middle and Upper Cambrian).—Throughout much of its area the Honaker is a thick-bedded bluish dolomite indistinguishable from the Copper Ridge and other dolomites described below. It represents the Rutledge and Maryville limestones where the parting Rogersville shale is absent.

Nolichucky shale (Upper Cambrian).—The Nolichucky consists of soft dark-gray or olive-green shale with limestone in thin or thick beds, many of which have thin clayey bands like the banded beds in the Rutledge and Maryville. A persistent bed of such banded limestone occurs at the top of the formation in southwestern Virginia. The Nolichucky carries a fairly abundant fauna of trilobites and brachiopods, among which are *Crepicephalus texanus* and other species of this genus, *Coosia* sp., *Kingstonia* sp., ptychoparian trilobites, and, very widely distributed, *Dicellomus politus*. These are all of early Upper Cambrian age.

Elbrook limestone (Middle and Upper Cambrian).—In the southeastern part of the Valley, extending southwest from Pennsylvania into Virginia, is an aggregation of fine-grained earthy dolomite or limestone, partly shaly, partly thick-bedded, known as the Elbrook limestone. This unit is probably the equivalent of the Honaker and the overlying Nolichucky shale where the Nolichucky is not separable.

Copper Ridge dolomite (Upper Cambrian of United States Geological Survey).—The Copper Ridge dolomite succeeds the Nolichucky shale in the northwestern part of the Valley and Ridge province. Between the two is believed to be a great hiatus, owing to the absence of the Brierfield, Ketona, and Bibb dolomites of Alabama, about 2,500 feet (762 meters) thick. These three formations, together with the Copper Ridge and the Chepultepec dolomite (which in Alabama overlies the Copper Ridge), comprise the rocks that Ulrich includes in his Ozarkian system in the Valley and Ridge province.

The Copper Ridge is composed of compact to coarsely crystalline bluish and gray thick-bedded dolomite, with beds of sandstone scattered through it. These sandstones are distinctive of both the Copper Ridge and the Conococheague limestone, described below. The Copper Ridge is 1,200 feet (365 meters) thick. It is unfossiliferous in Virginia.

Conococheague limestone (Upper Cambrian of United States Geological Survey).—The Conococheague limestone occurs along the southeast side of the Appalachian Valley from Pennsylvania to and probably beyond Greenville, in northeastern Tennessee. It cccupies approximately the same stratigraphic position as the Copper Ridge dolomite and like the Copper Ridge is referred by Ulrich to his Ozarkian system. It is composed mainly of thick-bedded blue limestone ranging from high-calcium to high-magnesium limestone or even dolomite, but fairly pure calcium rock largely predominates. Many of the layers of limestone are banded with argillaceous impurities, and layers of edgewise conglomerate are common. Its distinctive feature, like that of the Copper Ridge, consists of beds of sandstone which are scattered through it from bottom to top. The argillaceous bands, forming crinkled laminae standing out in relief on weathered surfaces, are highly characteristic. In Maryland its most conspicuous fossil is a large *Cryptozoon* which forms reefs. (See pl. 7, *A*.) Trilobites (Saukiinae) from the Conococheague indicate its approximate correspondence with the Potsdam and Hoyt formations of northeastern New York, which Ulrich also refers to his Ozarkian system.[1] From its stratigraphic relations and its sandstone beds it is regarded as probably equivalent to the Copper Ridge.

Chepultepec dolomite (Upper Cambrian of United States Geological Survey).—So far as known, the Chepultepec, which consists of dolomite like that of the underlying Copper Ridge, is represented in the country traversed by this excursion only in Tennessee, a few miles southeast of Cumberland Gap, where two of its most diagnostic fossils, *Helicotoma uniangulata* and *Clarkoceras* sp., were found. Apparently only the feather edge of the Chepultepec is present there, at the top of a thick section of Copper Ridge dolomite.

ORDOVICIAN

BEEKMANTOWN GROUP

The formations of the Beekmantown group constitute the "Canadian system" of Ulrich.

Stonehenge limestone.—The Stonehenge limestone, the basal formation of the Beekmantown, is mostly a blue thick to thin bedded limestone carrying many layers of edgewise conglomerate, possibly 100 feet (30 meters) thick. It contains gastropods similar to those in the Nittany. So far as known it is confined

[1] It has just been determined by Ulrich (August, 1932), through the occurrence of certain cephalopods, that the upper few hundred feet of the Conococheague corresponds to the Gasconade of Missouri and the Chepultepec of Alabama.

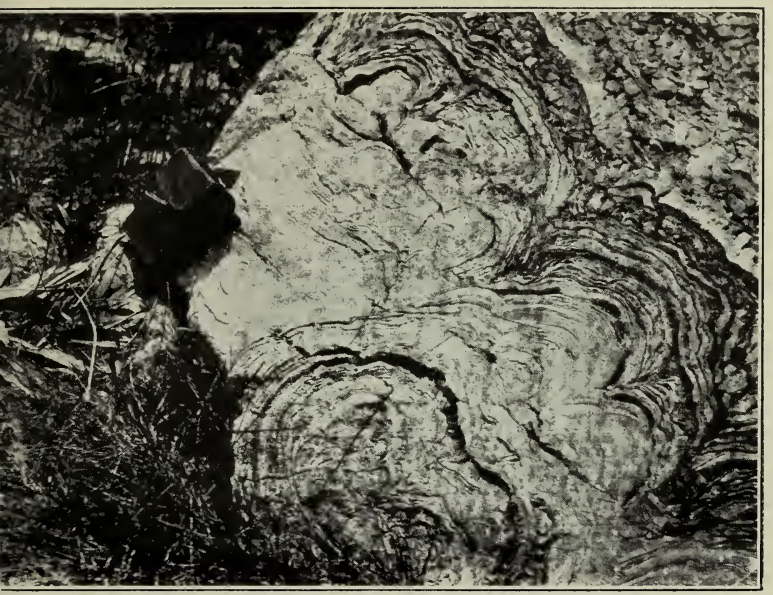
to central and eastern Pennsylvania, Maryland, and northern Virginia. It will be seen near Hagerstown, Maryland.

Nittany dolomite.—The Nittany dolomite is in all respects like the Copper Ridge except that it has no sandstone beds. It is 500 to 1,000 feet (152 to 305 meters) thick. This is one of the most persistent and widely distributed of geologic units, everywhere marked by chert beds containing *Lecanospira*, represented by *L.* (*Ophileta*) *compacta* Salter and many other species. The genus has been found from the northwest Highlands of Scotland, where it occurs in the upper part of the Durness limestone, through Newfoundland, Quebec, the Champlain Valley, the Appalachian Valley from Pennsylvania to Alabama, and westward through Texas into Oklahoma, where it occurs in the Arbuckle limestone.

The Copper Ridge and Beekmantown dolomites form essentially one mass in Virginia and northern Tennessee and constitute the main part of what has been called the Knox dolomite.

It is doubtless hard for one unacquainted with the facts to understand why this homogeneous mass of dolomite, 2,400 feet (732 meters) thick in southwestern Virginia, should be divided near the middle into two formations and be assigned to separate systems. This procedure is warranted, however, by the fact that, as proved at the locality a few miles southeast of Cumberland Gap, Tennessee, where the thin Chepultepec (see p. 74) occurs in the middle of the mass, it is immediately overlain by beds that yield chert with *Lecanospira* and *Histricurus* typical of the Nittany dolomite of the Beekmantown. Both the Stonehenge limestone (basal Beekmantown) and the greater part of the Chepultepec, 1,000 feet (305 meters) thick in Alabama, are absent in the Cumberland Gap locality; the Copper Ridge and Nittany are nearly in contact here and, so far as known, completely in contact northeast of Tennessee; and the contact is about the middle of the whole dolomite mass.

Beekmantown of post-Nittany age.—Overlying the Nittany there is throughout southwestern Virginia a varying thickness of cherty dolomite carrying a fairly abundant gastropod and cephalopod fauna of the age of the Jefferson City, Cotter, and Powell dolomites of Arkansas and Missouri. *Ceratopea*, *Hormotoma*, *Coelocaulus*, *Oraspira*, and *Tarphyceras* are perhaps the most common fossils. Locally in southwestern Virginia the formation includes layers of pure light-gray compact limestone in the upper part. Also on the northwest side of the Valley and Ridge province in southwestern Virginia there is at the top a persistent zone of red shale and purplish mottled dolomite with a maximum thickness of 50 feet (15 meters). This post-Nittany part of the Beekmantown group, 200 to 800 feet (61 to



. CRYPTOZOA IN CONOCOCHEAGUE LIMESTONE 1 MILE (1.6 KILOMETERS) SOUTH OF CLEAR SPRING, MARYLAND

Heads of *Cryptozoon proliferum*, a form of algal growth, about 2 feet across.

B. SLIGHTLY OVERTURNED WEST LIMB OF IRON GATE ARCH

½ miles (2.4 kilometers) southeast of Clifton Forge, Virginia. Keefer sandstone member at top of Clinton formation. Looking northeast. Note slight fault with apparent movement to the southeast in upper right-hand corner.

244 meters) thick in southwestern Virginia, thickens northward and at Staunton, Virginia, is apparently 1,500 feet (457 meters) thick. This part corresponds to the Bellefonte dolomite of central Pennsylvania, which has a thickness of 1,000 to 2,000 feet (305 to 610 meters) of dolomite and carries a few of the same fossils, including rare specimens of *Ceratopea*.

Ruedemann regards the Deepkill and Schaghticoke beds of eastern New York as of Beekmantown age, and these beds, through such fossils as *Dictyonema flabelliforme*, *Didymograptus bifidus*, and *Phyllograptus*, are correlated with the upper part of the Tremadoc and the Llanivirnian of Wales and with the Skidavian of England. Hence, the Beekmantown of the Valley of Virginia is correlated with those formations of Great Britain.

STONES RIVER GROUP

In its type region, the Nashville region of middle Tennessee, the Stones River group comprises four formations—in ascending order the Murfreesboro limestone, Pierce limestone (thin), Ridley limestone, and Lebanon limestone. In the Appalachian Valley the group is represented by the Murfreesboro limestone at the base, the Mosheim limestone, and the Lenoir limestone (correlated with the Ridley), at the top. The Pierce and Lebanon have not been recognized in the Valley. The Mosheim is regarded as a distinct formation of Atlantic origin, not represented in middle Tennessee.

In the Appalachian Valley the Murfreesboro is recognized only in the northwestern belts of outcrop in the southwestern counties of Virginia. The Mosheim and Lenoir are widely distributed in the Valley, although the Mosheim is locally absent. In places, too, it is somewhat difficult to separate these components of the Stones River group, and in such areas they are included together on the accompanying route maps as Stones River. Where the Mosheim and Lenoir only are present they are mapped together.

Murfreesboro limestone.—The Murfreesboro limestone is of variable composition and thickness. Near Bluefield, West Virginia, it is rather pure and thick bedded, and apparently forms much the greater part of the Stones River, which is about 1,000 feet (305 meters) thick in all. In Lee County, in the southwest corner of Virginia, it is composed of thin and thick evenly bedded limestone, some of which is argillaceous and shaly, 200 feet (61 meters) thick. Some of this will be seen along the road southwest of Jonesville, Virginia. In places it includes thick layers of pure, compact, high-calcium limestone like the Mosheim next described. It usually yields on weathering much fossil-

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iferous blocky chert, which reveals its presence. At the bottom locally, immediately overlying mottled beds in the top of the Beekmantown, are a few layers, perhaps 10 to 20 feet (3 to 6 meters) in all, of thick-bedded argillaceous dolomite weathering dark gray and in places sprinkled through with generally small angular fragments of chert, suggesting a basal conglomerate in which the chert has been derived from the underlying Beekmantown.

The reasons for identifying this limestone as the Murfreesboro of the Nashville region are too complex to be stated here in full. The determination rests partly on its stratigraphic position and the fact that, among other fossils, it contains *Helicotoma tennesseensis*, which is common in the Murfreesboro of middle Tennessee.

Mosheim limestone (of early Chazy age).—The Mosheim is a thick-bedded compact light-gray fine-grained pure limestone, much sought for lime burning and cement manufacture. In places it carries many large gastropods. It generally ranges from a few feet to 50 feet (15 meters) in thickness but in places reaches 100 feet (30 meters). Commonly it is absent in this region.

Lenoir limestone.—The Lenoir is generally a granular crinoidal dark thick-bedded fossiliferous limestone containing chert in black nodules or thin platy layers. Over extensive areas it is largely composed of nodular limestone that weathers to characteristic loose irregular cobbles. *Maclurea magna* is common, and by means of this fossil the Lenoir is correlated with the Crown Point limestone (middle Chazy) of the Lake Champlain region. It ranges in thickness from 25 to 500 feet or more (7.6 to 152 meters), the maximum thickness being in the Knoxville region, Tennessee.

BLOUNT GROUP

The five formations of the Blount (pronounced blunt) group described below are present in the middle of the Ordovician system of Virginia and Tennessee as a thick intercalated series, which is entirely absent in Pennsylvania and Alabama. (See pl. 2.)

Holston marble.—The Holston is a thick-bedded, coarsely crystalline, bluish-gray marble, locally with sporadic reddish or pinkish layers in Virginia. In Tennessee, where it is largely red, it is commercially known as "Tennessee marble" and extensively used in building. In Virginia it has been called locally "Murat limestone." The northwesternmost belt of outcrop feathers out northeastward at Tazewell, Virginia; farther southeast it extends northeastward to Lexington, Virginia. The thickness ranges from a few feet to 250 feet (76 meters).

Whitesburg limestone.—The Whitesburg limestone is a generally coarse-grained, fragmental, nodular dark bluish-gray bed 20 to 70 feet (6 to 21 meters) thick in Virginia but reaching a thickness of perhaps 500 feet (152 meters) near Whitesburg, Tennessee, its type locality. It is highly fossiliferous, about 175 species of fossils having been identified from it. It is one of the few Ordovician formations in the Valley in which *Agnostus* occurs. It persists beneath the Athens shale from northern Virginia to Alabama.

Athens shale, Athens limestone.—The lower part of the Athens consists of black fissile graptolite-bearing shale; the upper part ranges from black compact, rather thin-bedded limestone with black shale partings that produce a characteristic banded structure to thick-bedded greenish arkosic coarse-grained sandstone with shale partings and beds carrying graptolites. In some localities, as at Harrisonburg, Virginia, nearly the whole thickness is black limestone; in other places it is shale and sandstone. The thickness ranges from a few hundred feet to 3,000 feet (914 meters) and, east of Bristol, possibly much more. The formation is nowhere present northwest of Clinch Mountain or in its line of strike northward. The Athens is characterized by the world-wide *Nemagraptus gracilis* graptolite fauna, by means of which it is correlated with the Normanskill shale of New York, the Glenkiln shale of Scotland, and part of the Llandeilian of England and Wales.

Tellico sandstone.—The Tellico consists of red sandstone and shale with some limestone and marble, part of which is red like the Holston. It is possibly 1,000 feet (305 meters) thick as a maximum in the Knoxville region of Tennessee. It does not occur in Virginia or farther north, although the coarse arkosic sandstone in the Athens has been in places incorrectly identified as Tellico.

Ottosee limestone.—The Ottosee consists of shale and thin irregularly layered to nodular dark-bluish crystalline, highly fossiliferous limestone, 500 feet (152 meters) thick in Virginia. It is not known north of the latitude of Tazewell. It appears to correspond to the basal part of the Sevier shale southeast of Knoxville, Tennessee.

BLACK RIVER GROUP

Lowville limestone, Moccasin limestone.—The Lowville and Moccasin formations are complementary facies of each other. The Lowville, which is present along the northwest side of the Appalachian Valley and Ridge province, is mainly a bluish limestone, perhaps 1,000 feet (305 meters) in maximum thickness. The Moccasin limestone occurs in the median belts southeast of the belts in which the Lowville occurs. The lower part of the

Moccasin is generally a gray limestone like the Lowville, but the upper and much thicker part of the typical Moccasin is marked by a preponderance of red argillaceous limestone weathering to a red mudrock. In much of the Moccasin area the gray limestone in the lower part includes layers of the red in varying proportions. These lower gray beds with the intercalated red layers carry the diagnostic Lowville fossils *Beatricea gracilis* and *Tetradium cellulosum*. In the red beds are scattered layers of blue limestone with *Tetradium cellulosum* and *Leperditella*.

Chambersburg limestone.—The Chambersburg is a moderately thick-bedded dark limestone like that in the upper part of the Athens, which, over large areas in northern Virginia, it immediately succeeds, owing to the absence of the Tellico, Ottosee, Lowville, and Moccasin. The Chambersburg is also marked by highly nodular layers like those of the Lenoir limestone. The Chambersburg in Pennsylvania as originally described by Stose and Ulrich included the Lowville, but subsequently the name was restricted by Ulrich to the upper or post-Lowville part of the mass, and Lowville limestone was applied to the lower part. Like the succeeding Martinsburg shale the Chambersburg limestone contains thin beds of volcanic ash or bentonite.

Martinsburg shale.—Gray shale with thin sandstone in the upper part and with thin-layered argillaceous dark limestone in the lower part, 1,500 to 2,000 feet (457 to 610 meters) thick and perhaps more in Massanutten Mountain, constitutes the Martinsburg shale. The basal 100 feet (30 meters) of the Martinsburg in southwestern Virginia carries one or more thin beds of altered volcanic ash (bentonite). At the top there is a persistent and very characteristic thick-bedded calcareous sandy rock full of phosphatic (?) pebbles, which weathers to brown friable sandstone usually about 50 feet (15 meters) thick. It carries many specimens of *Orthorhyncula linneyi*, *Byssonichia radiata*, and many other pelecypods. This bed has been recognized from central Pennsylvania south to the latitude of Morristown, Tennessee, where *Orthorhyncula* occurs near the summit of Clinch Mountain. It is one of the best horizon markers of the Appalachian Valley. The Martinsburg in the southeastern belts of the Valley, including the Massanutten Mountain syncline, has continuous outcrops through Maryland and Pennsylvania to the Hudson River Valley of New York.

The lower part of the Martinsburg, containing limestone beds, is of Trenton (Middle Ordovician) age; the upper, more purely clastic part, is Upper Ordovician, corresponding to the Lorraine of New York and to the Eden and Maysville groups of the Cincinnati region. The basal 500 feet (152 meters) or less of the shale

mapped as Martinsburg in the Massanutten syncline is of Athens age and older than true Martinsburg shale, though for convenience it is for the present included in the Martinsburg shale of that area.

A starfish provisionally referred to the genus *Cnemidactis*, recently discovered in the upper part of the Martinsburg, suggests correlation with the Drummock limestone of Scotland.

Limestone of Trenton age.—In the vicinity of Cumberland Gap and Big Stone Gap in southwestern Virginia, on the northwest side of the Valley, limestone 200 to 300 feet (61 to 91 meters) thick, corresponding to the Cannon and Catheys limestones of the Nashville dome in middle Tennessee, has been recognized directly beneath the Reedsville shale described below. It corresponds to the lower part of the Martinsburg shale on the southeast side of the Valley.

Reedsville shale.—Overlying the limestones of Trenton age in southwestern Virginia is 500 to 1,000 feet (152 to 305 meters) of shale of Martinsburg type which has been named the Reedsville shale. The Reedsville is the equivalent of the post-Trenton part of the Martinsburg.

Juniata formation.[2]—Red mudrock and fine-grained thick-bedded, usually reddish or brown sandstone 100 to 500 feet (30 to 152 meters) thick underlie the Clinch sandstone in Maryland and in most of Virginia except the extreme southwestern counties.

Sequatchie formation.[2]—In southwestern Virginia the shale beneath the Clinch includes thin fossiliferous impure limestones which increase in thickness southwestward, but it also includes red layers like those of the Juniata that in some localities form the major portion of the whole. It is equivalent to the Juniata but is given a separate name because of its different character. It is a greenish limy shale facies, transitional between the clastic Appalachian Valley facies (Juniata) and the largely limestone facies (Richmond) of the Ohio-Indiana region. The Sequatchie and Juniata correspond to the Queenston red shale of western New York and Ontario, which is the same as the lower part of the original Medina of New York.

SILURIAN

Clinch sandstone, Tuscarora quartzite.—A medium thick bedded to very massive hard gray sandstone or quartzite, with fine quartz conglomerate common in the base, is called Clinch sand-

[2] The United States Geological Survey and most other American geologists classify the Juniata and Sequatchie formations as Upper Ordovician, because they are of Richmond age, but the New York State Geological Survey and Ulrich include them, as well as the Richmond, in the Silurian.

stone in southern Virginia and Tennessee and Tuscarora quartzite in northern Virginia, Maryland, and Pennsylvania. Its thickness ranges from a few feet to perhaps 200 feet (61 meters). This formation is equivalent to the upper (white) Medina of New York. It is the main ridge maker of the Appalachian Valley and Ridge province, and Clinch Mountain is a typical example.

Clinton formation.—In Virginia the Clinton formation has three divisions. The lower division (Cacapon (cay'pon) sandstone member) is composed of shale and a hard, dense dark-red ferruginous vitreous sandstone, which is the distinguishing feature. In the extreme southwestern part of Virginia the lower part of the Clinton, probably corresponding to this member, contains workable beds of fossiliferous hematite. The middle division of the Clinton consists of shale overlain by well-bedded hard gray sandstone, which is an expansion of the Keefer sandstone of Pennsylvania and Maryland. In some places most of the middle part is sandstone. (See pl. 17.) The upper division of the Clinton is made up of soft fossiliferous shale and thin limestone correlated with the Rochester shale of New York.

In their maximum development, in the region from Clifton Forge to Monterey, Virginia, the lower division is 300 feet (91 meters) thick, the middle division 200 feet (61 meters), and the upper division 50 feet (15 meters). At the Maryland boundary the entire Clinton is not over 600 feet (183 meters) thick, and in most of Virginia it is generally much less. Near the south end of Walker Mountain, 15 miles (24 kilometers) west of Marion, the Clinch or Clinton or both have thinned to 18 feet (5.4 meters) and are underlain by Juniata and overlain by impure fossiliferous limestone and chert of Onondaga age.

Massanutten sandstone.—In the Massanutten Mountains is a sandstone 500 to 600 feet (152 to 183 meters) thick of the character of the Clinch sandstone and of the Keefer sandstone of the Clinton. It is thought likely that this sandstone corresponds to the combined Clinch and Clinton, like the Shawangunk (shon'gum) conglomerate of eastern Pennsylvania and New Jersey, so the name Massanutten sandstone, commonly used for this formation, is retained here.

CAYUGA GROUP

In Virginia the four formations of the Cayuga group as described below have been recognized only locally. In Maryland and farther north they are well developed and therefore will be described separately. They are known (in ascending order) as McKenzie formation, Bloomsburg shale, Wills Creek shale, and Tonoloway limestone. They are grouped as a unit on the accompanying route maps.

McKenzie formation.—In Maryland the McKenzie consists of thin-bedded gray crystalline limestone in gray shale. In Virginia, north of Monterey, and in Great North Mountain, west of Winchester, it is a bluish clay shale weathering yellow with thin layers of fossiliferous limestone containing abundant ostracodes (*Kloedenella*), the whole 75 feet (23 meters) thick.

Bloomsburg shale.—The Bloomsburg is a red shale, or, more accurately, red mudrock, and red sandstone, perhaps 100 feet (30 meters) thick in the Winchester region of Virginia and in northern West Virginia and Maryland. In Massanutten Mountain and in Little North Mountain and Great North Mountain west and southwest of Winchester, Virginia, it lies immediately above the Tuscarora quartzite except locally, where a thin bed of Clinton or McKenzie lies below it.

Wills Creek shale.—In Maryland the Wills Creek comprises soft light-gray calcareous papery shale and finely laminated impure limestone and cement rock. A few miles north of Monterey, Virginia, 30 feet (9 meters) of sandstone and 50 feet (15 meters) of shale just above the McKenzie may represent the Wills Creek. Similar sandstone with the same species of fossils occurs near Craig Healing Spring, southwest of Newcastle, Virginia, and indicates the extension of the Wills Creek to that locality. Northwest of Winchester it appears to be thicker.

Tonoloway limestone.—The Tonoloway is a thin-bedded to straticulate or even shaly dark limestone with ostracodes and brachiopods, 400 feet (122 meters) thick in Maryland and 200 feet (61 meters) in Virginia. It extends southwestward as far as Newcastle, Virginia, and probably also occurs throughout the Massanutten Mountain area.

DEVONIAN

Helderberg group.—In Virginia the Helderberg group is represented by dark-gray, somewhat fossiliferous limestone, with sandstone beds in the lower 300 feet (91 meters) in the Covington region of Bath and Alleghany Counties, southwestern Virginia; one of the sandstone beds is 100 feet (30 meters) thick. This lower part is equivalent to the Keyser limestone of Maryland and West Virginia and contains some of its characteristic fossils, such as *Chonetes jerseyensis* and *Cladopora rectilineata.* Above is limestone, in part fairly pure and in part argillaceous and cherty, 200 feet (61 meters) thick. This represents the Coeymans, New Scotland, and Becraft limestones of Maryland. The total thickness of the Helderberg in the Covington region is about 500 feet (152 meters). Farther southwest, from Pearisburg to Big Stone Gap, Virginia, the Helderberg is represented by the Becraft, which is very sandy and weathers to coarse friable

sandstone, locally bearing minable quantities of manganese ore. This member is fossiliferous, *Aspidocrinus* cf. *A. scutellum* type being fairly common, as in the Becraft limestone of New York. Owing to lithologic similarity the Becraft in Virginia has usually been identified as the Oriskany, which is the next overlying formation but which is generally absent where the sandstone facies of the Becraft occurs.

Oriskany group.—In Maryland the Oriskany has two divisions—the Ridgeley sandstone above and the Shriver chert below. The Shriver is a dark siliceous shale with chert nodules, 100 feet (30 meters) or so thick. It probably persists into Virginia near the Maryland boundary but has not been recognized as far south as Covington, Alleghany County. The Ridgeley is a thick-bedded calcareous, highly fossiliferous sandstone, weathering to coarse friable sandstone pitted with molds of large fossil shells. It is about 200 feet (61 meters) thick in the vicinity of Cumberland, Maryland, but thins to 50 feet (15 meters) or less in Alleghany County, Virginia. *Spirifer arenosus* and *Rensselaeria ovoides* are the common fossils.

Onondaga limestone.—In the extreme southwestern part of Virginia the Onondaga consists of mostly limestone and chert, 10 to 100 feet (3 to 30 meters) thick and is treated as a separate formation. Such characteristic Onondaga fossils as *Amphigenia elongata*, *A. curta*, and *Spirifer duodenaria* occur in it in that region. Farther north, however, in the Valley Ridges division of the Appalachian Valley and Ridge province, it is prevailingly a yellow or olive-green shale, 60 feet (18 meters) thick, overlying the Oriskany sandstone. This bed also carries a good representation of the Onondaga fauna. In these areas, however, it is included for mapping as the basal member of the Romney shale, as in the type locality of the Romney and throughout most of Virginia.

Romney shale.—The name Romney is applied to the entire mass of prevailingly black fissile shale lying between the Oriskany sandstone below and the Portage (Brallier) shale above. In its type locality, Romney, West Virginia, and in northern Virginia, generally it includes representatives of the following units named in ascending order: Onondaga shale, Marcellus shale, Hamilton formation, Genesee shale, and black or dark shale of basal Portage (Naples) age. In southern Virginia, where the Onondaga, being limestone, is excluded and the Hamilton has not been recognized, the term so-called Romney is used in this report for a large thickness of black shale occupying the approximate position of the Romney.

Portage group (*Brallier shale*).—The Brallier shale (upper part of the Portage group) is predominantly siliceous and argillaceous green shale with thin to moderately thick, very evenly surfaced, blocky-jointed layers of fine-grained greenish sandstone. The Brallier ranges in thickness from a few hundred to 4,000 feet (1,219 meters). It corresponds to the upper part of the Portage group of New York—that is, to the Gardeau shale and the Hatch shale and flags and possibly the Nunda sandstone, of the section at Portage, New York—and to the Brallier shale of central Pennsylvania. It is generally unfossiliferous but here and there yields a few specimens of the Portage fauna, such as *Buchiola*, *Paracardium*, and *Probeloceras*. It constitutes the lower part of the Jennings shale of Darton and others and of the Kimberling shale of Campbell.

Chemung formation.—The Brallier passes by imperceptible lithologic stages into the overlying Chemung formation, which is composed of greenish or bluish clay shale and mudrock with thick beds of sandstone. In some sections the upper part of the Chemung includes red beds, indicating transition to the overlying Catskill. The Chemung and Brallier are fairly distinct lithologically a moderate distance either below or above the boundary between them, which is fixed at the horizon at which the large fossils of the Chemung appear, such as *Ambocoelia umbonata*, *Spirifer disjunctus*, *Leiorhynchus mesacostale*, and species of *Productella* and *Leptodesma*. These fossils afford a criterion for the boundary which gives consistent results throughout the Appalachian Valley. The maximum thickness of the Chemung is possibly 2,000 feet (610 meters) in northern Virginia. Its thickness decreases constantly southward, and it thins out entirely in the southern part of the State, where it has not been recognized.

Catskill formation.—The Catskill is composed of red mudrock and red sandstone. It is as much as 2,000 feet (610 meters) thick in northern Virginia but like the Chemung thins out entirely southward and probably does not extend south of latitude 38°. It is nearly unfossiliferous.

CARBONIFEROUS[3]

MISSISSIPPIAN

Big Stone Gap shale.—A thick fissile to platy black shale overlies the Portage shale in southwestern Virginia, and the two have been mapped in many reports as Chattanooga shale. The scanty minute fossils are not clearly distinctive. The Big Stone Gap shale is regarded by most recent writers as lowermost Mississippian, but some geologists consider it uppermost Devonian.

Pocono and Price sandstones and New Providence formation.—The formation named Pocono sandstone in Maryland, Pennsylvania, and northern Virginia and Price sandstone in southern Virginia is mainly thick-bedded coarse sandstone and conglomerate in Maryland and northern Virginia, and similar sandstone with more or less shale in southern Virginia. It carries coal from central Pennsylvania south to the latitude of Abingdon, Virginia. In the region between Pulaski and Blacksburg, Virginia, the coal is of semianthracite grade and occurs in beds of minable thickness. The Price is 1,000 to 1,750 feet (305 to 533 meters) thick. In the southwestern counties of Virginia the equivalent rocks of different character have been called the New Providence formation, because they are equivalent to a Kentucky and Indiana formation of that name. The New Providence here consists of shale with thick layers of crumbly sandy shale and thin layers of sandstone, partly ferruginous. The Pocono and Price are mostly of fresh-water origin and nonfossiliferous; the New Providence is marine and fossiliferous and is equivalent to the lower part of the Osage group of the interior of the United States.

Maccrady shale.—Red mudrock and thick sandstone, 50 to 500 feet (15 to 152 meters) thick, make up the Maccrady shale, which is best developed in the vicinity of Blacksburg, Virginia, and possibly in Monroe County, West Virginia, bordering Virginia just north of the New River. A similar shale carries New Providence (early Osage) fossils at the south end of the Powell Mountain syncline, east of Big Stone Gap, Virginia, and is therefore of Osage age.

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[3] The United States Geological Survey adheres to the following classification:
Carboniferous system:
Permian series.
Pennsylvanian series.
Mississippian series.
Mr. Butts prefers to regard the Pennsylvanian and Mississippian as systems, which is the usage of the geological surveys of many of the States in which these rocks occur.

Fort Payne chert.—The Fort Payne formaton, partly equivalent to the Keokuk limestone of the interior, is apparently represented in the southern Appalachian region only at Cumberland Gap, at the southwestern extremity of Virginia, by about 15 feet (4.5 meters) of thin-bedded chert immediately overlying the New Providence formation and exposed on the road at the entrance to the gap.

Newman and Greenbrier limestones.—The Newman limestone of southwestern Virginia and the Greenbrier limestone of the belt passing through Bluefield, West Virginia, include the Warsaw, St. Louis, Ste. Genevieve, Gasper, and Cove Creek limestones. In parts of Virginia the subdivisions are separately mapped and will be described separately.

These groups of formations are not exactly equivalent, as shown in the table below.

Southwestern Virginia		Near Bluefield, W. Va.	
Pennington		Pennington.	
Newman	Glen Dean	Bluefield shale.	
	Gasper	Greenbrier	Gasper.
	Ste. Genevieve		Ste. Genevieve.
	St. Louis		St. Louis.
	Warsaw		Warsaw.
		Maccrady.	
Price		Price.	

Warsaw formation.—The Warsaw consists of shaly gray calcareous fossiliferous rock, with some calcareous sandstone and two thin beds of black fissile shale at top. It occurs in the syncline of Mississippian rocks next southeast of Clinch Mountain, from Saltville, Virginia, southwestward into northern Tennessee, and perhaps is thinly represented along the northwest belts, next to the coal fields, from Richlands, Virginia, to Bluefield, West Virginia. It is 600 feet (183 meters) thick at a maximum.

St. Louis limestone.—The St. Louis is mainly black cherty limestone with *Lithostrotion* and *Syringopora*, 300 feet (91 meters) in maximum thickness but as little as 10 feet (3 meters) thick in the northwestern belts next to the coal measures.

Ste. Genevieve limestone.—The Ste. Genevieve is a thick-bedded light-gray oolitic limestone about 100 feet (30 meters) thick along the northwestern margin of the Valley and Ridge province. It changes near Durbin, West Virginia (see pl. 1), to highly cross-bedded sandy limestone which continues northeastward into central and southwestern Pennsylvania, where it is known as the Loyalhanna ("Siliceous") limestone. In the deep syncline just southeast of Clinch Mountain very argillaceous limestone or calcareous shale, becoming shale on leaching, but with thick beds of gray fossiliferous crinoidal pure lime-

stone, some of which are slightly cross-bedded, and some beds of impure limestone full of nodular black chert, represents the Ste. Genevieve, as shown by the occurrence of its principal guide fossil, *Platycrinus penicillus* (*huntsvillae*). This fossil extends through 1,300 feet (396 meters) above the St. Louis limestone in the eastern syncline and gives at least that thickness to the Ste. Genevieve. This 1,300 feet is the lower part of about 2,379 feet (725 meters) of similar rock whose upper part corresponds to the Gasper limestone, next described.

Gasper limestone.—The Gasper is lithologically about the same as the Ste. Genevieve, both in the northwestern part of the Valley, where it is about 100 feet (30 meters) thick, and in the syncline southeast of Clinch Mountain, where it may be 1,100 feet (335 meters). *Talarocrinus* and *Pterotocrinus serratus*, characteristic Gasper fossils, occur in the upper part of this mass.

Cove Creek limestone.—Argillaceous limestone with white-weathering beds of purer fine-grained limestone, 1,100 feet (335 meters) thick, is called the Cove Creek limestone. It occurs in the syncline southeast of Clinch Mountain.

Bluefield shale.—The Bluefield is a calcareous fossiliferous shale, generally weathering yellowish but probably olive-green in fresh condition, 800 to 1,000 feet (244 to 305 meters) thick, developed in the Bluefield region, West Virginia. This probably corresponds partly to the Cove Creek limestone of the syncline southeast of Clinch Mountain and to the Glen Dean limestone of Lee and Wise Counties, Virginia.

Pennington formation, Hinton formation.—Red shale or mudrock, red sandstone, gray sandstone, and a small proportion of argillaceous limestone make up the Pennington formation in southwestern Virginia and the partly equivalent Hinton formation in west-central Virginia and West Virginia. The Hinton has a maximum thickness of 1,500 feet (457 meters) near Bluefield, West Virginia, and Tazewell, Virginia, but the partly equivalent Pennington formation is only 150 feet (46 meters) thick at Cumberland Gap. It is sparingly fossiliferous.

Princeton conglomerate.—The Princeton is rather coarse thick-bedded conglomeratic sandstone about 50 feet (15 meters) thick, especially well developed at Princeton, West Virginia, and of considerable areal extent in that region.

Bluestone formation.—The Bluestone, the uppermost formation of Mississippian age in Virginia, is mainly dark and gray sandstone with a small proportion of red shale in thin layers. It is about 450 feet (137 meters) thick west of Princeton, West Virginia. It will not be traversed on this excursion.

PENNSYLVANIAN ("COAL MEASURES")

All the Pennsylvanian rocks in Virginia belong to the oldest or Pottsville group represented in the anthracite coal fields of eastern Pennsylvania. The oldest division of this group in Virginia, the Lee formation or sandstone, carries the celebrated Pocahontas "smokeless" coals in an extensive area southwest of Bluefield, West Virginia, not traversed on this excursion. Overlying the Pottsville group in western Pennsylvania, Ohio, and West Virginia are the Pennsylvanian rocks of the Allegheny formation, coal bearing, 300 feet (91 meters) thick; Conemaugh formation, with little coal, 600 feet (182 meters) thick; and Monongahela formation, coal bearing, with the celebrated Pittsburgh coal bed at the base, 250 feet (76 meters) thick.

PERMIAN

Dunkard group.—Overlying the Monongahela formation in an oval area in West Virginia and Ohio, crossed by the Ohio River, is the Dunkard group, of Permian age, composed of shale, partly red, and sandstone, with thin coal beds. Its thickness is about 1,500 feet (457 meters). The Dunkard is the youngest Paleozoic deposit of the United States east of the Mississippi River.

ITINERARY

WASHINGTON TO CUMBERLAND, MARYLAND

Washington is in the valley of the Potomac, and at the city the river is at sea level. The road rises rapidly out of the lowland along the river to the Piedmont upland, at an altitude of about 400 feet (122 meters), into which the gorge of the Potomac is cut. This upland is covered in places by an outwash deposit of gravel and sand spread by the Potomac when the river flowed at this level, probably in Pliocene time. The upland is an old peneplain of probably late Tertiary age which bevels pre-Cambrian crystalline rocks of various kinds.

From Washington to Gaithersburg these rocks are the Wissahickon mica schist intruded by granitic and basic rocks, with thin basic lava flows north of Rockville, but the weathering is so deep on the upland that their character can not be readily distinguished. Northwest of Gaithersburg nearly to the Frederick Valley the pre-Cambrian schist is chiefly a phyllite mylonite (or phyllonite), indicating that an overthrust is being approached. This rock weathers to thin blue and green slaty fragments.

As the route approaches Hyattstown (see pl. 3) Sugarloaf Mountain [1][4] rises on the left above the upland as an elongated hill which, viewed from the north near Urbana, looks more like a single peak. As seen from the south it has a conical form, hence the name. It is composed of lower Cambrian quartzite (Weverton) inclosed in a tightly compressed overturned syncline. From a point 1 mile (1.6 kilometers) northwest of Hyattstown to a point 2 miles (3.2 kilometers) northwest of Urbana, Lower Cambrian slate and quartzite (Loudoun formation) lie in a syncline on the pre-Cambrian rocks, and the higher Weverton quartzite of Sugarloaf Mountain is in the center of this syncline. (See fig. 2.) The pre-Cambrian schists carrying this syncline of Cambrian rocks have been thrust westward on the Martic overthrust onto the Cambrian Harpers phyllite and Antietam quartzite, which lie east of the Frederick Valley syncline. (See fig. 2.) The Cambrian and pre-Cambrian rocks are so similar, however, that the fault can be distinguished only with difficulty.

The Frederick Valley is a lowland in the Piedmont province, a synclinal valley underlain by Ordovician (Frederick and Beekmantown) limestones. The Frederick is a thin-bedded platy limestone extensively used in stone fences along the roads. It contains a few fossils of Lower Ordovician (probably Chazy) age. It overlies the Beekmantown limestone (also Lower Ordovician), which is extensively quarried in the Frederick Valley for lime, and on the margins of the syncline it unconformably overlaps the Antietam quartzite. This overlapping is well shown at the small anticlines of Antietam forming a line of hills [2] at the east side of the valley. (See pl. 3.)

North of Frederick Triassic rocks many thousand feet thick overlie these older rocks unconformably. They consist largely of red sandstone and shale, which dip gently northwest, having been tilted by post-Triassic faulting. Northwest of Frederick, where the Triassic rocks have been entirely eroded, the limestone floor extends to the normal fault that bounds the lowland on the west.

West and south of Frederick to the Potomac River (see pl. 4) a band of Triassic rocks 2 miles (3.2 kilometers) wide is preserved on the down-faulted block.

[3] At the base of the Triassic is a coarse limestone conglomerate (not seen along the route) representing a fanglomerate deposited at the foot of Catoctin Mountain, on the west, which during part of Triassic time was still covered by Paleozoic limestones.

[4] Numbers in brackets correspond to locality numbers shown on route map.

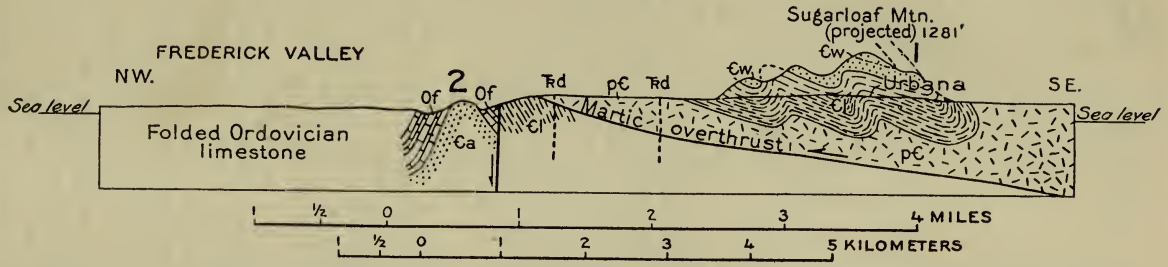

FIGURE 2.—Sketch section from Frederick Valley to Sugarloaf Mountain, Maryland. Shows pre-Cambrian rocks with a syncline of Cambrian quartzite forming Sugarloaf Mountain [1] of the Martic overthrust block overriding Cambrian rocks and an anticline of Antietam quartzite [2] beneath Frederick limestone in the Frederick Valley

Triassic	Trd	Diabase dike.
Ordovician	Of	Frederick limestone.
		Unconformity.
Cambrian	Ca	Antietam quartzite and Harpers phyllite.
	Cw	Weverton quartzite.
	Cl	Loudoun formation (quartzite and sandy phyllite).
Pre-Cambrian	pC	Slate and schist.

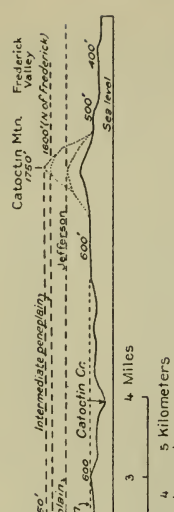

FIGURE 3.—Generalized profile from Cumberland Valley to Frederick Valley, Maryland. Shows the Kittatinny peneplain at about 1,750 feet (533 meters), the Harrisburg partial peneplain at 600 feet (183 meters), and younger river terraces at 500 and 400 feet (152 and 122 meters)

In the Frederick Valley and in other intermontane valleys several peneplaned surfaces are observable. The floor of the Frederick Valley has a general altitude of 400 feet (122 meters), representing an old partial peneplain which was cut across Ordovician limestones and Triassic sandstone and into which the stream gorges have been incised. At the foot of Catoctin Mountain along the west side of the valley is a noticeable bench at about 500 feet (152 meters), which is covered by outwash gravel at the mouths of mountain gorges north of Frederick. The floor of the Middletown Valley, west of Catoctin Mountain, has a general level of 600 feet (183 meters), and the greenstone that crops out on this floor is everywhere deeply decayed. Just west of Harpers Ferry, at the edge of the Cumberland Valley, a flat bench at 500 feet (152 meters) is preserved along the Shenandoah River beside the excursion route, and the 600-foot (183-meter) level is preserved on top of Bolivar Heights and other low ridges.

These level surfaces represent partial peneplains which can be recognized throughout the region. (See fig. 3.) The 600-foot (183-meter) level, which forms the floor of the Middletown and other valleys, is called the Harrisburg peneplain and is probably equivalent to the Bryn Mawr terrace and gravel, of Pliocene age, on high benches in eastern Pennsylvania and Maryland. The 500-foot (152-meter) level is mainly a terrace bordering the streams and is mantled at many places near the Potomac with river gravel which is probably equivalent to the Brandywine gravel in eastern Maryland, of early Pleistocene age. Other lower gravel-covered terraces along the river and its tributaries and the 400-foot (122-meter)

plain in the Frederick Valley are partial peneplains of later Pleistocene age.

There is also evidence in the region of higher and older peneplains that are very much dissected. The general level top of Catoctin Mountain west of Frederick, at an altitude of about 1,200 to 1,400 feet (366 to 427 meters) and that of South Mountain at the river, at 1,250 feet (381 meters), represent an intermediate peneplain called the Weverton, supposed to be of early Tertiary age. The higher level tops of the Blue Ridge, at about 1,600 feet (488 meters), and of Catoctin Mountain north of Frederick, where it rises abruptly to 1,600 feet, represent a still higher intermediate peneplain. The highest level on Catoctin and South Mountain ranges from 1,750 feet (533 meters) north of Frederick to 2,000 feet (610 meters) in northern Maryland and Pennsylvania, and this is called the Kittatinny (Schooley) peneplain and is supposed to be of early Cretaceous age.

The Blue Ridge-Catoctin Mountain anticlinorium lies west of the Frederick Valley and of the belt of Triassic rocks. This great arch of older rocks separates the Piedmont province from the Great Appalachian Valley or Cumberland Valley. (See fig. 4.)

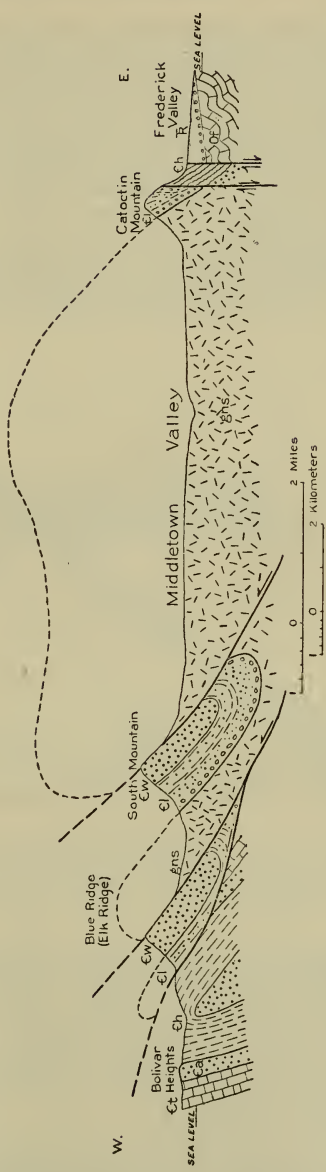

FIGURE 4.—Section of Blue Ridge-Catoctin Mountain anticlinorium. Ŧr, Triassic sandstone; Of, Frederick limestone; €t, Tomstown dolomite; €a, Antietam quartzite; €h, Harpers phyllite; €w, Weverton quartzite; €l, Loudoun formation; gns, pre-Cambrian greenstone

[4] The east side of the anticlinorium is marked by the post-Triassic normal fault already mentioned, by which the Paleozoic limestone and Triassic rocks of the Frederick Valley have been dropped down 6,000 feet (1,829 meters) or more. The pre-Cambrian basement of the anticlinorium in Maryland is composed of altered rhyolite and basalt flows intruded by granite. The rhyolite is not exposed along the route of the excursion. The basalt is largely greenstone schist but in places is distinctly amygdaloidal.

The basal Cambrian Loudoun formation (slate and quartzite) and Weverton quartzite occur in three synclines in the anti-

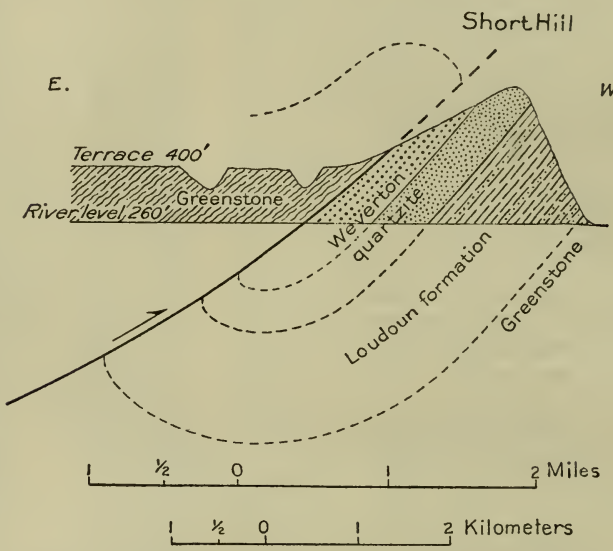

FIGURE 5.—Sketch section of Short Hill (South Mountain), south of Potomac River, as seen from the north side of the river

clinorium, and these harder rocks form linear ridges. All these synclines are tightly folded and overturned to the northwest, their east limbs are broken, and pre-Cambrian greenstone is thrust over the Weverton quartzite. (See fig. 4.)

[5] Catoctin Mountain, which is crossed in the gap east of Jefferson, is formed of the Loudoun formation in the eastern syncline. (See fig. 4.)

[6] South Mountain, cut through by the Potomac River at Weverton, is formed of Weverton and Loudoun quartzite in the central syncline. Its short extension into Virginia is called Short Hill. (See fig. 5.)

[7] The western syncline forms the Blue Ridge, in Maryland locally called Elk Ridge, cut through by the Potomac River just east of Harpers Ferry. The massive white quartzite of the upper Weverton in the syncline is locally overturned toward the southeast in a flat-lying recumbent fold, as is well shown in the river cliffs above the road along the north bank, at the point marked 7 in Plate 4.

[8] The dark quartzite of the underlying Loudoun, which forms the western part of the river cliff to the railroad bridge over the Potomac River, is overthrust westward onto the Harpers quartzose phyllite (Lower Cambrian), just north of the bridge.

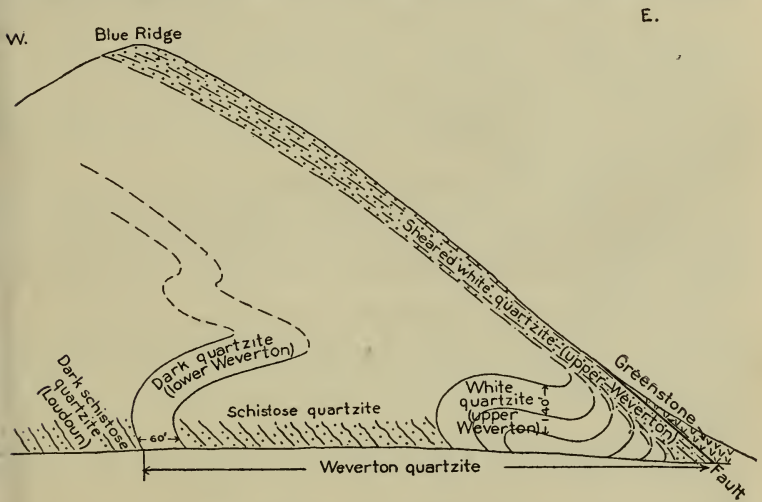

FIGURE 6.—Sketch section of Blue Ridge (Elk Ridge locally) east of Harpers Ferry, West Virginia, showing pre-Cambrian greenstone thrust over tightly folded upper Weverton quartzite

The fault, which at this point might seem to be only a slight break, really has great horizontal movement, as is shown 10 miles (16 kilometers) to the north, 2 miles (3.2 kilometers) southeast of Keedysville, where the fault passes around the north end of Elk Ridge, composed of Weverton quartzite. (See pl. 5.) The fault plane is nearly horizontal at Rohrersville, where it cuts across the Pleasant Valley anticline and the Elk Ridge syncline to the west slope of Elk Ridge. The Harpers quartzose phyllite, which is overridden by this thrust fault at the Potomac Gap, is the core of another anticline which at Keedysville plunges north under the limestone of Hagerstown Valley.

Picturesque and historic Harpers Ferry, some of whose passageways are steps carved out of Harpers phyllite, lies at the junction of the Shenandoah and Potomac Rivers, just west of the Blue Ridge gap. The gap is narrow and rocky, and the quartzite that makes the summit of the Blue Ridge is exposed in high rocky cliffs on both sides of the Potomac River. (See Guidebook 7, pl. 1.)

[9] From the heights in the town a fine view of the gap in the Blue Ridge can be had. The Potomac River once flowed on a land surface that stood above the present tops of the mountains, and as the land rose the river cut down across the hard rocks and made the rocky gap through the ridge. Remnants of some of the lower stages of downcutting of the river are preserved in the terraces along the stream. The 500-foot (152-meter) level on which the river once flowed is well preserved at the point of view on the heights of Harpers Ferry between the Shenandoah and Potomac, and other remnants of this bench can be seen down the river through the gap.

[10] At Bolivar Heights, west of Harpers Ferry, the Antietam quartzite, which overlies the Harpers, makes a low foothill. It dips steeply east, being overturned, and passes beneath the overturned Tomstown dolomite of the Cumberland Valley in normal rising sequence.

[11] At Halltown, West Virginia, the Tomstown dolomite is succeeded by purplish sandstone and shale of the Waynesboro formation, and these beds are followed by the yellow earthy-weathering Elbrook limestone. Both formations are of Cambrian age.

From Charlestown, West Virginia, to Hagerstown, Maryland, the route follows the strike of the rocks, and no route map is given.

[12] Hagerstown, Maryland, is built on the limestones of the Beekmantown group, and the siliceous edgewise conglomerates of the Stonehenge member make hills and are exposed in road cuts in the city, and the rock is extensively used as building stone in retaining walls. West of Hagerstown the limestones are closely folded and beds are repeated many times across the wide flat valley, called the Cumberland Valley in Pennsylvania and Maryland and the Shenandoah Valley in Virginia. The deeper synclines in the center of the valley inclose higher Ordovician limestone and the Martinsburg shale, of Middle and Upper Ordovician age. (See pl. 6.)

[13] At Wilson, where the road crosses Conococheague Creek (see pl. 6), the upper highly fossiliferous platy beds of the Chambersburg limestone (Middle Ordovician) are well exposed in vertical position on the west limb of a deep syncline that incloses

Martinsburg shale. This is the Massanutten syncline, which to the south in Virginia deepens and incloses Silurian rocks that form Massanutten Mountain, which will be seen on later days.

The large meanders of Conococheague Creek, deeply incised in the Martinsburg shale in this syncline, were developed on the valley-floor peneplain (altitude 560 feet or 171 meters), probably in Pliocene time.

[14] A low hill of Martinsburg shale marks another deep syncline in the limestone valley.

[15] South of Clear Spring, near the west side of the valley, the Conococheague limestone, of Upper Cambrian age (part of the proposed Ozarkian system of Ulrich), is characterized by remarkable reefs of algal growth (*Cryptozoon*). (See pl. 7, *A*.)

[16] At the west edge of the Cumberland Valley Cambrian limestones, as low as the Waynesboro formation, rise to the surface on an anticline that is overthrust on the Tuscarora sandstone (basal Silurian), which forms Little North Mountain. The fault splits, and at the road followed by the excursion only a small wedge of Martinsburg shale lies between Waynesboro limestone (Cambrian) and the Clinton formation (Silurian), and the Clinton in turn is overthrust on the Oriskany sandstone and Romney shale (Devonian) in the syncline beyond. (See fig. 7.)

Little North Mountain is the first ridge of the western division of the Valley and Ridge province, which is characterized by high parallel ridges and mountains. To the north in Pennsylvania, where there is no break in the fold, this ridge is a high continuous barrier, but from Maryland southward into Virginia it is a low ridge broken by many gaps where the resistant Tuscarora sandstone is greatly thinned and weakened or is entirely absent at the surface as a result of intense squeezing and overthrusting.

[17] Fairview Mountain, a high anticline of Tuscarora sandstone to the north, plunges southward so that the road passes over its low south end. West of this mountain the late Silurian and Lower Devonian rocks are exposed, and around Indian Springs nearly flat-lying Oriskany sandstone in a gentle syncline makes low ridges, the slopes of which are strewn with porous sandstone blocks pitted with large fossil molds.

[18] Fossils are numerous here in the Marcellus and Hamilton shales, and good collections of *Spirifer*, *Phacops*, and other forms can be obtained.

[19] At Parkhead a hard conglomeratic sandstone in the Chemung makes a ridge on the east limb of a syncline which deepens to the south, inclosing red Catskill formation across the river, and in the distance may be seen the Meadow Branch Mountains, composed of hard Carboniferous sandstones in this syncline. This is the easternmost occurrence of Carboniferous rocks in this

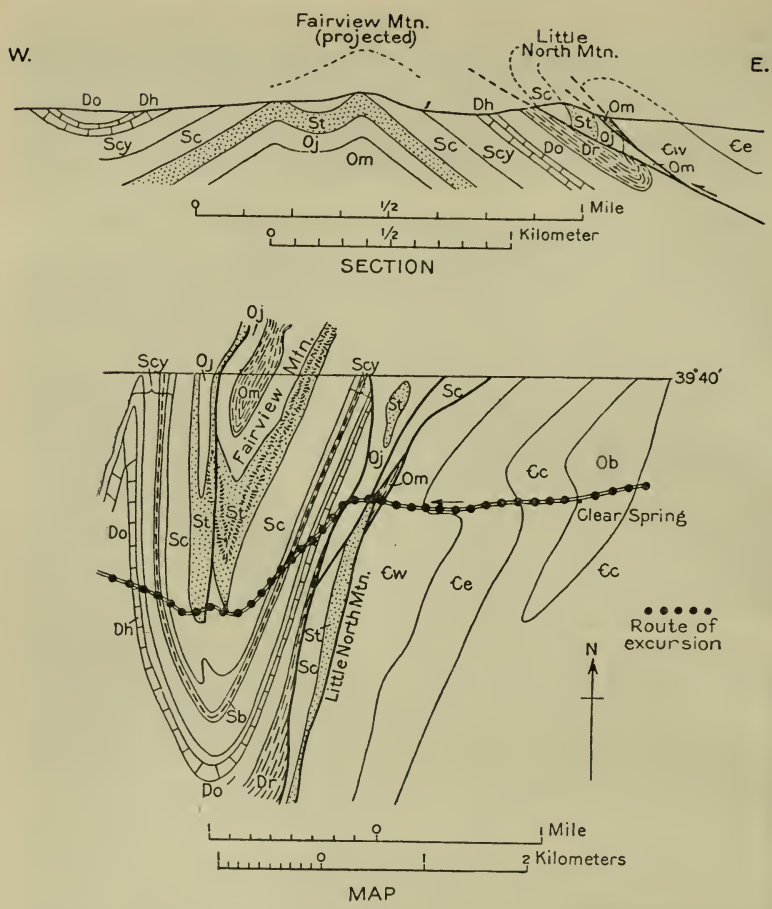

FIGURE 7.—Detailed geologic map and structure section of Fairview Mountain and Little North Mountain, showing the overthrust split into several faults, and the southward plunge of Fairview Mountain anticline

Devonian	Dr	Romney shale.
	Do	Oriskany sandstone.
	Dh	Helderberg limestone.
Silurian	Scy	Cayuga formation.
	Sb	Bloomsburg red member of Cayuga.
	Sc	Clinton formation.
	St	Tuscarora sandstone.
Ordovician	Oj	Juniata formation.
	Om	Martinsburg shale.
	Ob	Beekmantown limestone.
Cambrian	Cc	Conococheague limestone.
	Ce	Elbrook limestone.
	Cw	Waynesboro shale.

region. They carry thin beds of low-volatile coal similar to that in the anthracite basin of southeastern Pennsylvania, with which they are in trend.

[20] An anticline in the Devonian shale rises to the north, and Keefer Mountain, in the distance, is composed of the Tuscarora sandstone brought up by the anticline.

[21] Red beds of the Catskill formation, at the top of the Devonian, are inclosed in a syncline.

At Hancock the excursion party turns south across the Potomac River on a side trip to Berkeley Springs and Cacapon Mountain. The road to Berkeley Springs follows a valley cut in Romney shale, of Onondaga, Marcellus, and Hamilton age.

[22] The Oriskany sandstone in this region is nearly pure silica and is extensively quarried and mined at and near Berkeley Springs for glass sand. Many molds and internal casts of large shells mark its weathered surface, and crinoid heads are occasionally found at the quarries.

The spring water at Berkeley Springs, which has a temperature of 73°, issues from the Oriskany sandstone at its contact with the overlying Romney shale, its high temperature being due apparently to the depth in the syncline from which circulating water has risen.

[23] At Sir Johns Run characteristically even-bedded Keefer sandstone at the top of the Clinton makes prominent ledges dipping 40° E. on the east limb of the Cacapon Mountain anticline.

[24] Cacapon Mountain, west of Berkeley Springs, is composed of Tuscarora sandstone (basal Silurian) exposed in a northward-plunging anticline. The mountain rises to considerable prominence to the south and disappears abruptly to the north. (See pl. 6.) From the top of Cacapon Mountain a grand view to the west is had of the gap cut by the Potomac River in Sideling Hill, which represents the second syncline in which the Carboniferous rocks are inclosed. (See pl. 8.) Remnants of the valley-floor peneplain (Harrisburg), which is here about 900 feet (274 meters) in altitude, cut on the harder sandstones of the Upper Devonian, can be seen in the distance on each side of the gap. Just below the viewpoint on Cacapon Mountain are the noted Fluted Rocks (see pl. 9), composed of closely and angularly folded Keefer sandstone, the top member of the Clinton, exposed in the bluff of the Great Cacapon River.

From this point the party returns to Hancock.

West of Hancock the Helderberg limestone (basal Devonian) and limestone and shale of the Cayuga (Silurian) are exposed in the Cacapon Mountain anticline. (See profile section, pl. 10.)

[25] A dry red mudrock (Bloomsburg), equivalent to part of the salt-bearing Salina formation of New York, makes conspicuous fluted outcrops in the axis of this anticline.

The first ridge (Tonoloway) to be crossed west of Hancock (see pl. 10) is composed of Oriskany sandstone dipping steeply west on the limb of the Cacapon Mountain anticline. Beyond Tonoloway Ridge higher Devonian beds follow in generally rising sequence but with minor folding. A great thickness of unfossiliferous uppermost Devonian red sandstone (Catskill) is capped by Carboniferous sandstone in the axis of a syncline [26] on the next high ridge (Sideling Hill). Thin coal beds have been prospected in these Carboniferous rocks.

[27] The next high mountain to be crossed is Town Hill, another syncline of Carboniferous sandstone with wide exposures of red Catskill sandstone on its sides. This syncline and the Sideling Hill syncline deepen northward and unite into the Broad Top coal field in Pennsylvanian rocks in southern Pennsylvania.

[28] Green Ridge is a high, sharp, straight ridge composed of a bed of hard conglomeratic sandstone in the Chemung on the west limb of the Town Hill syncline.

The next mountain crossed is Polish Mountain, a shallower syncline capped by hard beds in the Chemung. At Flintstone the road passes through a stream gap in Iron Ore Ridge, composed of Oriskany and Helderberg beds dipping east into the Polish Mountain-Ragged Mountain syncline. Between this ridge and Martin Mountain, to the west, is a plunging anticline which exposes Clinton along the road but which rises to the north so that the underlying Tuscarora sandstone makes the massive Tussey Mountain, in Pennsylvania. Martin Mountain, the next to be crossed, is another shallow syncline, capped by Oriskany sandstone. In the next valley early Silurian rocks are again exposed in a plunging anticline which rises to the north as Evitts Mountain, composed of Tuscarora sandstone.

Cumberland is on the west limb of a syncline of Lower Devonian shales, and Shriver Ridge, composed of Oriskany sandstone and Helderberg limestone, is cut through by Wills Creek at the town.

[29] A mile west of Cumberland Wills Creek cuts a rocky gorge through Wills Mountain, an anticlinal ridge of Tuscarora sandstone, which makes an imposing rock arch.

[30] At Corriganville, 2 miles (3.2 kilometers) northwest, the vertical ledges of Oriskany sandstone and cherty Helderberg limestone on the west limb of the Wills Mountain anticline are called the Devils Backbone.

[31] To the west the steep escarpment of the Allegheny Front, the eastern edge of the Allegheny Plateau, rises as a great wall capped by Pottsville conglomerate, the base of the Pennsylvanian "Coal Measures."

Frostburg, on the summit of the plateau, lies at the north edge of the Georges Creek bituminous coal field, and in the hills to the

A. SIDELING HILL GAP, POTOMAC RIVER

Looking west from Cacapon Mountain. Gap in the distance; Tonoloway Ridge on the right. Several river terraces shown on both sides of the river.

B. NEAR VIEW OF 900-FOOT RIVER TERRACE AT FOOT OF SIDELING HILL

Sideling Hill gap in the distance. The terrace is the remnant of the Harrisburg peneplain.

FLUTED ROCKS, ON GREAT CACAPON RIVER

Keefer sandstone member at top of Clinton formation.

north fire clay associated with some of the coal beds is extensively mined.

CUMBERLAND, MARYLAND, TO WINCHESTER, VIRGINIA

As the stretch from Cumberland to New Creek is along the strike of formations, no route map is given. From Cumberland to Keyser the road follows the Potomac Valley. On the southeast (left) is Knobly Mountain, the northern part of which is monoclinal and is composed of Lower Devonian strata on the east flank of the Wills Mountain anticline. At Cresaptown the plunging end of Tuscarora sandstone on the axis of this anticline is crossed. From Pinto, altitude 650 feet (198 meters), to Dans Rock, at the top of the Allegheny Plateau to the west, altitude 2,882 feet (878 meters), is exposed a complete section from the Helderberg limestone, at the base of the Devonian, to the Pottsville formation, at the base of the Pennsylvanian. Knobly Mountain, south of Pinto, is a symmetrical anticline of Lower Devonian rocks, the southward extension of the Wills Mountain anticline. Fort Hill, on the left, is a monoclinal ridge of Oriskany sandstone and Helderberg limestone on the west flank of a small anticline cut through by the river.

At Keyser turn east three-quarters of a mile (1.2 kilometers) to a quarry in Lower Devonian (Helderberg) limestone. The section is fully exposed from the Tonoloway limestone, the top formation of the Silurian, to the Ridgely sandstone, the top of the Oriskany. The section here as given by Swartz is as follows:

Section at quarry east of Keyser, West Virginia [5]

	Feet	Meters
Devonian:		
Oriskany sandstone—		
Ridgeley member	210	64
Shriver member	67	20
Helderberg limestone—		
New Scotland member	43	13
Coeymans member	10	3
Keyser member	281	86
Silurian: Tonoloway limestone.		

The boundary between the Keyser and Tonoloway, and therefore between the Silurian and Devonian, is not easily located, but the base of the Keyser is marked by an assemblage of brachiopods not common in the Tonoloway, which consists of laminated dark limestone with *Leperditia alta* common and generally the only fossil in the top layers.

Continuing southwest along New Creek to New Creek Village the road is close to the top of the Oriskany sandstone, which can be seen dipping steeply off New Creek Mountain, to the left.

[5] Swartz, C. K., Maryland Geol. Survey, Lower Devonian, p. 167, 1913.

The route from New Creek, West Virginia, to Winchester, Virginia (see pl. 11), passes through a gap in New Creek Mountain, where the nearly vertical beds of the Oriskany, Helderberg, and Cayuga are well shown. A short distance beyond, a belt of Clinton, about 1 mile (1.6 kilometers) wide, at the axis of the Wills Mountain anticline, is crossed. Southeast of this belt of Silurian the road is on Devonian rocks to Hanging Rock, West Virginia. This is a region of open folds without faults.

Three miles (4.8 kilometers) west of Romney the road passes through Mill Creek Mountain, an anticlinal ridge of Oriskany sandstone with a core of Helderberg limestone. The slopes of this mountain in the vicinity of Romney are devoted to apple culture, and several large orchards are to be seen from the town. The black shale on the flanks of the anticline has recently been drilled for petroleum without success.

The uppermost formation of the Devonian, the Catskill, composed of red shale and sandstone and yielding a very red soil, crops out in two broad synclinal belts east of Romney. At Pleasantdale the axis of the Sideling Hill syncline is crossed, and several miles southwest of that place may be seen the ends of two ridges formed by Pocono sandstone, the base of the Carboniferous. The Pocono carries poor coal beds here.

Between Hanging Rock and Loom the road crosses obliquely an anticline of Silurian rocks, exposing the upper part of the Clinton at the axis. From Loom nearly to the Virginia State line the road is on Helderberg limestone, Oriskany sandstone, and black Devonian shale in a sucession of broad anticlines and synclines. The State line is on the Chemung formation. From the State line to Gore, Virginia, the road is on a broad, deep syncline inclosing a wide belt of red Catskill rocks. (See pl. 12.) Its axis is near Parishville. The total thickness of Devonian here is at least 5,000 feet (1,524 meters).

About 1½ miles (2.4 kilometers) east of Gore the road passes over the end of a northward-plunging anticline. The Tuscarora quartzite in this anticline forms Great North Mountain, and the Oriskany sandstone makes low flanking ridges on each side. Capon Springs, 12 miles (19 kilometers) southwest of Gore, Rock Enon Springs, 5 miles (8 kilometers) southwest of Gore, and many other springs issue from the Oriskany on the flanks of the fold. Owing to the northeast pitch of the Great North Mountain anticline the Tuscarora does not crop out on the highway, the lowest formations exposed there being yellow shale with abundant *Kloedenella* at the top of the McKenzie formation, and the Bloomsburg formation, red shale and sandstone, both of lower Cayuga (Silurian) age. The red Bloomsburg is conspicuously exposed in two distinct anticlines, the crest of

the western one, a very symmetrical arch, giving a fine exposure of the Bloomsburg just to the left of the road at the point indicated as the axis on the map.

East of the Great North Mountain anticline the rocks dip southeast into a syncline of Catskill red rocks, the axis of which is about midway between Hogue Creek and Chambersville.

At Chambersville the Cayuga rocks, mainly Bloomsburg, emerge on the east side of the syncline and in the gap of Little North Mountain. At that place they are nearly in contact with the Martinsburg shale on the southeast through the absence of the McKenzie and Clinton and the local thinness of the Tuscarora. *Cryptolithus*, a characteristic Trenton or Eden trilobite, occurs only a short distance east of red Bloomsburg rock. There is no evidence of beds of Maysville age, and it is probable that there is a small fault bringing the beds of Eden age into contact with the Tuscarora and nearly cutting that formation out entirely. Tuscarora quartzite, which forms Little North Mountain both to the north and to the south, is only 2 or 3 feet (0.6 to 0.9 meter) thick in the road cut in the gap, but is about 50 feet (15 meters) thick on the slope a few hundred feet above the road on the left.

About one-third of a mile (0.5 kilometer) southeast of Chambersville is the great fault that extends for miles along the southeast foot of Little North Mountain, whereby the Elbrook limestone is overthrust onto Martinsburg shale or, locally at least, onto still younger formations.

The Conococheague limestone is fairly well exposed between Chambersville and Winchester in an outcrop about 3 miles (4.8 kilometers) wide. Its characteristic crinkled clayey laminations, which weather in relief, and layers of sandstone, which are another characteristic feature from Pennsylvania to Tennessee, are well shown in a number of road cuts. The great width of the outcrop of the Conococheague limestone between Chambersville and Winchester, with general dip steeply to the southeast, implies either a series of thrust faults or closely compressed overturned folds. Reversal of dip was observed in two belts on the northwest side of the area. The occurrence of several sandstone beds of very similar character in some of the low road cuts suggests that these are the same beds repeated by faulting.

The main part of the city of Winchester is located on Beekmantown limestone, which is not exposed near the route of travel. The Mosheim limestone, next above the Beekmantown, and the Chambersburg limestone and its contact with the overlying Martinsburg shale are well exposed on Abrams Creek in the eastern environs of the town.

Formations between New Creek, West Virginia, and Harrisonburg, Virginia

System	Series	Group	New Creek to Winchester			Winchester to Harrisonburg, including Massanutten Mountain			
			Formation	Thickness		Formation		Thickness	
				Feet	Meters			Feet	Meters
Carboniferous.	Mississippian.		Pocono [a]	1,000	305				
Devonian.	Upper Dev.		Catskill	2,000	610				
			Chemung	2,500	762				
		Portage.	Brallier	1,750	533				
			Lower Portage.						
		Romney.	Genesee?.						
	Middle Dev.		Hamilton	1,000	395	Hamilton	Romney.	1,000 ±	305 ±
			Marcellus	250	76	Marcellus		500 ±	152 ±
			Onondaga	100	30	Onondaga		100 ±	30 ±
	Lower Dev.		Oriskany	200	61	Oriskany		25 ±	78 ±
		Helderberg.	Becraft. New Scotland. Coeymans. Keyser.	133–600	41–183	Helderberg represented		50 ±	15 ±

Silurian.		Cayuga.	Tonoloway	300	91	Tonoloway	100±	30±
			Wills Creek	400	122	*Wills Creek.*		
			Bloomsburg	200	61	Bloomsburg	300±	91±
			McKenzie	150	46	*McKenzie?.*		
		Niagara.	*Lockport.*			*Lockport.*		
			Clinton	600±	183	Massanutten sandstone. Clinton?	600	183
			Tuscarora	400	122	Massanutten sandstone. Tuscarora.		
Ordovician.			Juniata [b]	500	152	*Juniata.*		
			Oswego?	400	122	*Oswego.*		
			Martinsburg	2,000	610	Martinsburg	3,500	1,067
			Chambersburg	250	76	Chambersburg	250	76
			Lowville.			*Lowville.*		
		Blount.	*Ottossee.*			Ottosee.		
			Tellico.			*Tellico.*		
			Athens.			Athens	10–1,000	3–305
			Whitesburg.			Whitesburg	5–50	1–15
			Holston.			*Holston.*		
		Stones River.	Lenoir	50	15	Lenoir	50–100	15–30
			Mosheim	50	15	Mosheim	50	15
			Murfreesboro.			*Murfreesboro.*		

[a] Mississippian system of many authors.
[b] Ulrich, Butts, and Stose regard this as Silurian.

NOTE.—Formations that are absent are printed in italics.

Formations between New Creek, West Virginia, and Harrisonburg, Virginia—Continued

System	Series	Group	New Creek to Winchester			Winchester to Harrisonburg, including Massanutten Mountain		
			Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters
Ordovician.			*Jasper* (Arkansas)	50	15	Hiatus.		
			Joachim (Arkansas)	90	27			
			St. Peter (Arkansas)	150	46			
			Everton (Arkansas)	100	30			
	(c)	Beekmantown.	Post-Nittany	1,500	457	Post-Nittany	1,500	457
			Nittany	500	152	Nittany	500±	152±
			Stonehenge	100	30	Stonehenge	100	30±
Cambrian.		(d)	*Chepultepec.*			*Chepultepec.*		
			Conococheague	2,000	610	Conococheague	2,000	610
			Bibb (Alabama)	500	152			
			Ketona (Alabama)	600	183			
			Brierfield (Alabama)	1,500	457			
			Elbrook	1,500	457			

[c] Canadian system of Ulrich and Butts. Post-Nittany=Bellefonte of Pennsylvania.
[d] Chepultepec to Brierfield=Ozarkian system of Ulrich and Butts.

NOTE.—Formations that are absent are printed in italics.

WINCHESTER TO HARRISONBURG, VIRGINIA

Winchester is situated in the heart of the Shenandoah Valley, and the route to Harrisonburg follows the strike of the valley and the limestone strata. (See pl. 13.) The width of the nearly flat valley at Winchester is about 17 miles (27 kilometers).

Opposite Strasburg is the northeast end of the Massanutten Mountains, a complex of structural ridges made by steeply dipping Massanutten sandstone. The mountains divide the valley into two parts, one followed by the North Fork of the Shenandoah River and the other by the South Fork. The northwest ridge of the Massanutten Mountains rises 1,000 to 1,500 feet (305 to 457 meters) above the valley of the North Fork and is visible from the route between Strasburg and Harrisonburg, opposite which is The Peak, the southwest end of Massanutten Mountain.

This part of the Appalachian Valley is one of the great apple-growing regions of the United States. Stock and grain raising are equally important branches of farming.

At the crossing of Abrams Creek, in the southwest environs of Winchester, is a good exposure of the Stonehenge limestone, which is a persistent, very thick-bedded limestone and the basal member of the Beekmantown group. At Abrams Creek a few specimens of a large flat coiled gastropod, probably a species of *Eccyliopterus* characteristic of the Stonehenge of the region, can be seen. Southward to Stephens City the road crosses obliquely the Beekmantown, Mosheim, Lenoir, and Chambersburg limestones onto the Martinsburg shale. At Stephens City the Mosheim limestone is extensively quarried for high-calcium limestone, some of the rock running over 98 per cent $CaCO_3$. From Stephens City to Strasburg the road lies near the contact of the Chambersburg limestone and Martinsburg shale, first one and then the other being in view. The festooning pattern of the boundaries in the vicinity of Strasburg seems to be caused by the northward plunging of subordinate folds in the northwest limb of the Massanutten Mountain syncline.

Little North Mountain, 5 miles (8 kilometers) west of the highway, becomes more prominent west of Strasburg, where the Tuscarora sandstone is in full development, and it is a nearly continuous ridge as far as Edinburg. South of the latitude of Edinburg is another stretch where Little North Mountain is broken down to low hills because the Tuscarora is either thin or faulted out.

At Strasburg is the best display of the Chambersburg limestone, of upper Black River age, named from Chambersburg, Pennsylvania. At Tumbling Run, about 2 miles (3.2 kilometers) southwest of Strasburg, is a completely exposed section

from the top of the Beekmantown through the Mosheim, Lenoir, Athens(?), and Chambersburg limestone into the basal slaty (Trenton) part of the Martinsburg. There will be an opportunity to collect specimens of *Nidulites*, a fossil of undetermined relations characteristic of the Chambersburg. Several thin beds of bentonite, an altered volcanic ash, are exposed at the base of the Chambersburg, and on the main road about a quarter of a mile (0.4 kilometer) beyond Tumbling Run several more beds are exposed in the base of the Martinsburg.

Also in the quarter mile beyond Tumbling Run the calcareous slaty beds of Trenton age in the base of the Martinsburg are fully exposed in the road cut on the right, and the exposure is continuous down through the upper 100 feet (30 meters) or more of the underlying Chambersburg. The massive bed, 30 feet (9 meters) thick, with *Christiania*, widely present in the top of the Chambersburg, is well displayed here.

Two miles (3.2 kilometers) southwest of Tumbling Run and 1 mile (1.6 kilometers) northeast of Toms Brook the road passes onto Beekmantown dolomite, which it follows to a point south of Edinburg and which is well shown in the road cuts between Woodstock and Edinburg. On the left of the road at and southwest of Toms Brook the Mosheim limestone is well displayed, and at Toms Brook there is a large quarry in it. The dip is very uniformly about 40° SE.

About three-quarters of a mile (1.2 kilometers) southwest of Edinburg the road passes onto Conococheague limestone, on which it is located most of the way to Mount Jackson and half a mile (0.8 kilometer) beyond. An excellent display of the formation may be seen along Crooked Creek above the railroad bridge in Mount Jackson.

Southward from Mount Jackson (see pl. 14) the road passes obliquely across the formations to the contact between the Chambersburg and Martinsburg, half a mile (0.8 kilometer) north of New Market.

There is an excellent display of the Chambersburg, with *Nidulites*, just below the Soldiers Monument on the right about 1 mile (1.6 kilometers) north of New Market.

Looking north from New Market the observer can see the south end of an outlying synclinal ridge (Short Mountain) of the Massanutten Mountains, capped with Massanutten sandstone.

From New Market the road to Luray Caverns goes northeast over Massanutten Mountain through New Market Gap.

Southward from New Market the road follows closely the Chambersburg limestone to the vicinity of Tenth Legion, where it passes onto Athens limestone, on which it continues to Harrisonburg. The wide outcrop of the Athens is caused by gentle folding. (See section A–A, pl. 14.)

The Spotswood Trail, skirting the southwest end of Massanutten Mountain, was the route followed by Governor Spotswood, of Virginia, and the Knights of the Golden Horseshoe in 1717 on the first trip of exploration by white men across the Blue Ridge.

The route traversed is in the main cavern region of Virginia. About 2 miles (3.2 kilometers) southwest of Mount Jackson are the Shenandoah Caverns, in the Conococheague limestone. Luray Caverns, northeast of New Market, to be visited in the evening, are probably the most widely known caves in Virginia. They are in inverted flat-lying dolomite of Beekmantown age—the division of the Beekmantown known as the Nittany dolomite. The roof is about 60 feet (18 meters) below the earth's surface, and the greatest explored depth is about 270 feet (82 meters) below the surface. They seem to extend downward to about 100 feet (30 meters) above the level of the Shenandoah River, which is 2½ miles (4 kilometers) northwest of the entrance to the cave. The other caves, which lie southwest of New Market, are, in order, the Endless Caverns, in the Mosheim limestone and Beekmantown dolomite; the Virginia Cavern, in the Mosheim limestone; the Massanutten Cavern, in the Mosheim limestone; and the Grand Cavern, in the Conococheague limestone. All these are shown on Plate 14.

HARRISONBURG TO NATURAL BRIDGE, VIRGINIA

From Harrisonburg to Mount Crawford the road is on the Athens limestone except for about 1 mile (1.6 kilometers) just north of Mount Crawford. (See pl. 14.)

About half a mile (0.8 kilometer) north of Burketown the road crosses a fault by which the Elbrook dolomite is overthrust westward onto the Beekmantown (Nittany) dolomite. Less than a mile (1.6 kilometers) west of the road between Mount Crawford and Burketown is a semioval klippe, or detached outlier of this faulted mass, about 6 square miles (15.5 square kilometers) in extent, composed of Conococheague and Nittany dolomites. Its north end is marked by a prominent bluff three-quarters of a mile (1.2 kilometers) southwest of Mount Crawford and visible from the road. Wise (Grattan) Hill to the southwest, also visible from the vicinity of Mount Crawford, is near the center of this area. This remnant has been separated by erosion from the main overthrust mass by a space of about half a mile (0.8 kilometer). (See pl. 14.) Beneath the klippe are intensely plicated and steeply inclined Athens, Chambersburg, and Martinsburg rocks, as shown in section B–B′ of Plate 14. The section, however, does not pass through the north end of the klippe, where the Conococheague limestone overlies the Martinsburg shale.

This is one of the best examples of a klippe in the Appalachian Valley.

Between Burketown and Staunton (stan'ton) the overthrust mass of Elbrook extends northwest about 2 miles (3.2 kilometers) beyond the general line of outcrop of the fault, covers several of the younger formations, and is folded into a syncline occupied by a narrow strip of Conococheague limestone. Two miles (3.2 kilometers) southwest of Fort Defiance the road passes onto the Athens shale, which occupies a narrow belt around the great syncline of Martinsburg shale stretching 5 miles (8 kilometers) to the southeast.

At the quarry half a mile (0.8 kilometer) east of Staunton are exposed irregular contacts of the Mosheim limestone on the Beekmantown dolomite and of the Lenoir limestone on the Mosheim. The prominent rounded hills to the south, called Betsy Bell and Mary Gray, probably owe their prominence to a thick mantle of heavy chert, residual from Beekmantown (Nittany) dolomite.

Formations between Waynesboro and Covington, Virginia

System	Series	Group	Waynesboro to Staunton and Buffalo Gap			Buffalo Gap to Elliott Knob			Warm Springs to Covington		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Carboniferous.	Mississippian.					Pocono	500	152			
Devonian.	Upper Dev.					Catskill Chemung Portage (Brallier)	1,000 3,000 3,700	305 914 1,128	*Catskill.* Chemung Portage (Brallier)	2,000 3,300	610 1,006
	Mid. Dev.					Romney	1,000	305	Romney	1,000	305
	Lower Dev.					Oriskany Helderberg	50 200	15 61	Oriskany Helderberg	75 500	23 152
Silurian.		Cayuga.				Tonoloway *Wills Creek.* *Bloomsburg.* *McKenzie.*	75	23	Tonoloway *Wills Creek.* *Bloomsburg.* *McKenzie.*	300	91
		Niagara.				*Lockport.* Clinton	250	76	*Lockport.* Clinton	500	152

Formations between Waynesboro and Covington, Virginia—Continued

System	Series	Group	Waynesboro to Staunton and Buffalo Gap			Buffalo Gap to Elliott Knob			Warm Springs to Covington		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Silurian.						Clinch	100	30	Clinch	150	46
Ordovician.						*Juniata.*			Juniata	400	122
						Oswego.			*Oswego.*		
			Martinsburg	3,000	914	Martinsburg	2,000	610	Martinsburg	1,500	457
			Chambersburg	200	61	Chambersburg	200	61	*Chambersburg.*		
			Lowville.			*Lowville.*			Lowville	500	152
		Blount.	*Ottosee.*								
			Tellico.								
			Athens	500	152				Hiatus.		
			Whitesburg?								
			Holston.								
		Stones River.	Lenoir	100	30				Lenoir	200+	61+
			Mosheim	50	15				Mosheim	50	15
			Murfreesboro.						*Murfreesboro.*		
			Jasper (Arkansas).								
			Joachim (Arkansas).						Hiatus.		
			St. Peter (Arkansas).								

Ordovician.			*Everton* (Arkansas).								
		Beekmantown.	Post-Nittany	1,500	457				Post-Nittany	500+	152+
			Nittany	500±	152±						
			Stonehenge?								
Cambrian.			*Chepultepec.*								
			Conococheague	2,000	610						
			Bibb.								
			Ketona.								
			Brierfield.								
			Elbrook	1,800	549						
			Waynesboro	1,500	457						
			Tomstown	1,200	366						
			Antietam	500	152						
			Harpers	2,000	610						
			Weverton	800	244						
			Loudoun.								
			Pre-Cambrian.								

At Staunton (see pl. 15) the route turns west to Buffalo Gap, and several belts of Elbrook, Conococheague, and Beekmantown, repeated by folding, are crossed. Good exposures of Conococheague limestone can be seen at several places. Just west of Westview sandstone beds characteristic of the formation are exposed.

In Buffalo Gap through Little North Mountain the road crosses first the Clinch sandstone[6] and then the Keefer sandstone member of the Clinton. Both dip steeply to the southeast, being overturned. They appear to be considerably thinned by squeezing. This mountain marks the west edge of the great limestone valley but is represented only by scattered outliers for several miles north of Buffalo Gap, because the hard Clinch sandstone is either thin or absent or is cut out by the great persistent overthrust fault along the southeast base of Little North Mountain.

Between Buffalo Gap and Goshen the road follows a valley eroded on the black or dark Romney shale and the Helderberg limestone. The Helderberg shows in old quarries just southeast of Craigsville, near which are active quarries for cement. Northwest of the road is a wide area of Upper Devonian in a deep syncline, which incloses the basal Mississippian Pocono sandstone that caps Elliot Knob, one of the highest peaks in the region, 4,473 feet (1,363 meters) above sea level.

At Goshen the road turns west across a wide synclinal outcrop of Portage group (Brallier shale) extending nearly to Panther Gap through Mill Mountain, which is an overturned anticlinal ridge of sandstones of the Clinch and Clinton. At the east entrance to the gap the Onondaga shale and the underlying Oriskany sandstone are exposed dipping steeply east, and in the stream below the road the Helderberg limestone is seen. Then the Clinton and the upper part of the Clinch in an asymmetric anticline are well exposed. This is a good place to examine the divisions of the Clinton—the Keefer sandstone above and the Cacapon sandstone below. After passing the axis of the anticline in the center of the gap the route crosses the same formation in reverse order, dipping east but more steeply than on the east limb.

From Panther Gap to Bath Alum Springs the road is on broad synclines of Romney and Portage (Brallier shale) most of the distance; thence over Warm Spring Mountain and to Warm Springs it is mostly on Silurian and Ordovician. The conspicuous cliffs on the northeast side of the Cowpasture River 2 miles

[6] From Buffalo Gap south the name Clinch is used, instead of Tuscarora, for this unit.

(3.2 kilometers) northwest of Millboro Springs consist of Portage shale.

East of Bath Alum an anticline is crossed bringing to outcrop Cayuga limestone and shale and the Clinton formation. Another anticline forms Little Piney Mountain, just east of Warm Spring Mountain.

The red shale of the Juniata formation is exposed on the summit of Warm Spring Mountain below the Clinch, and the Martinsburg shale underlying the Juniata crops out on the slope down to Warm Springs.

Warm Spring Valley is an anticlinal limestone valley about 15 miles (24 kilometers) long and is noted for its springs and associated beautiful hotels and grounds. At Hot Springs there are eight springs in about an acre. The combined flow of six of these is about 300 gallons (1,136 liters) a minute. Two of these have a temperature of 105° F. and are the hottest in the Warm Springs district. Two others have temperatures of 95° and 98°. The springs appear to issue from Lowville limestone, and the theory has been advanced that the Lowville is a water carrier and that the temperature of the water was acquired at the depth to which this limestone descends in the syncline between the point of intake of the water, a few miles northwest of Hot Springs, and the point of issue.

The road leaves Warm Spring Valley on the west side about midway between Healing Springs and Covington (see pl. 16) through a narrow gateway cut through nearly vertical Clinch sandstone which makes Little Mountain.

At the lower side of this passage Falling Spring Creek, which drains this part of Warm Spring Valley, has built up a thick deposit of travertine, forming a cliff over which the water falls. This rock is being quarried for fertilizer.

From a point about half a mile (0.8 kilometer) south of the falls nearly to Covington the road is on the Romney and Portage (Brallier) shales, and the Portage is exceptionally well displayed in the road cuts. Much of the way to Covington the winding road is perched far above the Jackson River, offering a grand view of the river valley.

The road follows the Jackson River eastward from Covington. At Island Ford, about 4 miles (6.4 kilometers) east of Covington, the Helderberg-Oriskany succession is exposed. Here thick sandstone beds are present in the Helderberg, contrasting strongly with the sandstone-free section of the Helderberg seen at Keyser, West Virginia. Next above the lower and thicker sandstone of the Helderberg, named the Clifton Forge sandstone, is pure limestone with abundant corals of which *Cladopora rectilineata* is one of the best guide fossils of the Keyser limestone, the

basal division of the Helderberg and of the Devonian system in the eastern United States. At Island Ford, too, is characteristic Oriskany sandstone with *Spirifer arenosus* and *Rensselaeria ovoides*.

Between Island Ford and Low Moor the upper division of the Helderberg, the Becraft limestone, is well exposed at a number of places, and just south of Low Moor are old mines in this limestone beneath a roof of Oriskany sandstone. The limestone was used for flux.

Iron mining was formerly a large industry in this region. The iron ore is probably a limonite replacing Onondaga limestone at the top of the Oriskany sandstone or of very sandy layers in the Becraft limestone.

Between Low Moor and Clifton Forge the Brallier and Romney shales are conspicuously exposed.

About 1½ miles (2.4 kilometers) southeast of Clifton Forge, in the Iron Gate, the gap through which the Jackson River flows through Rich Patch Mountain, is the beautifully displayed arch of Clinch sandstone shown in Plate 17. This fold is an example of an anticline with steeper northwest limb, common in the Appalachian region. (See pl. 7, *B*.) Above the arch of Clinch sandstone in the lower walls of the gorge is a relatively unexposed section occupied by the Cacapon member of the Clinton formation, and next above, forming the top of the gorge, is the Keefer sandstone member of the Clinton. On the slopes on each side of the arch the Clifton Forge sandstone of the Helderberg appears. In the depression at the surface between the Keefer and Clifton Forge sandstones the weak Tonoloway limestone (uppermost Silurian) crops out.

East of Clifton Forge the road is on Lower and Upper Devonian rocks. The underlying Clinch and Clinton sandstones make prominent ridges which inclose the synclinal valleys.

On the crest of North Mountain the road passes through the outcrop of the Clinton formation and Clinch sandstone of the Silurian onto Martinsburg shale, and thence southeastward to Lexington it crosses various older formations and faults, as shown on Plate 16. Two miles (3.2 kilometers) northwest of Lexington the road enters a large area of Holston limestone, formerly called "Murat limestone," which is well exposed. About 1 mile (1.6 kilometers) from Lexington is encountered Athens shale or thin-bedded limestone, possibly 2,000 feet (610 meters) thick, formerly called "Liberty Hall limestone." Lexington is located upon its outcrop.

IRON GATE ARCH, 1½ MILES (2.4 KILOMETERS) SOUTHEAST OF CLIFTON FORGE, VIRGINIA

The lower sandstone is the Clinch, 65 feet (20 meters) thick; the upper sandstone is the Keefer member of the Clinton; between the two is the Cacapon sandstone member of the Clinton. The northwest limb (left) is steep or slightly overturned, as shown in Plate 7, *B*. The length of the Clinch ledge is estimated at 1,000 feet (305 meters). A slight fault cuts the Keefer on the left, with displacement eastward.

Formations between Clifton Forge and Pearisburg, Virginia

System	Series	Group	Clifton Forge to Iron Gate and Lexington			Natural Bridge to Roanoke			Roanoke to Pearisburg		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Carboniferous.	Mississippian.								Pocono	1,700	518
Devonian.	Upper Dev.		Chemung Portage (Brallier)	2,000 2,000	610 610				*Catskill.* Chemung Portage (Brallier).	2,000 2,000	610 610
	Mid. Dev.		Romney	1,000	305				Romney	1,000	305
	Lower Dev.		Oriskany	25	8				*Oriskany.*		
		Helderberg.	Becraft. New Scotland Coeymans. Keyser.	200	61				Becraft. New Scotland Coeymans. Keyser.	50	15

Formations between Clifton Forge and Pearisburg, Virginia—Continued

System	Series	Group	Clifton Forge to Iron Gate and Lexington			Natural Bridge to Roanoke			Roanoke to Pearisburg		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Silurian.		Cayuga.	Tonoloway *Wills Creek.* *Bloomsburg.* *McKenzie.*	150	46				*Tonoloway.* *Wills Creek.* *Bloomsburg.* *McKenzie.*		
		Niagara.	*Lockport.*						*Lockport.*		
			Clinton {Keefer Cacapon	200 350	61 107				Clinton	150	46
			Clinch	100	30				Clinch	50	15
Ordovician.			Juniata *Oswego.* Martinsburg Chambersburg *Lowville.*	250 1,500 350	76 457 107				Juniata *Oswego.* Martinsburg *Chambersburg.* Moccasin	100 1,500 200	30 457 61
		Blount.	Ottosee. *Tellico.* Athens Whitesburg Holston	2,000 50 250	610 15 76	Athens Whitesburg Holston	2,000 50 50	610 15 15	Ottosee. *Tellico.* Athens Whitesburg?. Holston?.	1,400	427

		Stones River	Lenoir	50	15	Lenoir	50	15	Lenoir	100	30
			Mosheim *Murfreesboro.*	25	8	Mosheim *Murfreesboro.*	50	15	Mosheim Murfreesboro.	50	15
Ordovician.			*Jasper* (Arkansas). *Joachim* (Arkansas). *St. Peter* (Arkansas). *Everton* (Arkansas).			Hiatus.			Hiatus.		
		Beekmantown.	Post-Nittany Nittany *Stonehenge.*	600 600	183 183	Post-Nittany Nittany *Stonehenge.*	200 1,000	61 305	Post-Nittany Nittany *Stonehenge.*	200 1,000	61 305
Cambrian.			*Chepultepec.* Conococheague *Bibb* (Alabama). *Ketona* (Alabama). *Brierfield* (Alabama).	2,500	762	*Chepultepec* Conococheague Hiatus. Elbrook Waynesboro Tomstown Antietam	3,000 1,800 7,500 1,200 800	914 549 2,286 366 244	*Chepultepec.* Conococheague Hiatus. Elbrook Rome Shady Erwin	2,500 1,800 1,500 1,200 (?)	762 549 457 366

Between the Holston and the Athens here there is a good development of the highly characteristic Whitesburg limestone. (See p. 17.) It was included in the "Liberty Hall" limestone and is the source of the "Liberty Hall" fauna collected at this place.[7]

Four miles (6.4 kilometers) south of Lexington and about 1 mile (1.6 kilometers) from Buffalo Creek a bed of volcanic ash in the Martinsburg shale shows on the left side of the road.

Natural Bridge, one of the most interesting of natural phenomena, will be visited in the evening, when it is artificially illuminated. It is formed in nearly horizontal Conococheague limestone near the axis of a syncline. This feature resulted from underground drainage and erosion, with the collapse of the roof of the subterranean channel except at the bridge. Cedar Creek, a branch of the James River, 1 mile (1.6 kilometers) to the south, established a subterranean solution channel at about the level of the bottom of the bridge, which is about 1,150 feet (350 meters) above the sea. Afterward it deepened its passageway to its present level by ordinary erosion. The height of the roof above the stream, about 150 feet (46 meters), is the measure of this erosion.

NATURAL BRIDGE, VIRGINIA, TO BLUEFIELD, WEST VIRGINIA

The road follows the limestone valley from Natural Bridge southwestward. (See pl. 18.) The valley gradually narrows and at Buchanan is constricted to a narrow passage between the Blue Ridge on the left (east) and Purgatory Mountain, one of the valley ridges of Clinch sandstone, on the right (west). The James River flows through this narrow passage. The Elbrook limestone overrides the Clinch sandstone at the south end of Purgatory Mountain on a fault, apparently continuous with the great Pulaski overthrust to the southwest. The Pulaski fault swings north around the south end of Purgatory Mountain and extends fully 11 miles (18 kilometers) northwest of Buchanan. (See pl. 18.) A fenster in this great overthrust mass on this fault occurs a few miles to the south.

At a quarry on the James River about 1 mile (1.6 kilometers) east of Buchanan the Tomstown dolomite is exposed in contact with the Antietam sandstone. This is of interest, because the Tomstown is the oldest of the carbonate rocks of the Valley and because this is an excellent exposure of its apparently conformable contact with the underlying quartzite.

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[7] Bassler, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, p. 110, 1909.

From Buchanan for several miles southwest the limestone valley again widens, but between Troutville and Cloverdale it is constricted to less than 2 miles (3.2 kilometers). Here Fullhardt Knob, on the left, at the southwest end of this part of the Blue Ridge, is composed of basal Cambrian quartzite, which is thrust westward nearly to Tinker Mountain, which rises abruptly on the right and consists of Clinch (Silurian) sandstone. The quartzite here is overlain apparently in normal sequence by the Tomstown dolomite and the Waynesboro formation, both of which seem to be also part of the overthrust mass.

Two miles (3.2 kilometers) east of Cloverdale, Coyner and Read Mountains, composed mainly of Silurian and Devonian rocks, rise boldly above the valley of Elbrook and Conococheague limestone. The mountains are interpreted as an upbowed fenster or window in the Pulaski overthrust mass, as shown in the profile section of Plate 19. Farther east Porters Mountain, composed of pre-Cambrian rocks, is overthrust on the valley rocks of the Pulaski thrust mass, so that here one overthrust mass is superposed upon another in shingle fashion. The large area of Waynesboro in the valley of the North Fork of Goose Creek, southeast of the Blue Ridge, is interpreted as a semifenster in this second overthrust mass.

Formations between Christiansburg and Tazewell, Virginia

System	Series	Group	Christiansburg to Pearisburg			Narrows to Bluefield			Tazewell		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Carboniferous.	Pennsylvanian.					"Coal Measures."	5,000	1,524			
	Mississippian.					Bluestone	500	152			
						Princeton	50	15			
						Hinton (Pennington)	2,000	610			
						Bluefield	800	244			
						Gasper	400	122			
						Ste. Genevieve	400	122			
						St. Louis	50	15			
						Warsaw	25	8			
						Keokuk.					
			Maccrady	500	152	Maccrady	25	8			
			Price	1,700	518	Price	350	107			
Devonian.	Upper Dev.		*Catskill.*			*Catskill.*					
			Chemung	1,300	396	Chemung.					
			Portage (Brallier)	4,000	1,219	Portage (Brallier).	1,000	305			
	Mid. Dev.		Romney	300	91	Romney	400	122			

			Oriskany.			*Oriskany.*					
Devonian.	Lower Dev	Helderberg.	Becraft. *New Scotland.* *Coeymans.* *Keyser.*			Becraft. *New Scotland.* *Coeymans.* *Keyser.*					
Silurian.		Cayuga.	*Tonoloway.* *Wills Creek.* *Bloomsburg.* *McKenzie.*			Cayuga?					
		Niagara.	*Lockport.* Clinton	250	76	Clinton	250	76			
			Clinch	50	15	Clinch	100	30	Clinch	150	46
Ordovician.		Blount.	Juniata *Oswego.* Martinsburg *Chambersburg.* Moccasin	150 1,300 650	46 396 198	Juniata *Oswego.* Martinsburg *Chambersburg.* Moccasin	300 1,500 650	91 457 198	Juniata *Oswego.* Martinsburg *Chambersburg.* Moccasin	350 1,500 900	107 457 274
			Ottosee. *Tellico.* *Athens.* *Whitesburg.* Holston.			*Ottosee.* *Tellico.* *Athens.* *Whitesburg.* *Holston.*			Ottosee (basal Sevier?). *Tellico.* *Athens.* *Whitesburg.* Holston	10 10	3 3
			Stones River *Jasper* (Arkansas). *Joachim* (Arkansas).	350	107	Stones River	1,000	305	Stones River	200	61

Formations between Christiansburg and Tazewell, Virginia—Continued

System	Series	Group	Christiansburg to Pearisburg			Narrows to Bluefield			Tazewell		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Ordovician.			*St. Peter* (Arkansas). *Everton* (Arkansas).			Hiatus.			Hiatus.		
		Beekmantown.	Post-Nittany	600	183	Post-Nittany	400	122	Post-Nittany	400	122
			Nittany	800	244	Nittany	800	244	Nittany	800	244
			Stonehenge.			*Stonehenge.*			*Stonehenge.*		
Cambrian.			*Chepultepec.*			*Chepultepec.*			*Chepultepec.*		
			Copper Ridge	1,200	366	Copper Ridge	1,200	366	Copper Ridge	1,200	366
			Bibb (Alabama). *Ketona* (Alabama). *Brierfield* (Alabama).			Hiatus.			Hiatus.		
			Nolichucky	200	61	Nolichucky?			Nolichucky	200	61
			Honaker	1,000	305				Honaker	1,000	305
			Rome (Watauga)	1,200	366				Rome	1,200+	366+

Between Roanoke and Christiansburg the route lies nearly along the strike of the limestones of the valley and therefore is not completely shown on a route map. Fort Lewis Mountain, at the right, beyond Salem, is on the normal northwest limb of a syncline occupied by Upper Devonian and basal Mississippian (Pocono) rocks. The strata dip southeast toward the road and the horizontal beds at the axis of the syncline can be seen in places on the southeast slope of the mountain. The overturned southeast limb of the syncline is buried or cut out by the overthrust on the Salem fault, which lies some distance northwest of the road.

At Christiansburg the route turns to the right. (See pl. 19.) Between Christiansburg and Blacksburg is the interesting Price Mountain fenster through Cambrian rocks, somewhat doubtfully referred to the Rome (Watauga) formation, which have been shoved many miles northwestward on the Pulaski fault.[8] The rocks in the fenster are Price sandstone (basal Mississippian), carrying beds of semianthracite coal. These coal beds, which crop out in the fenster, are known to underlie the Cambrian limestones in the country surrounding the fenster, where they have been found in borings at depths of as much as 2,000 feet (610 meters). The coal is hard, similar to Welsh anthracite, but not quite so thoroughly metamorphosed as the Pennsylvania anthracite. Near the route of travel there is one main bed 5 to 11 feet (1.5 to 3.4 meters) thick with partings. This coal is about the age of the Scottish sub-Carboniferous coals and together with them is older than any other known commercial coals except possibly some of the Devonian coals of Svalbard (Spitsbergen).

The Pulaski fault emerges 1½ miles (2.4 kilometers) northwest of Blacksburg at the edge of the thick mass of red Maccrady shale. The dolomite in contact on the south side of the fault is probably of Middle Cambrian age (Elbrook). The principal coal bed in the Price reappears a short distance beyond the red shale and is exposed in an old mine by the roadside on the right.

Northwestward the route descends in the sequence. The first mountain to be crossed, Brush Mountain, is composed of Price sandstone, and the second, Gap Mountain, of Clinch sandstone.

A mile and a half (2.4 kilometers) northwest of Newport is a notable exhibit of the Moccasin limestone, a facies of the Lowville limestone, very strongly affected by slaty cleavage. The bedding dips about 30° SE., and the cleavage is nearly or quite vertical.

The limestone exposed along Sinking Creek is Lenoir and Stones River, and the dolomite beyond nearly to Ripplemead is

[8] Campbell, M. R., and Holden, R. J., The Valley coal fields of Virginia; Virginia Geol. Survey Bull. 25, pp. 76–86, 1925.

Beekmantown, main'y Nittany, on a gentle anticline. The cherty limestone of the Stones River reappears on the northwest limb of the anticline half a mile (0.8 kilometer) southeast of Ripplemead.

The quarry at the left of the road on the west bluff of the river ust north of Ripplemead is mainly in the Mosheim limestone, which is here well developed between the lowermost Stones River and the Lenoir. The conspicuous ledge of limestone, about 40 feet (12 meters) thick, dipping south, seen in the east bluff across the river, is also Mosheim. The lowermost Stones River beneath the Mosheim is well exposed in the old quarry north of the ledge at the mouth of the ravine, and the big quarry still farther north is in Nittany dolomite, quarried for broken stone. The abundant chert along the road from Ripplemead to Pearisburg is derived from the Stones River limestone.

The sequence in the Pearisburg section is notable for the absence of all of the Blount group and the Chambersburg limestone, as can be seen by comparison of sections. The Moccasin limestone of Lowville age is in contact with the Lenoir limestone, as is the Lowville in Alabama and in Pennsylvania.

The level upland between Ripplemead and Pearisburg, about 2,100 feet (640 meters) above sea level, is an old peneplain surface, and there is river gravel on the top of the spur at the same level north of the river west of Stony Creek, as marked on the map. These surfaces are 500 feet (152 meters) above the river.

The abundant large boulders on terraces west of Pembroke are river borne, having been deposited by the New River during some Pleistocene stage of its history.

At the village of Narrows the road crosses to the north side of the New River, and about half a mile (0.8 kilometer) beyond the bridge it crosses a fault by which the Copper Ridge dolomite is thrust over Lower Devonian (Helderberg), which is also exposed in a fenster in this overthrust mass 2 miles (3.2 kilometers) southwest of Narrows. (See pl. 19.)

A little over a mile north of the bridge the road enters the Narrows, cut through East River and Peters Mountains. At the east entrance first the Clinton crops out and then the Clinch sandstone, which makes a southeastward-dipping ledge that extends from the level of the river to the summit of the mountain on both sides of the river. Below the Clinch the red sandstone and shale of the Juniata and the underlying Martinsburg shale are clearly exposed in the road cut.

Just below the Juniata the thick bluish-gray beds of the *Orthorhyncula* zone are present. (See p. 16.) In Pennsylvania this zone is succeeded by the Oswego sandstone, 1,200 feet

(366 meters) thick at a maximum, and the Oswego by the Juniata, 1,500 feet (457 meters) thick in places. Along the southeast side of the Valley in Virginia the *Orthorhyncula* zone is immediately succeeded in Massanutten Mountain by the Massanutten sandstone, and at Max Meadows, 8 miles (12.8 kilometers) east of Wytheville, by the Clinch sandstone, the Oswego and Juniata being absent. On Draper Mountain where crossed by the route about 8 miles (12.8 kilometers) northeast of Max Meadows about 300 feet (91 meters) of Juniata is present and is immediately underlain by the *Orthorhyncula* zone.

The more shaly beds in the upper part of the Martinsburg constitute the Eden and Maysville (Upper Ordovician or Cincinnatian). The predominantly thin-bedded limestone in the lower part is the Trenton constituent, at the base of which, through 100 feet (30 meters) of thickness, are several thin beds of altered volcanic ash, or bentonite.

The Moccasin, Lenoir, Mosheim, and lowermost Stones River (Murfreesboro) limestones are exposed along the railroad track below the highway, and the Nittany dolomite in the highway cut.

At about the northwest end of the Narrows the Nittany (Beekmantown) is thrust, on the St. Clair fault plane, over Upper Devonian shale. The relation of this fault to the Upper Devonian (Portage) shale can be better understood from exposures near St. Clair railroad station, southwest of Bluefield, West Virginia.

Between the St. Clair fault and Rich Creek nearly the full sequence of the Mississippian can be seen exposed on the west bluff of the river. The strata are overturned and dip 60° S.

From Rich Creek to Princeton, West Virginia, the road is on nearly horizontal Pennington (Hinton) formation marked by red shale. (See pl. 20.)

At Princeton the Princeton conglomerate is a thin bed separating the Pennington from the Bluestone, the uppermost formation of the Mississippian of the Appalachian Valley and about the age of the youngest Mississippian anywhere else. The lower Pennsylvanian coal measures of the Pocahontas field cap the hills a few miles northwest of Princeton.

From Princeton to Bluefield the Mississippian beds are crossed in descending order. Bluefield is located mainly on middle and lower Mississippian and Upper Devonian rocks. The Portage (Brallier) shale here underlies the Mississippian, there being a hiatus of several thousand feet of Chemung and Catskill beds which were seen at this horizon between Washington and Cumberland, Maryland, and between Romney, West Virginia, and Winchester, Virginia.

BLUEFIELD, WEST VIRGINIA, TO BRISTOL, VIRGINIA

The route goes westward from Bluefield for about 5½ miles (8.8 kilometers) along the Mississippian limestone valley, with Devonian shale hills on the left. (See pl. 20.) It then turns south to St. Clair railroad station, where it crosses the St. Clair fault, on which a thin wedge of Beekmantown dolomite is thrust over Upper Devonian Portage (Brallier) shale, which is exposed in a railroad cut near the station. The dolomite is overlain by about 1,000 feet (305 meters) of Stones River limestone exposed for a third of a mile (0.5 kilometer) along the road to a second fault by which the Copper Ridge dolomite (Ozarkian of Ulrich and Butts) is thrust against the Stones River. About midway between St. Clair and Springville the road lies near the contact of the Copper Ridge and Nittany for a distance, and there is a good exhibit of one of the sandstone beds of the Copper Ridge similar to beds in the Conococheague limestone. The quarries at Five Oaks and half a mile (0.8 kilometer) east of North Tazewell are in the Stones River limestone. At the bend of the road just west of Five Oaks is a good exhibit of the Moccasin limestone. Just above the Moccasin at Five Oaks are one or more beds of bentonite in the base of the Martinsburg shale.

On the base of the slope on the south just above the railroad station at North Tazewell is a good display of the dove-colored limestone in the lower part of the Moccasin. This carries *Tetradium* and other Lowville fossils. The Holston and Ottosee limestones, which are some hundreds of feet thick a few miles southwest of Tazewell, are thinned at North Tazewell to about 17 feet (5 meters), and this is the northernmost point at which either of these limestones is known in the two northwestern belts of outcrop. In a belt farther southeast the Holston reaches the New River a few miles south of Pearisburg, and still farther southeast it extends in detached areas as far northeast as Lexington, Virginia, as already seen.

From North Tazewell the route goes across a wide synclinal belt of Martinsburg shale to Tazewell. Just southwest of the angle of the road on entering the town is a good exposure of the thick-bedded coarse-grained limestone of the Holston rising southeastward in the syncline. The road runs southwest beyond Tazewell for 2 miles (3.2 kilometers), on Moccasin most of the way, and then turns sharply north and recrosses the syncline to Pisgah. Several good exposures of the strongly plicated thin-bedded Martinsburg are present about the middle of this belt.

From Pisgah to a point 1½ miles (2.4 kilometers) northeast of Wardell the road closely follows the strike, being on Stones River most of the way. Along the short stretch where the road is north of the Clinch River for half a mile (0.8 kilometer) east of

Pounding Mill, the road follows the contact of the Beekmantown and Stones River, affording a good view of the pinkish top layers of the Beekmantown. For nearly 2 miles (3.2 kilometers), passing by the filling station, the road runs very near the same contact, the thick-bedded cherty limestone on the right of the road being lower Stones River (Murfreesboro).

The Stones River here includes Murfreesboro, Mosheim, and Lenoir, and the Mosheim is quarried at Pounding Mill.

On the left of the road from Pounding Mill to a point beyond the filling station the Holston limestone is conspicuously exposed much of the way, and then its outcrop is crossed diagonally on the descent to Wardell.

Deskin and Paint Lick Mountains, the conspicuous ridges on the left between Pisgah and Wardell, are synclinal mountains of Martinsburg shale capped by flat Clinch sandstone. At Wardell the road turns south across a syncline of Martinsburg shale. The rocks so well displayed along Little Indian Creek for 2 miles (3.2 kilometers), beginning about 2 miles southwest of Wardell, are, in order of occurrence, red Moccasin, nodular Ottosee, thick-bedded Holston, and Lenoir. These are repeated by folding, which is well shown on the left of the road. The contact between the contrasting Holston and Ottosee, completely exposed, is perfectly regular, although there is a hiatus representing the time interval of the Athens shale, 3,000 feet (914 meters) in maximum thickness elsewhere, which is absent here as everywhere northwest of Clinch Mountain.

About 3 miles (4.8 kilometers) south of Wardell the road turns to a strongly westward direction and follows closely the general strike to Lebanon. For a considerable distance beyond the turn the road runs about on a fault in vertical thick-bedded Holston limestone and crosses obliquely a regular sequence of typical Ottosee, Holston, and Stones River onto Beekmantown dolomite, which is excellently exposed for a mile or so on both sides of Belfast Mills. Half a mile (0.8 kilometer) west of Old Rosedale the road crosses a fault from the Beekmantown onto the Nolichucky shale, which it follows nearly to Elway and then passes onto the Copper Ridge dolomite.

From Elway it turns northwest, recrossing the Nolichucky onto the Honaker dolomite, on which it continues to Lebanon. The fine pasture lands on the Honaker in the vicinity of Lebanon are noticeable.

House and Barn Mountain and Elk Garden Ridge, northwest of the road from Belfast Mills to and beyond Elway, are synclinal ridges capped by horizontal Clinch sandstone and are in continuation of the Deskin and Paint Lick axes.

One mile (1.6 kilometers) southwest of Lebanon the road turns northwest obliquely across the strike and crosses the Moccasin, Ottosee, and Holston onto the Stones River, then turns southwest and follows the strike to Dickensonville, nearly 10 miles (16 kilometers) southwest of Lebanon. For most of this stretch the road is on Stones River, marked by an abundance of rather small pieces of blocky gray chert. In places the road shifts onto the Stones River-Beekmantown contact, marked by reddish shaly material and layers of pinkish dolomite.

Formations between St. Paul and Abingdon, Virginia

System	Series	Group	St. Paul to Brookside Inn			Brookside Inn to Greendale			Greendale			Abingdon		
			Formation	Thickness		Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters		Feet	Meters
Carboniferous.	Mississippian.					Pennington	1,000	305						
						Cove Creek	1,000	305						
						Gasper	1,000	305						
						Ste. Genevieve	1,300	396						
						St. Louis	300	91						
						Warsaw	600	183						
						Keokuk.								
						Maccrady	60	18						
						Price	750	229						
Devonian.						*Catskill.*								
						Chemung	200	61						
						Portage (Brallier)	1,600	488						
						So-called Romney	160	48						
						Onondaga	100	30						
						Oriskany.								
						Helderberg.								

Formations between St. Paul and Abingdon, Virginia—Continued

System	Series	Group	St. Paul to Brookside Inn			Brookside Inn to Greendale			Greendale			Abingdon		
			Formation	Thickness		Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters			Meters
Silurian.						*Cayuga.*								
		Niagara.				*Lockport.* Clinton	300	91						
						Clinch	125	38						
Ordovician.						Juniata	300	91						
						Oswego. Martinsburg	1,800	549						
			Moccasin	700	213	Moccasin	550	168						
		Blount.	Ottosee (basal Sevier). *Tellico.* *Athens.* *Whitesburg.*	400	121	Ottosee *Tellico.* *Athens.* *Whitesburg.*	450	137				Athens Whitesburg? *Holston.*	2,000	610
			Holston	300	91	Holston	250	76						
			Stones River	100	30	Stones River	100	30				Lenoir Mosheim *Murfreesboro.*	20 20	6 6

Ordovician			*Jasper* (Arkansas). *Joachim* (Arkansas). *St. Peter* (Arkansas). *Everton* (Arkansas).			Hiatus.						Hiatus.		
	Beekmantown.		Post-Nittany. Nittany. *Stonehenge.*			Post-Nittany-- Nittany------ *Stonehenge.*	400 800	122 244	Post-Nittany -- Nittany------ Stonehenge?---	400 800 50	122 244 15	Post-Nittany -- Nittany------ Stonehenge?---	100 500 600	30 152 183
Cambrian.			*Chepultepec.* Copper Ridge--- *Bibb* (Alabama)-- *Ketona*--------- *Brierfield* (Alabama)-------- Nolichucky-----	1,200 500 600 1,500 300	366 152 183 457 91	*Chepultepec.* Copper Ridge-- Hiatus. Nolichucky----	1,200 500	366 152	*Chepultepec.* Copper Ridge-- Hiatus. Nolichucky----	1,200 800	366 244	*Chepultepec.* Conococheague. Hiatus. Nolichucky----	2,000 500	610 152
			Maryville[a]------ Rogersville[a]----- Rutledge[a]------	550 100 250	168 30 76	Honaker------	1,000	305	Honaker------	1,600	488	Honaker------	1,500	457
			Rome----------	1,000	305	Rome----------	1,100	335						

[a] Exposed near St. Paul.

At Dickensonville, 6 miles (9.6 kilometers) southeast of St. Paul (see pl. 21), the route turns south to Abingdon. The thick-bedded coarse-grained Holston is excellently displayed, and southward the nodular Ottosee and thin-bedded Lowville, passing upward into gray and reddish argillaceous limestone of the Moccasin type, are passed in turn.

A few hundred yards southeast of the Brookside Inn the Copper Creek fault is crossed, where the Lower Cambrian Rome is thrust over the Ordovician (Lowville and Moccasin). From this fault southeast to the Saltville fault at Greendale, a distance of 11 miles (18 kilometers) across the strike, a nearly complete stratigraphic succession up nearly to the top of the Mississippian is very largely exposed in regular order, the sequence being broken only by the absence of the Athens shale and Tellico sandstone.

Next to the fault about 1,100 feet (335 meters) of Rome is exposed, marked by beds of red shale with impure fossiliferous limestone bands. Trilobites of ptychoparian types have been collected at several horizons throughout the formation here. Next above the Rome are the Rutledge and Maryville limestones, or Honaker limestone, as it is called where, as here, the intervening Rogersville shale is absent. The Maryville is exposed at the quarry half a mile (0.8 kilometer) south of the old post office of Creswell. Still higher, reaching to the top of the slope south of Creswell, is the Nolichucky shale, fairly fossiliferous. Dolomite of the Copper Ridge begins at the crest of this low ridge and extends to Bolton.

A short distance south of Bolton sandstone beds occur in the Copper Ridge.

The boundary between the Copper Ridge on the left and the Beekmantown (Nittany) on the right is close to the road in the valley for half a mile (0.8 kilometer) east of Bolton. Nittany fossils occur in the chert on the slope to the right. The post-Nittany part of the Beekmantown is marked by piles of fossiliferous chert in fields on the left, above the road, midway between Hawkins Mill and Hansonville.

A short distance southeast of Hansonville the Holston limestone is exposed, and this belt continues southwestward into the type region of the Holston at Knoxville, Tennessee. Above the Holston is the more or less nodular and fossiliferous Ottosee limestone, the Athens shale, normally between the two, being here absent also.

In Little Moccasin Gap, the saddle at the top of the hill, is the Moccasin limestone, which also shows down the slope to the southeast. The blue limestone at the summit of Little Moccasin Gap is basal Lowville. It carries here one of the diagnostic Lowville fossils, *Beatricea gracilis*. One or more beds of red

shale of Moccasin type occur in the bottom of this limestone and just above the Ottosee.

The overlying Martinsburg shale makes the steep slopes above the saddle on each side and is overlain near the tops of the hills by a considerable thickness of red Juniata shale, its presence shown by the red color of its soil.

Down the narrow valley, half a mile (0.8 kilometer) southeast of the saddle, in a quarry in the basal beds of the Martinsburg, is exposed a bed of volcanic ash (bentonite), 18 inches (45 centimeters) thick, which directly overlies reddish limestone of the Moccasin, and 11 feet (3 meters) above the bentonite bed is profusely fossiliferous limestone of Trenton age. All the volcanic ash beds known in this part of the valley are at this general horizon.

The Clinch and Clinton are exposed beyond in the gap in Clinch Mountain, from which the Clinch sandstone receives its name. A ledge of the Clinch dipping south is visible on the left descending from a point high on the mountain side nearly to the level of the road, and the full thickness of both Clinch and Clinton is exposed in the road about 1 mile (1.6 kilometers) south of the North Fork of the Holston River. Middle and Upper Devonian, consisting of Onondaga chert and limestone (not exposed), black shale (not exposed), and a large thickness of Portage (Brallier shale), are next passed in succession. Both Onondaga and the overlying black shale are exposed within half a mile (0.8 kilometer) east of the road.

At the North Fork of the Holston River the broad belt of middle and upper Mississippian rocks is entered. This belt is 2 miles (3.2 kilometers) wide, the dip is 30° SE. nearly to the Saltville fault, and the thickness of the upper Mississippian beds (above the Pocono) is about 5,000 feet (1,524 meters), nearly the full thickness being exposed.

The great Saltville overthrust on which the Honaker dolomite is thrust over late Mississippian rocks, with an estimated stratigraphic displacement of about 14,000 feet (4,267 meters), is crossed at Greendale. About 11 miles (18 kilometers) southwest on this fault the Rome formation is raised into contact with the same Mississippian formation, the displacement being here possibly as much as 16,000 feet (4,877 meters). Beyond this fault, southeast of Greendale, two belts, each with a sequence of Cambrian and Beekmantown rocks, are passed before reaching Abingdon, the repetition being due to thrust faults, which are shown on the map.

Abingdon is located on the Conococheague limestone, which the road follows from Abingdon to Bristol. On Wolf Creek in Abingdon the Nolichucky and Conococheague sequence and the sandstones marking the base of the Conococheague can be observed.

Formations between Bristol, Virginia, and Tazewell, Tennessee

System	Series	Group	Walker Mountain, northwest of Bristol			Walker Mountain to Powell Mountain			Cumberland Gap to Tazewell		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Carboniferous.	Pennsylvanian.								"Coal Measures"	4,000	1,219
	Mississippian.					Pennington	1,000	305	Pennington	150	46
									Hiatus?.		
						Cove Creek	1,000	305	Glen Dean	250	76
									Hiatus?.		
						Gasper?	1,000	305	Gasper	125	38
						Hiatus?.			Hiatus?.		
						Ste. Genevieve	1,300	396	Ste. Genevieve	125	38
						St. Louis	125	38	St. Louis	10	3
						Warsaw	500	152	Warsaw.		
						Fort Payne.			Fort Payne	15	5
						Maccrady	60	18	*Maccrady.*		
						Price	800	243	Price	325	99
Devonian.						*Catskill.*			*Catskill.*		
						Chemung.			*Chemung.*		
						Portage?	1,500	457	Portage?	500	152
						Romney.			*Romney.*		
						Oriskany.			*Oriskany.*		
						Helderberg	50	15	*Helderberg.*		

Silurian.		Niagara.				*Cayuga.*			*Cayuga.*		
						Lockport. Clinton	400	122	*Lockport.* Clinton	400	122
						Clinch	75	23	Clinch	50	15
Ordovician.						Juniata	300	91	Sequatchie	450	137
						Oswego. Reedsville	1,200	366	*Oswego.* Reedsville	400	122
						Martinsburg: Trenton	300	91	Trenton	300	91
						Chambersburg. Moccasin	700	213	*Chambersburg.* Lowville	1,000	305
		Blount.				Ottosee	200	61	Hiatus.		
						Tellico. *Athens.* *Whitesburg.* Holston	400	122			
		Stones River.				Lenoir	50	15	Lenoir	50	15
						Mosheim	50	15	Mosheim	50	15
						Murfreesboro	100	30	Murfreesboro	250	76
						Joachim (Arkansas). *St. Peter* (Arkansas). *Everton* (Arkansas).			Hiatus.		
		Beekmantown.	Post-Nittany	200	61	Post-Nittany	200	61	Post-Nittany	200	61
			Nittany	800	244	Nittany	1,000	305	Nittany	1,000	305
			Stonehenge.			*Stonehenge.*			*Stonehenge.*		

Formations between Bristol, Virginia, and Tazewell, Tennessee—Continued

System	Series	Group	Walker Mountain, northwest of Bristol			Walker Mountain to Powell Mountain			Cumberland Gap to Tazewell		
			Formation	Thickness		Formation	Thickness		Formation	Thickness	
				Feet	Meters		Feet	Meters		Feet	Meters
Cambrian.			*Chepultepec.* Copper Ridge *Bibb* (Alabama). *Ketona* (Alabama). *Brierfield* (Alabama). Nolichucky.	1,200	366	*Chepultepec.* Copper Ridge Hiatus. Nolichucky	1,200 500	366 152	Chepultepec (thin). Copper Ridge	1,200	366
			Honaker	1,200	366	Maryville Rogersville Rutledge	500 100 200	152 30 61			
			Rome	1,000+	305+	Rome	1,200+	366			

BRISTOL, VIRGINIA, TO MORRISTOWN, TENNESSEE, BY WAY OF CUMBERLAND GAP

Most of the route from Bristol, Virginia, to Morristown, Tennessee, goes through the area mapped in the Bristol, Estillville, Maynardville and Morristown folios of the Geologic Atlas of the United States. (See pl. 22.) From Bristol to Clinchport, Tennessee, the section seen from Dickensonville to Abingdon is crossed in reverse order.

The Saltville overthrust is crossed 8 miles (13 kilometers) west-northwest of Bristol, and the partly red Rome formation can be seen in virtual contact with upper Mississippian (Pennington formation), which is full of fenestellid Bryozoa. The stratigraphic displacement is about 16,000 feet (4,877 meters). The fault here is compound, a sliver of Ordovician and Silurian being dragged up and cropping out in a strip a few hundred feet wide just southeast of the main fault and mostly just northeast of the road. Five miles (8 kilometers) west of the outcrop of the fault a small klippe of Honaker dolomite lies on the Pennington. (For the stratigraphic displacement see table.) This is another of the very few occurrences of such outlying fault remnants known in the Great Valley.

The route crosses the northwestern part of the wide syncline of Mississippian rocks southeast of the North Fork of the Holston River nearly normal to the strike, follows the strike along Cove Creek, turns again across the strike, and then crosses the river half a mile (0.8 kilometer) south of Hilton. About a quarter of a mile (0.4 kilometer) south of the railroad at Hilton the contact of the Mississippian (Price sandstone) and the Upper Devonian (Portage) is passed. The Price makes the conspicuous ridge Pine Mountain.

From Hilton to Big Moccasin Gap through Clinch Mountain the road follows Poor Valley on Upper Devonian shale between Pine Mountain on the left and Clinch Mountain on the right.

From Big Moccasin Gap to Gate City the route crosses the Martinsburg, red Moccasin, and nodular Ottosee, which carries *Echinosphaerites*.

At Gate City the road enters the Holston marble, which shows in places along the roadside as pink or reddish layers similar to the typical Holston or "Tennessee" marble. This is the same belt that is continuous into the type area at Knoxville, Tennessee. The Holston has been extensively quarried 2 miles (3.2 kilometers) west of Gate City for use in cement making at Kingston, Tennessee, and an abandoned quarry on the right at Speers Ferry railroad station is in this formation.

Beyond the railroad trestle at Speers Ferry station the road follows the gorge of Troublesome Creek to the Clinch River,

which follows a valley cut in Nolichucky shale. Copper Ridge, south of this valley, extends 44 miles (71 kilometers) southwestward into Tennessee, where occurs the exposure on which Ulrich based the name Copper Ridge dolomite.

The dolomite largely exposed in the Troublesome Creek section is 2,400 feet (732 meters) thick, about equally divided between Beekmantown (mainly Nittany) above and Copper Ridge (Ozarkian of Ulrich) below. No lithologic differences can be detected between the dolomite in the two formations, but there is a hiatus in the middle of the mass, owing to the absence of the Chepultepec dolomite, which in Alabama is 1,000 feet (305 meters) thick and characterized by the *Helicotoma uniangulata* fauna. This fossiliferous zone has been observed in the middle of the dolomite mass southwest of Cumberland Gap, farther on.

Half a mile (0.8 kilometer) or so beyond the bridge across the Clinch River and just north of the mouth of Copper Creek, which joins the river on the right, is the Copper Creek fault, which brings up the Cambrian Rome formation against Ordovician limestone. The fault can be seen from the road by looking up to the railroad cut on the right, 100 feet (30 meters) above the road.

A side trip will be taken 2 miles (3.2 kilometers) north of Clinchport to see the Natural Tunnel. This tunnel, which is so large that a railroad train passes through it, is a remnant of a subterranean channel, similar to that at Natural Bridge and produced by the same process. The height of the roof is 90 feet (27 meters), and it is about 1,400 feet (427 meters) above sea level. Stock Creek when flowing at that level established a subterranean passage, and the channel has since been deepened to its present level by ordinary erosion and the roof has caved in except at the tunnel.

The road runs southwest from Clinchport for 2 miles (3.2 kilometers) along a narrow valley, much of the way near the contact of the Rome formation and the Rutledge limestone. The Rutledge is the thick-bedded limestone in the lower part of the bluff on the left. At a number of places the gray shale of the Rogersville is well displayed higher on the bluff, and above that the Maryville limestone. This sequence extends along this belt for 150 miles (241 kilometers), from St. Paul, Virginia, to a point 30 miles (48 kilometers) southwest of Knoxville, Tennessee. Above the Maryville is the Nolichucky shale, known from southern Tennessee to the New River south of Pearisburg, Virginia.

About 2 miles (3.2 kilometers) southwest of Clinchport the road turns northwest over Purchase Ridge, an anticline of Copper Ridge dolomite. On the northwest slope of this ridge is an excellent exposure of the Nolichucky and Copper Ridge

succession. Beyond the North Fork of the Clinch River a fault is crossed by which the Rutledge limestone is brought into contact with the Devonian black shale.

At Pattonsville a narrow belt of Upper Devonian black shale occurs in a syncline at the southwest end of Powell Mountain, and this black shale is inclosed by Helderberg sandstone and Cayuga limestone. At the sharp bend in the road 1¼ miles (2 kilometers) north of Pattonsville a considerable thickness of the same thick-bedded coarse friable sandstone with an abundance of Helderberg brachiopods is exposed. It is probably of Becraft (latest Helderberg) age.

The road, following a diagonal course to the summit of the high ridge to the west, also named Powell Mountain, is on the Clinton formation, which is in general well exposed. The crest of the mountain is made of Clinch sandstone dipping southeast, below which on the west slope in descending succession are red Juniata formation and Martinsburg shale.

At Stickleyville typical Lowville limestone is passed, and then in turn Stones River limestone, Beekmantown dolomite, and Copper Ridge dolomite, which extends to a fault 1 mile (1.6 kilometers) northwest of Stickleyville. Beyond the fault over Wallen Ridge the same succession of rocks is repeated as on Powell Mountain, all dipping southeast. Wallen Ridge is a monocline of Clinch sandstone. The long level stretch of road from the northwest foot of Wallen Ridge nearly to the Powell River is on almost horizontal Lowville limestone, below which is thick-bedded Stones River limestone. The dolomite, which extends from the Powell River nearly to Pennington Gap, is post-Nittany and Nittany and perhaps includes some Copper Ridge on the crest of the anticline; the heavy limestone along the road on the northeast outskirts of the village of Pennington Gap is Stones River.

For 6 miles (9.6 kilometers) southwest of Pennington Gap village the road is on Lowville limestone; then, owing to a sharp bend in the strike, shown in Figure 8, it crosses the overlying Trenton, Reedsville, Sequatchie, Clinch, Clinton, and Cayuga, standing nearly vertical.

At Ben Hur the Ordovician (Beekmantown and Stones River) is faulted against the Devonian black shale. In this belt the limestones of Trenton age can be differentiated, so that the overlying (Cincinnatian) part of what is elsewhere called Martinsburg is named the Reedsville shale, a name brought down into southwestern Virginia from Reedsville, central Pennsylvania, where similar conditions exist. At the top of the Reedsville here, as at the top of the Martinsburg generally, the *Orthorhyncula* zone is present.

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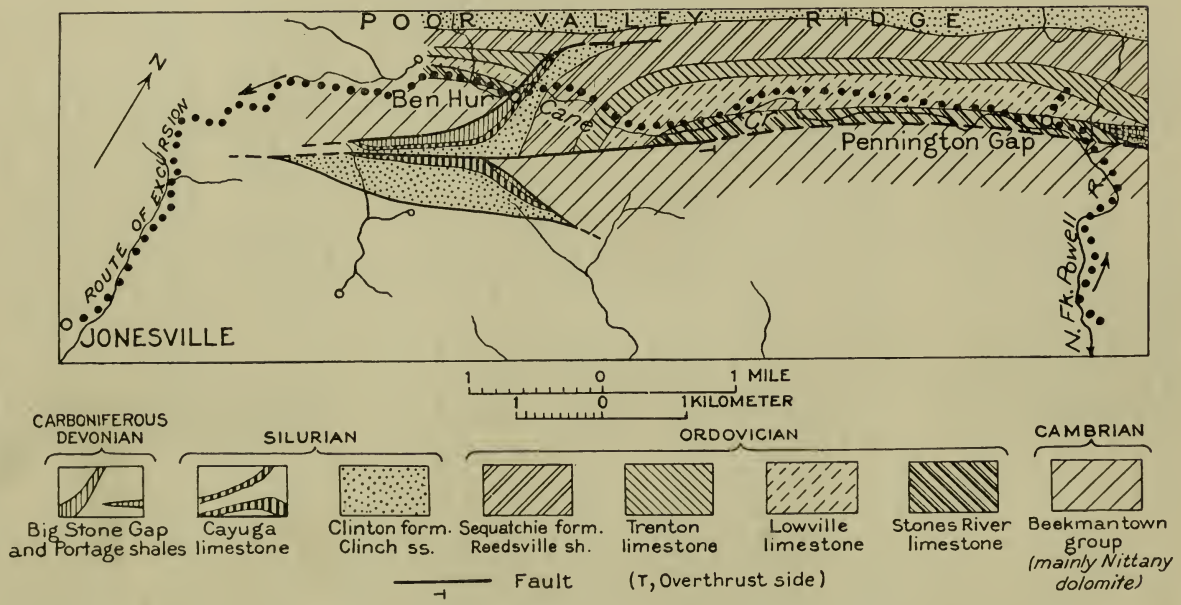

FIGURE 8.—Route map, Pennington Gap to Jonesville, Virginia

From Ben Hur to Cumberland Gap the road is mainly on Beekmantown and other Lower Ordovician formations. Beautiful exposures of the Stones River limestone occur along the road southwest of Jonesville, and there is a good exposure of the Mosheim limestone at Hardy Creek, 10 miles (16 kilometers) due west of Jonesville. From Hardy Creek to Rose Hill the route is mostly on Lowville—the dove-colored limestone facies entirely, the red Moccasin facies being absent. The route passes onto thick-bedded Stones River limestone at the crossing of Martin Creek just northeast of Rose Hill and follows it to a point about a mile northeast of Ewing, where it shifts southeastward to the contact of the Beekmantown and Stones River, which it follows the rest of the way to Ewing.

Two miles (3.2 kilometers) southeast of Ewing is one of several fensters in which the Clinton formation, with its characteristic ostracodes and fossiliferous red hematite ore, is exposed beneath a flat overthrust mass of Copper Ridge dolomite and Nolichucky shale, as illustrated in Plate 23. The iron ore was formerly mined here.

The whole surrounding country is a great overthrust mass 25 miles (40 kilometers) wide and 127 miles (204 kilometers) long, the thrust plane of which crops out at the northwest base of Pine Mountain, Kentucky, 10 miles (16 kilometers) northwest of Cumberland Mountain, the escarpment bordering the northwest side of the valley here.

Cumberland Gap, at the extreme southwest tip of Virginia (see pl. 24), is of historic as well as geomorphic and geologic interest. Through this low gap in the great mountain barrier the stream of settlers headed by the celebrated Daniel Boone poured into Kentucky and the Ohio Valley from Virginia and North Carolina in the last half of the eighteenth century. It is also of strategic military importance and was the site of notable operations in the Civil War.

The rocks of the cliff on the south face of the Pinnacle consist of Gasper and Ste. Genevieve limestones, which extend to the Mississippi River without notable change of character.

Immediately southeast of Cumberland Gap (see pl. 24), along the Louisville & Nashville Railroad on the left, the Clinton formation with thin beds of fossil iron ore is exposed. At the north portal of the tunnel 2,000 feet (610 meters) southeast of Cumberland Gap and just under the Clinton is limestone carrying a representation of the Brassfield fauna of Ohio (Medina).

In the low col above the tunnel and stratigraphically a little lower than the limestone, a gritty sandstone crops out which carries a few species of fossils, including *Helopora fragilis*, *Pterinea* (one or more species), and other small pelecypods

identical with or closely related to species of the Albion sandstone (upper Medina) of New York. This area is in the region in which there is lateral transition northwestward from the more quartzose Tuscarora and Clinch facies in the Appalachian Valley on the southeast to the fossiliferous Brassfield facies of the same horizon in Ohio and Ontario on the northwest.

Below the gritty sandstone just mentioned is partly reddish argillaceous limestone and shale of the Juniata horizon, in this region designated Sequatchie formation because it is approaching the limy fossiliferous Richmond facies of the Juniata, etc., in Sequatchie Valley, Tennessee, about 100 miles (161 kilometers) southwest of Cumberland Gap. This limestone here has yielded *Drepanella richardsoni* and other fossils of the Richmond of the type region of Ohio and Indiana. Below it follow the Reedsville, the Trenton, which crops out near Harrogate, and, southeast of that place, a wide belt of typical Lowville limestone about 1,000 feet (305 meters) thick.

In the top of the Reedsville and just under the Sequatchie are many species of pelecypods of the omnipresent *Orthorhyncula* fauna. *Orthorhyncula linneyi* also occurs. In the Trenton occur *Rhynchotrema increbescens* and *Hebertella* cf. *H. frankfortensis*.

The passage to the Nittany (Beekmantown), 3 miles (4.8 kilometers) southeast of Cumberland Gap, is marked by much dense gray chert scattered about on the surface, and this continues for some distance down the slope toward the Powell River. A short distance southeast of the summit of the hill where the descent to the Powell River begins a little chert with the *Helicotoma uniangulata* fauna marks the division between the Ordovician Nittany (Beekmantown) and the Copper Ridge dolomite. The Copper Ridge is well exposed in the road cut nearly down to the Powell River and contains a few beds of coarse sandstone characteristic of the Copper Ridge and Conococheague.

South of the Powell River nearly to Tazewell, Tennessee, the route is for most of the way on slightly undulating dolomite (Copper Ridge) on the broad crest of a low anticline. At Tazewell the road passes over the Stones River limestone and then the Lowville limestone on the southeast limb of the anticline.

Four miles (6.4 kilometers) southeast of Tazewell the Rome formation is overthrust from the southeast onto the Upper Ordovician (Reedsville) shale and between this fault and the Saltville fault, 1½ miles (2.4 kilometers) southeast of Clinch Mountain, the belts of Cambrian (including the Ozarkian of Ulrich) and Ordovician rocks, dipping invariably to the southeast, are thrice repeated by thrust faulting.

About a mile (1.6 kilometers) south of the bridge across the Clinch River are large glades in the very fossiliferous Ottosee

limestone which afford excellent conditions for collecting fossils. The Ottosee is succeeded by the Moccasin with blue layers containing *Beatricea gracilis*, a guide fossil of the Lowville, and this in turn abuts against the Rome formation, which is overthrust from the southeast on a fault that crops out a short distance north of Indian Creek. Then the Rome, Rutledge, Rogersville, Maryville, and Nolichucky are crossed to the entrance to the gap through Copper Ridge, in which is the type section of the Copper Ridge dolomite. Overlying the Nolichucky at the entrance to the gap is about 2,600 feet (792 meters) of thick-bedded dolomite, of which the lower 1,200 feet (366 meters) is Copper Ridge and the rest Beekmantown. The Beekmantown is succeeded at the north entrance to the gap, less than half a mile (0.8 kilometer) northwest of Thorn Hill, by a good thickness of the light dove-colored limestone of the Mosheim.

At the crest of Clinch Mountain the red Juniata is underlain by the *Orthorhyncula* zone (of Cincinnatian age) with *Orthorhyncula*, and this is the most southern place in the Valley at which it is known.

At the fault 1½ miles (2.4 kilometers) southeast of Clinch Mountain the Rome formation is thrust over the Price formation (basal Mississippian). This is the Saltville fault, crossed earlier in the day northwest of Bristol.

For 6 miles (9.6 kilometers) southeast of the Saltville fault the route crosses a broad syncline with a wide area of Copper Ridge dolomite in the middle flanked by Upper Cambrian formations cropping out on both sides. From the south side of another small fault to Morristown the road first crosses narrow belts of Maryville and Nolichucky onto a broad area of Copper Ridge and Beekmantown dolomite extending to Morristown. Low undulating southeast dip accounts for the width of this outcrop.

MORRISTOWN, TENNESSEE, TO BRISTOL, VIRGINIA

The route from Morristown back to Bristol, Virginia, is covered largely by the Morristown, Greeneville, Roan Mountain, and Bristol folios of the Geologic Atlas of the United States and is not shown on a route map.

The route follows for 7 miles (11 kilometers) the road northeast of Russellville, along undifferentiated dolomites of Upper Cambrian and Beekmantown age, then turns eastward to Rogersville Junction (Bull Gap).

About 1½ miles (2.4 kilometers) west of this town begins a good exhibit of the sequence from the top of the Beekmantown dolomite to the Moccasin limestone exposed in Bull Gap. The sequence is Beekmantown, a hiatus (lowermost Stones River and

Mosheim absent), Lenoir limestone, another hiatus (Holston marble absent), Whitesburg limestone, Athens shale, perhaps Tellico formation, Ottosee formation, and Lowville and Moccasin limestones; the four preceding the last are included in the Blount group (upper Chazy), developed only in parts of the Great Valley between northern Virginia and Alabama.

After crossing a small creek about on the Athens-Whitesburg contact, 1 mile (1.6 kilometers) west of Rogersville Junction, a belt of Athens shale over a mile wide and dipping strongly east is crossed. The Athens seems to be more than 3,000 feet (914 meters) thick here. Between Rogersville Junction and Bull Gap through Bays Mountain the upper part of the Athens (shale and thin limestone) and the Tellico and Ottosee (shale and limestone) are crossed. In the gap the Moccasin is, as usual, blue limestone below and red rock above. It lies in a compressed syncline and makes Bays Mountain.

Southeast from Bull Gap a belt 5 miles (8 kilometers) wide of undifferentiated Ottosee and Athens is crossed in reverse order, thence for 9½ miles (15 kilometers) to Greeneville alternating belts of the above-named units in anticlines and synclines are crossed.

Mosheim, the type locality of the Mosheim limestone, lies about 1 mile (1.6 kilometers) south of the highway followed by the excursion and 7 miles (11 kilometers) west-northwest of Greeneville. The Mosheim there exposed may be 100 feet (30 meters) thick.

A mile west of Greeneville a fault brings the Honaker (Upper and Middle Cambrian) up against Athens shale. After crossing a narrow outcrop of Nolichucky shale 1½ miles (2.4 kilometers) northwest of Greeneville, the road passes onto Conococheague limestone, on which Greeneville is partly built. Probably a narrow strip of Nittany also underlies Greeneville, and in the southeast environs of the town is a narrow strip of Athens.

From Greeneville to Limestone the highway crosses obliquely a belt 7 miles (11 kilometers) wide occupied mainly by Conococheague limestone, broken by narrow anticlinal bands of Honaker and Nolichucky.

For about 1 mile (1.6 kilometers) northwest of Limestone there is, along Mill Brook, an almost completely exposed section of vertical strata beginning on the northwest with the Nolichucky shale and including in turn southeastward the Conococheague limestone (Ozarkian of Ulrich) with characteristic sandstone beds, 1,650 feet (503 meters) thick; limestone and dolomite of the Beekmantown, about 1,200 feet (366 meters) thick; Lenoir limestone, 50 feet (15 meters) thick; and Athens shale, several hundred feet thick, occupying a syncline. (See fig. 9.) In the

town of Limestone the Lenoir limestone crops out conspicuously from beneath the Athens on the east limb of the syncline.

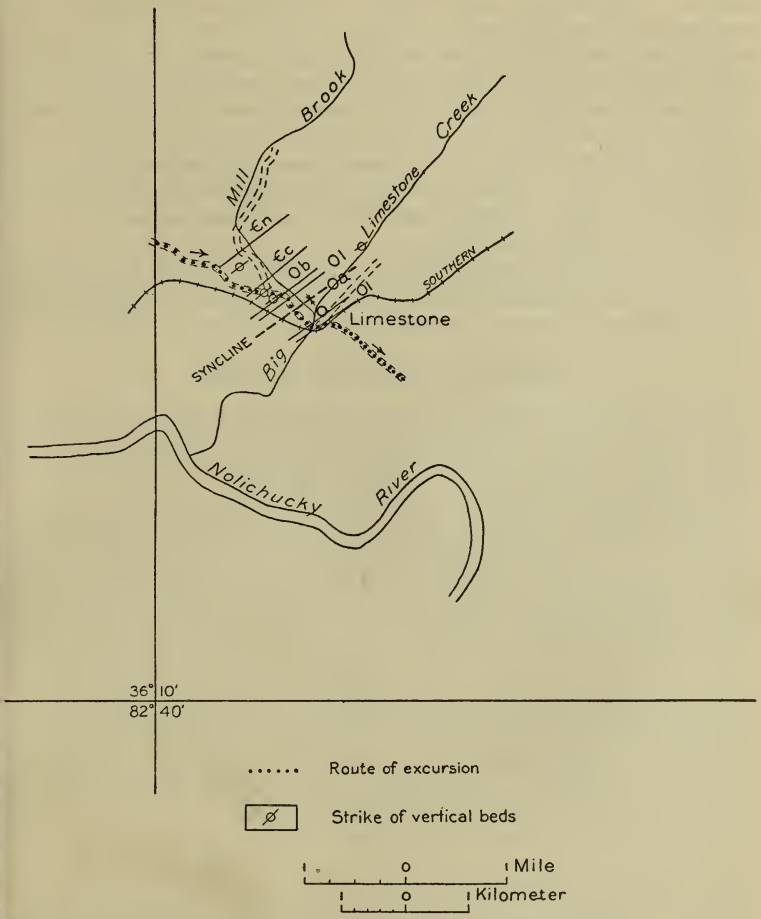

FIGURE 9.—Map and section along Mill Brook 1 mile (1.6 kilometers) northwest of Limestone, Tennessee. Shows a fully exposed section from Nolichucky shale to Athens shale. Oa, Athens shale; Ol, Lenoir limestone; Ob, Beekmantown limestone; €c, Conococheague limestone; €n, Nolichucky shale.

From Limestone to Johnson City and beyond to the small town of Watauga the road is mainly on undifferentiated Conococheague and Beekmantown, mostly Nittany.

Cherokee Mountain, an outer ridge of the Appalachian Mountains, is first seen from Jonesboro. Its north end stands out as a prominent peak when viewed from the west. It is composed of complexly folded and faulted Cambrian quartzites and shales forming a klippe, or outlying remnant of an overthrust mass, separated by erosion from its roots in the mountains 5 to 10 miles (8 to 16 kilometers) to the southeast. It is for three-fourths of its periphery bordered by the Conococheague limestone of the valley, over which the quartzites of Cherokee Mountain have been thrust. (See pl. 25.) The structure is greatly complicated by minor faulting and slicing, as interpreted by Keith in the Roan Mountain folio.

For 3 miles (4.8 kilometers) between Watauga and Piney Flats a syncline of Athens shale is crossed, and thence through Bluff City to Bristol the road is mostly onConococheague and Nittany.

BRISTOL TO ROANOKE, VIRGINIA

From Bristol a side trip will be taken eastward over Holston Mountain and Iron Mountain on the road to Mountain City, Tennessee, to see the older siliceous Cambrian sequence and the great klippe of these rocks. (See pl. 26.)

From Bristol southeast for 2 miles (3.2 kilometers) the road is mostly on Conococheague, which also underlies the city. A narrow belt of Nolichucky and Honaker faulted against the top of the Beekmantown is then crossed, and for the next 2 miles the road follows the top of the Beekmantown, skirting the southwest end of a broad syncline of Athens shale that pitches northeast away from the road. The southeast angle of this syncline is crossed where the road bends sharply to the northeast, 4 miles (6.4 kilometers) from Bristol. The road then follows a northeast course on Conococheague limestone for 6 miles (9.6 kilometers) to a sharp southeast bend about 1 mile (1.6 kilometers) northwest of the South Fork of the Holston River.

About half a mile (0.8 kilometer) from the river the road crosses an outcrop of Lenoir limestone about 25 feet (7.6 meters) thick carrying the Lenoir (middle Chazy) guide fossil *Maclurea magna*. The contact with the overlying Athens shale is exposed, the Holston and Whitesburg limestones being absent. The shale close to the base is full of Normanskill (Glenkiln) graptolites. The road is on Athens for about 5 miles (8 kilometers), and across this wide belt the shale dips steeply southeast and appears to be 5,000 to 10,000 feet (1,524 to 3,048 meters) thick but probably is much less owing to unobserved folding. The black shale has interbedded coarse greenish arkosic sandstone, a facies which is confined to the southeastern belts of the Athens and is in sharp contrast with the black limestone facies of some

of the northwestern belts, as seen at Harrisonburg, Virginia. The Normanskill (Athens) graptolites occur in the shaly partings in the sandstone.

At the west foot of Holston Mountain is the great Holston-Iron Mountain overthrust fault, whereby the Unicoi sandstone (basal Cambrian) is thrust over the Athens shale (Ordovician) on a nearly flat plane. (See pl. 26.) Athens graptolites have been collected about 200 feet (61 meters) vertically below the fault. The stratigraphic throw of the fault may be as much as 15,000 feet (4,572 meters) from beds near the base of the Cambrian to the Athens shale. The horizontal displacement is probably over 10 miles (16 kilometers). On the slope of Holston Mountain, above the fault, about 1,000 feet (305 meters) of Unicoi quartzite, dipping 30°–50° SE., is passed through. Next to the fault is arkosic quartzite, probably basal beds of the Cambrian, which are crushed and greatly disturbed and iron stained near the fault. Above are hard white feldspathic quartzite, red ferruginous quartzite, and thick-bedded light-gray quartzite, all Unicoi. In ascending the main ridge to the top of Holston Mountain the route passes over possibly 2,000 feet (610 meters) of Hampton shale, which is largely gray to buff shale with thin-bedded dark quartzite. Just below the top of the mountain thick blocky white quartzite at the base of the Erwin is reached. Thick-bedded gray quartzite of the Erwin crops out on the east (dip) slope of the mountain to Shady Valley, and the top is marked by highly ferruginous beds. The Erwin is about 1,000 feet (305 meters) thick. Shady Valley is a syncline of Shady dolomite, which is named from this valley.

On ascending Iron Mountain, to the east, the same Cambrian quartzites are encountered in reverse (descending) order, dipping 30°–50° NW. On the southeast slope of Iron Mountain a thin bed of amygdaloidal greenstone is inclosed in coarse arkosic quartzite. This is interpreted as a lava bed within the Cambrian.

Formations between Bristol, Virginia, and Mountain City, Tennessee

System	Series	Group	Formation	Thickness	
				Feet	Meters
Ordovician.		Blount.	Athens *Whitesburg.* *Holston.*	5,000±	1,524±
		Stones River.	Lenoir *Mosheim.* *Murfreesboro.*	100	30
			Jasper (Arkansas). *Joachim* (Arkansas). *St. Peter* (Arkansas). *Everton* (Arkansas).		
		Beekmantown.	Post-Nittany Nittany *Stonehenge.*	100 400	30 122
Cambrian.			*Chepultepec.* Conococheague *Bibb* (Alabama). *Ketona* (Alabama). *Brierfield* (Alabama). Elbrook Rome (Watauga) Shady Erwin Hampton Unicoi	2,000 1,500 1,200 1,000 650 1,800 1,000+	610 457 366 305 198 549 305+
			Pre-Cambrian.		

At the east foot of Iron Mountain arkosic sandstone at the base of the Cambrian is underlain by thin almost horizontally sheared pre-Cambrian granite, which in turn overlies sheared and brecciated Cambrian dolomite. This fault contact is believed to be the east edge of the Holston-Iron Mountain overthrust, which emerges on the west slope of the mountain, the mass of Holston Mountain, Shady Valley, and Iron Mountain forming a great klippe. The fault plane of the klippe has been eroded over the limestone and shale valley to the southeast to and beyond Mountain City, and its roots are in Pine Mountain, 3½ miles (4 kilometers) east of Mountain City, where pre-Cambrian granite is thrust over Shady dolomite and Rome (Watauga) shale. (See pl. 26.)

The route is retraced to Bristol. Thence the Great Valley is followed to Roanoke. The limestone formations are the same as those previously seen, and only special features will be described.

For 2 miles (3.2 kilometers) southwest of Marion the limestone facies of the Athens is exposed in the railroad cuts. This exposure seems to be in a fenster or half fenster in the Pulaski overthrust mass.

Near the filling station at Rural Retreat is the south end of Pine Ridge, which extends northeast to Wytheville. This ridge follows a syncline occupied by the Athens shale, with black shale on the limbs and thick-bedded sandstone in the axis, which follows the crest of the ridge. This is a distinct sandstone facies of the Athens and belongs to the overthrust mass that has been moved several miles northwestward from its original position. It is the same facies as that of the wide area of Athens crossed on the trip to Mountain City earlier in the day. No limestone is present in this facies of the Athens.

The highway along the southeast base of Pine Ridge is on Conococheague limestone with Beekmantown limestone between the highway and the base of the ridge.

East from Wytheville the Conococheague is first passed in the northeast environs of the town, and then the Elbrook limestone to a point a quarter of a mile (0.4 kilometer) beyond the railroad crossing, where the road passes onto the red Rome shale, which is exposed in the field on the right. About 2 miles (3.2 kilometers east of Wytheville, near the east end of the bridge over Reed Creek, the road crosses the Pulaski overthrust and passes from the Rome shale of the overthrust mass onto the southeast edge of a fenster in the thrust block, as shown in Plate 27. This is one of the most perfect examples of a fenster, being rather a small area of autochthonous rocks completely surrounded by a single formation—the Rome (Watauga).

The conspicuous bluff of vertical limestone on the left in plain view on approaching the fenster is Conococheague. The road keeps within the fenster for about a mile (1.6 kilometers), being on Conococheague limestone and Beekmantown (Nittany) dolomite, both of which are fully exposed on the left.

The Athens in this fenster is of the limestone facies, the same as that in the fenster or half fenster at Marion.

After passing through the fenster the road recrosses the Pulaski overthrust back onto the Rome (Watauga) shale, which it follows to the head of the sharp meander of Reed Creek just east of the filling station and 2½ miles (4 kilometers) east of Fort Chiswell. (See pl. 27.) In the bluff at the head of this meander is an excellent display of some of the types of weathered calcare-

ous rocks of the Rome (Watauga) formation, including beds of yellow ocher or ocherous rock.

Just beyond this meander the road crosses onto the Elbrook limestone in the southwest point of a syncline that pitches northeastward; it keeps on the Elbrook for 3 miles (4.8 kilometers), crosses a narrow strip of Rome shale and then crosses the Pulaski overthrust from the Rome onto Chambersburg limestone, which it follows for 4 miles (6.4 kilometers). This is the southwesternmost known occurrence of Chambersburg limestone. The road then crosses obliquely the Athens shale onto the Beekmantown limestone, the Lenoir and Mosheim limestones, which generally intervene between the Athens and Beekmantown, being locally absent here.

The ridge on the left (north) of the road from Reed Creek to and 1½ miles (2.4 kilometers) beyond Draper is Draper Mountain, composed largely of Clinch sandstone. The prominent knob at the southwest end of Draper Mountain is Hamilton Knob, and that at the northeast end is Peak Creek Knob.

About 3 miles (4.8 kilometers) southwest of Draper the route turns north and crosses Draper Mountain to Pulaski. At and a little beyond the first curve in the road are good exposures of Chambersburg limestone repeated by small folds. Above it in the synclines is a small thickness of basal Martinsburg shale and sandstone. For about three-quarters of a mile (1.2 kilometers) north of the curve the road crosses an anticline with poorly exposed Athens shale and limestone. At the curve at the beginning of the ascent of Draper Mountain the Martinsburg shale is exposed and continues upward to the beginning of the red Juniata shale associated with white and gray sandstone perhaps 300 feet (91 meters) thick. At its base is the omnipresent *Orthorhyncula* zone of the Martinsburg with *Orthorhyncula linneyi* and large and abundant *Lingula nickelsi*. The dip is nearly vertical. At the top of Draper Mountain is a good display of white Clinch sandstone, followed by sandstone and ferruginous and green shale of the Clinton, perhaps 100 feet (30 meters) thick. This is followed by crinoidal sandstone 30 feet (9 meters) thick, probably of Helderberg (Becraft) age, and that in turn by about the same thickness of chert of Onondaga age. Above the Onondaga is perhaps 100 feet (30 meters) of black shale, possibly of Marcellus age. Then follows a large thickness of soft pink-weathering shale with goniatites (Probeloceras) and other fossils of lower Portage (Naples) age and probably still older black shale of Marcellus age. This is succeeded lower down the slope by Brallier shale, Chemung formation, and Pocono formation with coal near the top, half a mile (0.8 kilometer) or so south of Pulaski. This section is noteworthy

because at the west base of Hamilton Knob, 6 miles (9.6 kilometers) southwest, the Juniata, Clinton, Helderberg, and Onondaga are absent—the Clinch rests on the *Orthorhyncula* zone and immediately underlies the black shale.

Just south of Pulaski the road passes over the Pulaski fault again onto the overthrust mass of Rome (Watauga shale), then in the northwest environs enters on Elbrook limestone, which it follows for 5 miles (8 kilometers), and then onto a large oval area of Conococheague limestone, which extends from a point 1½ miles (2.4 kilometers) west of Dublin to and beyond the railroad crossing 5 miles (8 kilometers) northeast of Dublin. There are good exposures of the Conococheague along this stretch. About 6 miles (9.6 kilometers) northeast of Dublin the road passes onto the Elbrook limestone, which it follows to the top of the hill 1½ miles (2.4 kilometers) beyond Radford, where it crosses over the Pulaski fault again onto Upper Devonian black shale in a fenster which the road follows for several miles. At the left is Price Mountain, formed of Price sandstone (Mississippian) above the black shale in the fenster. About 4 miles (6.4 kilometers) east of Radford the road recrosses the Pulaski fault and passes in succession onto Elbrook, Conococheague, and Beekmantown limestones to Christiansburg. The road from Christiansburg to Roanoke was traveled previously and will not be described here.

The top of the Blue Ridge Plateau southwest of Roanoke at an altitude of 3,000 feet (914 meters) is a remnant of an old peneplain called the Summit peneplain (possibly equivalent to the Kittatinny in Pennsylvania). The drainage on the plateau flows sluggishly in shallow valleys in general southwestward, away from the brink of the escarpment, which is 1,000 feet (305 meters) high and 2,000 feet (610 meters) above the Roanoke River. (See fig. 10.) The peneplain surface extends at this level several miles to the south. Above the plateau surface there are higher knobs and peaks, which are remnants of an older surface about 4,000 feet (1,219 meters) in altitude.

ROANOKE, VIRGINIA, TO WASHINGTON

The road from Roanoke to a point east of Montvale follows a valley underlain by the Waynesboro formation and Elbrook limestone. Much of the valley around Roanoke is a flat floor about 1,000 feet (305 meters) above sea level—the Valley Floor peneplain. Mills and Coyners Mountains, west of the road 4 miles (6.4 kilometers) from Roanoke, are in a fenster of Ordovician, Silurian, and Devonian rocks rising through the overthrust Lower Cambrian limestone of the Pulaski overthrust block. This was seen from the west on entering Roanoke on the fourth day.

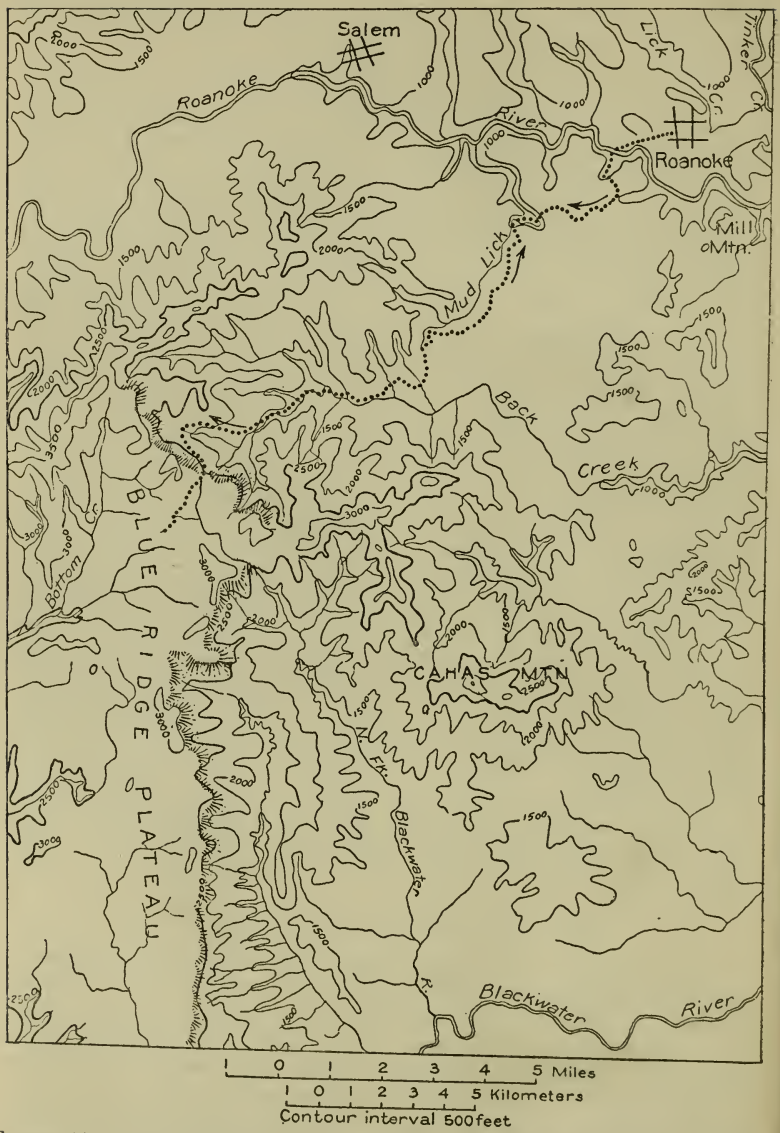

FIGURE 10.—Blue Ridge Plateau, an old erosion surface southwest of Roanoke, Virginia

The valley around Montvale is a semifenster in an overthrust of pre-Cambrian rock and Unicoi quartzite; Porters Mountain, on the east, and the Blue Ridge, on the west, are parts of this thrust block. (See pl. 18.)

Two miles east of Montvale the road crosses a deep reentrant in the front of the thrust block and enters the pre-Cambrian crystalline area of the Blue Ridge anticlinorium through the gap of Goose Creek, at an altitude of 1,000 feet (305 meters). This flat valley is also a part of the Valley Floor peneplain. No route map covers this part of the trip.

Crystalline rock formations of the Piedmont and Blue Ridge provinces

	Blue Ridge-Catoctin Mountain anticlinorium	Eastern belt
Triassic.	Sedimentary rocks and intrusive diabase.	
Late Paleozoic.		Petersburg granite.
Ordovician.		Quantico slate and associated rhyolite.
Cambrian.	Weverton quartzite. Loudoun formation.	
Pre-Cambrian.	Felsite dikes. Blue quartz pegmatite (albitite). Marshall granite. Catoctin greenstone. Hypersthene granodiorite. Aporhyolite. Metagabbro, metaperidotite, soapstone, amphibolite, and hornblende schist. Lovingston granite gneiss. Lynchburg gneiss. White marble.	Pegmatite. Granite ("Columbia"). Greenstone and aporhyolite. Metagabbro. Wissahickon schist. Cockeysville marble.

The road crosses the Marshall granite, which has few exposures for 8 miles (13 kilometers) but where exposed to the south is much crushed by thrust faulting. Six miles (9.6 kilometers) to the north the twin Peaks of Otter, made of intrusive hypersthene granodiorite, rise sharply to altitudes of 3,875 and 4,001 feet (1,182 and 1,220 meters).

Two miles (3.2 kilometers) east of Bedford there is a narrow belt of Lovingston granite gneiss intruded into the Lynchburg gneiss, on which Bedford is located.

For 14 miles (23 kilometers) east to Forest the road crosses Lovingston granite gneiss with areas of Lynchburg gneiss. Good outcrops of the granite gneiss are seen at the Otter River bridge.

East of Forest to Lynchburg the rock is Lynchburg gneiss, the oldest sedimentary rock of the region. It is well exposed in anticlinal folds on the left bank of the James River northeast of Lynchburg and is injected by hornblende gabbro.

Lynchburg is built on a series of river terraces which rise in three steps from the James.

After crossing the James the road goes north 18 miles (29 kilometers) to Amherst Courthouse across Lynchburg gneiss injected with Lovingston granite gneiss. The Lovingston extends 11 miles (18 kilometers) north of Amherst to Claypool, where it is intruded by a white pegmatite composed of albitized feldspar and blue quartz. This rock carries rutile, which is mined at Roseland by the American Rutile Co., and ilmenite and rutile are mined 2 miles (3.2 kilometers) north of the road from dikes of nelsonite, an ultrabasic igneous rock composed of the minerals ilmenite and apatite, locally with rutile as the dominant mineral.

These deposits will be seen in greater detail on excursion B–6.

Near Roseland the road turns south to Colleen, thence north through Lovingston granite gneiss, which forms mountains 2,000 feet (610 meters) high on both sides of the road. To the west can be seen the higher summits of the Blue Ridge at about 3,500 feet (1,067 meters).

The Lovingston granite gneiss crops out conspicuously to Hickory Creek, 3 miles (4.8 kilometers) east of the Rockfish River, where a thrust zone in the pre-Cambrian rocks is exposed; the granite gneiss with injection hornblende gneiss is crushed to an augen gneiss and to granite mylonite. The road follows this shear zone northeast to Covesville in a valley due to the greater softness of the augen gneiss.

For 8 miles (13 kilometers) northeast of Covesville to the outskirts of Charlottesville the road passes through good exposures of Lovingston granite gneiss.

The University of Virginia is on the western edge of Charlottesville, which is located on hornblende gneiss and infolded Lower Cambrian quartzite and slate, just west of Southwestern Mountain, which forms the eastern edge of the Blue Ridge anticlinorium. Monticello, the former home of Thomas Jefferson, third President of the United States and author of

the Declaration of Independence, is located on a low foothill above the Rivanna River. Charlottesville will be visited by excursions B–4 and B–5. The road follows the breach in the mountains made by this river and then skirts the eastern edge of Southwestern Mountain to Keswick. These mountains are formed of hard metabasalt, a basalt metamorphosed to a green epidote—uralite schist that borders the east and west sides of the Blue Ridge anticlinorium for many miles. It is a part of great lava flows of late pre-Cambrian time. To the northeast at the Potomac River it is the pre-Cambrian basement crossed from Jefferson, Maryland, to Harpers Ferry, West Virginia, on the first day of this trip. The metabasalt weathers to a deep-red soil that is a striking feature of the crystalline belt south of Washington. The deep-red color and great depth of weathering south of the Potomac River are largely the result of a warm climate.

The eastern border of the mountains is a normal fault of Triassic age, west of which the rocks of the Blue Ridge anticlinorium have been uplifted in respect to those on the east.

The rocks east of the fault, which are crossed for 10 miles (16 kilometers) between Keswick and Gordonsville, are pre-Cambrian crystalline schists (Wissahickon schist) of the Glenarm series (Algonkian), intruded by granite and gabbro. This is the western belt of these rocks, and they are phyllitic in appearance, as the result of crushing in late Paleozoic overthrusting which carried them westward over the rocks of the Blue Ridge anticlinorium.

From Gordonsville to Orange, about 10 miles (16 kilometers), the road follows the edge of the metabasalt mountains and passes through basal Cambrian slate and quartzite, which overlie the metabasalt in a narrow synclinal belt near the boundary normal fault.

The Piedmont Upland, which the road follows east of Orange, is very flat and is part of a peneplain long exposed to weathering. The soil is deep, and the surficial part of the soil has been leached to a considerable depth and is sandy, with a little residual iron. The subsoil is thick red-streaked clay with a few fragments of bedrock, and the weathering of the bedrock below the subsoil is very deep, so that fresh rock is exposed only in stream cuts.

The road from Orange to Fredericksburg passes through many battle fields of the Civil War of 1861–1865—the Wilderness, Chancellorsville, Salem Church, and Fredericksburg—which are marked by many battle monuments.

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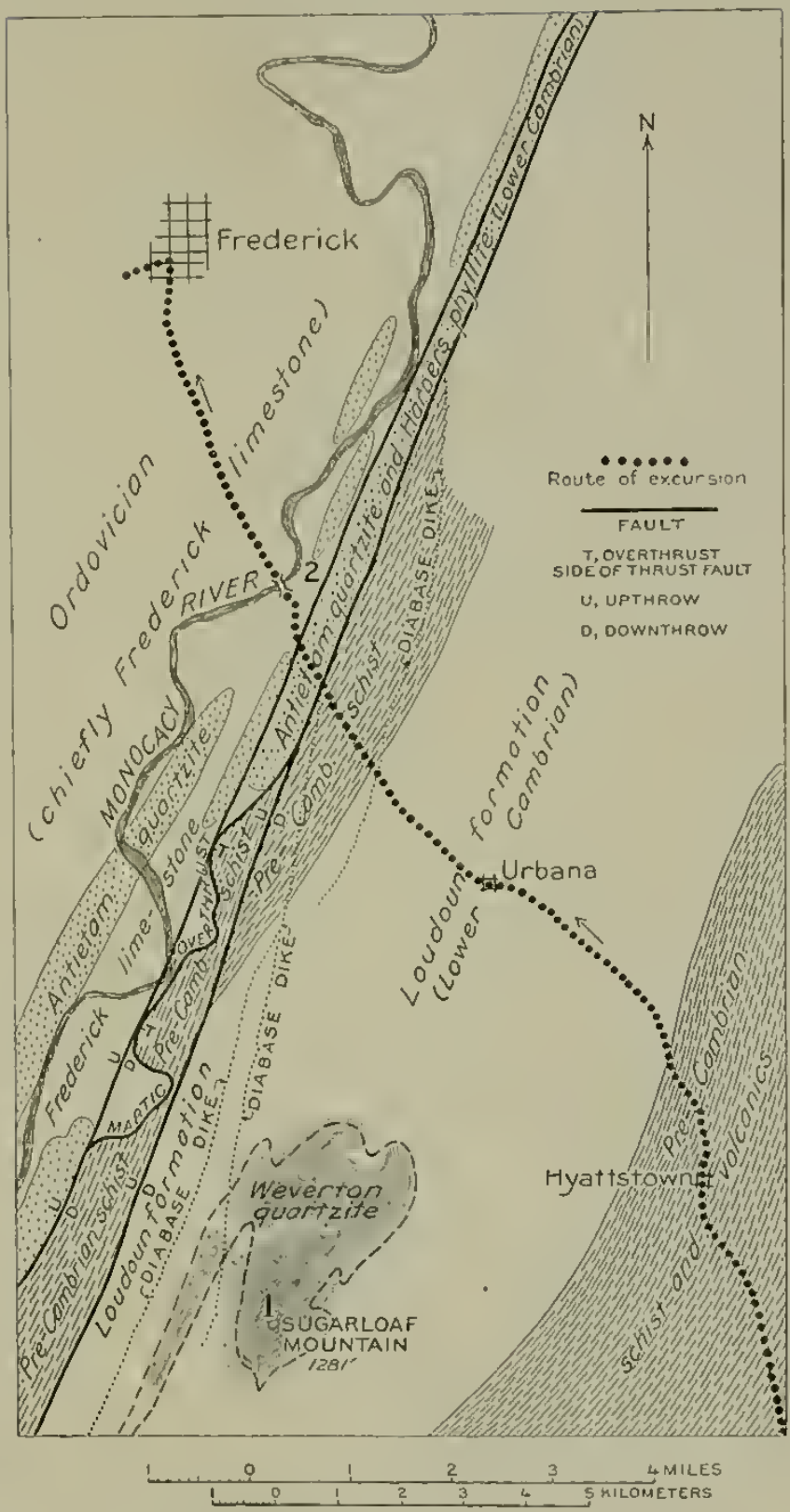
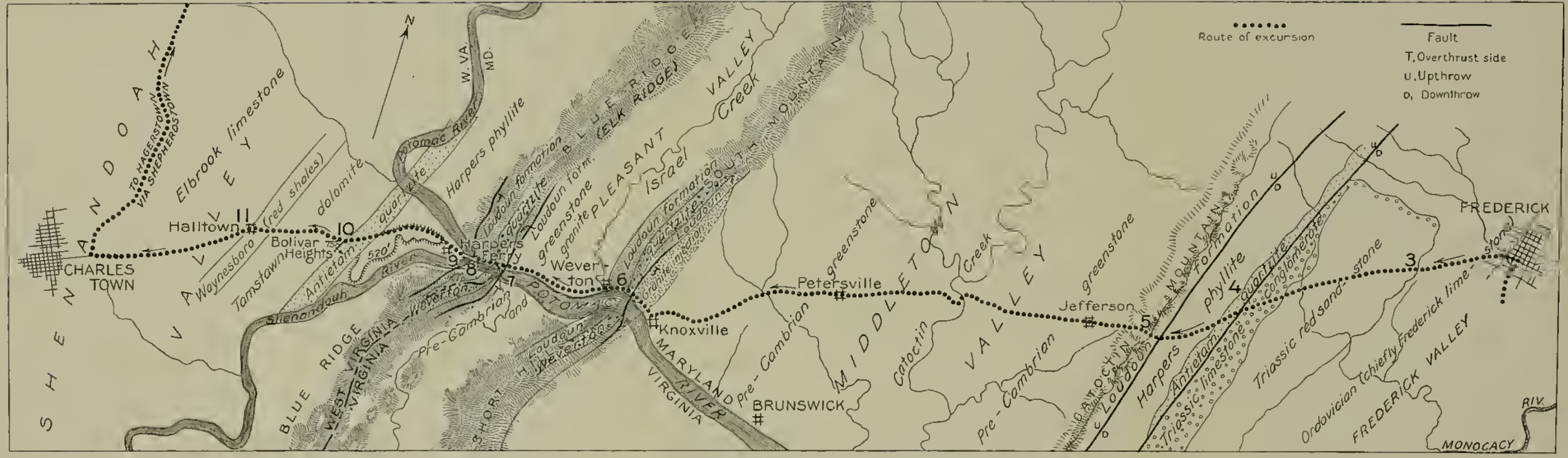
Fredericksburg is at the Fall Line, at the western edge of the Coastal Plain deposits, where they overlap onto the pre-Cambrian crystalline rocks, seen in the rocky bed of the Rappahannock River. For 54 miles (87 kilometers) north to Washington the road crosses Cretaceous and younger deposits.

At Dumfries, at the bridge over Quantico Creek, 20 miles (32 kilometers) north of Fredericksburg, there is an outcrop of late Ordovician blue slate (Quantico), which is in a narrow syncline in the pre-Cambrian crystalline rocks.



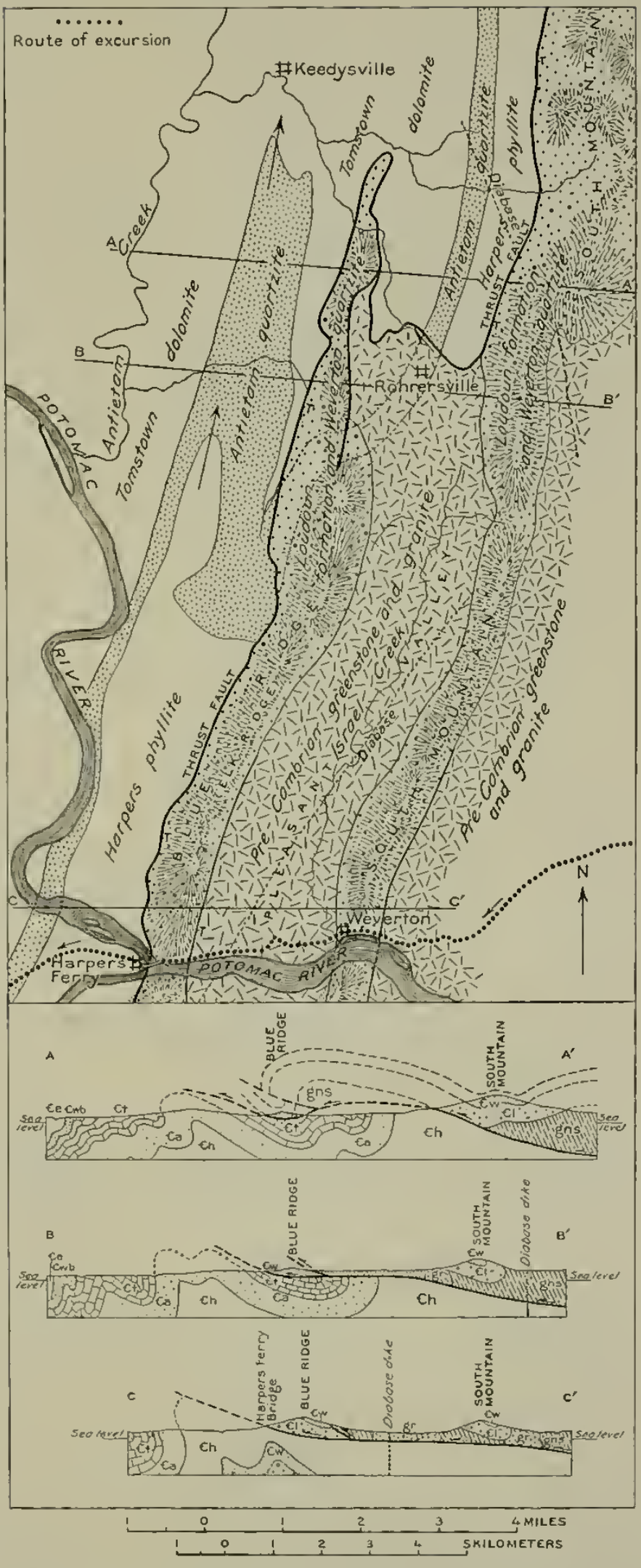
ROUTE MAP, HYATTSTOWN TO FREDERICK, MARYLAND

Numbers indicate localities referred to in text.



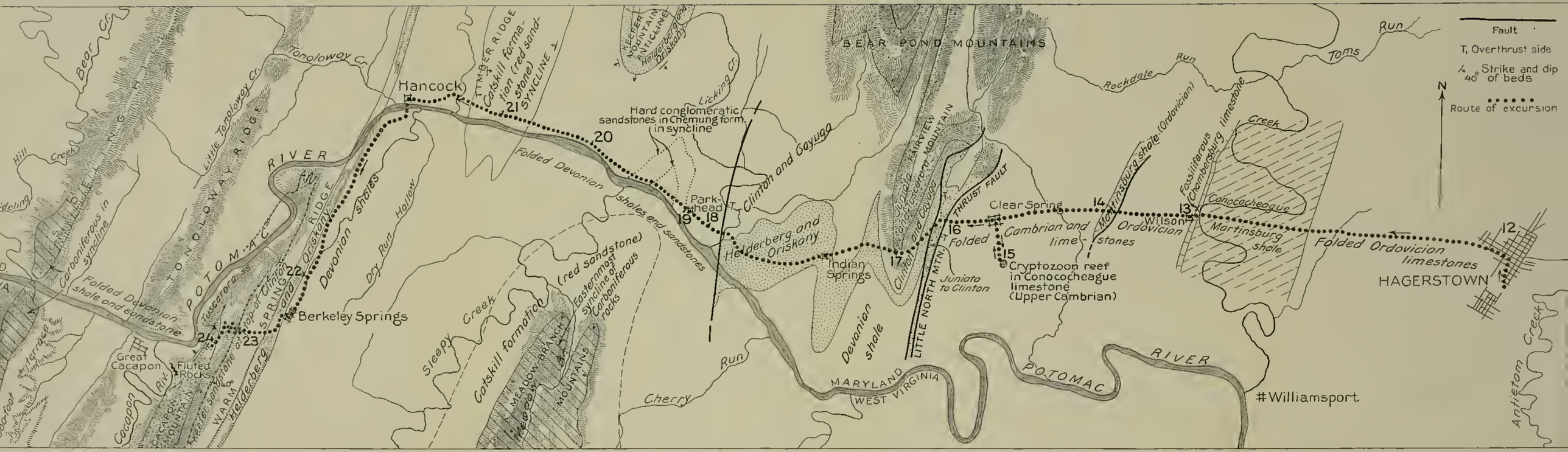
ROUTE MAP, FREDERICK, MARYLAND, TO CHARLES TOWN, WEST VIRGINIA

Numbers indicate localities referred to in text.



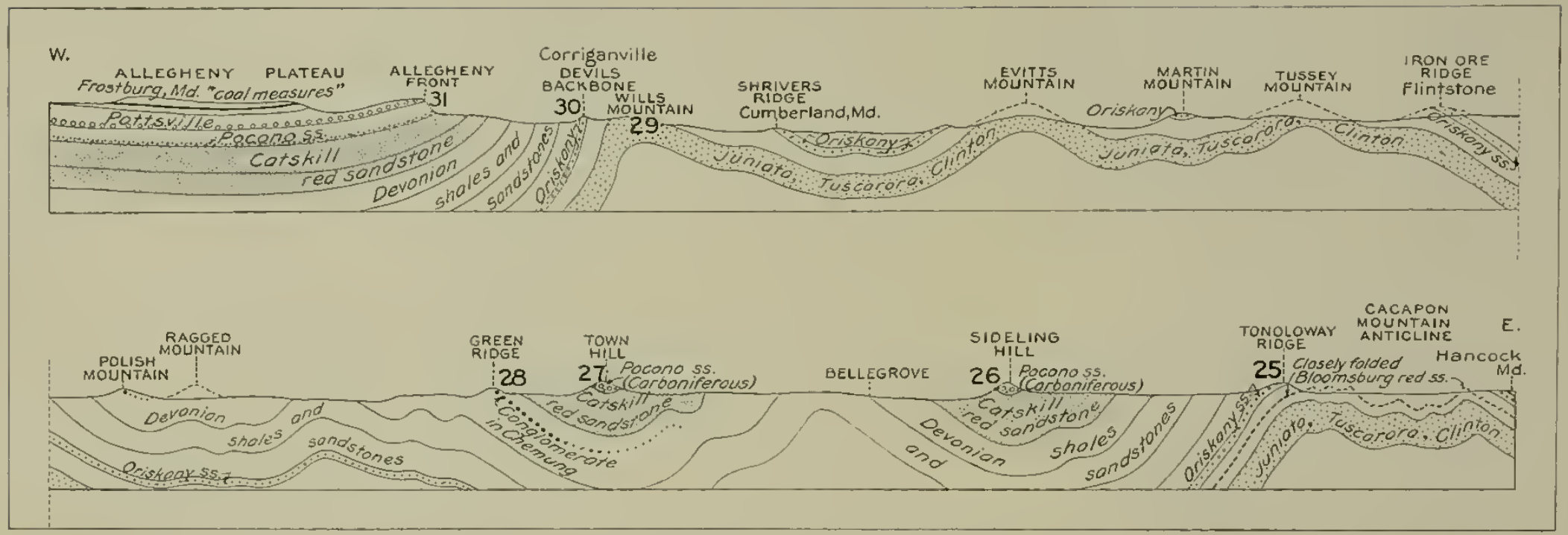
GEOLOGIC MAP AND SECTIONS, AREA NORTHEAST OF HARPERS FERRY, WEST VIRGINIA

Ce, Elbrook limestone; Cwb, Waynesboro formation; Ct, Tomstown dolomite; Ca, Antietam quartzite; Ch, Harpers phyllite; Cw, Weverton quartzite; Cl, Loudoun formation; gns, pre-Cambrian greenstone; gr, pre-Cambrian granite.



ROUTE MAP, HAGERSTOWN, MARYLAND, TO CACAPON MOUNTAIN, WEST VIRGINIA

Numbers indicate localities referred to in text.

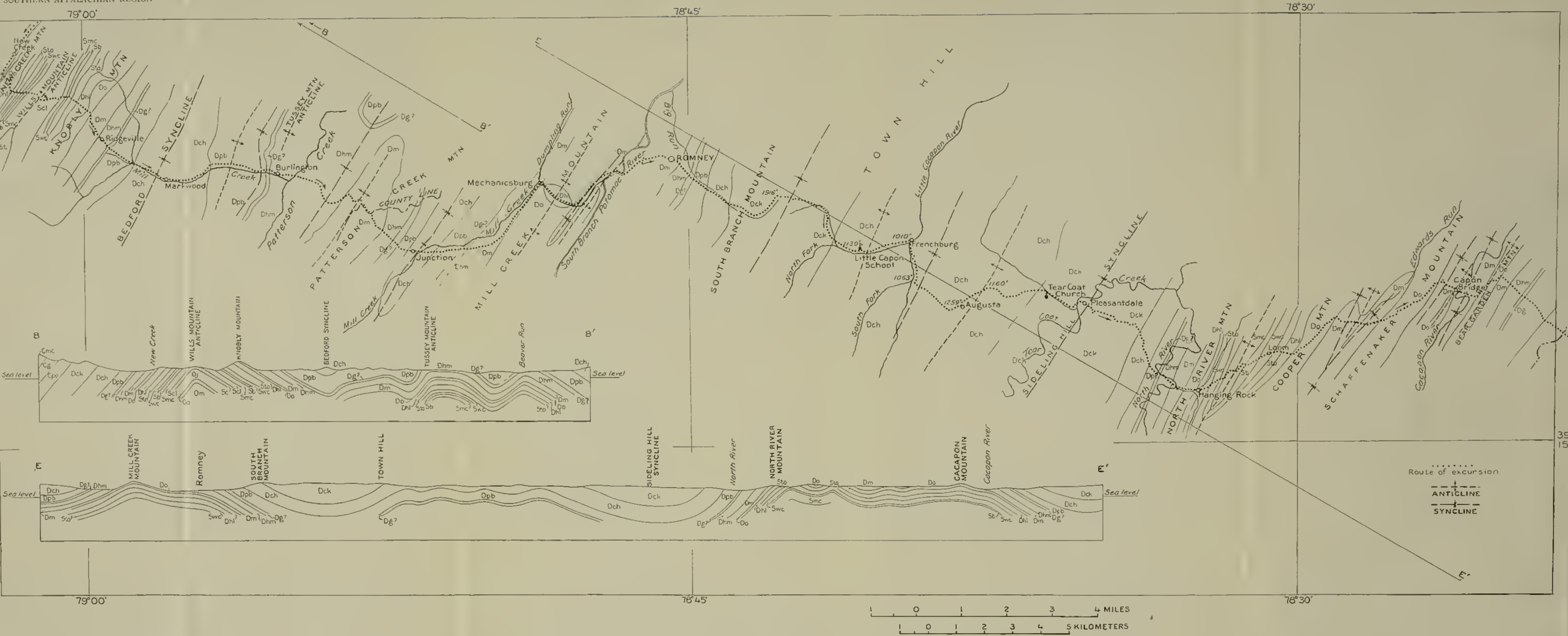


1 0 1 2 3 4 MILES

1 0 1 2 3 4 5 KILOMETERS

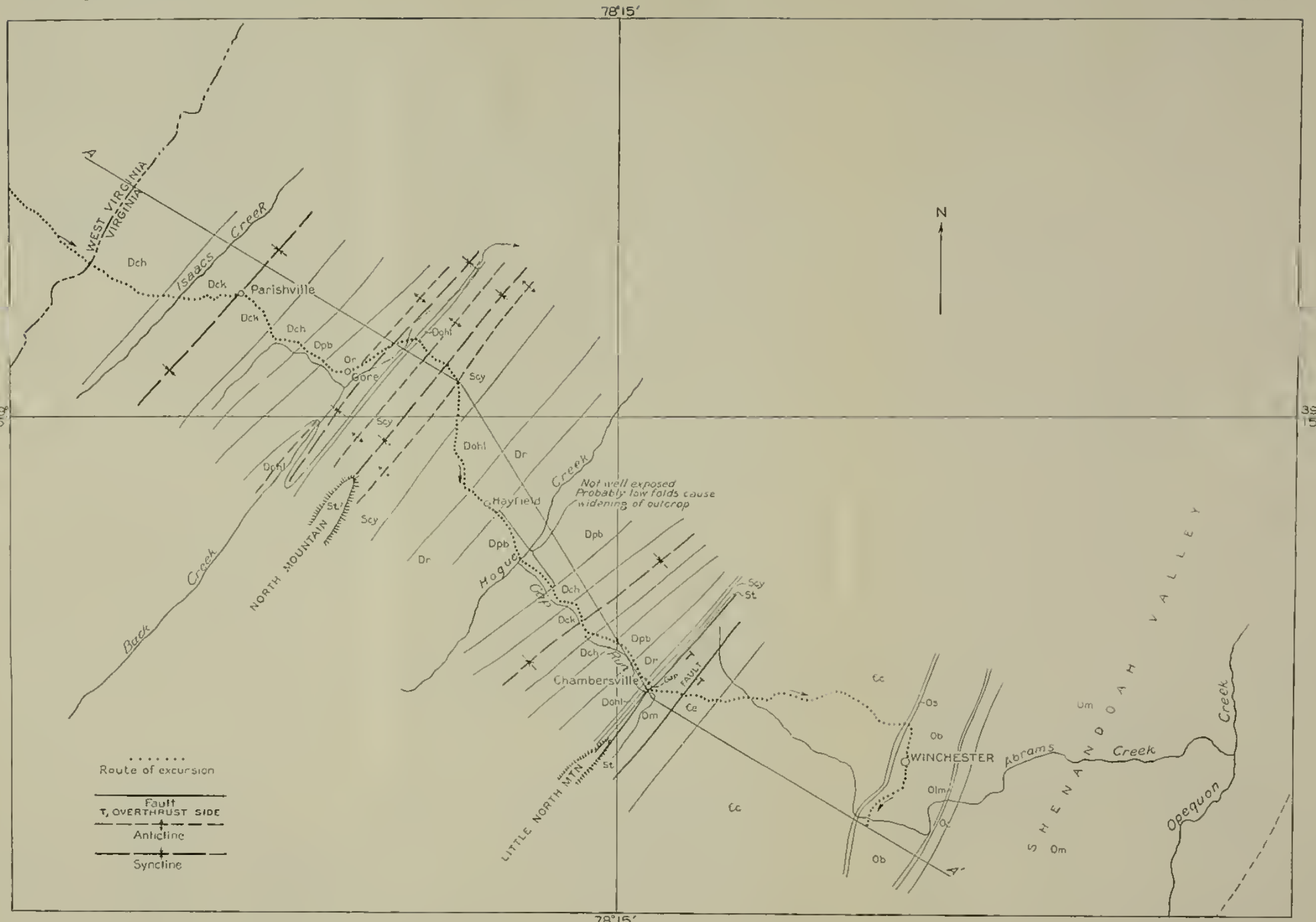
SECTION ALONG ROUTE, HANCOCK TO CUMBERLAND, MARYLAND, AND ALLEGHENY FRONT

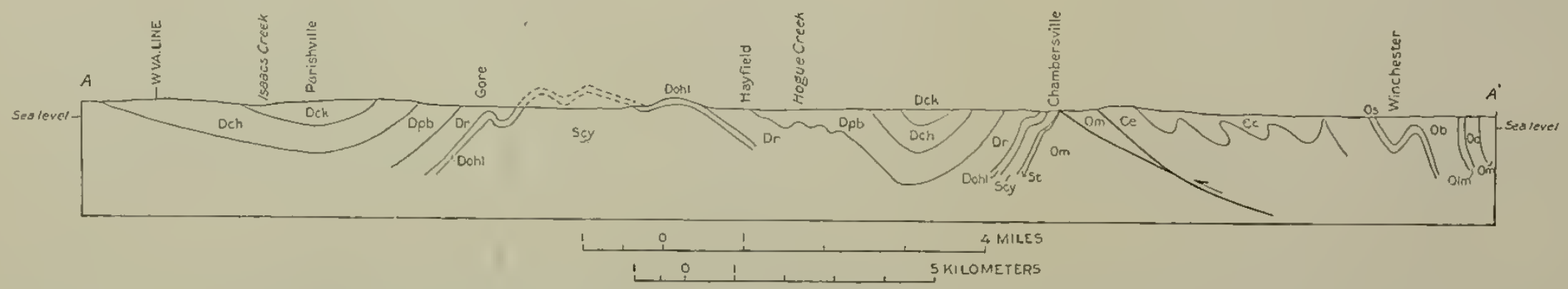
Numbers indicate localities referred to in text.



ROUTE MAP AND SECTIONS, NEW CREEK, WEST VIRGINIA, TO VIRGINIA STATE LINE

Reproduced from reports on Mineral and Hampshire Counties, West Virginia, West Virginia Geological Survey, 1924 and 1927; with changes in nomenclature by Charles Butts. Cmc, Mauch Chunk shale; Cg, Greenbrier limestone; Cpo, Pocono sandstone; Dck, Catskill formation; Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dg?, Genesee? shale; Dhm, Hamilton formation; Dm, Marcellus shale; Do, Oriskany sandstone; Dhl, Helderberg limestone; Sto, Tonoloway limestone; Swc, Wills Creek shale; Sb, Bloomsburg shale; Smc, McKenzie formation; Sel, Clinton formation; St, Sc, Tuscarora quartzite; Oj, Juniata formation; Oo, Oswego sandstone; Om, Martinsburg shale.



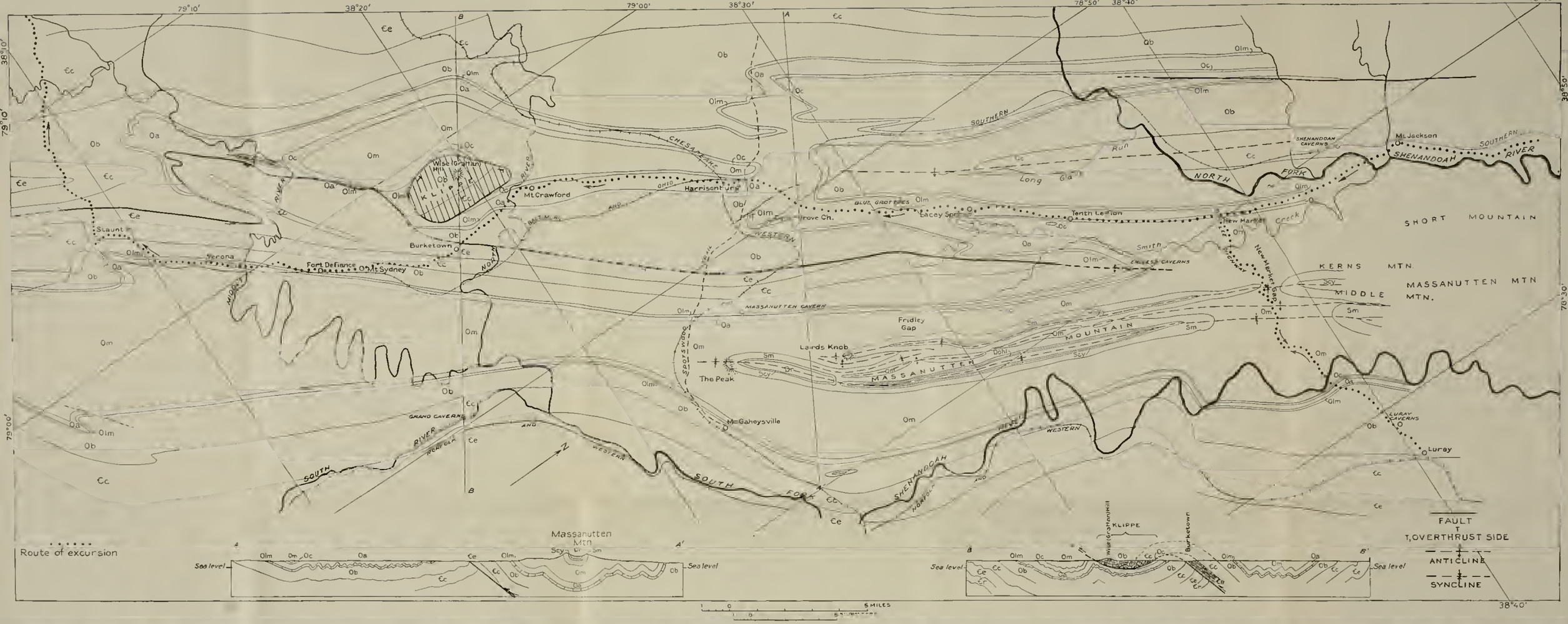


ROUTE MAP AND SECTION, WEST VIRGINIA STATE LINE TO WINCHESTER, VIRGINIA

Dck, Catskill formation; Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dr, Romney shale; Dohl, Oriskany and Helderberg formations; Scy, Cayuga group (McKenzie, Bloomsburg, Wills Creek, Tonoloway); St, Tuscarora sandstone; Om, Martinsburg shale; Oc, Chambersburg limestone; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown limestone (Nittany and post-Nittany); Os, Stonehenge limestone; Cc, Conococheague limestone; Ce, Elbrook dolomite.

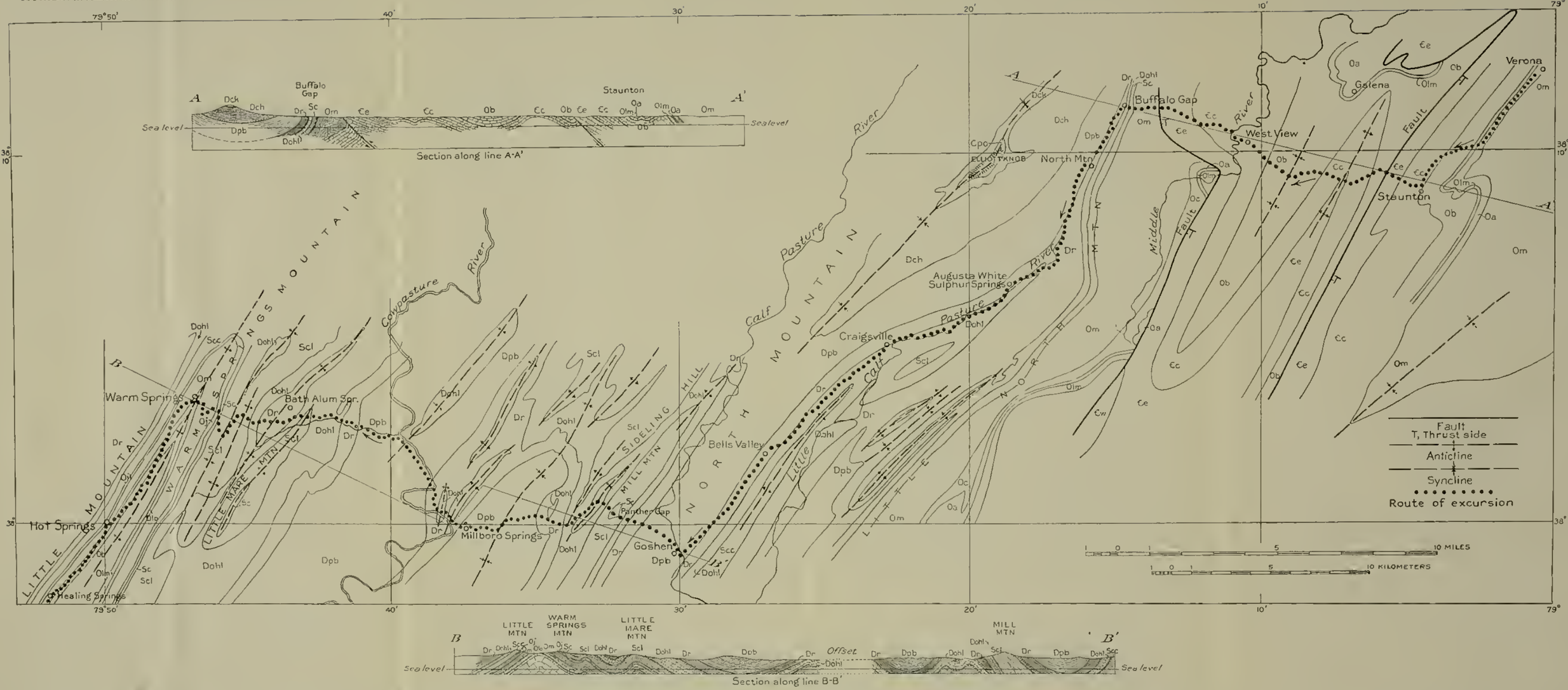
ROUTE MAP, WINCHESTER TO LURAY, VIRGINIA, AND SECTION ACROSS SHENANDOAH VALLEY AND MASSANUTTEN MOUNTAIN

Dck, Catskill formation; Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dr, Romney shale; Dohl, Oriskany and Helderberg formations; Scy, Cayuga group; Sct, Clinton and Tuscarora formations; Sm, Massanutten sandstone; Om, Martinsburg shale; Oc, Chambersburg limestone; Oa, Athens shale; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown limestone (Nittany and post-Nittany); Os, Stonehenge limestone; €c, Conococheague limestone; €e, Elbrook limestone.



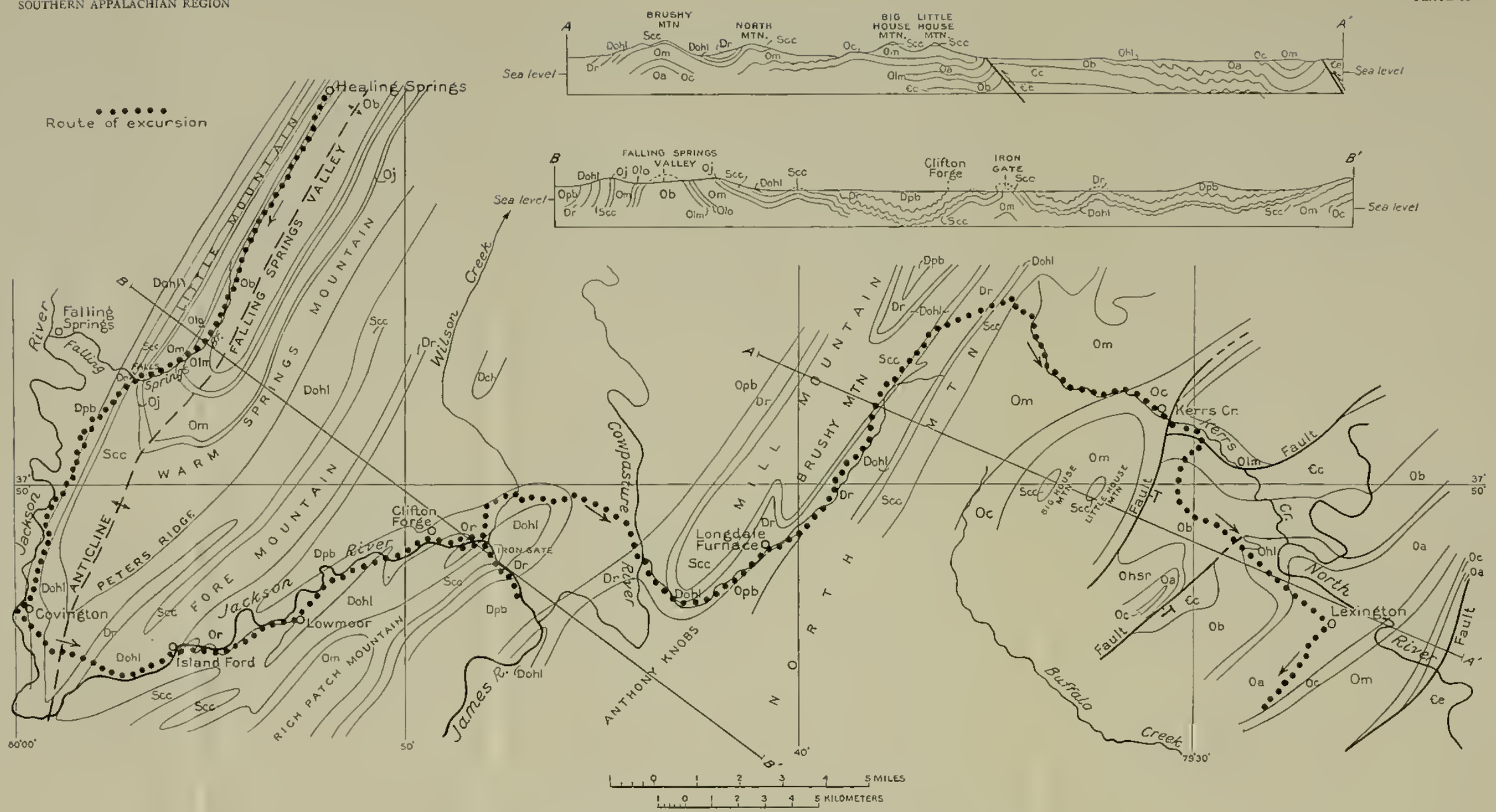
ROUTE MAP AND SECTIONS, MOUNT JACKSON TO STAUNTON, VIRGINIA

Dr, Romney shale; Scy, Cayuga group, Sm, Massanutten sandstone, Om, Martinsburg shale; Oc, Chambersburg limestone; Oa, Athens shale; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown (Nittany and post-Nittany dolomites); €c, Conococheague limestone, €e, Elbrook limestone; €r, Rome formation.



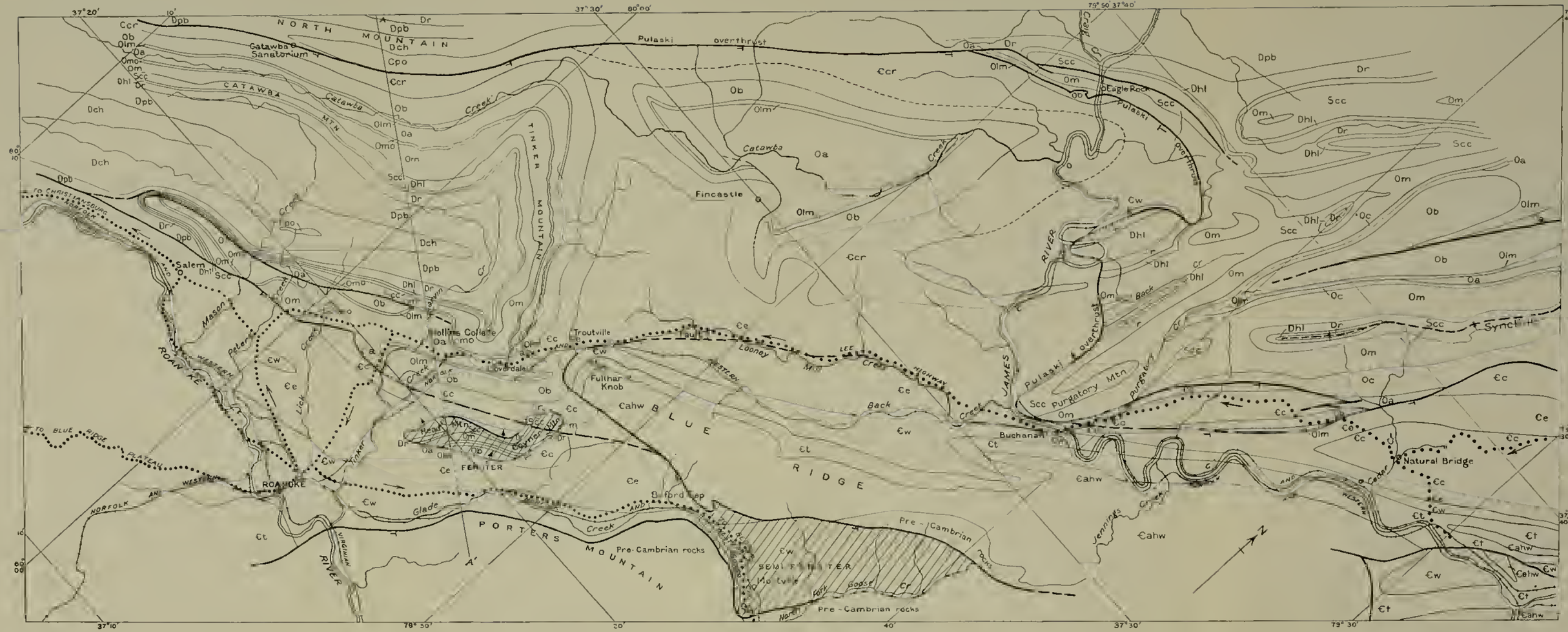
ROUTE MAP AND SECTIONS, STAUNTON TO HEALING SPRINGS, VIRGINIA

Cpo, Pocono formation; Dck, Catskill formation; Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dr, Romney shale; Dohl, Oriskany and Helderberg formations; Scl, Clinton formation; Se, Clinch sandstone; Scc, Clinton and Clinch; Oj, Juniata formation; Om, Martinsburg shale; Oc, Chambersburg limestone; Olo, Lowville limestone; Oa, Athens shale; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown dolomite (Nittany and post-Nittany); Cc, Conococheague limestone; Ce, Elbrook dolomite; Cw, Waynesboro formation.



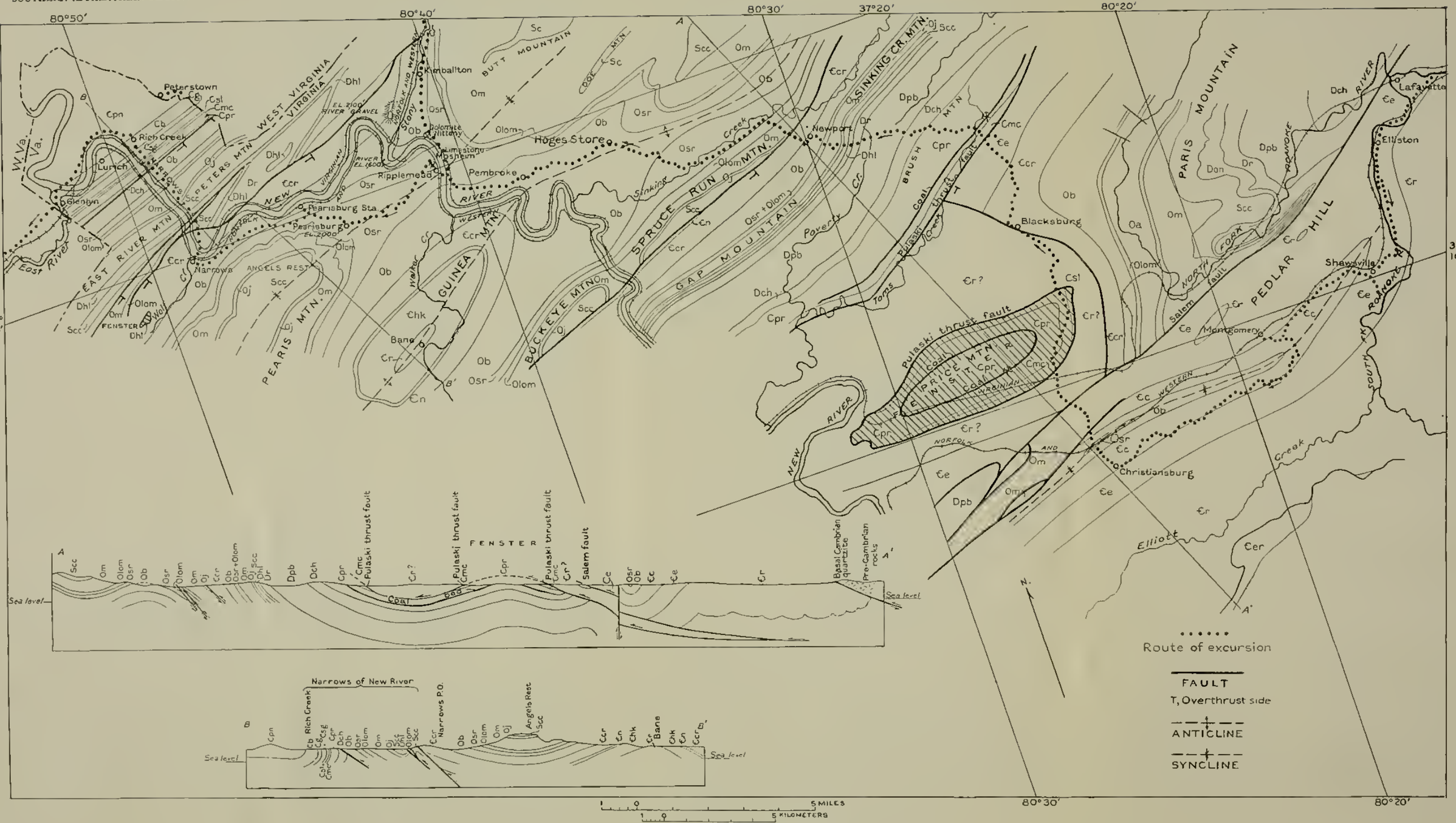
ROUTE MAP AND SECTIONS, HEALING SPRINGS TO LEXINGTON, VIRGINIA

Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dr, Romney shale; Dohl, Oriskany and Helderberg formations; Scc, Clinton formation and Clinch sandstone; Oj, Juniata formation; Om, Martinsburg shale; Oc, Chambersburg limestone; Olo, Lowville limestone; Oa, Athens shale; Ohl, Holston limestone; Ohsr, Holston and Stones River limestones; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown dolomite (Nittany and post-Nittany); Cc, Conococheague limestone; Ce, Elbrook limestone.



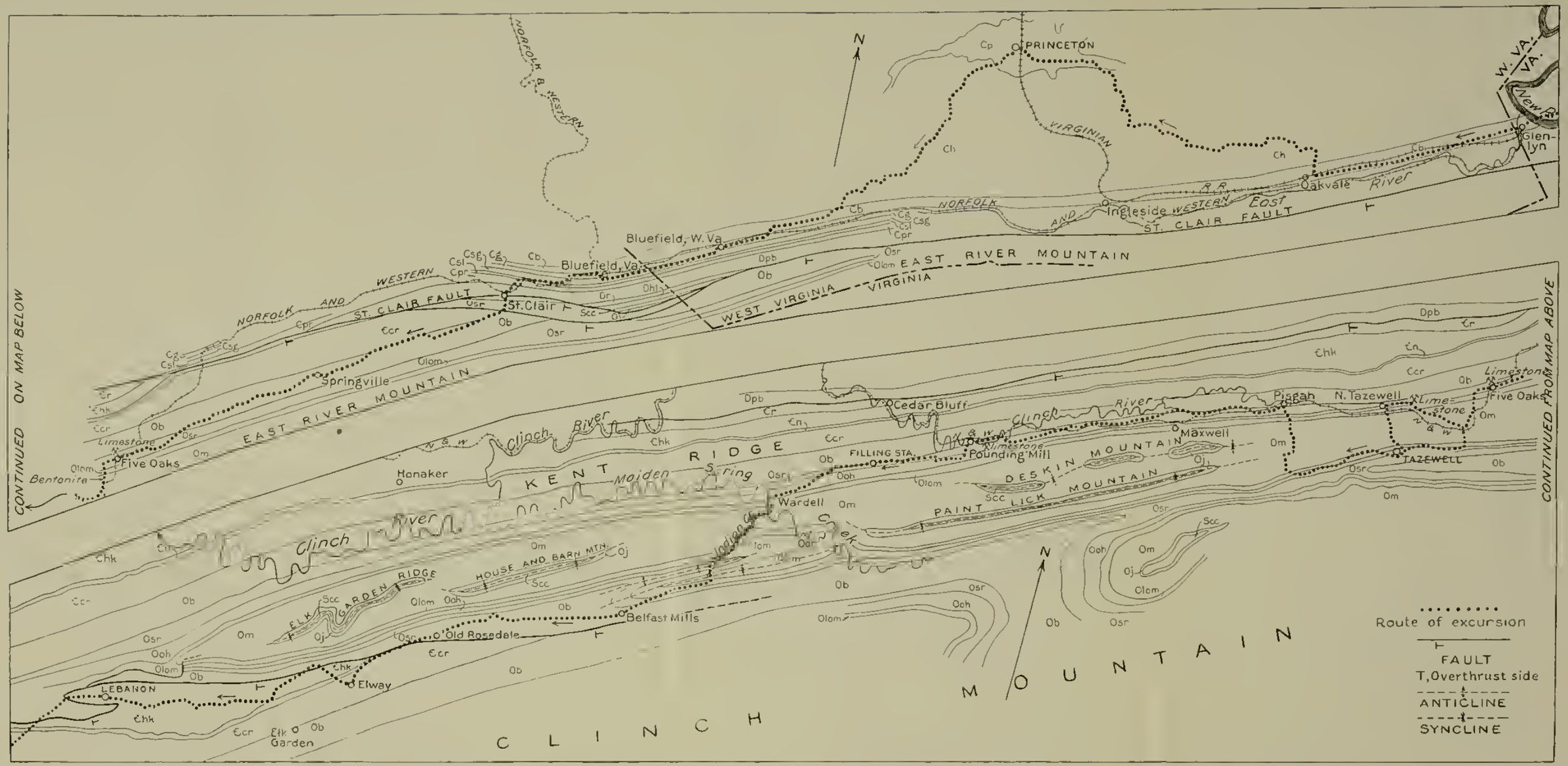
ROUTE MAP, NATURAL BRIDGE TO ROANOKE, VIRGINIA, AND SECTION THROUGH READ MOUNTAIN FENSTER

Cpo, Pocono formation; Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dr, Romney shale; Dhl, Helderberg limestone; Scc, Clinton and Clinch formations; Om, Martinsburg shale; Oc, Chambersburg limestone; Omo, Moccasin formation; Oa, Athens shale; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown dolomite (Nittany and post-Nittany); Ce, Conococheague limestone; Ccr, Copper Ridge dolomite; Ce, Elbrook dolomite; Cw, Waynesboro formation; Ct, Tomstown dolomite; Cahw, Antietam, Harpers, and Weverton formations.



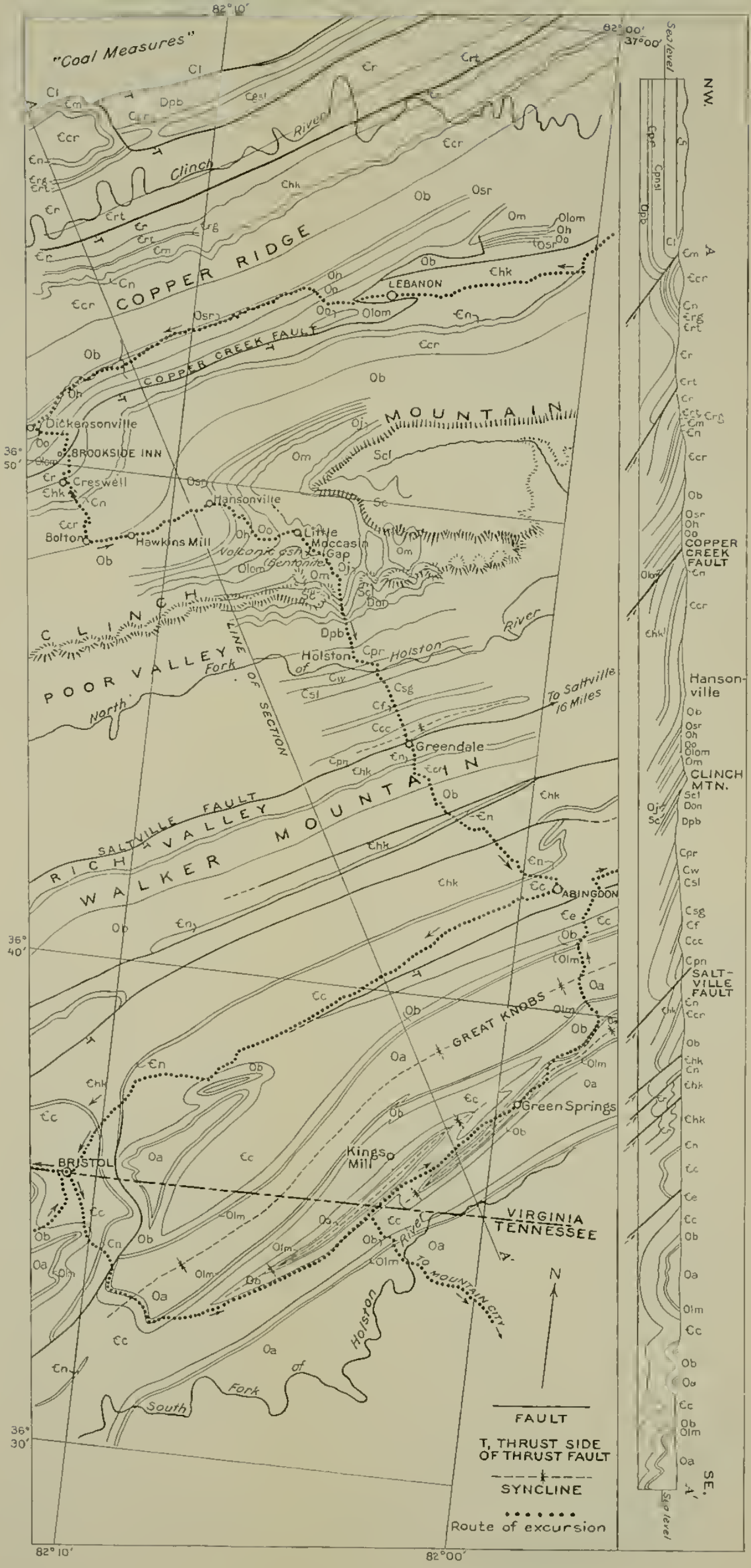
ROUTE MAP AND SECTIONS, ELLISTON TO GLENLYN, VIRGINIA

Elliston is 5.7 miles (9.1 kilometers) southwest along the road from the edge of the area shown on Plate 18. Cpn, Pennington formation; Cb, Bluefield shale; Cg, Gasper limestone; Csg, Ste. Genevieve limestone; Csl, St. Louis limestone; Cmc, Maccrady shale; Cpr, Price formation; Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dr, Romney shale; Don, Onondaga limestone; Dhl, Helderberg limestone; Scc, Clinch sandstone and Clinton formation; Oj, Juniata formation; Om, Martinsburg shale; Olom, Lowville and Moccasin formations; Oa, Athens shale; Osr, Stones River limestone, including Lenoir and Mosheim; Ob, Beekmantown dolomite (Nittany and post-Nittany); Ccr, Copper Ridge dolomite; Cc, Conococheague limestone; Cn, Nolichucky shale; Ce, Elbrook dolomite; Chk, Honaker dolomite; Cr, Rome (Waynesboro) formation; Cer, Erwin quartzite.



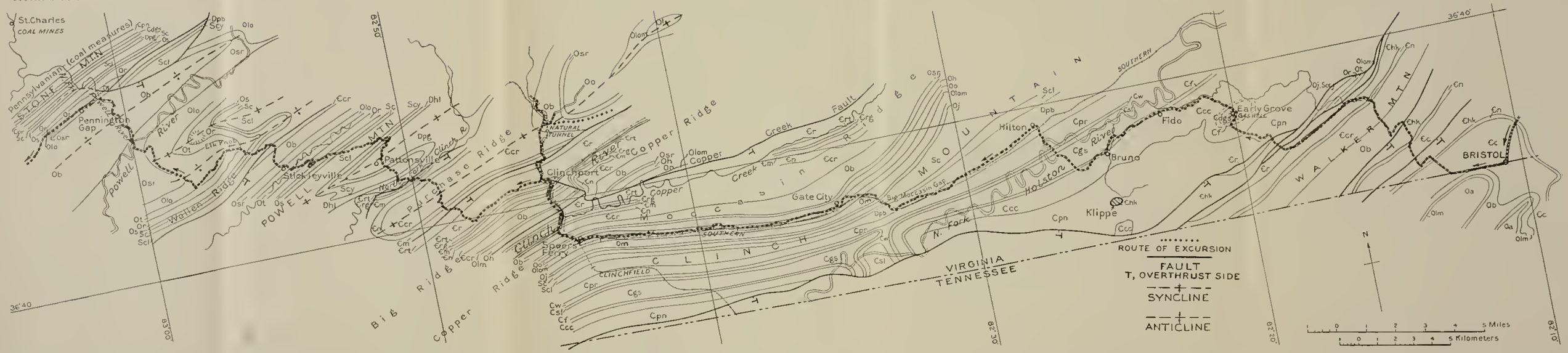
ROUTE MAP, GLENLYN TO LEBANON, VIRGINIA

Cpr, Princeton conglomerate; Ch, Hinton (Pennington) formation; Cb, Bluefield shale; Cg, Gasper limestone; Csg, Ste. Genevieve limestone; Csl, St. Louis limestone; Cpr, Price formation; Dpb, Portage (Brallier) shale; Dr, Romney shale; Dhl, Helderberg limestone; Scc, Clinch sandstone and Clinton formation; Oj, Juniata formation; Om, Martinsburg shale; Olom, Lowville and Moccasin limestones; Ooh, Ottosee formation and Holston limestone; Osr, Stones River limestone, mainly pre-Lenoir; Ob, Beekmantown dolomite (Nittany and post-Nittany); Ccr, Copper Ridge dolomite; Cn, Nolichucky shale; Chk, Honaker dolomite; Cr, Rome formation.



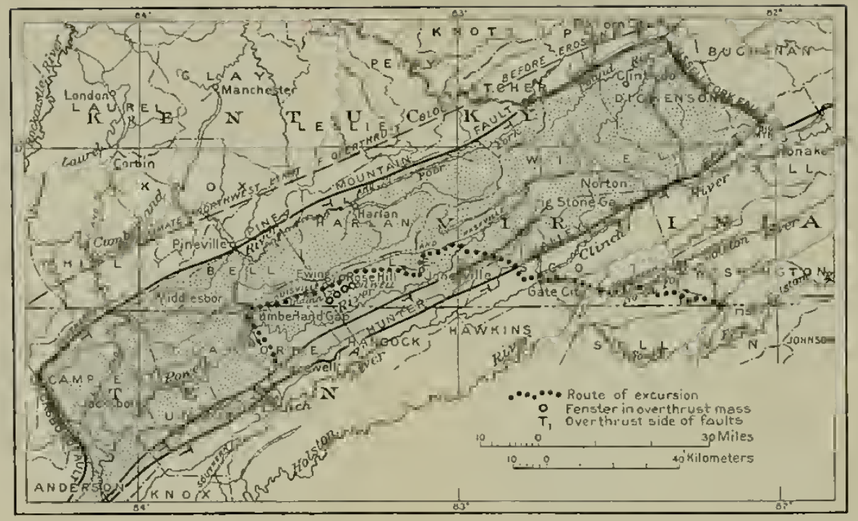
ROUTE MAP AND SECTION, LEBANON TO BRISTOL, VIRGINIA

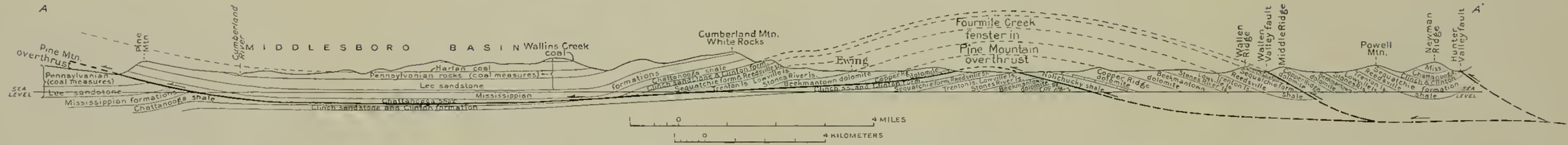
Cn, Norton formation; Cl, Lee formation; Cpnsl, Pennington to St. Louis formations; Cpn, Pennington formation; Ccc, Cove Creek limestone; Cf, Fido sandstone; Csg, Gasper and Ste. Genevieve limestones; Cgsl, Gasper, Ste. Genevieve, and St. Louis limestones; Csl, St. Louis limestone; Cw, Warsaw formation; Cpr, Price formation; Dpb, Portage (Brallier) shale; Don, Onondaga limestone; Scl, Clinton formation; Sc, Clinch sandstone; Oj, Juniata formation; Om, Martinsburg shale; Olom, Lowville and Moccasin limestones; Oo, Ottosee limestone; Oa, Athens shale; Oh, Holston limestone; Olm, Lenoir and Mosheim limestones; Osr, Stones River limestone; Ob, Beekmantown dolomite (Nittany and post-Nittany); Ccr, Copper Ridge dolomite; Cc, Conococheague limestone; Cn, Nolichucky shale; Cm, Maryville limestone; Crg, Rogersville shale; Crt, Rutledge limestone; Chk, Honaker dolomite; Ce, Elbrook dolomite; Cr, Rome formation.



ROUTE MAP, BRISTOL TO PENNINGTON GAP, VIRGINIA

Cpn, Pennington formation; Ccc, Cove Creek limestone; Cf, Fido sandstone; Cgs, Gasper and Ste. Genevieve limestones; Cdgs, Glen Dean, Gasper, and Ste. Genevieve limestones; Csl, St. Louis limestone; Cw, Warsaw limestone; Cpr, Price formation; Dpg, Portage and Big Stone Gap shale; Dpb, Portage (Brallier) shale; Dhl, Helderberg limestone; Scy, Cayuga group; Scl, Clinton formation; Sc, Clinch sandstone; Scc, Clinton and Clinch; Os, Sequatchie (Juniata) formation; Oj, Juniata formation; Om, Martinsburg shale; Or, Reedsville shale; Ot, Trenton limestone; Olo, Lowville limestone; Olom, Lowville-Moccasin limestone; Oo, Ottosee limestone; Oa, Athens shale; Oh, Holston limestone; Olm, Lenoir and Mosheim limestones; Osr, Stones River limestone; Ob, Beekmantown dolomite (Nittany and post-Nittany); Ccr, Copper Ridge dolomite; Cc, Conococheague limestone; Cn, Nolichucky shale: Cm, Maryville limestone; Crg, Rogersville shale; Crt, Rutledge limestone; Chk, Honaker dolomite; Cr, Rome formation.

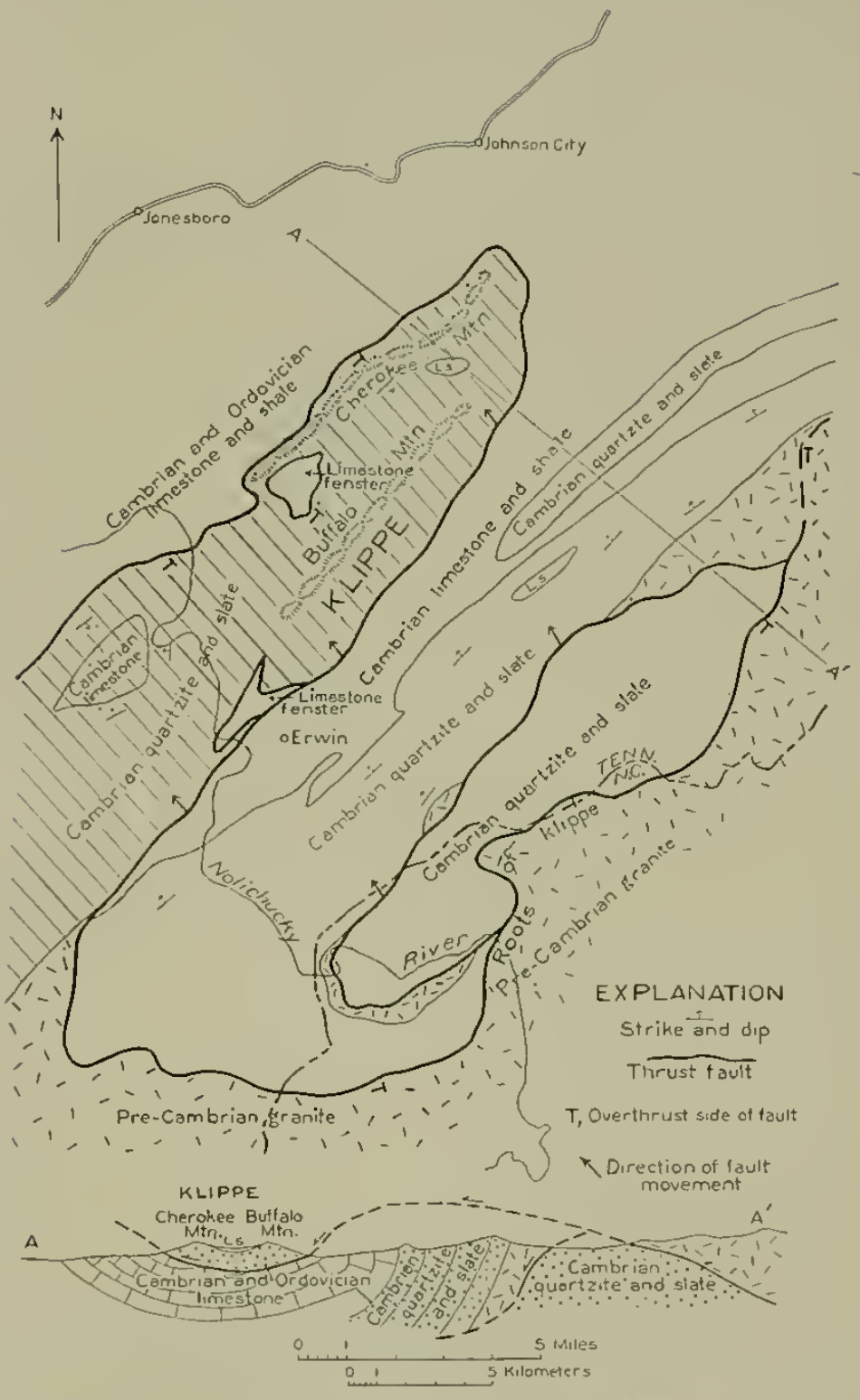




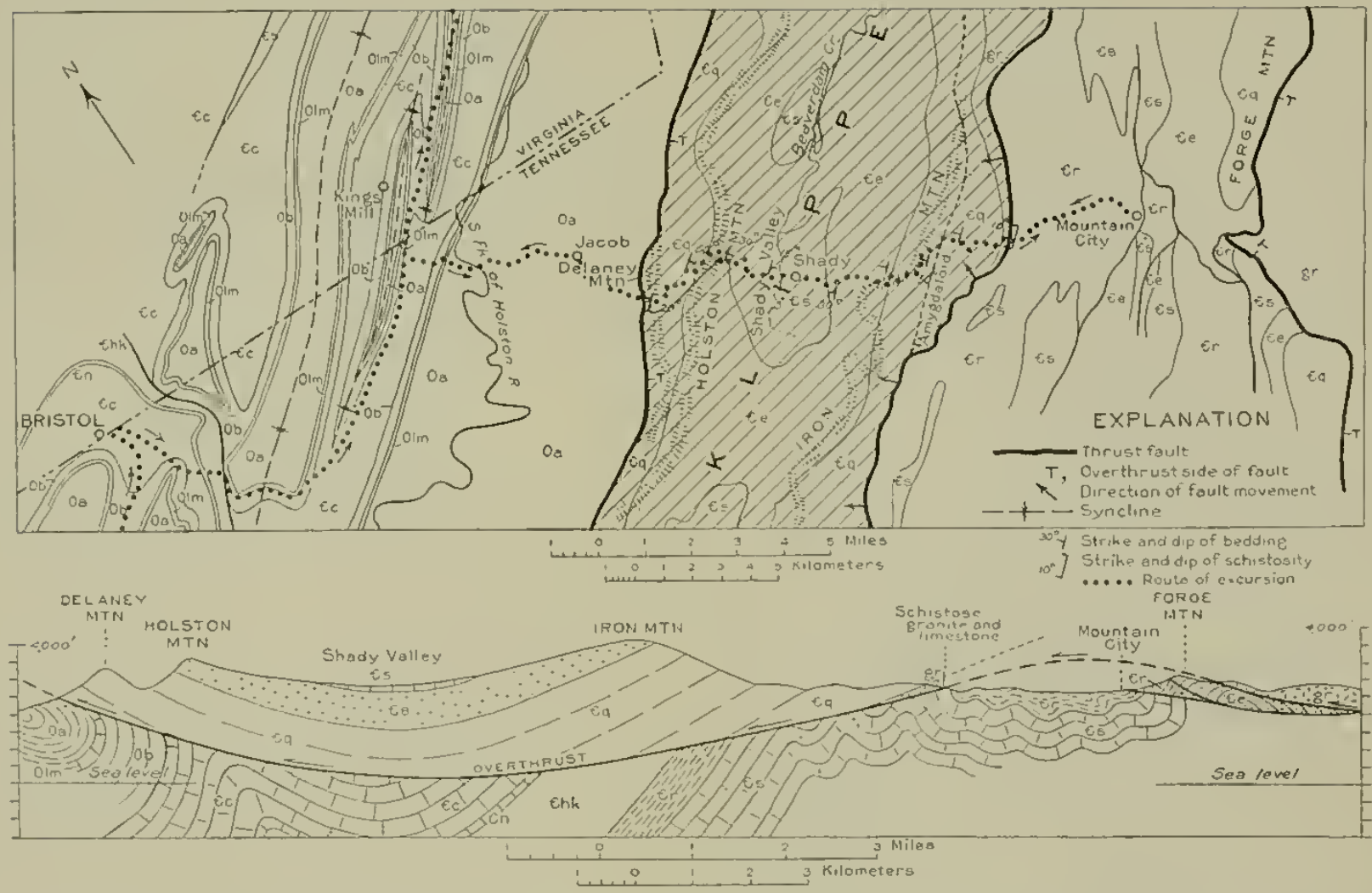
MAP AND SECTION OF CUMBERLAND OVERTHRUST BLOCK

ROUTE MAP, CUMBERLAND GAP TO MORRISTOWN, TENNESSEE

Cpdgs, Pennington formation and Glen Dean, Gasper, and Ste. Genevieve limestones; Cgs, Gasper and Ste. Genevieve limestones; Cpr, Price formation; Dpbs, Portage and Big Stone Gap shales; Scl, Clinton formation; Sc, Clinch sandstone; Os, Sequatchie formation; Oj, Juniata formation; Or, Reedsville shale; Ot, Trenton limestone, Olo, Lowville limestone; Olom, Lowville-Moccasin limestone; Oo, Ottosee limestone; Oh, Holston limestone; Olm, Lenoir and Mosheim limestones; Osr, Stones River limestone; Ob, Beekmantown dolomite (Nittany and post-Nittany); Cch, Chepultepec dolomite; Ccr, Copper Ridge dolomite; Cc, Conococheague limestone; Cn, Nolichucky shale; Cm, Maryville limestone; Crg, Rogersville shale; Crt, Rutledge limestone; Cr, Rome formation.

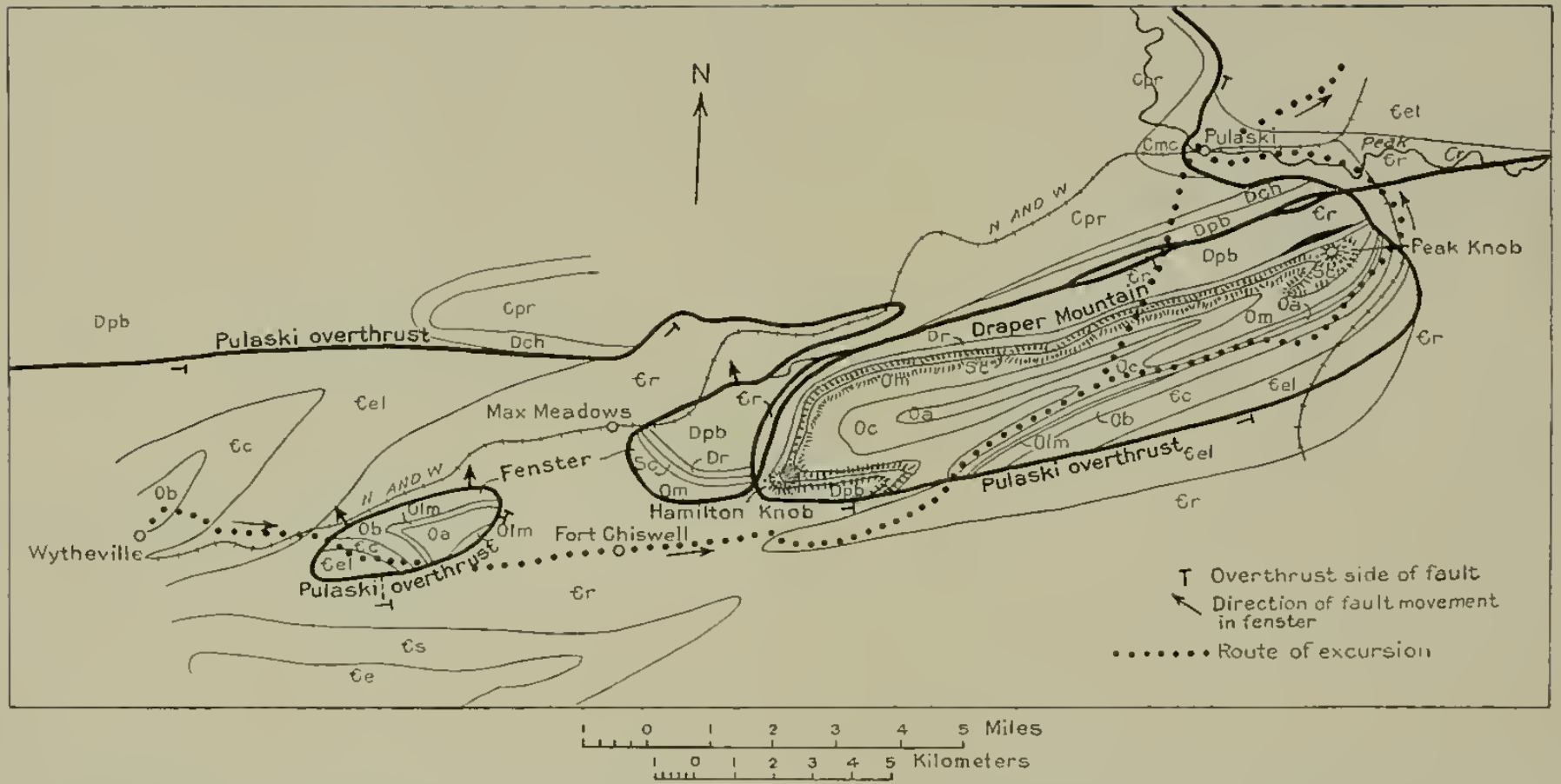


GENERALIZED MAP AND SECTION OF THE CHEROKEE MOUNTAIN KLIPPE, TENNESSEE



ROUTE MAP, BRISTOL, VIRGINIA, TO MOUNTAIN CITY, TENNESSEE, AND SECTION FROM DELANEY MOUNTAIN TO MOUNTAIN CITY

Oa, Athens shale; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown dolomite (Nittany and post-Nittany); Cc, Conococheague limestone; Cn, Nolichucky shale; Chk, Honaker dolomite; Cr, Rome formation; Cs, Shady dolomite; Ce, Erwin quartzite; Cq, Cambrian quartzite and shale, undifferentiated; gr, pre-Cambrian granite.



MAP OF FENSTER IN OVERTHRUST BLOCK OF ROME FORMATION 3 MILES (4.8 KILOMETERS) EAST OF WYTHEVILLE, VIRGINIA

Cmc, Maccrady red shale; Cpr, Price formation; Dch, Chemung formation; Dpb, Portage (Brallier) shale; Dr, Romney shale (so called); Sc, Clinch sandstone; Om, Martinsburg shale; Oc, Chambersburg limestone; Oa, Athens shale; Olm, Lenoir and Mosheim limestones; Ob, Beekmantown dolomite; Cc, Conococheague limestone; Cel, Elbrook limestone; Cr, Rome (Watauga) formation; Cs, Shady dolomite; Ce, Erwin quartzite.