COMMONWEALTH OF VIRGINIA
VIRGINIA CONSERVATION COMMISSION
VIRGINIA GEOLOGICAL SURVEY
ARTHUR BEVAN, *State Geologist*

Guide Leaflet No. 1

Guidebook
Field Conference of Pennsylvania Geologists
Virginia—1938

COMPILED BY ARTHUR BEVAN WITH THE COLLABORATION OF
CHARLES BUTTS, FRANK M. SWARTZ, ANNA I.
JONAS, A. S. FURCRON, EARL A. TRAGER,
AND JOSEPH K. ROBERTS

UNIVERSITY, VIRGINIA
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RICHMOND:

DIVISION OF PURCHASE AND PRINTING

1938

VIRGINIA CONSERVATION COMMISSION

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., May 10, 1938.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit and to recommend for publication Guide Leaflet No. 1 of the Virginia Geological Survey series of guide leaflets.

It has been prepared by various geologists for the use of the Field Conference of Pennsylvania Geologists, in Virginia and near-by parts of West Virginia and Maryland, during the period May 28-30, 1938. It is expected that this guide leaflet will not only be indispensable to this particular conference but will also be of considerable service to other geologists who will from time to time traverse part, or all, of this route. This leaflet should also be useful in the schools of that part of Virginia covered by the itinerary and to residents and others who are interested in the local geology and geography.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, May 12, 1938.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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GENERAL SUMMARY

ARTHUR BEVAN

The Paleozoic formations that crop out along most of the route of the conference range from Middle Cambrian (Waynesboro or Rome) to Upper Devonian ("Catskill"), inclusive. Lower Cambrian rocks occur along the west flank of the Blue Ridge. Pre-Cambrian formations and remnants of Lower Cambrian rocks (Loudoun formation) are exposed along the route (Skyline Drive) in Shenandoah National Park. Other pre-Cambrian rocks are exposed locally along the route from the Blue Ridge to the vicinity of Aldie (U. S. No. 50). Triassic rocks crop out from a point about 1 mile east of Aldie to Leesburg and beyond.

A generalized geologic column of the formations along the conference route is given below. The estimated thicknesses of the Paleozoic formations are by Butts and Swartz, except that thicknesses of the Antietam, Harpers, and Loudoun formations have been estimated by Anna I. Jonas and G. W. Stose.

Generalized geologic column of formations in northern Virginia and near-by parts of West Virginia and Maryland

System	Formation		Estimated Thickness[1] (Feet)
Triassic	Diabase		.....
	Bull Run shale		.....
	Manassas sandstone		.....
	Border conglomerate		.....
Devonian	Hampshire (formerly Catskill)		1,000
	Chemung formation		2,500
	Brallier shale		1,500
	Naples shale		50–100
	Hamilton shale		1,100
	Marcellus shale		50–500
	Onondaga shale		75
	Oriskany	Ridgeley sandstone	0(?)–200
		Shriver chert	0–70
	Helderberg	Becraft limestone	50
		New Scotland limestone	0–40
		Coeymans limestone	14–40(?)
		Keyser limestone	20–280

[1]Estimated thickness of the Paleozoic formations above the Antietam quartzite by Charles Butts and Frank Swartz; below the Tomstown (Shady) dolomite by Anna I. Jonas and G. W. Stose.

SYSTEM	FORMATION	ESTIMATED THICKNESS[1] (Feet)
Silurian	Cayugan: Tonoloway limestone	450–610
	Cayugan: Wills Creek shale	225–460
	Cayugan: Bloomsburg shale	20–200
	Cayugan: McKenzie formation	0(?)–300
	Clinton: Rochester shale	0–25
	Clinton: Keefer sandstone	0(?)–50
	Clinton: Rose Hill shale	60–550
	Tuscarora (Clinch) sandstone	380–800
Ordovician	Juniata formation	0–800
	(Oswego sandstone)	0–500(?)
	Martinsburg shale	3,000
	Chambersburg limestone	200
	Athens formation	150
	Stones River: Lenoir limestone	50
	Stones River: Mosheim limestone	50
	Beekmantown dolomite	2,500+
Ozarkian (?)	Chepultepec limestone	200
	Conococheague limestone	2,500
Cambrian	Elbrook dolomite	1,500
	Waynesboro (Rome) formation	1,500
	Tomstown (Shady) dolomite	1,000
	Antietam (Erwin) quartzite	500–1,000
	Harpers (Hampton) shale	1,200–2,000
	Weverton quartzite	200–1,000
	Loudoun formation	0–800
Cambrian (?)	Greenstone dikes	
Pre-Cambrian	Unakite	
	Granite and granodiorite[2]	
	Catoctin greenstone	

[1]Estimated thickness of the Paleozoic formation above the Antietam quartzite by Charles Butts and Frank Swartz; below the Tomstown (Shady) dolomite by Anna I. Jonas and G. W. Stose.

[2]Anna I. Jonas and G. W. Stose believe that this granite is older than the Catoctin greenstone but A. S. Furcron believes that it is younger.

ITINERARY

CUMBERLAND, MD., TO KEYSER, W. VA.

FRANK M. SWARTZ

Drive west on U. S. No. 40. **Caution:** Railroad crossings, sharp curves and congested traffic. Continue through the "Narrows," cut by Wills Creek through Wills Mountain.

Lover's Leap, the summit on the north site of the gap, has an altitude of 1,680 feet, which is 940 feet above the level of Wills Creek at its base. White Tuscarora sandstone, 380 feet thick, is exposed in a great arch and forms the mountain. This anticline has the typical form of the Appalachian folds, with a steep northwestern limb and a more gentle southeastern limb. About 400 feet of red Juniata shale and sandstone are exposed below the Tuscarora, the lower part of the cliff being concealed by talus. This is the only locality where Juniata beds are exposed in Maryland west of the North Mountain anticline, 40 miles east of Cumberland. The Wills Mountain anticline rises toward the north, and beyond the Pennsylvania line the Juniata is reported to be 800 feet thick.

Turn around at intersection U. S. No. 40 and Maryland No. 35 (from right), through Cities Service filling station. Return on U. S. No. 40 to the east end of the gap.

Stop 1—35 minutes. Park cars on section of old road to right. **Caution:** Must back out on return from section.

Tuscarora to Wills Creek beds will be examined on the south side of Wills Creek, in the east limb of the anticline. The Rochester and lower McKenzie are not well exposed here. This is the north end of Rose Hill, and is the type locality for the Rose Hill shale. A condensed geologic section is given in Appendix A.

This is the first of four stops from Cumberland, Md., to Keyser, W. Va., which will exhibit in ascending order the Silurian sequence of western Maryland, together with uppermost Ordovician and Lower Devonian strata. (See Pl. 1.) The sections provide a virtually complete foot-by-foot exposure of the Silurian deposits. Through the labors of C. K. Swartz and W. F. Prouty on the sediments and macrofossils, and of E. O. Ulrich and R. S. Bassler on the ostracoda, this may well be considered one of the classic regions for the Silurian rocks of this continent. The system is thicker here than in western New York (Pl. 1), and, in general, deposition was more continuous. A large number of faunal zones, characterized especially by ostracoda, have been recognized. The succession established here has furthermore served as a basis for studies of the Silurian in eastern and central Pennsylvania and in the Virginias. (See Pls. 1 and 2, and Fig. 2.)

The Lower Devonian-Silurian rocks of the Cumberland area are summarized below. The faunal zones are numbered in accordance with the zones shown in Pls. 1 and 2, and Fig. 1.

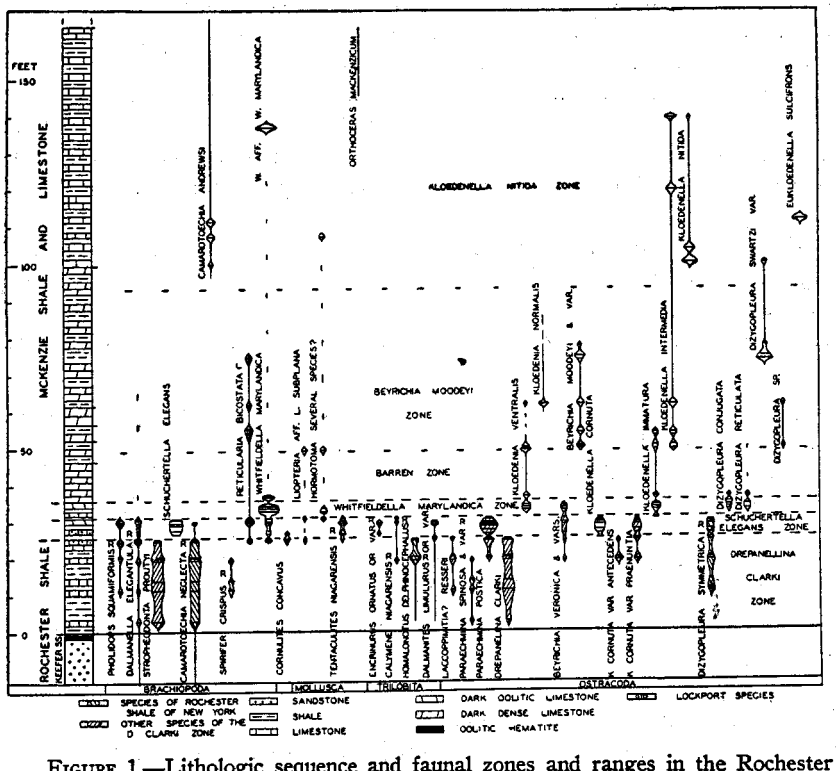

FIGURE 1.—Lithologic sequence and faunal zones and ranges in the Rochester and lower McKenzie formations at the south end of Rose Hill, Maryland; by F. M. Swartz. In the graph for each species, the horizontal lines show the horizons at which the material was collected and the widths of these lines are roughly indicative of abundance. (Reprinted by permission of the author, from Bull. Geol. Soc. America, vol. 46, no. 8, Fig. 3, 1935.)

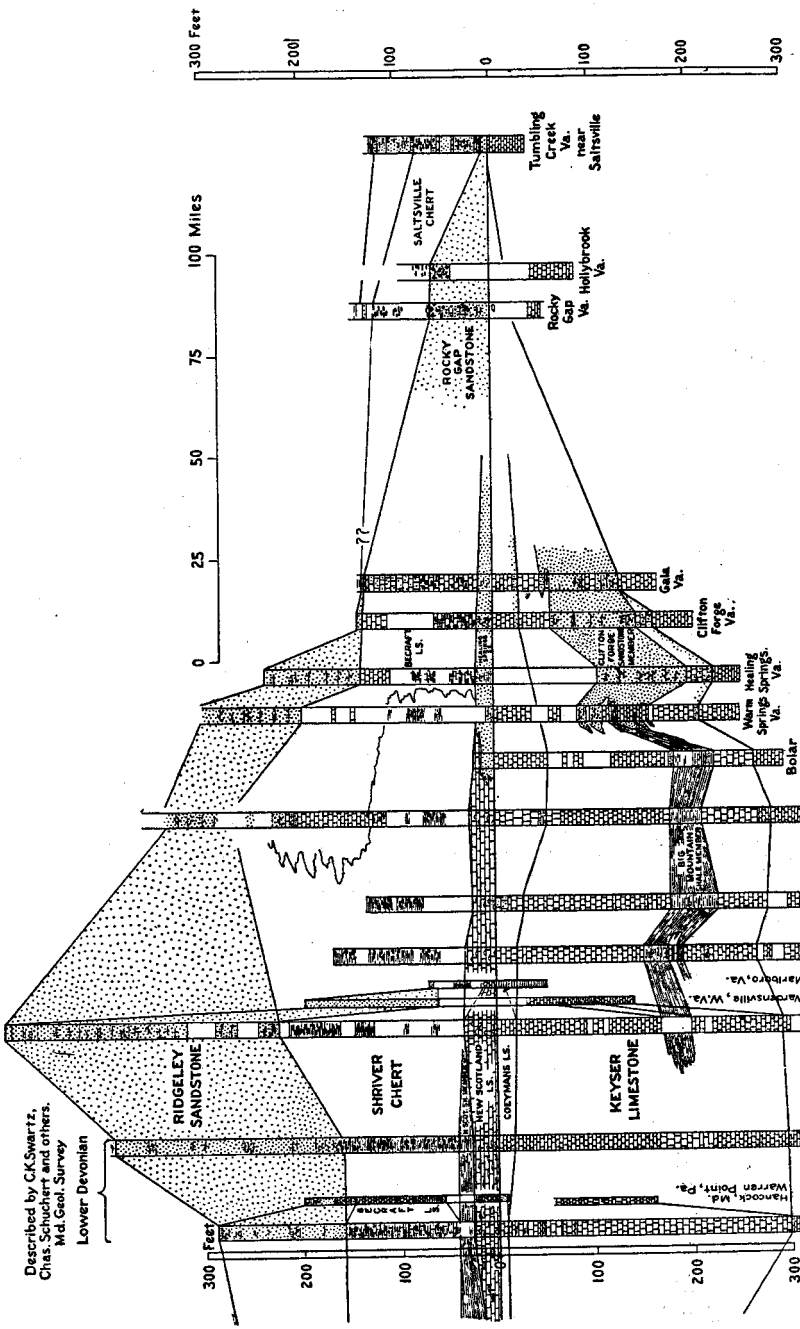

FIGURE 2.—Oriskany, Helderberg, and Keyser sections from Cumberland, Md., and Keyser, W. Va., to southwestern Virginia; by F. M. Swartz. (Reprinted by permission of the author, from Proc. Pennsylvania Acad. Science, vol. 3, Fig. 4, 1929.)

Silurian and Lower Devonian in the Cumberland-Keyser area

	Thickness (Feet)
Lower Devonian	
Oriskany group:	
Ridgeley sandstone: Fossiliferous, rather coarse-grained, calcareous sandstone. *Spirifer arenosus* zone (29). At Keyser	210
Shriver chert: Siliceous shale and impure dark-colored chert. *Thilipsura robusta, T. confluens* zone. At Keyser	67
Helderberg group:	
New Scotland limestone: Fossiliferous cherty limestone; 14-foot shale member at top. *Spirifer macropleurus* zone (27). At Keyser	42
Coeymans limestone: Thick-bedded crinoidal limestone. *Gypidula coeymanensis* zone (26). At Keyser	14½
Silurian or Devonian	
Keyser limestone: Thin-bedded limestone above; thick-bedded and some thin-bedded limestone at middle; lumpy limestone below. *Tentaculites gyracanthus* zone near top; *Gypidula coeymanensis* var., *Merista typa, Camarotoechia gigantea* zone (25) near middle; *Chonetes jerseyensis* zone (24) through lower half. At Keyser	280
Silurian	
Tonoloway limestone: Mostly laminated, dense or finely crystalline limestone; some calcareous shale, especially in upper part. *Hindella congregata* zone (22), 190 to 370 feet; *Spirifer vanuxemi* at 208 feet. At Pinto	610
Wills Creek shale: Thin-bedded calcareous shale, thick-bedded mudrock weathering green, and impure limestone. At base, Bloomsburg member, partly red, 20 feet. This is a tongue from the Bloomsburg red beds of Pennsylvania. (See Pl. 1.) Lower *Spirifer vanuxemi* zone (20) at 230 feet. At Pinto	460
McKenzie shale and limestone: Thin-bedded calcareous shale, and much interbedded, generally dense dark-colored limestone, predominant in lower part, with lenses of flat limestone pebble conglomerate.	
Kloedenella gibberosa, Beyrichia mesleri zone with *Uncinulus obtusiplicatus.* (18)	
Kloedenella nitida zone (17)	

Orthoceras mackenzicum, Hormotoma zone (16)
Beyrichia moodeyi zone (15)
Whitfieldella marylandica coquina zone (14)
Schuchertella elegans zone (13) (Rochester?)
At Cumberland 300

Clinton group:
Rochester shale: Thin-bedded shale; much interbedded highly fossiliferous blue-gray limestone. *Drepanellina clarki, Dalmanites limulurus* zone (12). At south end of Rose Hill..... 25½
Keefer sandstone: Calcareous sandstone; Roberts iron ore at top. At south end of Rose Hill..... 13½
Rose Hill shale: Thin-bedded olive-drab to purplish shale, with some thin-bedded greenish sandstone near base; Cresaptown iron sandstone 167 to 178 feet above base. Ostracode zones established by E. O. Ulrich and R. S. Bassler:
Mastigobolbina typus zone (10)
Bonnemaia rudis zone (9)
Zygosella postica zone (6)
Mastigobolbina lata zone (5)
Zygobolbina emaciata zone (4)
Zygobolba decora zone (2)
Zygobolba anticostiensis zone (1)
Zygobolba erecta zone (in Pennsylvania)
At Cumberland 550
Tuscarora sandstone: Thick-bedded, hard, whitish, quartzitic sandstone. *Arthrophycus* trails. At Cumberland.... 380

Ordovician
Juniata formation: Dark-red shale and sandstone; considered Silurian by Ulrich, Butts, and others. On Wills Mountain in Pennsylvania..... 800

Return to Cumberland via U. S. No. 40 to intersection with U. S. No. 220; then right; go short block; then turn left via U. S. No. 220 and follow car tracks. **Caution:** Sharp curves ahead.

Stop 2—25 minutes. Park cars at right on old section of road. Walk to railroad tracks below and east of the highway; turn left.

The upper Rose Hill, Keefer, Rochester, and lower McKenzie are well exposed at the south end of Rose Hill. Roberts iron ore, extensively worked at one time in this region, is near the top of the Keefer sandstone. The lithologic and faunal sequences listed below occur above the Keefer sandstone. The faunal ranges are illustrated

in detail in Fig. 1. The upper 165 feet of the McKenzie is concealed. A condensed geologic section is given in Appendix B.

Beds and faunal zones above the Keefer sandstone at south end of Rose Hill, Maryland

LITHOLOGIC DIVISIONS	THICKNESS (Feet)	FAUNAL ZONES
Interbedded limestone and shale.....	65	*Kloedenella nitida.*
Thin- to medium-bedded, dense dark-colored limestone, mostly barren, and interbedded dark-gray shale. Numerous lenses of flat pebble limestone conglomerate....	64	*Beyrichia moodeyi;* recurrent *Kloedenia ventralis.* Lens with *Whitfieldella* near base.
Shale and fossiliferous limestone; at top, dark-colored limestone with pebbles.....	4	*Whitfieldella marylandica* coquinas; *Kloedenia ventralis.*
Shale and arenaceous limestone; at top, dark-colored limestone with pebbles.		*Schuchertella elegans,* with cf. *Dalmanites limulurus.*
Shale and very fossiliferous limestone.....	25½	*Drepanellina clarki,* with *Dalmanites limulurus.*
Keefer sandstone		

This section illustrates the interesting and still troublesome problems concerning the position and nature of the Rochester-McKenzie boundary and the age and correlation of the McKenzie. Early workers included the upper, or McKenzie, beds of the above sequence in the "Niagaran" or "Rochester" of Maryland. In 1911 and 1912 Ulrich pointed out that the Rochester faunas of the *Dalmanites limulurus* (*Drepanellina clarki*) zone largely disappear in higher beds, and concluded then, and with Bassler in 1923, that the McKenzie formation is not only post-Rochester but also post-Lockport in age. (See Pl. 1.) Near Altoona, Pa., they believed that the requisite unconformity cutting out beds of Lockport age can be recognized at about the top of the *Whitfieldella* coquinas, and reported that both there and in Maryland this boundary represents a complete change in the ostracoda.

Later studies by F. M. Swartz in central Pennsylvania showed that *Kloedenia ventralis* and some other ostracoda cross the supposed unconformity, and previously unrecognized faunal changes were found to

separate the *Whitfieldella marylandica* coquina and *Schuchertella elegans* zones from each other and from the *Drepanellina clarki* zone in which they had previously been included. Changes closely similar to those shown in Fig. 1 were found to be persistent from Danville and Williamsport in Pennsylvania to Monterey, Va. The faunal change between the *Drepanellina clarki* and *Schuchertella elegans* zones is especially abrupt in Pennsylvania, and has been used with some hesitation as the base of the McKenzie. The top of the *Schuchertella elegans* zone would be better in some respects, since it marks the disappearance of several of the higher ranging species of the Rochester of New York, and the most complete change in the ostracoda. However, the boundary is not very sharply defined as seen in the field.

None of the observed faunal changes seems sufficiently pronounced to mark a hiatus representing all of Lockport time. For this reason, and because tongues with a limited number of Lockport corals appear in the McKenzie at the most northerly outcrops in Pennsylvania, it has been suggested that the McKenzie and Lockport may be largely contemporaneous facies: the McKenzie representing shallow, frequently muddied areas with swarms of ostracoda, and with brachiopod and molluscan faunas in some places individually abundant but lacking in diversity; the Lockport more open seas, with coralline and cephalopod faunas but without ostracoda.

The persistence and relative uniformity of the very thin *Schuchertella elegans* and *Whitfieldella* coquina zones from north-central Pennsylvania to west-central Virginia, is a remarkable stratigraphic feature. Recent work has brought out one anomalous occurrence. At 25 miles east of Cumberland, near Hancock, these two zones have a combined thickness of 3 feet. The species appear at the horizons at which they are introduced at other studied localities; but many of them range to higher levels. This is notably true of *Drepanellina clarki,* which persists in abundance through the *Whitfieldella* coquina zone. Whether this feature is due to reworking is not clear.

Continue south on U. S. No. 220. Enter Cresaptown, after crossing axis of the Wills Creek anticline, which has plunged towards the south. Knobly Mountain to the east, across the North Fork of the Potomac, is a monoclinal ridge of Helderberg-Oriskany beds in the east limb of the anticline. The Silurian-Devonian rocks of the anticline dip westward below the Pottsville conglomerate at the crest of Dans Mountain, 3 miles west of Cresaptown. Dans Rock, on Dans Mountain, has an altitude of 2,898 feet, about 2,100 feet higher than Cresaptown. Dans Mountain forms the eastern margin of the Georges Creek, or Frostburg, coal basin.

About 1 mile south of Cresaptown, turn sharp left on narrow paved road to Pinto; continue for 0.7 mile.

Stop 3—35 minutes. Park cars on right side of road, north of underpass. Walk east along railroad tracks through the west limb of the Wills Creek anticline to the Keefer sandstone, and examine the rocks in ascending order on the return trip. A condensed geologic section is given in Appendix C.

This is the type locality for the McKenzie formation, from McKenzie station at the east end of the cut. The Rochester and lower McKenzie are much disturbed by faulting. The upper McKenzie is well exposed, with *Uncinulus obtusiplicatus* and characteristic ostracoda. The Wills Creek and most of the Tonoloway are finely exposed, with nearly vertical dip, in high cliffs along the tracks. The Bloomsburg member at the base of the Wills Creek is 20 feet thick, with the impure Cedar Cliff limestone 8 to 16 feet above the base. Above the limestone are 2 feet of reddish sandstone, a last tongue from the Bloomsburg red beds which are 2,000 feet thick near the Delaware Water Gap. The Wills Creek consists largely of thin-bedded calcareous shale and impure limestone. There is, however, a fair proportion of the thicker bedded mudrock, which weathers pea-green and into irregular fragments, and which becomes more abundant, together with pink and reddish beds of similar lithology, as the Wills Creek begins to grade into Bloomsburg toward the northeast. Ostracoda occur in the lower part and *Spirifer vanuxemi* at 230 feet, but in general these beds are comparatively barren.

The Tonoloway begins with a 6- to 9-foot ledge of thick-bedded dark-colored limestone. It is formed chiefly of laminated dense limestone, which eventually weathers into thin plates. Some beds are magnesian and weather earthy; others are shaly. Near the top, about 130 feet of calcareous shale and shaly limestone are largely concealed. There is little, if any, coarsely crystalline limestone, and only one 1-foot bed of calcareous sandstone, occurring at 396 feet. The sequence differs markedly in these respects from the section which will be seen at Massanutten Mountain in northern Virginia.

Fossils are in general difficult to find, and most beds appear to be barren. A considerable fauna has been obtained, however, from the Tonoloway at this locality. *Hindella congregata,* the most characteristic brachiopod, is reported in abundance at 215 to 220 and at 370 feet. A *Spirifer vanuxemi* zone believed to correspond to the zone in the lower Tonoloway of the Massanutten syncline, and elsewhere in Virginia, occurs at 208 feet. *Schuchertella rugosa* is abundant on a surface at 298 feet, but should be left for future visitors.

The characteristic lumpy limestone of the lower Keyser is exposed along the railroad near the road underpass. Better exposures of the Keyser will be seen at Keyser, W. Va.

Retrace route to U. S. No. 220; turn sharp left and drive to Keyser (12½ miles). The road follows middle Devonian shales about to Rawlings; then cuts through Helderberg-Oriskany beds brought to the surface by a subsidiary anticline on the west side of the Wills Mountain anticline. Dans Mountain, made by Pocono-Pottsville beds, parallels the road to the west. The ridges to the east are made by Oriskany-Helderberg beds; the Tuscarora sandstone lying below the surface at the axis of the Wills Mountain anticline.

Cross railroad and North Fork of the Potomac into Keyser, W. Va. Continue about 0.5 mile to the intersection of U. S. No. 220 with West Virginia No. 46. Turn sharp left on No. 46; drive east 0.7 mile through Keyser; then turn left on narrow winding gravel road and follow it 0.2 mile to the large quarry on the right side of the road.

KEYSER, W. VA., TO WINCHESTER, VA.

CHARLES BUTTS

Stop 4—30 minutes. At large limestone quarry south of the Baltimore & Ohio Railroad. Park cars on quarry floor.

The Keyser, Coeymans (?), New Scotland, Shriver chert, and Ridgeley sandstone are exposed in sequence. F. M. Swartz is inclined to regard the Shriver as Becraft, which otherwise is not present in the section. A condensed geologic section is given in Appendix D.

Return to U. S. No. 220 through Keyser; turn south along New Creek and continue about 7 miles to New Creek village. The road is on the flood plain or the Oriskany (Ridgeley) sandstone most of the way. A narrow strip mapped as Marcellus, but probably Onondaga, is exposed on the east bank of New Creek at the foot of New Creek Mountain on the southeast (left). This strip of Onondaga begins at a point 2 miles south of the railroad in Keyser and extends southward for 2 miles along the creek. Continue 0.7 mile south of the village of New Creek to the junction of U. S. No. 220 with U. S. No. 50. **Caution:** Dangerous intersection. Turn east on U. S. No. 50. (See Pls. 3 and 4.)

Stop 5—15 minutes. Park cars along road.

Just across the bridge over New Creek at the road intersection, the Ridgeley sandstone, 75 feet thick and vertical, is exposed. It contains an abundance of *Spirifer arenosus*. Then descending the section, the Shriver, the cherty New Scotland with diagnostic *Spirifer macropleurus* and, on the axis of a narrow anticline, the upper part of the Keyser with diagnostic *Cladopora rectilineata* and other corals, are exposed.

The Helderberg exposed here is a small inlier in the gap cut through New Creek Mountain by a small tributary of New Creek.

Continuing eastward along U. S. No. 50, a narrow syncline in the Oriskany is crossed, on the southeast limb of which the New Scotland, Keyser and Wills Creek are crossed, down to the Clinton formation. The Clinton crops out on the Wills Creek anticline, the axis of which is 1 mile in a straight line from the intersection of U. S. No. 220 with U. S. No. 50.

Stop 6—15 minutes. Park cars along road.

At the top of the Clinton here, a *Dalmanites,* perhaps *D. limulurus,* and *Schuchertella,* cf. *S. subplana,* occur. Both are characteristic fossils of the Rochester shale, which is probably represented in the top of the Clinton. The Bloomsburg shale has been mapped here but, as no red shale occurs here, it is probable that the Bloomsburg is absent. The Keefer sandstone, which occurs normally below the Rochester shale, is also absent here, although it is a conspicuous and persistent bed in Timber Mountain (just east of Hanging Rock on map) farther east in West Virginia, as will be observed later, and in Great North Mountain, Virginia.

After passing the axis of the Wills Mountain anticline in the middle of the Clinton belt, the formations are recrossed in ascending order. Just west of the intersection of the roads at the big barn on the north (left), another narrow strip of Bloomsburg has been mapped, but no rocks of Bloomsburg character are present. The white rock debris on the slope east of the intersection is mingled New Scotland chert and Ridgeley (Oriskany) sandstone. The Ridgeley contains *Spirifer arenosus* in abundance.

Just through the gap in the Oriskany-Helderberg ridge here, the Oriskany and the Onondaga in contact are exposed at the angle of the road where it turns south along the slope three-fourths of a mile northwest of the village of Ridgeville. One of the diagnostic Onondaga fossils, *Anoplotheca acutiplicata,* occurs here.

Stop 7—15 minutes. Park cars along road.

Just down the road from the Onondaga outcrop, the overlying black, fissile Marcellus shale is exposed.

A quarter of a mile southeast of Ridgeville a narrow band of Naples black shale has been mapped but is not exposed. Just beyond is a belt of Brallier (Portage) shale three-fourths of a mile wide. The name Brallier is used because this shale, while of Portage age, does not include all of the Portage as defined by J. M. Clarke, and also because the equivalent of the Brallier has been subdivided into the Hatch and Gardeau shales in the type Portage region. In the main, the Brallier represents the Hatch and Gardeau.

Stop 8—10 minutes. Park cars along road.

Collect here the most typical Brallier fossil, *Peridichnites biseriatus,* which is fairly abundant. It is widely distributed in the Brallier, at least from central Pennsylvania to the Warm Springs area in Bath County, Virginia. It has been used by Butts as an index fossil of the Brallier since 1903, when it was found in the Brallier along the Pennsylvania Railroad west of Altoona, Pa.

The boundary between the Brallier and the Chemung on the west passes through, or near, the cemetery on the north (left), 1 mile southeast of Ridgeville. Here *Spirifer mesicostalis* occurs in the bluff just north of the cemetery and west of the ravine back of the cemetery. In the bank of the creek immediately east of the cemetery and north of the road, the Chemung is plainly visible from the road. It is marked by (1) sandstone beds somewhat thicker than any in the Brallier, (2) rather coarse lumpy shale, and (3) layers crowded with fossils. *Atrypa reticularis, Spirifer mesicostalis,* and *Cyclonemina,* especially the latter, occur. Several calcareous layers up to 6 inches thick are almost exclusively composed of *Cyclonemina.*

East of Markwood, which is near the axis of the broad Bedford syncline, a wide belt of Chemung and Brallier on the southeast limb of the syncline is passed. The great width of the outcrop is caused by repeated reversals causing sharp narrow anticlines and synclines, which are plainly visible in the road cuts, and by two major axes within the Brallier shale.

Stop 9—15 minutes. Park cars along road.

One-fourth mile west of Burlington is a broad folded belt of black Naples shale, which in places contains abundant *Paricardium doris, Probeloceras lutheri* and other diminutive fossils characteristic of this zone.

West of, but nearer Burlington, the contact of the Naples beds with the Hamilton is exposed. Thence southeast the belt of Hamilton, traversed by an anticline and a syncline, is about 2 miles wide. A belt of Marcellus 1 mile wide, including an anticline bringing up the Oriskany, is crossed by the crooked stretch of road 2 miles east of Burlington. Half a mile northwest of Junction, Naples black shale is exposed in a rather wide belt on the north side of the road. It is crowded with fossils such as *Paracardium, Buchiola,* and *Proboloceras.* East of Junction is a wide belt of Brallier, Chemung, Hamilton and Marcellus, which extends to the base of Mill Creek Mountain. Beside the road northward along the base of the mountain, the Onondaga shale, weathered gray and dipping steeply toward the road, is exposed for a short distance. Farther along, the Oriskany sandstone is exposed to Mechanicsburg. At Mechanicsburg turn southeast and pass through an

anticlinal inlier of Oriskany, New Scotland, and Keyser. This is a very symmetrical arch.

Stop 10—5 minutes. Park cars along road. At the spring at Fountain Inn for water.

Emerging from the gap on the east, note the Onondaga shale here, in part about as black as the Marcellus shale. One-fourth mile north, the Oriskany sandstone, on a minor fold, is exposed along the road for several hundred feet. Then for a distance south of the railroad crossing at West Romney, the Onondaga is exposed on the southeast limb of a minor fold. On the slope above the strip of Oriskany, the Onondaga persists in a minor syncline at the base of the mountain.

Northeast from West Romney through Romney, the road is on Marcellus shale which is well exposed on the slope up to Romney. This wide belt of shale is notable from the fact that the subsequent South Fork of the Potomac River follows it, more or less closely, for many miles. This subsequent valley continues for 100 miles southward into the Hot Springs district, Bath County, Virginia, where it is represented by Back Creek Valley which is also eroded on the same belt of black shale.

Stop 11—50 minutes. Lunch at New Century Hotel. Park cars in line on right side of street, headed east.

For 1½ miles southeast of Romney the road crosses Hamilton, Naples, Brallier, and Chemung, mostly not exposed; then a synclinal belt of the Hampshire formation (see discussion below), plainly recognizable, 1½ miles wide in a straight line, to the contact with the Chemung one-quarter of a mile west of Shanks. The Chemung belt is 6 miles across by the road and 4½ miles in a straight line across the strike. The width results from repetition due to three minor axes about equally spaced in the width of the belt, but on the whole the wide belt is anticlinal. One and a half miles by the road northwest of Augusta, another wide synclinal belt of Hampshire is entered, the synclinal axis being drawn near Pleasantdale in the middle of the belt.

The transitional character of the passage of the Chemung into Hampshire is perhaps the most significant aspect of these sections. In every place several beds of red shale occur below the main body of red rock, and interbedded with such red beds are layers carrying a sparse Chemung fauna. Seemingly the boundary line should be so drawn as to include all the fossiliferous beds in the Chemung, at least up to the level where the red rocks are greatly preponderant. In fact, there is no boundary, but the passage from one formation to the other is transitional, much more so than on the Allegheny Front in central Pennsylvania.

The use of the name Hampshire instead of Catskill will doubtless provoke inquiry. The explanation is that, as demonstrated by recent work by Chadwick and Cooper, the red beds ("Catskill") of the Allegheny Front are entirely younger than the Catskill of the Catskill Mountains. If the former were present in the Catskill region, they would lie above the top of the Catskill Mountains. The red beds of the Catskill in the Catskill Mountains are of Portage (Oneonta) and Hamilton age. For that reason it is proposed to restore Darton's name Hampshire for the western red beds.

At Hanging Rock, a wide belt of notable open folding is entered, which extends eastward nearly to the Virginia State line. The sequence is Onondaga, Oriskany, New Scotland, Keyser, hiatus (Tonoloway absent), Wills Creek, Bloomsburg, McKenzie, Keefer sandstone member of the Clinton, and Clinton. The Clinton does not extend quite down to the road. The Keefer on the south tip of a pitching anticline and for 1 mile northwest along the strike is conspicuously exposed here.[1] The anticlinal area is typical Clinton, containing characteristic ostracodes just below the Keefer sandstone.

Stop 12—10 minutes. Park cars along road. Explanation of the section here.

Northeastward the formations are again crossed in the reverse order. The broad belt of Oriskany on the southeast slope of Cooper Mountain is notable. The Onondaga, 75 feet thick, is fully exposed at the sharp bend of the road at the foot of the mountain. Here occurs one of the main guide fossils of the Onondaga, the ostracode, *Amphissites favulosa,* which is ubiquitous from Perry County, Pennsylvania, to Washington County, southwest Virginia.

Stop 13—5 minutes. Park cars along road.

About half way across the valley on the Marcellus shale, the sandstone noticeably displayed on the left is Oriskany on the nose of a southwest pitching anticlinal spur. Schaffenaker Mountain, an anticline in the Oriskany, is next crossed. Just west of Capon Bridge, a synclinal axis in the Marcellus is passed in a deep cut. Here is a notable display of slaty cleavage cutting the bedding. Just south of the road in the village, the Oriskany is exposed on the nose of a northward pitching minor fold. Probably the Oriskany reaches its maximum thickness, of 200 feet or more, in this locality. One mile east of Capon Bridge, by the road, the route crosses the summit of Bear Garden Mountain, another anticline in the Oriskany.

[1] It should be noted that the road has been changed here from its position as shown on the topographic map of the Hanging Rock quadrangle. It passes south around the tip of the anticline instead of crossing the axis on the Clinton farther north.

At the east foot of the mountain, cross Mill Branch. Half a mile farther southwest is a good exposure of a persistent sandstone member at the top of the Hamilton. Just southeast of the Hamilton outcrop, across a bridge, is a covered space of a few hundred feet, probably occupied by Brallier shale. Then there is a long exposure of Brallier and Chemung, with interruptions, dipping 40° SE., which continue to the Virginia State line at the top of the hill, or Timber Ridge. The boundary between the Brallier and Chemung is placed at the intersection of the road to the north, slightly more than half a mile west of the State line. About 900 feet from the intersection is a chocolate-colored sandstone of a type common in the Chemung of Virginia. Fossils occur in the Brallier, at a few levels, of a type that suggests the Ithaca horizon of New York. A little red shale and conglomerate occur below the chocolate-colored sandstone and *Tropidoleptus* occurs in association with it. Neither feature is known to occur in the Brallier, except possibly and very rarely a thin reddish layer. About 700 feet up the hill from the red sandstone, *Spirifer disjunctus* and *Sp. mesistrialis* occur. At the summit of the ridge on the State line, there is a sandstone with an abundance of *Schizodus* and *Spirifer disjunctus*. The Chemung, with a dip of 20° SE., continues down the grade in Virginia to within 800 feet of Isaac Creek (Johnson Creek on Winchester map). Fossils, *Spirifer mesicostalis, Sp. mesistrialis,* and *Leptodesma* occur practically to this point.

Southeast from Isaac Creek, over the hill past a filling station and road intersection on the south (right), and still farther southeast around the great hairpin curve to the bend in the road 1,500 feet beyond the apex of the curve, red shale and sandstone form a conspicuous, if not predominant, constituent of the rocks, but considerable gray sandstone is interbedded. For this red formation the restoration of Darton's name, Hampshire formation, is proposed, since it has been amply demonstrated that it cannot be any part of the typical Catskill formation. This belt occupies a syncline, the axis of which is 1,500 feet southeast of the filling station at the top of the hill mentioned above and at the apex of the strong northward curve near the intersection of a side road to the north. Its position will be apparent from the reversal of the dip just northwest of the intersection. South of the apex of the hairpin curve just mentioned above, the road crosses the strike at a low angle for 1,500 feet. Along this stretch is much gray sandstone, but just around the bend of the road is a nearly continuous mass of red shale, 130 feet thick, that is considered to be the basal member of the Hampshire ("Catskill") formation.

Just around the last-mentioned curve and 60 feet below the basal red bed of the Hampshire, interbedded in red shale, is a layer of rusty

rotten rock 4 inches thick, evidently calcareous in the fresh condition, which contains *Spirifer mesistrialis* and *Sp. mesicostalis*. These fossils are regarded as Chemung. Their occurence interbedded with red shale and the additional occurrences of thin layers of red and chocolate-colored shale and interbedded fossiliferous layers through a considerable thickness of the immediately underlying beds, shows well the transitional change from the Chemung to the Hampshire prevailing in Virginia. About 600 feet below the top of the Chemung, a fragment of *Lepidodendron* or *Protolepidodendron* was found. At 600 feet lower are two thin layers of conglomerate, densely packed with small quartz pebbles the size of beans. Such conglomerate layers are common in the Chemung everywhere but have not been observed in the underlying Brallier. The Chemung-Brallier contact is placed at a shallow ravine 1,200 feet beyond the Shady Rest road house. The total thickness of the Chemung as here delimited is about 2,700 feet.

Stop 14—10 minutes. Park cars along road.

Passing the narrow ravine with beds containing Chemung fossils, there is a short space covered with thin sandstone debris containing fossils of Ithaca aspect; then there is an exposure of vertical and contorted beds for 300 feet; then a covered space for 700 feet; then an exposure of thin siliceous shale and thin, rusty layers of sandstone for 1,400 feet; then a covered space of 300 feet to the contact of the Brallier and Hamilton. Fossils, including *Schizophoria* and *Peridichnites*, occur in the 1,400 feet of exposure noted just above. *Peridichnites* is everywhere characteristic of the Brallier shale. As will be noted, the uppermost Brallier is hard to distinguish lithologically from the lowermost Chemung. The distinction is based mostly on fossil evidence. There is nowhere in this part of Virginia any evidence of the Naples beds, which are present in West Virginia, as already noted, and here the Hamilton immediately underlies the Brallier.

The top of the Hamilton here exposed, as referred to just above, is a rather thick-bedded sandstone about 100 feet thick. This bed is universally present in this part of Virginia. The Hamilton is a dark-colored rock with massive beds characterized by a peculiar hackly fracture. This feature is present in the formation in central Pennsylvania. On long weathering, the massive rock breaks down to small rusty chips, as shown on the left of the road just beyond Gore, next to be passed. The Hamilton is fairly fossiliferous, in places abundantly so. *Spirifer mucronatus* and *Tropidoleptus carinatus* are perhaps the most abundant species. The Hamilton is exposed for 300 feet east of Gore. Beyond is a flat area nearly a mile wide, extending to Back Creek. The Hamilton, however, underlies most of this space for the outcrop is spread out by an anticline, the axis of which lies about one-quarter mile east of Gore.

Slightly to the southwest of Gore, a mile distant but visible from the road, is a high knob on this anticline occupied by the Oriskany sandstone which is being quarried there for glass and other sand.

West of Back Creek, perhaps one-quarter of a mile, the Marcellus, Oriskany, and New Scotland member of the Helderberg cross the road, as is known from actual exposures within half a mile to the north and to the south of the road.

After crossing the bridge over Back Creek, **drive slowly** around the north end of Great North Mountain. Just east of the bridge the Keyser limestone shows slightly for 450 feet in a field on the right of the road. It is then fully exposed for another 450 feet, to the beginning of the Wills Creek shale which, in a vertical attitude, is exposed for 300 feet farther. The lower Keyser here contains a persistent sandstone about 10 feet thick, which makes a low narrow ridge. Next below the Wills Creek is the Bloomsburg red shale and sandstone, rising to a very symmetrical arch which is well shown to the north (left) of the road at the big brick house. This anticline is one of the several subordinate folds that enter into the complex structure of the Great North Mountain anticline. Just beyond the arch, at the intersection of the road to the north, the Bloomsburg dips into a minor syncline occupied by the Wills Creek shale; then the Bloomsburg, seen on the south (right), rises to a second anticline on the crest of which the McKenzie shale is brought up and is exposed below, and in contact with, the red Bloomsburg. The weathered McKenzie is a fissile yellow shale. At this exposure some small chips are covered with minute ostracodes, *Kloedenia* and *Eukloedenella.* The McKenzie is 100 feet or more thick. It is immediately underlain by the Keefer sandstone member of the Clinton, which rises and crops out upon the slope of the mountain 500 feet south of the road. For about half a mile southeast, almost along the strike, the McKenzie is more or less exposed, dipping 40° toward the road; then the Bloomsburg finally descends below road level.

For about a mile along the road, making a small angle with the strike, the section ascends through the Wills Creek and Keyser to the axis of a syncline, crossing which the section descends through the basal Keyser (exposed in cut) to a narrow outcrop of Wills Creek, on an anticlinal axis which passes through the orchard on the northeast. A short distance beyond this axis the New Scotland chert (Helderberg) and Oriskany sandstone descend to the road at a pronounced curve about half a mile northwest of Hayfield, where the road takes an eastward course. Due to the lower dip here, the Oriskany crops out a few hundred feet along the road. It contains *Spirifer arenosus,* which is best shown at the house along the side road to the southwest.

Above the Oriskany here, the Onondaga shows in the field to the north (left). The Marcellus shows in the road for half the distance to Hayfield. At Hayfield the Onondaga rises to crop out on a minor anticline. A short distance beyond, it is succeeded by the Marcellus shale. The Marcellus and Hamilton occupy the level ground to the intersection of the roads one-quarter of a mile southeast of the bridge across Hogue Creek, where the outcrop of the Brallier shale begins.

From this point southeast the section ascends through the Brallier, Chemung, and Hampshire to a plainly exposed synclinal axis one-quarter of a mile southeast of a pronounced southward curve in the road. The axis is in a thick body of red rock. From this axis the rocks are crossed in reverse order down to the Wills Creek shale and sandstone at Chambersville. The transition of the Chemung to the Hampshire through interbedded layers of red shale and thin beds with Chemung fossils is perfectly shown in both limbs of the syncline. No sharp lithologic boundary between the Chemung and Hampshire exists.

For 1,100 feet west of the filling station at Chambersville, the vertical Hamilton formation is fully exposed and is about 1,150 feet thick. At the top is the same thick-bedded sandstone as that a short distance west of Gore. For a few hundred feet southeast of the filling station, the Marcellus, Onondaga, Oriskany, New Scotland, and Keyser limestone underlie the road, as shown by actual exposures a short distance to the northeast and by small exposures and scattered debris along the road.

About 750 feet southeast of the filling station is an exposure of Wills Creek beds in contact with the Martinsburg shale, either due to a fault or a hiatus. The Tuscarora, Clinton, McKenzie, and Bloomsburg are absent. The Tuscarora is apparently 100 feet thick on the top of Round Hill three-quarters of a mile to the north. It can be traced in constantly decreasing thickness to only 1 foot thick about 200 to 300 feet northeast of the road. It reappears in full thickness on the end of Little North Mountain across the narrow valley to the southwest. The Wills Creek is identified by its ostracods; the Martinsburg by *Cryptolithus* and *Sowerbyella,* which occur but a short distance below the contact—marked by a distinct gash. The beds are all overturned.

Stop 15—10 minutes. Park cars along road.

About 1,500 feet east of the Wills Creek-Martinsburg contact is the outcrop of the Little North Mountain fault, one of the great overthrusts of the Valley region and the only one in the northern part of the Valley in Virginia. On the slope above the road is a church that stands on the Martinsburg shale; by the road side on the left and just beyond two houses, are exposures of argillaceous shaly beds of the Elbrook limestone of Middle Cambrian age. The stratigraphic displacement is

at least 6,000 feet, but the fault does not express itself in the slightest degree topographically and its presence is known only by the abnormal contact that plainly exists here. The width of the Elbrook outcrop has not been determined nor the position of its contact with the overlying Conococheague limestone.

The presence of sandstone 3,000 feet southeast of the fault, near Pingley's filling station on the left, shows the Conococheague limestone at that place. The Elbrook-Conococheague contact lies between Pingley's and the fault. Observations at Opequon, 2¾ miles to the southwest on the strike, indicate that the outcrop of the Elbrook is at least half a mile wide west of that place.

From Pingley's filling station to Winchester, the road is on the Conococheague limestone which is well exposed and dips almost constantly to the southeast, at a steep angle, for 3½ miles to its top in Winchester. As the Conococheague is not known to be more than 2,000 feet thick, a succession of minor overfolds or a schuppen structure is clearly indicated. A characteristic feature of the Conococheague is the presence of beds of sandstone at different and probably inconstant levels. Some of these beds can be traced for considerable distances and it is hoped that by tracing some outcrops to convergence, some light may be thrown upon the structure of the Conococheague belt. The sandstone beds are a constant feature of the Conococheague and the Copper Ridge dolomite and do not occur, except possibly very rarely and of limited extent, in any of the other adjacent limestone formations.

Stop 16—10 minutes. Park cars along road. To examine sandstone beds in the Conococheague.

In the shallow cut on the summit of the low ridge (Winchester historic marker) about half a mile west of the city, 5 beds of sandstone occur in the Conococheague dolomite and limestone. They were visible when the cut was made but are obscure now. From the top of a low ridge half a mile southwest of Winchester a fine view can be had across the Harrisburg peneplain to the Blue Ridge 12 miles distant.

WINCHESTER, VA., TO WATERLICK, VA.

CHARLES BUTTS

Park cars, headed west, on the north (right) side of Piccadilly Street, opposite the George Washington Hotel.

Drive west to Braddock Street, then turn left on Braddock Street. After 4 blocks, note stone house which was the headquarters of Washington when making surveys for Lord Fairfax in 1748, and also was the starting point for the ill-fated expedition

of Braddock against Fort Duquesne in 1755. Continuing southwest, note Handley School and grounds on right. Here enter U. S. No. 11, a main highway extending from New Orleans to Canada north of Lake Champlain.

Stop 17—20 minutes. Park cars along road. Enter field through gate. (See Pl. 5.)

The Chepultepec limestone occurs 100 feet to the west. The top member of the Conococheague limestone, with thin siliceous laminae standing in prominent relief, occurs on the bank just below the Chepultepec. This sequence is persistent and has been traced for 35 miles northeast and southwest through this region. The siliceous lamination is characteristic of the Conococheague and was first described by Stose in the Mercersburg-Chambersburg folio (No. 170), in 1909. A thick layer of Chepultepec here is crowded with the silicified brachiopod, *Tetralobula,* Cooper, and many fine specimens have been etched out of this limestone. This bed, with *Tetralobula* and also *Finkelnburgia,* is known to extend southwest for 45 miles from Winchester.

A short distance southwest from this stop the Chepultepec is exposed in a road bank on the right, in front of "The Elms" tourist home. On the south of the low sag in the road and one-fourth of a mile from "The Elms" is another exposure of the Chepultepec on the left side of the road. The prominent limestone ledges in the field on the left along here are basal Beekmantown (Nittany horizon); the ledges on the right are in the Chepultepec.

Southwest through Kernstown and nearly to the Baltimore & Ohio Railroad crossing, the road crosses the Beekmantown which strikes diagonally across the road. A short distance across the track is a small exposure of Mosheim limestone which succeeds the Beekmantown in this region. The Lenoir is just above the Mosheim. Neither is much exposed beside the road. From this locality nearly to Stephens City the road is on Chambersburg limestone, which immediately succeeds the Lenoir in this region. Between the Chambersburg and Lenoir is a great hiatus in which the Blount group, aggregating a maximum thickness of many thousand feet, is absent.

Southwest nearly to Stephens City the road is on Chambersburg limestone; then it passes onto the Martinsburg shale on which it continues nearly to Vaucluse 2½ miles southwest of Stephens City. Just south of Stephens City a big quarry and limeworks can be seen on the right. The quarry is on an anticlinal nose in the Mosheim limestone, which pitches to the northwest. There are

other quarries on this outcrop of Mosheim between Stephens City and Strasburg. At Vaucluse is a sharp bend in the strike to the southeast and the road crosses the Chambersburg, Lenoir, and Mosheim onto the Beekmantown dolomite which is exposed on the southeast (left) side of the road just opposite the side road to the northwest and just north of the low point in the main road. Continuing southwest, U. S. No. 11 recrosses the formations onto the Chambersburg which it follows through Middletown.

From the road north of Middletown, a good view to the northwest can be had, across the Harrisburg or Valley-floor peneplain, to Paddy Mountain in the distance. If the atmosphere is clear, a notable arch in the Tuscarora quartzite can be seen in the gap of Paddy Run through the ridge. The upland adjacent to Cedar Creek and 100 to 200 feet above the creek is strewn with waterworn gravel showing the existence of an old terrace level.

Between Stephens City and Middletown the imposing north buttress of Massanutten Mountain is in view on the left.

Just beyond Middletown the road passes onto Martinsburg shale which shows on the left. A mile and a half farther, at the intersection of a road to the north, the Chambersburg recrosses the road from the right and is well exposed up to its contact with the Martinsburg.

Stop 18—5 minutes. A point 15 miles from Winchester. Park cars along road. To note the contact of the Chambersburg and Martinsburg.

For a mile beyond this point, the road crosses a synclinal reentrant of the Martinsburg shale and then, at the junction of a road to the north, crosses into the Chambersburg limestone which is well exposed onward to Strasburg.

At Strasburg, turn right through the town. Pass an evident axis in a synclinal reentrant of the Martinsburg and come to a continuous exposure of the Chambersburg limestone for a distance of about 1 mile. The massive bed first encountered at the top of this exposure is the *Christiania* bed (Greencastle limestone of Ulrich).

Stop 19—45 minutes. Park cars along road.

At Tumbling Run, 2 miles southwest of Strasburg. Walk along the road up Tumbling Run across a fully exposed section of the Chambersburg, Lenoir, and Mosheim limestones down to the contact of the Mosheim and Beekmantown. Near the base of the Chambersburg is a thin sandy bed and several thin beds of bentonite. Between the Chambersburg and Lenoir are 50 feet or

so of thin-bedded limestone of uncertain age but perhaps Whitesburg. Below this limestone is 50 feet or so of cherty fossiliferous Lenoir, and below the Lenoir, 50 feet or less of typical Mosheim with *Tetradium syringoporoides*. The top of the Beekmantown is exposed in the field by the road side just beyond the bridge over the creek. Retrace the road a short distance and cross the ravine and creek to the old road south of the creek, where *Nidulites pyriformis* is abundant in the limestone. Continue south along the old road to its junction with U. S. No. 11 and thence back to the cars; passing Chambersburg with *Christiania* bed, into basal Martinsburg which is finely exposed in cuts along the road. Beds of bentonite occur in both the Chambersburg and basal Martinsburg here; also *Cryptolithus* and *Diplograptus amplexicaulis* in the basal Martinsburg, showing its Trenton age.

Return to Strasburg and continue to the intersection of U. S. No. 11 and Virginia No. 55. Drive eastward along the north base of Massanutten Mountain on Martinsburg shale, which begins to be exposed, dipping eastward, about half a mile east of Strasburg. East of the river bridge the axis of the Massanutten syncline has been crossed and the reversed dip is shown in a pit just south of the road. At Waterlick, turn south (right). On Martinsburg to the entrance to the gap of Passage Creek through the north end of Massanutten Mountain. The striking, sharp, unsymmetrical ridge seen on the approach is a dip slope on the Massanutten sandstone on the right (northwest) slope of the ridge, and the still steeper slope to the left (southeast) of the crest is upon the outcrop of the eroded edges of the sandstone. The top of the Martinsburg is exposed at the entrance to the gorge.

MASSANUTTEN MOUNTAIN SYNCLINE: WATERLICK TO SUMMIT OF POWELLS MOUNTAIN

FRANK M. SWARTZ

Stop 20—20 minutes. Park cars along road. (See Pl. 7.)

Entrance to gorge where Passage Creek cuts through Tuscarora sandstone at the north end of Massanutten Mountain, which extends southwestward along the middle of Shenandoah Valley for a distance of 50 miles. The mountain is formed by the upturned edges of Tuscarora sandstone at the margins of a synclinal body of Silurian and Devonian rocks (Pl. 7). It is of special interest because it preserves the most southeasterly rem-

nant of these rocks in this general latitude. Massanutten Mountain is also of interest in that it is a large linear monadnock on the "Valley-floor" peneplain.

The following Silurian sequence occurs in the area:[2]

Silurian formations in the Massanutten Mountain area, Virginia

	Thickness (Feet)
Devonian:	
Romney shale.	
Coeymans (?) limestone (not seen); locally	40
Silurian or Devonian:	
Keyser limestone	20–50
Sandstone member at top, comparable to the Clifton Forge sandstone of west-central Virginia	1½–31
Silurian:	
Tonoloway limestone; Indian Spring red bed member, 50 feet, below middle	400
Indian Spring red bed member, below middle	50
Wills Creek shale and sandstone (not seen)	225
Bloomsburg red sandstone	200
Clinton sandstone and shale	0(?)–250
Tuscarora sandstone	800
Ordovician:	
Martinsburg shale and sandstone.	

At the entrance to the gorge of Passage Creek, 85 feet of greenish argillaceous Martinsburg sandstone (Ordovician) is exposed along the road. Unidentified fossils occur at 45 and 75 feet. The contact with the overlying Tuscarora sandstone is concealed by a 35-foot covered interval. The Tuscarora sandstone is thick bedded, hard, whitish, somewhat conglomeratic and quartzitic. It forms high bluffs along the road and towering cliffs on the opposite side of the gorge, southeast of Passage Creek.

The red Juniata formation, which occurs below the Tuscarora at Cumberland, Md., and is several hundred feet thick at Fetzers Gap, 9 miles west of Strasburg, Va., is absent here. This corresponds to its disappearance below the Tuscarora-Shawangunk in eastern Pennsylvania.

Drive south 4,300 feet, along road, from base of the Tuscarora.

[2] The Silurian sections of the Massanutten Mountain area here discussed are summarized from unpublished studies by Charles K. Swartz and Frank M. Swartz.

Stop 21—20 minutes. Park cars along road.

The upper Tuscarora and 220 feet of Clinton beds are exposed along the road. The Clinton consists of greenish gray sandstones and arenaceous shales, with brown "iron" sandstone 84 to 97 feet above the top of the Tuscarora, and with some red beds in the upper 20 feet. These beds are believed to be an eastern, coarser, continental facies representing part of the Clinton formation[3] near Cumberland, Md. The invertebrate fossils which are so profuse in, and characteristic of, the Clinton and McKenzie farther west have not been observed here; instead, carbonaceous films suggestive of plant "chowders" occur 11 feet above the "iron" sandstone and at other horizons. These strata lie, however, between the Tuscarora (below) and the Bloomsburg (above); and "iron" sandstones are characteristic of the Clinton farther west.

The Tuscarora sandstone thickens from 380 feet at Cumberland, Md., to 815 feet here. The Clinton-McKenzie beds thin from 900 to 250 feet. Much of the Clinton may well have graded into Tuscarora in this area, in the same fashion in which it passes laterally into Shawangunk conglomerate in eastern Pennsylvania.

Drive south 1,460 feet across a concealed interval, 550 feet thick, which includes, in ascending order, Bloomsburg red shale, 200 feet; Willis Creek shale and sandstone, 225 feet; and lower Tonoloway, 100 feet.

Stop 22—15 minutes. Park cars along road.

Poor exposures of the middle Tonoloway Indian Spring red bed member, 50 feet; underlying shale and sandstone, 35 feet; and overlying argillaceous Tonoloway limestone, 70 feet. The limestone is fossiliferous, containing *Stropheodonta bipartita, Chonetes* n. sp., *Hindella rotundata,* and unidentified ostracoda. The upper Tonoloway is concealed.

Drive south along road through Dilbeck. Exposures of Devonian shales. Continue through Detrick toward Seven Fountains.

Stop 23—30 minutes. Park cars in indicated space.

At the farm of Mr. William Lichliter, less than half a mile north of Seven Fountains. Walk east 600 feet from the road by the residence, crossing a small hill and hollow to Indian Spring red bed, seen near top of last section, and exposed here in a small run. Return through section in ascending order.

The section here is as follows:

[3] They may represent also some part of the McKenzie formation.

Geologic section near Seven Fountains, Va.

	Thickness (Feet)
Romney shale:	
Unconformity: Oriskany-Helderberg beds absent.	
Keyser limestone:	
Sandstone member; west of Dilbeck the presumable extension of this sandstone carries diagnostic and well-preserved middle Keyser fossils	1½
Lower limestone member; uneven bedded limestone, with *Chonetes jerseyensis* fauna	20
Tonoloway limestone:	
Argillaceous limestone and calcareous shale	50
Thick-bedded crystalline, mostly crinoidal limestone; fossiliferous; *Hindella congregata* and other fossils at various levels	72
Concealed	14
Calcareous sandstone, making crest of hill	6
Arenaceous limestone and some sandstone; very fossiliferous uneven bedded limestone, containing *Spirifer fontinalis* n. sp. and other fossils 13 to 40 feet above base; *Beyrichia tonolowayensis* at 5 feet above base	67
Calcareous sandstone	4
Laminated limestone with *Leperditia* sp. below; exposed in small quarry	12
Calcareous shale, some impure limestone, some sandstone; mostly concealed	36
Indian Springs red bed member; exposed	8
Concealed to base of Tonoloway	140±

Nearer shore conditions are suggested by the red bed member and numerous sandstone horizons of the Tonoloway, which are absent near Cumberland, Md. The crinoidal limestone indicates development for a time of more open sea conditions than are represented near Cumberland.

The "Oriskany" sandstone reported from the Massanutten Mountain area is in part, if not wholly, Keyser in age. Well preserved *Chonetes jerseyensis, Camarotoechia gigantea, Merista typa,* all especially diagnostic Keyser species, were obtained in these sandstones near Boyers Furnace, west of Dilbeck. This fauna was not obtained at Seven Fountains. At Boyers Furnace the sandstone is about 30 feet thick. It is overlain by about 40 feet of

crystalline limestone, suggestive of Coeymans limestone, though diagnostic fossils were not found in it. The limestone is overlain in turn by Romney shale, but there is a small concealed interval across the contact.

Return to Detrick and continue straight through on the road (Virginia No. 261) toward Woodstock.

Stop 24—15 minutes. Park cars along road.

The Bloomsburg red sandstone is exposed in the eastern limb of a large subsidiary anticline in the Massanutten syncline. The Bloomsburg red beds, concealed above the Clinton formation at the gorge of Passage Creek, are well exposed here. The overlying Wills Creek and Tonoloway are concealed. There is exposed 185 feet of predominantly red sandstone and shale, representing the bulk of the Bloomsburg as developed in this area. Next lower is 60 feet of dominantly green, in part conglomeratic, sandstone, with some red beds above the base and higher. These beds are transitional between the Clinton and the Bloomsburg and are probably best considered as Clinton. They are underlain by thick-bedded hard whitish Tuscarora sandstone, measuring 830 feet in the other limb of this anticline and 770 feet on Powells Mountain.

The thickness relations here and at Cumberland can again be summarized as follows:

FORMATION	CUMBERLAND	PASSAGE CREEK	WOODSTOCK ROAD
Bloomsburg red beds	36 feet red and green		185 feet red shale and sandstone
Clinton-McKenzie	890 feet fossiliferous shale and limestone	220 feet sandstone and shale	60 feet
Tuscarora sandstone	380 feet	815 feet	800 feet

It is suggested that the Clinton and Tuscarora interfinger, but that has not been conclusively demonstrated.

Continue westward on the Woodstock road through the anticline in the Tuscarora and a syncline in the upper Silurian and Devonian. The Bloomsburg is exposed near the top of Powells Mountain.

Stop 25—40 minutes. Park cars in open space at top of Powells Mountain. Lunch here.

The Tuscarora is exposed with high dip to the southeast. There is a fine view across Shenandoah Valley, from the lookout

south of the road. Cambrian and Ordovician rocks lie beneath the Valley floor. Tuscarora sandstone occurs in the first ridges west of the Valley. The "Seven Bends of the Shenandoah" are in the foreground.

On the west side of Powells Mountain, conglomeratic Tuscarora sandstone is well exposed near the mountain top. Its contact with the underlying Martinsburg shale is exposed 2,900 feet along the road, 245 feet below the summit.

POWELLS MOUNTAIN TO LURAY, VA.

CHARLES BUTTS

Walk south along the crest of Powells Mountain for about 500 feet to the fire tower. Observe the notable incised meanders in Shenandoah River at the northwest base of the mountain. To the west is the Harrisburg, or Valley-floor, peneplain. Little North Mountain, a Tuscarora sandstone ridge, bounds the valley on the northwest; perhaps Paddy Mountain shows in the extreme distance. Woodstock is in the middle of the valley. Looking southeast, the anticlinal ridge penetrated by Woodstock gap is the first ridge; beyond is the broad valley on the Hamilton and other shales, and bounding the view on the southeast is Massanutten Mountain proper, as named on the Luray topographic map. It is thus seen that Massanutten Mountain, as the whole area is generally understood, is a somewhat composite feature. Return to Detrick.

Stop 26—10 minutes. Park cars along road. (See Pl. 5.)

At the big bend in the road half a mile from Detrick, note the fossiliferous Hamilton. At Detrick turn right. Continue on Hamilton for several miles.

At the intersection with Virginia No. 266, turn left. Near the intersection and also a few hundred feet beyond the bridge, are exposures of shale that may be Marcellus. On Marcellus to road intersection. Keep left. Pass Camp Roosevelt, the first C. C. C. Camp to be established.

About 0.3 mile beyond, note a shale pit in Onondaga, on the left. Ostracods have been collected here. Beyond the pit and on dip slope crossed diagonally by the road, the Bloomsburg gives evidence of its presence well up toward the summit of the mountain, but the top of the Massanutten sandstone crops out somewhat below the summit. Cross the top of Massanutten Moun-

tain about 5¼ miles from intersection with No. 266, mentioned above. Good views of Page Valley and the Blue Ridge.

Descending the mountain, the Massanutten sandstone is clearly exposed for a long distance. The concealed contact with the Martinsburg shale probably is near the bottom of the exposure. For the remainder of the long distance down the mountain slope, the road is on the Martinsburg. At points on this part of the road, a good view of Kennedy Peak, on the crest of the mountain some distance northeast of the road crossing, is obtained.

Ascending the slope southeast of Bixler Bridge, the Chambersburg limestone, probably the Athens shale, Lenoir, Mosheim, and Beekmantown—the last three on a small anticline—are crossed. They show in the field on the left, half way up the slope. Slightly higher up the slope but below the first house, the Athens reappears and probably continues to the road intersection just below the church on the top of the hill. Graptolites occur here in the Athens. The structure across this belt has not been satisfactorily worked out in detail by the writer.

Road intersection at top of a hill. There are no exposures along this route to Luray, but the road is on Beekmantown. Turn right; after 500 feet, turn left; turn right at the next intersection; then turn left at the next road and drive to Hamburg. One mile west of the last intersection, note the high-level gravel on top of the hill. Farther along, note chert in fence. It is probably Nittany. From this point also note Cave Hill on the east (left), beneath which are Luray Caverns.

At Hamburg, intersection with Lee Highway (U. S. No. 211). Turn right and drive southwest 1 mile.

Stop 27—15 minutes. Park cars along road.

On the slope below the flat ground of the hill, the top of the Beekmantown, the Moheim, Lenoir, Athens, Chambersburg, and Martinsburg crop out, all dipping toward the southeast at about 30 degrees, the younger formations all apparently dipping beneath the older.

In Luray Caverns the Beekmantown (Nittany) also dips about 10° SE., and is apparently overturned in conformity with the rocks southwest of Hamburg. The dolomite of the caverns is known to be Nittany from the fact that a species of *Lecanospira* occurs in chert on the summit of Cave Hill.

Drive to Luray for night stop. Optional night trip through Luray Caverns.

LURAY, VA., TO PANORAMA AND FRONT ROYAL, VA.

ANNA I. JONAS

GENERAL STATEMENT

Three miles east of Luray, Va., the route leaves the Great Valley of Virginia and ascends the Blue Ridge (U. S. No. 211) to Thornton Gap, or Panorama. Here the route follows the Skyline Drive northward through the north part of Shenandoah National Park to Front Royal. (See Pls. 8 and 9, and Appendix E.)

The Catoctin-Blue Ridge anticlinorium is made up of pre-Cambrian rocks, with infolded Lower Cambrian quartzites, that form the western front of the Blue Ridge on the west and Catoctin Mountain on the east. The western border of the anticlinorium is a thrust fault which has carried pre-Cambrian and Lower Cambrian rocks northwestward over the Paleozoic rocks of the Great Valley. In northern Virginia the Border fault on the west side of the Triassic rocks forms the eastern boundary of the anticlinorium. Along this normal fault the pre-Cambrian and Lower Cambrian rocks of the anticlinorium have been uplifted in respect to the Triassic rocks to the east. The area of the anticlinorium is included in the Blue Ridge and Piedmont provinces. In northern Virginia the Blue Ridge proper occurs along the western border of the anticlinorium. It is a relatively narrow ridge with the Great Valley to the west and the Piedmont plateau to the east of it.

The Skyline Drive from Panorama to Front Royal lies along thet Blue Ridge crest and the highest of the peaks along the route is Hogback Mountain, 3,474 feet in altitude. The eastern border of the Blue Ridge is bounded by an irregular escarpment of about 1,000 to 1,500 feet in height. The Piedmont plateau east of the Blue Ridge is a rolling plateau that gradually rises westward to the foot of the Blue Ridge. In northern Virginia, only the western part of the anticlinorium is in the Blue Ridge. The greater part of it is included in the Piedmont plateau. The Triassic plain east of the mountain border fault is also part of the Piedmont province.

In northern Virginia the center of the anticlinorium is formed by the pre-Cambrian igneous complex. Pre-Cambrian basaltic flows lie on the flanks of the igneous complex and the Lower Cambrian quartzites lie in synclines along the western and eastern borders. The western synclinal area of quartzite is on the western border of the Blue Ridge from Loudoun Heights, Va., south of

Harpers Ferry, southwestward. For a distance of 10 miles southwest of Front Royal, the quartzites are cut off by the Blue Ridge overthrust. The eastern synclinal area forms Catoctin Mountain and Bull Run Mountain. In the area from Leesburg to a point south of Aldie, the greater part of the Lower Cambrian quartzites of this syncline are faulted out by the normal Triassic fault.

A third syncline of Lower Cambrian quartzite in the western part of the anticlinorium enters Virginia south of Weverton, Md., where it forms South Mountain in Maryland and Short Hill in Virginia. This syncline rises, or is faulted out, north of the road from Snickers Gap to Leesburg (Virginia No. 7).

PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks of the Catoctin-Blue Ridge anticlinorium comprise schists of sedimentary origin, intrusive igneous rocks, and volcanic flows and tuffs. The oldest sedimentary rocks have been injected and metamorphosed by igneous intrusions, and in northern Virginia occur only as injection gneiss and thin layers in the igneous complex. On the geologic map of Virginia (1928), the igneous rocks were divided into the Lovingston granite gneiss, a biotite augen gneiss; the Marshall granite, a quartz monzonite characterized by blue quartz pegmatite; and hypersthene granodiorite. This separation was very generalized. Subsequent detailed work has led to many subdivisions of these types and more exact knowledge of the relative ages of the intrusions. The oldest rock known is a series of argillaceous sediments, now metamorphosed to a biotite-garnet-kyanite gneiss. These sediments were intruded by gabbro or diorite, in which the original pyroxene has been altered in part to hornblende and biotite. The granitic intrusions were later. They have formed injection gneiss and mixed rocks by mechanical and chemical action. These mixed rocks are biotite augen gneisses; granodiorite, in which the green perthitic feldspars are a replacement; and green-banded granitic rocks containing garnet, in which the garnet is altered to biotite. The latest phase of the granitic intrusion was coarse-grained cross-cutting pegmatite composed largely of microcline and blue quartz. The feldspars are white, pink or deep red in color. Replacement of the hypersthene granodiorite by pink feldspar, blue quartz, and epidote has produced in many places a striking rock called unakite.

In the eastern part of the Catoctin-Blue Ridge anticlinorium in northern Virginia, and forming a large part of it south of Lynchburg, is the Lynchburg gneiss, a formation composed of biotite

gneiss, schist, graphic slate and quartzite. This formation appears to overlie the granitic intrusive rocks with a basal conglomerate exposed south of Charlottesville. The Lynchburg gneiss is intruded by dikes and sills of metagabbro and ultrabasic rocks, altered in part to talc and serpentine.

The metabasalt (Catoctin greenstone) and aporhyolite flows which border the eastern and western sides of the Catoctin-Blue Ridge anticlinorium in northern Virginia are younger than the intrusive complex which forms the center of the anticline. The Catoctin metabasalt flows and tuffs and agglomerates at their base overlie also the Fauquier formation of Furcron,[4] in the area near Warrenton. The Fauquier formation may be the equivalent of the Lynchburg gneiss.

Evidence derived from detailed work in southern Maryland, northern Virginia, and southwestern Virginia has shown that the volcanic flows overlie the folded and eroded igneous complex. The age of the pegmatitic phase of the granitic intrusions has been determined as 850 million years by analyses of the contained allanite from Amherst County, Virginia.[5] The flows, both metabasalt and aporhyolite, belong to the latest part of pre-Cambrian time. Related metadiabase and porphyry dikes cut the igneous complex. In the area south of Thornton Gap, Furcron reports that, at a few places, pegmatite intrudes metabasalt. This pegmatite may be similar in age to that occurring in the Blue Ridge of North Carolina, for which an age of about 584 million years was determined by analysis of monazite contained in it.

CAMBRIAN ROCKS

The oldest (Lower Cambrian) rocks crop out along the western front of the Blue Ridge and in the South Mountain and Catoctin Mountain synclines.

The Loudoun formation is a heterogeneous formation composed of conglomerate, quartzite, and slate from a few feet to 800 feet thick. The conglomerate and quartzite beds are in many places ferruginous, green or purple, and generally arkosic. The Weverton quartzite is a thicker bedded arkosic quartzite, with white quartzite in its upper part, from 200 to 1,000 feet thick. Both formations are equivalent to the Unicoi quartzite of the area southwest of Roanoke. In the area from Front Royal southwestward, a basalt flow occurs in these Lower Cambrian quartzites. This flow is not present in the Lower Cambrian section in

[4] Furcron, A. S., Unpublished manuscript in files of Virginia Geological Survey.
[5] Marble, J. P., Age of allanite from Amherst County: Am. Jour. Sci., 5th ser., vol. 30, pp. 349-352, 1935.

Maryland and Pennsylvania and it is not known to occur north of Front Royal or in West Virginia. A flow has been reported at the base of the Loudoun north of Beahms Gap.[6]

The Harpers phyllite overlies the Weverton quartzite and consists of gray siliceous and argillaceous slate, or phyllite, and thin-bedded quartzite, probably 1,200 to 2,000 feet thick. It commonly forms valleys between the underlying Weverton and the overlying Antietam quartzite.

The Antietam quartzite is a thick-bedded hard gray to white quartzite, 500 to 1,000 feet thick. It contains fossils, chiefly trilobites and *Obolella,* in the upper part. It underlies the Lower Cambrian Tomstown (Shady) dolomite, into which it grades through calcareous quartzite beds.

ITINERARY

Stop 28—10 minutes. Park cars along road. (See Pl. 8.)

Leaving Luray on U. S. No. 211, the road crosses anticlines of Antietam quartzite 4 miles east of Luray. The thrust fault along the western side of the Blue Ridge separates these anticlines from Loudoun quartzite that borders the thrust and overlies Catoctin metabasalt. The metabasalt is well exposed on the switchback west of Thornton Gap. It contains amygdules and much secondary epidote and quartz. The metabasalt continues to Panorama and is exposed for 4 miles northward along the Skyline Drive to a point north of Beahms Gap.

Stop 29, Panorama—10 minutes. Park cars in indicated parking space. The route now follows the Skyline Drive northward through the north part of Shenandoah National Park. **Caution:** Park only in indicated places and drive carefully through traffic.

Just south of Panorama rises Marys Rock, a high hill composed of the granitic complex. (See Appendix E.)

Stop 30—15 minutes. Park cars at indicated place.

Half a mile north of Beahms Gap, the road passes over a narrow synclinal fold of the Loudoun formation. North of the bend in the road, the Skyline Drive passes just east of the contact of the Loudoun and the metabasalt. The Loudoun, which here forms the Blue Ridge crest west of the Skyline Drive, is a purple arkosic quartzite and conglomerate. The metabasalt is green or purple amygdaloid containing jasper. Turning east through Elk Wallow Gap, the road crosses 3 miles of pre-Cambrian metabasalt to Hogback Mountain, where the granitic complex is exposed. It is composed of hornblende diorite and diorite

[6] Furcron, A. S., and Woodward, H. P., A basal Cambrian lava flow in northern Virginia: Jour. Geology, vol. 44, no. 1, pp. 45-51, 1936.

injected with granite and white injection gneiss, in places garnetiferous.

Stop 31—15 minutes. Park cars at indicated place.

Hogback Mountain is the southern border of a semicircular area of the granitic complex surrounded by the overlying metabasalt which, for the most part, caps the Blue Ridge to Front Royal. The granite complex, with Browntown in the center, occupies lower ground in an area 6 miles wide, from just north of Gravel Springs Gap northwestward to the Blue Ridge overthrust. This fault has carried the intrusive complex northwest over the Paleozoic rocks of the Valley.

The Blue Ridge crest, including Mt. Marshall, for 6 miles northeast of Hogback Mountain, is capped by the Catoctin metabasalt. At Jenkins Gap and Compton Gap erosion has removed the flows and exposed the underlying granitic rocks and granodiorite. These rocks are cut by pink and white pegmatite and, north of Compton Gap, by dikes of metadiabase. Compton Peak is capped by green amygdaloidal metabasalt.

Stop 32—15 minutes. Park cars at indicated place.

From Lands Run Gap northward to Front Royal, the Skyline Drive passes over Catoctin metabasalt. The rock is stained with copper carbonate just north of Lands Run Gap. West of the crest the granite complex lies only 500 to 700 feet down the slope below the Catoctin. At Front Royal the Catoctin metabasalt overrides the limestones of the Valley.

FRONT ROYAL, VA., TO ASHBY GAP[7]

ARTHUR BEVAN

Leaving Front Royal, the route follows Virginia No. 3 northward through Riverton (2 miles). Note the large limestone quarry to the right, in which the sequence is Beekmantown (far right) to Martinsburg (in road cut). The variety of limestone here is used for several products, including a special cement and rock wool. Follow No. 3 to the intersection with Virginia No. 277 (10 miles), over a rather wide expanse of the Beekmantown.

Turn right on No. 277, continue eastward for 2 miles to White Post, then turn left and follow Virginia No. 12 for 2 miles to its intersection with U. S. No. 50 at Boyce. This part of the route is over Beekmantown, including the Stonehenge member north of White Post, then Conococheague limestone near Boyce.

[7] Based mainly upon Virginia Geol. Survey Bull. 42, by Charles Butts, and the Geologic Map of Virginia (1928).

At Boyce, turn sharp right into U. S. No. 50 and continue for about 27 miles southeastward through Millwood, Ashby Gap in the Blue Ridge, Upperville, and Middleburg, to the intersection with U. S. No. 15, just east of Aldie. Note the broad, gently undulatory expanse of the Valley-floor peneplain which truncates steeply dipping Lower Paleozoic rocks, and the sharp contrast with the Blue Ridge. East of Ashby Gap, note the character of the Piedmont surface.

A belt of typical banded Conococheague limestone is crossed between Boyce and Millwood; then in descending order, Elbrook dolomite, Waynesboro (Rome) shale, and Tomstown (Shady) dolomite. The Tomstown occurs in a fairly wide belt west of Shenandoah River and crops out locally along the river in this part of the State.

Note Shenandoah River and its flood plain. The North and South forks of Shenandoah River unite just below Riverton.

Ascending the Blue Ridge to Ashby Gap, the road crosses in succession, the basal Cambrian rocks, comprising the Antietam quartzite, Harpers shale or phyllite, Weverton quartzite, and the Loudoun formation. If time permits, brief stops will be made to examine these rocks and to observe the geomorphology as visible from Ashby Gap. One of the geomorphologic problems is the origin and age of the Piedmont surface.

ASHBY GAP TO ALDIE, VA.

ANNA I. JONAS

U. S. No. 50 from Millwood to Aldie, Va., crosses the Blue Ridge through Ashby Gap. As the rocks in this area are not well exposed and the geology has not been studied in detail (due to a lack of modern topographic maps), only a generalized description of this area will be given. East of Shenandoah River dark-colored shale and thin quartzite resembling the Loudoun formation extend nearly to Ashby Gap at the top of the Blue Ridge. Here the rock is Catoctin metabasalt that extends southeastward for about 4 miles. Boulders of metabasalt and intrusive rocks strew the surface to Upperville. Granitic rocks underlie the area east of Upperville. At Goose Creek, Catoctin schist is exposed. An alternation of these rocks is crossed to Middleburg. The Loudoun formation also occurs in several synclines. It is a coarse, arkosic quartzite, in places containing large pebbles of granitic rocks. Aldie is located on the Catoctin metabasalt that underlies the Lower Cambrian quartzites of the Catoctin Mountain syncline. At Aldie these quartzites are almost entirely faulted out by the Border fault.

At the intersection of U. S. No. 50 and U. S. No. 15, turn left (north) across Triassic sedimentary rocks and intrusive diabase. Cross Goose Creek at Oatlands, just east of the low ridge made by the Lou-

doun formation lying west of the Border fault. Four miles north of Oatlands, the road bears northeast to Leesburg across Triassic rocks.

TRIASSIC NEAR LEESBURG, VIRGINIA

JOSEPH K. ROBERTS

At Oak Hill, in a field just north of the marker on U. S. No. 15 designating the residence of Mr. Frank Littleton, is the shale quarry from which the slabs containing dinosaur tracks have been found and used around Oak Hill. This is the Bull Run shale, near the western contact of the Triassic with the older rocks. South of Leesburg, on the east (right) side of U. S. No. 15 are large boulders of the Border conglomerate.

Stop 33—15 minutes. Within the corporation limits of Leesburg, to the east, a quarry in the Border conglomerate is now in operation. This conglomerate is made up of round to sub-round pebbles and boulders of limestone, and subordinate amounts of quartz and other materials, held in a cement of lime, iron oxides, and silica. The lime burnt from this conglomerate forms a clinker, due to the silica, and it runs rather high in silica.

A short distance east of the quarry can be seen the Triassic diabase. From this contact Earl V. Shannon[8] has described xonotlite.

Follow Virginia No. 7 and turn east (right) at Leesburg. Diabase boulders are numerous along the road. Crossing Goose Creek, the supposed captured stream which formerly flowed through Snickers Gap from the Valley of Virginia, take the first road to the south (right) and follow to the Washington & Old Dominion Railway; then turn right and drive into the old quarry.

Stop 34—15 minutes. Here will be found the diabase, gabbro, and minerals as described by Earl V. Shannon.[9]

Return to Leesburg by the same route and follow U. S. No. 15 north. Along the road to Lucketts will be seen the limestone conglomerate in various stages of weathering. North of Lucketts, take a private road to the right, leading to a dairy barn. On this road are fine flat-lying exposures and enormous boulders of the Border conglomerate showing the gray limestone pebbles and boulders contained in a red, iron-stained matrix.

Follow U. S. No. 15 to Point of Rocks bridge over the Potomac into Maryland and north through Frederick.

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[8] Shannon, Earl V., An occurrence of xonotlite at Leesburg, Virginia: Am. Mineralogist, vol. 10, no. 1, pp. 12-13, 1925; Mineralogy and petrography of Triassic limestone conglomerate metamorphosed by intrusive diabase at Leesburg, Virginia: U. S. Nat. Mus. Proc., vol. 66, art. 28, 1925.

[9] Shannon, Earl V., The mineralogy and petrology of intrusive diabase at Goose Creek, Loudoun County, Virginia: U. S. Nat. Mus. Proc., vol. 66, art. 2, 1924.

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APPENDIX A

SILURIAN SECTION ON WILLS MOUNTAIN, NEAR CUMBERLAND, MD.[10]

AFTER W. F. PROUTY AND C. K. SWARTZ

The section along the Western Maryland Railway and its immediate vicinity east of the "Narrows," the gorge cut by Wills Creek through Wills Mountain, affords a nearly continuous exposure of the strata between the top of the Tuscarora formation and the *Whitfieldella marylandica* zone at the top of the Rochester formation.

Formation	Thickness Ft.	In.
Bloomsburg formation: red and greenish sandstone	3	6
McKenzie formation: shale and sandstone with some thin beds of limestone; some beds very fossiliferous	294	7
Rochester formation: drab shale with some thin beds of limestone containing numerous fossils; fossils in some shale beds	35	1
Keefer sandstone: massive, calcareous, with some poorly preserved fossils	11	0
Rose Hill formation: vari-colored shale with numerous thin beds of sandstone; fossils at numerous horizons	552	0
Tuscarora formation: sandstone with some shale; few fossils	38	0
	934	2

[10] Condensed and adapted from Maryland Geol. Survey volume on "Silurian," pp. 68-74, 1923, where a detailed section is given.

APPENDIX B

SECTION AT ROSE HILL SOUTH OF CUMBERLAND, MD.[11]

AFTER W. F. PROUTY AND C. K. SWARTZ

An excellent section of the lower part of the McKenzie formation, the Rochester formation, and the upper beds of the Rose Hill formation is seen in the cut of the Baltimore and Ohio Railroad at the southern end of Rose Hill, 1¾ miles southwest of Cumberland.[12] This is one of the finest localities in the State for the examination of the Rochester formation and its contact with the immediately adjoining strata and affords an excellent collecting ground for the fossils found in them. It is complicated by faulting, rendering precise measurement of its thickness difficult.

The thickness assigned the Rochester formation is much greater in this section than elsewhere in Maryland. The McKenzie-Rochester contact is not marked clearly by lithological change but is determined by change in the ostracod faunas.

Formation	Thickness Ft.	In.
McKenzie formation: limestone, with shale partings, and shale; fossils near base and top	109	0
Rochester formation: interbedded shale and limestone; very fossiliferous. Fossiliferous oolitic iron "ore," the "Roberts iron ore," 8 inches thick, at bottom	53	2
Keefer sandstone: shaly and massive sandstone	11	9
Rose Hill formation: shale and sandstone with a thin limestone bed; fossiliferous; exposed	98	6
	272	5

[11] Condensed and adapted from Maryland Geol. Survey volume on "Silurian," pp. 64-68, 1923, where a detailed section is given.

[12] The Rose Hill formation receives its name from the section at the northern end of Rose Hill in Cumberland, described idem, p. 68.

APPENDIX C

SECTION AT PINTO, MD., ALONG BALTIMORE & OHIO RAILROAD[13]

AFTER W. F. PROUTY AND C. K. SWARTZ

The finest section of the McKenzie formation and of the upper part of the Clinton in Maryland is seen at Pinto, a station on the Baltimore and Ohio Railroad, 8 miles southwest of Cumberland. The Potomac River flows across the western limb of the Wills Mountain anticline cutting the strata, which stand nearly vertical.

Formation	Thickness Ft.	In.
Helderberg limestone: very massive, nodular, fossiliferous.		
Tonoloway formation: limestone, chiefly thin-bedded to laminated and argillaceous, and calcareous shales; contains numerous fossiliferous beds and bands.....	610	10
Wills Creek formation: limestone and shale with some mudrock and sandstone; ostracodes at numerous horizons	438	8
Bloomsburg sandstone: sandstone and shale with limestone in lower part; Cedar Cliff sandstone, 14 inches thick, at 11½ feet above base.....	20	8
McKenzie formation: mainly drab shale and limestone with some limestone pebble conglomerate; fossils at numerous horizons	241	6
Rochester formation: limestone and shale, containing numerous fossils; Roberts iron ore, 6 inches thick, at base	31	0
Keefer sandstone: hard, calcareous sandstone.....	7	0
	1,349	8

[13] Condensed and adapted from Maryland Geol. Survey volume on "Silurian," pp. 58-61, 114-126, 1923, where a detailed section is given.

APPENDIX D

SECTION IN QUARRY SOUTHEAST OF KEYSER, W. VA.[14]

AFTER C. K. SWARTZ AND OTHERS

The Helderberg formation is admirably exposed in the extensive quarries of the Standard Lime and Stone Company situated about three-fourths of a mile southeast of Keyser, West Virginia, along the Baltimore and Ohio Railroad. Two quarries are worked here. The eastern quarry is in the Tonoloway while the western embraces beds extending from the top of the Tonoloway to the base of the Oriskany. Both the upper and lower limits of the Helderberg formation are well shown. This is one of the finest exposures in the region and it is from it that the Keyser member receives its name.

Formation	Thickness Ft.	In.
Helderberg group:		
Coeymans limestone: massive, crinoidal, very fossiliferous.		
Keyser limestone: chiefly thick-bedded, though some thin-bedded, limestone; lower beds nodular; very fossiliferous at numerous horizons. Many cystids between 90 and 133 feet above base. A thick coral zone at 186 feet above base	281	
Tonoloway formation: calcareous shale	8	
Concealed below.		
	289	

[14] Condensed and adapted from Maryland Geological Survey volume on "Lower Devonian," pp. 133-136, 1913, where a detailed section is given.

APPENDIX E

LOG OF SKYLINE DRIVE FROM THORNTON GAP TO FRONT ROYAL, VIRGINIA

EARL A. TRAGER

Mileage

0.0 Junction of Lee Highway (U. S. No. 211) and Skyline Drive in Shenandoah National Park. Turn right (south).

0.8 North end of tunnel through Marys Rock. A fault and dike of black diabase (Triassic ?) are visible at the right (west) side of the tunnel entrance; the country rock is hypersthene granodiorite. (See Pls. 8 and 9.)

0.9 Parking area at south end of the tunnel through Marys Rock. The view to the left (east) embraces the valley of Thornton River by means of which the Lee Highway ascends the Blue Ridge to Thornton Gap. Beyond the foot of the Blue Ridge are outliers and the rolling expanse of the Piedmont province. To the right (west) of the parking area is an exposure of granodiorite which contains many almost vertical faults.

1.8 From this point, return to Thornton Gap and continue northward on the Skyline Drive.

0.0 **Note.—Reset speedometer at this point.**

4.8 To the left (west) is an exposure of Cambrian sediments: Purplish shale, quartz conglomerate, and gray arkosic sandstone. This small area of sediments is one of the infolded remnants of the sedimentary cover, which owes its preservation to the protection of the surrounding, more resistant rocks. To the right (east) is a view of the "coves" of the headwaters of Thornton River.

8.4 To the left (west) of the Drive, Catoctin greenstone contains large amygdules or vugs, some as large as 1 foot in diameter, with variable amounts of mineral filling: Quartz, fibrous epidote, chlorite, calcite, and feldspars.

10.8 Hogback Mountain Overlook. Powells Mountain and the folded Appalachian ridges are visible to the westward, beyond the prominent eastern ridge of Massanutten Mountain. Below

is Gimlet Ridge, projecting as a spur into Shenandoah Valley. To the northward is Dickeys Ridge, another spur, down which at Front Royal, the Skyline Drive descends from the Blue Ridge to Shenandoah Valley. On the right (east) of the Drive, granodiorite contains numerous iron-stained streaks.

11.7 In the exposure to the left (west) of the road, 4 augite dikes of Triassic (?) age are visible in the granodiorite.

21.2 To the left (west) columnar jointing is well developed in basalt; to the right (east) is an excellent view of the Piedmont plateau and outliers of the Blue Ridge.

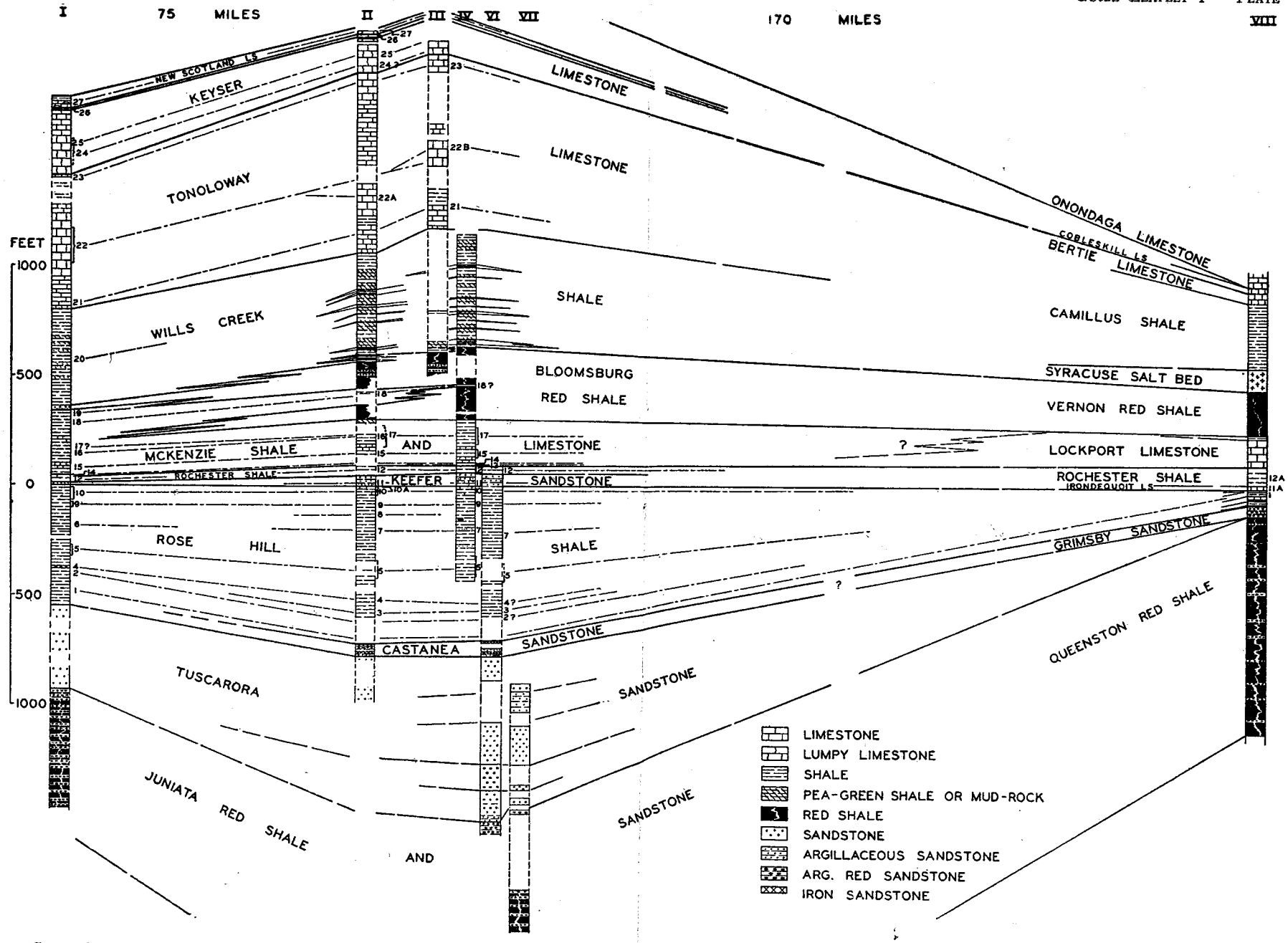
21.7 To the right (east), note the contact of the Catoctin flows and the granitic group. The age relationship and evidence of intrusion are doubtful.

28.7 Parking Overlook, elevation 1,920 feet. Shenandoah Valley is to the left (west). From here one obtains an excellent view of the incised meanders in the Valley-floor peneplain. Catoctin schist is visible to the right (east).

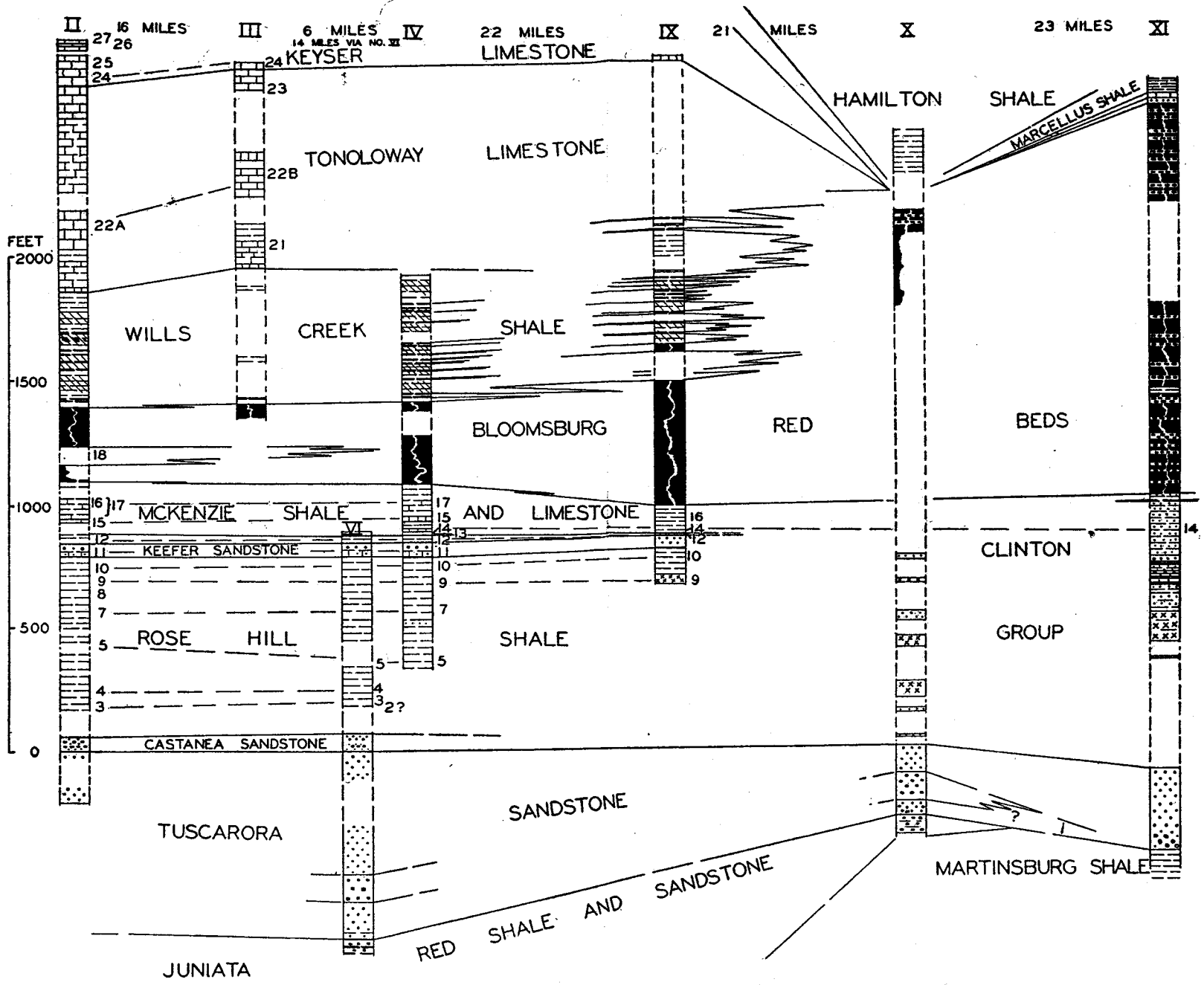
30.6 Catoctin exposed on the right (east) is less altered than at most exposures. An amygdaloidal zone exists at the southern end of the cut, 0.1 mile to the south. Perhaps this is a contact of flows.

32.1 North boundary, Shenandoah National Park.

33.0 Front Royal.



Comparison of Silurian sections of central Pennsylvania, western Maryland, and western New York, by Frank M. Swartz. I. Composite section near Cumberland, Md., after C. K. Swartz, W. F. Prouty, and others; II, Section at Mt. Union, Pa.; III, Section at Strodes Mill, Pa.; IV, Section at Lewistown, Pa.; VI, Section at Kishacoquillas Gap, Pa.; VII, Section on Long Mountain, Pa.; VIII, Composite section near Rochester, N. Y., after E. O. Ulrich, R. S. Bassler, P. D. Torrey and others. Details of formational horizons and faunal zones given by F. M. Swartz in Bull. Geol. Soc. America, vol. 45, no. 1, Fig. 2, 1934, from which this plate is reproduced by permission of the author.

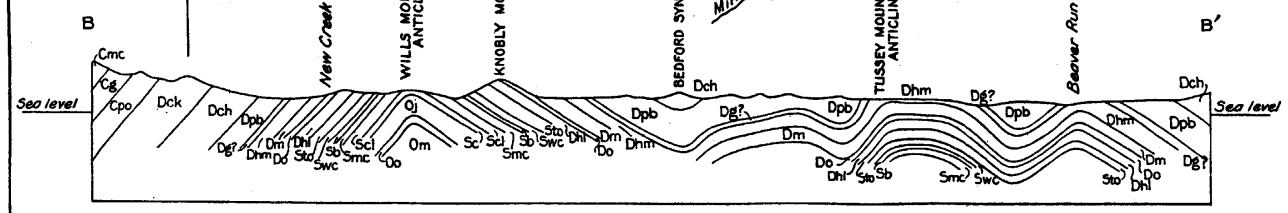


Comparison of Silurian sections in central and eastern Pennsylvania, by Frank M. Swartz. Lithology symbols and faunal zones as on Pl. 1. II, Section at Mt. Union, Pa.; III, Section at Strodes Mills, Pa.; IV, Section at Lewistown, Pa.; VI, Section at Kishacoquillas Gap, Pa.; IX, Composite section near Loysville, Pa. (after C. K. and F. M. Swartz, Bull. Geol. Soc. America, vol. 42, pp. 625-628, 1931); X, Section in Susquehanna Gap, 4 miles north of Harrisburg, Pa. (*op. cit.*); XI, Section at Swatara Gap, Pa. (*op. cit.*). Reproduced by permission of the author, from Bull. Geol. Soc. America, vol. 45, no. 1, Fig. 3, 1934.

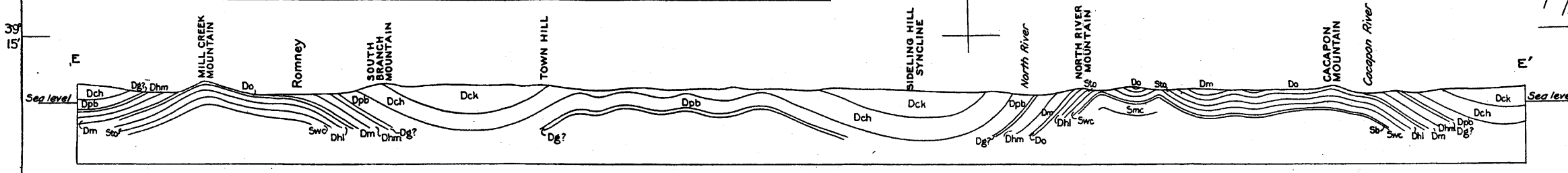
79°00′ 78°45′ 78°30′

New Creek Mtn · New Creek · Wills Mountain Anticline · Knobly Mtn · Ridgeville · Bedford Syncline · Burlington · Tussey Mtn Anticline · Patterson Creek · Patterson Creek County Line · Mechanicsburg · Junction · Mill Creek · Mill Creek Mountain · Dumpling Run · South Branch Potomac River · Big Run · Romney · South Branch Mountain · Town Hill · Little Cacapon River · North Fork · Little Capon School · Frenchburg · Augusta · South Fork · Tear Coat Church · Pleasantdale · Sideling Hill Syncline · Cook Creek · North River · North River Mtn · Hanging Rock · Cooper Mtn · Schaffenaker Mountain · Edwards Run · Cacapon River · Capon Bridge · Bear Garden Mtn

B — B′



E — E′



Route of excursion
ANTICLINE
SYNCLINE

0 1 2 3 4 MILES
0 1 2 3 4 5 KILOMETERS

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; Scl, Clinton formation; St, Sc, Tuscarora quartzite; Oj, Juniata formation; Oo, Oswego sandstone; Om, Martinsburg shale.

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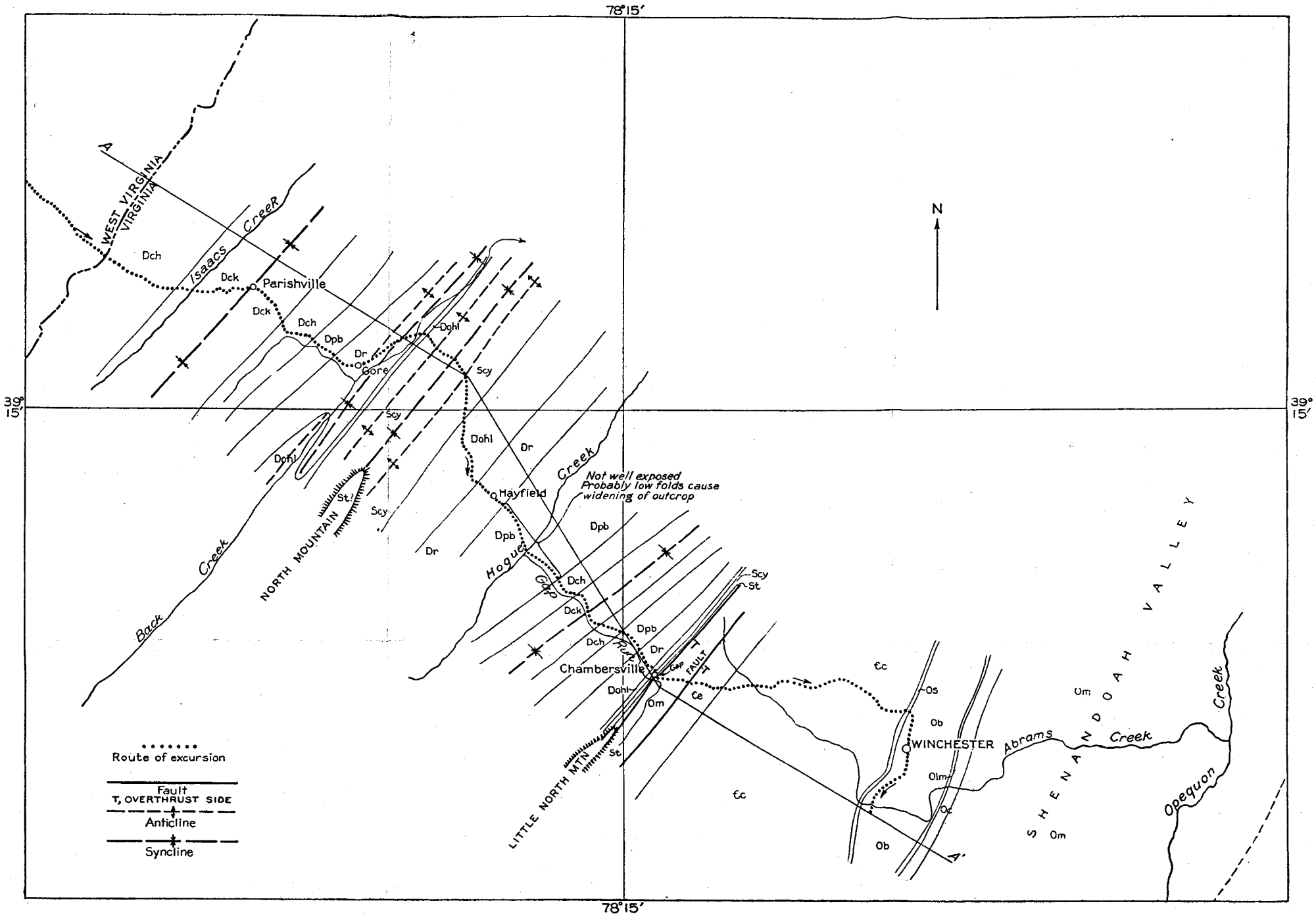

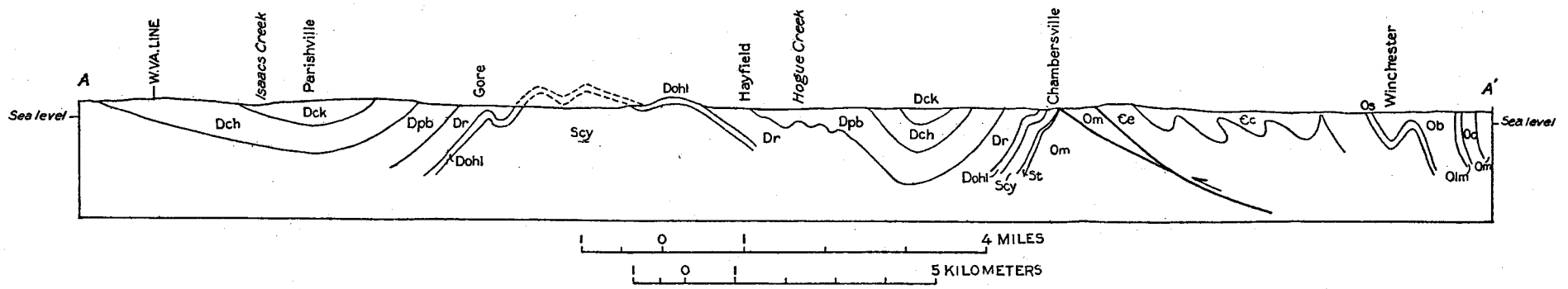

ROUTE MAP AND SECTION, WEST VIRGINIA STATE LINE TO WINCHESTER, VIRGINIA

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; €c, Conococheague limestone; €e, Elbrook dolomite.

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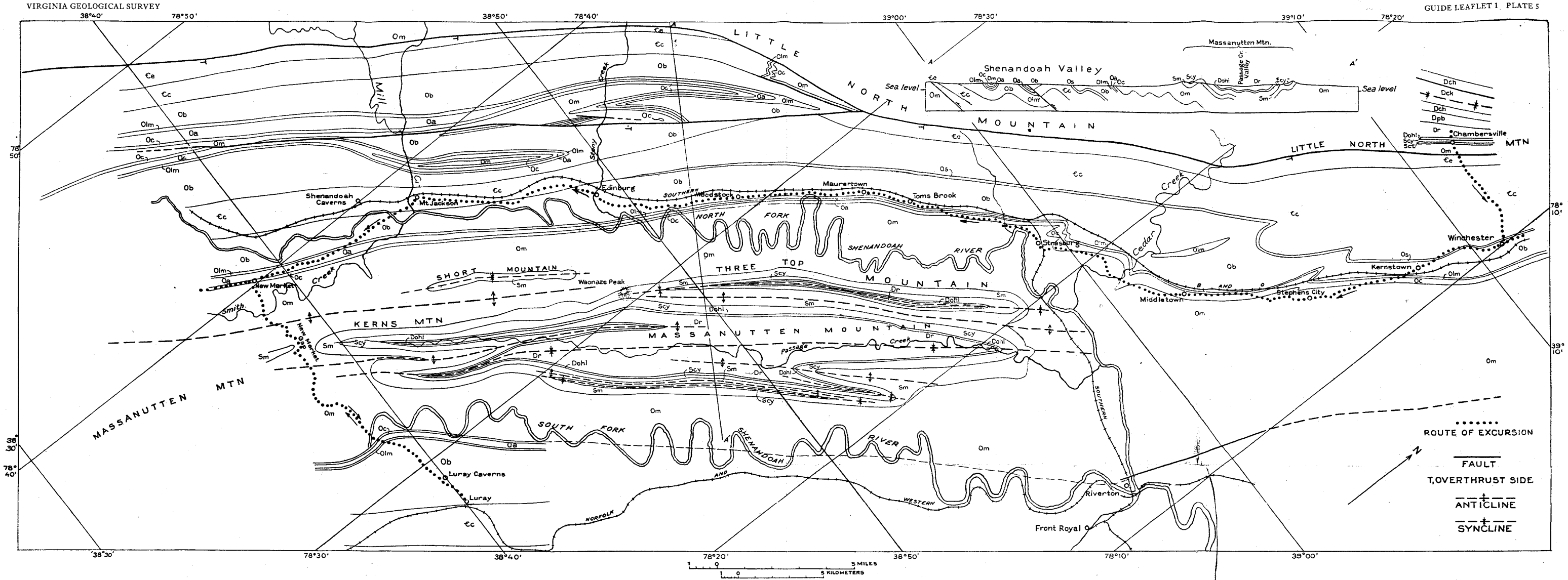

ROUTE MAP, WINCHESTER TO LURAY, VIRGINIA, AND SECTION ACROSS SHENANDOAH VALLEY AND MASSANUTTEN MOUNTAIN

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.

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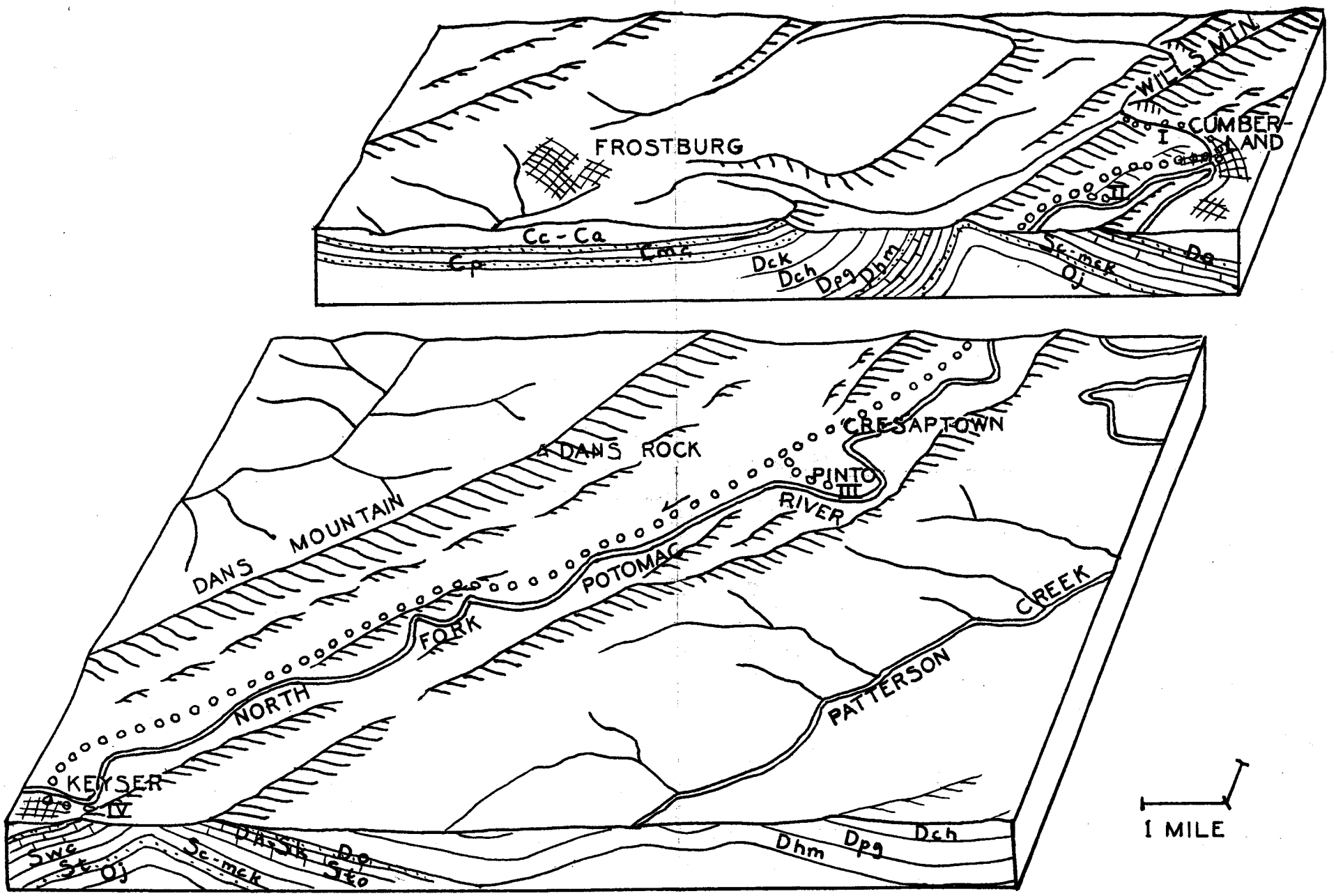


DIAGRAM OF PARTS OF THE FROSTBURG, MD., AND ROMNEY, W. VA., QUADRANGLES

FRANK M. SWARTZ

Based upon U. S. Geological Survey topographic maps. Cc-Ca, Conemaugh-Alleghany; Cpv, Pottsville; Cmc, Mauch Chunk-Greenbrier; Cp, Pocono; Dck, Catskill-Hampshire; Dch, Chemung; Dpg, Portage-Genessee; Dhm, Hamilton-Marcellus; Do, Oriskany; Dh-Sk, Helderberg-Keyser; Sto, Tonoloway; Swc, Wills Creek; Sc-mck, McKenzie-Clinton; St., Tuscarora; Oj, Juniata. I, Cumberland Narrows, north end of Rose Hill, Md.; II, South end of Rose Hill; III, Pinto, Md.; IV, Quarry east of Keyser, W. Va. 0000, Route of excursion.

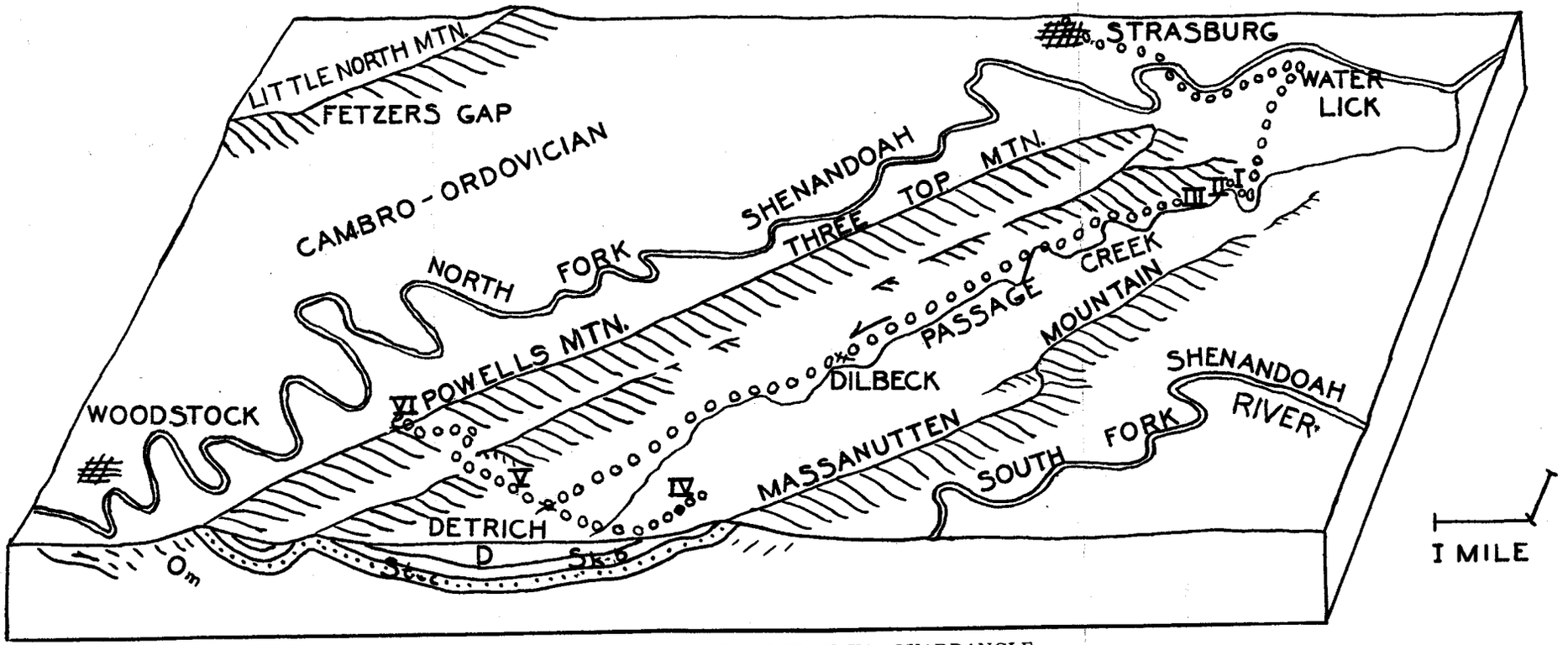


DIAGRAM OF THE NORTHWEST PART OF THE LURAY, VA., QUADRANGLE

FRANK M. SWARTZ

Based upon U. S. Geological Survey topographic map. D, Devonian shales; Sk-b, Keyser-Tonoloway-Wills Creek-Bloomsburg; St-c, Clinton-Tuscarora; Om, Martinsburg. I-III, Gorge of Passage Creek; IV, North of Seven Fountains; V, Anticline east of Detrick; VI, Top of Powells Mountain. 0000, Route of excursion.

EXPLANATION

CAMBRIAN

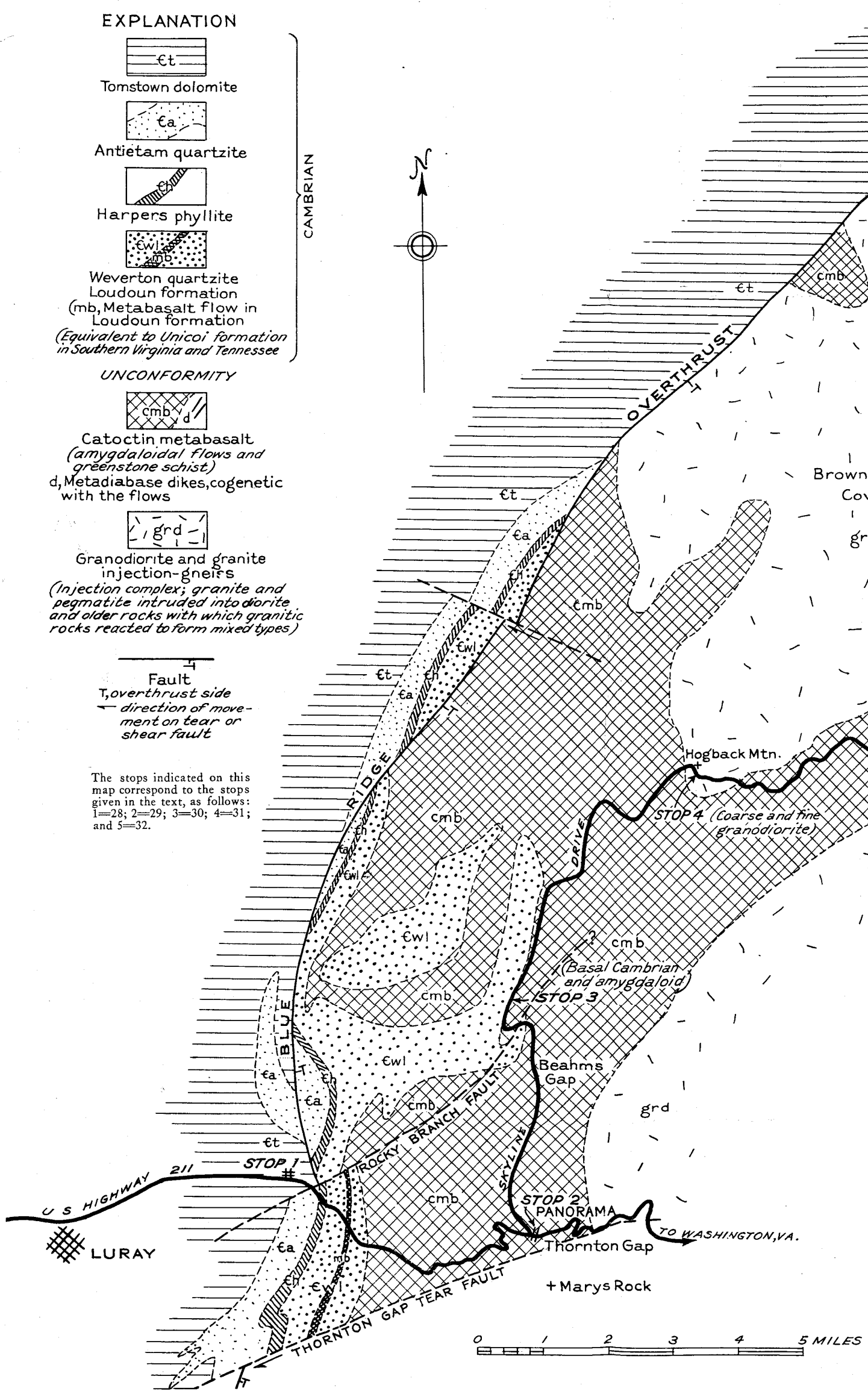
- €t — Tomstown dolomite
- €a — Antietam quartzite
- €h — Harpers phyllite
- €wl, mb — Weverton quartzite, Loudoun formation (mb, Metabasalt flow in Loudoun formation) *(Equivalent to Unicoi formation in Southern Virginia and Tennessee)*

UNCONFORMITY

- cmb, d — Catoctin metabasalt *(amygdaloidal flows and greenstone schist)*; d, Metadiabase dikes, cogenetic with the flows
- grd — Granodiorite and granite injection-gneiss *(Injection complex; granite and pegmatite intruded into diorite and older rocks with which granitic rocks reacted to form mixed types)*

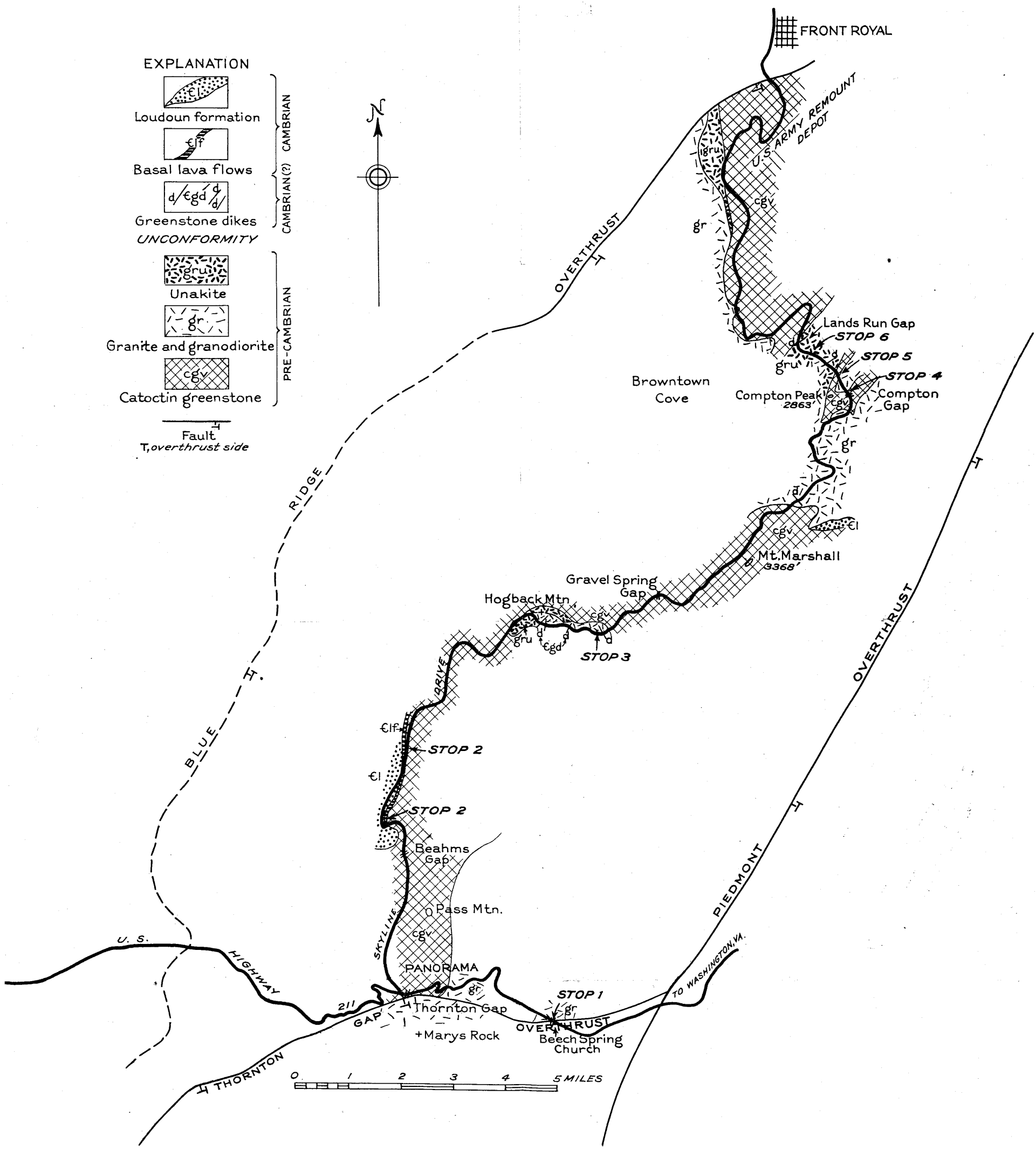
Fault
T, overthrust side
← direction of movement on tear or shear fault

The stops indicated on this map correspond to the stops given in the text, as follows: 1=28; 2=29; 3=30; 4=31; and 5=32.



SKETCH MAP OF THE GEOLOGY OF THE NORTHWEST PART OF THE BLUE RIDGE BETWEEN LURAY AND FRONT ROYAL, VA.

ANNA I. JONAS AND G. W. STOSE



GEOLOGIC MAP OF THE SKYLINE DRIVE IN SHENANDOAH NATIONAL PARK BETWEEN PANORAMA (THORNTON GAP) AND FRONT ROYAL, VA.

A. S. Furcron

(1) U. S. No. 211, just west of Beech Spring, north side of road; sheared and mylonitic granite (gr) in cliffs and in field above. (2) Skyline Drive, between Beahms and Elkwallow gaps; Loudoun formation (Cl) and underlying basal Cambrian flows (Clf). (3) Skyline Drive, Hogback Mountain, north side of Drive; greenstone dike (Cgd), intruding granodiorite (gr). (4) Skyline Drive, southeast of Compton Gap, west side of Drive; columnar jointing in Catoctin greenstone (cgv). (5) Skyline Drive, slightly northwest of Compton Gap, north side of Drive; cliffs of granodiorite (gr), containing angular to rounded inclusions of greenstone ranging from the size of a marble to that of one's head. (6) Skyline Drive, between Compton and Lands Run gaps, north side of Drive; granodiorite (gr) and unakite (gru) intruding Old Rag granite in cliffs. Reprinted from XVI Inter. Geol. Congress, Guidebook 3, by permission of the Director, U. S. Geological Survey.

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