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COMMONWEALTH OF VIRGINIA

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 55

Geology of the Draper Mountain Area, Virginia

BY

BYRON N. COOPER

UNIVERSITY, VIRGINIA
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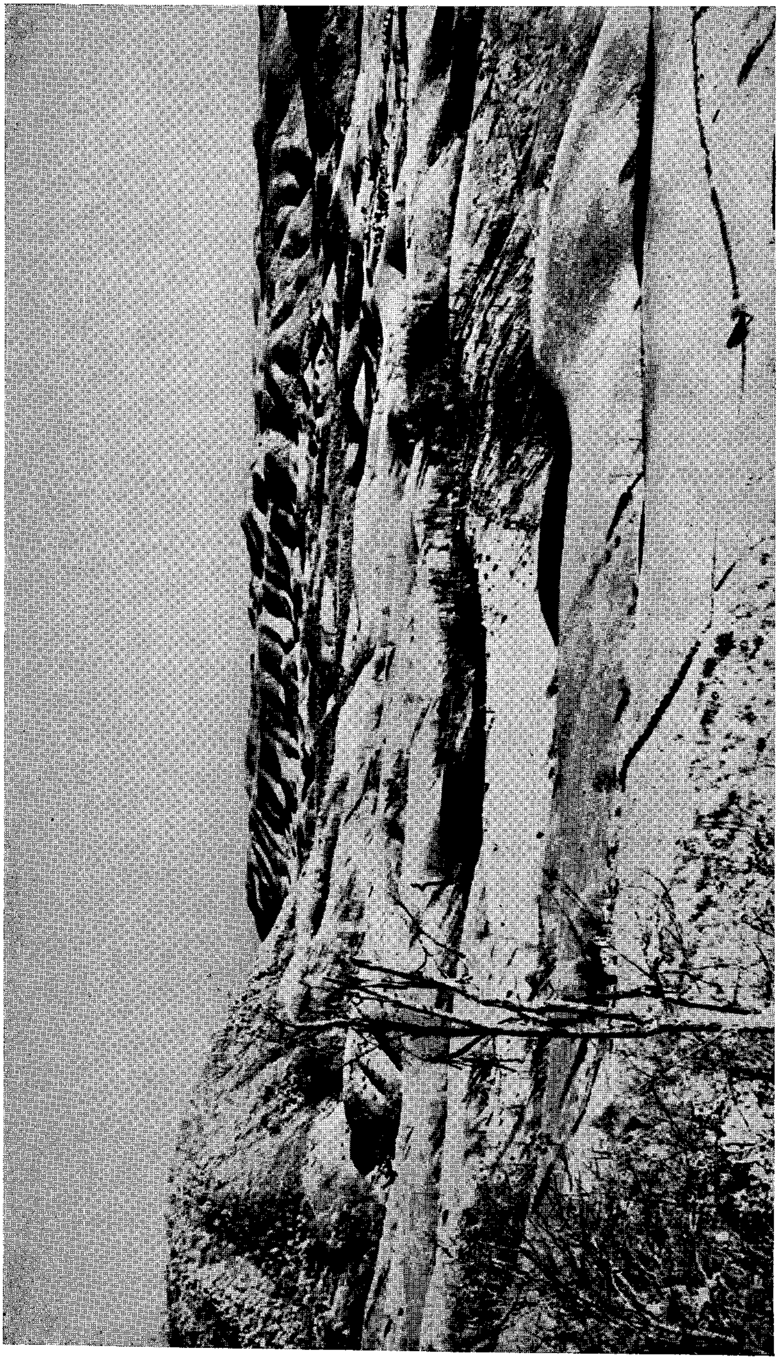
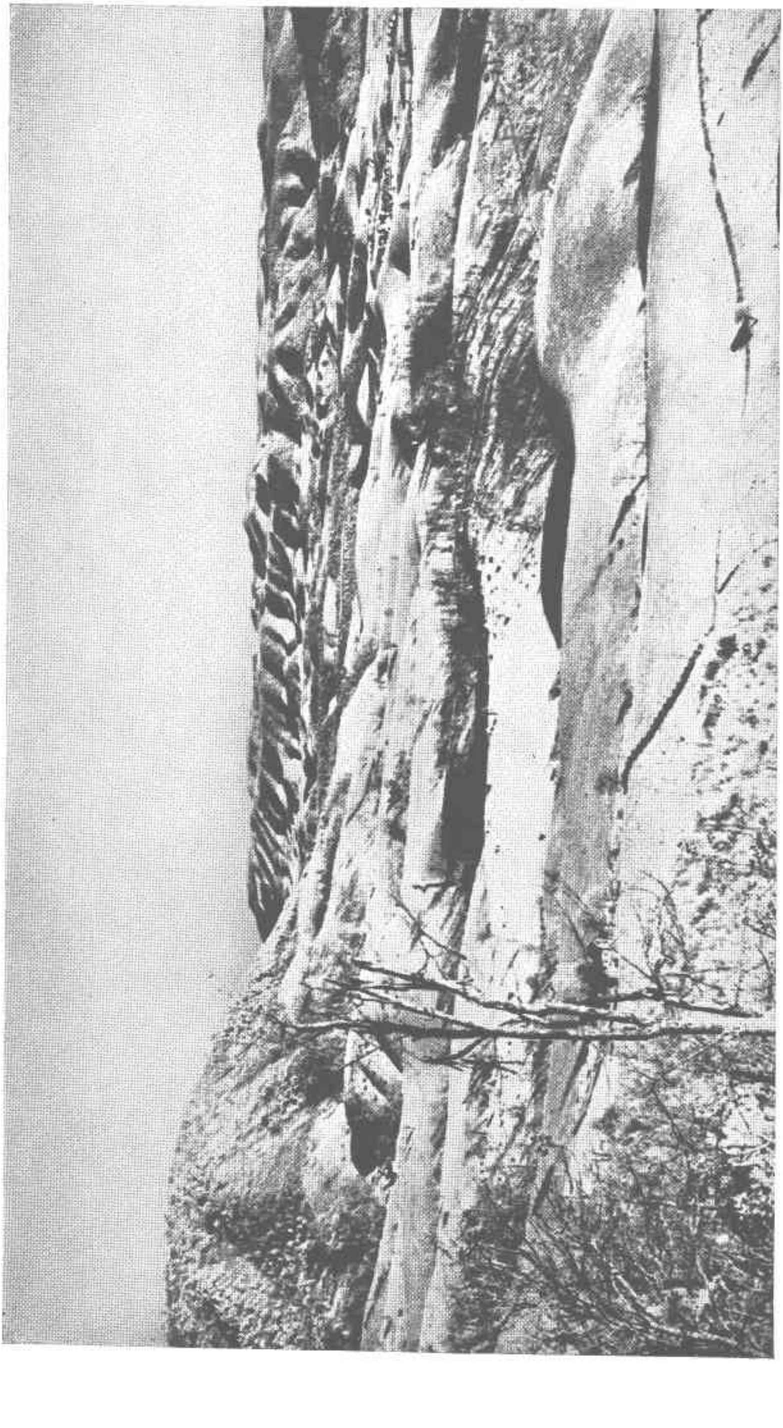


View looking southeast from the crest of Draper Mountain, showing Draper Valley in the foreground and the dissected Blue Ridge plateau in the background. The village of Draper, Virginia, is to right of center.



View looking southeast from the crest of Draper Mountain, showing Draper Valley in the foreground and the dissected Blue Ridge plateau in the background. The village of Draper, Virginia, is to right of center.

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., February 20, 1939.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 55 of the Virginia Geological Survey series of reports a manuscript and illustrations of a report on the *Geology of the Draper Mountain Area, Virginia,* by Dr. Byron N. Cooper, of the University of Wichita, Wichita, Kansas. The field work on which this report is based was done principally during the summer of 1936, at no cost to the Geological Survey except field expenses.

In this report, the complex geology of Draper Mountain and its environs in Pulaski and Wythe counties—one of the most interesting geological districts in the State—is described and interpreted. The description includes the numerous formations into which the succession of sedimentary rocks has been divided, the diverse features of the structural arrangement of these rocks, the topographic features of the district, and the known mineral resources. Several perplexing problems of the relations of the formations and the origin of the structures are discussed.

This report should be of interest to all those who wish accurate, up-to-date information about the rocks and mineral resources of this part of the State.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, February 24, 1939.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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Geology of the Draper Mountain Area, Virginia[1]

By Byron N. Cooper

ABSTRACT

The Draper Mountain area contains sedimentary rocks ranging from Lower Cambrian to Middle Mississippian, inclusive. Approximately 16,000 feet of beds are exposed and these are divisible into 24 formations. The succession of strata in this area is rather complete, but there are several hiatuses. With the exception of the hiatus between the Silurian and Devonian systems and of that between the Devonian and Mississippian systems, they represent relatively short time-breaks.

The rocks are broken by several low-angle overthrust faults of great horizontal displacement. The central overridden mass, the Draper Mountain autochthon, is a breached fenster which is partly surrounded by portions of two great overthrust sheets. A striking structural feature is the folded low-angle thrust planes, which thus appear at the surface in many places as high-angle faults. The great overthrust sheets have been locally broken by faults whose roots are in the overridden rocks of the Draper Mountain autochthon. Geologic phenomena associated with low-angle thrust-faulting are well displayed.

The Draper Mountain area contains semianthracite coal, iron, construction stone, limestone suitable for lime-burning, large available quantities of white quartz sand, and some marble.

[1] A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the Department of Geology, in the Graduate College of the State University of Iowa.

INTRODUCTION

LOCATION OF THE AREA

The Draper Mountain area lies midway between Roanoke, Virginia, and Bristol, Virginia-Tennessee, and includes portions of eastern Wythe County and western Pulaski County. (See Fig. 1.) The northern boundary of the area is the southeast slope of Brushy Mountain and Chestnut Ridge. The western boundary is the meridian of 80° 58′ west longitude. The southern boundary is approximately at 36° 55½′ north latitude. The eastern border of the area is an irregular line varying between 80° 44′ and 80° 45′ west longitude. The area as mapped contains approximately 110 square miles. (See Pls. 1 and 2.)

All except the easternmost part of the area has been recently topographically mapped on a scale of 1:62,500. The northern third is in the southern part of the Pulaski quadrangle (Pl. 13), and the southern part is covered by the Max Meadows quadrangle. The easternmost part of the area, which is covered only by an inadequate topographic map on a scale of 1:125,000, was mapped by the writer by compass traverse and altimeter.

Pulaski is located in the northeastern part and Max Meadows in the west-central part of the area. Both towns are on the main line of the Bristol branch of the Norfolk and Western Railway. Draper is located in the southeastern part of the area on the Galax branch of the same railroad. The Lee Highway (U. S. 11) crosses the area through Fort Chiswell and Pulaski. State highways 99, 100, and 101 connect the southeastern part of the area with Pulaski.

ACKNOWLEDGMENTS

The writer is indebted to the Virginia Geological Survey under whose auspices the survey was made. He received in particular much help from Dr. Charles Butts, including advice and criticism in the field and during the writing of the report. The writer wishes to express his appreciation for the cooperation and criticism of Dr. Arthur Bevan, State Geologist, relative to many complex field problems and for certain photographs. He wishes to thank also Mr. A. A. L. Mathews of Virginia Polytechnic Institute, and Dr. R. S. Edmundson of the Virginia Geological Survey who spent several days in the field and made suggestions which were very helpful. Mr. G. L. Armbrister of Max Meadows gave information about the occurrence and distribution of the coal beds. The writer was ably assisted in the field for nine weeks of the summer of 1936 by Mr. Joseph E. Banks, then a graduate

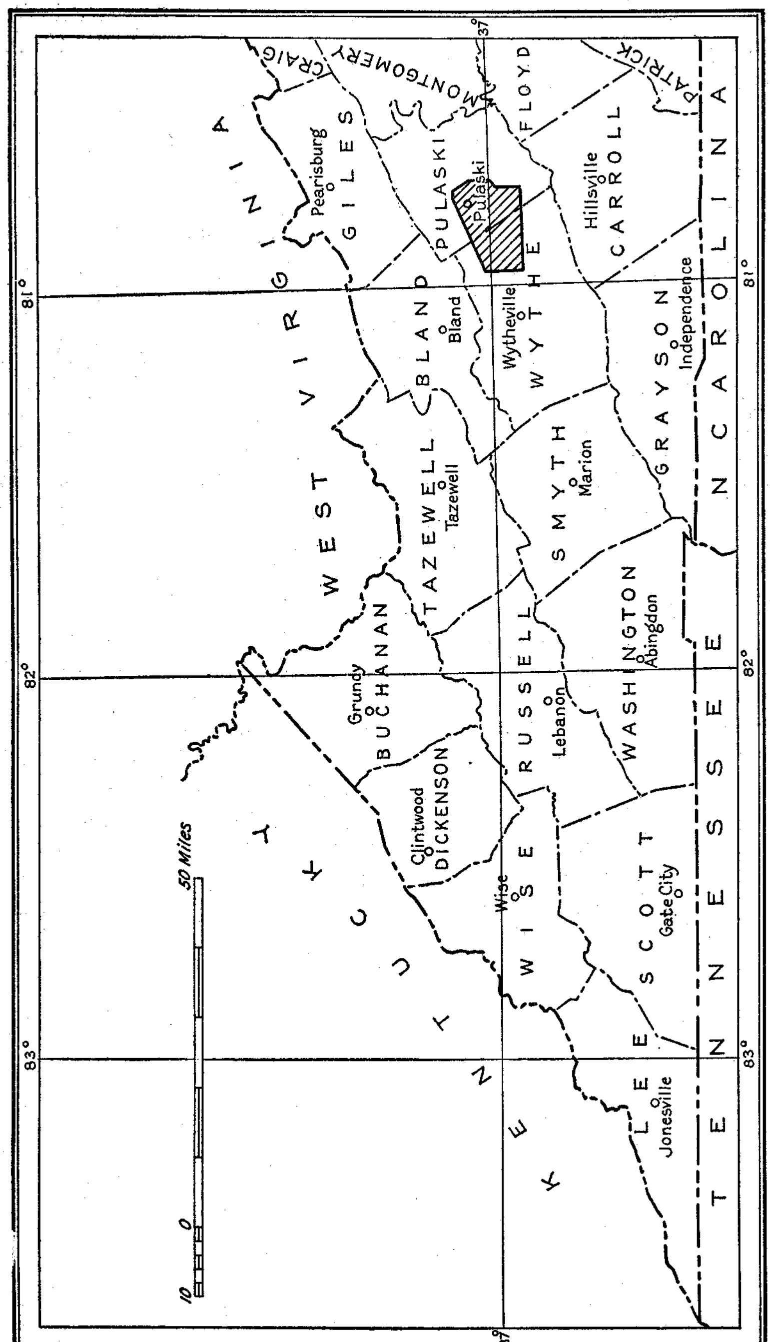


FIGURE 1.—Index map of southwestern Virgina, showing location of the Draper Mountain area.

student in the State University of Iowa. To the residents of the area the writer expresses his appreciation of their cooperation and courtesy.

TOPOGRAPHY

The Draper Mountain area, which lies in the southwestern part of the Appalachian Valley and Ridge province, is a maturely dissected tract within the New River drainage basin. The topography is rugged with a maximum relief of approximately 1,500 feet. The highest point in the area is Peak Knob, the altitude of which is 3,376 feet, and the lowest point, 1,877 feet above sea level, is along New River near Reed Junction. Draper Mountain, a crescent-shaped ridge rising abruptly above the gently rolling Cambrian-Ordovician limestone and shale terranes to the south and west, encloses the canoe-shaped Draper Valley. (See Pl. 2.) The open, cultivated land south of Draper Mountain contrasts sharply with the wild, densely forested area northwest of Max Meadows and west of Pulaski, which is underlain by Devonian and Mississippian sandstones and shales. The Devonian and Mississippian rocks in every attitude are conducive to the development of a rough topography. The Draper Mountain area is bordered on the northwest by Brushy Mountain whose summit is comparable in height to that of Draper Mountain.

The larger part of this area is drained by two tributaries of New River. Reed Creek and its tributaries drain that portion which lies in Wythe County. The upper reaches of Peak Creek drain the area north of Draper Mountain and east of Clark Station. The part south of Draper Mountain and in Pulaski County is drained by several small tributaries which empty directly into New River. The meandering New River which flows in a deep gorge across the western part of Virginia is a regionally rejuvenated stream.

STRATIGRAPHY

GENERAL FEATURES

The formations of the Draper Mountain area range from Lower Cambrian to Middle Mississippian, inclusive, and comprise 24 sedimentary units. They have an aggregate thickness of 15,000 to 20,000 feet and they represent a rather complete record of sedimentation in a part of the Appalachian geosyncline between the limiting geological dates. (See Pl. 3.)

The rocks of the area comprise a wide variety of lithologic types. Most of the Cambrian rocks are clastic; most of the uppermost Cambrian[2] and the Ordovician rocks are limestones and dolomites of exsolutional and organic origin; and the post-Ordovician rocks are almost wholly clastic. With the exception of a part of one formation, the rocks of the area are marine sediments deposited in the shallow waters of a geosynclinal sea which covered large portions of the continental interior during most of the Paleozoic era. Nearly all of the beds contain marine fossils, and it is by means of these that the age of the rock formations has been determined. (See Pl. 3.)

CAMBRIAN SYSTEM

ERWIN QUARTZITE

Name.—The Erwin quartzite was named by Keith[3] from a locality near the town of Erwin, Unicoi County, Tennessee, in the Roan Mountain quadrangle.

Distribution.—Outcrops of the Erwin quartzite in the Draper Mountain area are confined to the upper slopes of Lick Mountain. East of Lots Gap the Erwin is the only formation composing that ridge. (See Pl. 1.)

Lithology.—Surface indications on the eastern end of Lick Mountain indicate that all the Erwin quartzite there has disintegrated to great depths into sand. The quarry operations recently started in Lots Gap have revealed granular disintegration to a depth of 35 feet. Due to the nearly vertical attitude of the strata east of these quarries, ground water has circulated freely within the rock, dissolving a part of the interstitial quartz cement.

---

[2] In the preparation of this manuscript, the author used the terms Ozarkian and Canadian, following the former usage of the Virginia Geological Survey. Those systemic terms are used on the geologic map and other illustrations. In the editing of the text, however, the terms Ozarkian and Canadian have been omitted in accordance with the present usage of the Virginia Geological Survey.

[3] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranberry folio (No. 90), p. 5, 1903.

Many of the exposures on Lick Mountain are superficially hard and firm due to a case-hardened quartz veneer which has been produced by the surface evaporation of silica-bearing waters. Stratification planes which are apparent in the weathered rock reveal that the original quartzite was medium to thick bedded. (See Pl. 4A.)

Natural exposures of the Erwin are buff to brown due to surface stains of iron oxide. In the quarries in Lots Gap, the Erwin is a white rock and here the iron content is very low.

Most of the grains of the disintegrated rock are very angular due to adhering fragments of interstitial quartz, but the original grains of quartz sand are curvilinear to subround in shape. (See Fig. 2.)

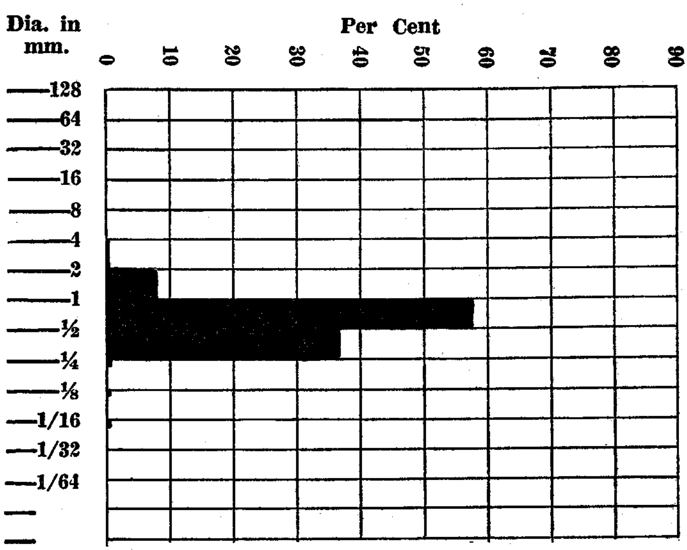
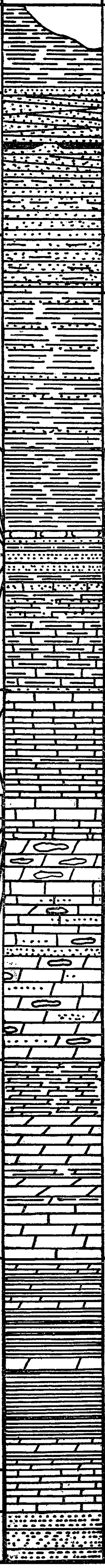


FIGURE 2.—Graph showing the size grade distribution of the weathered Erwin quartzite. A composite sample from the face of the Lick Mountain Sand Co.'s quarry in Lots Gap.

The grains are frosted and the individual pits in the surface of the grains are comparatively deep and jagged. The original grains have been secondarily enlarged by the development of a film of quartz over the pitted surface of the grains. The chief accessory mineral constituents of the sand are pink garnet, zoned euhedral zircon, ilmenite, and rutile.

The Erwin in its weathered state is almost as resistant to erosion as is the fresh, brittle quartzite. On Lick Mountain, which is a klippe, the Erwin probably occupied at one time a wider tract than it does at present, and the broad apron of sand at the foot of the steeper

System	Formation	Columnar Section	Thickness (Feet)	Character of Rocks
Mississippian	Maccrady		500	Red mudrock, shale, and sandstone.
	Price		1250	Cross-bedded quartz sandstone and arkose, containing intercalated beds of semianthracite coal. Lower 400 feet composed of even-bedded ferruginous sandstone and shale. Lenses of quartz-pebble conglomerate.
Devonian	Chemung		500	Even-bedded calcareous sandstone and noncalcareous shale.
	Brallier		1500	Olive-drab siliceous shale and even-bedded siltstone and sandstone.
	Millboro		750	Black shale; pinkish-buff shale.
	Onondaga		65	Massive and bedded white chert.
	Becraft		30	Coarse-grained quartz sandstone.
Silurian	Clinton		35	Lumpy red and yellow shales.
	Clinch		130	Light-gray quartzitic sandstone.
	Juniata		200	Red mudrock and white sandstone.
Ordovician	Martinsburg		1000	Gray limestone, gray calcareous shale and siltstone, and reddish sandstone.
	Chambersburg		150	Nodular black limestone.
	Athens		800	Thin-bedded black limestone and black fissile shale.
	Whitesburg		10	Dark-gray limestone.
	Holston		200	Chert; pinkish, gray limestone.
	Lenoir		50	Medium-bedded, nodular limestone.
Canadian	Mosheim		25	Dove-gray vaughanite
	Bellefonte		35	Porous white chert.
	Nittany		550	Dove-gray dolomite and varicolored marble. Residual chert.
Ozarkian	Conococheague		1500	Gray dolomite and limestone, intercalated beds of sandstone, and residual chert. Oolites common in dolomite and chert. Calcareous beds are finely laminated.
Cambrian	Elbrook		1800	Thin-bedded, platy gray limestone, and dark-gray dolomite with argillaceous partings. En echelon calcite veins abundant.
	Rome		2000	Red, green, and yellow shales and siltstones. Many intercalations of argillaceous dolomite.
	Shady		400	Thin-bedded ribbony limestone.
	Erwin		400	Disintegrated white quartzite.



COLUMNAR SECTION OF THE BEDROCK FORMATIONS IN THE DRAPER MOUNTAIN AREA, VIRGINIA.

Note: Since the cut for this columnar section was prepared the Virginia Geological Survey has discontinued the use of Ozarkian and Canadian as systemic terms. Hence the Conococheague limestone should be included in the Cambrian, and the Bellefonte-Nittany formations in the Ordovician.

slopes probably represents a residuum of Erwin which was a part of a once larger mountain. The east end of Lick Mountain can be adequately described as a huge pile of sand about 400 feet thick.

The Erwin is a ridgemaker and produces rugged topography. It makes steep slopes, some steeper than 45 degrees. Ridges formed by the Erwin are characteristically free from a dense undergrowth of vegetation but support an abundance of larger plants, particularly coniferous types.

Correlation.—Except for a few structures which are suggestive of *Scolithus* tubes, the Erwin has yielded no recognizable fossils in this area although elsewhere it contains a few fragments of olenellid trilobites and linguloid brachiopods which attest its early Cambrian age. The Erwin is recognized by its rather distinctive lithology and by its stratigraphic position. It forms the upper part of the Chilhowee group of basal Cambrian clastics. Normally it is underlain by the Hampton shale and overlain by the Shady formation and is supposed to include equivalents of the Nebo sandstone, Murray shale, and Hesse sandstone of the Knoxville, Tennessee area.

SHADY FORMATION

Name.—The type locality of the Shady formation is near the town of Shady, Johnson County, Tennessee. The formation was named by Keith.[4]

Distribution.—The Shady formation occupies a small area south of New River, near Reed Junction, in the southeastern corner of the Draper Mountain area. (See Pl. 1.)

Lithology.—This area contains so little Shady that an adequate description of it is impossible. Only a part of the Patterson member,[5] the lowest subdivision of the Shady, is present and it is not typical of the lithology of the Shady. The rocks are thin-bedded ribbony magnesian limestones, nodular thin-bedded argillaceous limestones, and medium-bedded dolomites. Most of the beds are gray or buff on weathered surfaces and light gray where fresh. Considerable carbonaceous material is present and south of Reed Junction this material is concentrated in streaks along the bedding planes. Currier[6] has made a detailed study of the Shady formation in this general region.

[4] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranberry folio (No. 90), p. 5, 1903.

[5] Butts, Charles, Geologic map of the Appalachian Valley of Virginia, with explanatory text: Virginia Geol. Survey Bull. 42, p. 3, 1933.

[6] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 16-37, 1935.

ROME FORMATION

Name.—The Rome formation was named by Hayes[7] for Rome, Floyd County, Georgia. During the period of pioneer geologic reconnaissance in the Appalachian region, from 1880-1915, many names were applied to this formation. In the southern Appalachian region all except two of these many names, Rome and Watauga, have lapsed into disuse. Woodward[8] has pointed out that Rome has priority over Watauga.

Distribution.—The Rome formation occupies a wide belt in the southern part of the Draper Mountain area. It borders the northeast end of Draper Mountain and occupies the larger part of a narrow Cambrian belt on its north flank. It occupies also a considerable area north and west of Max Meadows. Red shales are exposed at many places, for example, north of Fort Chiswell on the Max Meadows road, south of Fort Chiswell on the Jacksons Ferry road, north of Graham Forge along the road that leads from that village to the Lee Highway (U. S. 11), and along State Highway 99 northeast of Peak Knob. (See Pl. 4B.) Green and yellow shales of the Rome are conspicuous north of Pine Run Church and along the banks of Reed Creek north of Camp Carry Brook. Dolomite beds in the Rome are well exposed north and south of the road which connects U. S. Highway 52 with the Lee Highway. Dolomitic shales are exposed in the Horseshoe Bend and along the east side of the Fort Chiswell-Max Meadows road, one-fourth of a mile north of Fort Chiswell. (See Pl. 1.)

Lithology.—The outstanding feature of the Rome is its heterogeneous lithology, which is amply displayed in the Draper Mountain area. The chief lithologic types found in the Rome are red, green, and yellow shales, thin-bedded argillaceous limestone, buff siltstone, brown sandstone and arkose, thin-bedded argillaceous dolomitic limestone, and blue-gray dolomite. The Rome beds, which form the base of one of the great overthrust sheets of this area, have been dynamically metamorphosed so that they resemble sericite and chlorite phyllites.

The most characteristic lithologic type in the Rome is red shale, more properly designated as vinaceous-drab. The rock is finely laminated, but appears in many exposures to be a medium- to thick-bedded argillaceous rock. Fresh exposures of red shale are massive, but the same rock on weathering reveals its true shaly character. The clastic material of the red shale is composed almost wholly of aluminous

[7] Hayes, C. W., Overthrust faults in the southern Appalachians: Geol. Soc. America Bull., vol. 2, p. 143, 1891.
[8] Woodward, H. P., Age and nomenclature of the Rome (Watauga) formation of the Appalachian Valley: Jour. Geology, vol. 37, pp. 594-595, 1929.

silicates, of which sericite, chlorite, and various clay minerals are abundant, with considerable detrital quartz. Some horizons appear to contain dolomite. The red beds contain a small percentage of iron, in the form of hematite. In the phyllite zone part of the hematite is changed to specularite. The weathered red Rome disintegrates into irregular or polygonal chips. The invariable presence of these chips in Rome soils is an important criterion by which outcrop belts can be recognized.

The green shales are composed largely of sericitic and clayey material with subordinate amounts of clastic muscovite. Commonly the sericitic green shales are fractured and the resultant cracks are filled with quartz, calcite, and dolomite. This type of Rome occurs as thin intercalations within vinaceous-drab shale and as thick bodies containing minor intercalations of red shale. The green shale disintegrates into a yellow-brown soil containing chips of green shale. It is slightly calcareous, but most of the soluble material is in the form of secondary veins and vugs. The bedding and cleavage surfaces are smooth and have a soapy feel.

The ocherous-yellow shales are porous, noncalcareous, silty rocks which contain considerable clastic muscovite and quartz. On weathered exposures this shale resembles bentonite in color and texture, but it is distinguishable from the latter by its quartz content and by its lack of appreciable adsorbent properties. Yellow shales are commonly interbedded with the other types of shales. In the fresh state they are calcareous, but when weathered many have the character of ocher. It is mainly from these beds that fossils are obtained.

The limestones and dolomites of the Rome are sufficiently distinctive to be distinguished from the Elbrook formation with which the Rome is closely associated in the Draper Mountain area. Without exception, the Rome dolomites are nearly black, coarsely crystalline, ferruginous, and silty. They occur in beds 1 to 15 feet thick, have a noticeably higher specific gravity than other Rome beds, and contain considerable ferruginous material. More common exsolutional types are thin- to thick-bedded dolomitic limestones. They contain considerable silty and clayey material and weather brown. The rocks are commonly streaked with discontinuous carbonaceous stringers which are parallel to the bedding. On weathering they break down into a shaly rubble. The Rome dolomites contain from 20 to 50 per cent insoluble material, largely detrital clay and quartz. There are minor intercalations of salmon-pink thin-bedded limestone containing little insoluble material.

Certain portions of the Rome, where it borders Draper Mountain, have been silicified, and large chertified blocks of crinkled, drag-folded Rome are common on the lower foothills of that ridge. In the same area large masses of red, green, and brown Rome have been changed to porous aggregates of minute quartz crystals. These blocks litter the surface of hills north of the Lee Highway in eastern Wythe County east of Horseshoe Bend. Chert is not common in the Rome except in the localities just described. In this area the Rome contains very little sandstone although beds of buff or brown siltstone are intercalated in the vinaceous-drab shales. Microscopic examination reveals that they are markedly feldspathic.

Thickness.—Because of innumerable repetitions of strata by drag folding and minor faulting, it is impossible to determine accurately the thickness of the formation. Near Delton, south of Draper, an excellent section of Rome is exposed for considerable distance along the Galax branch of the Norfolk and Western Railway. In this section, as in all other extensive sections of the formation, there are many isoclinal folds which repeat the beds many times.

Topographic expression.—Rome terranes are characterized by a knobby topography: the hills are commonly conical and from 50 to 150 feet high. This topography is characteristic of the formation wherever it crops out in the southern part of the Appalachian Valley.

Fossils and correlation.—Fossils are very scarce in the Rome formation. *Olenellus romensis* Resser, a diagnostic Rome fossil, occurs in green shale one-fourth of a mile north of Fort Chiswell and several types of unidentifiable linguloid brachiopods were found in yellow shales north of the confluence of McGavock and Reed creeks. On the basis of its fossils and its stratigraphic relations in regions where its contacts with overlying and underlying formations are conformable, the Rome is believed to be upper Lower and Middle Cambrian. The Rome is equivalent to the Montevallo and Chocolocco shales of central Alabama, to the †Buena Vista or Waynesboro shale of central and northern Virginia, and to the †Watauga shale of eastern Tennessee and western North Carolina. On the northwestern side of the Appalachian Valley in southwest Virginia, the Rome has also been called the †Russell formation.

ELBROOK FORMATION

Name.—The Elbrook formation was named by Stose[9] from the town of Elbrook, Franklin County, Pennsylvania.

Distribution.—The Elbrook formation has a wide distribution in this area. A wide salient extends northeast of Max Meadows to the

[9] Stose, G. W., Sedimentary rocks of South Mountain, Pennsylvania: Jour. Geology, vol. 14, p. 209, 1906.

Pulaski-Wythe county line. A long area extends from a point three-fourths of a mile southwest of Fort Chiswell northeast to the Pulaski county line where it is concealed by the Rome formation which has been thrust over it. A short distance east of the divide between the branches of Pine Run the belt appears again and extends to a point about 1½ miles northeast of Draper. The larger part of the town of Pulaski rests upon Elbrook. (See Pl. 1.)

Lithology.—The Elbrook is composed of platy to blocky gray dolomitic limestone and medium- to thick-bedded blue-gray dolomitic limestone. As it is considerably folded and fractured, it is difficult to relate the various lithologic types to their proper stratigraphic position; however, from a study of exposed sections of Elbrook outside of, but close to, the Draper Mountain area, the writer was able to accomplish this. The thickness of the formation in the Draper Mountain area is not known.

Approximately 1,200 feet of the formation is composed of platy to blocky light-gray dolomitic limestone. On fresh exposures these beds appear to be medium bedded, but weathering brings out the true shaly character of the beds. (See Pl. 4C.) Weathered surfaces of this part of the Elbrook are whitish gray, several shades lighter than the fresh rock, and are rough and gritty. Most of the shaly and platy beds are wavy and some are minutely crumpled. The deformed platy bedding of the Elbrook is easily distinguished from the fracture-cleaved and crinkled surfaces of the Rome. The Elbrook can be split into thin slabs about three-sixteenths of an inch thick, whereas the Rome shales are generally too fractured to split along any one plane with any degree of regularity. The Rome shales break into small thin flaky chips. The platy portion of the Elbrook contains considerable insoluble argillaceous material which constitutes about 20 per cent of the rock. Intercalated with this are a few beds of medium-bedded pearl-gray vaughanite. These beds weather to about the same color as the platy, dolomitic beds, and because of this, casual examination often fails to reveal their presence. There are locally thin intercalations of sericitic green shale which resemble the similarly colored shales of the Rome, and within these bands are numerous flattish nodules of vitreous chert.

There is also a sequence of about 500 feet of dark, bluish-gray, argillaceous, slightly dolomitic limestone. These beds have a peculiar lithology which is distinct from that of other beds in the Elbrook. These beds contain wavy, discontinuous laminations, about one-fourth of an inch thick, of buff-colored clay. These laminations are not conspicuous on fresh surfaces, but exposures of the upper Elbrook in this area are sufficiently weathered to show this striking detail. These rocks are medium bedded, but gradually on weathering this character is obliterated by a platy parting which is controlled by the laminae. There is a small proportion of platy and green shaly material in this part of the Elbrook and locally the latter contains elongated nodules of black and gray chert. This sequence is strikingly similar to the Maryville limestone which occurs in the vicinity of Castlewood, Russell County, Virginia. (See Pl. 5A.)

Most of the beds of the Elbrook are dolomitic and all are calcareous. Most of the minute projections on weathered surfaces are small cuboid rhombs of dolomite, which in weathering are not dissolved as rapidly as the larger rhombs of the surrounding calcite.

The Elbrook contains an abundance of distinctive en echelon calcite veins which are inclined at an agle of about 45° to the bedding. These are sufficiently abundant and conspicuous to serve as an aid in the recognition of the Elbrook. They are particularly well developed along the east side of the private road which extends from Horseshoe Bend south along Reed Creek. The veins average 2 to 3 inches in length and one-fourth of an inch in width. During the period of faulting and folding whereby the rocks of this area came to assume their present attitude and position, en echelon fractures were opened in the Elbrook as the beds adjusted themselves to folding by slipping over one another. At a later time the fractures were filled with calcite. (See Pl. 5B.)

The platy lithology of part of the Elbrook is well shown at the north side of the railroad tracks opposite the road bridge over Miller Creek at the east end of Max Meadows. The laminated character of the upper Elbrook is evident in excavations for the altered route of U. S. Highway 11 a short distance east of Kessling School, and along the private road south of Horseshoe Bend. Distinctive pearl-gray limestone believed to be Elbrook is poorly exposed along an abandoned lane 600 feet southeast of Gunton Park crossing. Along a path leading east from the east end of the Pulaski Reservoir, blocky Elbrook beds are exposed, but the Elbrook in this locality has been secondarily silicified by ground water.

Fossils and correlation.—The Elbrook contains very few fossils. South of Poletown and in the immediate vicinity of Max Meadows a small nodular form of *Cryptozoon* is present. The age of the Elbrook of southwestern Virginia is ascertained chiefly by a change of facies which takes place a few miles west of Rural Retreat in Wythe County, where the Elbrook grades laterally into the Honaker and Nolichucky formations whose ages are well established.

The Elbrook corresponds to the Rutledge-Rogersville-Maryville-Nolichucky sequence of limestones and shales of northeastern Tennessee and to the Conasauga formation of Alabama. The Elbrook, according to Butts,[10] is of late Middle and early Upper Cambrian age.

UNCONFORMITY (?)

The Elbrook of the Draper Mountain area is bounded above and below by overthrust faults, and at no place in the area is there a normal formational contact between the Elbrook and the Conococheague. The relations of the Elbrook in the Draper Mountain area are obscure. Nowhere is the Elbrook clearly overlain by the next youngest formation, the Conococheague limestone. Elsewhere in Virginia, where the Conococheague overlies the Elbrook, there is a hiatus between them, indicated by the absence of the Brierfield, Ketona, and Bibb formations. In Alabama and adjacent portions of Tennessee the latter formations occur beneath the Conococheague equivalent and above the correlative of the Elbrook. They are included in the Lower Ozarkian of Ulrich. In view of the widespread unconformity between the Elbrook and Conococheague in Virginia, it is reasonable to conclude that there are no beds of this age at or beneath the surface in the Draper Mountain area.

CONOCOCHEAGUE FORMATION

Name.—The Conococheague formation was named by Stose[11] from exposures along the banks of a creek of the same name, at Scotland, Franklin County, Pennsylvania.

Distribution.—The Conococheague occupies a wide belt which extends from McGavock Creek on the west to a point three-fourths of a mile east of Draper. In sharp contrast to the well-exposed Conococheague belts of adjacent areas, there are comparatively few exposures of this formation in the Draper Mountain area. (See Pl. 1.) The Conococheague limestone crops out in the southeastern part of the Appalachian Valley from central Pennsylvania southwest to Tennessee where it has been called the Jonesboro limestone.[12] It is represented in the northwestern portion of the southern Appalachian Valley by the Copper Ridge dolomite. The Conococheague and Copper Ridge grade laterally into one another and the latter represents a dolomitic facies of the former. On the basis of lithology, the formation in the Draper Mountain area is properly called Conococheague, but in the same belt

[10] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, pp. 6-8, 1933.

[11] Stose, G. W., The Cambro-Ordovician limestones of the Appalachian Valley in southern Pennsylvania: Jour. Geology, vol. 16, p. 701, 1908.

[12] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 9, 1933.

of outcrop 40 miles to the southwest, near Marion, Virginia, the lithology is more characteristic of the Copper Ridge facies. (See Pl. 6A.)

Lithology.—Not all of the Conococheague is exposed in this area, because the lower part of the formation is buried beneath the overthrust Elbrook and Rome formations, but approximately 1,500 feet of the formation is exposed between Oglesby School and Draper.

The lower 1,000 feet is composed chiefly of dark blue-gray dolomitic limestone, which contains minute laminations of argillaceous and silty material that are accentuated by weathering. This finely corrugated appearance is not duplicated in any other limestone in the Appalachian region. The laminations in the Conococheague are more closely spaced than those of the upper Elbrook.

The same beds of Conococheague contain considerable quartz sand. In nearly every exposure of Conococheague, weathered surfaces of some beds reveal the presence of thin, streaky concentrations of quartz grains. Where several of these thin streaks converge, distinct bands of sand are formed. Besides these concentrations there are horizons of medium-bedded calcareous quartz sandstone which range from less than 1 foot to 25 feet in thickness. These sandstones are not confined to certain zones within the Conococheague but vary in their stratigraphic position from place to place. The sandstones are not valuable key horizons because they are not laterally persistent, and they appear to grade in all directions into typical Conococheague limestone. Most of the exposures of these sandstones are leached of their calcareous cement and consequently are saccharoidal. In natural outcrops the sandstones are buff or brown, but in the fresh state they have the blue-gray color of the typical Conococheague limestone. Topographically, these sandy horizons make low ridges which are locally conspicuous.

The lower 1,000 feet of the Conococheague also contains numerous beds of oolitic limestone. The oolites are predominantly calcareous but some are siliceous. They are sufficiently abundant in many beds to warrant the name, "oolite." The oolites are commonly about 1 millimeter in diameter and are set in a matrix of dolomitic limestone. The oolitic layers are less aboundant than the arenaceous beds and the former are easily confused with the latter in superficial appearance. Most of the oolitic beds weather to oolitic chert which litters the surface of the Conococheague terrane. The color of the chert ranges from white to black.

Another very characteristic lithologic type in the lower two-thirds of the formation is edgewise conglomerate which is characteristic of the Upper Cambrian and Lower Ordovician dolomites and limestones of the eastern United States. Commonly the conglomeratic character of these beds is apparent only on weathered surfaces; on freshly broken surfaces the conglomerates appear to be ordinary dolomite or limestone. The clastic fragments are elongate and tabular and range from a millimeter or less to 3 inches in greatest diameter. They are oriented at various angles to the bedding, and commonly their edges overlap one another. Most of the pebbles are angular and show very little abrasion. Detrital quartz is an important constituent of the limestone conglomerate beds. It is believed that most of the edgewise conglomerate is composed of fragments formed by desiccation and mud-cracking of limestone beds on diurnally exposed tidal flats, and that these fragments were transported a short distance seaward during high tide and incorporated with other sediments.

Another striking feature of the lower two-thirds of the Conococheague in this area is the occurrence of horizons of drusy, euhedral quartz crystals. These appear to be oolite beds which have been leached of lime and the remaining quartz and oolite grains have been subsequently enlarged. The enlargement has resulted in the development of doubly terminated euhedral quartz crystals. Most of these crystals are simple in habit, but some beds contain fantastically geniculate crystals to the complete exclusion of simple types. Microscopic examination of these crystals reveal nuclei which represent siliceous oolites and are concentrically laminated due to secondary coloring of some of the concentric shells by hydrous iron compounds. These horizons of euhedral quartz crystals are buff to black, depending upon the content of hydrous iron compounds. They vary in thickness from less than 1 inch to 3 feet. Like the sandstones and oolites from which they are derived, these beds are not laterally persistent, nor are they confined to certain horizons within the formation.

Chert is also characteristic of the lower 1,000 feet of the Conococheague. It is generally white or light gray, and breaks into small blocky pieces with sharp edges. It is not porous or spongy, as are the cherts of other formations in this area, but is uniformly dense, and commonly occurs in the form of small whitish angular blocks an inch or so in diameter. Some of the chert is oolitic and this variety is dark colored. The chert of the Conococheague is derived from the weathering of siliceous dolomitic limestones.

The lithology of the upper 500 feet of the formation is very different. The beds are composed of crinkly laminated dolomitic limestone alternating with beds of pure light blue-gray to pearl-gray vaughanite. The bedding between limestone and dolomite beds is very irregular, and it is likely that nearly every bedding surface represents a diastem. The limestone layers contain little or no clastic material and are practically 100 per cent soluble. The associated dolomitic beds are similar to the dolomitic beds in the lower part of the formation, and they contain considerable clastic material. In the lower part of this upper division dolomite predominates, but in the middle and upper portions vaughanite predominates. In this upper zone, there are a few sandstone horizons, but they are not as abundant as in the lower portions.

The best exposure of the lower 1,000 feet of the formation is along the west bank of Little Pine Run, just north of the Elbrook-Conococheague fault contact, half a mile south of Oglesby School. Opposite the old Oglesby homestead on the west side of the creek there is a conspicuous bed of black drusy quartz crystals which are fantastically twinned. The nuclei of these crystals are banded amber-colored oolites. Sandstone horizons are exposed along the east side of the road leading to Graham School about 200 and 400 yards south of the Lee Highway (U. S. 11). Another is well exposed along the road north of Draper Valley Church near the Lee Highway. The siliceous and oolitic characteristics of the dolomite are well shown in an abandoned quarry along the south side of the road leading from the Lee Highway to Graham School. The upper part of the Conococheague is exposed south of the Lee Highway in the first north-south stream valley east of Barrett Ridge, half a mile southwest of Draper School.

The Conococheague weathers to a burnt-sienna-colored soil.

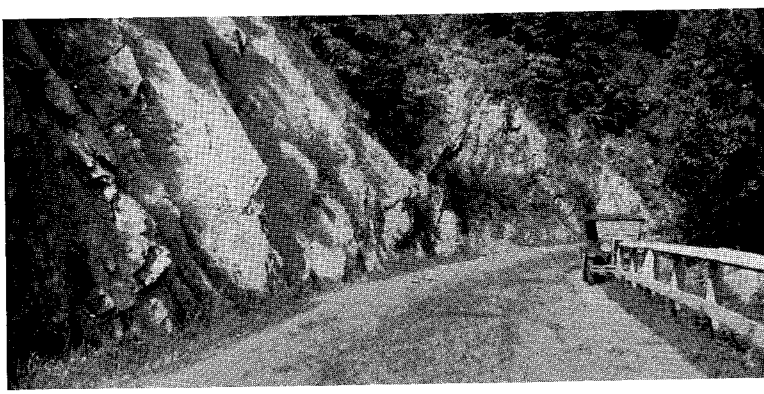
Fossils and correlation.—The only fossil which the writer found in the Conococheague is *Cryptozoon* sp. Butts[13] reports a very few poorly preserved gastropods in the formation in the vicinity of Dublin; however, the lithologic similarity and stratigraphic relations of the beds under consideration with the Conococheague of the type locality and the almost continuous tracing along the outcrop between the two areas are sufficient evidence that they should be called Conococheague. The Conococheague is Ozarkian, according to Ulrich, but is regarded as Upper Cambrian by most geologists.

UNCONFORMITY

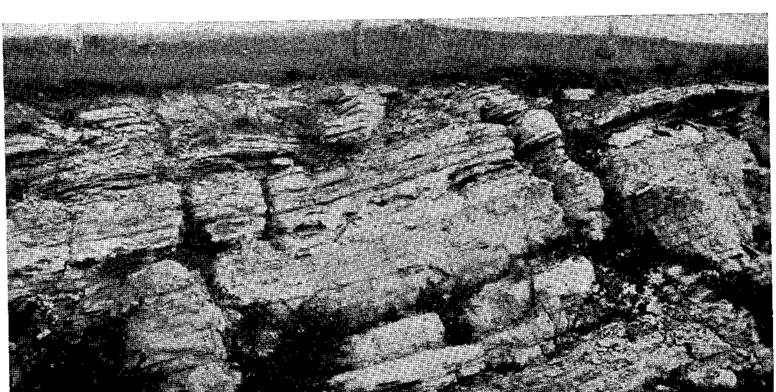
Normally overlying the Conococheague formation are the Chepultepec and Stonehenge formations, but in the Draper Mountain area the Chepultepec has not been detected and the Conococheague is apparently directly overlain by the Nittany formation. In places sandstone beds occur directly below limestone containing *Lecanospira.* (See Pl. 6A.) Since sandstone horizons are recognized as characteristic lithologic features of the Conococheague and since the distinctive genus, *Lecanospira,* is a characteristic Nittany fossil, it is possible that the Chepultepec and Stonehenge formations are absent in this area. Detailed paleontologic

[13] Butts, Charles, personal communication.

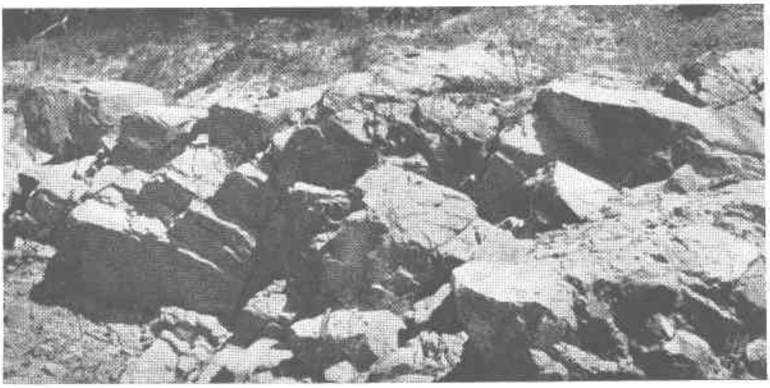
A. Exposure of case-hardened Erwin quartzite in Lots Gap on Lick Mountain.



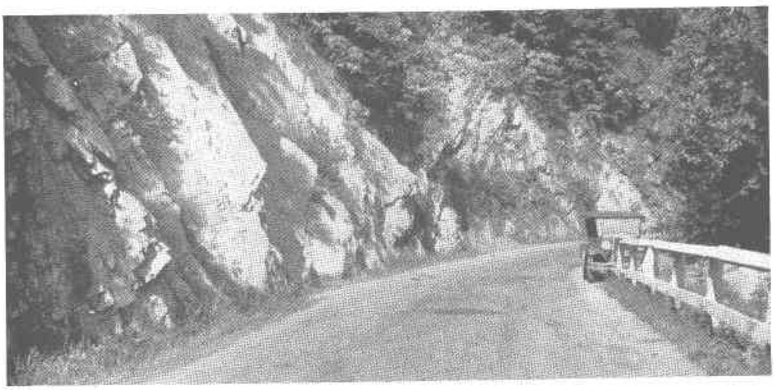
B. Rome beds along State Highway 99, 2 miles southeast of Pulaski. At the base of Peak Knob.



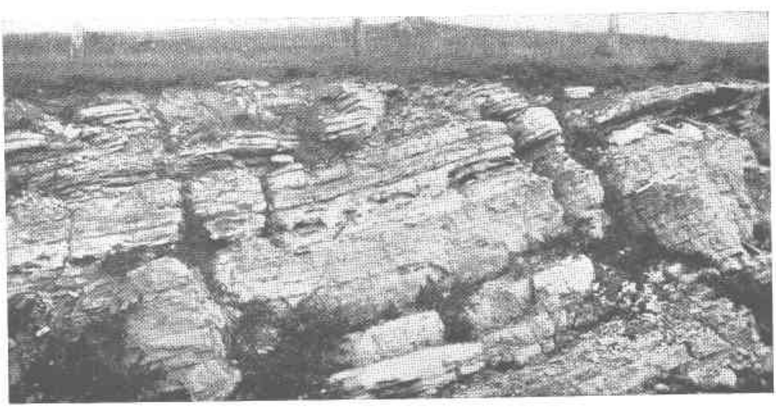
C. Platy Elbrook beds along the Lee Highway, 1½ miles east of Pulaski, Virginia.



A. Exposure of case-hardened Erwin quartzite in Lots Gap on Lick Mountain.



B. Rome beds along State Highway 99, 2 miles southeast of Pulaski. At the base of Peak Knob.



C. Platy Elbrook beds along the Lee Highway, 1½ miles east of Pulaski, Virginia.

A. Elbrook limestone south of Horseshoe Bend along Reed Creek. It shows well the type of lamination characteristic of the Maryville limestone. Photograph by Arthur Bevan.

B. En echelon calcite veins in dark-gray Elbrook beds. A short distance south of Horseshoe Bend on Reed Creek. Photograph by Arthur Bevan.

A. Elbrook limestone south of Horseshoe Bend along Reed Creek. It shows well the type of lamination characteristic of the Maryville limestone. Photograph by Arthur Bevan.

B. En echelon calcite veins in dark-gray Elbrook beds. A short distance south of Horseshoe Bend on Reed Creek. Photograph by Arthur Bevan.

investigation may disclose a thin development of these supposedly missing formations. In the vicinity of Marion, 40 miles southwest of this area, the Chepultepec and Stonehenge together are 350 feet thick.

ORDOVICIAN SYSTEM

NITTANY FORMATION

Name.—The Nittany formation, named the "Nittany dolomite" by Ulrich,[14] has its type locality in the Nittany Valley, Center County, Pennsylvania.

Distribution.—The Nittany formation extends from a point half a mile west of McGavock Creek northeast to the county line where it is offset by a fault. On the north side of the fault the Nittany can be followed north to Oglesby School and thence northeast to the east end of a fenster, 1 mile east of Draper. (See Pl. 1.)

Lithology.—The Nittany formation in this area is composed of light-gray limestone, dolomitic limestone, and dolomite. The formation consists of two distinct and persistent lithologic types, upon the basis of which the formation can be divided into members. For the Draper Mountain area in particular, it is advisable to subdivide the Nittany because of the economic possibilities of one of these proposed subdivisions. (See Pl. 6A.)

Oglesby marble member.—The lower part of the Nittany, for which the name Oglesby marble member is here proposed, is best exposed along the lane leading south from the Lee Highway at the Pulaski-Wythe county line, near Oglesby School, from which place its name is taken. (See Pls. 1 and 6A.)

The Oglesby member is composed of very fine grained vaughanitic limestone of various colors. The beds average 2 feet in thickness, are remarkably free of fractures, and are broken by rather widely spaced strike joints. The rock is composed of microcrystalline calcite and contains less than two per cent of insoluble material. On fresh surfaces the rock has a vitreous appearance, breaks with a conchoidal fracture, and emits a distinct ring when struck with a hammer. The Oglesby has its fullest and most varied development in the type locality. A generalized section at this locality is given below.

[14] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 552, 658, pl. 27, 1911.

Oglesby marble member along local road, south of the Lee Highway, near Oglesby School, Virginia[a]

	Thickness Feet
Nittany formation	
Draper dolomite member	
Oglesby marble member (120-155 feet)	
4. Medium- to thick-bedded light bluish-gray vaughanite, containing nodular pockets of hollow oolites....	40
3. Thick-bedded purplish-gray vaughanite and intercalated beds of edgewise conglomerate. The matrix of the latter is light purplish gray and the pebbles are of dense white vaughanite. Beds directly above and below the conglomerates are variegated greenish gray to bluish-gray	50
2. Bluish-gray medium-bedded vaughanite interbedded with pinkish- to pearl-gray vaughanite and greenish argillaceous laminated limestone, which contains numerous vermiform and lenticular fragments of pinkish vaughanite showing algal structures	20–40
1. Bluish-gray thick-bedded vaughanite containing intersecting argillaceous and siliceous stringers which form a projecting fretwork on weathered surfaces	10–25

Pinkish-gray and bluish-gray vaughanites are the predominant and persistent lithologic types in the Oglesby marble member. In the field north of the intersection of State highways 100 and 101 at Draper, the Oglesby member is 155 feet thick and is composed of beds similar to "No. 1" in the foregoing section. Here, there is a thickness of approximately 80 feet of chert, dolomite and limestone, below the Oglesby member, which is also of Nittany age, so that it cannot be said that the Oglesby marble member marks the base of the Nittany formation in the vicinity of Draper. On the geologic map of the area (Pl. 1), these beds are mapped with the Oglesby marble member. Near the point where this member passes beneath the fill of the Galax branch of the Norfolk and Western Railway, it is only 8 feet thick. Three-fourths of a mile southwest of Draper School and east

[a] Section begins with the first limestone bed south of the Lee Highway.

of Barrett Ridge the Oglesby member is approximately 100 feet thick and contains representatives of some of the lithologic types previously described from the type locality.

Draper dolomite member.—The type locality of the Draper dolomite or upper member of the Nittany formation is south of the Lee Highway about three-fourths of a mile southwest of Draper School, near Draper, Virginia, where the member has its maximum development. The member is also exposed just north of the intersection of State highways 100 and 101, but due to an unconformity, only about half of the thickness of the dolomite is present. (See Pl. 6A.)

The Draper dolomite member is composed of medium-bedded light-gray dolomitic limestone and dolomite. Most of the beds are siliceous and slightly argillaceous. Weathered surfaces are rough and welted and have a dull rusty brown color. The thicker beds are commonly fluted and castellated where they crop out. The lower 25 to 75 feet of the Draper is composed of coarsely crystalline dolomite which contains less than 10 per cent calcite. The dolomite rhombs are 1 to 3 mm. in diameter and are somewhat abraded and rounded, giving the rock a distinctive clastic texture. The dolomite contains considerable siliceous material of indeterminate mineral composition. The weathered rock is highly saccharoidal and disintegrates into a gritty aggregate of dolomite rhombs.

The upper 300 to 400 feet of the Draper dolomite member is composed of light-gray, fine-grained dolomitic limestone. The rock is rather siliceous and contains 3 to 5 per cent of silty material. Weathered surfaces are rough and are covered with welts and pits similar to those of the Bighorn dolomite.[15] The dolomitic limestones are considerably fractured, the cracks being filled with calcite veins. The bedding is uniform in the lower part of the member but irregular in the upper portion.

Many weathered exposures of the Draper dolomite member are a mass of chert which appears to have replaced the carbonate minerals of the rock. It is common to find entire exposures chertified with the bedding of the original calcareous rock still apparent. The chert is generally gray and rather porous. Large irregular, cauliflower-shaped masses of chert litter the surface of all of the outcrop area of the Nittany formation. Most of this chert is derived from the upper Draper dolomite member and probably little comes from the pure limestones of the Oglesby marble member. The absence of chert in fresh exposures and

[15] Blackwelder, Eliot, Origin of the Bighorn dolomite of Wyoming: Geol. Soc. America Bull., vol. 24, pp. 610-613, 1913.

its abundance in outcrops strongly suggests that it is of epigenetic origin. The chert of the Nittany is easily distinguished from that of the underlying Conococheague formation on the basis of these characteristics. In addition the Nittany chert in this area is not oolitic and contains fossils in moderate abundance which are diagnostic of Nittany age.

Fossils and correlation.—The following fossils were collected from the Nittany of the Draper Mountain area:

Lecanospira conferta Ulrich and Butts
Lecanospira biconcava Ulrich and Bridge
Lecanospira sigmoidea Ulrich and Bridge
Lecanospira compacta (Salter)
Hormotoma sp.
Eccyliopteris sp.
Roubidouxia umbilicata Ulrich and Bridge?

Fossils are abundant in the lower part of the Oglesby marble member exposed a short distance east of the private road near the county line, 300 yards south of the Lee Highway. With the exception of *Eccyliopteris* the forms named above occur in both members of the Nittany. *Lecanospira conferta* and *L. compacta* are common in the chert of the upper Draper dolomitic limestone member.

The presence of the distinctive and diagnostic genus, *Lecanospira,* is evidence of the middle Beekmantown age of the Nittany formation. The Nittany or equivalent beds are known from Canada to Alabama and in Texas, Oklahoma, and Missouri. The Nittany forms the upper part of the Knox dolomite of Tennessee, and in Alabama the formation is known as the Longview limestone. Species referred to *Lecanospira* have recently been described by Powell[16] from the Oneota of the Upper Mississippi Valley region; however, it is not yet well established that the Oneota species are true *Lecanospiras.*

BELLEFONTE FORMATION

Name.—This formation was named the Bellefonte dolomite by Ulrich[17] from exposures at Bellefonte, Center County, Pennsylvania.

Distribution.—The Bellefonte occurs only in certain localities in the Draper Mountain area. In most places the Nittany directly

[16] Powell, L. H., A study of the Ozarkian faunas of southeastern Minnesota: Pub. Sci. Mus. St. Paul Inst., Bull. 1, pp. 65-67, 1935.
[17] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 552, 553, 652-660, pl. 27, 1911.

underlies the Mosheim formation (Lower Ordovician), but in some places a thin representative of Bellefonte is present between the Nittany and Mosheim. The absence of the Bellefonte equivalent is due to uplift and erosion or to nondeposition. The remaining patches of Bellefonte crop out locally between the Nittany and the Mosheim formations on the northwest side of Barrett Ridge and its westward extension which parallels the Lee Highway as far southwest as Oglesby School; just south of the Lee Highway along the road leading south to Draper Valley Church; a short distance south of the filling station at the intersection of U. S. Highway 11 and State Highway 101; and about 50 yards south of the Lee Highway along the road leading south to Graham School. (See Pl. 1.)

Lithology.—In the Draper Mountain area, the Bellefonte as exposed at the surface is composed entirely of chert. The rock is pinkish to light gray and shows distinct bedding. On thoroughly weathered exposures, the chert is brown and crumbly. There are two distinct varieties, a spongy, scoriaceous chert which has a characteristic "worm-eaten" appearance, and a more compact variety marked by an abundance of dolocasts[18] which are shown on the surface of a block of chert by rhomb-shaped cavities. In the fresh state the Bellefonte is probably a magnesian limestone, with much of the dolomite in the form of rhombs. During the processes of weathering the calcite is replaced by chert to an unknown depth, and the less soluble dolomite rhombs remain unchanged and become surrounded by chert. On further weathering these dolomite rhombs are dissolved out, leaving rhomb-shaped cavities in the chert. Some of the Bellefonte chert contains considerable detrital quartz in grains of ¼ to ⅛ mm. size, and it is quite common to see weathered surfaces covered with a veneer of quartz grains which have been concentrated on the surface in the process of weathering. The soil derived from the Bellefonte is filled with small and large blocks of this chert.

The greatest thickness of the Bellefonte in this area is considerably less than 50 feet. In most places the formation is very thin or absent.

Stratigraphic relations.—The Bellefonte is conformable with the underlying Draper dolomite member of the Nittany formation.

Fossils and correlation.—The following fossils were collected from exposures 50 yards south of the Lee Highway along the road to Graham School:

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[18] McQueen, H. S., Insoluble residues as a guide in stratigraphic studies: Missouri Bur. Geology and Mines, Biennial Rept. of State Geologist for 1929-1930, pp. 128-131, pl. Xa, 1931.

Ceratopea keithi Ulrich
Ophileta sp.
Ophileta solida Butts
Orospira bigranosa (Shumard)
Orospira sp.
Helicotoma peccatonica Sardeson
Hormotoma artemesia (Billings)
Turritoma acrea (Billings)

The distinctive and diagnostic *Ceratopea* is characteristic of upper Canadian beds wherever found. It is known in the Appalachian region from Canada to Alabama. *Orospira* is equally distinctive of this horizon. The Bellefonte is equivalent to the Newala limestone of Alabama, to the upper 2,000 feet of the Arbuckle limestone of Oklahoma, to the Cotter and Powell formations of Missouri and Arkansas, and to a part of the Shakopee dolomite[19] of the upper Mississippi Valley. It may be the correlative of the Fort Cassin beds of the upper Beekmantown of New York State.

UNCONFORMITY

A hiatus between the Bellefonte and the overlying Mosheim formations is indicated by the absence of the Murfreesboro limestone, which underlies the Mosheim on the northwestern side of the southern Appalachian Valley, and by the absence of pre-Murfreesboro formations of Ordovician age (Buffalo River group) which are present in the Mississippi Valley region. Physical evidence of a stratigraphic break between the Mosheim and the underlying Ordovician is indicated by the patchy distribution of the Bellefonte chert which apparently was largely eroded away during the post-Bellefonte, pre-Mosheim erosion interval. The relief of this surface of unconformity is possibly not more than 50 feet. The absence of the Murfreesboro and older Ordovician formations in southeastern belts of the southern Appalachian Valley is an indication of a rather widespread emergence of the eastern part of the geosynclinal sea bottom during post-Nittany, pre-Mosheim time.

[19] Stauffer, C. R., Mollusca from the Shakopee dolomite: Jour. Paleontology, vol. 11, pp. 66-68, 1937.

STONES RIVER GROUP

MOSHEIM LIMESTONE

Name.—The Mosheim was named by Ulrich[20] from exposures of the formation near Mosheim, Greene County, Tennessee.

Distribution.—The Mosheim crops out in a narrow belt just south of the Lee Highway from a point half a mile west of McGavock Creek northeast to Draper. It is absent north of the intersection of State highways 100 and 101 and in the area to the east. The best exposures are located one-fourth of a mile south of the Lee Highway along the eastern side of McGavock Creek and on the east bank of Little Pine Run half a mile south of the point where the Lee Highway crosses the Pulaski-Wythe county line. (See Pl 1.)

Lithology.—The Mosheim is a dove-gray, medium-bedded vaughanite. It contains relatively little insoluble material and is highly suitable for lime-burning purposes. The rock breaks with a conchoidal fracture and emits a ring when struck with a hammer. The main body of the Mosheim is composed of microcrystalline calcite, but disseminated through this material are large rhombs of calcite 1 to 2 mm. in diameter. Thin irregular stringers of large calcite rhombs are common in some of the beds. The Mosheim weathers to a light gray and weathered surfaces commonly are rounded and fluted. Along Little Pine Run half a mile south of Oglesby School the Mosheim is 60 feet thick, but elsewhere in the area it is generally less than 25 feet thick. (See Pl. 6B.) It resembles the Oglesby marble member in many respects, but it lacks the conglomerate character, Nittany fossils, and the variability of color, of that formation.

Fossils.—The fine, compact texture of the Mosheim makes it difficult to extract its fossils. It contains an abundance of gastropods as shown by etched outlines of the whorls on weathered surfaces. In this area, as in others of the southern Appalachian region, *Lophospira* and *Liospira* are the most common, and of these a species suggesting *Lophospira bicincta* is most abundant. Weathered surfaces of Mosheim beds contain etched cross-sections of the diagnostic *Tetradium syringoporoides* in great abundance. The Mosheim has a widespread but thin development in the Appalachian region south of Roanoke.

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[20] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 413-414, 538, 543-547, 557, 636, pl. 27, 1911.

LENOIR LIMESTONE

Name.—The Lenoir limestone was named by Safford and Killebrew[21] from Lenoir City, Loudoun County, Tennessee.

Distribution.—The Lenoir is one of the most widely distributed stratigraphic units in the Appalachian Valley. It and the Mosheim crop out in adjoining belts which have similar geographic distributions. Like the Mosheim, the Lenoir in the Draper Mountain fenster is absent north and east of Draper. (See Pl. 1.)

Lithology.—The Lenoir of the Draper Mountain area is similar in lithology to the Lenoir of other areas. Two distinct types of rock are present. The lower 40 feet is composed of even-bedded medium-crystalline, black limestone which contains conspicuous amounts of disseminated pyrite and carbonaceous material. The upper 50 feet is composed of thin-bedded nodular to lenticular bands of fine-grained dark-gray limestone, which are separated by thin wavy partings of clayey, silty material. The limestone bands and nodules weather more rapidly than do the clastic partings and a projecting mesh of these intersecting clayey partings give a honeycombed appearance to weathered exposures. These two lithologic subdivisions are well exposed on the east side of the road one-fourth of a mile south of the Lee Highway along McGavock Creek. (See Pl. 6C.) The Lenoir, which here has its thickest development in the Draper Mountain area, is 90 feet thick. In localities to the northeast, the Lenoir is generally much thinner and averages only 35 feet in thickness. In places where the Mosheim and Lenoir are rather well exposed, the Lenoir is thickest where the Mosheim is thinnest, and where the Mosheim is well developed, as along Little Pine Run half a mile south of Oglesby School, the Lenoir is very thin. The nodular portion of the Lenoir is not conspicuous except in the locality along McGavock Creek, and the lower medium-bedded Lenoir appears to represent the formation in most places in the Draper Mountain area.

The formation contains considerable hydrocarbonaceous material, which probably represents a more or less non-volatile residue of petroliferous material. This material gives the rock its black color and causes it to emit an oily odor when struck with a hammer.

Fossils and correlation.—Due to the steep inclination and poor exposure of the Lenoir in this area, fossils do not appear to be abundant. The writer collected the following fossils:

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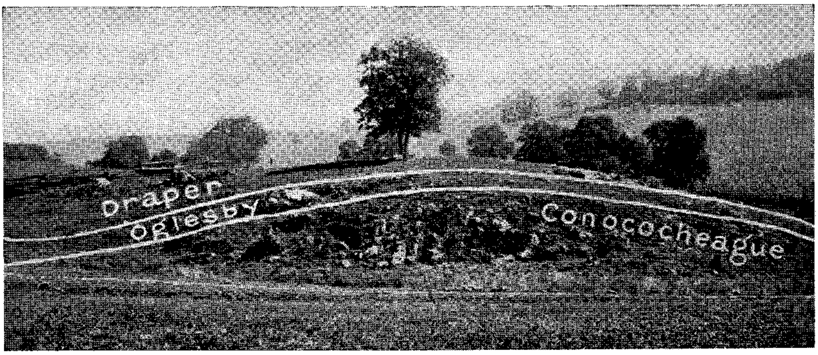
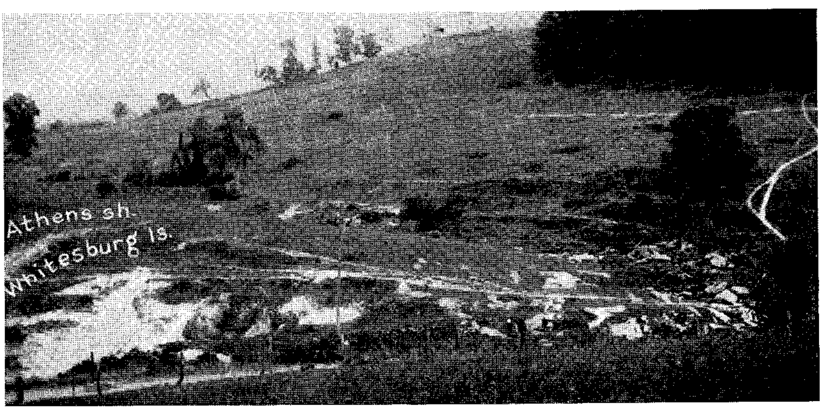
[21] Safford, J. M., and Killebrew, J. B., The elementary geology of Tennessee . . . , pp. 108, 123, 130-131, 137, Nashville. 1876.

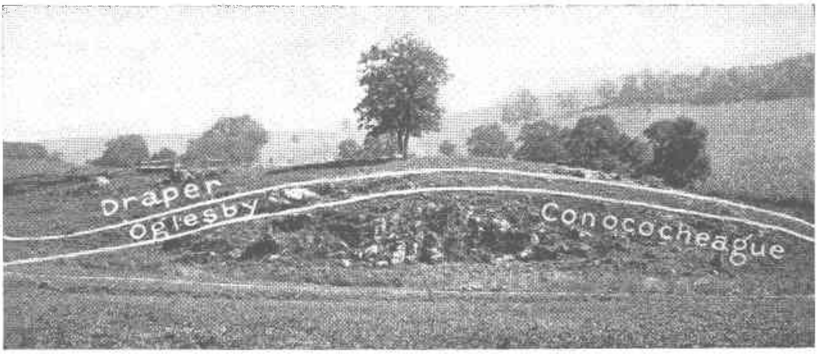


A. Conococheague sandstone and dolomite overlain by Oglesby marble. In the background is Nittany chert. The exposure is three-fourths of a mile east of Draper and south of the railway tracks.

B. Mosheim limestone near the forks of Little Pine Run. It is 60 feet thick here. About half a mile south of Oglesby School.

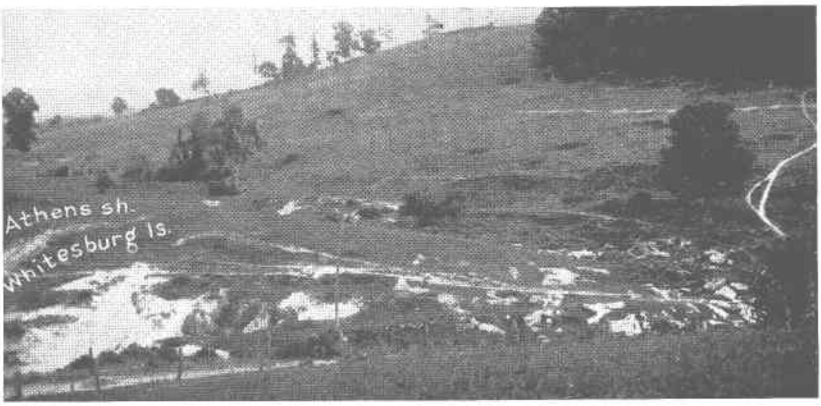


C. Vertical Mosheim, Lenoir, and Whitesburg limestones in the McGavock Creek section.

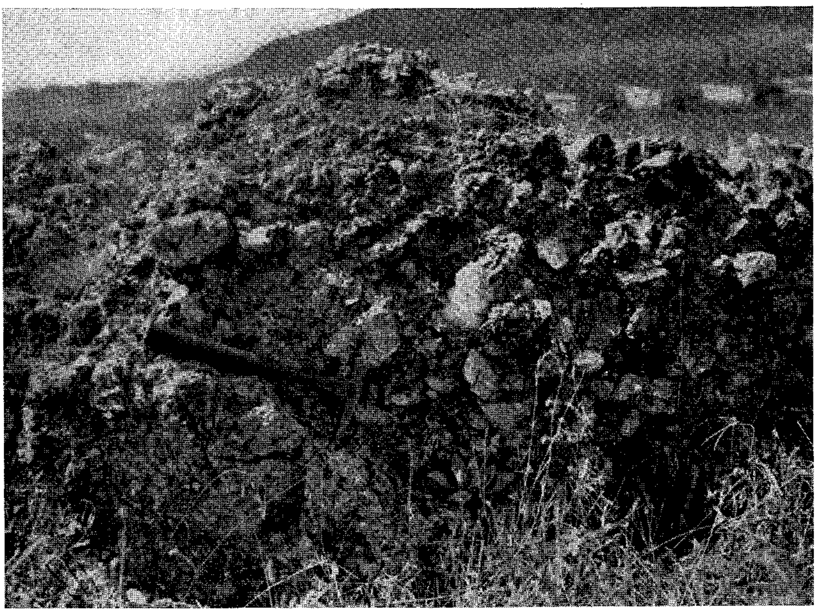


A. Conococheague sandstone and dolomite overlain by Oglesby marble. In the background is Nittany chert. The exposure is three-fourths of a mile east of Draper and south of the railway tracks.

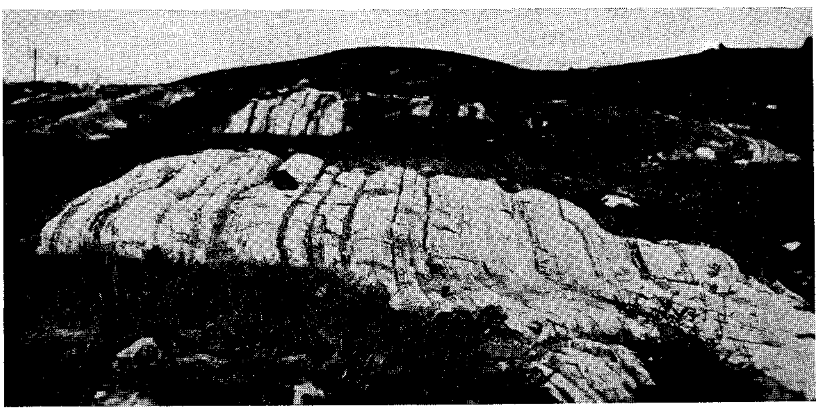
B. Mosheim limestone near the forks of Little Pine Run. It is 60 feet thick here. About half a mile south of Oglesby School.



C. Vertical Mosheim, Lenoir, and Whitesburg limestones in the McGavock Creek section.

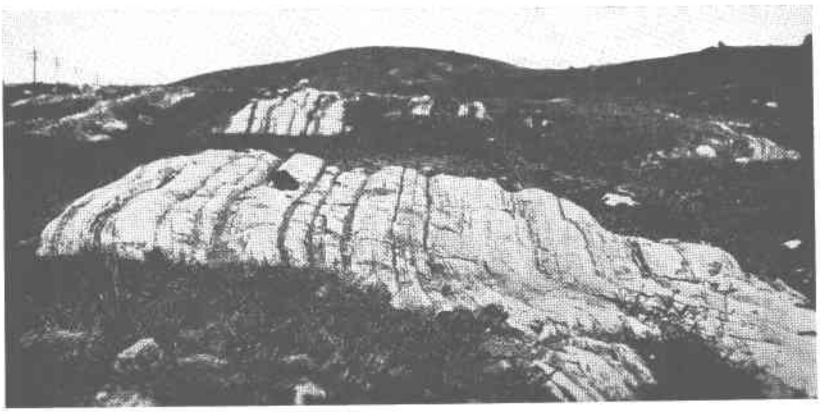


A. Chert conglomerate at base of the Holston limestone. About 500 feet north of the intersection of State highways 100 and 101, at Draper, Virginia. Photograph by Arthur Bevan.



B. Beds of vertical Athens limestone separated by black shale partings. North of Barrett Ridge along the south side of State Highway 101.

A. Chert conglomerate at base of the Holston limestone. About 500 feet north of the intersection of State highways 100 and 101, at Draper, Virginia. Photograph by Arthur Bevan.



B. Beds of vertical Athens limestone separated by black shale partings. North of Barrett Ridge along the south side of State Highway 101.

Girvanella sp.
Anthaspidella sp.
Multicostella platys (Billings)
Hesperorthis aff. H. tricenaria (Conrad)
Hebertella sp.
Dinorthis sp. (Hall)
Valcourea sp.
Cyrtonella virginiensis (?) Butts
Maclurea magna Emmons
Sinuites sp.
Homotelus sp.

Maclurea magna is characteristic of the Lenoir wherever it occurs and is recognized as a valid guide fossil of that formation. The Lenoir corresponds to the Crown Point limestone of New York State, Lemont limestone of Pennsylvania, and to the Ridley limestone of the Central Basin of Tennessee.

UNCONFORMITY

In the McGavock Creek section the nodular Lenoir is directly overlain by the Whitesburg limestone with apparent physical conformity. (See Pl. 6C.) Northeastward toward Draper the contact between the two is an erosional surface of small relief. It is evident from Plate 1, which shows the areal geology in the vicinity of Draper, that a short distance west of Draper the break at the base of the Whitesburg becomes a disconformity of striking magnitude. In the vicinity of the intersection of State highways 100 and 101 the relief of this unconformable surface is as much as 400 feet. This erosional surface has been carved in the Lenoir, Mosheim, Bellefonte, and Nittany formations. West of the intersection where the unconformity truncates the Lenoir and Mosheim, the oldest formation above the unconformable surface is not the Whitesburg but the Holston. The surface of the unconformity underlies the Holston and cuts the Lenoir, which indicates that the unconformity is of post-Lenoir, pre-Holston age. It is possible that not all of the Lenoir nor all of the Holston is present in this area and that the erosional surface might have been carved either in late Lenoir or early Holston time. The time required to cut the striking erosional surface, as exposed in this area, was geologically very short. The significance of this break has already been indicated.[22]

[22] Cooper, B. N., Lower Paleozoic unconformities in Pulaski County, Virginia: Geol. Soc. America Proc. for 1936, pp. 68-69, 1937.

BLOUNT GROUP

HOLSTON FORMATION

Name.—The Holston formation was originally defined by Keith[23] as a member of the Chickamauga limestone. The name comes from the Holston River along which the beds are well exposed in the vicinity of Devil's Nose, near Morristown, Tennessee. Subsequent to Keith's original definition, the term "Holston" has been elevated to formation rank.

Distribution.—The Holston crops out in a belt extending from State Highway 101 on the west to a point three-fourths of a mile northeast of Draper on the east; also in a small area at the east foot of Barrett Ridge. It is present only where the Lenoir is thin or absent, and occurs in the extensive trench cut into the Lenoir, Mosheim, Bellefonte, and Nittany formations. (See Pl. 1.)

Lithology.—Directly north of the intersection of State highways 100 and 101, the Holston formation has its thickest development. (See Pl. 7A.) The stratigraphic relations of the formation here are rather unusual. A measured section at this locality is given below:

Holston formation north of the intersection of State highways 100 and 101, near Draper, Virginia[a]

	Thickness Feet
Whitesburg formation	
Holston formation (208 feet)	
5. Dark-gray nodular argillaceous medium-grained limestone containing thin bands of coarsely crystalline pinkish limestone	55
4. Dark-gray coarsely crystalline limestone in thin beds	100
3. Pink to gray coarsely crystalline limestone composed of slightly abraded rhombs of pink calcite; reddish trilobite fragments abundant in some layers	30

[23] Keith, Arthur, U. S. Geol. Surv. Geol. Atlas, Knoxville folio (No. 16), map, 1895; U. S. Geol. Survey Geol. Atlas, Maynardville folio (No. 75), p. 3, 1901.

[a] The section ends 50 feet north of road at the base of the Nittany formation.

	Thickness Feet
2. Pinkish coarsely crystalline clastic limestone, containing many red trilobite fragments and fragments of Nittany chert and dolomite and Mosheim and Lenoir limestones	15
1. Coarse detrital chert conglomerate, composed of residual rubble from the Nittany dolomite	8
Nittany formation (315 feet)	
2. Draper dolomite member: medium-gray coarse- and fine-grained magnesian limestones and dolomites	80
1. Oglesby marble member: light bluish-gray medium-bedded limestone	155
Interbedded dolomite, chert, and vaughanite	80

East of the intersection of State highways 100 and 101 the Holston is composed almost entirely of light-gray coarsely crystalline limestone. The conglomeratic beds, described above, appear to be confined to that locality. Most of the Holston is coarsely crystalline, but there are some beds of fine-grained texture in exposures 300 feet east of the point where the Holston belt crosses State Highway 100. These beds are composed largely of bryozoan remains. The pinkish color of part of the Holston is a rather characteristic feature, but only a small part of the formation is of that color.

The Holston is composed of rather large fragments of calcite which appear to be of organic origin. They probably represent fragments of shells and other hard parts of invertebrates. Many of the calcite rhombs show some abrasion and it is proper to call most of the beds clastic limestones. Many of the beds are indurated coquinas. Most of the pink beds in this area contain an abundance of reddish fragments of trilobites. There is little evidence of recrystallization of calcite in the formation, but locally, where calcite veins penetrate the rock, recrystallization of the calcite rhombs bordering the veins is apparent. Exclusive of the conglomeratic beds, the formation contains little else but calcite.

Fossils and correlation.—The Holston contains an abundance of well-preserved fossils; however, the systematic paleontology of the formation has not been satisfactorily worked out. Most of the common forms in the Holston have never been described. Of the wide variety of fossils collected by the writer, only the following were identified:

Lichenaria sp.
Helopora
Arthroclema sp.
Leptaena sp.
Cliftonia sp.
Mimella sp.
Camarotoechia plena (Hall)
Paleoglossa gibbosa Willard
Oxoplecia holstonensis Willard
Orthoceras sp.
Isotelus sp.
Bumastus sp.
Homotelus sp.
Hyboaspis shuleri Raymond

The Holston of this area is faunally similar to the Holston of other regions. The stratigraphic position of the formation, above the Lenoir and below the Whitesburg, is additional evidence by which it can be correlated. In Tennessee the Holston is locally known as the "Tennessee marble," but the correlation of the Holston with all similar pink marble beds of the southern Appalachian region is apt to lead to serious error. The striking "Tennessee marble" lithology is not confined to the Holston but is known to occur in younger formations as well.[24]

WHITESBURG LIMESTONE

Name.—The Whitesburg limestone was named by Ulrich[25] from Whitesburg, Hamblen County, Tennessee. The exact definition of the formation was given by Ulrich[26] in 1930.

Distribution.—The Whitesburg crops out as a thin band of limestone below the Athens and above the Lenoir formations or above the Holston where that formation is present. On the geologic map it is mapped with the Athens under the symbol Oaw. (See Pls. 1 and 6C.)

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[24] Cooper, B. N., Stratigraphy and structure of the Marion area, Virginia: Virginia Geol. Survey Bull. 46, pp. 145-147, 1936.

[25] Ulrich, E. O., *in* Marble deposits of East Tennessee: Tenn. Dept. Educ., Div. Geol., Bull. 28, p. 34; Bull. 31, p. 16, 1924.

[26] Ulrich, E. O., Ordovician trilobites of the family *Telephidae* and concerned stratigraphic relationships: U. S. Nat. Mus. Proc., vol. 76, art. 21, p. 2 (footnote), 1930.

Lithology.—The Whitesburg is composed of thin-bedded, coarsely crystalline limestone. It is very similar in color and texture to the dark-gray Holston limestones which underlie it north of the intersection of State highways 100 and 101. As the Holston occurs only locally in this area, the Whitesburg, in most places, lies on the Lenoir. In the McGavock Creek section, where the Whitesburg overlies the nodular Lenoir, the difference in lithology of the two formations is striking. The Whitesburg is generally distinguished from the Holston in that it is thin-bedded and contains an abundance of black chitinous trilobite fragments. In the McGavock Creek section, the Whitesburg is 6 to 8 feet thick, and it normally maintains about the same thickness throughout the area. North of the intersection of State highways 100 and 101 it is 40 feet thick. The greater thickness of the Whitesburg here is probably due to the fact that the underlying Holston did not fill the erosional trough. As this area may have been below the profile of equilibrium of the sea bottom, it presumably received more material than other areas.

Stratigraphic relations.—In areas southwest and west of the intersection of State highways 100 and 101 the Whitesburg lies unconformably upon the nodular Lenoir, but there is little or no physical evidence of a break between the two formations. North and east of this locality, the Whitesburg lies conformably upon the Holston. It is conformably overlain by the Athens formation.

Fossils and correlation.—The following fossils were collected from the Whitesburg of this area:

Sowerbyella sp.
Cliftonia sp.
Nicolella sp.
Sinuites sp.
Ctenodonta sp.
Bronteopsis gregaria Raymond
Homotelus obtusus (Hall)
Homotelus sp.
Bumastus longiops Raymond
Pterygometopus transsectus Raymond

The Whitesburg age of the beds containing these fossils is indicated by the presence of *Bronteopsis gregaria,* a common associate of *Arthrorhachis elspethi.* The latter is considered by Butts to be the most reliable Whitesburg index fossil. The Whitesburg is reported to be a persistent horizon at the base of the Athens throughout southwestern Virginia, eastern Tennessee, and Alabama.

ATHENS LIMESTONE

Name.—The Athens was named by Hayes[27] from Athens, McMinn County, Tennessee.

Distribution.—The Athens crops out in a wide belt which extends from the south base of Crocket Knob northeastward to a point about one mile east of Draper, where it passes under the overthrust Cambrian rocks. The Athens also crops out in a wide linear belt in Draper Valley. (See Pl. 1.)

Lithology.—The Athens of the Draper Mountain area is composed of black thin-bedded limestone and black fissile shale which forms thin partings between the limestone layers. The limestone layers are 2 to 8 inches thick and are uniformly bedded. (See Pl. 7B.) They are easily distinguished from other limestones in this area. They contain considerable quantities of black, slightly irridescent carbonaceous material as well as 20 to 30 per cent of finely divided argillaceous material and break with a distinctive conchoidal fracture. The rock is very fine grained and dense and when struck with a hammer has a distinct ring. The Athens weathers to a light-gray color which differs from that of the beds above and below it. It is 600 to 800 feet thick in this area. The criteria by which the Athens can be recognized include the peculiar manner in which the formation yielded to stress at the time of the Appalachian orogeny. In nearly every exposure vertical Athens beds have been contorted into most intricate drag folds, which are the most characteristic feature of the formation. (See Pl. 8A.)

The shaly part of the formation is calcareous in the fresh condition, but most of the natural exposures of these beds are sufficiently weathered to be surficially free of calcium carbonate. In some places the shale is platy and fissile, but most exposures of this type of Athens are composed of "shoe-pegs" of shale which owe their shape to fracture cleavage.

The Athens contains many peculiar gray to black calcite veins composed of large calcite rhombs 3 to 15 millimeters in diameter and the interstices are filled with a waxy, irridescent carbonaceous substance. Many of these veins are parallel to the bedding and are bordered by slickensided surfaces.

Fossils and correlation.—The Athens contains an abundance of fossils, but because of the firm, dense nature of the limestone most of them can be obtained only from shale beds. It carries the *Nemagraptus gracilis* fauna of the Normanskill shale of New York State.

[27] Hayes, C. W., U. S. Geol. Surv., Geol. Atlas, Kingston folio (No. 4), p. 2, 1894.

In this area *Didymograptus sagittacaulis* Gurley, *Climacograptus bicornis* Hall and *C. scharenbergi* Lapworth, and *Dicellograptus sextans* Hall are common representatives. A large species of *Lingula* and species of *Dionide* have been collected by Butts[28] from the Athens east of Draper. The Athens is equivalent to the *Nemagraptus gracillis* zone of the Normanskill shale of New York.

UNCONFORMITY

In the Draper Mountain area the Athens is unconformably overlain by the Chambersburg limestone. There is no visible evidence of a break between these two formations, and were it not for the fact that many feet of beds are missing between the two formations the Athens and Chambersburg might be considered as conformable formations. In areas to the southwest, and only a few miles away, the Athens is overlain by the Ottosee formation (upper Blount group) which is about 200 feet thick. Furthermore, in the same localities, the Ottosee is overlain by the Moccasin formation whose thickness is comparable with that of the Ottosee. In some parts of northern Virginia, Maryland, and Pennsylvania the Chambersburg is underlain by the Lowville limestone, of which the Moccasin of southwest Virginia is a facies. Hence, there is a hiatus between the Athens and the Chambersburg limestones in the Draper Mountain area.

BLACK RIVER GROUP

CHAMBERSBURG LIMESTONE

Name.—Chambersburg was proposed as a formation name by Stose,[29] and as originally defined by him it included the Lowville formation, beds of upper Black River age, and Trenton strata. Subsequently, Ulrich, Butts, and Stose have delimited the Chambersburg to include only the post-Lowville, pre-Trenton strata.

Distribution.—The Chambersburg adjoins the outcrops of the Athens formation in Draper Valley. A thin belt of Chambersburg lies along the low foothills on the south side of Draper Valley and in the conspicuous breach in this line of hills it connects with another belt which borders the foothills on the south. The latter belt extends as far west as the south base of Crocket Knob and extends eastward to the east end of the Draper Mountain fenster. (See Pl. 8B.) A thin but continuous belt crops out

[28] Butts, Charles, personal communication.
[29] Stose, G. W., The sedimentary rocks of South Mountain, Pennsylvania: Jour. Geology, vol. 14, p. 211, 1906.

in the foothills and is bordered by two thin belts of Martinsburg shale and sandstone. A small patch of the formation crops out in a ravine southwest of Crocket Knob where it has been exposed by the removal of the overthrust Cambrian which once covered it. (See Pl. 1.)

Lithology.—The Chambersburg is a dark bluish-gray to black medium-bedded, argillaceous limestone. In this area it contains thin wavy clayey partings which cause the rock to break into nodular to cobbly fragments on weathering. On the weathered outcrop these intersecting clay partings form a projecting network which gives the rock a honeycombed appearance resembling weathered surfaces of the nodular Lenoir. In the belt which lies in the foothills the beds have been tightly squeezed and these argillaceous partings have become slip surfaces along which the "cobbles" and "nodules" have moved over one another. The abundant carbonaceous material in the rock was squeezed out and mixed with the clay of the partings to form smooth irridescent wavy seams which surround the "cobbles" and "nodules." The exposures of the formation in the cuts of U. S. Highway 11 where that highway passes through the foothills, show an orientation of the characteristic "cobbles" and "nodules" parallel or subparallel to the axial plane of an anticline. They are inclined to the bedding at angles up to 90 degrees. This is the result of adjustment of the formation to the stresses which attended the Appalachian folding. (See Pl. 21A.)

In some gorges, where the formation invariably appears to be vertical, the Chambersburg outcrop is as much as 300 feet wide. The illusion of a vertical attitude is caused by the fact that erosion has levelled off the tops of close folds exposing the ends of the reoriented "cobbles" and "nodules" which lie athwart the true bedding.

Near Connor Valley School, the uppermost part of the Chambersburg is composed of light-gray pinkish vaughanite containing an abundance of characteristic fossils. This type of lithology in the Chambersburg is unknown elsewhere in the Draper Mountain area.

The Chambersburg weathers to a cobbly and nodular rubble which obscures many of the outcrops in Draper Valley. In many respects the Chambersburg is very similar to the upper nodular Lenoir. West of Draper the Lenoir is confined to the area south of the Lee Highway (U. S. 11), whereas the Chambersburg is found only north of that highway.

The thickness of the formation, as measured on the north side of Draper Valley, is approximately 150 feet.

Fossils and correlation.—In the adjustment of the Chambersburg to the stresses attending the Appalachian orogeny, most of the contained fossils have been broken and distorted almost beyond recognition. In Pennsylvania and Maryland the Chambersburg formation is reported to contain an abundance and wide variety of fossils. The few species collected from this area, as listed below, are sufficiently representative of the prolific Chambersburg fauna to serve as a guide to the recognition and correlation of the formation.

Receptaculites occidentalis Salter
Dystactyospongia sp.
Nidulites pyriformis Bassler
Carabocrinus sp.
Stictoporella sp.
Rhinidictya neglecta Ulrich
Pholidops sp.
Dinorthis pectinella (Emmons)
Bellerophon sp.
Cyclonema sp.
Homotelus simplex Raymond
Pterygometypus callicephalus Hall

The occurrence of *Nidulites* in association with the other forms listed above is diagnostic of the Chambersburg. A similar if not conspecific form of *Nidulites* occurs in the Ottosee formation in association with *Receptaculites,* and the faunal assemblage of the latter formation is very similar in many other respects to that of the younger Chambersburg formation. The Chambersburg in this area could easily be confused with the Ottosee formation; however, the distinctive "cobbly" lithology and the faunal assemblage listed above definitely indicate Chambersburg age. The Draper Mountain area contains the most southwesterly exposures of the typical Chambersburg limestone known in the Appalachian Valley region. Beds tentatively correlated with the Chambersburg and recently defined by Mathews[30] are present in the northwestern belts of the southern Appalachian Valley, and are called the Eggleston formation.

[30] Mathews, A. A. L., Marble prospects in Giles County, Virginia: Virginia Geol. Survey Bull. 40, p. 11 (footnote), 1934.

TRENTON, EDEN, AND MAYSVILLE GROUPS

MARTINSBURG FORMATION

Name.—The Martinsburg was named by Geiger and Keith[31] for Martinsburg, West Virginia. The Martinsburg is not to be considered as a stratigraphic unit in the usual meaning of the term "formation." The Martinsburg contains a thick sequence of beds of varied lithology and diverse ages which for practical purposes of mapping are in many areas considered as a unit.

Distribution.—The Martinsburg occupies a broad belt on the upper slopes bordering Draper Valley. The lower part of the formation crops out in the foothills on the south side of Draper Valley. (See Pl. 8C.) Northwest of the intersection of State highways 100 and 101 the Martinsburg occupies an exceptionally wide belt in the northeastern head of the valley. A wide expanse of the formation extends eastward from the south slopes of Peak Knob to the east end of the Draper Mountain fenster. Southwest of Crocket Knob the Martinsburg passes under the overthrust Cambrian rocks, but emerges again at Poletown and flanking the south slopes of Ramsay Mountain, extends as far west as Max Meadows. (See Pl. 1.)

Lithology.—Although the Martinsburg crops out extensively in this area, only in the gorge of Reed Creek south of Ramsay Mountain is the entire formation exposed in the fresh condition. Here the Martinsburg is 800 to 1,000 feet thick.

The lower 50 feet of the formation is composed of fine-grained bluish-gray calcareous sandstone and intercalated drab-colored calcareous shale and siltstone. About 35 feet from the base are three separate horizons of bentonite; the lowest and thickest is 6 to 8 inches thick. Above the basal 50 feet, is 600 to 800 feet of thin-bedded, coarsely crystalline, bluish-gray, fossiliferous limestone; laminated gray calcareous siltstone with conspicuous cuneiform jointing; and gray to buff calcareous shales. The bedding is irregular and most of the layers are better described as thin lenses rather than as beds. The predominant type of rock in this group of beds is laminated calcareous siltstone. The siltstone is approximately 25 per cent soluble, the shales approximately 15 per cent soluble, and the limestone about 95 per cent soluble. Bedding is platy or blocky with the latter type predominating.

The lower two-thirds of the above described beds is of Trenton age, and the upper third is of Eden age. Lack of continuous exposures prevents exact determination of the thicknesses of the Trenton and the Eden beds in the Draper Mountain area.

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[31] Geiger, H. R., and Keith, Arthur, Geol. Soc. America Bull., vol. 2, pp. 156-163, pl. 4, 1891.

Toward the top of the formation sandstone becomes predominant. In the fresh condition the sandstones are medium bedded, firmly cemented, and very hard. In the uppermost 50 feet, these sandstones are rather fine grained and are reddish or greenish drab. The greenish beds contain 10 to 15 per cent glauconite. These sandstones are of Maysville age.

The Martinsburg weathers readily, and with the exception of a few exposures in the gorges cut into the line of foothills on the sides of Draper Valley, the formation appears as dull, yellow-brown shale and siltstone. The upper sandstones in the weathered condition are porous, spongy-looking rocks of brown or buff color, and are so soft as to be easily comminuted in the hand. If the Martinsburg were described from weathered exposures only, it could be said that the formation consisted of brownish to buff shale, sandstone, and siltstone.

Half a mile east of Connor Valley School, the lower part of the Martinsburg is composed of vinaceous-drab siltstone interbedded with light-green siltstone. Here the original bedding, except as indicated by the color banding, has been obliterated by fracture cleavage. The same colored sandstones are conspicuous on the north side of Draper Valley. Along the abandoned road over Draper Mountain just north of Hamilton Knob, is exposed several hundred feet of platy or splintery fractured olive-drab shale. This material is probably a leached residue of calcareous shales and siltstones, such as is exposed in the gorge south of Ramsay Mountain.

The formation yields a rather fertile soil composed largely of leached shale chips and humus. In the western head of Draper Valley below Hamilton Knob, the soil derived from the Martinsburg lies on slopes steeper than 50 degrees and makes good grazing land.

Fossils.—The Martinsburg contains an abundance of fossils, but they are difficult to extract from the unweathered rock. The abundance of fossils is indicated by the numerous holes on the surface of the leached rock. In weathering the shells are dissolved, and molds only are left in the leached part. The following forms were collected from the Martinsburg of this area:

Diplograptus amplexicaulis Hall
Prasopora simulatrix Ulrich
Mesotrypa sp.
Hallopora ampla Ulrich
Hallopora onealli sigillarioides (Nickles)
Lingula nicklesi Bassler
Plectorthis fissicosta Hall
Hebertella sinuata Hall and Clarke

Hebertella alveata Foerste
Dinorthis pectinella (Emmons)
Dalmanella rogata (Sardeson)
Dalmanella multisecta (Meek)
Dalmanella fertilis Bassler
Sowerbyella rugosus (Meek)
Sowerbyella curdsvillensis (Foerste)
Rafinesquina alternata Emmons
Orthorhynchula linneyi James
Zygospira modesta Hall
Pterinea demissa Conrad
Ctenodonta obliqua Hall
Byssonychia radiata Hall
Modiolopsis modiolaris Conrad
Rhytimya compressa Ulrich
Sinuites cancellatus Ulrich
Endoceras angusticameratum Hall
Endoceras sp.
Spyroceras bilineatum (Hall)
Geisonoceras sp.
Calyptaulax sp.
Eurychilinia striatamarginata (Miller)

The fossils listed above include diagnostic Trenton, Eden, and Maysville forms, and it is definitely known that beds of these three ages are present within the Martinsburg formation of this area. Beds of Trenton age in this area can generally be recognized by the presence of *Diplograptus amplexicaulis, Prasopora simulatrix, Sowerbyella rugosa, Endoceras angusticameratum, Dinorthis pectinella, Hallopora ampla, Sinuites cancellatus,* and *Spyroceras bilineatum.* The Eden portion is characterized by *Hallopora onealli sigillarioides, Sowerbyella rugosus, Dalmanella multisecta, Ctenodonta obliqua,* and a species of *Geisonoceras.* The Maysville portion, which constitutes the upper 60 feet of the Martinsburg in this area, is characterized by *Orthorhynchula linneyi, Byssonychia radiata, Lingula nicklesi, Plectorthis fissicosta, Zygospira modesta, Rhytima compressa, Pterinea demissa, Modiolopsis modiolaris,* and *Hebertella sinuata.*

UNCONFORMITY

An unconformity between the Martinsburg formation and the overlying Juniata is indicated by the absence of the Oswego sandstone. The latter intervenes between these two formations in northern Virginia and farther north.

JUNIATA FORMATION

Name.—The Juniata was named by Darton,[32] but the name was not completely defined nor was a type locality designated in the original description.

Distribution.—The Juniata crops out in a narrow belt near the crest of Draper Mountain. Its distribution is confined to the ridges of Draper Mountain, and it appears to be absent, due to an unconformity, southeast of Peak Knob and west of Hamilton Knob. (See Pl. 1.)

Lithology.—The Juniata is composed of red mudrock, red siltstone and fine-grained sandstone, and pinkish to white quartzitic sandstone. In this area the formation is about 200 feet thick. It appears to thin rapidly northeast and southwest along the main ridge of Draper Mountain. (See Pl. 9A.) The lower 100 feet is composed chiefly of red mudrock and siltstone, the bedding planes of which contain mud cracks and ripple marks. Intercalated with this material are red and white sandstone beds of varying thickness. The upper 100 feet is composed mostly of white to pinkish quartzitic sandstone with minor proportions of intercalated red mudrock and shale. The top of the formation is more or less arbitrarily drawn at the top of the highest red shale bed. The Juniata of this area is not typical of the lithology of the formation as it occurs elsewhere in the southern Appalachian region.

Age and correlation.—According to Butts,[33] the Juniata is of Richmond age and corresponds to the Queenston shale of the Niagara gorge. It is equivalent to the Sequatchie limestone of Tennessee and represents a non-marine or possibly a debouchure facies of the marine Sequatchie.

SILURIAN SYSTEM

CLINCH SANDSTONE

Name.—The Clinch formation was originally named the "Clinch Mountain sandstone" by Safford,[34] from Clinch Mountain, Tennessee, but subsequently he shortened the name to Clinch sandstone. In 1896 the name Clinch sandstone was restricted to massive sandstone of early

[32] Darton, N. H., U. S. Geol. Surv., Geol. Atlas, Piedmont folio (No. 28), p. 2, 1896.

[33] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 23, 1933.

[34] Safford, J. M., A geological reconnaissance of the State of Tennessee . . . , Nashville, p. 157, 1856.

Silurian age, and the red Bays sandstone, underlying the Clinch sandstone, was separated and defined as a formation.[35]

Distribution.—The Clinch sandstone is a ridge maker of the first order in the Draper Mountain area. It crops out along the crests of the ridges of Draper Mountain and continues westward from Hamilton Knob through Poletown, forming the summit of Ramsay Mountain. (See Pls. 9B and 17.) The formation is well exposed in the gorge of Reed Creek at the west end of Ramsay Mountain. It follows along the southeast side of Miller Creek east of Max Meadows northeast to a point where the stream passes beneath the old railroad bridge. A conspicuous hill immediately north of the bridge is capped with Clinch sandstone. The formation is fully exposed on top of Draper Mountain along U. S. Highway 11. The steep slope west of Hamilton Knob is paved with beds of the Clinch formation. (See Pl. 1.)

Lithology.—The formation is composed of blocky to thick-bedded coarse-grained quartz sandstone and quartzite. The beds are highly indurated and the grains of sand are firmly cemented by quartz. The individual grains of the sandstones are subrounded and frosted and have been secondarily enlarged. The Clinch contains lenses of subrounded quartz pebbles that are elliptical in cross section.

The bedding of the formation is irregular and individual layers show intricate cross lamination. Most of the beds are whitish on fresh surfaces, but the upper 50 feet of the formation is composed of finely laminated pinkish to reddish beds and of some beds that are almost black. Weathered exposures are buff to brown. The beds appear to be as firm and resistant in weathered exposures as on fresh surfaces, but it is probable that the surfaces of the exposures are somewhat case-hardened. The beds of the formation are broken by widely-spaced joints. On the northwest slope of Draper Mountain are large Clinch boulders as much as 20 feet across. These boulders are as firm and as indurated as the fresh rock.

The formation in this area is 15 to 130 feet thick. It is thickest in the vicinity of Peak Knob and thinnest in the exposures at Poletown.

Fossils and correlation.—The Clinch contains practically no fossils, except the abundant and apparently diagnostic *Arthrophycus alleghenienss,* of which excellent specimens are exposed on the bedding faces of blocks which line U. S. Highway 11 just northwest of the cut through Draper Mountain. The Clinch corresponds to the Tuscarora sandstone or quartzite of the northern Appalachian region and to the Albion (White Medina) sandstone of New York State. In it is included the strand facies of the Brassfield limestone of Kentucky and Ohio.

[35] Keith, Arthur, U. S. Geol. Survey: Geol. Atlas, Knoxville folio (No. 16), p. 4, 1896.

CLINTON FORMATION

Name.—The Clinton formation was named by Conrad,[36] from exposures in the town of Clinton, Oneida County, New York.

Distribution.—The Clinton is poorly developed in this area, but is present on Draper Mountain from Hamilton Knob to Peak Knob. The formation is generally absent west of Hamilton Knob, but is present in one locality on the south slope of Ramsay Mountain half a mile west of Poletown. The formation is well exposed just north of the crest of Draper Mountain along U. S. Highway 11. (See Pl. 1.)

Lithology.—The Clinton is composed of soft, lumpy, dark-red shale, thin-bedded sandstone, and unctuous green and yellow shales. The red beds contain hematite, but in this area the iron content of any one bed does not exceed 15 per cent. Shale is the predominant type of rock in the Clinton on Draper Mountain. In near-by areas to the northwest, the lower part of the Clinton is composed partly of distinctive dark-red to blackish sandstone, to which the name Cacapon is elsewhere applied. This facies of the Clinton is only feebly developed in this area. A few thin dark-red sandstone beds are intercalated in the shales on Draper Mountain. These beds consist of small shot-like pellets of hematite in a matrix of fine-grained ferruginous sandstone. The term "pellet conglomerate" is applicable to this type of lithology. Beds of this type are highly characteristic of the Cacapon facies of the Clinton in Virginia.

The formation is as much as 40 feet thick in this area.

Fossils and correlation.—Fossils are not common in the Clinton of this area, but one form, the diagnostic *Coelospira hemispherica,* occurs in the exposure of the Clinton on Ramsay Mountain. On the basis of lithology and stratigraphic position, the Cacapon facies is believed to be equivalent to the lower, iron-bearing portion of the Clinton beds of the southern Appalachian region, including the upper part of the Red Mountain formation of Alabama and Georgia.[37]

UNCONFORMITY

An important stratigraphic break occurs between the Clinton formation and the overlying Becraft (Helderberg) sandstone. This hiatus is indicated by the absence of the Keefer sandstone of upper Clinton age, the McKenzie, Bloomsburg, Wills Creek, and Tonoloway formations of Cayugan age, and the Keyser, Coeymans, and New Scotland

[36] Conrad, T. A., Phila. Acad. Nat. Sci. Jour., vol. 8, pt. 1, pp. 228-235, 1839.
[37] Butts, Charles, personal communication.

formations of Helderberg age. Subsequent to the deposition of the Clinton shale and sandstone, this part of the Appalachian region apparently was lifted above the sea and subjected to erosion during the post-Cacapon, pre-Becraft interval.

DEVONIAN SYSTEM

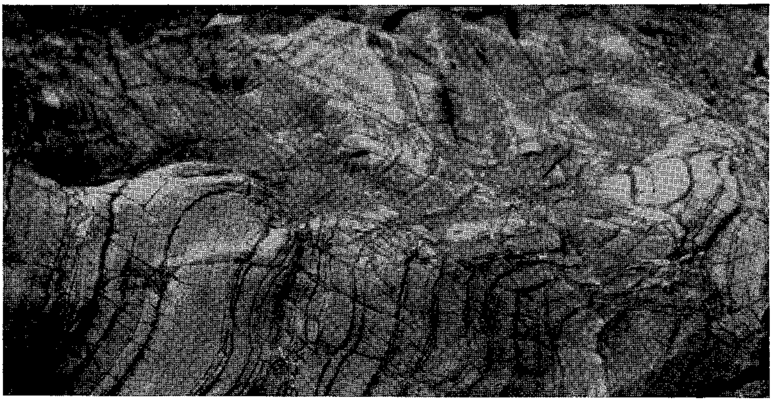
BECRAFT (?) SANDSTONE

Name.—The Becraft, a limestone in the type locality, was named from Becraft Mountain, Columbia County, New York, by James Hall[38] in 1894. In Virginia south of James River, Becraft fossils occur in a sandstone formation which in many localities has been called the Oriskany sandstone. It is now recognized that this sandstone probably represents a sandy facies of the typical Becraft limestone of northern Virginia, and areas farther north.

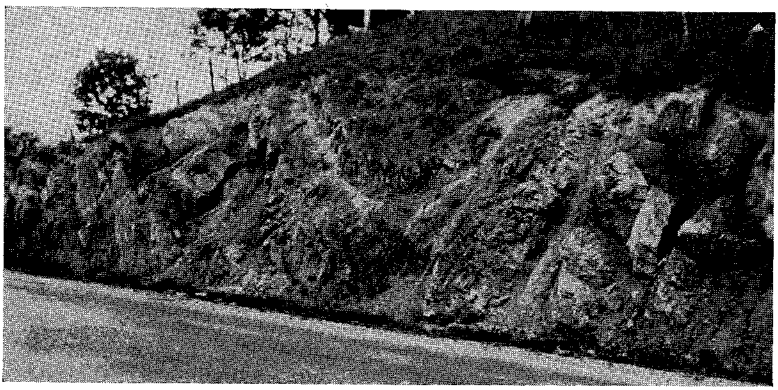
Distribution.—The Becraft (?) occurs on the northwest side of Draper Mountain just below the crest of the ridge. The exposed sandstone was observed at only two places on Draper Mountain, namely, along the Lee Highway and along an abandoned road north of Hamilton Knob. The distribution of the formation can not be inferred from these exposures because the Becraft (?) belt is largely covered with float derived from the Clinch formation. The sandstone is present on Ramsay Mountain, but is thinner there than on Draper Mountain. (See Pl. 1.)

Lithology.—In the Draper Mountain area the Becraft (?) is composed of medium- to thick-bedded, coarse-grained quartz sandstone, which on weathered exposures is buff to brown in color. The rock appears to be devoid of cementing material and is saccharoidal, but on weathering it has been case-hardened and superficially resembles the resistant Clinch beds which cap the ridge. It is probable that the formation has a calcareous cement which has been removed from surface exposures by solution. The Becraft (?) contains beds of quartz conglomerate which are considerably coarser than similar beds in the Clinch formation. The individual grains of the Becraft (?) sandstones are subrounded and polished, and the larger grains and pebbles do not show the peculiar egg-shape of the Clinch pebbles. Except for surficially case-hardened exposures, the Becraft (?) can be distinguished from the Clinch by its saccharoidal character. The Becraft (?) in this area occurs a short distance below the crests of the ridges of Draper and Ramsay mountains.

[38] Hall, James, Twelfth Annual Report of the State Geologist for the year 1892: New York Senate Doc. no. 40, pp. 9-13, 1893.

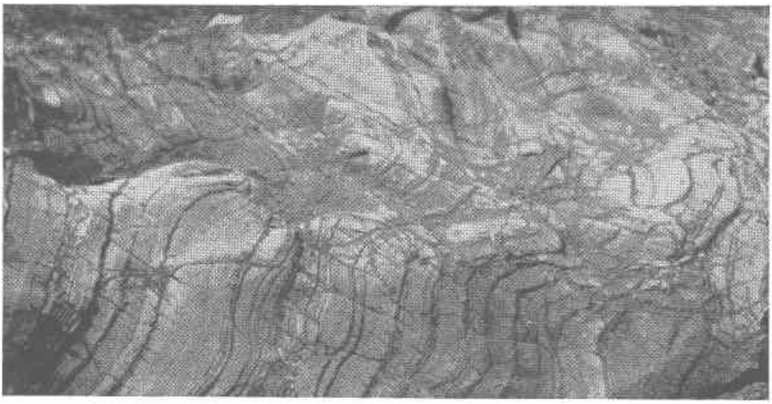


A. Contortion in the Athens limestone, north of the Lee Highway opposite the McGavock Creek road.

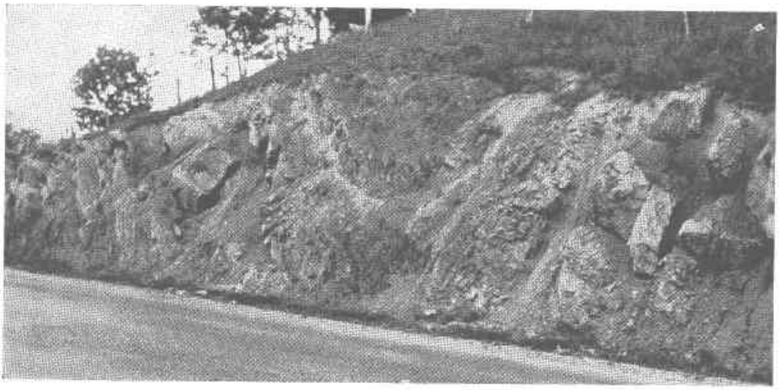


B. Syncline of lower Martinsburg sandstone bounded by nodular Chambersburg limestones. In Lee Highway cut south of Draper, Virginia.

C. Topographic expression of the lower Martinsburg sandstones and shales. Looking southwest from Draper Valley towards Crocket Knob.

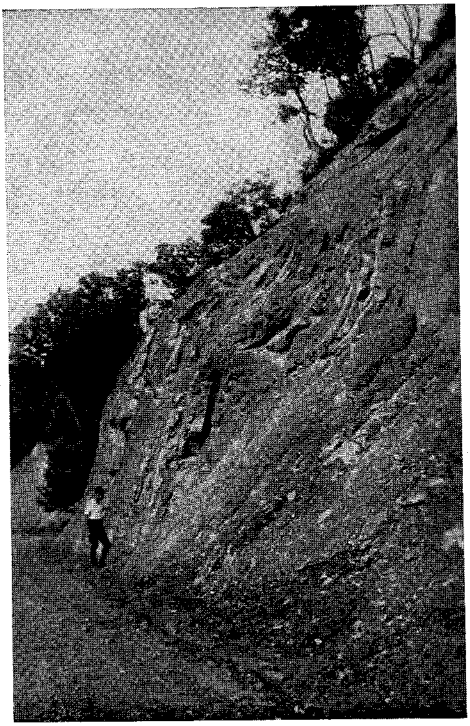


A. Contortion in the Athens limestone, north of the Lee Highway opposite the McGavock Creek road.

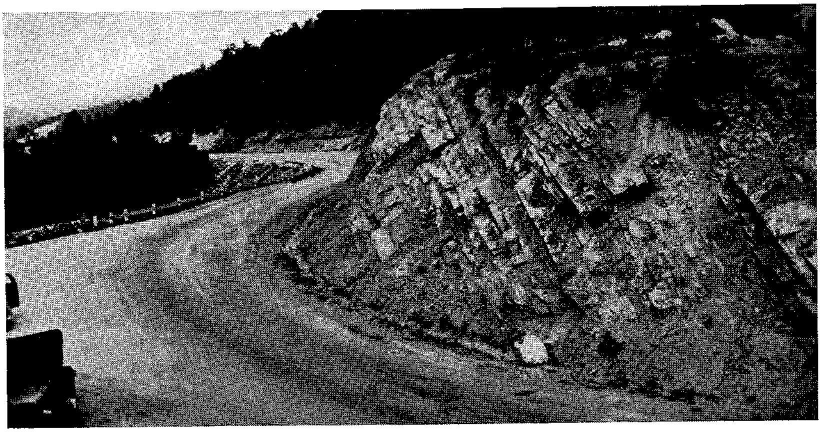


B. Syncline of lower Martinsburg sandstone bounded by nodular Chambersburg limestones. In Lee Highway cut south of Draper, Virginia.

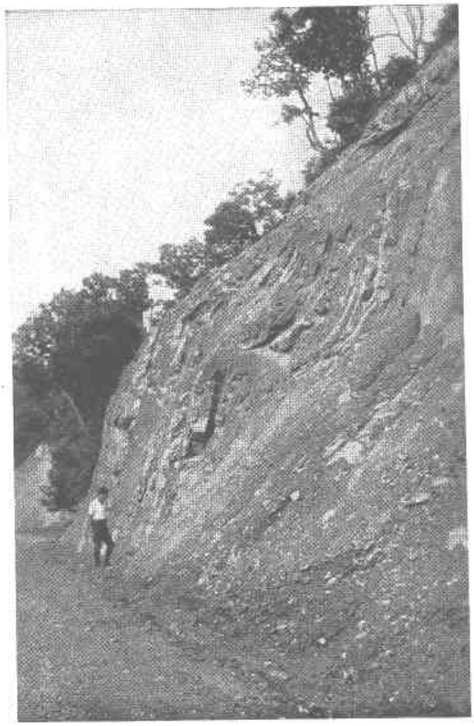
C. Topographic expression of the lower Martinsburg sandstones and shales. Looking southwest from Draper Valley towards Crocket Knob.



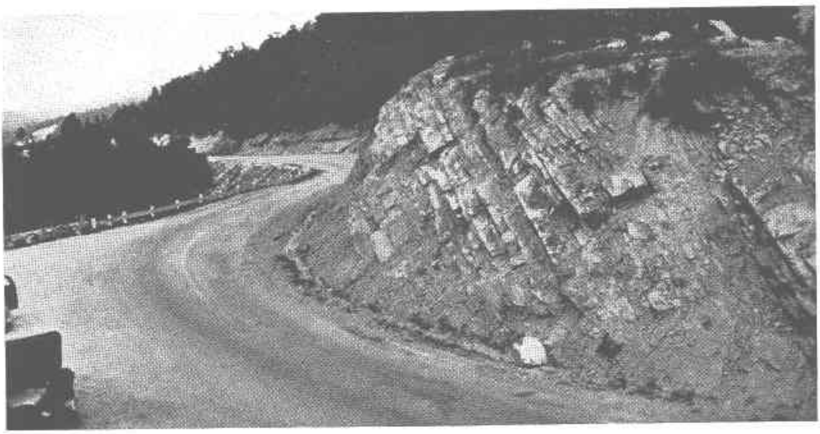
A. Steeply dipping Juniata sandstone and mudrock along the Lee Highway, southeast of the crest of Draper Mountain.



B. Overturned Clinch sandstone beds. The beds dip 60° SE., on the northwest limb of the Draper Mountain anticline, along the Lee Highway.



A. Steeply dipping Juniata sandstone and mudrock along the Lee Highway, southeast of the crest of Draper Mountain.



B. Overturned Clinch sandstone beds. The beds dip 60° SE., on the northwest limb of the Draper Mountain anticline, along the Lee Highway.

Fossils and correlation.—The Becraft (?) in this area contains few fossils and the writer found only one specimen that could be generically identified, a small species of *Rhipidomella.*

As there is an unconformity both above and below the Becraft (?) in this area and since no diagnostic fossils were found, some objection might be raised as to the propriety of designating the sandstone as Becraft in age. In some respects, the rock resembles the younger Oriskany sandstone, but the latter carries an abundance of fossils even in its coarsest facies. According to Butts[39] the beds in question closely resemble the Becraft sandstone as it occurs on Flat Top Mountain in Bland County, Virginia. This locality has yielded many specimens of the diagnostic *Aspidocrinus scutelliformis.*

UNCONFORMITY (?)

The sandstone just described is overlain in this region by the Onondaga chert. If the sandstone is of Becraft age, then a hiatus exists between the sandstone and the overlying chert as indicated by the absence of the Oriskany sandstone.

ONONDAGA CHERT

Name.—The Onondaga formation was named by Hall[40] from Onondaga, Onondaga County, New York. The name was redefined by him in 1894.

Distribution.—The Onondaga formation crops out in a long belt between Max Meadows on the west and the east end of the fenster east of Peak Knob. It also occurs on spurs below Hamilton and Peak knobs, in a small anticline at the southwest end of Ramsay Mountain, and on the hill north of the railroad tracks and just east of Miller Creek a short distance northeast of Max Meadows. (See Pl. 1.)

Lithology.—The Onondaga is composed of massive and bedded white chert. The chert is probably of secondary origin as is indicated by the abundance of fossils in the formation and by molds of calcite crystals. The calcite has been removed from most of these molds, probably as the result of secondary silification of a limestone. On weathered exposures the chert is gray to buff but on fresh exposures it is white. The fresh rock breaks with a hackly fracture and natural exposures are extremely rough and jagged. In the east environs of Max Meadows, along the south side of the railroad tracks, the Onondaga

[39] Butts, Charles, personal communication.

[40] Hall, James, Third annual report of the fourth geological district of the State of New York: New York Geological Survey, 3rd Ann. Rept., pp. 293-309, 1839.

is a dense, black, bedded chert, very different in appearance from the formation in other parts of the area.

The Onondaga is 10 to 75 feet thick, and where U. S. Highway 11 crosses the belt of outcrop it is approximately 65 feet thick.

Fossils and correlation.—The following fossils were collected from the Onondaga of this area:

Dalmanella lenticularis (Vanuxem)
Orbiculoidea sp.
Orthotetes pandora (Hall)
Chonetes mucronatus Hall
Anoplia nucleata (Hall)
Amphigenia curta Hall
Spirifer duodenaria Hall
Cyrtina hamiltonensis Hall
Ambocoelia umbonata (Conrad)
Anoplotheca acutiplicata (Conrad)
Diaphorostoma lineata (Conrad)

The Onondaga is of early Middle Devonian age. In part of the northern Appalachian region, particularly in West Virginia, Maryland, and northern Virginia, the Onondaga forms the basal part of the so-called †Romney shale.

MILLBORO SHALE

NAME

The name Millboro has recently been proposed by Butts[41] to replace the term "Black shale of Devonian Age,"[42] which was tentatively used to distinguish a Devonian black shale, composed of beds of Marcellus and of early Naples age, from the Romney shale which includes beds of Onondaga and Hamilton age. In belts where the name Millboro applies, the "black shale" contains no Onondaga, which is mapped separately where present, and no beds of Hamilton, Tully, or Genesee age.

On the basis of lithology and fossils the Millboro formation in this area is easily differentiated into two members, namely, the Marcellus member below and the Naples member above.

MARCELLUS MEMBER

Lithology.—The Marcellus member is composed of fissile black shale which is highly siliceous and contains considerable carbonaceous

[41] Butts, Charles, manuscript in files of the Virginia Geol. Survey.
[42] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 32, 1933.

material. Shear planes in the shale are lined with graphitic material which has an irridescent luster. Some of the beds in the lower part contain 2 to 5 per cent pyrite in the form of fossil replacements and as botryoidal aggregates. On weathered outcrops the Millboro superficially resembles coal and prospectors have frequently confused these black shales with coal horizons in the Price (Mississippian) formation. The Marcellus shale weathers to a rusty brown color, and outcrops are somewhat bleached along bedding planes. The Marcellus is 100 to 150 feet thick in this area.

Fossils.—The Marcellus member is abundantly fossiliferous. The following forms were collected:

Schizobolus concentricus (Vanuxem)
Schizobolus truncatus (Hall)
Chonetes lepidus (Hall)
Leiorhynchnus limitare (Vanuxem)
Buchiola halli (Clarke)
Nucula corbuliformis Hall
Actinopteria muricata Hall
Loxonema sp.
Styliolina fissurella (Hall) sp.
Tentaculites
Bactrites aciculum Hall

NAPLES MEMBER

Description.—The Naples member is composed of carrot-red to apricot-buff shales and fine-grained siltstones. The shales are soft, lumpy, and unctuous and lack the characteristic fissility of the Marcellus shales. The siltstones are thin bedded and lumpy. The shear planes, fractures, and bedding planes of this member are lined with a bright carmine-red coating of iron oxide. Most of the fossils in the shale are coated with iron oxide. The highly distinctive color and lithology of these beds makes them easily differentiated from the Marcellus shales. Most of the beds of the Naples member are best described as fine-grained argillaceous siltstones. The thickness of the Naples can not be accurately determined, because of drag folding and crumpling of the beds, but it is probably 500 to 600 feet.

Fossils.—The Naples member contains an abundance of fossils of which the following forms were collected:

Ontaria sp.
Paracardium doris Hall
Buchiola halli Clarke

Nuculites oblongatus Conrad
Lunulicardium crinitum Clarke
Pterochaenia fragilis (Hall)
Pleurotomaria genundewa Clarke
Manticoceras sp.
Tornoceras uniangulare (Conrad)
Probeloceras lutheri (Clarke)
Spathiocaris emersoni Clarke

DISTRIBUTION

The Millboro extends in a continuous belt from Max Meadows to the east end of the Draper Mountain fenster. It crops out on the northwest flanks of Draper and Ramsay mountains. The lower 25 feet of the Marcellus member is exposed in the hill north of the railroad tracks and east of Miller Creek, a short distance northeast of Max Meadows. The black shales of the Marcellus crop out in a bluff a short distance east of the road in Poletown, and along the Lee Highway on the northwest side of Draper Mountain. The Naples shales and siltstones are fully exposed along U. S. Highway 11 on Draper Mountain, above the abandoned ore pit on the east side of the road. The same beds are displayed on the northwest flanks of Ramsay Mountain, especially at the old Max Meadows water reservoir site. All of the Millboro is well shown along the banks of Clayton Mine Hollow above the old ore pits and prospect holes. (See Pl. 1.)

AGE, RELATIONS, AND CORRELATION

The Millboro contains beds of Marcellus and Naples age which are separated by an unconformity, indicated by the absence of beds of Hamilton, Tully and Genesee age. The Marcellus forms the lower part of the Hamilton group of Willard[43] in Pennsylvania. The Marcellus and Naples are represented in the Romney shale *sensu stricta,* as it occurs in West Virginia, Maryland, and northern Virginia. The Naples member of the Millboro is early Portage in age.

BRALLIER FORMATION

Name.—The Brallier formation was named by Butts[44] from Brallier Station, Bedford County, Pennsylvania.

Distribution.—The Brallier crops out in a broad belt from Max Meadows to Clayton Mine Hollow, where it is concealed by an over-

[43] Willard, Bradford, Hamilton correlations: Am. Jour. Sci., 5th ser., vol. 33, pp. 264-278, 1937.
[44] Butts, Charles, Geologic section of Blair and Huntingdon counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, pp. 523, 531, 536, 1918.

thrust fault. The formation is considerably thinned northeast of the Pulaski water reservoir due to this fault. The Brallier is partly exposed on the lower slopes of Little Brush Mountain just east of the Miller Creek road. (See Pl. 1.)

Description.—The Brallier is composed of interbedded yellowish-brown micaceous clay shales, olive-drab micaceous and siliceous shales, greenish-gray siltstones and sandstones, and reddish-brown sandstones. In the fresh state most of the Brallier is greenish gray, but on weathering it becomes buff to brown. The shales disintegrate into small flattish chips and soil derived from the Brallier is largely composed of such chips. Bedding surfaces of the shale layers are crenulated and furrowed, or warty and dimpled. Many surfaces of beds show highly characteristic tracks and trails which are believed to be organic in origin.

The lower part of the Brallier shows a lithologic transition from the Naples shale below—a transition so striking that it reveals the conformability of the Brallier with the underlying beds. The upper part of the formation is more arenaceous than the lower part, suggesting a transition into the overlying arenaceous Chemung formation. The Brallier resembles in some respects the Chemung, but it is different from most of the Naples beds beneath it. In every instance, however, the Chemung can be distinguished from the Brallier by fossils.

The thickness of the Brallier in this area varies greatly. Northeast of Poletown the formation is 1,000 to 1,200 feet thick, but between Poletown and Max Meadows it appears to be 1,500 to 2,000 feet thick. As the Brallier is composed of incompetent beds which have been intricately drag folded and crumpled, it is probable that some of the apparent increase in thickness in the area west of Poletown is the result of repetition by folding.

Fossils and correlation.—The Brallier contains in its lower part diminutive representatives of the Naples fauna and the contact between the two formations is faunally as well as lithologically gradational. The most characteristic fossil and the only one present in great abundance, is *Pteridichnites biseriatus* Swartz, a biserate worm trail. According to Butts[45] this fossil is diagnostic of the Brallier beds and was used by him as an indicator of the Brallier long before the fossil received a name.

The Brallier is of Portage age and corresponds to the Hatch, Grimes, and Gardeau formations of New York State and lithologically resembles these formations to a high degree. It is equivalent to the Woodmont member of the Jennings formation of Maryland. It cor-

[45] Butts, Charles, personal communication.

responds to the lower part of the †Kimberling shale as formerly used in this part of Virginia.

CHEMUNG FORMATION

Name.—The Chemung formation was named by James Hall[46] from exposures west of Chemung, Chemung County, New York.

Distribution.—The Chemung crops out in a belt extending from Beaverdam Creek northeast of Max Meadows to Clayton Mine Hollow southeast of Pulaski. The formation is partly exposed along the lower slopes of Little Brush Mountain north of Max Meadows. Other areas are shown in Plate 1.

Lithology.—The Chemung formation is composed of sandstone and shale which are 400 to 500 feet thick. The lower 150 feet is composed of dark-gray sandstones and olive-drab, siliceous and micaceous shales. The sandstones are blocky and thin bedded and the sandy beds are calcareous. Above this zone are 50 to 75 feet of dark-maroon thick-bedded calcareous sandstone, interbedded with light-gray calcareous sandstone. Some beds are discontinuous and lenticular. Next above, are 50 feet of thick-bedded calcareous gray sandstone in regular beds. Above this zone are 125 feet of very thick-bedded gray calcareous sandstone, and thin intercalations of olive-drab micaceous and siliceous shale. Some of these beds are 8 to 10 feet thick. The upper 100 to 150 feet of the formation is composed of thin-bedded gray to greenish sandstones intercalated in olive-drab siliceous and micaceous shales.

The Chemung sandstones and siltstones in the fresh state are highly calcareous. On weathering calcareous fossil remains are dissolved, leaving a spongy, "worm-eaten" residue of loosely consolidated sand and silt. The shales are not appreciably calcareous, even where fresh.

The lower boundary of the formation is gradational and is arbitrarily set at the lowest occurrence of the Chemung fauna. The upper boundary is not well marked lithologically and can be recognized only by careful examination of fossils. (See Pl. 10A.) The top of the Chemung is drawn at the base of the lowest occurrence of *Spiriferina,* which genus is apparently of post-Devonian age. Hence beds in which it occurs in this region are of Mississippian (Price) age.

Fossils and correlation.—In this area the Chemung formation yielded the following fossils:

Ophiuroids
Crinoids

[46] Op. cit., pp. 322-326.

Rhombopora sp.
Douvillina cuyuta (Hall)
Orthotetes chemungensis (Conrad)
Chonetes sp.
Chonetes scitulus Hall
Productella lachrymosa (Conrad)
Camarotoechia sp.
Camarotoechia sappho Hall
Atrypa spinosa Hall
Spirifer disjunctus Sowerby
Spirifer mesicostalis Hall
Spirifer mesistrialis Hall
Ambocoelia umbonata (Conrad)
Leptodesma sp.
Mytilarca chemungensis Conrad
Sphenotus contractus Hall
Conularia sp.

The Chemung formation is Upper Devonian in age. It is equivalent to the upper part of the †Kimberling shale and to the upper part of the Jennings formation.

UNCONFORMITY

An important stratigraphic break between the Chemung and the overlying Price (Osage) formation is indicated by the absence of late Devonian Bradfordian group or Hampshire formation and of beds of Kinderhook age. Following the Chemung stage of deposition, this part of the sea bottom apparently was elevated and subjected to erosion during late Devonian and early Mississippian time.

MISSISSIPPIAN SYSTEM

OSAGE SERIES

PRICE FORMATION

Name.—The name Price was introduced as the "Price sandstone" by Campbell,[47] and the type locality is on Price Mountain, Montgomery County, Virginia. In 1925, he[48] discarded the specific lithologic designation and substituted the word formation.

[47] Campbell, M. R., Paleozoic overlaps in Montgomery and Pulaski counties, Virginia: Geol. Soc. America Bull., vol. 5, pp. 171, 177, pl. 4, 1894.

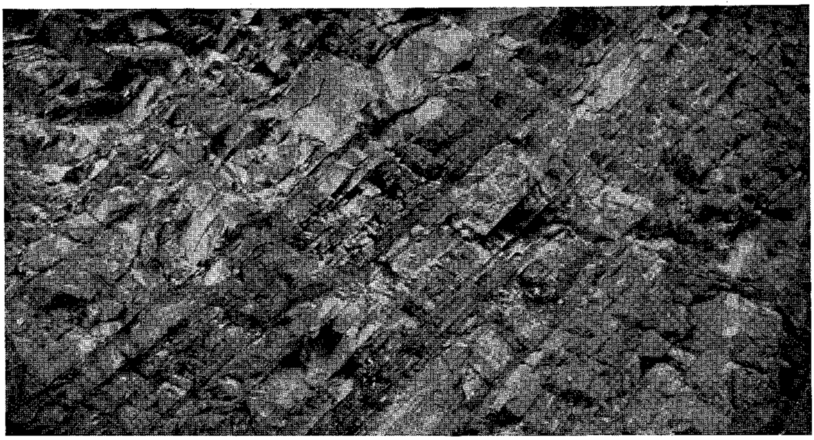
[48] Campbell, M. R., The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 23, 1925.

Distribution.—The Price formation occupies a wide belt between the crests of Caseknife Ridge and Brushy Mountain (also called Chestnut Ridge). This belt northeast of Max Meadows, and the upper part of the Price at the northwest foot of Caseknife Ridge, are covered by overthrust Cambrian formations. Half a mile southwest of Pulaski the broad Price belt bifurcates; the southern limb of the fork extends southeast and makes the crest of Caseknife Ridge; the northern branch swings northward about three-fourths of a mile west of Pulaski and flanks the south and east slopes of Chestnut Ridge. The Price forms the crest of Brushy Mountain and flanks the southeast slopes of that ridge. (See Pl. 1.)

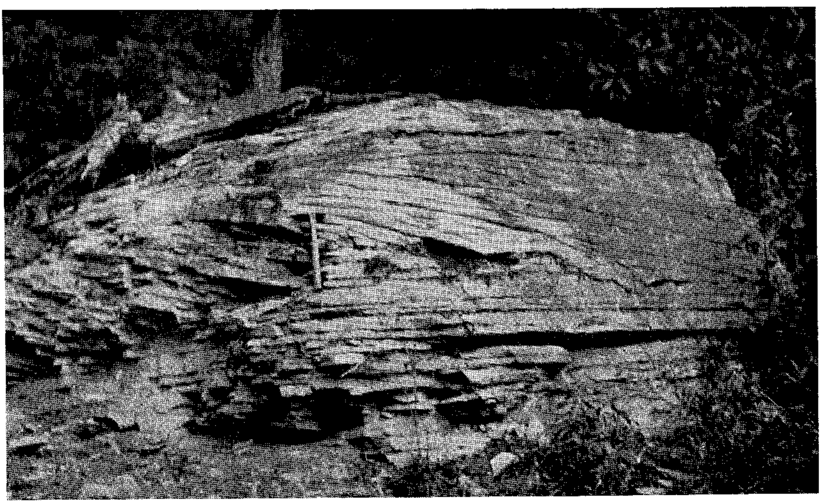
Lithology.—The Price formation[49] is composed of a variety of sediments, but by far the most characteristic are coarse-grained, cross-bedded sandstones. Most of this type of sandstone is micaceous and quartzose but numerous beds of arkose are intercalated. The arkoses are readily distinguishable on weathered surfaces through cream-colored blotches of weathered feldspar grains. Fresh surfaces are greenish gray to dark gray. Bleaching by weathering causes most of the exposures to appear whitish and saccharoidal. The finer grained and more ferruginous layers weather to a rusty color which is very characteristic, and they contain an abundance of marine fossils. The rocks are well cemented by iron oxide and silica. Cross-bedded structures are abundantly developed in the coarse-grained sandstones and arkoses. They consist of individual flaggy to thick-bedded sandstone layers, all of which are bevelled by beds above and below. The angular discordance of some of the beds is as high as 40 degrees. Compensating for their present orientation, which is due in part to folding, the original dips of these "foresets" in a large number of exposures are toward the southeast—in the direction of the Piedmont crystalline area, the site of old Appalachia. (See Pl. 10B.) Scattered through these beds are lenticular beds and lenses of quartz pebble conglomerate, some of which attain a thickness of 10 feet. It is only in gorges cut through the ridges that the lenses can be seen in place.

The rocks described above, which represent the bulk of the Price, above the coal beds, are approximately 600 feet thick. Between 200 and 300 feet of this type of clastic material also underlies the coal beds, and were it not for the intercalated coal, it would be difficult to subdivide the upper 800 feet of the Price. The type of lithology below the coal is exposed along U. S. Highway 11 just south of Calfee Park, south of Pulaski. The best exposures of the cross-bedded sandstones above the coal are in the gorge of Miller Creek in Little Brush and

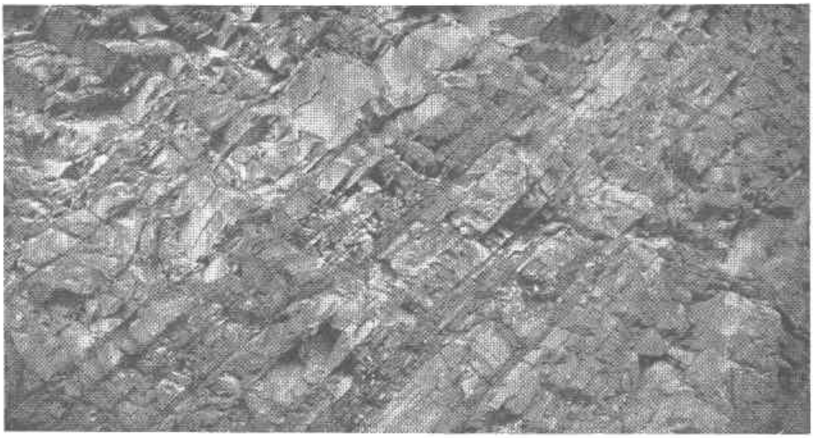
[49] Cooper, B. N., The Price formation in the Draper Mountain area, Virginia: Jour. Geology, vol. 45, no. 4, pp. 414-431, 1937.



A. Uniform bedding in sandstone and shale of the type that occurs at the contact of the Chemung and Price formations.



B. Cross-bedding in the Price formation; exposed along the road in the gorge of Miller Creek north of Max Meadows, Virginia.



A. Uniform bedding in sandstone and shale of the type that occurs at the contact of the Chemung and Price formations.

B. Cross-bedding in the Price formation; exposed along the road in the gorge of Miller Creek north of Max Meadows, Virginia.

Brushy mountains, north of Max Meadows. Here they occur beneath the overlying red Maccrady formation in the northwest limb of a syncline overturned and thrust faulted on the southeast. The flaggy cross bedding is also well shown along the old stage road from Pulaski to Gunton Park, where that road begins its steep ascent to the crest of Caseknife Ridge, 2½ miles southwest of Pulaski.

Beneath the cross-bedded sandstone underlying the coal is a sequence of fine-grained, even-bedded, ferruginous sandstones, siltstones and shales about 400 feet thick. Most of these beds are highly fossiliferous. This part contains a few beds of black shale, maroon-drab sandstone, quartzite, quartz conglomerate, and concretionary siltstone. The maroon-drab sandstone is very similar to beds occurring in the Chemung formation.

The Price formation contains the oldest coal beds mined in the United States. The coal is of semianthracite rank and occurs in irregular beds. There are three rather thick and persistent coal beds identifiable in the Draper Mountain area, which together with associated thin coal lenses, clays, carbonaceous shales, and sandstones, form another distinct lithologic subdivision of the Price in this area. This unit is 75 to 100 feet thick. The lower coal bed, which is probably correlative with the Langhorne coal of adjacent areas, lies in most places on cross-bedded sandstone and is overlain by a characteristic bed of tough, gumbo-like clay which contains well-preserved plant fossils. The lower coal bed is the most uniform in thickness. In Cove Hollow, north of Max Meadows, on the Logdell Carwheel Company's property, a new prospect hole driven into the lower bed shows the presence of 5 feet 5 inches of good semianthracite coal. Approximately 18 feet above the Langhorne seam is another coal bed averaging about 4 feet in thickness. It is probably the partial equivalent of the Merrimac seam of Montgomery County. It is overlain in many places by a persistent stratum of black carbonaceous shale which contains excellent impressions of plants. This middle unit of coal and fossiliferous shale is exposed at the entrance of the old mine located at the side of the road in Miller Creek gorge, about 500 yards north of the forks of Miller Creek. About 40 feet above this bed is the third coal seam, known locally as the Gunton coal. The rocks intervening between the Merrimac and Gunton coals are micaceous carbonaceous sandstones, clays, and shales. The Gunton coal is very irregular in thickness. In the vicinity of Gunton Park, 7 miles west of Pulaski on the Norfolk and Western Railway, it is reported to be in places nearly 10 feet thick. In Cove Hollow, west of the Miller Creek road, it is about 3 feet thick. The irregularity in thickness of the coal beds is probably primary in part, but also partly the result of compression during the Appalachian folding by which action the coal was squeezed out in some places and thickened in others. It is difficult to distinguish the three beds in weathered exposures, for the coal disintegrates rapidly.

Red beds occur toward the top of the Price, above the coarse-grained cross-bedded sandstones overlying the coal. The overlying Maccrady formation is composed almost entirely of red or maroon mudrock, siltstone, and sandstone. The contact between the Price and Maccrady is gradational and, because of the paucity of fossils, is more or less arbitrarily determined. The upper 25 to 35 feet of the cross-bedded sandstones overlying the coal are reddish. This material grades upward into finer grained sandstone siltstone, and shale which are more reddish and more evenly bedded than the immediately underlying rocks. Many of the bedding surfaces of the red beds show an extensive development of mud cracks. Intercalated with these red rocks are thin horizons of fissile green siliceous shale. The upper boundary of the Price is best drawn in this area where the red beds become predominately mudrock and sandy shale.

Generally recognized as marking the base of the Price formation is the so-called "Ingles conglomerate," defined by Campbell[50] as the most distinctive "bed" in the formation. The name comes from Ingles Mountain, southwest of Radford, Va. The choice of the type locality was unfortunate, because there are no Mississippian rocks in that vicinity. Butts[51] has shown that the "Ingles" conglomerate on Ingles Mountain is an outlier of the Clinch sandstone of Silurian age. The writer has seen a more or less persistent conglomerate horizon at the base of the Price at many localities in near-by areas, and at one locality on Cloyds Mountain, along the Dublin-Pearisburg road, the conglomerate and intercalated cross-bedded sandstone are fully 75 feet thick. In the Draper Mountain area there is no persistent horizon of quartz conglomerate in the Price formation, but in several localities subordinate lenses of quartz conglomerate are intercalated in the shale and sandstone which comprise the lower 100 feet of the formation. These conglomerates are identical in character to conglomeratic lenses and lenticular beds occurring in the upper part of the formation. A horizon of quartz conglomerate, which is locally conspicuous, is exposed near the crest of Little Brush Mountain, east of Miller Creek gorge, but this conglomerate is at least 50 feet above the base of the Price. The Chemung formation beneath the Price also contains lenticular beds of quartz conglomerate, but the matrix of these is much finer grained than is the quartz sand matrix of the Price conglomerates.

[50] Campbell, M. R., The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 26-28, 1925.

[51] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 36, 1933.

The quartz conglomerate on Cloyds Mountain forms the basal part of the Price in that vicinity, but it is certain that there is no similar horizon at the base of the formation in the Draper Mountain area. On Cloyds Mountain the conglomerate is directly overlain by cross-bedded sandstone similar to that found below the coal near Pulaski. The absence of a sequence of fossiliferous beds above the Chemung and beneath the cross-bedded sandstone in the Cloyds Mountain section probably indicates either that the conglomerate zone at the base is partially equivalent to the lower 400 feet of fossiliferous beds of the Draper Mountain section or that it is younger than they are.

A generalized section of the Price formation in this area is given below.

Price formation in the Draper Mountain area, Virginia

	Thickness Feet
Maccrady formation	
Price formation (1,225 feet)	
6. Reddish shale and fine-grained sandstone	30
5. Strikingly cross-bedded quartz sandstone, arkose, and lenses of quartz pebble conglomerate. Minor proportions of more even-bedded sandstone and arkose	350
4. Ferruginous micaceous sandstone and shale	25
3. Coal beds and associated sandstones, shales, siltstones, and clays	70
2. Cross-bedded sandstone and arkose with intercalated lenses of quartz conglomerate	300
1. Fine-grained gray to brownish ferruginous sandstone, olive-drab shale, and quartz conglomerate. Contains abundant marine fossils	450
Chemung formation	

Fossils.—The lower 400 feet of the Price formation in the Draper Mountain area contains an abundance of marine fossils, some of which are present in nearly every bed. Campbell[52] noted "the presence here and there of marine fossil shells," but he failed to note that in some localities, as in the Draper Mountain area, fossils are abundant throughout the lower third of the formation. Holden and Reger[53] collected fossils below the coal beds, out of Reger's "Broad Ford sandstone" in

[52] Campbell, M. R., The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 24, 1925.

[53] Reger, D. B., Mercer, Monroe, and Summers counties: West Virginia Geol. Survey Report, pp. 520-525, 1926.

the vicinity of Poverty Gap, in Montgomery County, Virginia. Butts[54] has collected fossils from the Price at many localities in the southern Appalachian region. Miller[55] has described a single specimen of a goniatite [*Protocanites lyoni* (Meek and Worthen)] from the Price and has listed its faunal associates as collected and identified by Butts. No fossil lists based on collections in the Draper Mountain area have been published. The writer collected the following forms from the lower Price of that area:

Lepidodendron scobiniforme Meek
Triphyllopteris lescuriana Meek
Lingulodiscina (Oehlertella) pleurites Meek
Orthotetes crenistria (Phillips)
Chonetes cf. C. scitulus Hall
Chonetes sp.
Chonetes illinoisensis Worthen
Camarotoechia cf. C. sappho Hall
Camarotoechia cf. C. contracta Hall
Camarotoechia marshallensis Winchell
Leptodesma cf. L. propinquum Hall
Leptodesma cf. L. truncatum Hall
Romingerina julia (Winchell)
Spiriferina cf. S. depressa Herrick
Athyris ohioensis Winchell
Sphenotus flavius (Herrick)
Grammysia sp.
Edmondia sp.
Leda sp.
Cryptonella sp.
Schizodus sp.
Allorisma consanguinatum Herrick
Allorisma sp.
Cypricardella bellistriata Conrad
Bellerophon cf. B. helena Hall
Tropidodiscus cyrtolites (Hall)
Euphemus galericulatus (Winchell)
Straparollus sp.
Orthoceras indianiense Hall
Münsteroceras sp.
Taonurus oranus (?) Hall

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54 Butts, Charles, Oil and gas possibilities at Early Grove, Scott County, Virginia: Virginia Geol. Survey Bull. 27, pp. 11-12, 1927.

55 Miller, A. K., A Mississippian goniatite from Virginia: Jour. Paleontology, vol. 10, no. 1, pp. 69-72, 1936.

Above the thick-bedded gray sandstone containing *Productella hirsuta, P. lachrymosa, Spirifer mesicostalis,* and *Orthotetes chemungensis,* at the top of the Chemung formation, abundant representatives of species of *Camarotoechia* and *Chonetes* are almost the only fossils to be found in the lower 30 to 50 feet of the Price. Near the base of the Price a single *Spiriferina* was found. Above this horizon a greater variety of fossils occurs in abundance. Just north of the first road culvert on U. S. Highway 11 ascending Draper Mountain from Pulaski, the entire fauna listed above is found in a few feet of beds. The fossils decrease in variety above this horizon, but *Chonetes* and *Camarotoechia* persist upward to the black shale which underlies the lower zone of cross-bedded sandstone. In the black shale *Grammysia* and *Allorisma* are common. Above this horizon the only animal fossil found was *Taonurus.* Plant fossils are abundant in the coal-bearing part, and a variety can be collected from shale beds exposed along the road paralleling Valley Branch, just northeast of an old coal mine dump, 2¼ miles southwest of Pulaski. Another exposure of this shale is located along the south drive of Calfee Park near its junction with U. S. Highway 11. Probably quite a variety of undescribed species is present in these shales, but most of the fossils collected by the writer are referable to *Lepidodendron scobiniforme* Meek.

Age and correlation.—The Price formation, as indicated by the above fauna, is the approximate stratigraphic equivalent of the Cuyahoga formation of Ohio which is lower Osage in age. The diagnostic *Euphemus galericulatus* and *Tropidodiscus cyrtolites* as well as most of the other species listed are considered by Butts to be proof of this correlation. By actual tracing the Cuyahoga is proved to be continuous with the New Providence formation of Kentucky, which is correlated with the Burlington limestone of Iowa. The *Taonurus* which occurs in the Price is common in the New Providence in eastern Kentucky and in the Price formation in Virginia. The presence of *Münsteroceras,* common in the Rockford formation of Indiana, is taken to indicate that the Price, at least in part, might be Kinderhookian in age. Miller[56] has described several forms of goniatites, including species of this genus from the Burlington of Iowa, whose Osage age is not questioned. According to Butts[57] the Cuyahoga connects stratigraphically with the New Providence at Portsmouth, Ohio, and is continuous with the Pocono of Pennsylvania. The Price and the Pocono are essentially the same stratigraphic unit, and both names are used in Virginia. The term, Price, is reserved for rocks of New Providence age south of

[56] Miller, A. K., Burlington goniatites: Am. Jour. Sci., 5th ser., vol. 30, pp. 432-437, 1933.

[57] Cited by Miller, A. K., A Mississippian goniatite from Virginia: Jour. Paleontology, vol. 10, pp. 71-72, 1936.

James River, and Pocono is used north of that more or less arbitrary line. The Price formation of the Draper Mountain area probably represents a near-shore facies of the New Providence formation.

MACCRADY FORMATION

Name.—The Maccrady formation was named by Stose[58] from Maccrady, Smyth County, Virginia, but the name is now restricted to red beds at the base of Stose's original Maccrady.

Distribution.—The Maccrady extends in a narrow belt one-fourth of a mile wide from the forks of Miller Creek, north of Max Meadows, eastward to a point half a mile west of Clark Station. The formation also crops out in a belt through the western part of Pulaski and extends from the northwest foot of Caseknife Ridge north along the eastern foot of Chestnut Ridge. (See Pl. 1.)

Lithology.—The Maccrady formation is composed of red, vinaceous-drab shale; mudrock, sandstones, and siltstones of similar color; and greenish, brown, and buff micaceous sandstones and shales. The predominantly red color of the formation is a striking feature of its lithology. The shales and mudrocks are soft and lumpy and disintegrate readily into sterile soil. The sandstones and siltstones are more resistant but do not make conspicuous ridges as do the resistant beds of the Price. Sandstone and shale zones 5 to 50 feet thick are intercalated in the shales and mudrocks.

The lighter colored beds are more abundant in the upper 350 feet of the formation as exposed in this area. This does not mean the uppermost 350 feet of the formation as a whole, because in this area the Maccrady is the youngest bedrock formation exposed and an unknown thickness of the upper part of the formation has been removed by erosion. The maximum thickness of the Maccrady in this region is about 500 feet. The part of the formation exposed in the Draper Mountain area is so heterogeneous in lithology that it is impossible to recognize key horizons.

Fossils and correlation.—The Maccrady contains a few marine fossils of which the bryozoan genera, *Polypora* and *Fenestralina,* are most common, but these are by no means abundant. According to Butts,[59] the Maccrady is of New Providence age. Since the underlying Price is also of New Providence age it is probable that the two formations are conformable in this area.

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[58] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: Virginia Geol. Survey Bull. 8, pp. 51-60, 1913.

[59] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, pp. 37-38, 1933.

STRUCTURAL GEOLOGY

GENERAL FEATURES

The salient features of the geologic structure and of the history of previous geological investigations in this and adjacent areas have been adequately discussed by Campbell[60] and others. Their interpretation of the complex structure of this part of the Appalachian region has been a great help to the writer in his more detailed studies, the results of which are recorded in this report.

The Draper Mountain area is located at the western border of a belt of low-angle overthrust faults, which forms the southeastern part of the southern Appalachian Valley of Virginia. In addition to these structural features, and in some places superimposed upon them, there are in this area overturned folds and related moderate-angle overthrusts of the familiar Appalachian type. A striking structural feature of this area is the subsequent folding of the low-angle thrust sheets. This has been the controlling factor in the development of the fensters in Montgomery, Pulaski, and eastern Wythe counties, of which the Draper Mountain area is an example. (See Pl. 11.)

MAJOR FAULTS

GENERAL STATEMENT

According to the geologic map of Campbell[61] and Holden, the Cambrian formations, which almost surround the ridges of Draper Mountain, represent part of a single overthrust mass. Campbell and Holden considered the circuitous course of the contact between the Cambrian and younger rocks as the trace of a single overthrust fault, called by them the Pulaski fault. This interpretation was followed by Butts[62] in 1932 and 1933 when he interpreted the overthrust mass of Cambrian as composed of the Rome formation. It became apparent in the course of the writer's very detailed field work that the structural and stratigraphic features of the overthrust mass of Cambrian rocks were not as simple as heretofore conceived. The so-called Pulaski overthrust mass was found to contain parts of two formations, the Rome and Elbrook, and the contact between them was discovered to be a fault contact. The latter fault, heretofore unnamed and probably unrecognized, is another low-angle overthrust comparable in

[60] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 30-96, 228-230, 1925.

[61] Campbell, M. R., and others, op. cit., pl. 1.

[62] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, map, 1933; Southern Appalachian region: Internat. Geol. Cong., XVI, United States, 1933, Guidebook 3, pl. 27, 1932.

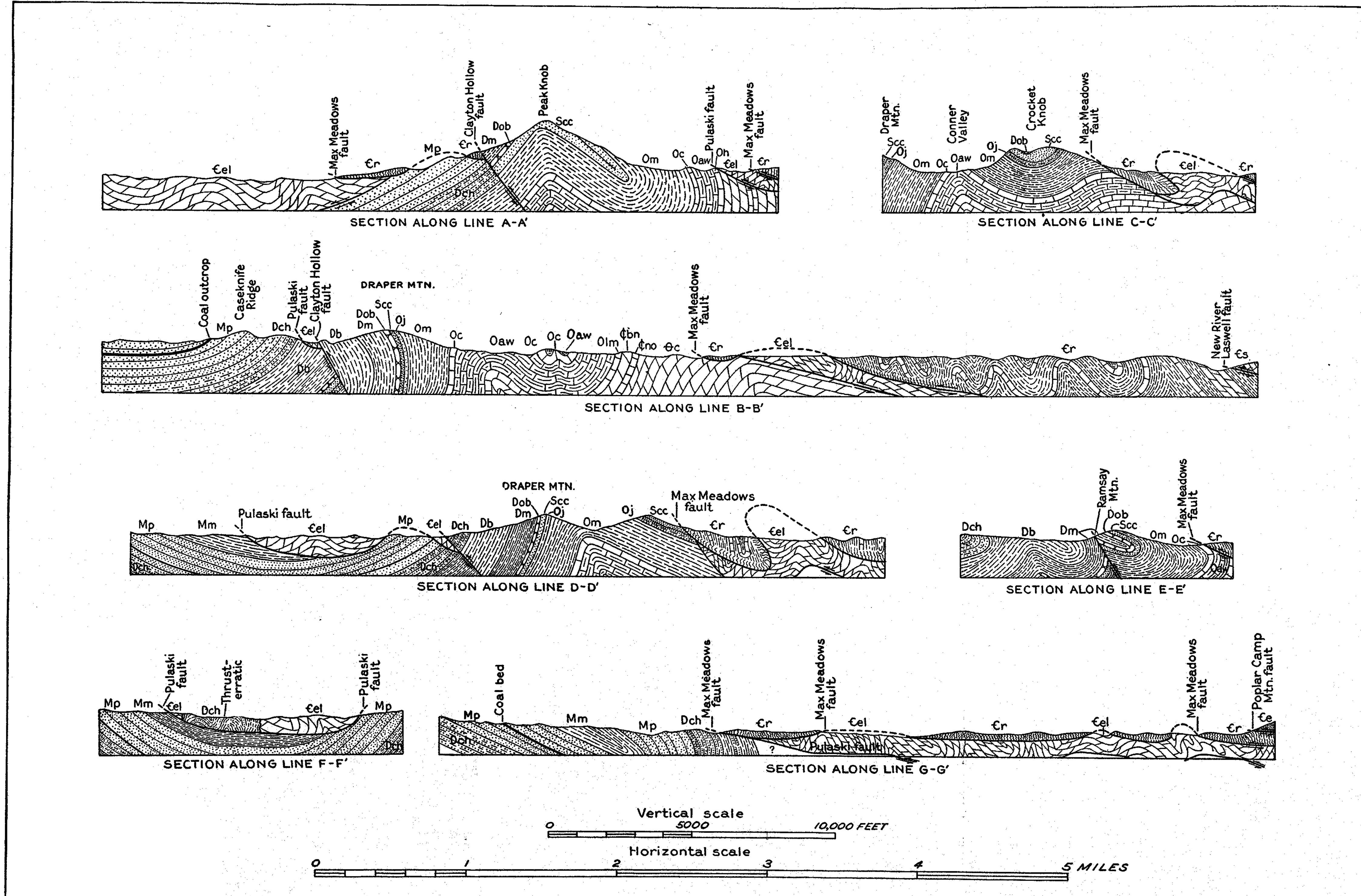
horizontal displacement to the Pulaski overthrust. The post-Cambrian rocks of the Draper Mountain area are in contact with part of two great overthrust masses, and the fault contacts which outline the breached Draper Mountain fenster represent the intersecting traces of two overthrust faults, one the trace of the Pulaski fault, as herein redefined, and the other the trace of a heretofore unrecognized but equally striking overthrust. The so-called Pulaski fault of Campbell and Holden in the type locality is not a structural entity, but comprises two distinct though closely related faults.

PULASKI FAULT

Redefinition.—It is necessary in discussing the Pulaski fault to distinguish it from the other similar fault with which it is closely associated in the Draper Mountain area. The Pulaski fault is here redefined as the older of these two related faults, and as the principal rupture whereby the Cambrian rocks of this area have come to overlie the post-Cambrian formations. Its trace is represented by the contact between the Elbrook and younger formations. The areas in which the Elbrook formation is exposed are remnant parts of the Pulaski overthrust mass. It will further serve to distinguish the two faults by stating that the overthrust sheet of the Pulaski fault, as herein redefined, together with the post-Cambrian rocks form the overridden block of the later overthrust mass. The Pulaski fault trace passes along the western side of Randolph Street in the town of Pulaski.

Geographic extent.—According to Campbell,[63] the so-called Pulaski fault can be traced continuously from the vicinity of Timberridge, Tenn., to Eagle Rock, Va. Butts [64] shows the fault extending farther northeast, to a point beyond Greenville, Va., and Woodward[65] has traced this fault as far northeast as Greenville. As stated by the writer in an earlier paper,[66] the southwestern termination of the Pulaski fault is more probably located in the Marion area, Smyth County, Virginia. In that locality, the Pulaski fault (called the Hungry Mother overthrust by the writer in an earlier paper) appears to end near the head of Wassum Valley, northwest of Marion. However, the fault in the Marion area is not like the Pulaski overthrust in the Draper Mountain area, for it is a high-angle fault and does not partake of the folded structures of its overridden block. The only fault continuing southwest from the Marion area, which is of regional significance,

[63] Campbell, M. R., and others, op. cit., pp. 76-77.
[64] Butts, Charles, idem.
[65] Woodward. H. P., Fault-line phenomena near Eagle Rock, Virginia: Am. Jour. Sci., 5th ser., vol. 31, p. 138, 1936.
[66] Cooper, B. N., The structure and stratigraphy of the Marion area, Virginia, *in* Contributions to Virginia geology: Virginia Geol. Survey Bull. 46, pp. 164-165. 1936.



GEOLOGIC STRUCTURE SECTIONS OF THE DRAPER MOUNTAIN AREA, VIRGINIA.

€e, Erwin quartzite; €s, Shady limestone; €r, Rome formation; €el, Elbrook formation; Ɵc, Conococheague limestone; ₵bn, Bellefonte-Nittany formations; ₵no, Oglesby marble member of the Nittany; Olm, Lenoir-Mosheim limestones; Oh, Holston limestone; Oaw, Athens-Whitesburg limestones; Oc, Chambersburg limestone; Om, Martinsburg formation; Oj, Juniata formation; Scc, Clinton-Clinch formations; Dob, Onondaga-Becraft formations; Dm, Millboro shale; Db, Brallier formation; Dch, Chemung formation; Mp, Price formation; Mm, Maccrady formation.

Note: Since the cut for these structure sections was prepared the Virginia Geological Survey has discontinued the use of Ozarkian and Canadian as systemic terms. Hence the Conococheague limestone should be included in the Cambrian, and the Bellefonte-Nittany formations in the Ordovician.

is the Seven Springs overthrust.[67] The overthrust which Campbell traced southwest of Marion was not the Pulaski fault but the Seven Springs overthrust, a distinct high-angle break. Detailed tracing and study of the Pulaski fault between Pulaski and Marion may reveal that the overthrust does not even extend as far southwest as Marion.

Surface indications.—The areas of outcrop of the Pulaski overthrust mass are locally differentiated from adjacent terranes by significant topographic features. In traversing the old stage road from Pulaski to Max Meadows, one descends from the rugged back country of Caseknife Ridge into a broad clearing which extends from Gunton Park to Max Meadows. This broad cleared tract is a northeast salient of the Pulaski overthrust mass and the bordering woodlands are underlain by Devonian and Mississippian rocks which were overridden by this salient. (See Pl. 12.) An abrupt topographic change also outlines the boundary of the Pulaski overthrust mass north and east of Pulaski. This abrupt change is well shown on the new topographic map of the Pulaski quadrangle (Pl. 13), but in most other places in Pulaski County the boundary of the overthrust mass is not so well shown topographically. The exact location of the trace of the fault can be determined only by a study of the outcrops of related rock formations. There are no good exposures of the fault contact at any point in the Draper Mountain area. It is impossible to measure a single dip of the fault surface, but generally it is a comparatively simple matter to infer the direction and the approximate amount of dip of the fault surface by observing the direction and the amount of offset of the fault trace where it crosses stream valleys.

Structural relations.—The horizontal displacement of the Pulaski fault is great, and it is apparent from the geologic map (Pl. 1) that the overthrust mass has moved northwestward at least 11 miles, and probably much more, from its original position. The stratigraphic separation is in the neighborhood of 13,000 feet and the throw is of approximately the same magnitude. There are probably few, if any, faults in the entire Appalachian region which surpass the Pulaski fault in displacement.

Peculiarities of the fault.—In enormity of displacement, this great fault is comparable to some of the great Alpine faults. The Elbrook formation, which forms the sole of the Pulaski overthrust block, shows little evidence of having ridden for many miles over the rocks below, although it was drag-folded and crumpled. The structures as they appear today, somewhat modified by later epochs of deformation, are

[67] Cooper, B. N., op. cit., pp. 162-164.

very complex. The same type of structures, however, are found in many other formations which have been deformed *in situ*. So far as the writer was able to observe, no zone of fault gouge occurs between the overthrust and overridden blocks. As the contact between the two blocks bounding the fault is nowhere sharp, it is possible that some fault gouge is present, but that it has weathered beyond recognition at the surface, forming a part of the covered interval between the two fault blocks. Were it not for the fact that the Elbrook obviously lies in contact with twenty-three formations which range in age from Ozarkian to Mississippian, the folded and crumpled structures within the formation could be adequately explained on the basis of deformation independent of the main faults.

Some mineralization in the form of secondary concentration has taken place along the Pulaski fault. Stringers and irregular masses of limonite and manganese oxides occur in many places along surface exposures of the fault. These are not everywhere conspicuous but locally, northeast of Max Meadows, concentrations of iron oxides are exposed in old prospect holes which border the belt of Elbrook. Where present in association with the Elbrook, iron and manganese oxides in any quantity are indicative of the Pulaski fault surface.

One of the characteristic features of the Elbrook in this area is the abundance of en echelon calcite veins. They represent fillings of gash fractures which were opened by the differential movement of beds of the Elbrook over one another. They are confined stratigraphically to the Elbrook and are helpful in its recognition.

For the sake of clarity, it is well to discuss and describe here the structural associate of the Pulaski fault, here named the Max Meadows fault. The remaining features of the Pulaski fault are related to events subsequent to the development of the Max Meadows overthrust, and these features apply to both faults.

MAX MEADOWS FAULT

General statement.—There are many criteria by which the Max Meadows fault can be recognized. Were it not for its relatively slight stratigraphic separation as compared to that of the Pulaski fault, it would be as conspicuous as the Pulaski overthrust. It has been previously stated that in some places the Rome formation can be differentiated from the Elbrook only with great difficulty. The criteria employed by the writer for the differentiation of these two formations were the bases upon which the duality of the so-called Pulaski fault of Campbell and Holden was established.

Definition.—The name Max Meadows fault is here given to the overthrust which marks the contact between the Rome and Elbrook formations in the vicinity of Max Meadows. (See Pl. 14A.) At this locality it is apparent that the Rome overlies the Elbrook. On the geologic map (Pl. 1), the Max Meadows fault is indicated by the contact between the Rome and younger formations.

Criteria for recognition.—From the geologic map, it is evident that in the vicinity of Max Meadows and Graham School the Rome formation occupies the higher ground and caps small hills which are partly or wholly surrounded by the Elbrook formation. The contact between these two formations follows the contour lines rather closely, indicating that it is essentially horizontal. The beds above and below the contact dip more than 45° and are not parallel to the contact of the two formations. Hence, the contact between the Rome and Elbrook is not a normal formation contact; the older Rome overlies the younger Elbrook. In other localities the fault contact between the two formations is steeply inclined and it is not easy to discern whether the Rome overlies the Elbrook, but from other lines of evidence, it is apparent that this is true throughout the Draper Mountain area.

The contact between the Rome and Elbrook is marked in many places by a zone of tectonic breccia. This breccia has its best development about 2½ miles west of Max Meadows, along the tracks of the Bristol branch of the Norfolk and Western Railway. (See Pl. 14.) In the east bank of Cove Creek (Speedwell, Va., quadrangle), the fault breccia is 75 to 100 feet thick. The same belt of breccia can be traced westward for several miles. It is present near Wytheville, where the Conococheague formation has been overridden by the Rome, three-fourths of a mile northeast of the highway (U. S. 11) bridge over the railroad tracks. It is well displayed along the north side of a near-by railroad cut in the conspicuous bluff formed by thick dolomite beds of the Rome. The breccia is well shown along the north side of U. S. Highway 11, about 100 yards west of the bridge over Reed Creek near Kessling School. Here on the south side of the cut are exposures of vertical Rome dolomite and shale beds, whereas in the north side of the cut are exposures of the fault breccia which lie upon truncated, low-dipping Elbrook beds. The fault breccia is exposed at three places along the road between U. S. Highway 11 and Poletown. (See Pl. 16.) One of the three zones can be traced eastward to the bluff at the north end of Horseshoe Bend on Reed Creek. (See Pl. 15.) The presence of the Max Meadows fault here is also shown by the discordance in strike and dip of the Rome and Elbrook formations at the northeast turn of the bend. Along the private road running south along the east side of Reed Creek, south of Horseshoe Bend, the fault breccia is well exposed. Other places where the fault breccia is well exposed are: along the east bank of Little Pine Run near the Wythe-Pulaski county line; along the McGavock Creek road, 1.1 miles south of U. S. Highway 11; in the valley of Pine Run south of Graham School; and along the south side of State Highway 99, just east of the city limits of Pulaski, at the base of a gravel-covered river terrace, and at several places along the fault in the vicinity of Max Meadows.

The breccia is composed principally of large and small irregular blocks and small rounded fragments of dolomite, dolomitic limestone, red and green phyllitic rock, and white quartzite. Individual fragments range in size from less than .01 mm. to more than 3 feet. (See Pl. 15.) In fresh exposures the breccia has a greenish color which is due to the abundance of sericite. The matrix of the breccia is composed of twinned calcite and dolomite, finely comminuted particles of chlorite, sericite, a sericite-like clay mineral, and angular to rounded fragments of quartz and quartzite. Some of the breccia contains as much as 10 per cent of euhedral pyrite crystals. Chalcopyrite in small amounts is common. Sphalerite, galena, fluorite, and barite are present in traces. It is evident from the character of the breccia that it contains material from the Rome, Elbrook, Shady, and Erwin formations.

The occurrence of the tectonic breccia along the Max Meadows fault has several interesting aspects. The amount of it along the fault surface varies considerably from place to place. It appears to have been heaped up in some places on the fault surface and to have been squeezed out at other places. The breccia is not confined to the fault surface. Open joints and fissures in both the overridden and overriding strata adjacent to the fault have been filled with the breccia. In some places the breccia occurs in pseudo "beds" within a shear zone whereas in other places it has definitely cross-cutting relations to the invaded beds of Rome and Elbrook. In some places the fault breccia is found within the Max Meadows overthrust block and the Pulaski overthrust mass 200 to 500 feet away from the nearest exposure of the Max Meadows fault surface. Presumably, during the time when the Max Meadows overthrust mass was advancing northwestward, the mass weight of the overthrust block developed sufficient attrition to crush large quantities of rock near and along the sole and tread of the overthrust. The tremendous weight of the overriding block caused some of the brecciated rubble to be squeezed out into open joints and fissures of the adjacent rocks and to assume "intrusive" relationships with the inclosing rocks. (See Pl. 16A and Fig. 3.)

Campbell[68] observed this type of breccia at many places in Montgomery and Pulaski counties, but he did not mention any relation be-

[68] Campbell, M. R., The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 17-19, 1925.

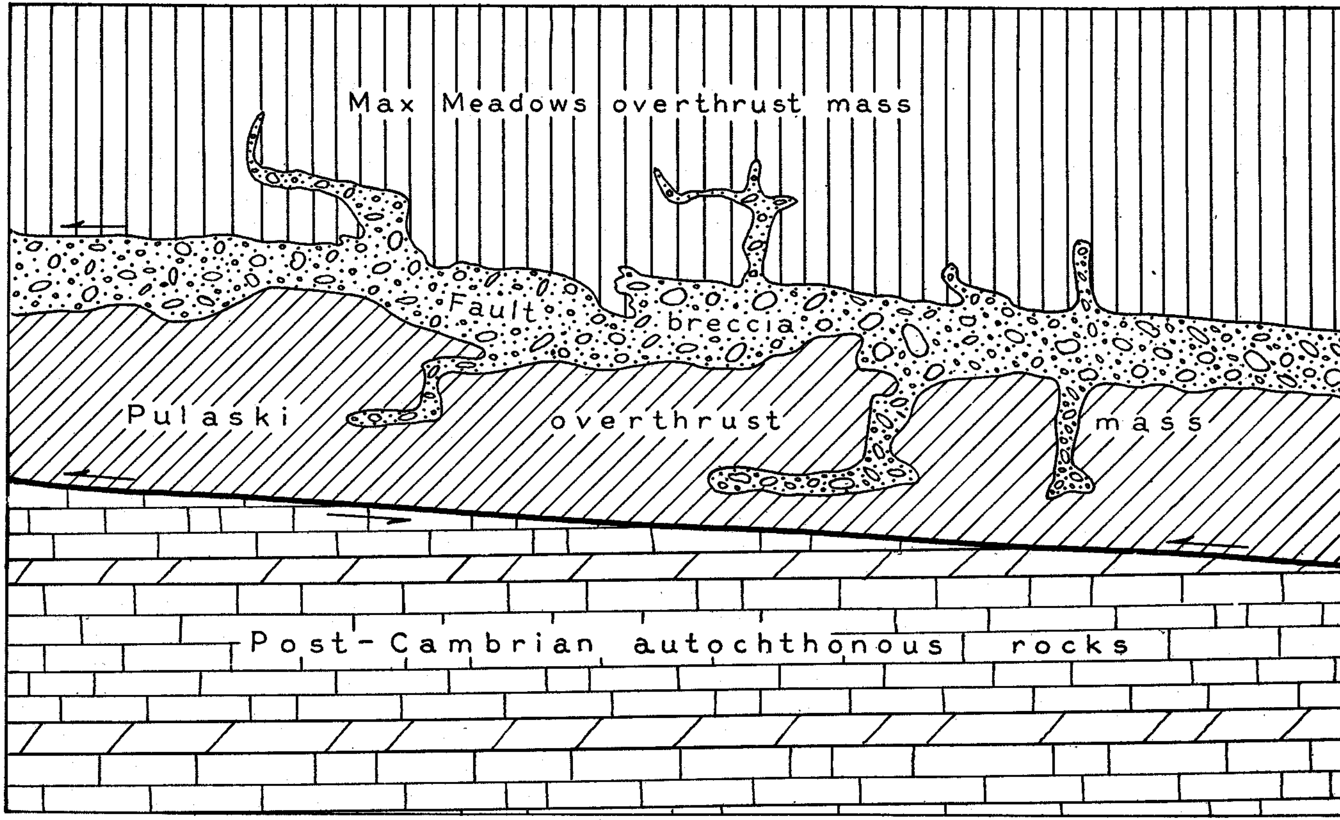


FIGURE 3.—Fault breccia along the Max Meadows overthrust. Parts of this breccia have been squeezed out into the rocks above and below the fault and occur in the form of cross-cutting, dikelike masses. The Pulaski fault is, in contrast, a clean-cut thrust. The original dips of these faults, which are shown in the diagram, have been greatly altered by folding, overturning, and rupturing of both of the thrust sheets and of the underlying autochthonous strata.

tween the occurrence of the breccia and the loci of faults. Because he and Holden mapped all of the overthrust rocks as a single structural unit, the presence of the Max Meadows fault was overlooked. At Peppers Ferry, in Montgomery County, there are exposures of breccia which Campbell called "calcareous tufa." He regarded the breccia as a surface deposit made in old stream channels, and as having a physiographic significance only. The material at Peppers Ferry is identical in lithologic character to the tectonic breccia of the Draper Mountain area, but the occurrence of the material at this point does not coincide with any known fault. It may be that the material at Peppers Ferry represents a part of the fault breccia that was squeezed out of the fault zone into cracks and joints within the rocks on either side of a near-by rupture plane.

This type of occurence is common in the Draper Mountain area. Along the private road extending south from the Horseshoe Bend of Reed Creek along U. S. Highway 11, from 3 to 10 feet of breccia occupies vertical joints and partings parallel to bedding. The beds above the breccia zone have not been displaced relative to the underlying strata, hence the locus of the breccia is not a fault. (See Pl. 16B.) The nearest outcrop of the Max Meadows fault is some 400 feet south of this breccia zone, and breccia zones are also present along the fault plane itself, as well as in adjacent fissures. According to the writer's interpretation, the breccia at a relatively short distance from the immediate locus of a fault is also of tectonic origin. Holden[69] has intimated recently that zones of this breccia can be used to recognize faults in Montgomery County, Virginia. In the Draper Mountain area, the presence of this type of breccia does not indicate the locus of a fault unless the material separates Rome and younger beds.

Currier[70] has described rubble breccias in the Shady dolomite of the near-by Austinville basin, which are very similar to the tectonic breccias of the Draper Mountain area. He believes that the origin of the breccia near Austinville is tectonic, since the material appears to be concentrated along known faults. Extensive zinc and lead mineralization has also taken place in the brecciated zones along those thrust faults. The Draper Mountain area is outside the bounds of that highly mineralized belt and the breccias which the writer studied contained only minute amounts of zinc and lead minerals.

The Rome formation, a part of which forms the sole of the Max Meadows overthrust block, shows some metamorphic effects of travel over the rocks beneath the fault, and a zone of variable width next to the fault and within the Rome formation is composed of rocks which

[69] Holden, R. J., personal communication, December 29, 1937.
[70] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 68-70, 1935.

have a definite metamorphic appearance. The rocks have, however, been altered only by dynamic metamorphism of a simple type. The Rome of this zone has rather well-developed flow cleavage which has largely obliterated the bedding. Specular hematite, chlorite, and sericite line the cleavage planes in the shaly beds. The rocks are thoroughly fractured, and the cracks have been filled with calcite, dolomite, chlorite, sericite, and specularite. The intimate manner in which the rocks have been drag folded probably accounts for the development of slaty cleavage and the formation of chlorite, sericite, and specular hematite along cleavage planes. This zone is best exposed in the valley leading northward to Reed Creek from U. S. Highway 11 at the Fort Chiswell Monument.

This belt of altered rocks is a further indication of the fault relation of the Rome formation to the underlying Elbrook. The writer believes that the Rome was appreciably metamorphosed as it was thrust over the Elbrook, and that in a zone of varying width above the fault, significant structural and mineralogical changes took place, so that a phyllitic rock was producd from ferruginous shale.

Geographic extent.—Due to the fact that its structural associate, the Pulaski fault, extends far northeast and southwest of the type locality, it seems logical that the Max Meadows fault may have a similar extent. The writer has not traced the fault outside of the area mapped. (See Pl. 1.) The identity of any overthrust fault with the Pulaski or Max Meadows fault can be established only by walking along the trace of the break from either of the type localities herein defined.

POPLAR CAMP MOUNTAIN FAULT

The southwestern corner of the area mapped by the writer includes the eastern end of Lick Mountain. Physiographically, Lick Mountain is similar to the Blue Ridge, and its anomalous position, 8 miles northwest of the Blue Ridge plateau, suggests that the mountain is an outlier of the Blue Ridge. The structural relations have been worked out by Currier[71] and others, who interpret Lick Mountain as a remnant portion of the once extensive Poplar Camp Mountain overthrust mass. This klippe is surrounded by the Poplar Camp Mountain overthrust trace, the same break which crops out along the west foot of the Blue Ridge (Poplar Camp and Iron mountains). The portion of the mountain mapped by the writer is composed entirely of Erwin quartzite which apparently rests upon the Rome formation. The fault plane around the base of the mountain is essentially horizontal. The apparent absence of the Shady formation between the Erwin and the

[71] Currier, L. W., op. cit., p. 60.

Rome suggests that the contact between the Rome and Erwin is a fault. The rocks of Lick Mountain, according to identifications of the Poplar Camp Mountain fault by Currier, have been thrust northwestward at least 8 miles. The stratigraphic separation is from 3,000 to 5,000 feet.

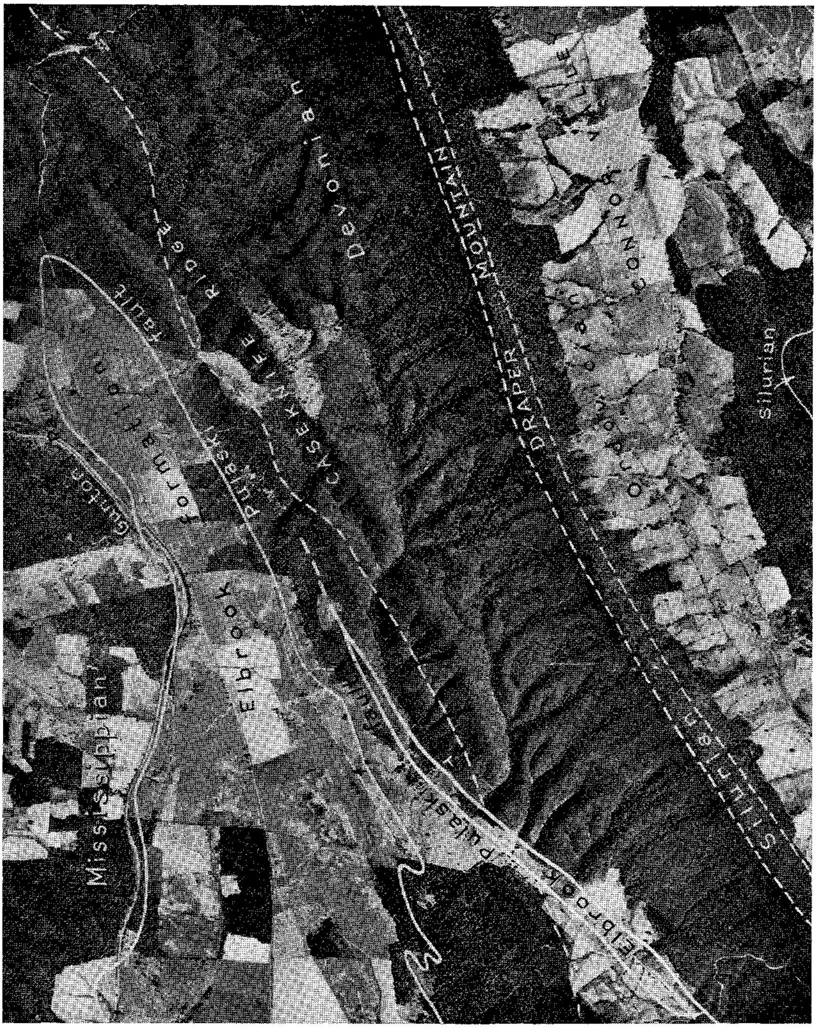
LASWELL FAULT

In the southeastern corner of the Draper Mountain area the Patterson member of the Shady dolomite lies in contact with the Rome formation, due to an overthrust. The fault extends along the south bank of New River west of Reed Junction. Associated with this overthrust are minor faults within the Rome and Shady formations. The writer has checked Currier's interpretation of this fault in the vicinity of Reed Junction and is satisfied that the extensive outcrop of Rome shale north of the river as far as Draper Valley Church contains no klippen of the Laswell and Sugar Grove overthrust masses nor any fensters in the Max Meadows overthrust mass. The fault surface of the Laswell thrust in the vicinity of Reed Junction dips about 45° SE., but this inclination is probably due to subsequent tilting.

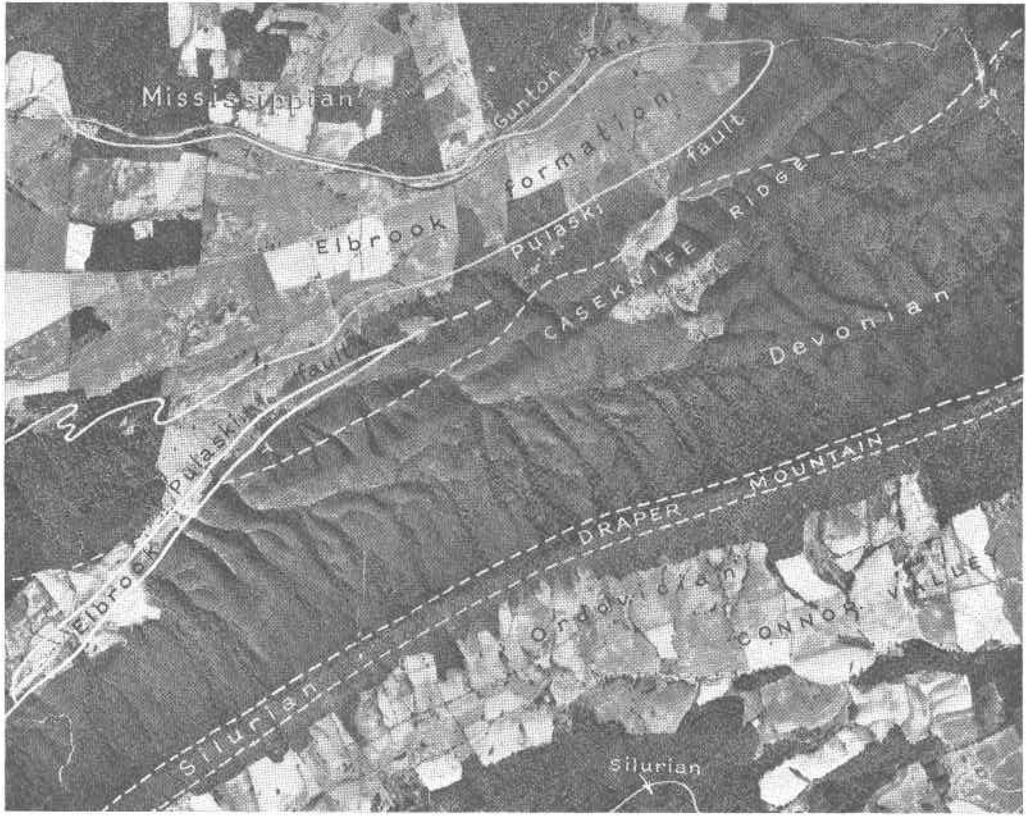
RELATION OF THE MAX MEADOWS AND PULASKI FAULTS TO REGIONAL STRUCTURE

Just northwest of the Blue Ridge plateau there is a series of en echelon low-angle overthrusts which are distinct from the thrust faults northwest of Little Walker, or Cloyds, Mountain. At the surface this series of faults appears to dip rather steeply, but this is due to tilting and folding, as prior to folding they were essentially horizontal thrusts. The faults northwest of Cloyds Mountain have always been, and still are, relatively high-angle breaks. They bear a close relation to overturned anticlines, and it is probable that they were formed by rupturing of the folds. On the other hand, the belt of extremely low-angle thrusts at the west foot of the Blue Ridge has no relation to folds. They appear to have had their roots in the pre-Cambrian basement rocks. In the Draper Mountain area it is apparent that the overridden post-Cambrian rocks were not folded until after they had been overridden by the Pulaski and Max Meadows overthrust masses. This is evident because the same folds have been developed in the overridden rocks and in the fault surfaces; and the bedding planes of the overridden rocks are essentially parallel to the fault surfaces.

There are no remnants of overthrust Cambrian rocks northwest of Little Walker, or Cloyds, Mountain, and everywhere the overthrust Cambrian formations impinge sharply against the southeast side of those barriers. It appears to the writer that both the Max Meadows

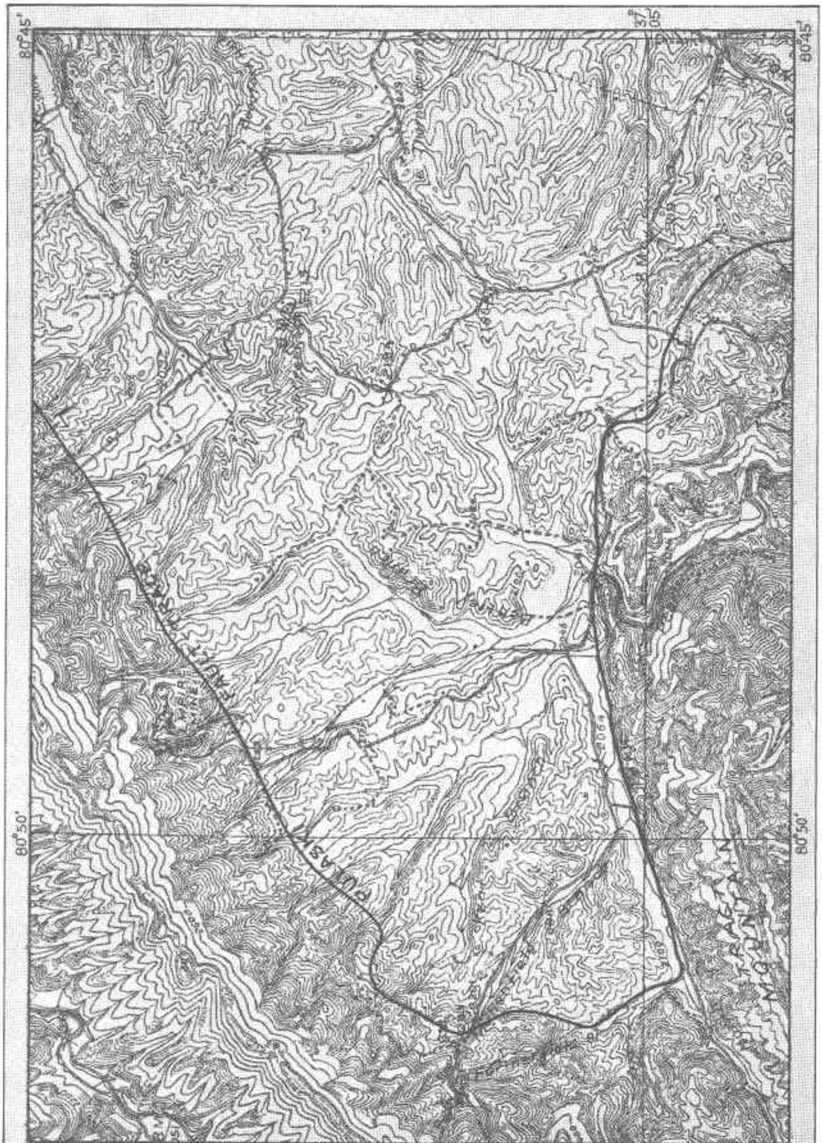


Aerial view of Gunton Park and vicinity. The tongue of Elbrook is a part of the Pulaski overthrust mass which here is in contact with the Price and Maccrady formations. The fault line is indicated by the boundary between the cleared fields and the wooded area. (Photograph courtesy of the U. S. Forest Service.)



Aerial view of Gunton Park and vicinity. The tongue of Elbrook is a part of the Pulaski overthrust mass which here is in contact with the Price and Maccrady formations. The fault line is indicated by the boundary between the cleared fields and the wooded area. (Photograph courtesy of the U. S. Forest Service.)

Topographic map of part of the Pulaski quadrangle, showing trace of the Pulaski fault and its effect on the topography. Base from U. S. Geological Survey advance sheet of the Pulaski quadrangle (1932-34).



Topographic map of part of the Pulaski quadrangle, showing trace of the Pulaski fault and its effect on the topography. Base from U. S. Geological Survey advance sheet of the Pulaski quadrangle (1932-34).

and Pulaski overthrust masses moved northwestward until stopped by an already developed structural front whose locus is indicated by the present Little Walker Mountain. If this condition is assumed, the folds and faults northwest of Little Walker and Cloyds mountains must have been made before the strata of the Draper Mountain area were deformed. On the other hand, it has been generally stated that the Appalachian structures arose progressively from the southeast to the northwest.[72]

The geologic structures in the Draper Mountain area point to certain conclusions regarding the sequence of events during the Appalachian revolution. Lateral compression applied against the southeast side of the Appalachian trough, folded and faulted the strata. The folds rose progressively from the northwest border southeastward as far as the locus of Little Walker, or Cloyds, Mountain. At the culmination of this episode, presumably all of the folds and faults northwest of a line from Pulaski to Max Meadows had been formed. The beds to the southeast remained essentially horizontal. Continued stress was relieved by the yielding of these relatively undeformed rocks, apparently by low-angle overthrust faulting along shearing planes which originally may have been in the pre-Cambrian basement. The first break was the Pulaski fault, along which the overthrust mass moved northwestward for at least 11 miles, until stopped by folds already formed along the present site of Brushy Mountain. Other stresses were relieved by the rupturing of the Pulaski overthrust mass. The first break in it was the Max Meadows fault, along which a part of the Pulaski overthrust mass was thrust over the other part. By successive rupturing of the Pulaski fault sheets, the Laswell and Sugar Grove overthrusts, and the Iron Mountain and Poplar Camp Mountain overthrusts were formed in turn. The thrust sheets above each of these faults rode over adjacent overthrust sheets to the northwest, thereby producing a true imbricate structure of regional proportions. The horizontal displacement of the Pulaski fault is a minimum of 11 miles, of the Max Meadows fault a minimum of 8 miles, of the Laswell and Sugar Grove faults a minimum of 2 to 3 miles each,[73] and the Iron Mountain and Poplar Camp Mountain faults a minimum of 8 miles. With the formation of this imbricate structure, a segment of the earth crust about 30 to 35 miles wide was "shortened" to a width of approximately 18 miles. The final surge of compressional forces upon the Appalachian tract folded the imbricate low-angle faults and overthrust sheets as well as the strata below the Pulaski fault.

[72] Willis, Bailey, The mechanics of Appalachian structure: U. S. Geol. Survey 13th Ann. Rept. pt. 2, pp. 211-281, 1893.

[73] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 59-61, 1933.

FOLDING OF THE PULASKI AND MAX MEADOWS THRUST SURFACES

It is customary to speak of the Pulaski and Max Meadows faults as "low-angle overthrusts," but this designation alludes only to the original condition. In the vicinity of Graham School and Max Meadows the Max Meadows fault is essentially horizontal, but in most places both it and the Pulaski fault appear at the surface as high-angle breaks. At the end of the episode in which the Max Meadows thrust and subsequent low-angle faults were produced, the fault planes of the two overthrusts may have had prevailing dips of less than 10°.

Subsequent to this complex faulting, additional compression was relieved by folding and minor overthrusting of all of the rocks of this area. As this later folding was imposed upon the folded beds of the overthrust masses, the present attitude of the overthrust Rome and Elbrook beds give no indication of, and appear to have no direct relation to, the position, size, and character of the folds formed by the later episode of deformation. Folds are generally considered with respect to bedding planes; however, the datum planes which form the basis for the interpretation of folds formed subsequent to overthrust faulting are not bedding planes but are the fault surfaces. The folds developed in the overthrust sheets of the Rome and Elbrook formations during this later episode of deformation are evident only from the attitude of the fault traces from place to place. The dip and strike of the Rome and Elbrook beds at any place are the result of at least two episodes of folding, one attending overthrusting and one subsequent to the formation of the imbricate structure.

MAJOR FOLDS

The major folds of this area are typical closed, overturned structures of the well-known southern Appalachian type. The general trend of these structures is N. 65° E., and they involve not only the Draper Mountain autochthon but also the Pulaski and Max Meadows overthrust sheets.

McGAVOCK CREEK ANTICLINE

The northwest limb of the McGavock Creek anticline is roughly coincident with the Lee Highway (U. S. 11), and State Highway 101, which extends from Kelleys filling station east to Draper. The position of the southeast limb can not be determined exactly, because it lies in the broad belt of Rome south of Graham School. A part of the southeast flank of the anticline is indicated by the trace of the Max Meadows fault on the southeast side of the long, narrow belt of Elbrook which extends from a point half a mile southwest of Fort Chiswell northeastward to the Wythe-Pulaski county line. The northwest limb of the fold is indicated by the Max Meadows fault as exposed in the northeast end of Horseshoe Bend along Reed Creek. The thrust surface has been folded and the anticline has been overturned to the northwest. This explains the facts that at Horseshoe Bend the Max Meadows fault dips to the southeast and that half a mile south of this point it also dips steeply to the southeast. If the axis of this structure were projected upon the surface, it would be represented by a northeast line crossing U. S. Highway 52 half a mile south of Fort Chiswell and extending northeast through a point half a mile south of Graham School.

The McGavock Creek anticline extends across the entire Draper Mountain area. The nearly horizontal Max Meadows fault surface in the vicinity of Graham School indicates the crest of the fold. The anticline is narrow southwest of Horseshoe Bend but opens to the northeast. The major structure is complicated by subsidiary folding and minor overthrust faulting south and southwest of Oglesby School and by minor zigzag folding at the east end of Barrett Ridge. This fold differs from most Appalachian structures in its areal expression. West of McGavock Creek the fold reveals itself areally in the Rome and Elbrook overthrust terranes. The belt of Elbrook surrounded by Rome appears to indicate a syncline; however, at the time this fold was made, the Elbrook lay *beneath* the Rome and not *above* it in normal stratigraphic sequence. The Max Meadows fault plane, which can be treated as if it were a bedding plane in working out this structure, has been arched upward thereby bringing within the reach of erosion the younger Cambrian rocks which now are beneath the Rome formation. The structural history of the Rome and Elbrook prior to the formation of this fold makes it apparent that it is an anticline rather than a syncline. The anticline is well shown in the post-Cambrian formations north of Draper Valley Church and south of U. S. Highway 11, where it is developed in the autochthonous rocks.

DRAPER MOUNTAIN ANTICLINE

The Draper Mountain anticline is a sharply overturned fold which involves all of the formations of this area. The fold, as developed in the Clinch formation, is indicated by the ridges of Draper Mountain. The southern border of the fold is marked by the line of low foothills on the south side of Draper Valley. The canoe-shaped Draper Valley is a striking topographic feature of the type abundantly developed in the Appalachian region. (See Pl. 17.) Where the Chambersburg and Athens formations crop out in the lower part of this valley they are vertical or slightly overturned to the northwest. The fold pitches sharply southwest of Hamilton Knob and rather steeply east of Peak Knob. It is possible to walk on bedding surfaces of the Clinch formation from 100 feet below Hamilton Knob southwestward to the base of the mountain east of Poletown. The entire slope below Hamilton Knob is paved with beds of the Clinch and the southwestward pitch-slope in this locality is nearly 50°. The unusually steep pitch of the Draper Mountain anticline west of Hamilton Knob may have been accentuated by cross folding, but there is scant field evidence to support this view. A nearly straight belt of Onondaga which bridges the gap between Draper and Ramsay mountains rather mitigates against cross folding. It is probable that the steep pitch of the anticline is due to the fact that at the time of formation of the Draper Mountain anticline there was a greater thickness of overthrust rocks in the area west of the site of Crocket Knob, and in consequence it could not be lifted to the same height as were the rocks east of Crocket Knob. That there was a greater thickness of overthrust strata west of Poletown is indicated by the proximity of the Poplar Camp Mountain overthrust block, which may be considered as a remnant of an overthrust sheet that extended formerly as far east as Camp Carry Brook and a similar distance north to Max Meadows. Thus interpreted, the steep southwest plunge of the Draper Mountain anticline is pitch. The eastern half of the Draper Mountain anticline pitches to the northeast, but only about 20°.

That the Draper Mountain anticline is overturned is evident from the southeast dip of the Clinch formation on the northwest limb of the anticline as exposed in the cuts of U. S. Highway 11 across Draper Mountain. The northwest limb of the anticline northeast of the water reservoir and north of Hamilton Knob broke locally with the formation of overthrust faults of small throw.

CROCKET KNOB SYNCLINE

The roots of a long, narrow syncline are well exposed in the line of foothills that extends from the base of Crocket Knob to Peak Knob. (See Pl. 18.) The fold is developed in the incompetent lower Martinsburg and Chambersburg formations. The position of the syncline is indicated by the incompetent drag folds developed in these two formations. The surface outlines of these drag structures are indicated by the narrow belts of Martinsburg and Chambersburg formations on the south side of Draper Valley. The line of low hills south of Draper Valley are remnants of a once continuous synclinal Clinch sandstone ridge which extended from Crocket Knob northeastward to Peak Knob—a ridge at one time comparable in height to Draper Mountain. (See Pl. 19.) Crocket Knob and the subordinate knob just below Peak Knob are remnant portions of the crest of that ridge. The south side of the pitching anticlinal hill east of Peak Knob exposes Clinch beds tightly folded into a syncline. This syncline, pressed close against the southeast flank of the Draper Mountain pitching anticline, is the eastward extension of the Crocket Knob syncline.

The syncline is well shown by the Clinch sandstone on Crocket Knob. The fold can be traced westward from this point, but it loses its areal expression where the Clinch, Juniata, and Martinsburg formations pass beneath the overthrust Rome and Elbrook formations southwest of Crocket Knob. The belt of Rome between Fort Chiswell and the Horseshoe Bend of Reed Creek represents, however, the same synclinal structure as developed in the Max Meadows overthrust mass. The fault plane of this overthrust mass dips steeply southeast at Horseshoe Bend and also where the Rome overlaps the Clinch south of Hamilton Knob. Hence, this syncline in the Max Meadows thrust plane is the western continuation of the Crocket Knob syncline. The writer was not able to trace the structure west of Fort Chiswell, and the fold appears to lose its surface identity in that area. It is evident that the Crocket Knob syncline was developed in the southeast limb of the Draper Mountain anticline, thereby shortening and greatly elevating that limb.

MILLER CREEK SYNCLINE

An overturned, isoclinal syncline is developed within the Price and Maccrady formations north and northeast of Max Meadows. This structure extends from the high hill northeast of Gunton Park westward to the V-shaped convergence of Brushy and Little Brush mountains. At the surface the trough of this structure is indicated by the oval, elongate outcrop area of the Maccrady formation. This structure, like its neighbors to the northwest, is believed to have been formed prior to the rupturing along the Pulaski fault. In this area it represents the southeasternmost structure developed prior to the episode of imbricate, low-angle thrusting. At one time it was probably an open, upright structure, but with the advance of the Pulaski overthrust mass against its southeastern limb it was overturned sharply to the northwest so that its southeastern limb dips some 60° SE.

GUNTON PARK SYNCLINE

The long tongue of the Pulaski overthrust mass which extends northeast of Max Meadows is not involved in the Miller Creek syncline, and belongs to another, gentler syncline of later origin. This fold was superimposed on the Miller Creek syncline, so that its southeastern limb was more overturned. The Gunton Park syncline involves all of the area mapped by the writer which is northwest of Draper Mountain and northeast of Max Meadows. It is a broad open structure. When the Draper Mountain anticline was formed, the Pulaski and Max Meadows fault surfaces and the strata of the overridden block southeast of the sites of Pulaski and Gunton Park were strongly arched, but a belt northwest of Draper Mountain remained passive. Due to this down lagging, the two overthrust blocks and the lower overridden block appear to have been warped into a syncline. Whereas this structure is the result of passive deformation, the Miller Creek syncline is the result of active and rigorous deformation. Erosion has destroyed almost all evidence of this structure as developed in the overthrust blocks. At one time, Cambrian rocks must have been continuous between Max Meadows and Pulaski, and the Draper Mountain autochthon was then a true fenster, homologous with that of Price Mountain, near Blacksburg, in Montgomery County, Virginia.

OTHER STRUCTURAL FEATURES

STRUCTURE OF RAMSAY MOUNTAIN

Ramsay Mountain represents the western extension of the northwestern limb of the Draper Mountain anticline. (See Pl. 20A.) The rocks composing this ridge are almost completely inverted and are considerably more overturned than those east of Poletown. During the folding whereby the structures of the autochthonous strata were formed, the beds west of Hamilton Knob did not arch upward in a comparatively simple fashion, as did the beds forming the Draper Mountain anticline; instead they appear to have yielded by differential rotation in a horizontal plane. The northwestern limb of the Draper Mountain anticline continues westward as far as the knob at the eastern end of Ramsay Mountain. In the exposures at the east foot of this mountain, the beds do not appear to be overturned more than are the same beds north of Hamilton Knob. West of the east knob of Ramsay Mountain, the rocks are broken by a pivot fault which was produced by torsion as well as by shear. West of this point the beds are upside down, as is shown by a small anticline in the inverted beds which areally appears as a syncline. This inversion has been accomplished by the rotation of the beds in a vertical plane through an arc of about 60°. The writer was not able to discern in the field whether the overthrust Rome and Elbrook formations were involved in this structure. If these masses were involved, it would seem probable that an infolded belt of Cambrian should occur immediately north of the mountain, but its absence might indicate that the inversion of the beds of Ramsay Mountain did not involve the overthrust masses but took place prior to the formation of the Draper Mountain anticline.

Overthrust faulting has occurred in the beds at the west and northwest ends of Ramsay Mountain. That these faults had considerable displacement is evidenced by a klippe of Clinch sandstone, Onondaga chert, and Marcellus black shale which caps the conical hill north of the railroad tracks and east of Miller Creek, half a mile northeast of Max Meadows. (See Pl. 20B.) The horizontal displacement of the faults in Ramsay Mountain probably do not exceed 2,000 feet. The change in strike of the strata between Poletown and Max Meadows indicates that there was differential rotation in a horizontal plane of the rocks of Ramsay Mountain and that the structures of the Draper Mountain area articulate with the older structures north of Max Meadows.

FENSTERS

A fenster is an exposed portion of overridden rocks which is surrounded by an overthrust mass; that is, erosion has cut through the overthrust sheet into the underlying rocks. A breached fenster is one still mostly surrounded by part of an overthrust block. The development of fensters is more or less confined to areas of low-angle overthrust faulting. The simplest type of fenster is produced by low-angle thrust faulting followed by deep erosion. The other type of fenster is produced by low-angle thrusting, followed by crenulation of the fault plane, and erosion subsequent to both of these deformations. To distinguish the two types, the writer proposes to call those involving the additional factor of folding, "anticlinal fensters."

The Draper Mountain autochthon is a breached, anticlinal fenster which has been formed by the crenulation of two thrust sheets and subsequent erosion through both of them. The younger of the two overthrust masses, the Max Meadows sheet, has been almost eroded from the northwest side of Draper Mountain, but destruction of the older mass, the Pulaski sheet, has been only partial. As Campbell[74] pointed out, Draper Mountain was once a true fenster. At that time, the Rome and Elbrook formations were continuous between Max Meadows and Pulaski. At the present stage of dissection, the Draper Mountain autochthon is a breached, anticlinal, compound fenster.

The narrow elongate area of Elbrook almost surrounded by the Max Meadows overthrust sheet of Rome is also a breached, anticlinal, fenster. The Elbrook near Graham School can be similarly interpreted. The narrow band of Elbrook east and west of Fort Chiswell may be a similar feature, but further detailed mapping west of this area along the Lee Highway (U. S. No. 11), may show that this band of Elbrook is a fenster completely surrounded by the Rome formation.

[74] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 84-85, 1925.

THRUST ERRATIC NORTHEAST OF MAX MEADOWS

Just east of the point where the Gunton Park-Max Meadows road crosses the Bristol branch of the Norfolk and Western Railway, a bilobate area of Chemung sandstone and shale is completely surrounded by the Elbrook formation of the Pulaski overthrust sheet. The position of this area of Chemung is anomalous. It is not a fenster in the Pulaski overthrust sheet since the Price and Maccrady formations underlie the Pulaski overthrust in this vicinity, and if the Elbrook were stripped from the area north of the railroad tracks the Price and Maccrady formations would be exposed. Moreover, the dips and strikes of the Chemung, which vary within short distances, are wholly incongruous with the orientation of the Price and Maccrady formations. The Chemung, like the Elbrook, is intimately crumpled, fractured, and mangled. The contact between the Elbrook and the Chemung is very irregular, and north of the railroad, large local blocks of Elbrook appear to dovetail with crumpled wedges of Chemung shale and sandstone. The manner in which the Elbrook engulfs the Chemung obviates the possibility that the Chemung was thrust over the Elbrook. It is evident that the Chemung lies within the Elbrook and above the Pulaski fault.

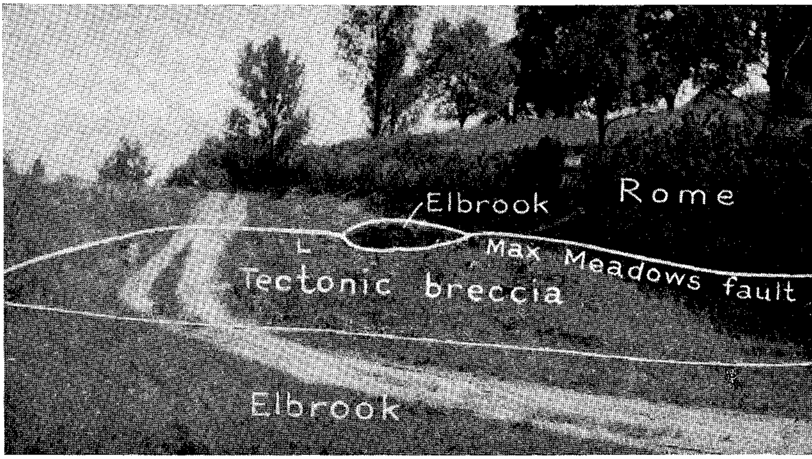
To the writer, the field relations necessitate the following conclusion regarding this area of Chemung which lies almost wholly within the Elbrook. As the Pulaski overthrust block advanced northwestward, irregular blocks or slices of incompetent beds were gouged or plucked from the overridden rocks, engulfed within the broken and fractured overthrust mass, and transported northwestward, thus resulting in the anomalous position and relations of the Chemung strata. The bottom of the block appears to rest upon the tread of the Pulaski fault. Butts[75] suggests, however, that the Pulaski fault may have cut down through the Mississippian into the Chemung.

The contact of the Chemung block with the surrounding Elbrook is a fault, but it is a type of fault heretofore undescribed.

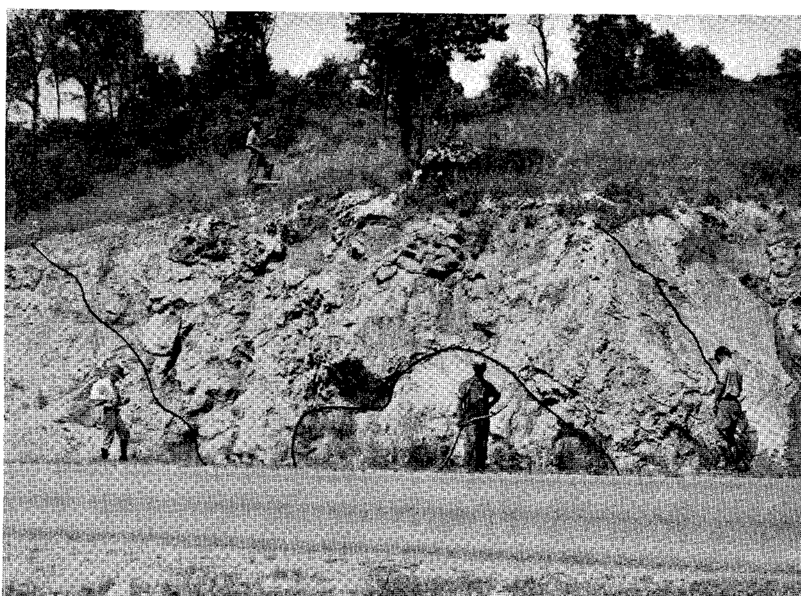
The foregoing interpretation is based upon an analogue—the acquisition, transportation, and deposition of erratics by glaciers. The overthrust sheet is analogous to an overriding glacier, whereas the Chemung block is comparable to a block of bedrock plucked by a glacier. For the structural feature which this outlier of Chemung typifies, the writer proposes the name, "thrust erratic," and for the irregular fault which bounds the Chemung block, the name, "pluck fault," is proposed.

Parts of the Elbrook beds of the overthrust mass appear to have become wedged in some of the overridden shales and separated from the moving overthrust mass. Wedged within the Marcellus shale east of Poletown are several "plugs" of Elbrook dolomite which appear to have had such an origin.

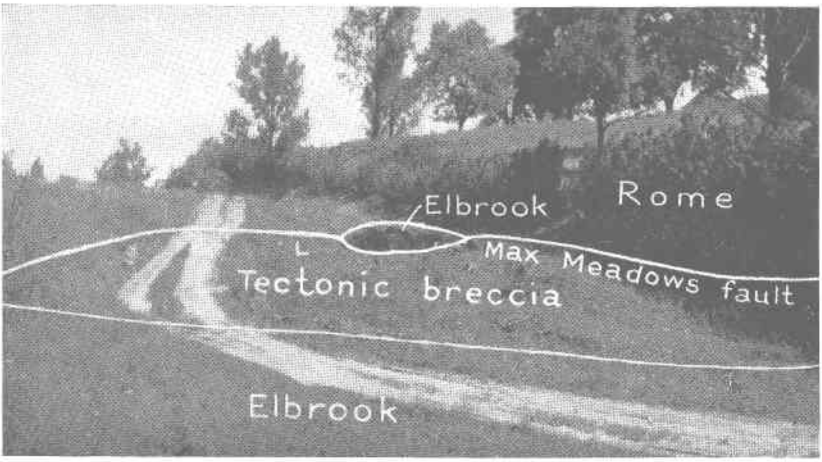
[75] Butts, Charles, personal communication.



A. Max Meadows fault and associated breccia, at west edge of the town of Max Meadows, Virginia.



B. Breccia zone in the Conococheague limestone, 4 miles west of Fort Chiswell, along the Lee Highway. Photograph by Arthur Bevan.



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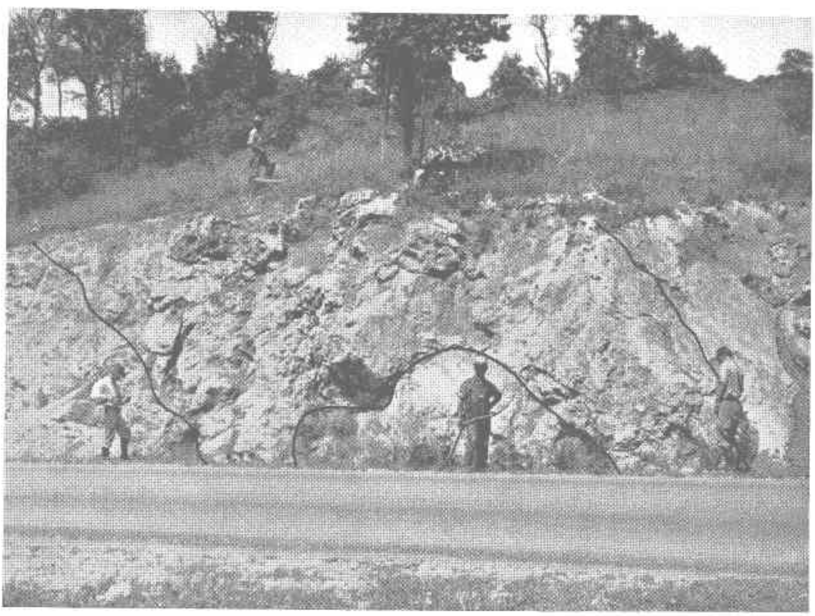
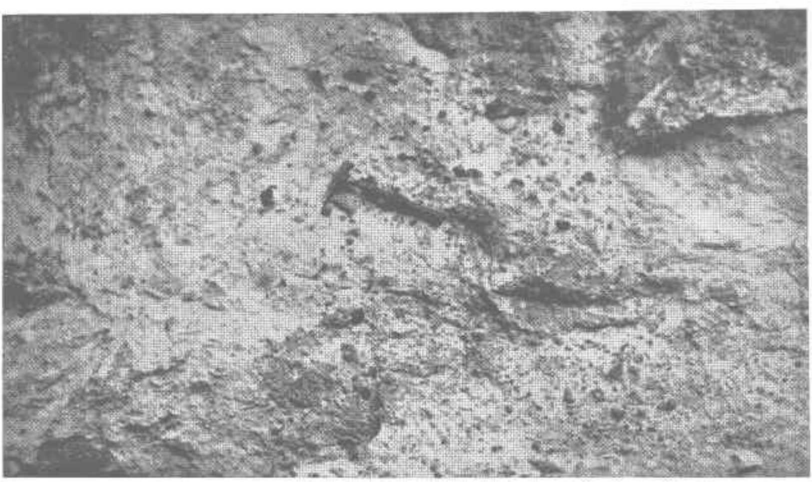


B. Breccia zone in the Conococheague limestone, 4 miles west of Fort Chiswell, along the Lee Highway. Photograph by Arthur Bevan.

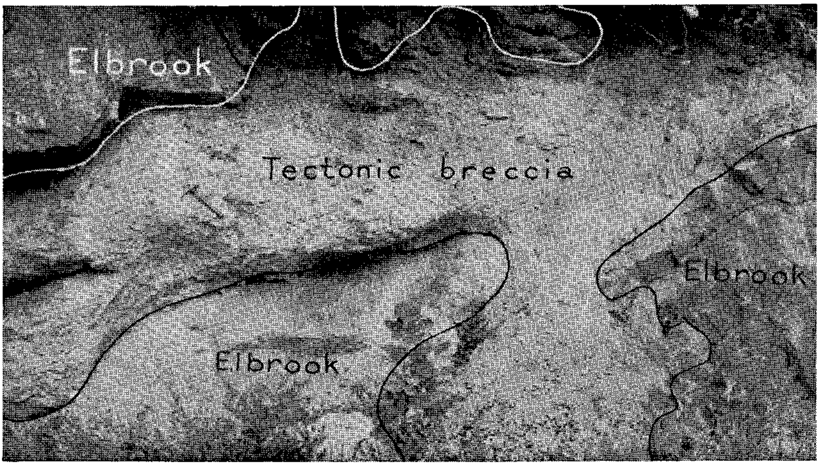
A. Folded tectonic breccia zone south of Horseshoe Bend. The gouge and breccia are well developed here. Photograph by Arthur Bevan.

B. Lithology of the tectonic breccia. Near view of breccia shown above.

A. Folded tectonic breccia zone south of Horseshoe Bend. The gouge and breccia are well developed here. Photograph by Arthur Bevan.

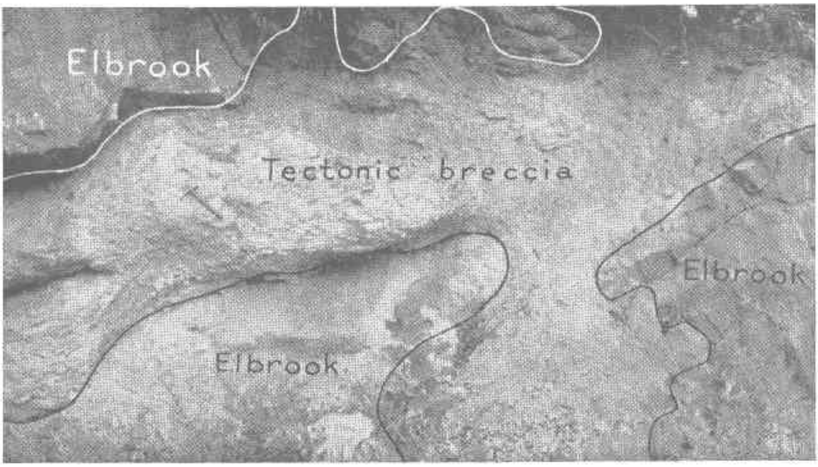


B. Lithology of the tectonic breccia. Near view of breccia shown above.

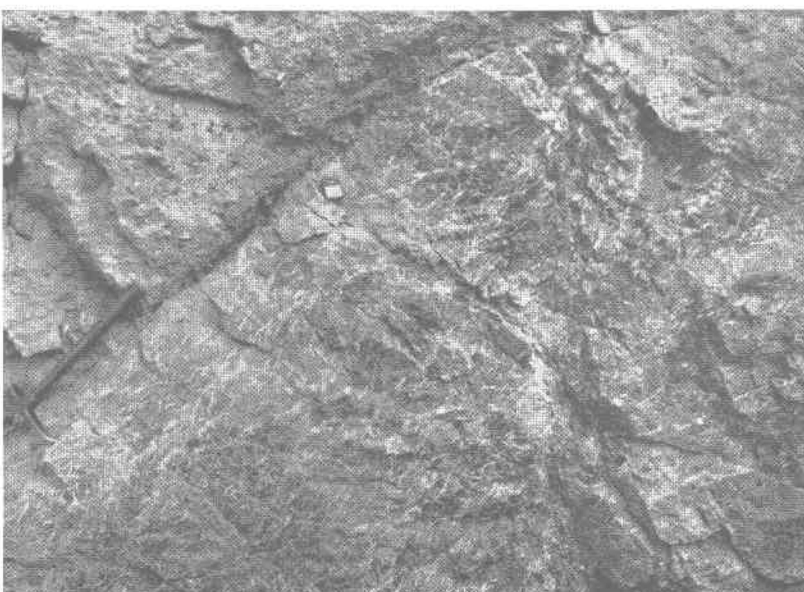


A. Tectonic breccia in Elbrook dolomitic limestone south of Horseshoe Bend, along Reed Creek.

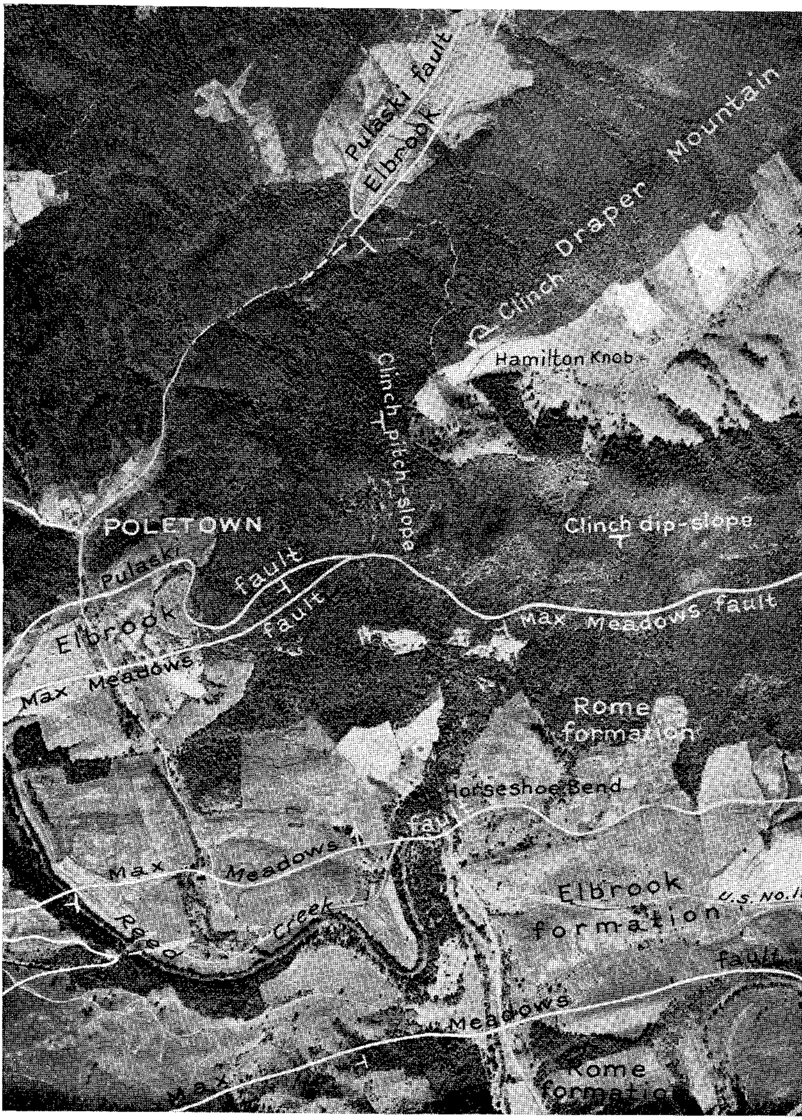
B. Sharp contact between breccia and greatly fractured Elbrook limestone along Reed Creek south of Horseshoe Bend. The hammer is along the contact. Photograph by Arthur Bevan.



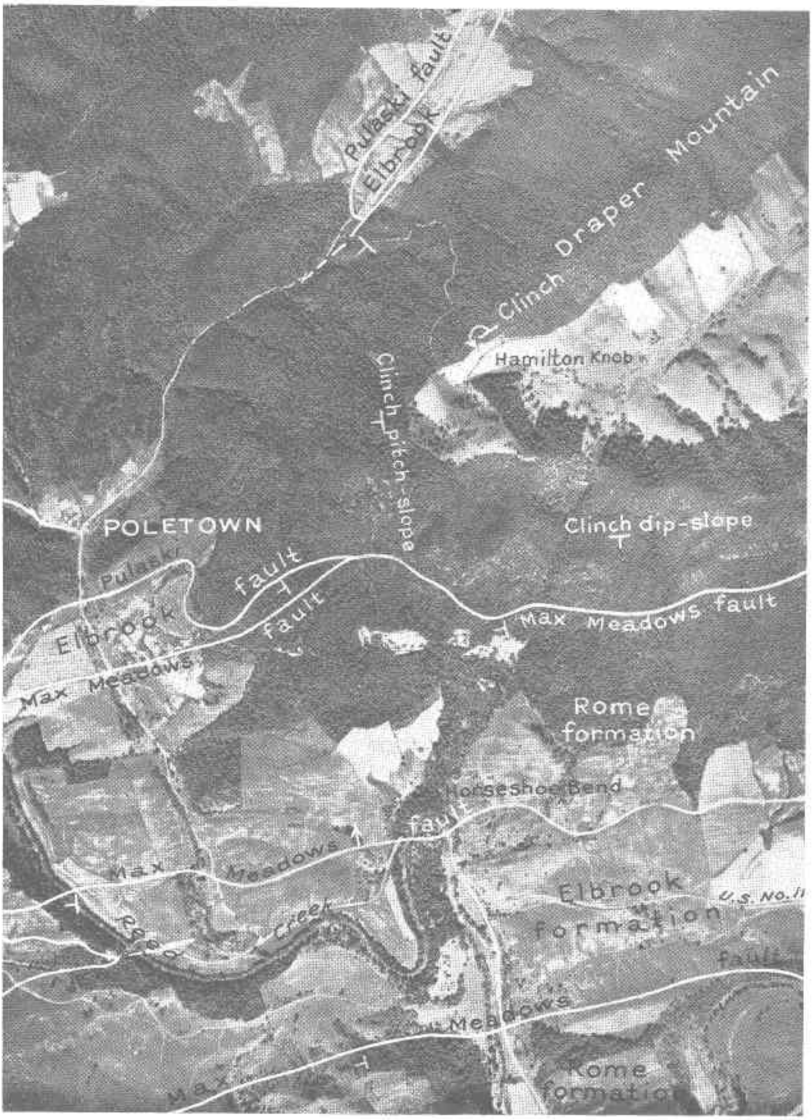
A. Tectonic breccia in Elbrook dolomitic limestone south of Horseshoe Bend, along Reed Creek.



B. Sharp contact between breccia and greatly fractured Elbrook limestone along Reed Creek south of Horseshoe Bend. The hammer is along the contact. Photograph by Arthur Bevan.



Aerial view of southwest end of Draper Mountain near Poletown. The Draper Mountain anticline plunges sharply east of Poletown. The structure is well shown in the Clinch formation which bounds the mountain slopes south and west of Hamilton Knob. The overthrust Rome and Elbrook formations south of the mountain are parts of the Max Meadows and Pulaski overthrust sheets, respectively. (Photograph courtesy of the U. S. Forest Service.)



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BANDS OF CAMBRIAN ROCKS NORTH OF DRAPER MOUNTAIN

A striking feature of the areal and structural geology of the Draper Mountain area is the presence of narrow belts of Cambrian rocks on the north side of Draper Mountain. (See Pl. 12.) These bands have been known for more than 50 years. McCreath and d'Invilliers[76] who first recorded their general distribution, interpreted them as Devonian and as representing limestone beds within the enclosing strata. Campbell and Holden discovered the fact that the limestone bands cut across formations, and that they were similar in lithology to the overthrust limestones northeast of Max Meadows. They reached the conclusion that the limestone belts north of Draper Mountain are isolated portions of the overthrust Cambrian rocks. They stated these conclusions as follows:[77]

"The conditions and movements which resulted in the engulfing of the thin band of Shenandoah [Cambrian] limestone in the Devonian sandstones and shales just north of Draper Mountain are difficult to conceive and the writers are free to confess that any explanation they may put forward is offered only as a suggestion, but with the hope that some other geologist may be able to suggest something very much better. The only explanation that the writers can offer is that after the great overthrust and before the rocks between Pulaski and Max Meadows had been folded as extensively as they are today, a narrow tongue of this limestone, in many respects probably resembling the limestone tongue extending from Max Meadows to Gunton Park, lay in a slight valley along the present course of the outcrop. If then we suppose that another epoch of folding ensued, it is conceivable that this tongue of limestone might have been so crushed by the shales and sandstones on its two sides that it was tilted on edge and really engulfed by the Devonian rocks,—in other words the softer rocks of the Devonian simply flowed about and almost concealed the resistant limestone mass."

The apparent key to the interpretation of these bands, all of which undoubtedly have the same origin, was discovered by the writer in Clayton Mine Hollow north of Peak Knob. From exposures in this ravine it is apparent that the entire Chemung formation is absent by faulting and the band of Cambrian rocks lies between the Price and the Millboro formations. This limestone band is bounded on the south side by an overthrust fault which represents a rupture in the northwestern limb of the Draper Mountain anticline. The band is bounded on the north side of the trace of the Pulaski and Max Meadows faults. The Cambrian beds, having been thrust over the Devonian and Mis-

[76] McCreath, A. S., and d'Invilliers, E. V., The New River-Cripple Creek mineral region of Virginia: pp. 1-177 and map, Harrisburg, Pa., 1887.

[77] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 84 and pl. 1, sections F-F' and G-G', 1925.

sissippian strata at the time of the Pulaski overthrust, were cut by an overthrust fault which developed in the northwestern limb of the Draper Mountain anticline and were buried as a portion of the overridden block of that fault. Thus a narrow wedge of Cambrian strata was buried beneath the Devonian rocks which were thrust over it. Subsequent erosion has planed off this overthrust block exposing the Cambrian strata. (See Fig. 4.)

This band of Cambrian rocks can be traced from Clayton Mine Hollow eastward for half a mile where it joins the main overthrust Cambrian mass which swings around the east base of Peak Knob. West of Clayton Mine Hollow, the band can be traced for about 1 mile, but a short distance farther west the trace of the fault which bounds the Cambrian band on the north bends slightly to the south, causing the limestone mass to lie wholly within the outcrop belt of the Brallier formation. The band can be traced still farther west to the head of Valley Branch. The point where it crosses U. S. Highway 11 is indicated by the abandoned ore pit on the east side of the road. Near the head of Valley Branch the Cambrian band is absent, but half a mile west of this point of disappearance it appears again and it is exposed in the wooded tract east of the Pulaski water reservoir. (See Pl. 19.)

The belt is represented by the Rome formation of the Max Meadows overthrust block as far west as U. S. Highway 11, but west of this point it is composed of Elbrook in the Pulaski overthrust block. Its outcrop is variously indicated by chert float, by secondary residual concentrations of limonitic iron which lie along the fault contacts bordering the band on either side, by limestone-derived soil, by red shale fragments in the soil, and by abandoned ore pits and prospect pits.

The stresses which resulted in the formation of the Draper Mountain anticline were not wholly dissipated by the development of this fold or by its sharp overturning. The unrelieved stresses caused the northwestern flank of the anticline to break locally. The resultant fault, or faults, broke through the overthrust rocks as well as the autochthonous strata, and a small wedge of Cambrian beds were caught and buried as a part of the overridden block below this fault. Subsequent erosion has revealed its presence.

Between Poletown and Summit Hill Church is another band of Cambrian rocks, apparently Elbrook limestone, which lies athwart the outcrop of the Chemung and Price formations. The writer interprets this band as having been formed in the same way as the more extensive belt to the northeast. He considers that the belt is bounded on the northwest by a trace of the Pulaski fault and on the southeast side by a small overthrust which represents a local rupture of the northwest limb of the Draper Mountain anticline. (See Pl. 17.)

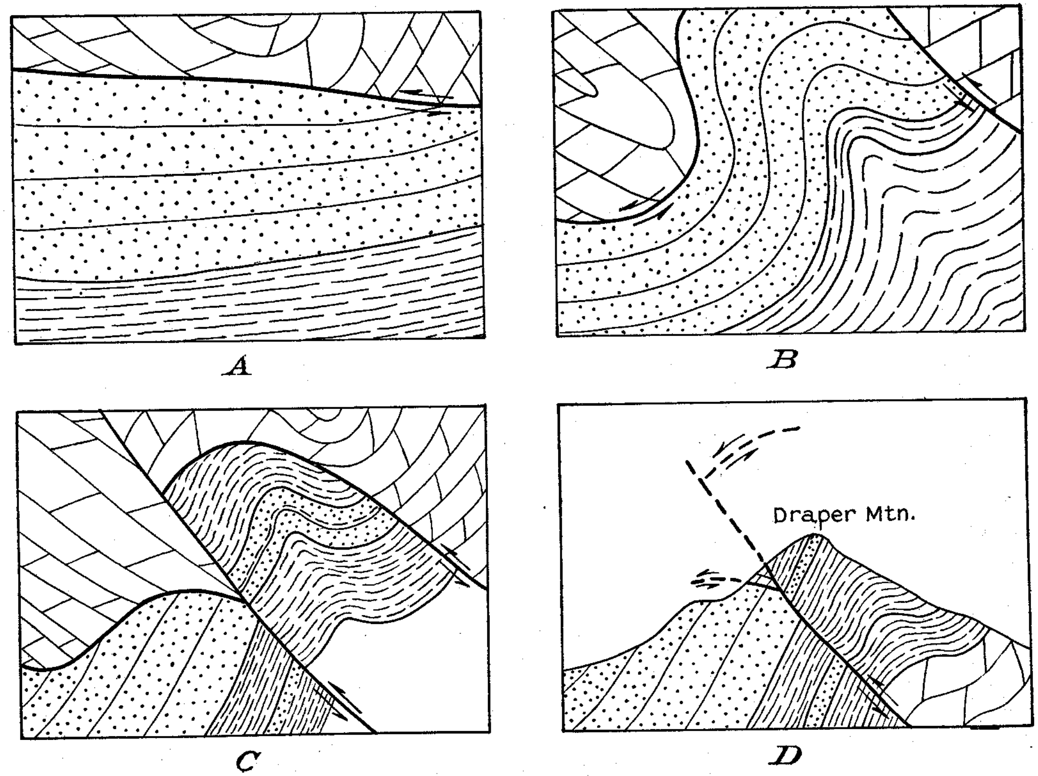


FIGURE 4.—Sketches illustrating the origin of the Cambrian belts north of Draper Mountain. A, Cambrian formations were thrust over Devonian and Mississippian rocks along the Pulaski and Max Meadows low-angle overthrusts (not shown), prior to the folding of the overridden strata. B, The overthrust sheets and autochthonous strata were folded, with the development of the Draper Mountain anticline. C, As a further relief to the stresses, a rupture developed in the northwest flank of this anticline, whereby Devonian shales were thrust along the Clayton Hollow fault, over parts of the Pulaski and Max Meadows overthrust masses. D, Erosion has removed all but a portion of the overthrust Cambrian rocks which were buried beneath the overthrust block of the later Clayton Hollow fault.

Campbell and Holden[78] believed that a narrow belt of Cambrian on the northwest side of Draper Mountain is practically continuous, but the writer found no evidence of this in the field. There is no fault around the base of Hamilton Knob as postulated by Campbell and Holden.[79] They believed that this band connected with the Cambrian formations south of Poletown.

KLIPPEN

Klippen are isolated remnants of overthrust blocks which have become detached from the main overthrust block by erosion. The development of klippen, like that of fensters, is confined to belts of low-angle overthrusting. Their importance to the interpretation of the structure of this area is equal to that of fensters, and by means of both of these features it is possible to ascertain roughly the amount of crustal shortening which has taken place between the Blue Ridge and Brushy Mountain.

The eastern terminus of Lick Mountain as mapped by the writer is believed to be a part of a great klippe. It is bounded by the trace of the great Poplar Camp Mountain (Blue Ridge) overthrust. This mountain was formerly considered to be an anticline, whereby the Erwin quartzite was brought into view. The recent detailed work of Currier[80] and others has proved that the mountain is a klippe. The part of this mountain mapped by the writer is bounded on the north and east sides by a fault. The Erwin quartzite rests upon the truncated edges of the Rome formation, and the Shady dolomite is absent due to faulting. Lick Mountain represents a portion of the last of the great overthrust sheets in the Valley which advanced to the northwest during the Appalachian orogeny. It overrode all of the other, older overthrust sheets, except possibly the Pulaski overthrust mass. To the writer, Lick Mountain represents an erosional remnant of an overthrust mass which at one time reached as far north as Max Meadows. The long period of time during which weathering and erosion have acted upon this klippe accounts in part for the disintegrated state of the Erwin quartzite east of Lots Gap.

The isolated belts of Cambrian strata north of Draper Mountain are klippen, but their history is more involved than is that of Lick Mountain. Their original isolation from the parent overthrust masses is due to subsequent overthrust faulting. A wedge of Cambrian rocks of the Pulaski fault was buried by the overriding block of Devonian rocks above the Clayton Hollow overthrust fault. Subsequent erosion

[78] Campbell, M. R., and others, op. cit., p. 53.
[79] Op. cit., pl. 1.
[80] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, p. 60, 1935.

of this overthrust cover has revealed the Cambrian rocks. For isolated portions of an overthrust mass such as these, the term klippe is neither descriptively adequate nor free from misleading structural implications. Simple klippen are formed as a result of low-angle overthrust faulting and subsequent erosion. The Cambrian bands north of Draper Mountain owe their presence to low-angle overthrust faulting, subsequent folding, and overthrust faulting of both the overridden and overthrust blocks, followed by erosion.

FORMER EXTENT OF THE OVERTHRUST MASSES

Just how far northwest the overthrust masses formerly extended is problematical. There is no indication that they reached farther northwest than the southwest slope of Brushy (Little Walker or Cloyds) Mountain. There are strong indications that the Tract Mountain anticline and all of the structures to the northwest were formed prior to the northwest advance of the Pulaski overthrust block. Moreover, field evidence shows that the Miller Creek syncline was likewise formed prior to overthrusting, since the advancing overthrust mass above the Pulaski fault mashed and sheared the southeast limb of this structure east of Miller Creek. The Pulaski overthrust mass advanced against a high structural barrier whose front was approximately coincident with the site of Brushy Mountain and Little Brush Mountain. The eastern end of the Tract Mountain arch was probably a salient of that ancient structural front, which was overridden before the main body of the overthrust Pulaski block impinged against the principal structural barrier.

There is good reason to believe that the Lick Mountain area is a klippe of the Poplar Camp Mountain overthrust block. In harmony with what has already been said regarding the former extent of Lick Mountain, the writer believes that the Poplar Camp Mountain overthrust block once reached at least as far northwest as the site of Max Meadows. Butts[81] dissents from the above interpretation. He states:

"There are considerations that oppose this conclusion. The Pulaski thrust mass must have carried all the post-Rome formations at least up to the Maccrady. These were probably at least 20,000 feet thick. To assume that the thrust block reached only to its present northwest limits implies that erosion kept about an equal pace with the advance of the block during a time sufficient to remove all the superjacent beds and keep the front stationary at the assumed limit. It seems far more probable that all of the overthrust blocks, including the Pulaski, at the time of their maximum extent, extended far to the northwest, beyond the present traces of their fault planes. It must be rememberd that if

[81] Butts, Charles, personal communication.

the deformation began in the late Paleozoic, there has been at least 200 million years for the deformation and erosion to have brought about present conditions."

MINOR STRUCTURES

FOLDS

The Draper Mountain area, like any other Appalachian area, contains a countless number of small minor folds which are subsidiary minor effects attending the formation of the larger, major folds and overthrust faults. These structures are of interest and of importance in working out the larger structures to which many of them are related. The folding and crumpling of the Elbrook and Rome are apparent wherever these formations are exposed at the surface. The Athens, Chambersburg, and Martinsburg formations are composed of incompetent strata, which have been contorted into intricate drag folds.

FAULTS

Like any other Appalachian region, the Draper Mountain area abounds in normal faults of small displacement. These are especially well developed in the overthrust Cambrian rocks, particularly within the Rome formation. Overthrust faults of small displacement are exposed just east of the bridge over Reed Creek east of Max Meadows. Here the *Orthorhynchula* zone of the Martinsburg formation overlies the Marcellus member of the Millboro shale. Numerous small overthrusts within the Brallier shale are exposed along the road from Poletown to Max Meadows. Similar overthrusts are common within the Rome, Martinsburg, Millboro, Brallier, Chemung, and lower Price formations, all of which contain a large number of incompetent beds.

JOINTS

The diverse orientation of the joints in the Elbrook and Rome formations is in keeping with the complex structural history of the strata of the overthrust blocks. The rocks of the Draper Mountain autochthon have four distinct sets of joints. Two of them are at variable angles to the bedding, and one is parallel to the bedding. One set strikes approximately N. 30-50° W. and is perpendicular to the bedding planes. These joints are at right angles to the trend of the structures and were produced by tension acting parallel to one direction of elongation of the beds, that is, parallel to the trends of the folds. Two other sets parallel in strike the beds which they cut. These are inclined generally at angles of more than 45° to the bedding, intersecting each other at right angles, and are shear joints. The fourth set is parallel to and coincident with some of the bedding planes. They are the surfaces along which one or more beds have sheared with respect to beds above and below them. They may be easily confused with bedding.

CLEAVAGE

Fracture cleavage and flow cleavage are well developed within the phyllite zone of the Rome, which borders the trace of the Max Meadows fault, particularly north of the Fort Chiswell monument, where it obliterates the bedding. The basal Martinsburg siltstones and sandstones, which are involved in the drag folds of the Crocket Knob syncline, show flow cleavage. The Chambersburg formation has a peculiar type of cleavage which has been developed as a result of the nodular character of the rock itself. The long, lenticular nodules of the Chambersburg beds have been reoriented so that the planes of their greatest diameters are parallel to the axial planes of the folds. (See Pl. 21.)

SUMMARY OF TECTONIC HISTORY

All of the folded and faulted structures of the Draper Mountain area can be interpreted on the basis of one epoch of deformation of which several successive episodes can be recognized. There is no evidence in this area of cross folding of Appalachian structures subsequent to their formation, as postulated by Mathews.[82]

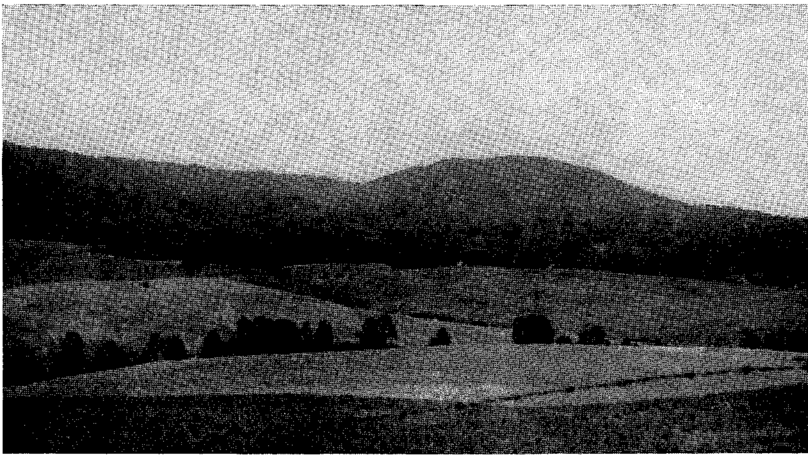
The Draper Mountain area affords no new data on the problem of the date of the Appalachian orogeny. More important is the sequence of events that produced the structures of this area. The distinguishable episodes of this epoch of deformation in the Draper Mountain area may be summarized in chronological order so far as possible, as follows:

1. Folding of the Appalachian tract as far southeast as the sites of Brushy and Little Brush mountains.
2. Formation of the Pulaski overthrust and the northwestward advance of the Pulaski overthrust mass, which ultimately impinged against the structural front already developed, north of Pulaski.
3. Rupture of the Pulaski overthrust mass, with the formation of the Max Meadows overthrust, followed by the formation of the Laswell and Sugar Grove overthrusts, in turn followed by the formation of the Blue Ridge overthrusts, producing the regional schuppen structure between the Blue Ridge and Brushy Mountain.

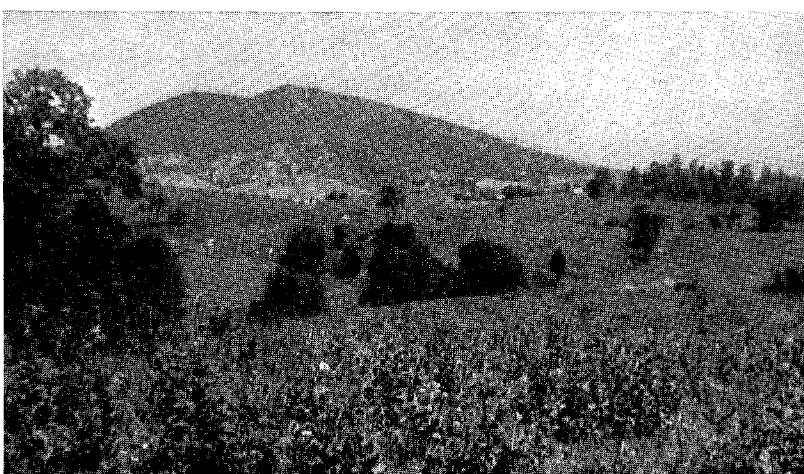
[82] Mathews, A. A. L., New lights on Giles County structure: Virginia Acad. Sci. Proc. for 1931-1932, p. 61, 1932.

4. Folding and faulting of all of the rocks of the Draper Mountain area, including the overthrust masses.

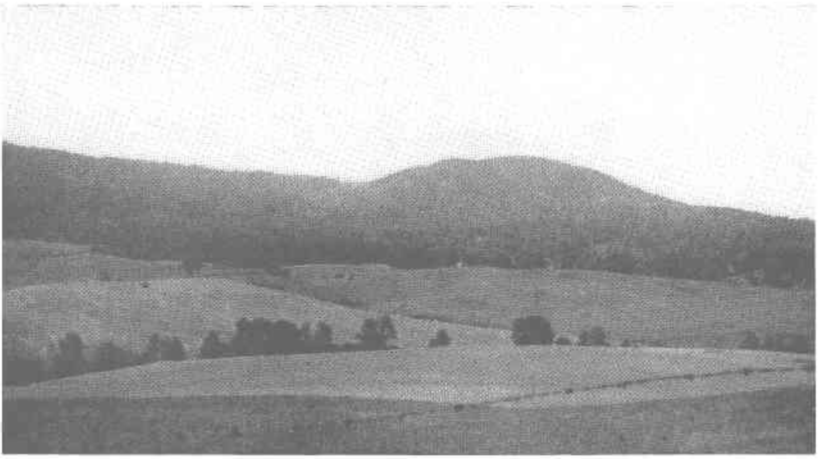
5. Discontinuous (?) rupture of the northwestern limb of the Draper Mountain anticline.



A. Crocket Knob, as seen from the Graham Forge road 1 mile south of the Lee Highway. This knob is a remnant of a synclinal mountain which once extended northeast to Peak Knob.



B. Peak Knob, looking north from a point 1½ miles northeast of Draper. The gentle slope east of Peak Knob represents the east pitch of the anticlinally folded Clinch sandstone.



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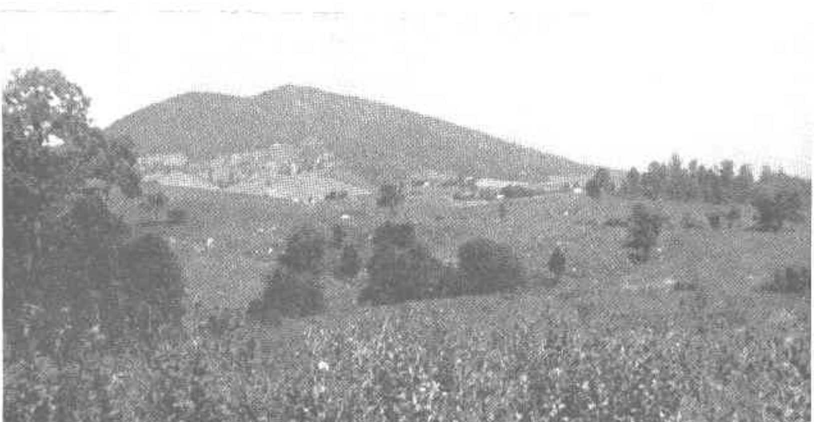

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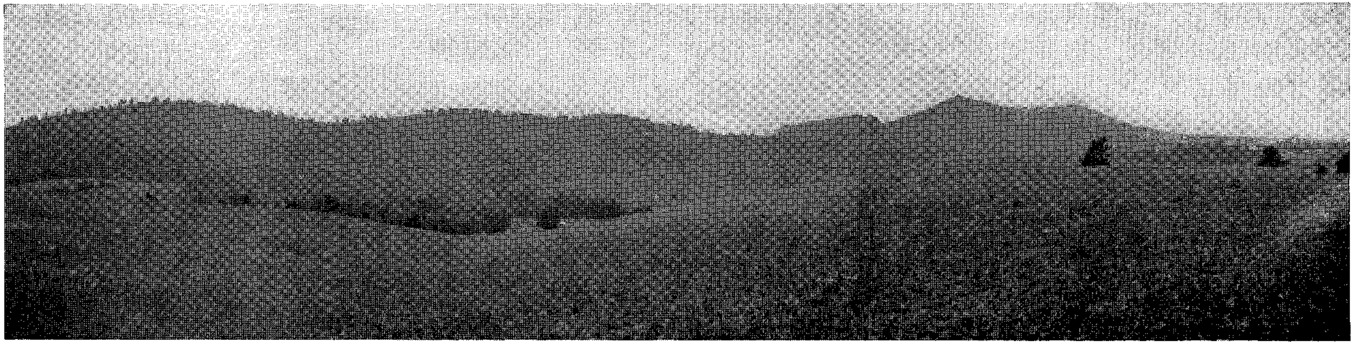
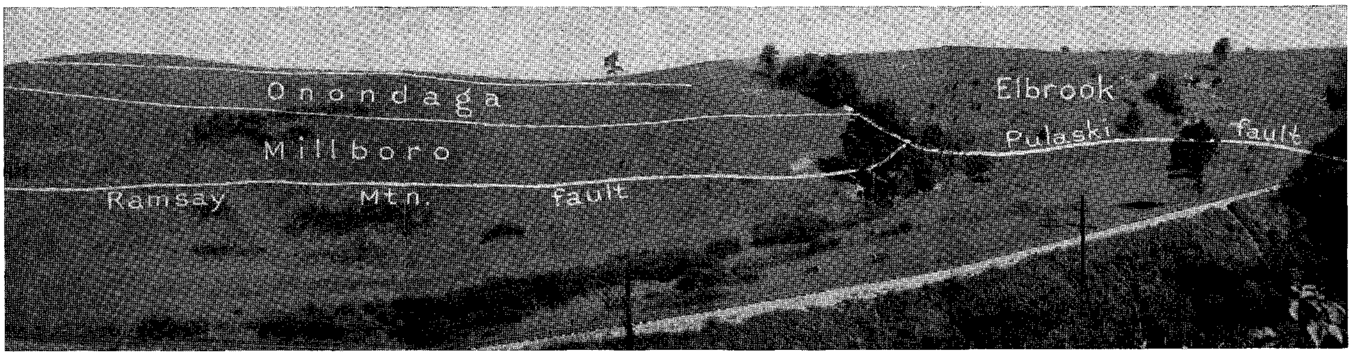
Aerial view of the area southwest of Pulaski. Caseknife Ridge is made by resistant beds in the Price and Chemung formations. The low ridges in the southeast corner are part of the line of Martinsburg foothills which border Draper and Connor valleys on the southeast. (Photograph courtesy of the U. S. Forest Service.)

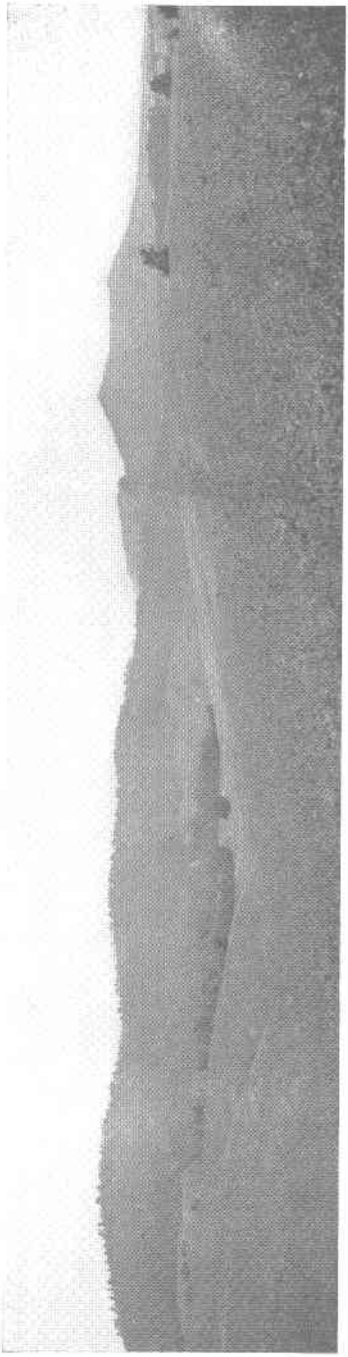
Aerial view of the area southwest of Pulaski. Caseknife Ridge is made by resistant beds in the Price and Chemung formations. The low ridges in the southeast corner are part of the line of Martinsburg foothills which border Draper and Connor valleys on the southeast. (Photograph courtesy of the U. S. Forest Service.)



A. Ramsay Mountain, on the left, is a low ridge on overturned Clinch and Onondaga beds. Hamilton Knob, the high point on the right, marks the western convergence of the ridges of Draper Mountain.



B. The conspicuous hill north of the railroad tracks in the east environs of Max Meadows is a klippe of rocks overthrust along the Ramsay Mountain pivot fault. The Clinch is exposed in a few places at the top of this hill. Where the Pulaski and Ramsay Mountain faults intersect, the trace of the latter fault bends abruptly and follows around the base of the other side of the hill. The Pulaski fault continues beneath the hill and crops out again at the southwest end of the hill. The rocks in the foreground are upper Brallier shales.



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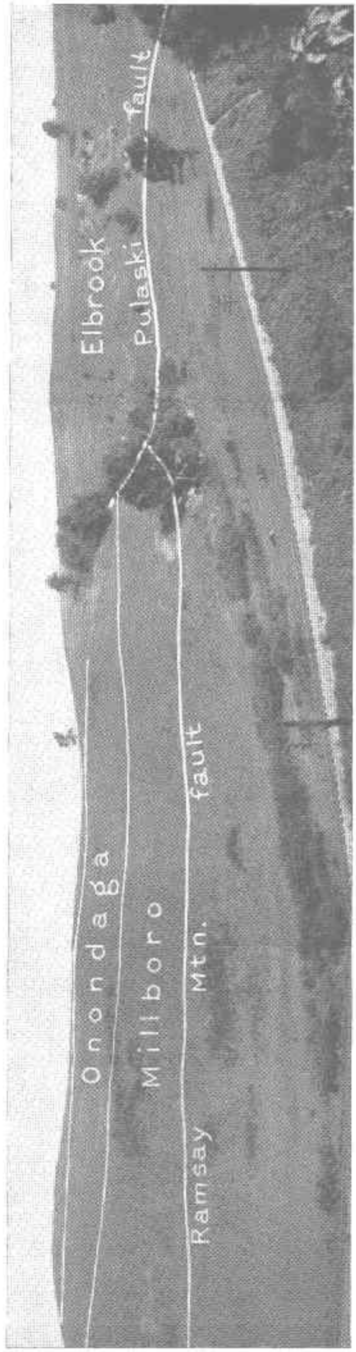

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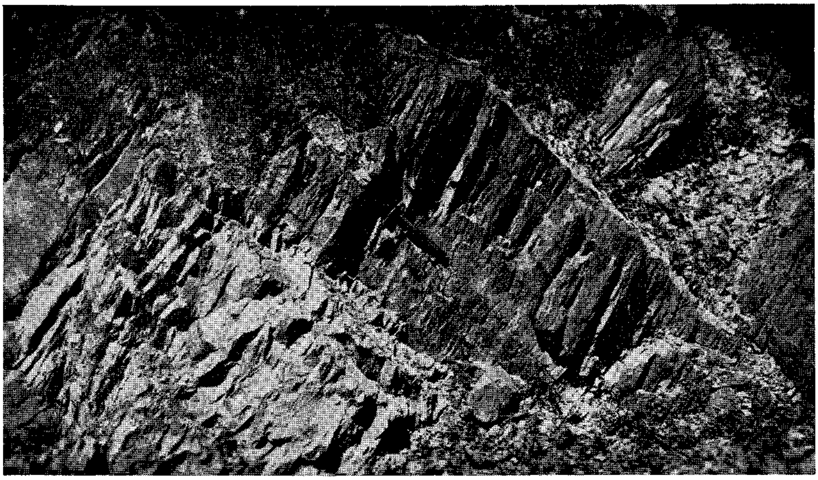
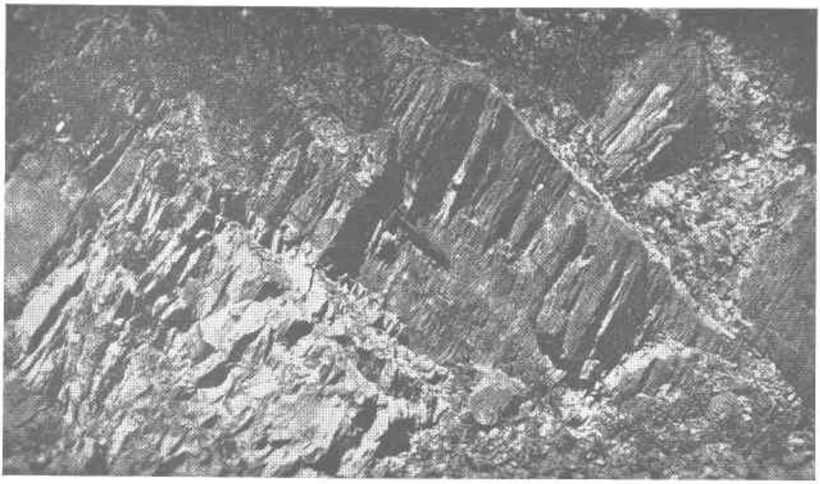
A. Nodular flow cleavage in the Chambersburg limestone, along the Lee Highway south of Draper Valley.



B. Fracture cleavage in the lower Martinsburg sandstones and shales, in the vicinity of Connor Valley School.

A. Nodular flow cleavage in the Chambersburg limestone, along the Lee Highway south of Draper Valley.



B. Fracture cleavage in the lower Martinsburg sandstones and shales, in the vicinity of Connor Valley School.

PHYSIOGRAPHY

EROSION SURFACES

GENERAL STATEMENT

The dissected erosion surfaces of the Draper Mountain area are no doubt related to those of adjacent areas. The regional geomorphology of this part of the Appalachian Valley has been adequately discussed by Wright[83] who has summarized and revised the conclusions of previous investigators. The general physiographic setting of the Draper Mountain and adjacent areas has been given by Stose.[84]

REMNANTS OF THE SCHOOLEY (UPLAND) EROSION SURFACE

The Schooley level is the highest and the oldest erosion surface which can be recognized in this part of the Appalachian region. Remnants are confined to the conspicuous knobs above the more or less even-crested ridges of Draper Mountain, at both ends of the mountain. Crocket Knob and Hamilton Knob, which rise above Connor Valley, are about 3,100 feet above sea level. Peak Knob, at the northeastern end of Draper Valley, rises 1,000 feet above the valley floor to an altitude of 3,376 feet. These three monadnocks are comparable in altitude to the local remnants of the Schooley peneplane recognized by Wright[85] in the vicinity of Hillsville, Va. (See Pl. 2.)

REMNANTS OF THE HARRISBURG (VALLEY) EROSION SURFACE

The even-crested summits of the main ridges of the Draper Mountain area and the more or less accordant levels of an undulating lowland surface below the ridge crests are both parts of the Harrisburg erosion surface. The even-crested ridges stand 200 to 500 feet above the lowland level. Many writers have interpreted the crestline of the ridges as an intermediate and separate erosion surface older than the Harrisburg level. The writer agrees with Wright that the ridge crests are of the same age as the accordant, dissected lowland surface below the ridges. The lowland was developed on easily eroded Cambrian-Ordovician limestone and shale belts, whereas the ridges are supported by resistant sandstone formations. The difference in elevations of the lowland surface and the ridges is a measure of the relative resistances to erosion of the rocks supporting the two levels, and is not an indication of two separate

[83] Wright, F. J., The older Appalachians of the South: Denison Univ. Bull., Jour. Sci. Lab., vol. 24, pp. 145-246, 1934; The newer Appalachians of the South: Idem, vol. 26, pp. 1-105, 1932.

[84] Stose, G. W., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 8-10, 1922.

[85] Wright, F. J., The older Appalachians of the South: Denison Univ. Bull., Jour. Sci. Lab., vol. 24, pp. 159-160, 1934.

erosion levels as formerly postulated. Thus interpreted, the ridges of the Draper Mountain area are benches or erosion outliers on the Harrisburg lowland erosion surface. The terminations of the Draper Mountain ridge west of Hamilton Knob and east of Peak Knob are identical with the pitch of the ridge-making Clinch formation. These are examples of the structural control of parts of the Harrisburg erosion surface. (See Pls. 22A and 22B.)

The ridges of Draper and Brushy mountains and of Caseknife Ridge are accordant in elevation. Ramsay and Little Brush mountains are considerably lower, although they are maintained by the same resistant formations. Structurally, Little Brush Mountain is a part of Brushy Mountain and Ramsay Mountain is a continuation of Draper Mountain. Ramsay and Little Brush mountains are lower because of the thinness and low dips of the ridge-making formations. The writer interprets the levels of Little Brush and Ramsay mountains as another bench level above the general Harrisburg surface. In summary, the more or less accordant levels at elevations of 2,600 to 2,800 feet, 2,400 feet, and 2,200 feet are remnants of the Harrisburg erosion surface.

POST-HARRISBURG EROSION

By the close of Harrisburg time, the extensive area east, south, and west of Draper Mountain had been reduced to a broad valley lowland. (See Pl. 2.) On this surface meandered New River and its tributaries, Peak Creek and Reed Creek. Subsequent rejuvenation of New River has caused that stream to entrench its course in this part of the State 200 to 300 feet below the Harrisburg lowland surface. Renewed erosion and entrenchment in the tributary valleys of Reed and Peak creeks has dissected much of the old Harrisburg lowland surface into a mature topography with a relief of some 200 feet. At the present stage of this cycle Reed Creek has entrenched itself as far upstream as Max Meadows and flows in a meandering gorge about 200 feet deep. West of Max Meadows, it flows in a comparatively broad valley flanked on either side by low, but conspicuous, terraces. The stream profile of Reed Creek between Max Meadows and its junction with the New River slopes 11.6 feet per mile, whereas the profile gradient between Max Meadows and Wytheville (13½ miles upstream) is only 4.9 feet per mile. This interrupted profile indicates that the valley bottom of Reed Creek below Max Meadows is post-Harrisburg in age, and suggests that the upper part of the stream above Max Meadows is still flowing in a valley established during Harrisburg time. Peak Creek has been entrenched a similar distance headward from its mouth. (See Pl. 22C.)

DIFFERENCES IN DEGREE OF DISSECTION OF THE HARRISBURG LOWLAND SURFACE

That part of the Draper Mountain area south of Little Brush Mountain and west of Reed Creek is a gently rolling tract underlain by the Rome and Elbrook formations of the Max Meadows and Pulaski overthrust masses. The same type of topography is developed in the Cambrian-Ordovician limestone and shale terranes south of Draper Mountain and east of Reed Creek; however, the Rome area east of Reed Creek is more intricately dissected than the limestone areas to the north or the shale and limestone areas west of the stream. This contrast is strikingly shown on the Max Meadows topographic sheet.

Although the Rome formation is present in most of the area west of Reed Creek, it is only a thin veneer over the Elbrook. The drainage of this area is largely by underground streams developed in the Elbrook. This conclusion is supported by the absence of permanent tributaries of Reed Creek, by the presence of numerous sink holes, and by the scarcity of intermittent streams. The limestone terranes north of Draper Valley Church and Graham School and south of Draper Mountain are also drained by underground streams and by a few intermittent streams. The areas drained by these underground streams have a topography with gently undulating divides and wide valleys. On the other hand, the extensive area of Rome east of Reed Creek is covered by a thick mantle of that formation. The drainage of this area is by means of permanent surface streams. The intermittent and the underground streams which flow southward over the limestone and dolomite belts north of Draper Valley Church and Graham School become permanent surface streams immediately upon entering the Rome belt of outcrop. Where the underground streams come to the surface, conspicuous "boils" and pools are formed, and in every instance they are found within a short distance of the contact between the Rome and younger formations. The surface streams of the extensive Rome area have had a more pronounced erosional effect upon the Harrisburg erosion surface than have the scarce, intermittent streams and the abundant underground streams of the areas to the north and west. Also, the thick mantle of Rome east of Reed Creek has permitted the development of a knobby topography such as is characteristic of Rome belts in the southern Appalachian region. The contact between the Rome and the overthrust Patterson limestone member of the Shady formation marks another topographic break south of which a gently undulating surface is present. The sharp contrasts within the belts of overthrust Cambrian formation are largely due to the anomalous structural position of the Elbrook and the Rome formations. The sharp, intricate dissection of the Harrisburg lowland surface east of Reed Creek may be due in part to New River.

Other sharp contrasts in topography are present where the overthrust Rome and Elbrook formations lie in contact with resistant formations of the Draper Mountain autochthon. These numerous somewhat anomalous topographic features are related to geologic structures, wherein beds of widely different ages and of variable resistances to erosion have been brought into contact by low-angle thrust faulting, and they were carved during Harrisburg and post-Harrisburg times.

GEOLOGIC AGE

Until recently, it was generally believed that the Schooley erosion surface was Cretaceous in age. The various erosion levels below that of the Schooley have been interpreted as Tertiary and Pleistocene in age. As a result of a critical restudy of Appalachian geomorphology by Shaw,[86] Knopf,[87] Ashley,[88] and others, it appears that the oldest recognizable peneplain probably is not older than Miocene or Pliocene. If this is true, practically all of the topographic features of the Draper Mountain area have been carved by erosion since late Tertiary time.

[86] Shaw, E. W., Ages of peneplains of the Appalachian province: Geol. Soc. America Bull., vol. 29, pp. 575-586, 1918.

[87] Knopf, E. B., Correlation of the residual erosion surfaces in the eastern Appalachian Highlands: Geol. Soc. America Bull., vol. 35, pp. 633-668, 1924.

[88] Ashley, G. H., Age of the Appalachian peneplains: Geol. Soc. America Bull., vol. 41, pp. 695-700, 1930.

MINERAL RESOURCES

GENERAL STATEMENT

Although the Draper Mountain area has been the site of considerable prospecting and mining, no comprehensive survey of its mineral resources has been made. A knowledge of the geologic relations and of the economic importance of these resources would have saved considerable money and perhaps would have made profitable their exploitation on a smaller scale.

IRON

Where the Rome formation of the Max Meadows overthrust block rests in contact with Silurian and Devonian formations of the Draper Mountain fenster there are locally secondary, residual concentrations of limonite. The fault contact between the overthrust and overridden blocks has been the locus of secondary concentration of iron compounds which were derived from the rocks of the overthrust mass. It is probable that much of the iron was derived from the Rome formation which lies directly above the fault, as the red Rome beds contain 3 to 5 per cent of hematite. Since there is considerable thickness of this material on the lower slopes of Draper Mountain, it is possible that all of the secondary concentrations along the Max Meadows fault plane were derived from the Rome formation.

The limonitic concentrations are large irregular shaped masses. Reniform and botryoidal structures are common. The chief impurity is silica, in the form of chert and drusy quartz. Manganese oxides and titanium compounds are present in quantities of less than 1 per cent. Phosphorus compounds are present locally in small quantities. Holden[89] gives the following analyses of ore samples from the Draper Mountain area:

Analyses of iron ores from the Draper Mountain area, Virginia

	1	2	3
Metallic iron	41.12	53.46	37.54
Metallic manganese	.51	.40	1.55
Phosphorus		1.22	.34
Silica		4.58	18.79

1. Sample of ore from the Clayton mine, dried at 212° F.
2. Sample of ore from the Peak Knob mines, dried at 212° F.
3. Sample of ore from the Locust Hill mine, analyzed in natural state.

[89] Holden, R. J., Iron, *in* Watson, T. L., Mineral resources of Virginia, pp. 451, 459. Lynchburg, Virginia: Virginia Jamestown Exposition Commission, 1907.

Within the Draper Mountain area there are several abandoned iron mines from which considerable quantities of ore have been taken. None of these has been worked within the last 12 years and some of the larger ones have been abandoned for more than 20 years. Most of the abandoned mines were examined by the writer.

Locust Hill mine.—The Locust Hill mine, the largest former producer of iron ore in this area, is located on the south slope of Draper Mountain, south of Hamilton Knob, about 3 miles southeast of Max Meadows. The old workings are along the fault contact between the Rome and Clinch formations. It appears that the ore was mined from a zone 50 to 100 feet wide. There are several small refuse piles which contain limonite ore of low grade and chertified shale. Formerly, a narrow-gauge railroad extended from the mine to Poletown, where the ore was washed and crushed. The treated ore was then transported over a narrow-gauge railroad to Max Meadows where it was smelted. The amount of ore taken from the mine during the period of its activity is unknown to the writer; however, sufficient ore was extracted to run for many years the old smelter in Max Meadows. According to several apparently reliable reports, operations in the Locust Hill mine were not abandoned because of lack of available ore but rather because of insufficient operating profit. There is still considerable equipment, near the old washer and crusher sites as well as near the mine itself.

Peak Knob mines.—The Peak Knob mines comprise several small mines along the trace of the Max Meadows fault on the northeast end of Draper Mountain, east of Peak Knob, which have been worked for iron ore. The principal workings are located some 200 yards southwest of the point where State Highway 99 crosses the tracks of the Galax branch of the Norfolk and Western Railway, and appear to have been along the fault contact of the Rome with the Clinch and Onondaga formations. Approximately 10 tons of hand-picked ore was on the ground at the time of the writer's visit. Most of the ore was extracted from shallow open pits, but the quantity recovered is not known. Apparently the highest grade of iron ore mined in this area came from the Peak Knob workings.

Clayton mine.—The Clayton mine is located 1¾ miles southeast of Pulaski in Clayton Mine Hollow. The Cambrian shales occupy a narrow band which is bordered on the north by the lower part of the Price formation. The chief workings appear to have been along the south side of this Cambrian shale belt near the Clayton Hollow fault. According to several reports this mine was at one time a good producer, but it has been abandoned for many years.

Pulaski mines.—The old workings of the Pulaski mines are visible from the Lee Highway (U. S. 11), about a mile south of Pulaski. The largest of these openings is located just east of the highway and extends eastward for about 250 feet. Several smaller pits are located west of the highway. The workings are located along the same narrow belt of Cambrian rocks which occur in Clayton Mine Hollow, but the workings near the highway are along the fault contact between the Brallier shale and the Rome shale. Considerable limonite crops out in the wooded area just north and east of the main opening east of the highway and fragments of ore are exposed in the bottom of the opening. According to a former foreman, after obtaining several thousand tons of ore, work was stopped due to the presence of large masses of "limestone" across the band of ore. Possibly the "limestone" was some silicified sandstone from the Brallier formation.

Other mines and prospects.—About 150 yards south of the point where the Gunton Park-Poletown road crosses the north fork of Brown Lick Branch there are several shallow pits and dump piles containing fragments of limonitic iron ore and chertified limestone. This prospect may be the Henson mine mentioned by Holden.[90] It has been abandoned for more than 30 years. A short distance west of the point where the same road crosses the south fork of Brown Lick Branch there are several small prospect pits, all of which are more or less hidden by dense growths of underbrush. A few pieces of iron-stained sandstone and shale were found near one of these pits, which are not located along the fault between the Cambrian and the Price formations.

There are several old abandoned ore pits along the contact between the Elbrook and Price formations 150 yards south of Gunton Park Station. Local refuse piles contain chertified limestone impregnated with stringers and irregular masses of limonite and pyrolusite. The small size of these workings indicates that little ore was extracted from them.

Summary.—Some of the old iron mines have yielded considerable ore which was treated and smelted in Max Meadows and Pulaski. At one time three furnaces were in operation in the town of Pulaski and another was in operation in Max Meadows. These furnaces were a mainstay of industrial activity in these two communities for more than 20 years. All of the mines and furnaces have been abandoned and the furnaces dismantled for several years now.

[90] Holden, R. J., op. cit., p. 459.

COAL

The coal deposits of this area have been treated by Campbell[91] and others who were fortunate enough to visit the mines when they were in operation. Not a single shaft or mine entry is now open, although there are many abandoned mines and prospect holes within the Draper Mountain area which were described and interpreted by Campbell. The reader is referred to his report for descriptions and locations of mines and prospects.

The writer has mapped the outcrops of the coal beds in the Price formation in this area, and the areal distribution of the coal-bearing part is indicated on the geologic map (Pl. 1). A new opening in coal beds of the Price formation on the Logdell Carwheel Company's property in Cove Hollow was visited by the writer with Mr. G. L. Armbrister. The new mine is about 1½ miles west of the Miller Creek road, and is reached by a dirt road which leads westward into Cove Hollow at the forks of Miller Creek. A prospect hole driven along the strike of the lower of two exposed coal beds showed 5 feet 5 inches of good semi-anthracite coal. The coal appears to be much more regular in thickness than is generally true of coal beds in this area. At this place the coal beds dip 23° S., and strike nearly east. The operator plans to prospect down the dip. As this mine is located on the northwest slope of the Miller Creek syncline the dip will become less steep toward the south. Although this mine has produced little coal to date, there is a ready market for coal from it and the operator plans to produce about 2,000 tons a year.

That no other coal mine is now being operated in the Draper Mountain area is not due to the absence of workable beds of coal or to inferior quality of the coal, but to the fact that it is doubtful whether a successful market could be developed for additional operations.

It appears to the writer that in many places in the Draper Mountain area coal can be mined on a profitable basis if operations are conducted on a small scale. With relatively little investment of capital one acquainted with the principles of coal mining can prospect along the line of outcrop of the coal beds, whose position is indicated on the geologic map (Pl. 1), and by the trial and error method locate a body of coal that may be mined. An operator who mines his own coal, transports it to a near-by suitable market, and sells it direct to private consumers, stands a reasonable chance of making a modest profit. In the event that the bed which he is following pinches out and he is forced to abandon the working, he will sustain only a minimum financial loss.

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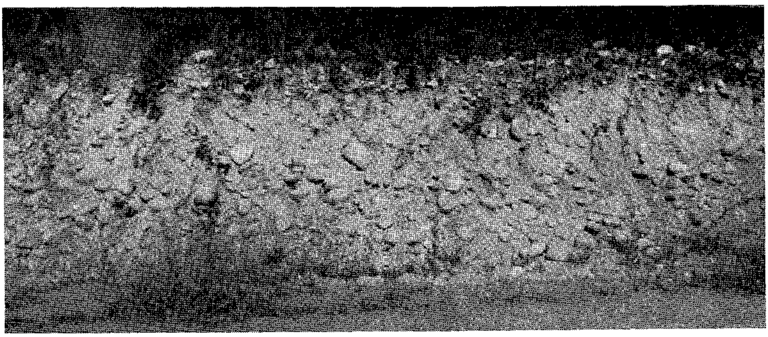
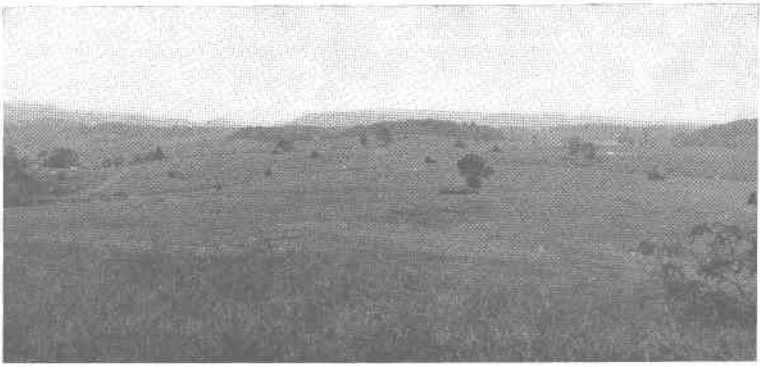
[91] Campbell, M. R., and others, The valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 216-240, 1925.

A. Harrisburg erosion surface looking towards the Blue Ridge, from a point about half a mile west of Oglesby School.

B. South towards the Blue Ridge from the top of Draper Mountain.



C. New River cobbles and gravels lying upon the uplifted Harrisburg surface, 3 miles south of Draper.



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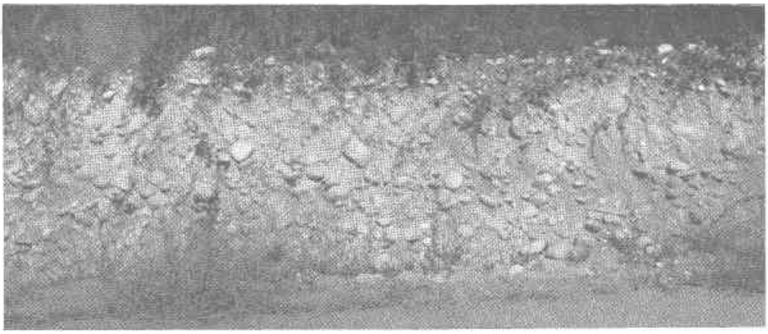

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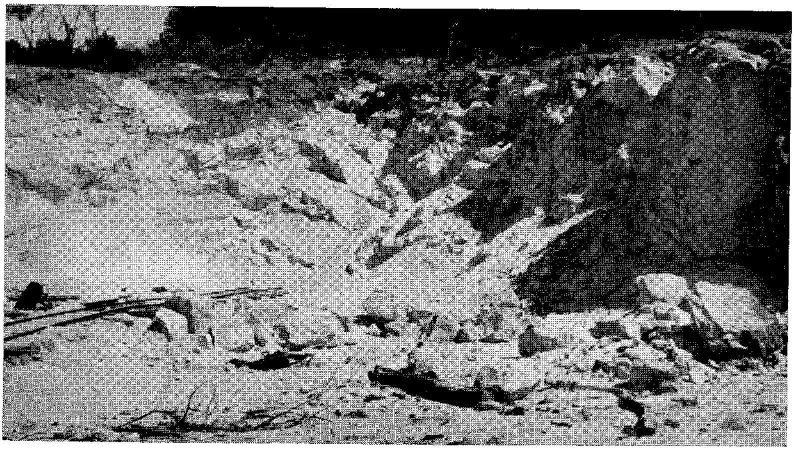
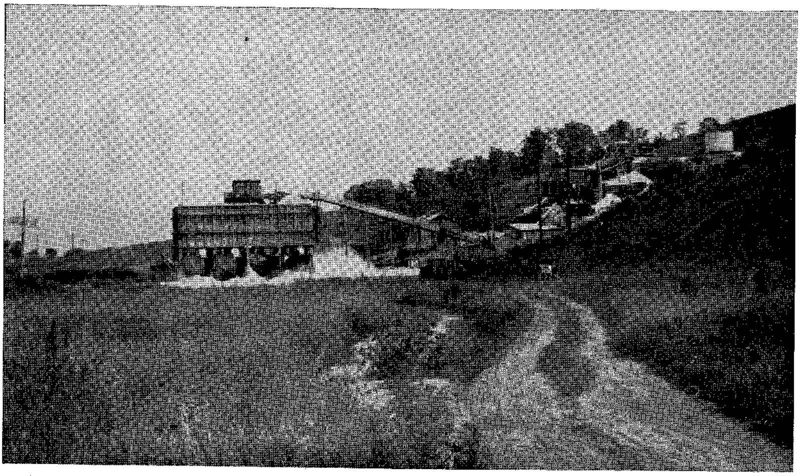
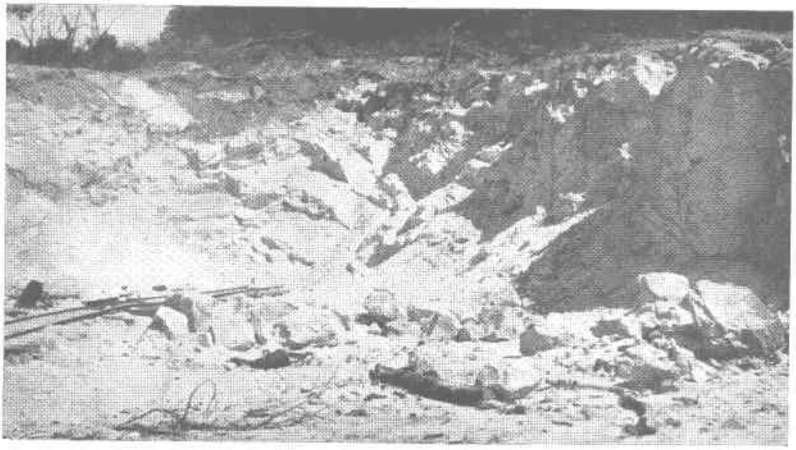


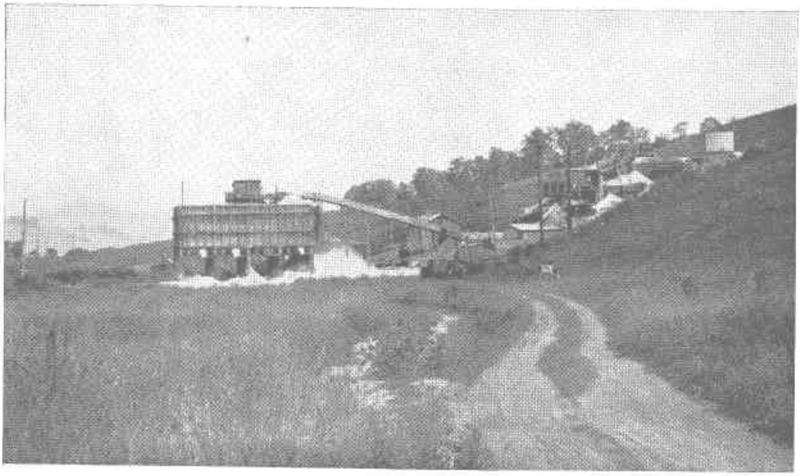
A. Quarry in deeply weathered Erwin quartzite at Lots Gap on Lick Mountain.



B. The friable Erwin sandstone obtained from Lots Gap is crushed and washed in this plant, located a quarter of a mile west of Fort Chiswell on the Lee Highway.



A. Quarry in deeply weathered Erwin quartzite at Lots Gap on Lick Mountain.



B. The friable Erwin sandstone obtained from Lots Gap is crushed and washed in this plant, located a quarter of a mile west of Fort Chiswell on the Lee Highway.

The coal beds which occur on the northwest slope of Draper Mountain can not be mined profitably on a small scale because the steep dip of the beds carries the coal far beneath the surface in a short distance from the outcrop. From the standpoint of dip of the coal beds, the most suitable places to prospect are along the southern slopes of Brushy Mountain and Chestnut Ridge and along the north-south trending outcrops of coal beds north of Caseknife Ridge and south of Chestnut Ridge and Brushy Mountain.

LIMESTONE

The cultivated areas south and west of Draper Mountain are covered with soil derived from the decomposition of limestones, dolomites, and shales of the Cambrian and lower Ordovician formations. Most of the land in this territory is used for grazing purposes; the remainder is utilized for grain crops. Practically all of this cultivated land would be improved by the use of lime. Many farmers have searched for suitable rock for agricultural lime, but with little or no success. There are relatively few limestone beds in this area that are low enough in magnesia, alumina, and silica to be burned for lime.

There are two zones in the Cambrian-Ordovician limestones and shales that contain beds suitable for agricultural lime. The Oglesby marble member of the Nittany formation contains many beds of limestone having more than 95 per cent of calcium carbonate. Almost any bed in the lower 60 feet of that member could be utilized for lime. The lack of a well-established lime kiln in this area to supply local demands, at least, would tend to make the use of the Oglesby limestones for lime a profitable enterprise. There are three locations which are best suited for such development. One is a few yards south of the Lee Highway (U. S. 11), along Oglesby lane, 100 yards southwest of Oglesby School. Some lime has been burned here for local private use. Another suitable site is located along the crest of the low southeast spur which extends east of Barrett Ridge, and which is not now accessible by road. This spur is almost entirely underlain by the Oglesby marble member, and topographically it is a favorably located site for quarrying operations. The Oglesby member here is approximately 65 feet thick, and all of the beds contain enough calcium carbonate to be suitable for agricultural lime. The third location is 100 feet northeast of the intersection of State highways 100 and 101. Here approximately 150 feet of the Oglesby occurs below the coarse-grained dolomite of the Draper member of the Nittany formation. Slight excavations would make available a considerable supply of suitable limestone.

The Mosheim formation, like the Oglesby, is relatively free of insoluble material and magnesia, but in most places it is too thin to be successfully worked. Just northeast of the forks of Little Pine Run, half a mile southwest of Oglesby School, the Mosheim is 50 to 75 feet thick. No extensive excavations could be undertaken in this locality because of nearness of the limestone to the stream, but a small quarry could be developed here. This site is accessible from the Lee Highway by Oglesby lane. Another site where the Mosheim is well developed and accessible is 200 yards south of State Highway 101, and 150 yards west of Dark Hollow Creek. The Mosheim here is about 40 feet thick and dips about 25° NW.

The Holston limestone which occurs north and east of Draper contains several thick, coarsely crystalline beds of almost pure limestone. These beds are well exposed north of the intersection of State highways 100 and 101. The lower 20 to 25 feet of the Holston formation here is composed of conglomerate. Above this is 25 to 50 feet of coarse-grained pinkish limestone which would be suitable for agricultural lime. The beds are vertical but this probably would not be a serious handicap in quarrying operations.

SAND

The end of Lick Mountain east of Lots Gap is composed of disintegrated Erwin quartzite. The rock is sufficiently friable to be comminuted by the gentlest shaking and washing operations. The sand is relatively free from iron, although some iron oxide occurs as a yellowish coating on the interstitial secondary quartz which loosely adheres to the quartz sand grains. (See Pls. 4A and 23.) Simple crushing methods loosen much of this interstitial silica, and by means of dry crushing and winnowing, almost all of the iron in the rock can be eliminated. The sand in Lick Mountain probably contains so little iron as to be suitable for glass sand. Access to the sand is to be had a short distance west of U. S. Highway 52, near the Fort Chiswell crossing. Two sand companies were operating in Lots Gap in 1937. The Jackson Sand Company was operating a quarry east of the road in Lots Gap and the Lick Mountain Sand Company had recently opened a quarry just west of the road. The material quarried is being hauled by truck to the crusher and washer located one-fourth mile west of Fort Chiswell, Virginia. The sand is used only for local construction purposes. (See Pl. 23B.)

CONSTRUCTION STONE

With the exception of a small quarry in the Elbrook formation 1 mile north of Pulaski operated by the State Department of Highways, no crushed-stone quarries are in operation in this area. The crushed rock used to resurface the Lee Highway (U. S. 11), near Fort Chiswell was shipped by railroad from stone quarries at Marion in Smyth County. A town as large as Pulaski could support a stone quarry furnishing crushed rock for road-building purposes. There are available sites in Pulaski along the Bristol branch of the Norfolk and Western Railway just east of the acid plant. There are also several suitable quarry sites along the Galax branch of the same railway in the immediate vicinity of Draper. Other locations are to be found in the vicinity of the State-operated quarry north of Pulaski, but these lack direct railroad facilities. Wherever the Elbrook formation crops out in the vicinity of transportation lines, there are abundant resources for crushed rock.

Blocks of Chemung sandstone have been and are being excavated from a small quarry at the side of the road in the gorge of Valley Branch, three-fourths of a mile southwest of Pulaski, for use in building bridge abutments in Pulaski County. The supply of such material is abundant, but the demand is small and sporadic.

MARBLE

Definition.—The term "marble" has two distinct connotations. In petrography "marble" connotes a calcareous rock which has been recrystallized as an effect of regional, dynamic, or thermal metamorphism. Commercially, "marble" is a term applied to any calcareous rock which takes a polish and which is suitable for building purposes. The Oglesby limestone or marble member is not a marble in the petrographic sense, but in the commercial sense it properly can be called a marble. Wherever present in this area the Oglesby has much the same lithology, although it varies considerably in thickness from place to place.

Oglesby marble.—In the Draper Mountain area, the Oglesby marble member of the Nittany formation is composed of very fine-grained limestone which takes a high polish. Many of the beds are strikingly colored and are suitable for use as decorative marbles. The amount of available material which under favorable market conditions would command a premium is considerable. Although it is doubtful whether present market conditions warrant any immediate development, the Oglesby marble is worthy of consideration as a potential resource.

The Oglesby marble would be highly suitable for both interior and exterior construction purposes. Lack of contaminating sulphides and dark-colored iron compounds insures that the marble will not stain and streak. The fineness of grain serves to retard the ravages of weathering and to preserve the polish of the surface. A careful examination of the beds revealed few cracks or fissures which might, if present, cause considerable wastage of stone.

Suitable quarry sites.—The most desirable location for the extraction of marble from the Oglesby member is at the type locality, along Oglesby lane, near Oglesby School, where the entire 150 feet of the member is exposed. The marble beds are exposed in the valley of the east fork of Little Pine Run, at the western end of a shallow, gentle anticline. Here dips are less than 15° and marble could be extracted from both limbs, as well as from the crest of this fold. There is no overburden. Blocks of stone 2 feet by 6 feet by 12 feet could be extracted.

The lithology of the marble beds has been discussed. Strikingly colored marbles highly suitable for ornamental purposes could be quarried from zones 2 and 3 (page 18), which are 100 feet in thickness. Varied shades of gray marble could be quarried from the lower 40 feet and from the upper 25 feet of the formation. Waste from quarrying operations could be utilized for lime as a by-product.

The site described above is situated on the property of Mrs. Ruby Oglesby. Some stone was excavated from this site by the Oglesby family and used in the building of the foundation of the old homestead (now largely rebuilt) located at the south end of Oglesby lane. The marble blocks in the foundation are in good condition and still retain, after 80 years of exposure, the delicate hues observed in the fresh rock.

Another suitable quarry site is located along the west fork of Dark Hollow Creek in the southeastern spur of Barrett Ridge. Zones 1 and 2 of the Oglesby in the type locality are fully represented here. In this vicinity the beds dip 20 to 25° SE. This locality is not directly connected with a main road as is the Oglesby prospect. The dips of the beds are nearly twice as steep as those in the type locality, and the thickness of the Oglesby member is about half of that on the Oglesby property. There is much less available decorative stone in this prospect than there is in the type locality.

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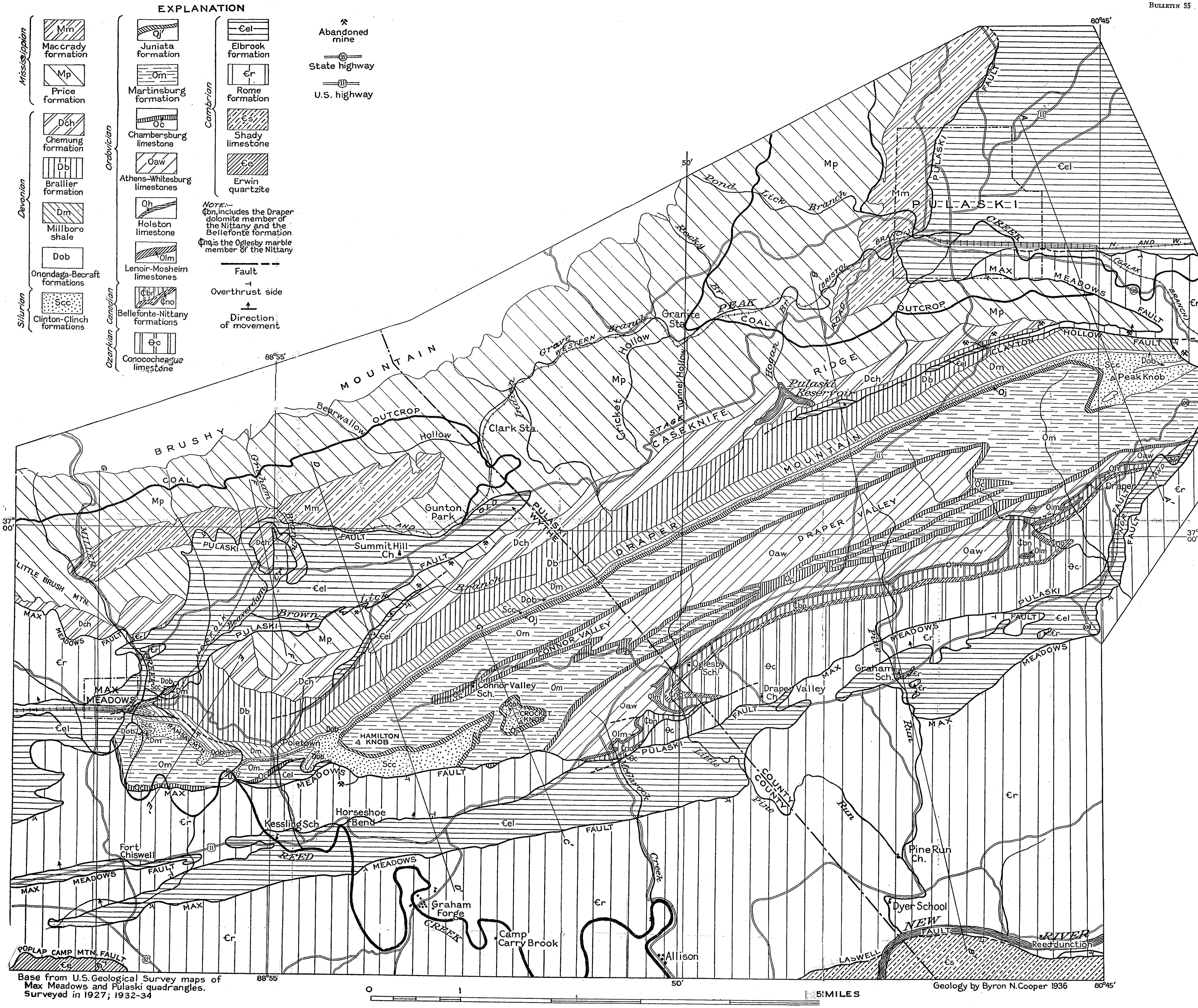

GEOLOGIC MAP OF THE DRAPER MOUNTAIN AREA, VIRGINIA.

Note: Since the cut for this map was prepared the Virginia Geological Survey has discontinued the use of Ozarkian and Canadian as systemic terms. Hence the Conococheague limestone should be included in the Cambrian, and the Bellefonte-Nittany formations in the Ordovician.