COMMONWEALTH OF VIRGINIA

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 51

Contributions to Virginia Geology---II

VIRGINIA
SIC SEMPER TYRANNIS

UNIVERSITY, VIRGINIA

1939

COMMONWEALTH OF VIRGINIA

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 51

Contributions to Virginia Geology---II

UNIVERSITY, VIRGINIA

1939

RICHMOND:
Division of Purchase and Printing
1939

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., April 15, 1938.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 51 of the Virginia Geological Survey series of reports the manuscript and illustrations of a volume entitled *Contributions to Virginia Geology—II*. This is the second volume in this series of contributions.

This bulletin contains eight articles by several geologists. Each article has been prepared as the result of detailed field work for the Geological Survey on specific projects related to comprehensive investigations of the mineral resources of the State. The articles, therefore, make important contributions to an understanding of the geologic relations of the rocks, mineral resources and ground-water supplies of certain parts of Virginia. They make also contributions of high rank to the interpretation of geologic data in Virginia, upon which future applications must be based.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, April 19, 1938.
RICHARD A. GILLIAM, *Executive Secretary and Treasurer.*

CONTENTS[1]

[1] The contents and illustrations of the individual papers are given with each paper.

ILLUSTRATIONS

TABLE

A SOUTHEASTERN LIMESTONE FACIES OF LOWER CAMBRIAN DOLOMITE IN WYTHE AND CARROLL, COUNTIES, VIRGINIA

BY

G. W. Stose and A. I. Jonas

Virginia Conservation Commission
VIRGINIA GEOLOGICAL SURVEY
Bulletin 51-A
UNIVERSITY, VIRGINIA
1938

CONTENTS

ILLUSTRATIONS

ABSTRACT

The equivalent of the Lower Cambrian dolomite in a small area on the southeastern edge of the Great Valley, southeast of Austinville, Virginia, contains a group of fossiliferous beds whose fauna, lithology, and stratigraphic position are comparable with the Kinzers formation of the York and Lancaster valleys of Pennsylvania. It is here proposed, therefore, to extend the names Vintage dolomite, Kinzers formation, and Ledger dolomite to the lower dolomite, the middle fossil-bearing beds, and the upper dolomite, respectively, of the Shady equivalents of this area. This fossil-bearing series of beds, although equivalent to the Shady dolomite of the Great Valley, is a different sedimentary facies deposited to the southeast of the main Appalachian geosyncline, and has been carried northwestward by thrust faulting to rest on the typical Shady dolomite.

A Southeastern Limestone Facies of Lower Cambrian Dolomite in Wythe and Carroll Counties, Virginia[1]

By G. W. Stose and A. I. Jonas

GENERAL STATEMENT OF PROBLEM

The area discussed in this paper is located in the south-central part of the Max Meadows and the adjoining part of the Speedwell quadrangles and lies in the northern part of Carroll County and the southern part of Wythe County, Virginia. (See Fig. 1.)

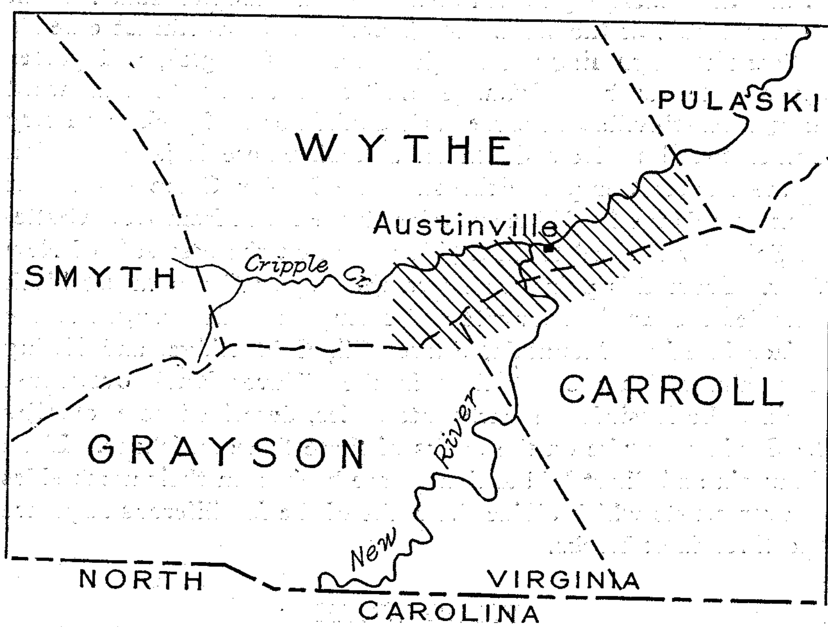


Figure 1.—Index map showing the location of the area described in this paper. The area mapped on Plate 1 is shown by the ruled pattern.

It is on the southeastern side of the Great Valley, just north of Poplar Camp Mountain and Ewing Mountain, where those mountains form the northwestern border of the Blue Ridge plateau. The rocks described are Lower Cambrian dolomites and limestones

[1] Published with the permission of the Director of the Federal Geological Survey.

containing fossiliferous beds not present in the equivalent Lower Cambrian Shady dolomite of the Great Valley to the northwest of this area. They form a belt 15 miles in length along the strike, extending from Gleaves Knob on the west to New Castleton School at the east. (See Pl. 1.) At its widest point this belt of rocks is not more than 2 miles wide. The eastern end of the belt of these fossiliferous rocks lies south of typical Shady dolomite on the south flank of Fosters Falls anticline, in the core of which Erwin quartzite is brought to the surface. Farther west they lie southeast of Shady dolomite that dips northward into the Ivanhoe syncline. This syncline encloses the Rome formation lying above Shady dolomite. The anticline and syncline mentioned above are folds in rocks typical of the Great Valley, and have been overridden on the southeast by the Gleaves Knob fault block, which contains the fossiliferous Lower Cambrian carbonate rocks described in this paper and the underlying Erwin quartzite and Hampton shale. From Gleaves Knob, at the west, the Gleaves Knob overthrust extends eastward through Eagle Cliff (just north of Eagle), and passes half a mile south of Ivanhoe, and then trends northeastward through Austinville and passes half a mile north of Jacksons Ferry southeastward to New Castleton School, where it is overridden by the Poplar Camp overthrust. The Poplar Camp overthrust block bounds the fossiliferous series on the south from New Castleton School westward to Little Mountain, on the east side of New River. From this point westward the Poplar Camp thrust block overrides the Erwin quartzite and Hampton shale brought to the surface in Little Mountain, Short Hill, Cold Ridge, and Ewing Mountain, which are anticlines in the Gleaves Knob overthrust block. The fossiliferous carbonate series, described here, overlies the Erwin quartzite on the flanks of these three anticlines. Little Mountain and Short Hill anticlines are broken on their north sides by overthrusts which divide the rocks of the fossiliferous sequence into three fault blocks.

FIELD WORK

This area, together with adjoining parts of the Great Valley, has been described recently by Currier.[2]

The writers have been engaged during parts of the years 1932-1938 in a geological survey of the Lower Cambrian arenaceous rocks and underlying pre-Cambrian crystalline rocks of the Max

[2] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 30-36, 1935.

Meadows, Galax, Speedwell, and Independence quadrangles, Virginia, for a forthcoming report on the geology of the Great Gossan Lead district. This field work has been done largely by the junior author, for the Virginia Geological Survey, with cooperation on the Lower Cambrian rocks by the senior author, of the Federal Survey. The study embraces also the region of Iron Mountain and Holston Mountain and the part of the Blue Ridge Plateau that lies southwest of them in Virginia. While mapping the Lower Cambrian arenaceous rocks that form the northwest border of the Blue Ridge Plateau, in which the Great Gossan Lead is located, the writers have studied also the adjacent limestones because of their intimate structural relation to the older rocks.

STRATIGRAPHY

DESCRIPTION OF ROCKS

The Shady dolomite of the Great Valley of Virginia is Lower Cambrian and rests on Erwin quartzite. It is in turn overlain by the Rome formation (Lower Cambrian) and this formation is followed by the Elbrook limestone (Middle and Upper Cambrian). The Shady dolomite and Rome formation are equivalent respectively to the Tomstown dolomite and Waynesboro formation in the Great Valley of the northern part of Virginia, Maryland, and southern Pennsylvania. The Elbrook limestone, which overlies the Waynesboro formation in Maryland and southern Pennsylvania and in the northern part of the Great Valley in Virginia, is continuous southwestward across Virginia, and in southwestern Virginia it overlies the Rome formation which is equivalent to the Waynesboro formation.

Both the Shady dolomite and Tomstown dolomite in the Great Valley are sparsely fossiliferous. On lithologic grounds they may be divided in most places into a lower blue argillaceous banded dolomite and an upper gray to white purer granular dolomite. In southwestern Virginia, Butts[3] divided the Shady dolomite into a lower ribboned limestone and dolomite, which he called the Patterson limestone member, and an upper saccharoidal dolomite member. Currier[4] locally included at the top of the saccharoidal dolomite member of the Shady a pure limestone which he called the Ivanhoe limestone member. The Ivanhoe limestone member

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

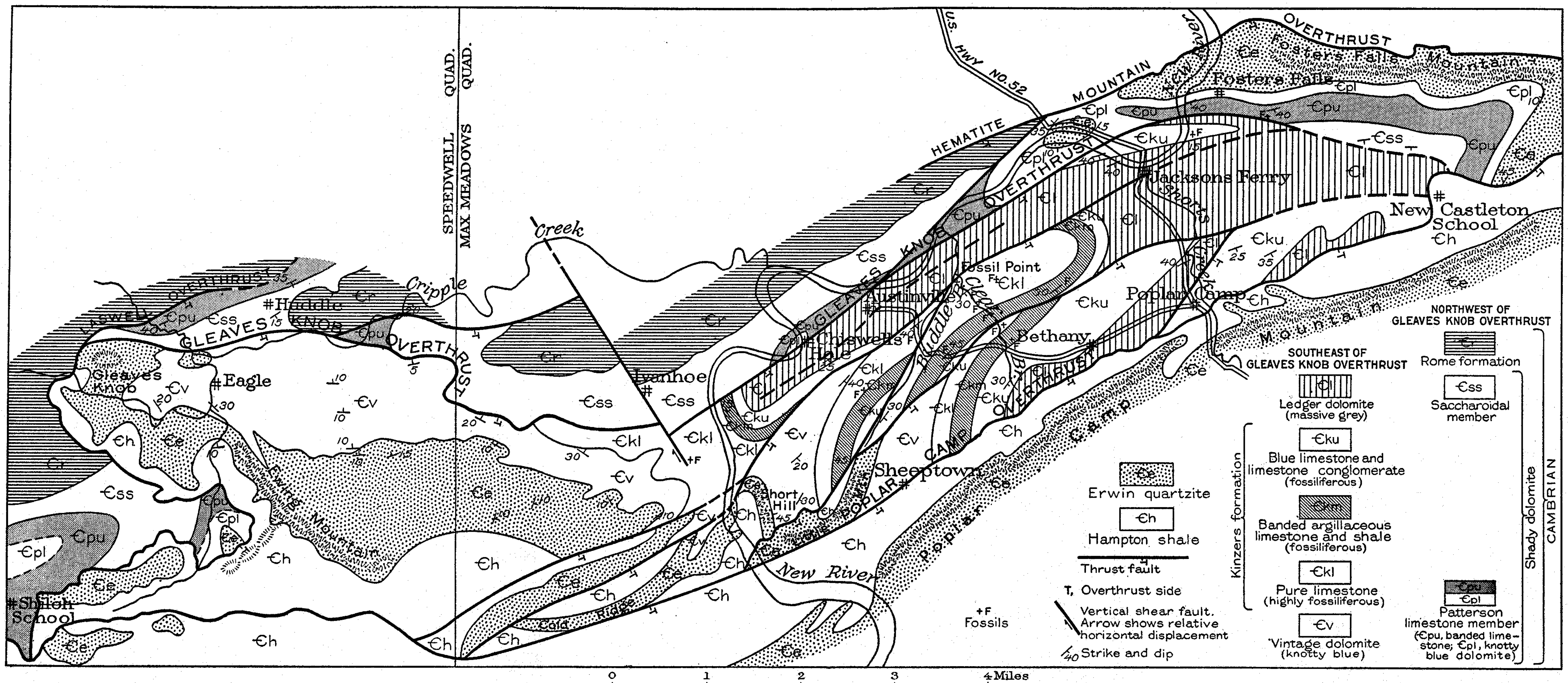
[4] Currier, L. W., op. cit., pp. 23-29.

as described by Currier[5] "is composed of thick massive beds of dense gray limestone containing a few relatively thin beds of light-gray to white dolomite, saccharoidal in part, and very thin reddish sandy and argillaceous partings." The Ivanhoe limestone member is well-bedded, whereas the saccharoidal dolomite below it is "for the most part massive," its beds are thick, and its bedding can be observed only in a section showing a considerable thickness of beds. The writers of this paper believe that lithologically the Ivanhoe limestone member more closely resembles the Rome formation, which contains similar pure, well-bedded, fine-grained limestone and dolomite with thin reddish sandy and argillaceous partings, that the Ivanhoe limestone member may more properly be included with the Rome, and that where present, it may form the base of the Rome.

Butts and Currier recognized that the fossiliferous limestones exposed southeast of Austinville are lithologically and faunally different from the typical Shady dolomite of the Great Valley and concluded[6] that the fossiliferous beds, some of which are crystalline pure carbonate rock, are equivalent to the Ivanhoe limestone member, which is also a pure carbonate rock, and therefore that the fossiliferous beds lie above the saccharoidal member of the Shady dolomite. Currier[7] gives a section of the Shady dolomite above the lower "sandy" dolomite from the Poplar Camp Mountain fault near Bethany, at the south, to a point 1 mile southeast of Austinville, at the north. The rocks in this section, which total 1488 feet thick, dip uniformly southeast from Buddle Branch, southeast of Austinville, to Bethany and are regarded by Currier as a continuous series, but he states[8] that "there is probability of repetition by faulting, though the positions and characteristics of the faults are not disclosed by the sparse exposures, which are not discriminative as to different beds." Butts[9] similarly regarded this section as a continuous series and measured more than 5000 feet of beds. The fossils he has identified will be published in his report.

The writers have found that the area that contains the fossiliferous rocks is crossed by several northeast-trending thrust faults that cut diagonally across the beds and repeat them several times. (See Pl. 1.) This repetition of characteristic beds is obvious to one traversing the road from Bethany to

[5] Op. cit., p. 27.
[6] Currier, L. W., op. cit., pp. 17, 27-35.
[7] Op. cit., pp. 31, 32.
[8] Op. cit., pp. 30, 31.
[9] Butts, Charles, manuscript on the "Geology of the Appalachian Valley in Virginia," to be published by the Virginia Geological Survey (Bull. 52).



Geologic map of an area in the vicinity of Austinville, Virginia. By G. W. Stose and A. I. Jonas, 1938.

Austinville. The true sequence and thickness of beds can only be determined by study of the rocks in each fault block, beginning with the known base of the Lower Cambrian dolomite where it rests on Erwin quartzite, and mapping the beds above in their true stratigraphic order within each fault block.

The Lower Cambrian dolomite was found to rest normally on Erwin quartzite on the northwest end of Little Mountain, west of Sheeptown, where it strikes north and dips east. Eastward, across the strike, this basal knotty, blue dolomite, similar to the lower part of the Shady dolomite of the Great Valley area, is succeeded by pure fossiliferous limestone and white marble, followed by hard sandy and argillaceous well-bedded limestones and shaly beds that make a ridge; then limestone conglomerates and well-bedded limestone; and finally light-gray, saccharoidal, thick-bedded dolomite. The ridge of hard argillaceous limestone of this block is crossed by the Austinville road 1 mile west of Bethany. This area is called the Little Mountain fault block. (See Pl. 5.)

A similar sequence was found in the Short Hill fault block to the northwest, beginning with the blue knotty dolomite at the base, which rests on the Erwin quartzite on Short Hill. In Short Hill, these rocks also strike north and dip east, but eastward the strike swings to the northeast. The hard argillaceous limestone and shale of this block crop out in the road along the side of the hill north of the east end of Little Mountain and in the hills to the northeast. These rocks are cut off diagonally by a branch of the Little Mountain fault and are repeated in the ridge that crosses the Bethany-Austinville road 1½ miles west of Bethany. This ridge trends northeast and continues beyond Clear Branch. The shale and argillaceous limestone that compose it are well exposed on the road three-quarters of a mile northwest of Bethany, where they are highly fossiliferous.

The sequence is repeated again in the Austinville block (Pl. 5) that lies north of the Short Hill overthrust, and forms the northern part of the Gleaves Knob overthrust block. The rocks in this block rise in the section northeastward from the top of the Erwin quartzite in Ewing Mountain, west of New River, to Austinville.

It is evident therefore that the section, instead of being continuous stratigraphically from Bethany to Austinville, is repeated four times by faults that break across anticlinal folds.

The sequence of beds as determined by the writers is as follows:

An upper formation of massive-bedded granular gray dolomite.

A fossiliferous formation, comprising three members:

- An upper conglomeratic limestone.
- A middle argillaceous and sandy limestone.
- A lower pure limestone.

A lower formation of knotty blue dolomite.

Erwin quartzite.

A detailed section of part of the lower member of the fossiliferous formation on Buddle Branch, south of the mouth of Clear Branch

	Feet
Massive crystalline white limestone (Archeocyathid reef; Pl. 2A)	20
Fine even-grained dove-colored to gray limestone (Fossils *A* in list on p. 16)	30±
Fine-grained crystalline limestone (Fossils *B* in list on p. 16)	10
Fine-grained limestone with earthy weathering beds (Fossils *C* in list on p. 16)	10
Red shaly argillaceous knotty limestone	5
Siliceous and magnesian limestone	10
Massive-bedded highly fossiliferous, granular crystalline limestone (Fossils *D* in list on p. 16)	10
Massive crystalline white limestone (Archeocyathid reef)	20
Crystalline fossiliferous limestone with fine argillaceous banding (Fossils *E* in list on p. 16)	20±
Fine-grained dove-colored limestone and coarse crystalline limestone	40±
	175±
Crystalline limestone and dolomite (not measured)	
Dove-colored fossiliferous limestone, just below mouth of Clear Branch (not measured)	

A section of part of the lower member of the fossiliferous formation on Clear Branch south of its junction with Buddle Branch is given just below. Thicknesses were not measured but have been estimated and compared with equivalent beds in the section on Buddle Branch given above.

Section of part of the lower member of the fossiliferous formation on Clear Branch

	Feet (Estimated)
Thick-bedded dense light-blue crystalline limestone	20±
Light-blue limestone laminated and mottled with earthy layers	30±
Coarse crystalline mottled white marble	20±
Thick-bedded white saccharoidal marble, weathering granular (Archeocyathid reef)	20±
Compact dove-colored limestone with large white marble masses (Archeocyathid reefs) / Thick-bedded dove-colored fine-grained limestone	30±
Fine conglomeratic limestone, weathering white (Reef?) / Earthy banded limestone; some beds highly fossiliferous / Thick-bedded white marble, weathering granular and crumbly / Thick-bedded dense gray fossiliferous crystalline limestone	45±
Thick-bedded blue banded limestone (Archeocyathid reef)	20±
Coarse-grained crystalline fossiliferous white marble, weathering dirty gray and crumbly (list of fossils page 16)	20±
	205±

Fault
Massive white dolomite

A partial section of the lower member of the fossiliferous formation at the abandoned quarry of the National Carbide Co., 1 mile south of Ivanhoe

	Feet
Argillaceous and siliceous banded blue limestone weathering to buff earthy reticulate fossiliferous network (Pl. 3B)	20
Compact blue limestone, weathering buff and earthy	20
Banded blue limestone and mottled blue limestone; contains Archeocyathid reef	50±
White marble	10
Banded blue limestone	20
	120±

The fossils collected in these beds are listed on page 17.

Detailed section of the middle member of the fossiliferous formation on Clear Creek, north of Bethany road

	Feet (Estimated)
Upper member	
Coarse limestone conglomerate	
Middle member	
Fissile olive shale	10±
Dark-colored conglomerate with white limestone fragments	
Dark-blue to white limestone with reticulate impure banding	20±
Fine even-grained dark-colored dense limestone with conchoidal fracture[a]	
Blue limestone with earthy banding and sun-crack fractures	
Compact blue limestone, banded with buff; conchoidal fracture	
Compact blue limestone with white specks; contains unidentifiable trilobite fragments	50±
White limestone, weathers buff, earthy and pitted; contains trilobites and *Nisusia*. (See list on page 17.)	
Thick-bedded blue dense sandy to argillaceous limestone with dark spots and rings	20
White limestone, weathers buff, earthy, and reticulate	
Light-gray to buff mottled dense limestone	50±
Compact gray to blue limestone	
	150±
Lower member	
Thick-bedded dense gray to white crystalline limestone	

[a] Probably the bed from which fossils were collected by Resser listed on page 17.

Detailed section of the upper member of the fossiliferous formation near Clear Branch, south of Bethany road

	Feet
Massive-bedded granular gray dolomite	
Upper member	
Compact blue limestone	40±
Light-gray limestone and fine conglomerate; Dark fine-grained limestone conglomerate with small white limestone specks	15
Concealed	30±
Fine-grained blue limestone	5
Hard slaty argillaceous limestone	5
Concealed	100±
Slaty to thin platy banded gray limestone	10±
Concealed	130±
Conglomerate of subangular gray platy sandy limestone fragments in contorted black argillaceous limestone matrix	5±
Platy siliceous blue limestone with black argillaceous partings	15±
Gray dolomite; Concealed; Gray dolomite; Dolomite with oolite and limestone pebbles	115±
Thick-bedded limestone conglomerate, in 3-feet beds, composed of fragments of white marble, fine-grained limestone, oolitic limestone, dark-colored fine-grained limestone, and platy limestone[a]	30
	500±
Middle member	
Fissile olive shale	

A generalized composite section of these carbonate rocks is as follows:

[a] On the east branch of Clear Creek, 1 mile north of Bethany, this bed is composed of pebbles of white marble up to 6 inches in diameter, dark oolitic and platy limestone, black dense limestone, and dolomite, in a dark-colored limestone matrix.

Generalized composite section of the Lower Cambrian fossiliferous and associated carbonate rocks southeast of Austinville

	Feet
Thick series of massive-bedded granular gray dolomite	
Upper member	
Thin-bedded platy blue limestone and thick-bedded bluish-gray limestone with coarse and fine limestone conglomerate. Some beds fossiliferous	500±
Middle member	
Blue banded argillaceous to siliceous limestone, weathering to buff earthy tripoli, and olive shale. Some beds highly fossiliferous. Some dolomite beds at base	150±
Lower member	
Coarse-grained crystalline white marble, light-blue to gray limestone, and fine-grained dove-colored limestone, highly fossiliferous. Some thick Archeocyathid reefs and other fossils	260±
	910±
Thick series of knotty blue dolomite	

The sections here given show that the fossiliferous formation, including pure carbonate beds, argillaceous and arenaceous beds with some dolomite, and conglomeratic limestone, lie between a lower blue knotty dolomite and an upper purer massive saccharoidal dolomite, and not above the saccharoidal dolomite. Therefore they are not equivalent to the Ivanhoe limestone member northwest of Austinville, which clearly lies above the saccharoidal member as shown by Butts[10] and by Currier.[11]

The name Patterson, given by Butts[12] to the lower ribboned blue dolomite and limestone of the Shady, is appropriate for these beds in the main part of the Great Valley north of the Gleaves Knob overthrust, because Patterson, the type locality, is located on these rocks. This name will therefore be used in this sense by the writers, with the understanding that it is not appropriate for the lower part of the Lower Cambrian carbonate rocks south of the Gleaves Knob fault, where the sequence is different. In

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

[11] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, pp. 27-29 and Pl. 1, 1935.

[12] Op. cit., p. 3.

the Valley south of Fosters Falls Mountain the Patterson limestone member has at the base a hard impure ribboned to knotty dark-blue dolomite, and, above, blue limestone with less banding and impure partings. A few trilobite fragments identified by Resser as *Paedeumias* sp., were found by the writers in this blue limestone south of Fosters Falls Mountain. This limestone is overlain by massive saccharoidal dolomite of the upper part of the Shady dolomite of the Great Valley type. A partial section of these rocks measured by the writers is as follows:

Partial section of typical Shady dolomite south of Fosters Falls Mountain

	Feet
Shady dolomite (typical facies of the Great Valley)	
Upper member	
Massive white saccharoidal dolomite	200±
Patterson limestone member	
Blue banded limestone with fine argillaceous partings. Contains a few trilobite fragments (*Paedeumias* sp.) and a zone of characteristic rounded flattened nodules, possibly of organic origin	120±
Tough, roughly banded, knotty blue dolomite	300±
	620±
Erwin quartzite	
Thin-bedded fossiliferous ferruginous quartzite	

FOSSILS

Fossils have been collected from many localities in the area by Brown, Butts, Resser, Currier, Michael, Callaghan, Goodwin, and others, and will be fully described by Resser and by Butts in forthcoming reports. The fossils collected by the writers and listed below were determined by Resser and only generic names are given. They are listed in stratigraphic order of the horizons at which they occur, insofar as that order can be determined.

Fossils from lower member of the fossiliferous formation.—Fossils collected by the writers from dove to white crystalline limestones at Fossil Point, in the Short Hill fault block, are as follows:

Archeocyathids
Bicaspis sp.
Bonnia sp.
Bonniella sp.
Brachiopod, new genus
like Nisusia?
Kootenia sp.
Kutorgina sp.
Nisusia sp.
Olenellus sp.
Paterina sp.
Proliostracus sp.
Ptychoparella sp.
Salterella sp.
Wanneria sp.
Yorkia sp.

The position of certain fossiliferous layers listed below with respect to two Archeocyathid reefs (Pl. 2A) is shown in the detailed section on page 10.

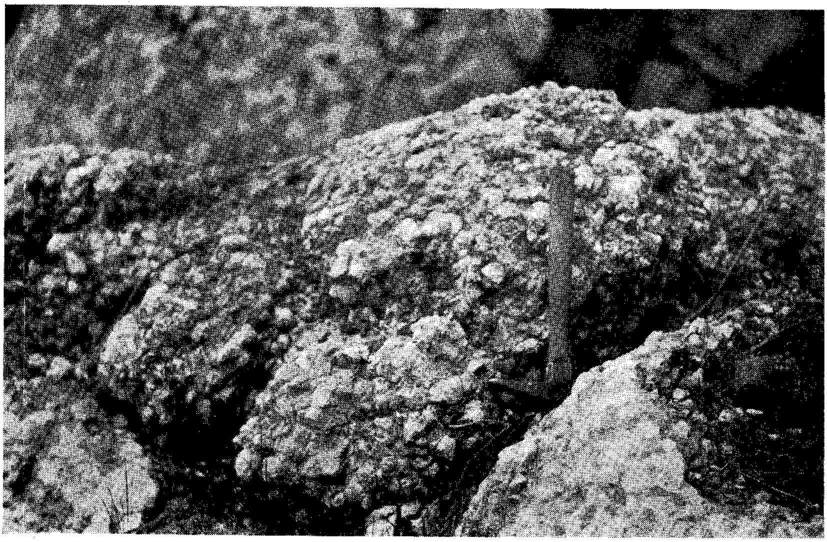
Reef of Archeocyathids
A Bicaspis sp.
Proliostracus sp.
B Bicaspis sp.
Bonnia sp.
Brachiopod (new genus like Nisusia?)
C Nisusia sp.
D Kutorgina sp.
Kootenia sp.
Paterina sp.
Ptychoparella sp.
Reef of Archeocyathids
E Bicaspis sp.
Bonniella sp.
Kutorgina sp.

Fossils collected on Clear Branch in the Short Hill fault block, at a higher horizon in the lower member than those listed above, are as follows:

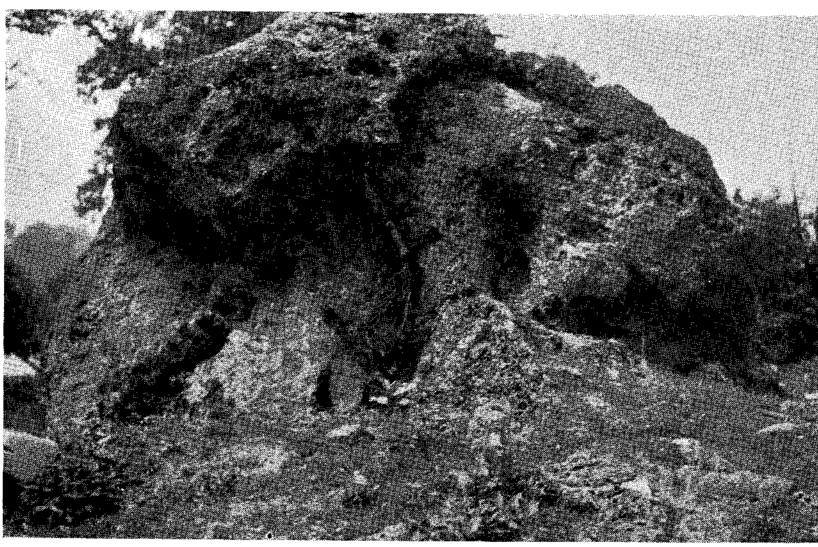
Bonnia sp.
Nisusia (2 species?)
Kutorgina sp.

Fossils from dove-colored limestone at about the same horizon as those from Fossil Point, were collected in the Short Hill block, 1 mile south of Austinville, and are as follows:

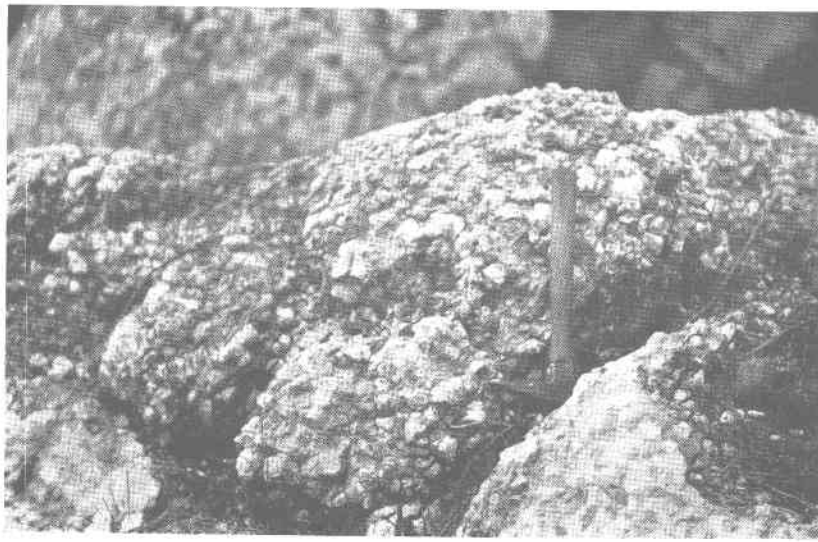
Bicaspis sp.
Bonniella sp.
Ptychoparella sp.



A. Archeocyathid reef in the lower member of the fossiliferous formation (Kinzers) at Fossil Point, 1 mile east of Austinville, Va. (See pp. 10 and 16.)

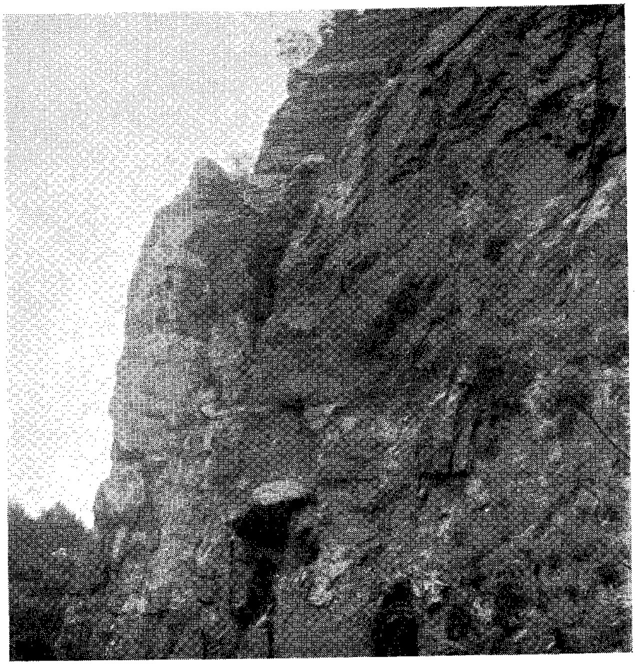


B. Residual mass of ferruginous chert and fault breccia on the floodplain of New River, 1½ miles northeast of Austinville, Va. (See p. 28.)



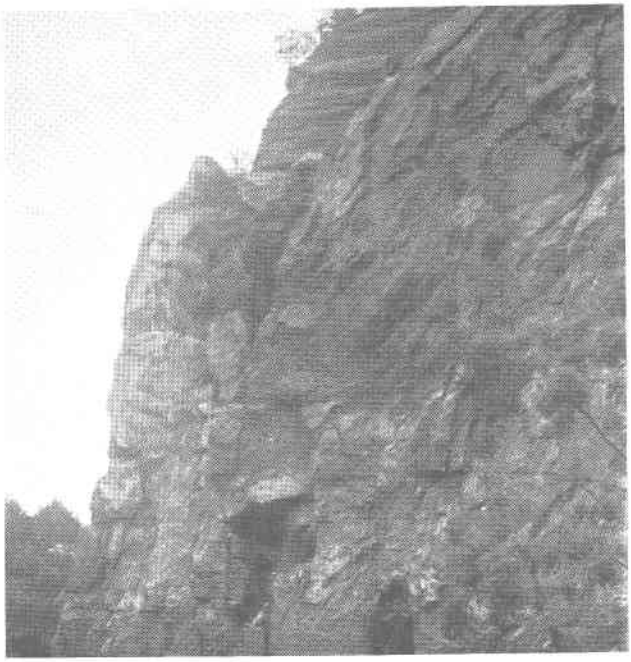
A. Archeocyathid reef in the lower member of the fossiliferous formation (Kinzers) at Fossil Point, 1 mile east of Austinville, Va. (See pp. 10 and 16.)

B. Residual mass of ferruginous chert and fault breccia on the floodplain of New River, 1½ miles northeast of Austinville, Va. (See p. 28.)



A. Limestones of the lower member of the fossiliferous formation (Kinzers) in the old quarry of the National Carbide Co., south of Ivanhoe, Va. (See pp. 11 and 17.)

B. Residual siliceous network from weathered impure limestone at the National Carbide Co. quarry, south of Ivanhoe, Va. (See p. 11.)



A. Limestones of the lower member of the fossiliferous formation (Kinzers) in the old quarry of the National Carbide Co., south of Ivanhoe, Va. (See pp. 11 and 17.)

B. Residual siliceous network from weathered impure limestone at the National Carbide Co. quarry, south of Ivanhoe, Va. (See p. 11.)

The writers collected the following fossils at the old quarry of the National Carbide Co., west of New River, 1 mile south of Ivanhoe:

Archeocyathids
Bonnia sp.
Salterella sp.
Wanneria sp.

The section of the rocks in the quarry (Pl. 3A), showing the position of the fossiliferous beds in relation to that of the Archeocyathid reefs is given on page 11.

Resser reports the occurrence of *Kootenia currieri* Resser and *Yorkia* sp. in weathered limestone on the highway half a mile south of Austinville. This limestone is in the lower member of the fossiliferous formation.

Fossils from the middle member of the fossiliferous formation.—Blue argillaceous limestone that weathers to a yellow earthy sandstone is highly fossiliferous. The position of this bed in the section is given on page 12. The fossils collected by the writers from this weathered limestone in the Little Mountain block, on Clear Branch an eighth of a mile north of the Bethany-Austinville road, are as follows:

Kootenia sp.
Ptychoparella sp.
Nisusia sp.

Fossils were collected by Resser from coarse-grained black limestone on Clear Branch just north of the Bethany-Austinville road. These beds are near the top of the middle member in the Little Mountain block and the blue limestone conglomerate of the upper member is exposed just south of the road. The approximate position of this bed in the section is given on page 12. The fossils are as follows:

Bonnia sp.
Kootenia currieri Resser
Kootenia virginiana Resser
Undeterminable trilobites
Nisusia sp.

Fossils from calcareous shale near the top of the middle member in the Short Hill block, at approximately the same horizon as those given in the two previous lists, were collected by the writers 1 mile north of Bethany in a road cut. They are as follows:

Amecephalina poulseni Resser
Nisusia sp.
Poliella virginica Resser
Ptychoparella michaeli Resser
Syspacephalus sp.

Fossils from the upper member of the fossiliferous formation.—No fossils were collected by the writers from the conglomerate-bearing beds and pure limestones of the upper member of the fossiliferous formation. Fossils collected by Butts from blue limestones in the cut of the Norfolk and Western Railway, on the south side of New River east of Jacksons Ferry, which are believed to be in the upper member of the fossiliferous formation, are as follows:

Kutorgina sp.
Nisusia sp.
Prozacanthoides sp.
Ptychoparella sp.

Currier also collected similar fossils from a blue limestone interbedded with conglomerates at the base of the upper member, 1 mile west of Bethany and south of the Austinville road.

Resser lists the following forms collected by various persons from the lower member of the fossiliferous formation in the Austinville area, chiefly at Fossil Point on Buddle Branch:

Archeocyathids
Austinvillia virginica Resser
Bicaspis austinvillensis Resser
Bonnia crassa Resser
Bonnia tensa Resser
Bonnia tenuis Resser
Bonniella bracteata Resser
Bonniella minor Resser
Bonniella tumida Resser
Bonniella virginica Resser
Helcionella buttsi Resser
Helcionella callahani Resser
Hyolithellus sp. undet.
Kootenia browni Resser
Kootenia virginiana Resser
Kutorgina sp.
Nisusia cf. festinata (Billings)
Olenellus austinvillensis Resser
Olenoides hybridus Resser
Olenoides nitidus Resser
Olenoides ornatus Resser
Paterina swantonensis (Walcott)
Proliostracus goodwini Resser
Proliostracus granulatus Resser
Prozacanthoides excavatus Resser
Prozacanthoides expansus Resser
Prozacanthoides virginicus Resser
Ptychoparella minor Resser
Ptychoparella taylori Resser
Scenella virginica Resser
Syspacephalus virginicus Resser
Zacanthopsis virginica Resser
Zacanthoides nitidus Resser

The genera and species credited to Resser in this paper are described and figured in a publication by the Geological Society of America.[12a]

The above fauna is stated by Resser to be the same as that occurring in the middle member of the Kinzers formation in the vicinity of York, Pa. The section and fauna of the Kinzers formation in the Pennsylvania area, as published by the writers,[13] have been revised in a forthcoming report on the Hanover-York district. A generalized section in that report is given below for comparison with the section of these beds in the Austinville area.

Section of Kinzers and associated formations near York, Pa.

	Feet
Ledger dolomite	
Massive granular gray dolomite	
Kinzers formation	
Upper member: Earthy fossiliferous limestone and interbedded argillaceous limestone	125-180
Middle member: Thick white mottled marble, granular limestone, and limestone - conglomerate; contains Archeocyathid reefs and other fossils	100-175
Lower member: Dark shale, highly fossiliferous in places	100-150
	325-505
Vintage dolomite	
Massive light-gray dolomite and knotty blue dolomite	

A list of the fossils obtained from the middle member of the Kinzers formation in the vicinity of York is given below for comparison with the preceding list of fossils from the lower member of the fossiliferous formation near Austinville.

Agnostus sp.
Archeocyathids
Bonnia bubaris Walcott
Bonnia capito Walcott
Cystid plates
Dawsonia parkeri (Walcott)
Hyolithes sp.
Kochiella sp.
Kootenia marcoui (Whitfield)
Kutorgina cingulata (Billings)
Nisusia festinata (Billings)
Obolus or Lingulella sp.
Olenellus sp.
Paterina bella (Billings)
Prozacanthoides sp.
Ptychoparella sp.
Salterella sp.
Yorkia wanneri Walcott

[12a] Resser, C. E., Cambrian system (restricted) of the Southern Appalachians: Geol. Soc. America Spec. Paper 15, pp. 24, 25, 1938.

[13] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pa.: U. S. Geol. Survey Bull. 840, pp. 23-26, 1933.

Impure calcareous beds that weather to earthy sandstones and comprise the upper member of the Kinzers formation near York, Pa., yield the following fossils:

Acrothele decipiens	Kutorgina sp.
Agnostus sp.	Nisusia sp.
Bonnia sp.	Paterina sp.
Cystid plates	Periomella sp.
Eoagnostus sp.	Salterella sp.
Hyolithes sp.	Syspacephalus? sp.
Kochiella sp.	Yorkia sp.

The uppermost beds of the formation in the city of York yield the following fossils:

Acrothele decipiens Walcott	Cystid plates
Acrothele yorkensis Walcott	Poliella [Bathyuriscus] bala (Walcott)
Agnostus, sp.	Prozacanthoides sp.
Chancia n. sp.	Ptychoparella sp.
Chancelloria yorkensis Walcott	

The fauna from these uppermost beds is said by Resser to be the same as that collected from near the top of the middle member of the fossiliferous formation, 1 mile north of Bethany, listed on page 18. It is said to be somewhat different from the fauna from lower horizons and to indicate a separate faunal zone.

Resser states that the fauna, as a whole, from the fossiliferous formation southeast of Austinville and from the limestones of the Kinzers formation in Pennsylvania is the same as that from the Forteau[14] limestone of Bonne Bay, Newfoundland.

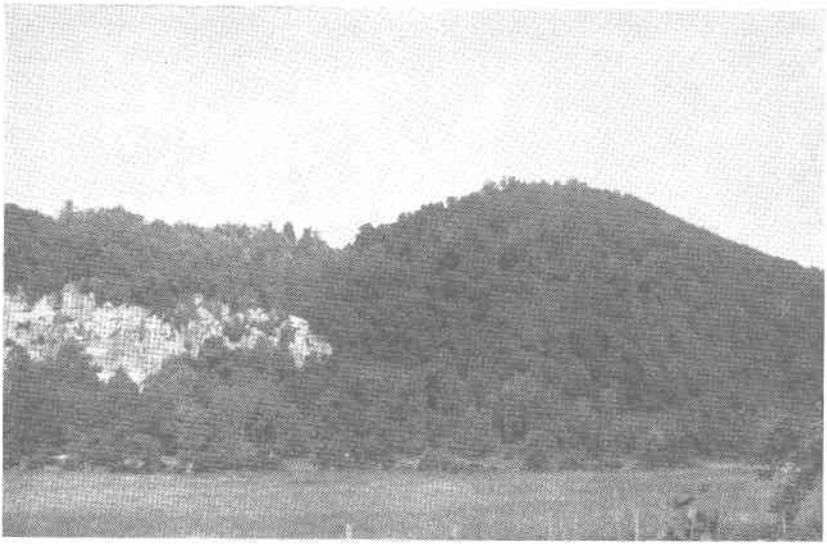
CORRELATION

The lithology and fauna of the Lower Cambrian beds above the Erwin quartzite, here described, resemble those of the Lower Cambrian sequence of the York and Lancaster valleys in Pennsylvania. The lower blue knotty dolomite closely resembles the Vintage dolomite. The overlying fossiliferous pure limestone and marble, argillaceous to sandy fossiliferous limestone, and conglomerate-bearing blue limestone are very similar to the Kinzers formation in their fossil content and heterogeneous lithology. The upper saccharoidal dolomite is identical in lithology with the Ledger dolomite. The resemblance of the lower and upper dolomites to the Vintage and Ledger dolomites is so close that their identity seems established. The middle fossiliferous zone

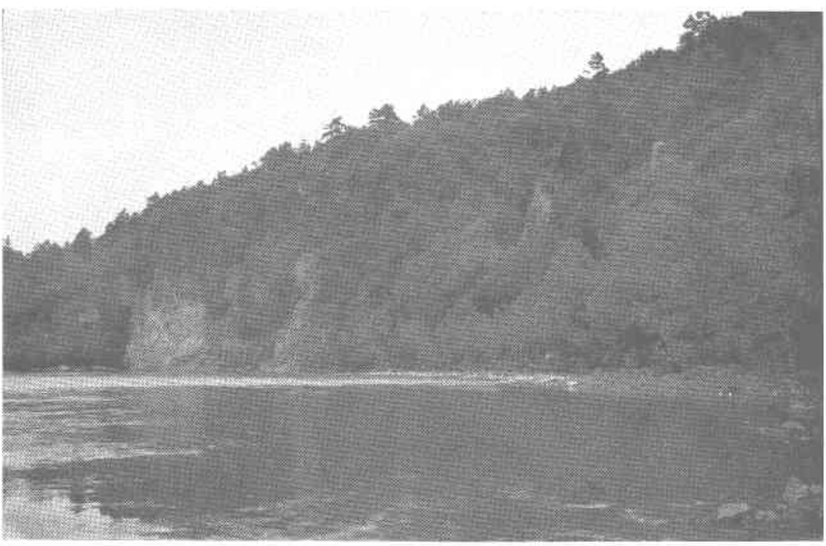
[14] Schuchert, Charles, and Dunbar, C. O., Stratigraphy of western Newfoundland: Geol. Soc. America Mem. 1, pp. 18-32, 1934.

A. Cliff across New River, 1½ miles southeast of Ivanhoe, Va., showing nearly horizontal limestone of the Austinville block. The upturned overthrust Erwin quartzite of the Short Hill block occurs in the high wooded hill at the right. (See p. 23.)

B. Limestone cliff at Chiswells Hole along New River, looking north. The cliff at the left exposes horizontal beds of the Patterson limestone member. The small ledge at the right in the trees is sheared limestone of the Kinzers formation in the overthrust Short Hill block. (See Fig. 3 and p. 27.)



A. Cliff across New River, 1½ miles southeast of Ivanhoe, Va., showing nearly horizontal limestone of the Austinville block. The upturned overthrust Erwin quartzite of the Short Hill block occurs in the high wooded hill at the right. (See p. 23.)



B. Limestone cliff at Chiswells Hole along New River, looking north. The cliff at the left exposes horizontal beds of the Patterson limestone member. The small ledge at the right in the trees is sheared limestone of the Kinzers formation in the overthrust Short Hill block. (See Fig. 3 and p. 27.)

has pure limestones, argillaceous to shaly beds, and conglomerates like those in the Kinzers formation, but lacks the *Olenellus* shale horizon which forms the lower member of the Kinzers formation in Pennsylvania. Such variation is not surprising considering the distance along the strike between these two areas and the variability of character and thickness of the beds in the Kinzers formation in different parts of the Pennsylvania area.[15] It is proposed therefore to extend the names Vintage dolomite, Kinzers formation, and Ledger dolomite to the comparable Lower Cambrian formations in the area southeast of Austinville. The generalized section of these rocks for the Austinville, Va., area is as follows:

Section of Lower Cambrian rocks near Austinville

	Feet
Ledger dolomite	
Massive-bedded granular gray dolomite	
Kinzers formation	
Thin slabby, fine-grained to compact blue limestone, thick dolomite, and limestone conglomerates; thick-bedded coarse limestone conglomerates at base	500±
Tough argillaceous to sandy ridge-making limestone, buff, and earthy-weathering impure limestone, thin shale, and thin dolomite	150±
Massive white crystalline and blue to dove-colored fine-grained fossiliferous limestone with Archeocyathid reefs	200±
	850±
Vintage dolomite	
Blue limestone	
Dark-blue knotty dolomite with siliceous banding	
Knotty blue dolomite and thin-layered hard blue siliceous limestone with irregular black argillaceous partings and white calcite blebs	
Erwin quartzite	
Granular rusty ferruginous fossiliferous quartzite, calcareous at the top, with phosphatic nodules and layers in places	
Thin-layered, dark-colored argillaceous-banded quartzite	
Hard vitreous white quartzite, scolithus-bearing in places with finely arkosic and pebbly layers	

Resser[16] has listed and figured a large fauna from the lower shale member of the Kinzers formation near York and Lancaster, Pa., and

[15] Stose, G. W., and Jonas, A. I., op. cit., pp. 23-26.
[16] Resser, C. E., and Howell, B. F., Lower Cambrian Olenellus zone of the Appalachians: Geol. Soc. America Bull., vol. 49, p. 205, 1938.

from the shale at the base of the Parker shale at the Parker quarry, Georgia, Vermont.[17] He figures two species of *Olenellus* and several other fossils that are found in the Rome formation and also in the shales of the Kinzers formation and Parker shale, and states[18] that the fauna listed from the lower shale member of the Kinzers formation in Pennsylvania "appears to correlate the Kinzers formation with the Rome formation." In the section from Pennsylvania,[19] the shale at the base of the Kinzers formation is overlain by 250± feet of fossiliferous limestones, and the Kinzers formation is overlain by the Ledger dolomite. It has been previously stated by the writers that the Vintage dolomite, Kinzers formation, and Ledger dolomite in Pennsylvania are the equivalent of the Tomstown dolomite of the Great Valley in Pennsylvania, and are a southeastern facies of that formation limited to an area of deposition lying southeast of the uplift represented by the Honeybrook, Chickies, Hellam, and Pigeon Hills anticlines.[20] They have been brought nearer to the dolomite facies of the Tomstown of the Great Valley by close folding and overthrusting. The Tomstown dolomite of the Great Valley sequence has at its top a light-gray granular dolomite comparable to the Ledger. The Tomstown dolomite is overlain by the Waynesboro formation, which is correlated with the Rome formation occurring farther to the southwest. The stratigraphic position of the Kinzers formation, therefore, is lower than that of the Waynesboro formation. In southwestern Virginia the fossiliferous beds of the Kinzers formation underlie Ledger dolomite which is equivalent to the saccharoidal upper part of the Shady dolomite. Therefore, the Kinzers of the Austinville area can not be equivalent to the Rome formation, which overlies the Ivanhoe limestone member and the Shady dolomite in the Great Valley sequence. The writers lay no claim to a knowledge of the faunal evidence, but merely suggest that the presence of *Ollenellus* and *Hyolithes* in both the lower and middle members of the Kinzers formation and in the Rome formation[20a] may not necessarily establish the faunal equivalence of the two formations but may indicate that the forms common to both may have a considerable vertical range in the Lower Cambrian. Resser[21] states "it is possible that some occurrences [of shale bearing the Olenellus zone] express lithologic facies rather than a stratigraphic zone. But . . . it may be assumed that the *Olenellus* zone is essentially a stratigraphic unit." In view of the stratigraphic evidence above presented, the writers hold the opposite opinion.

---

[17] Op. cit., p. 203.
[18] Op. cit., p. 205.
[19] Quoted on p. 19 of this report.
[20] Stose, G. W., and Jonas, A. I., op. cit., Pl. II, p. 50.
[20a] Op. cit., pp. 207, 215, 221.
[21] Op. cit., p. 200.

STRUCTURE

GENERAL FEATURES

The southeastern fossiliferous sequence, as has been stated, is contained in the Gleaves Knob overthrust block, and so far as is known, it is limited, in Virginia, to this block for it has not been found northeastward nor southwestward. The Gleaves Knob overthrust block lies on the southeastern border of the Great Valley, north and in front of the Poplar Camp overthrust. The Gleaves Knob overthrust passes under the Poplar Camp overthrust block at the northeast near New Castleton School, and at the southwest near Shiloh School to the west of Ewing Mountain. The Poplar Camp overthrust fault is a part of the great Holston Mountain overthrust movement.[22] This is a major overthrust fault which enters the area here described from the northeast and extends southwest along the front of Poplar Camp, Iron, and Holston mountains across Virginia to the Tennessee line, south of Damascus, Va., and southwestward into Tennessee. The Poplar Camp overthrust and its southwestern extension to the Tennessee line, and the generalized structure of the Holston Mountain overthrust block, are shown in a diagram in an earlier report.[23] The Holston Mountain overthrust block is composed of pre-Cambrian and Lower Cambrian rocks that have ridden northwestward over the rocks of the Great Valley, and in this area over the rocks of the Gleaves Knob overthrust block. Evidence that the Holston Mountain thrust block overlies rocks of the Great Valley sequence is found in the Taylors Valley window southeast of Holston Mountain[24] where the overthrust rocks have been eroded and there is exposed a part of the overridden block consisting of the Rome formation and underlying Shady dolomite of the Great Valley sequence. A detailed description of the Holston Mountain overthrust block will be included in the report of the geology of the Great Gossan Lead district.[25]

The Gleaves Knob overthrust block, which lies in front of the main part of the Holston Mountain overthrust block, contains the fossiliferous facies of the Shady dolomite. This southeastern facies, which is equivalent to the similar facies in the York and Lancaster valleys, Pennsylvania, has been moved northwestward by overthrusting and now lies on the Shady dolomite of the main Great Valley sequence.

[22] Stose, G. W., Jonas, A. I., and others, XVI International Geological Congress Guidebook 3, Excursion A-3, Southern Appalachian region, pp. 7, 86, Pl. 26, 1932.
[23] Jonas, A. I., Hypersthene granodiorite in Virginia: Geol. Soc. America Bull., vol. 46, no. 1, Fig. 1, 1935. (Presented before the Geological Society of America, Dec. 29, 1933.)
[24] Stose, G. W., and Jonas, A. I., op. cit.
[25] Manuscript being prepared for publication by the Virginia Geol. Survey.

GLEAVES KNOB OVERTHRUST BLOCK

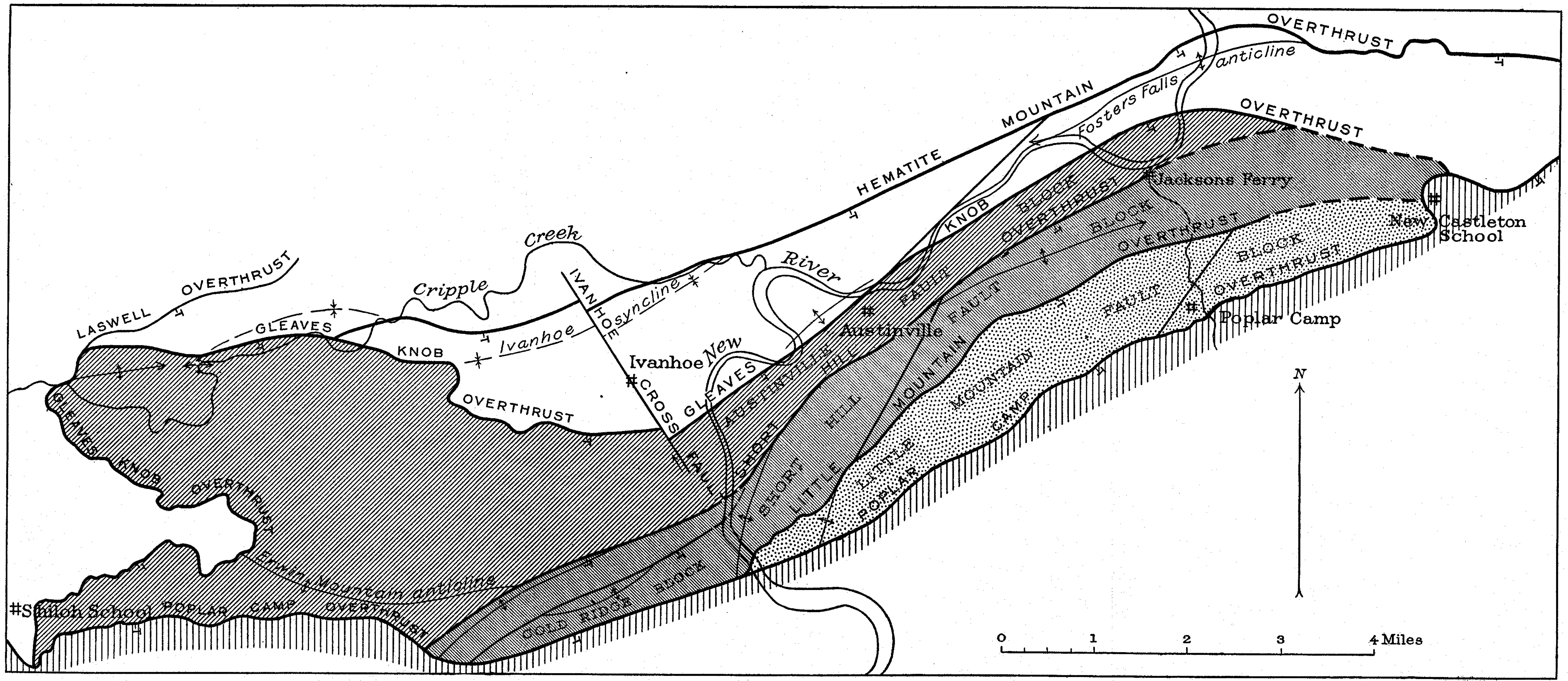
The Gleaves Knob thrust block is composed of three broken anticlines which are, from north to south, the Ewing Mountain anticline, of which Gleaves Knob is the western end; the Cold Ridge-Short Hill anticline; and the Little Mountain anticline. Hampton shale and Erwin quartzite are exposed in each anticline. The Lower Cambrian fossiliferous sequence normally overlies the Erwin quartzite in these anticlines. The Gleaves Knob block is broken into three long narrow slices by faults that lie on the northwest side of the Cold Ridge-Short Hill anticline and the Little Mountain anticline. These faults are the Short Hill and Little Mountain overthrusts. (See Pls. 4A and 5.) A minor thrust fault nearly parallel to Buddle Branch has broken the Short Hill block into two parts, and another minor overthrust has broken up the Little Mountain block. The Little Mountain fault in part corresponds to the Grays School fault of Currier[26] and the part of the Short Hill fault south of Austinville corresponds to a fault that Currier recognized but did not name.

The Short Hill and Little Mountain faults have broken the anticlines near their crests and have cut diagonally across the beds so that only the southeast-dipping limbs of the folds are preserved. Hampton shale and Erwin quartzite are exposed in the southwestern ends of the Erwin Mountain, Short Hill, and Little Mountain anticlines, and northeastward the faults transgress higher beds in the northeast-pitching folds, and may pass into anticlines that are unrecognizable in the massive Ledger dolomite at the eastern ends of the blocks. The repetition of the fossiliferous sequence in the area southeast of Austinville was caused by the Short Hill and Little Mountain overthrusts and their branches that cross the Gleaves Knob fault block.

Short Hill and Little Mountain anticlines may have been the eastern ends of longer minor anticlines of a larger fold of which the Ewing Mountain anticline is a part. Later these anticlines were broken along their crests during the northwestward movement of the Gleaves Knob overthrust. A theoretical restoration of the folds before rupture and overthrusting is shown in Figure 2.

The Poplar Camp overthrust has overridden the southeastern side of the Gleaves Knob block and has cut off that block at both ends. The amount of northwestward movement and the place of origin of the rocks making up the Gleaves Knob overthrust block are not known. It is known, however, that the rocks of the Poplar Camp overthrust have been carried northwestward a considerable distance and the Gleaves Knob block appears to have been pushed up in front of the advancing Poplar Camp overthrust.

[26] Op. cit., pp. 44, 57.



Map of the Gleaves Knob overthrust mass, showing major structural features. The Little Mountain, Cold Ridge-Short Hill, and Austinville fault blocks within the overthrust mass are shown by separate patterns. (See pp. 9 and 24.)

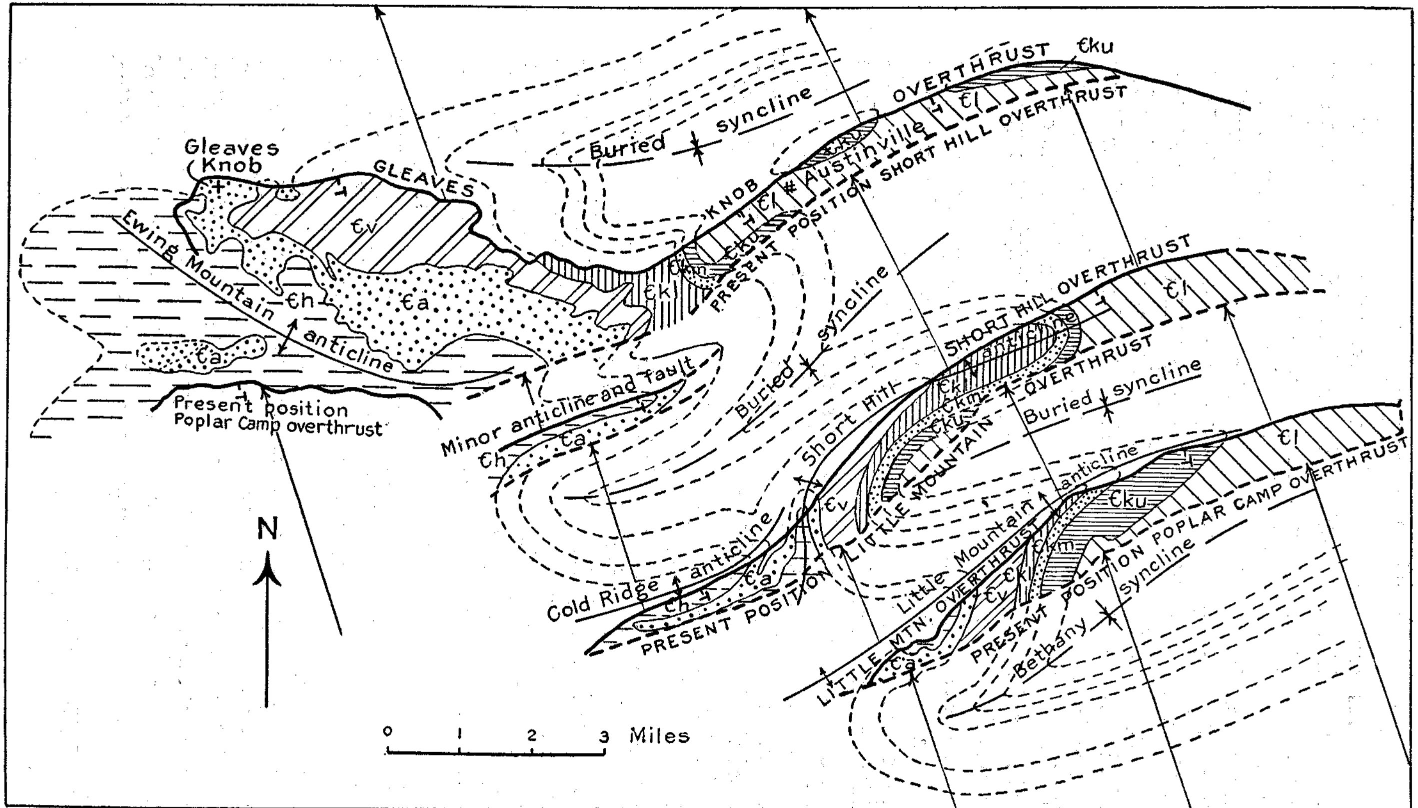


FIGURE 2.—Hypothetical restoration of folds in the Gleaves Knob block before their rupture and overthrusting. The amount of movement on the overthrusts is unknown. In this diagram, the overthrust blocks have been pulled back only enough to reconstruct the missing parts of known folds, and, therefore, the restoration is based on the minimum of shortening. Ꞓl, Ledger dolomite; Ꞓku, upper member Kinzers formation; Ꞓkm, middle member Kinzers formation; Ꞓlk, lower member Kinzers formation; Ꞓv, Vintage dolomite; Ꞓa, Antietam quartzite; Ꞓh, Harpers phyllite.

GLEAVES KNOB OVERTHRUST

The Gleaves Knob overthrust is most evident at its western end where it extends with sinuous outline from Shiloh School around a spur of Ewing Mountain into Cove Branch Hollow and then northwest around Gleaves Knob, where Erwin quartzite and Hampton shale in the overthrust block override the Shady dolomite and Rome formation in the lowland to the west. In the railroad cut along Cripple Creek south of Gleaves Knob, thin rhythmically bedded quartzite and dark argillaceous layers of the upper part of the Hampton shale, dipping 30° E., overlie, in overthrust relations, red shale and limestone of the Rome formation, which dips 45° E. At the contact, the thin quartzites are closely folded and broken by cleavage parallel to the axial planes of the folds, and the red shales of the Rome formation underlying the quartzites are much disturbed.

East of Gleaves Knob the overthrust trends nearly east and passes upward from the Erwin quartzite into the Vintage dolomite, which is overthrust on the saccharoidal upper member of the Shady dolomite. At Eagle Cliff, just north of Eagle, a small anticline in the Gleaves Knob block also brings Erwin quartzite to the surface. The quartzite is here exposed in the stream bed of Cripple Creek and in a tributary branch, and is overlain normally in the bluff north of the creek by dark knotty dolomite of the Vintage, with low east dips. In the bluff on the west side of the tributary, a short distance to the north, crushed Erwin quartzite is exposed overlying saccharoidal dolomite of the upper part of the Shady dolomite. Eastward, in the railroad cut at Catron, south of Huddle, the thrust fault is again exposed. Dark-blue knotty dolomite of the Vintage is closely folded, with folds overturned to the northwest, and the beds are confused and crushed at the contact with the gently northward-dipping saccharoidal dolomite member of the Shady, over which the Vintage dolomite is thrust. In the railroad cut just to the east, yellow-weathering earthy limestone and red shale of the Rome formation are exposed north of the fault. Southeastward, limonite float and ferruginous chert (Pl. 2B) mark the fault break at many places. Southwest and south of Ivanhoe the overthrust dolomite and limestone are brecciated and mineralized, galena being clearly visible in some prospect pits.

The Gleaves Knob overthrust is offset south of Ivanhoe by the Ivanhoe normal cross fault[27] which trends N. 15° W. through Ivanhoe, and offsets the beds of the Rome formation in the Ivanhoe syncline. The principal zinc mines of the Ivanhoe Mining and Smelting Corporation are located along this cross fault. East of New River the beds of the Kinzers formation on the limb of the Ewing Mountain anticline,

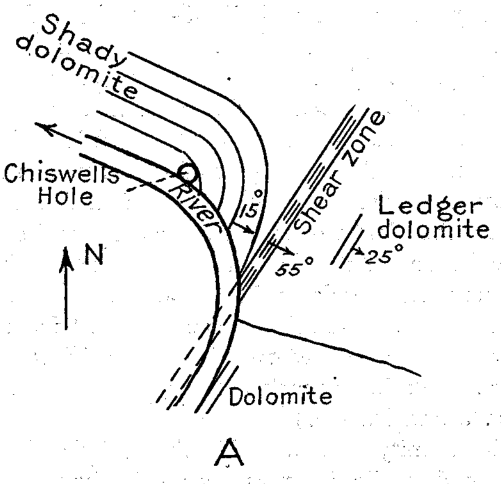
[27] Currier, L. W., op. cit., p. 103.

strike nearly due north and dip 5-10° E., and are cut off abruptly across the strike by the Gleaves Knob overthrust, but the fault is not here exposed. Just to the east, at Chiswells Hole[28] on the east bank of New River, Ledger dolomite, higher in the sequence in the Gleaves Knob block, is overthrust on a gentle anticline of massive blue knotty dolomite of the lower part of the Patterson limestone member of the Shady dolomite. According to the drill records of the Ivanhoe Mining Co. the Erwin quartzite is reported to lie at shallow depth beneath the Patterson member in the lowland north of the river. The ferruginous fault breccia at the contact of the Ledger dolomite and the Patterson member of the Shady can be traced from the river level south of Chiswells Hole northeastward up the cliff east of the Hole, where the Ledger dolomite is much brecciated and mineralized at the contact. (See Fig. 3 and Pl. 4B.)

In the vicinity of Austinville the fault is difficult to trace because the Ledger dolomite in most places is thrust over the similar saccharoidal upper member of the Shady dolomite, and the upland is here thickly covered with terrace gravel. It is clear that the fossiliferous sequence with distinctive lithology is limited to the area southeast of a line running northeast through Austinville, and that north of that line the Shady dolomite is of a different type, characteristic of the Great Valley sequence. Disturbed bedding, with strong northeast-trending cleavage, brecciation of the dolomite, and ferruginous chert have been observed at several places along a northeast-trending line that passes just north of Austinville, and is believed to mark the fault. Mineralized and brecciated dolomite and ferruginous chert in the railroad cut west of Austinville are also thought to mark the fault. At the Austinville ferry the fault evidently lies in the river between the blue dolomite of the Patterson member of the Shady on the north bank of the river, which dips north on the north limb of the Chiswells Hole anticline, and the south-dipping Ledger dolomite of the Gleaves Knob block exposed in the railroad cut on the south bank. Very much disturbed limestone exposed in the railroad cut just southwest of the mouth of Buddle Branch indicates the fault farther east.

A parallel zone of greatly brecciated and highly mineralized Ledger dolomite, one-fourth of a mile south of the Gleaves Knob thrust fault, probably represents a minor parallel break, or split-off of the main fault. The large abandoned open cuts of the Bertha Mining Co. at Austinville are located along this break, and the mine shaft to the east of the open-cut intersects this large ore body at a depth of 235 feet.[29] At the surface the shaft penetrates Ledger dolomite, which dips about 35° SE., and the ore breccia zone, which also dips 35° SE., is approx-

[28] Currier, L. W., op. cit., p. 101 and Pl. 15B.
[29] Currier, L. W., op. cit., p. 100.



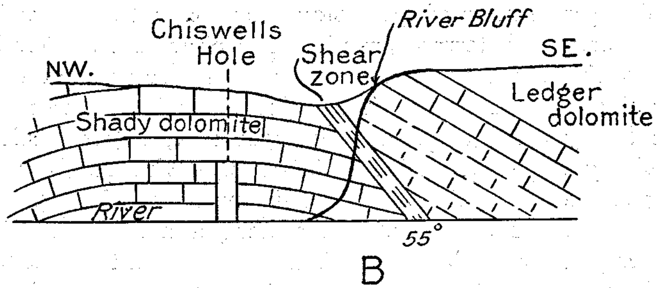


FIGURE 3.—A, Sketch plan of fault contact at Chiswells Hole on New River. The shaft here is in horizontal knotty blue dolomite of the lower part of the Patterson limestone member of the Shady dolomite, which is part of a gentle anticline with a dip of 15° SE. on its flank. Zinc and lead sulphides are disseminated in the dolomite. To the east is granular gray Ledger dolomite dipping 25° SE., which is sheared to shaly layers at the contact. This contact dips 55° SE. The brecciated dolomite at the contact is cemented by ferruginous chert. B, Sketch section across the shear zone at Chiswells Hole.

imately parallel to the bedding of the dolomite. In the main adit of the mine, which extends south from the river and intersects the shaft at the 235-foot level, other small ore bodies were encountered north of the shaft. These are parallel brecciated zones below the larger ore body and nearer the sole of the Gleaves Knob overthrust. Both the strike and cross faults in the mine workings are regarded by Brown[30] as due to compression. He reports that the richest and largest bodies of ores occur at the intersection of these two types of faults. The sketch map

[30] Brown, W. H., Quantitative study of ore zoning, Austinville mine, Wythe County, Virginia: Econ. Geology, vol. 30, no. 4, pp. 425-431, 1935.

in his paper[31] shows that the main strike fault is cut and offset by the cross faults. Although the level on which these faults are drawn is not indicated, it is probable that the strike fault shown in the drawing is the parallel break above the main overthrust, represented by the mineralized breccia zone at the 235-foot level in the shaft.

Three-fourths of a mile west of Jacksons Ferry the Gleaves Knob overthrust is exposed in the railroad cut and shows south-dipping blue limestone of the upper part of the Kinzers formation thrust over knotty blue dolomite, the lower part of the Patterson limestone member of the Shady dolomite, which dips 20° S. on the south flank of the Fosters Falls anticline. This dolomite overlies flat-lying Erwin quartzite exposed just to the west in the railroad cut. This quartzite is part of a gentle anticlinal area that makes quartzite riffles in the river and ledges on the lower slopes north of the river, and is part of the larger anticline that makes Fosters Falls Mountain to the east. This anticline is here named the Fosters Falls anticline, but was called the Austinville anticline by Currier[32] because he considered that it extended southwestward to Austinville.

Southwest of Fosters Falls, in the railroad cut along the river, the Ledger dolomite is exposed in an overthrust position on south-dipping blue limestone of the upper part of the Patterson member, which in turn overlies the ribboned dolomite of the lower part of the Patterson member in the Fosters Falls anticline. The underlying Erwin quartzite crops out at the falls. Eastward, to New Castleton School, the fault follows the lowland, where rock exposures are poor.

It is evident from the stratigraphic and structural relations here described, that the fossiliferous limestones of the Gleaves Knob overthrust block have discordant relations to the various members of the Shady dolomite to the north, and have been thrust northwestward onto Shady dolomite and higher beds of the Great Valley sequence. Currier[33] suggested that "It may be that these beds constitute a block of sediments belonging to an area of deposition nearer shore and at some distance from their present position, and that they were brought over the more common Shady beds into their present position by thrust faulting from the south or southeast. They may, indeed, have been closely allied to a connecting waterway between the Shady trough of southwestern Virginia and the York-Lancaster Basin of Pennsylvania, whence came the fauna now found in the Shady of the Austinville Basin." Brecciation and shearing of the dolomite, ferruginous chert, and mineralization in low-dipping ore bodies at and near the overthrust have been mentioned as evidences of the fault. Except along the north-south cross fracture

[31] Op. cit., Fig. 1, p. 427.
[32] Op. cit., pp. 47-48.
[33] Op. cit., p. 35.

south of Ivanhoe no large lead and zinc ore bodies have been found that are not associated with the Gleaves Knob overthrust and other parallel strike faults in the beds above the main overthrust. Further evidence of the fault is the fact that the fossiliferous beds do not occur in the Shady dolomite north of the Gleaves Knob overthrust. Drill records of the National Carbide Co. near their quarry east of Ivanhoe, in the area northwest of Austinville, show that the saccharoidal member of the Shady dolomite directly overlies the Patterson member and that no fossiliferous limestones were encountered down to the Erwin quartzite.[34]

CONCLUSIONS

The facts presented above are believed to warrant the conclusions that (1) the fossiliferous beds of Lower Cambrian age in the Austinville area differ faunally and lithologically from those of the equivalent Shady dolomite in the main part of the Great Valley, and represent a distinctly different facies deposited in an area southeast of the main part of the Appalachian geosyncline; (2) these rocks, in lithology and faunal content, resemble the southeastern facies of the Lower Cambrian Tomstown dolomite in Pennsylvania; (3) these rocks were overthrust northwestward onto the equivalent Shady dolomite typical of the Great Valley; and (4) the rocks which are now in juxtaposition, are of the same age but of different facies, and are separated by a tectonic discordance.

[34] Dickson, R. B., American Metal Co., Ltd., New York, N. Y., personal communication.

GEOLOGY OF POWELL VALLEY IN NORTH-EASTERN LEE COUNTY, VIRGINIA

BY

ROBERT L. BATES

VIRGINIA CONSERVATION COMMISSION
VIRGINIA GEOLOGICAL SURVEY
Bulletin 51-B
UNIVERSITY, VIRGINIA
1939

CONTENTS

ILLUSTRATIONS

TABLE

Geology of Powell Valley in Northeastern Lee County, Virginia[1]

By Robert L. Bates

INTRODUCTION

GEOGRAPHY

The area considered in this report lies in southwestern Virginia, in the northeastern part of Lee County. (See Fig. 4.) It includes that part of the county projecting northeastward, which is bounded on the northwest by Wise County and on the southeast by Scott County. The southern edge of the area is the parallel of 36° 45′. On the west and northwest the boundary is the Cumberland escarpment, represented in this region by Stone Mountain. All of the area has been surveyed topographically on a scale of 1:62,500, and is shown on the Big Stone Gap and Nolansburg quadrangles of the U. S. Geological Survey. In addition, the area has been mapped planimetrically by the Tennessee Valley Authority on a scale of 1:24,000, and is covered by the Olinger, Keokee, and Pennington Gap sheets.

The principal towns are Pennington Gap in the southwestern part of the area, and Big Stone Gap about 3 miles northeast of the Lee-Wise County line. These towns are connected by the Clinch Valley division of the Louisville and Nashville Railroad, and by State Highway 64, both of which extend nearly lengthwise of the area. The villages of Dryden and Olinger are on the railroad and are connected with the main highway by paved roads. A branch of the Southern Railway, which connects Bristol with the coal fields via Big Stone Gap, passes through the eastern part of the area.

The area is maturely dissected, with virtually the entire surface in slope. The maximum local relief is 2200 feet. The highest point in the area is on the Lee-Scott County line, where the summit of Powell Mountain rises to 3500 feet, and the lowest altitude is 1300 feet, along Powell River southwest of Dryden. The distance across the valley between Stone and Powell mountains is about 5 miles. Powell River and its tributaries drain all the

[1] This paper is a summary of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Geology, State University of Iowa, June, 1938.

area except the southeast part, where two streams join to form the North Fork of Clinch River.

The topography is controlled by the geologic structure, which is an anticline, asymmetrical in cross section. The fold has been breached by erosion. The upturned edges of the resistant formations make long ridges—Stone and Powell mountains, Wallen and River ridges—which, with the intervening narrow valleys, are characteristic features of the area. A prominent physiographic feature is Stocker Knob, a synclinal mass which has resisted the erosion that elsewhere penetrated more deeply into the anticline.

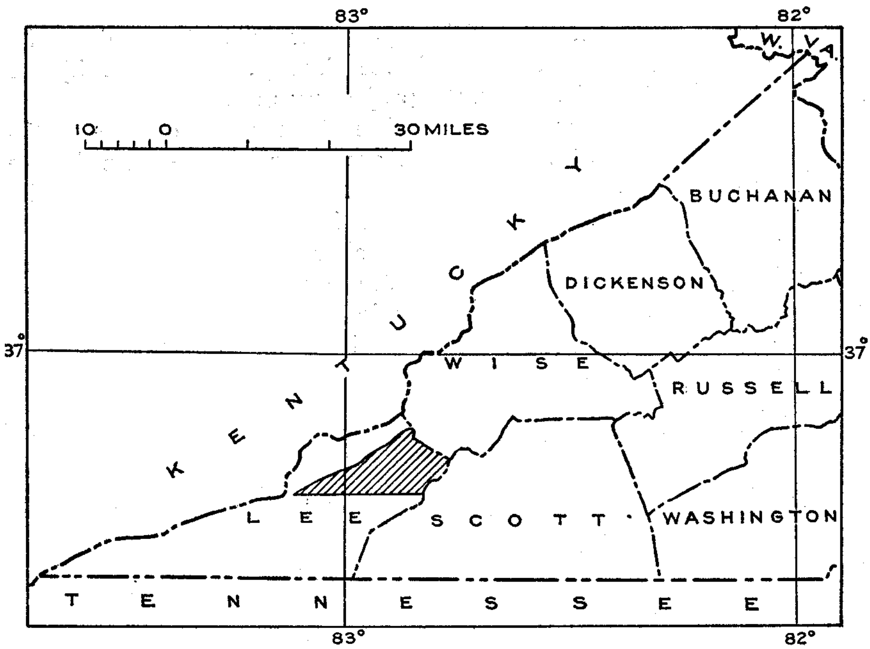


FIGURE 4.—Index map showing location of the Powell Valley area in northeastern Lee County, Virginia.

SCOPE OF THE REPORT

This report includes a large-scale geologic map of the area and a detailed discussion of the geology. The rock formations are described and fossils, which were collected from nearly all of them, are listed. The structure of the Powell Valley anticline in northeastern Lee County is discussed in some detail. A part of the report deals with the physiography of the area. Suggestions are made concerning the utilization of mineral resources.

ACKNOWLEDGMENTS

The writer's gratitude is hereby expressed to Dr. Arthur Bevan, State Geologist, and to the Virginia Geological Survey, for generous cooperation in this project. Dr. Charles Butts, who spent a day and a half in the field, gave stimulating counsel and suggestions, as well as aid in identifying fossils, which the writer appreciates. Dr. H. P. Woodward constructively criticized the mapping and the section on physiography. To Dr. Josiah Bridge the writer is indebted for friendly advice and help. Dr. J. H. Swartz and Mr. G. W. Stose, who have done previous geologic work in this region, were generous in supplying information and making suggestions. Messrs. A. S. Fry and James E. Goddard, of the Tennessee Valley Authority, Knoxville, provided maps of the area studied and put airplane photographs at the writer's disposal. Acknowledgment is made to Dr. R. J. Holden for suggestions on stratigraphy. To the members of the faculty in the Department of Geology, State University of Iowa, the writer extends thanks for aid in the writing of the report. Able assistance was given in the field by Mr. A. L. Morgan, III. Finally, the writer wishes to record the friendliness and interest of the residents of Wise and Lee counties.

STRATIGRAPHY

GENERAL STATEMENT

The rocks of northeastern Lee County are all sedimentary and range in age from Cambrian to Upper Pottsville (Pennsylvanian), inclusive. (See Pl. 6.) The Pennsylvanian strata immediately northwest of Powell Valley, which bear large amounts of coal, have been mapped and described in detail by Giles.[2] The youngest formation studied by the writer is the basal Pennsylvanian Lee conglomerate, which is closely involved in the structure of the Powell Valley anticline and makes the Cumberland escarpment in this region. The rocks from exposed Cambrian to the top of the Lee formation have a thickness in this area of some 9000 feet. They are divided into 19 formations.

As indicated in Table 1, the lithology varies widely. The Cambrian and Lower Ordovician rocks are dolomites and the rest of the Ordovician is largely limestone. The Devonian rocks are mostly shales. The Mississippian is represented by limestone, shale, and sandstone, and the Pennsylvanian contains conglomerate, sandstone, shale, and coal. Bentonite occurs at three horizons in the upper part of the Lowville formation, the aggregate thickness being not more than 4 feet. Locally, intense shearing has caused shales to assume a somewhat talcose appearance, but on the whole metamorphism has been negligible.

The pre-Pennsylvanian rocks, except the Pennington formation in part (Upper Mississippian), are marine in origin. They represent a long time of sedimentation. No evidence of marked erosional unconformity was seen, and it appears that deposition may have been essentially continuous until Pennington time. The Blount group (Ordovician), as described by Butts,[3] is, however, lacking in this area, without a perceptible unconformity to mark its position. The bentonite indicates falls of volcanic dust which recurred at intervals within the time of deposition of one formation. The coarsely clastic rocks of the Pennington formation and of the Pottsville strata are probably the result of very shallow-water deposition and stream action. The Pottsville contains a few marine fossils and abundant plant remains.

[2] Giles, A. W., The geology and coal resources of the coal-bearing portion of Lee County, Virginia: Virginia Geol. Survey Bull. 26, 1925.
[3] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 15-18, 1933.

TABLE 1.—*Geologic formations in Powell Valley, northeastern Lee County, Virginia*

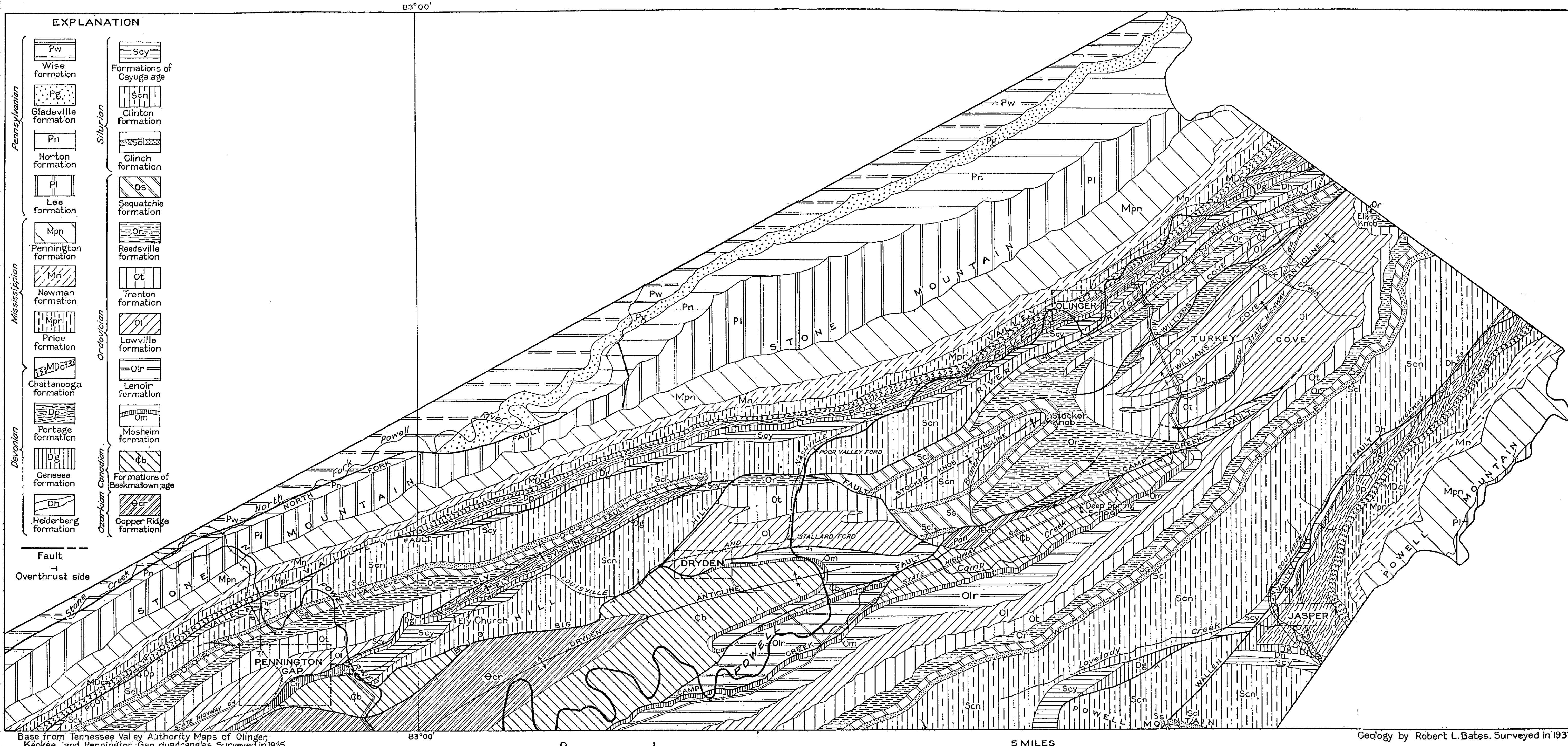
System		Formation	Symbol on Map	Thick-ness (feet)	CHARACTER OF ROCKS
1	2				
Carboniferous	Pennsylvanian	Lee formation	Pl	1650	Alternating thick units of sandy shale and coarse conglomeratic sandstone. The shale contains thin sandstone beds and impure coal seams. The sandstone and conglomerate are siliceous and highly resistant to erosion. The lowermost layer forms knife-edge ridges on Stone Mountain.
Carboniferous	Mississippian	Pennington formation	Mpn	1150	Thick beds of quartzitic sandstone and conglomerate separated by beds of sandy micaceous shale. The sandstone is green-brown, dense, and massive. The conglomerate is made up of rounded pebbles of white vein quartz in a matrix of sand cemented by silica. The shales carry fucoidal markings and vary in color. They are poorly exposed.
Carboniferous	Mississippian	Newman formation	Mn	750	Shaly limestone and calcareous shale in the upper part; massive light-gray pure crinoidal limestone, in part oolitic, in the lower third. Thin beds of argillaceous slabby limestone at the base contain nodules and thin layers of black chert.
Carboniferous	Mississippian	Price formation	Mpr	245	Interbedded thin layers of gray shale and dense sandstone. Purple-red beds at top show Maccrady horizon.
—?— Devonian	Mississippian —?— Devonian	Chattanooga formation	MDc	320	Splintery black shale in upper and lower parts, separated by drab-colored shale.
Devonian	Devonian	Portage formation	Dp	400	Interbedded drab-colored and black shales, with a few thin lenticular sandstone beds.
Devonian	Devonian	Genesee formation	Dg	200	Fissile coal-black shale.
Devonian	Devonian	Helderberg formation	Dh	0–100	Massive sandy limestone and calcareous sandstone.
Silurian	Silurian	Formation of Cayuga age	Scy	200	Dark-blue laminated limestone with calcite veinlets.
Silurian	Silurian	Clinton formation	Scn	400	Dense quartzitic sandstone in thin beds intercalated with red, brown, blue-gray, and greenish shale. Thin lenticular beds of hematite grade into red sandstone.
Silurian	Silurian	Clinch formation	Scl	100	Light-gray to white massive quartzitic sandstone.

TABLE 1.—*Geologic formations in Powell Valley, northeastern Lee County, Virginia—Continued*

System 1	System 2	Formation	Symbol on Map	Thickness (feet)	CHARACTER OF ROCKS
Ordovician	Ordovician	Sequatchie formation	Os	200	Red, green, and brown shale with thin sandstone beds. Thin argillaceous limestone near the base.
Ordovician	Ordovician	Reedsville formation	Or	400	Brown shale with thin beds of siltstone, sandstone, and limestone; contains many fossils.
Ordovician	Ordovician	Trenton formation	Ot	500	Dark gray-blue crystalline limestone in beds of medium thickness separated by partings of calcareous shale.
Ordovician	Ordovician	Lowville formation	Ol	500	Calcareous buff to greenish gray mudrock weathering to a crumbly, checky mass; bentonite in thin layers near the top. Lower part of the formation consists of very fine-grained thin-bedded limestone.
Ordovician	Ordovician	Lenoir formation	Olr	150	Dark granular limestone, with abundant chert.
Ordovician	Ordovician	Mosheim formation	Om	75	Light-gray massive dense limestone ("vaughanite").
Ordovician	Canadian	Formations of Beekmantown age	Ꞓb	1000	Dense homogeneous light-gray dolomite in thick beds. The upper half contains light-colored beds which are soft and earthy, interbedded with light gray subvaughanitic limestone of Mosheim type. The lower beds are fresh, hard, and tough. Light-gray chert occurs in residual soil but not in fresh rock.
Cambrian	Ozarkian	Copper Ridge formation[a]	Ꝋcr	1000	Thick-bedded light- to dark-gray dolomite with moderately coarse texture. Weathered surfaces are rough due to undissolved dolomite rhombs. Much milky white chert occurs, mostly in residual soil. Some of it is oolitic. Lenticular beds of quartz sandstone that weather brownish are characteristic of the formation.

1. Classification of U. S. Geological Survey.
2. Former classification of Virginia Geological Survey.

[a] May include Chepultepec, of Lower Ordovician age or Upper Ozarkian of Ulrich.



GEOLOGIC MAP OF POWELL VALLEY IN NORTHEASTERN LEE COUNTY, 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 Copper Ridge formation should be included in the Cambrian and the formations of Beekmantown age in the Ordovician.

CAMBRIAN SYSTEM

COPPER RIDGE FORMATION

Definition.—The Copper Ridge dolomite was named by Ulrich[4] from a prominent ridge made by the formation in southwestern Virginia and eastern Tennessee. It constitutes the middle part of the old Knox dolomite of the southern Appalachian region.

Description.—In the area studied, the Copper Ridge consists of thick-bedded dolomite. Most of the beds are light drab gray and crystalline. Roughness on weathered surfaces is caused by resistant grains of dolomite which stand out in relief. Much light gray to milky white chert occurs in the formation, almost entirely on weathered exposures and in residual soil. Much of the chert is composed of siliceous oolites set in a matrix of chalcedony. A specimen collected by the writer shows the contact between siliceous drab-gray crystalline dolomite and white oolitic chert. The chert appears to have replaced the dolomite along an extremely irregular contact, and there are a few "islands" of dolomite completely surrounded by chert. The chert in the Copper Ridge formation appears to have formed since the deposition of the dolomite.

Along State Highway 64, a mile southeast of Pennington Gap, a 3-foot layer of quartz sandstone in the Copper Ridge is exposed. Such beds of sandstone are characteristic of the formation. As a rule they are lenticular and but a few inches to a few feet thick. Pieces of sandstone, colored brown by iron oxide, are conspicuous features of residual soil from the Copper Ridge formation.

The full thickness of the formation is not measurable in this area, but it is estimated that at least 1000 feet are present. The Copper Ridge makes high hills and ridges, of which Big Hill, 2 miles east of Pennington Gap, is an example. The surface of the outcrop belt is covered with chert and sandstone float. Vegetation is limited mostly to grass and scrub pine.

Fossils and correlation.—Fossils are extremely scarce in the Copper Ridge. Bridge[5] states that in eastern Tennessee a fauna which has been discovered 500 feet below the top of this formation is Cambrian in age. If this determination is valid, it calls

[4] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 636, 1911.

[5] Bridge, Josiah, The correlation of the Upper Cambrian sections of Missouri and Texas with the section in the Upper Mississippi Valley: U. S. Geol. Survey Prof. Paper 186-L, p. 235, 1937.

in question the assignment of the Copper Ridge dolomite to the Ozarkian and the recognition of the latter as a separate system. The Copper Ridge forms the Middle Ozarkian of Ulrich, and according to Butts[6] is continuous with, and represents but a facies of, the Conococheague limestone of the southeastern belts of the Appalachian Valley from Pennsylvania to central Tennessee.[7]

Stratigraphic relations.—As the Copper Ridge is the lowest formation that crops out in the area, its relations to underlying beds are indeterminate. Outside this area it generally rests on the Nolichucky formation with an unconformity due to the absence of the Brierfield, Ketona, and Bibb dolomites which intervene at this horizon in Alabama. In northern and central Virginia the Copper Ridge is overlain by the Chepultepec limestone, the Upper Ozarkian of Ulrich. Butts[8] states that 4 miles southeast of Cumerland Gap, some 35 miles southwest of this area, the Chepultepec is present, but its thickness though unknown is slight. The Chepultepec, if present in this area, is separable only with much difficulty from the Copper Ridge, due to lithologic similarity and the absence of diagnostic fossils. Hence, in this report the two formations are discussed and mapped as a unit. Relations with the overlying beds of Beekmantown age appear conformable.

ORDOVICIAN SYSTEM

FORMATIONS OF BEEKMANTOWN AGE

Definition.—The term Beekmantown was first applied by Clarke and Schuchert,[9] the type locality being at Beekmantown, Clinton County, New York. Strata of Beekmantown age in central Pennsylvania constitute the Canadian system of Ulrich. In the central and southeastern Appalachian belts in Virginia, it is possible to use the formational subdivisions applied in Pennsylvania. In the northwestern belts, however, the entire system is dolomite of striking uniformity from bottom to top. As fossils are so scarce in this area, the writer did not attempt subdivision of the formation. Hence, the post-Copper Ridge, pre-Mosheim rocks are designated "Formations of Beekmantown Age."

Description.—The Beekmantown beds in this area consist largely of dense homogeneous light-gray dolomite in thick beds. In the upper part, notably near Deep Spring School, some of the

[6] Op. cit., p. 9.
[7] Personal communication.
[8] Op. cit., p. 10.
[9] Clarke, J. M., and Schuchert, Charles, The nomenclature of the New York series of geological formations: Am. Geologist, vol. 25, p. 117, 1900.

dolomite has the prevailing light color but, instead of being hard and tough, is soft and earthy. Some of these layers are so sectile that locally they are called "soapstone." From its stratigraphic position, this material appears to represent the upper formation (Bellefonte) of the Beekmantown group. No chert was seen in the fresh dolomite, but much occurs in the residual soil. Like that of the Copper Ridge, this chert is believed to be secondary in origin.

At a bridge on State Highway 64, half a mile southwest of its junction with State Highway 66 and 1 mile due north of Lovelady Gap, a 2-foot layer of limestone of Mosheim type occurs interbedded with Upper Beekmantown earthy dolomite. Its position is some 20 feet below the contact with the Mosheim. This type of limestone is reported by Butts to be rather common elsewhere in the upper part of the Beekmantown.

The manner of erosion of this particular limestone layer is of interest. It makes a miniature escarpment. On the dip slope to the escarpment, the limestone breaks into remarkably even blocks which closely resemble paving blocks. (See Pl. 7A.) The slope below the escarpment is littered with similar blocks of the limestone.

At no place in the area is it possible to measure a complete section of the Beekmantown formations. It is estimated that their thickness is approximately 1000 feet.

The topography produced on the Beekmantown is similar to that of the Copper Ridge formation. The soil is thin and cherty and where cleared is used chiefly for pasture.

Fossils and correlation.—Fossils are scarce in the Beekmantown. At Deep Spring School, *Maclurea* sp. and an orthoceroid were collected, and on the hillside immediately south of Pennington, a species of *Hormotoma* was found. All are indicative of the upper Beekmantown (Bellefonte) age of these beds. The fossils are preserved as molds in chert. The Beekmantown is correlated with the Shakopee of the upper Mississippi Valley. The lower part (Nittany) is comparable in age to the Roubidoux formation of Missouri and the Longview of Alabama, while the upper part (Bellefonte) is approximately equivalent to the Cotter and Powell formations of Missouri and the Newala of Alabama.

Stratigraphic relations.—So far as could be determined, the contacts of the beds of Beekmantown age are conformable and gradational at both bottom and top. The dolomites of the Copper Ridge and Beekmantown are very similar, and frequently can be distinguished in the field only by discontinuous layers of sandstone in the Copper Ridge. Relations between the Beekmantown and Mosheim beds also appear conformable, but there is a considerable hiatus, as the Murfreesboro, as well as other formations recognized elsewhere, is missing in this area. Both at the bridge mentioned above and on the road from the main highway to Dryden, thin beds of dense gray limestone of Mosheim type occur intercalated with dolomite in the top of the Beekmantown.

STONES RIVER GROUP

MOSHEIM FORMATION

Definition.—The Mosheim was first named by Ulrich,[10] from Mosheim, Green County, Tennessee.

Description.—The Mosheim is a light-gray dense finely crystalline limestone (vaughanite). Its conchoidal fracture and property of ringing when struck are characteristic. The formation weathers to rounded and fluted light-gray to light-blue masses. The following section gives its character and thickness:

Mosheim limestone south of Deep Spring School

	Thickness Feet
Lenoir limestone	
Limestone, dark colored, granular, slabby	
Mosheim limestone (72 feet)	
6. Limestone, light to medium gray, vaughanitic, pure, in beds 8 to 10 inches thick	20
5. Limestone, dense, argillaceous, in thin beds with clay partings	4
4. Limestone, light gray, vaughanitic, pure, in massive beds	12
3. Limestone, medium to dark gray, vaughanitic to dense granular, with a little chert	8
2. Limestone, dark, fine grained, with much black chert in beds and flattened nodules	10
1. Limestone, light to medium gray, vaughanitic, pure, in massive beds from 1 to 4 feet thick; weathers light blue gray with a rough surface	18
Covered (top of Beekmantown)	

[10] Op. cit., pp. 413-414, 538, 543-547.

Fossils and correlation.—Species of *Pterygometopus* and *Leperditia* were collected from beds close above the Beekmantown. The former is a characteristic fossil of the Murfreesboro formation, which at some localities in Virginia and Tennessee intervenes between the Beekmantown and the Mosheim. The typical lithology of the Murfreesboro does not occur in this area, and thin beds at its horizon, indicated by the fossils mentioned, are mapped with the Mosheim. The Murfreesboro occurs as a separate formation in the Central Basin of Tennessee, where it is overlain by the Pierce limestone. The Murfreesboro and the Mosheim are a part of the Stones River group, which is placed in the Chazyan series.

Stratigraphic relations.—There is no evidence of an erosional unconformity at the base of the Mosheim in this area. According to Ulrich,[11] the St. Peter sandstone of the upper Mississippi Valley is pre-Chazyan, hence pre-Murfreesboro. If this is a fact, the absence of the St. Peter between the Beekmantown and the Murfreesboro-Mosheim beds necessitates a hiatus at that horizon. According to Mrs. Edson,[12] however, there is "no evidence" in Minnesota, the Ozarks, and the Appalachians to show that the St. Peter is pre-Chazyan. She advances the tentative conclusion that the St. Peter is post-Chazyan and pre-Black River in age. If true, there is conformity between the Beekmantown and the Stones River in this area. Relations between the Mosheim and the overlying Lenoir limestone are conformable.

LENOIR FORMATION

Definition.—The name Lenoir was first used by Safford and Killebrew,[13] from Lenoir City, Loudon County, Tennessee.

Description.—The Lenoir is a dark-colored granular limestone, in most places argillaceous and abundantly cherty. The composition and thickness of the formation are shown in the following measured section:

---

[11] Op. cit., Pl. 27.

[12] Edson, F. C., Résumé of St. Peter stratigraphy: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 8, pp. 1110-1130, 1935.

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

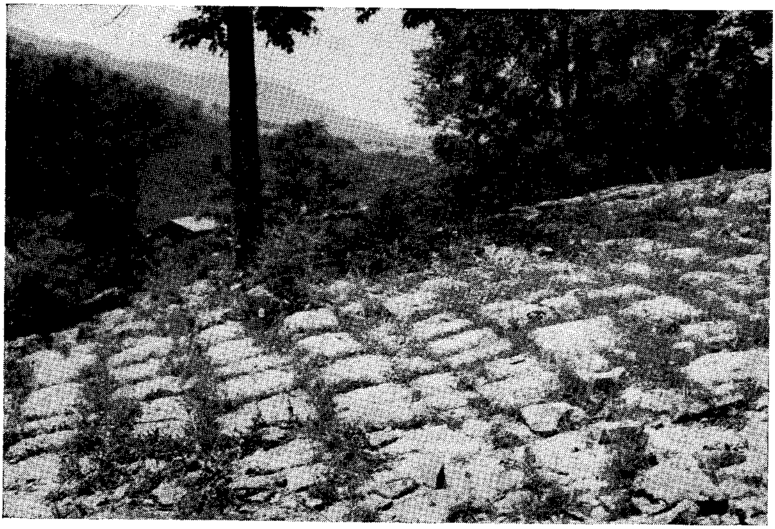
Lenoir limestone south of Deep Spring School

	Thickness Feet
Lowville limestone	
Limestone, dense, argillaceous, platy	
Covered	10
Lenoir limestone (124 feet)	
7. Limestone, dark, granular, cherty, impure, slabby; weathers to fluted surfaces	50
6. Limestone, light gray, vaughanitic, pure	8
5. Limestone, dark, with much nodular chert; weathers fluted and slabby	40
4. Limestone, medium gray, vaughanitic, one thick bed	3
3. Limestone, dark, slabby, partly vaughanitic; rubbly	8
2. Limestone, medium gray, vaughanitic	5
1. Limestone, dark, granular, thick and thin bedded, some slabby	10
Mosheim limestone	
Limestone, light gray, vaughanitic, pure	

Intervals 5 and 7 of the above section are typical of the Lenoir. The thickness of the formation varies, as is indicated at another exposure along Powell River near Stallard Ford, where about twice the above thickness was measured. The formation is highly soluble and sinks are common on its outcrop.

Fossils and correlation.—Species of the brachiopod *Leptaena* and of an ostracode, *Leperditia,* were collected from the Lenoir near Stallard Ford. The formation is late Stones River in age and is correlated with the Ridley formation of the Tennessee Basin, the Crown Point formation of the type Chazy section in New York, and the Lemont in Pennsylvania.

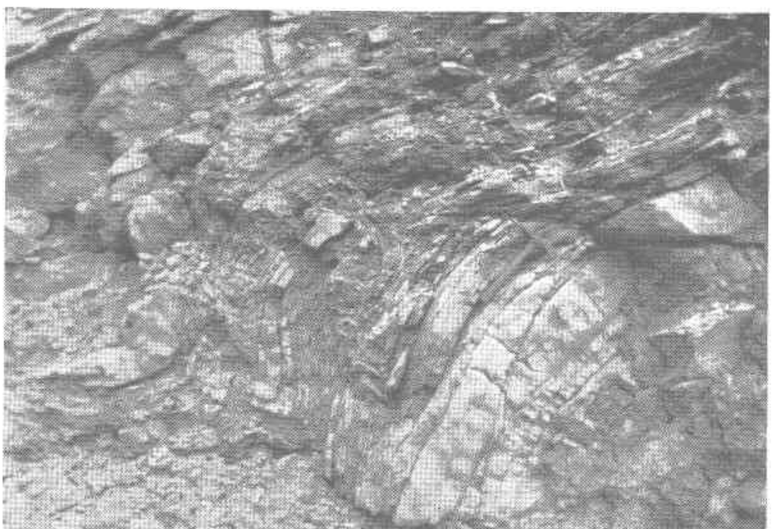
Stratigraphic relations.—The Lenoir lies conformably on the Mosheim. In this area it is succeeded unconformably by the Lowville formation of Black River age. The entire Upper Chazyan, the Blount group, is absent. This group in other parts of the Valley of Virginia comprises the Holston, Whitesburg, Athens, and Ottosee formations, which have a maximum thickness of several thousand feet. Hence, although to all appearances the dark-colored cherty limestone of the Lenoir grades up into the argillaceous impure shaly limestone of the Lowville, a time break of some magnitude exists between them. That such time breaks are



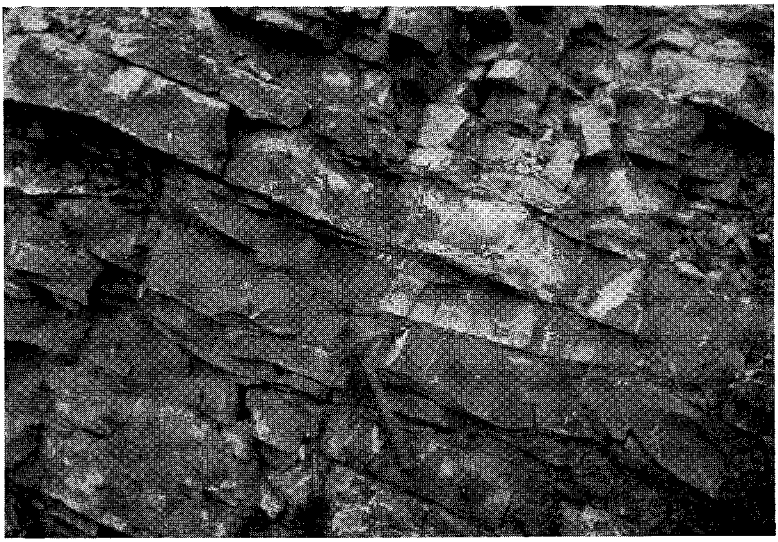
A. "Natural pavement" produced by weathering of a thin limestone bed in the Beekmantown dolomite. Near bridge over Camp Creek on State Highway 64, 1 mile north of Lovelady Gap. (See p. 45.) Photograph by Arthur Bevan.

B. Local fold in Lowville limestone. In Turkey Cove, half a mile south of the Lee-Wise county line.

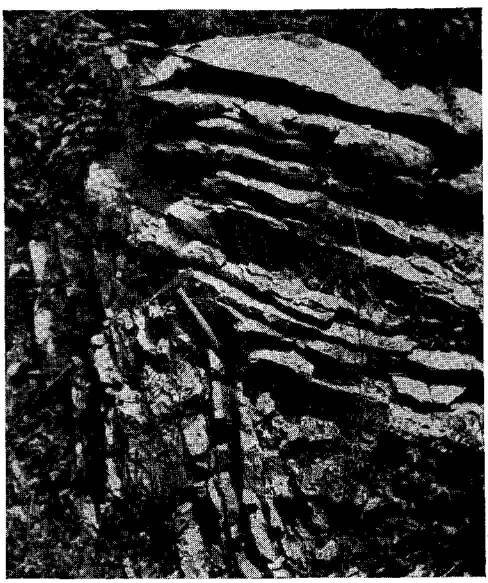
A. "Natural pavement" produced by weathering of a thin limestone bed in the Beekmantown dolomite. Near bridge over Camp Creek on State Highway 64, 1 mile north of Lovelady Gap. (See p. 45.) Photograph by Arthur Bevan.



B. Local fold in Lowville limestone. In Turkey Cove, half a mile south of the Lee-Wise county line.

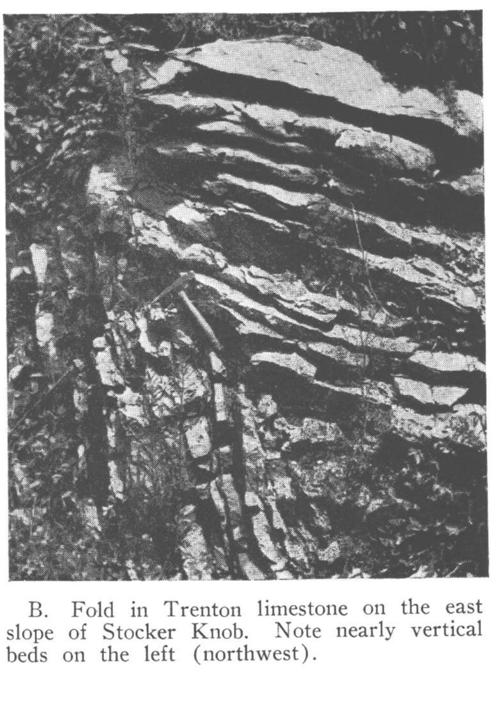


A. Trenton limestone along highway in Turkey Cove. Note the lenticular bed above hammer.



B. Fold in Trenton limestone on the east slope of Stocker Knob. Note nearly vertical beds on the left (northwest).

A. Trenton limestone along highway in Turkey Cove. Note the lenticular bed above hammer.



B. Fold in Trenton limestone on the east slope of Stocker Knob. Note nearly vertical beds on the left (northwest).

not always represented by a surface of relief has been stressed by Butts and by Cooper.[14]

BLACK RIVER GROUP

LOWVILLE FORMATION

Definition.—The term Lowville was introduced by Clarke and Schuchert,[15] from the town of the same name in Lewis County, New York. It replaced the old term "Birdseye."

Description.—In Powell Valley the Lowville is composed of two types of material. Occurring mostly in the lower two-thirds of the formation is a very fine-grained fossiliferous limestone which varies from pure to extremely argillaceous. Thin beds of this material weather shaly, but thick beds form slabs and plates on weathering. (See Pl. 7B.) Largely confined to the upper part of the formation is a calcareous mudrock which when fresh is buff and greenish gray. The weathering product of this mudrock is a crumbly, checky mass of loose pieces, many of which are roughly wedge-shaped. Low rounded exposures of this material, two or three feet across, are characteristic of field outcrops of the Lowville. A section of the Lowville near Deep Spring School

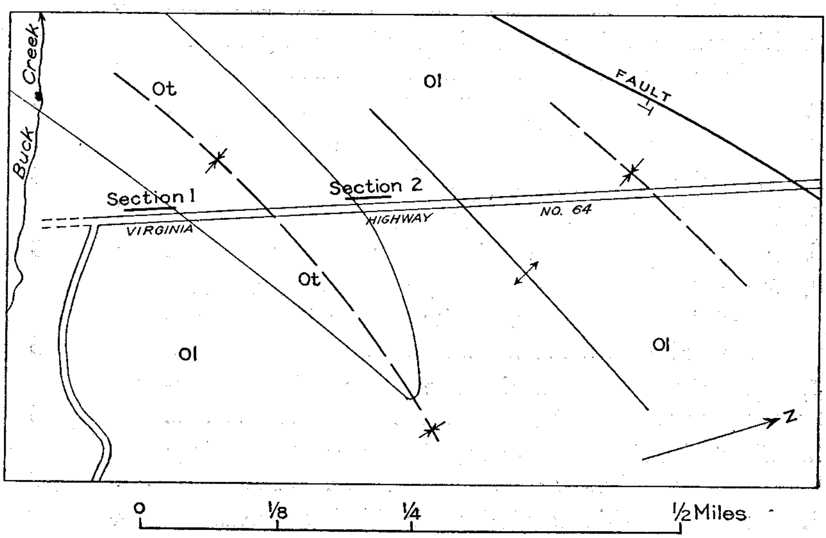


FIGURE 5.—Location of measured sections of bentonite in Turkey Cove, Lee County, Virginia.

[14] Cooper, B. N., Lower Paleozoic unconformities in Pulaski county, Virginia: Proc. Geol. Soc. America for 1936, p. 68, 1937.

[15] Op. cit.

was measured by Ulrich and is given in the report on the geology of Wise County.[16]

Bentonite.—Thin beds of bentonite at three horizons in the upper part of the Lowville are exposed along State Highway 64, in Turkey Cove. (See Fig. 5.) Folding of the rocks has repeated the exposures. The measured sections given below are numbered to correspond to the numbers on Figure 5.

Bentonite section No. 1; along State Highway 64, about one-eighth mile northeast of Buck Creek

	Thickness Ft.	In.
Trenton limestone		
Limestone, crystalline, in beds of medium thickness. Not measured.		
Lowville limestone (25 ft., 10 in.)		
15. Mudrock, dark green to brown, shaly		3
14. *Bentonite,* yellow to white, clayey		1
13. Limestone, blue gray, massive, uniform, dense	8	
12. Limestone, rubbly, argillaceous	1	
11. Limestone, thick bedded, massive, fine to medium crystalline	4	
10. Limestone, rubbly, with beds of crumbly brown shale	4	
9. Limestone, finely crystalline, hard		3
8. Shale, gray, rubbly, crumbly		4
7. *Bentonite,* yellow buff, soft, flaky		4
6. Mudrock, brown, shaly, crumbly	1	
5. *Bentonite,* buff, pure, with greasy luster	1	3
4. *Bentonite,* brown, micaceous, harder than the material below and above it; breaks into wedge-shaped pieces		6
3. *Bentonite,* buff, crumbly when dry; soft and unctuous when wet		8
2. Chert, black, with blocky fracture; grades into limestone below		2
1. Limestone, thin to medium bedded, dense	4	
Limestone, thin bedded to shaly, argillaceous. Not measured.		

[16] Eby, J. B., and others, The geology and mineral resources of Wise county and the coal-bearing portion of Scott county, Virginia: Virginia Geol. Survey Bull. 24, p. 25, 1923.

Bentonite section No. 2; about 300 yards northeast of section No. 1

	Thickness Ft.	In.
Trenton limestone		
Limestone, coarsely crystalline, thin bedded. Not measured.		
Lowville limestone (35± feet):		
19. Sandstone, brown, friable, shaly	1	
18. Mudrock, gray brown, checky, rubbly, nodular in places; grades upward into friable sandstone	1	6
17. Shale, brownish green, sandy		½
16. *Bentonite,* greasy, flaky; color varies from yellow buff to gray green to dark reddish gray		3–9
15. Limestone, gray, massive, blocky, dense, uniform	7	
14. Limestone, rubbly, thin bedded, some shale partings	2	
13. Limestone, gray, dense to medium granular, in thick beds	4	
12. Limestone, impure, rubbly, alternating with muddy shale	3	
11. Limestone, dense, hard, finely crystalline, blocky fracture; clayey outer layer		4
10. Shale, gray, sandy, crumbly		3
9. *Bentonite,* soft, buff, unctuous		6
8. *Bentonite,* hard, impure, clayey		3
7. Shale, greenish brown, crumbly		3
6. *Bentonite,* light buff, pure	1	
5. *Bentonite,* micaceous, gritty; breaks into angular wedge-shaped pieces; more compact than material above or below		6
4. *Bentonite,* yellow buff, crumbly when dry, and greasy when moist		4
3. Chert, black; fractures easily at right angles to bedding		3
2. Clay, dark chocolate brown; residual		1
1. Limestone, gray, subvaughanitic, thin bedded	12	
Limestone and mudrock. Not measured.		

A study has recently been made of Ordovician bentonites in southwestern Virginia.[17] Only four sections were measured in Lee County, none of which was in the part of Powell Valley discussed in this report. As this area is one of great importance in establishing, by means of bentonite, the stratigraphic relations of the Lowville formation in Tennessee, Kentucky and Virginia, it is hoped that the excellent sections above described will receive detailed study.

Fossils and correlation.—The following fossils were collected:

Rhinidictya nicholsoni Ulrich
Escharopora cf. confluens Ulrich
Zygospira recurvirostris Hall
Hebertella sp.
Lophospira cf. oweni Ulrich and Scofield
Hormotoma gracilis var. angustata (Hall)
Orthoceras sp.
Maclurea sp.

The two invariable guide fossils of the lower Black River strata from New York to Alabama, *Beatricea gracilis* Ulrich and *Tetradium cellulosum* (Hall), were observed on slabs of fine gray limestone on the old road over Turkey Cove Gap. Beds of Lowville age are included in the Chickamauga limestone of Alabama, and are recognized in the Central Tennessee Basin.

Stratigraphic relations.—In the median belts of the Appalachian Valley southwest of Roanoke, the Lowville is represented by a calcareous red mudrock, the Moccasin facies. Equivalence of the two facies is shown by the occurrence of diagnostic fossils in both. No typical red Moccasin beds were found in this area, but the greenish-gray mudrock in the upper part of the Lowville, described above, resembles it in all but color. The name Eggleston has been proposed[18] for a formation comprising beds of late Black River age which are younger than the Moccasin and older than the Trenton. On the basis of correlation by bentonite beds, Rosenkrans[19] comes to the conclusion that the beds in question are a facies of the Lowville and not a separate formation. This appears to the writer to be correct. Thus, of the three facies, Lowville, Moccasin, and Eggleston, the first and third are present in northeastern Lee County.

[17] Rosenkrans, R. R., Stratigraphy of Ordovician bentonite beds in southwestern Virginia: Virginia Geol. Survey Bull. 46-I, pp. 83-111, 1936.
[18] Mathews, A. A. L., Marble prospects in Giles county, Virginia: Virginia Geol. Survey Bull. 40, p. 11 (footnote), 1934.
[19] Op. cit., pp. 92, 99-101.

Overlying the Lowville in Pennsylvania is a limestone, the Chambersburg, which extends into Virginia as far south as Pulaski County. Its absence above the Lowville in this area suggests a hiatus. Field evidence indicates a lack of deposition rather than erosion.

TRENTON FORMATION

Definition.—The name Trenton was given by Vanuxem[20] to beds occurring at Trenton Falls, Oneida County, New York.

Description.—In this area the Trenton is a dark gray-blue crystalline limestone occurring in beds of medium thickness separated by shale partings. (See Pl. 8.) The shale is drab and calcareous, and increases locally to form a large part of the formation. The more typical Trenton is highly fossiliferous. The thickness is approximately 500 feet. With the Lowville, the Trenton makes the middle part of the northwest slope of Wallen Ridge, and it forms some of the low hills in Turkey Cove. Its high solubility results in many sinks and other solution cavities. On weathering, the Trenton yields a thick brown-red soil excellent for blue grass.

Fossils and correlation.—A large fauna occurs in the Trenton of this area. The following forms were collected:

Rhinidictya sp.
Hebertella frankfortensis Foerste
Hebertella sinuata Hall and Clarke
Dalmanella fertilis Bassler
Sowerbyella sericea (Sowerby)
Rhynchotrema increbescens Hall
Rafinesquina alternata Conrad
Strophomena cf. incurvata (Shepard)
Platystrophia cf. praecursor Foerste
Zygospira recurvirostris Hall
Ctenodonta cf. hartsvillensis Safford
Orthoceras sp.
Sinuites sp.
Cyrtolites subplanus Ulrich
Liospira cf. progne (Billings)
Lophospira cf. saffordi Ulrich
Lophospira medialis Ulrich and Scofield
Hormotoma salteri Ulrich
Helicotoma sp.
Ceraurus sp.

[20] Vanuxem, Lardner, Fourth annual report of the geological survey of the third district: New York Geol. Survey Ann. Rept. 4, pp. 364-367, 1840.

In Wise County immediately northeast of Turkey Cove, Stose[21] mapped two formations of Trenton age, the Cannon (Middle Trenton) and the Catheys (Upper Trenton). These formations are named from localities in the Central Tennessee Basin, where they are definitely separable. After a study of the sections in Wise County and the corresponding beds to the southwest in Lee County, the writer decided that such a division in this region is of doubtful value. The Trenton beds developed here are very uniform lithologically from bottom to top and thus are treated as a unit in this report. Beds of Lower Trenton age probably occur in this area, but if so they are thin and were not recognized. In central Tennessee the Hermitage and Bigbee formations occur at this horizon.

In the central and southeastern belts of the Appalachian Valley the Trenton becomes more shaly and merges upward into the Reedsville shale. The two are then referred to as one "formation," the Martinsburg. The Trenton is of approximately the same age as the Galena dolomite of the upper Mississippi Valley and the Kimmswick limestone of Missouri.

CINCINNATIAN SERIES

REEDSVILLE FORMATION

Definition.—The term Reedsville was listed without definition by Ulrich[22] in 1911. Its type locality is Reedsville, Pennsylvania. It was further described by Butts.[23]

Description.—The Reedsville in this area is a brown shale with thin beds of siltstone, sandstone, and limestone. The shale is soft and weathers either clayey or fissile. The siltstones and sandstones are also soft, the latter being readily friable when weathered. The limestone layers are bluish, coarsely crystalline, and highly fossiliferous, closely resembling the limestone of the Trenton. The thickness of the formation is about 400 feet. It forms steep slopes and spurs on which the soil is thin and sandy.

Fossils and correlation.—The Reedsville is abundantly fossiliferous. The collection made by the writer is as follows:

---

[21] Stose, G. W., Pre-Pennsylvanian rocks, *in* The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, pp. 26-28, 1923.

[22] Op. cit., Pl. 27.

[23] Butts, Charles, Geologic section of Blair and Huntingdon counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, p. 523, 1918.

Orthis sp., cf. Plectorthis
Heterorthis clytie (Hall)?
Hebertella sinuata Hall and Clarke
Dalmanella sp.
Rafinesquina alternata Conrad
Zygospira modesta Say
Byssonychia radiata Hall
Bellerophon? sp.
Cyrtolites ornatus Conrad
Lophospira sp.
Eotomaria? sp.
Sinuites cancellata Hall
Calymene granulosa (Foerste)

The lower beds of the Reedsville are of Eden age, as is shown by characteristic fossils from other areas. Its upper part carries Lower Maysville fossils, including *Rafinesquina alternata, Zygospira modesta,* and *Byssonychia radiata.* In the median and southeast belts of the Appalachian Valley the Reedsville forms the upper part of the Martinsburg "formation," which contains beds of Trenton, Eden, and Maysville ages. The occurrence in Powell Valley of *Cyrtolites ornatus,* a typical form of the Leipers of Tennessee, suggests the partial equivalence of the Reedsville and the Leipers.

Stratigraphic relations.—The Reedsville shale overlies the Trenton limestone conformably. A hiatus between the Reedsville and the succeeding Sequatchie formation is indicated by the absence of the Oswego sandstone of northern Virginia and areas farther north. The Reedsville is thought to be the partial equivalent of the McMillan formation of late Maysville age in the Cincinnati area.

SEQUATCHIE FORMATION

Definition.—The Sequatchie was named by Ulrich,[24] from Sequatchie Valley, Tennessee. He designated it "the representative of the Richmond in the southern Appalachians."

Description.—Due to recent road building in Turkey Cove, good sections of the Sequatchie have been exposed. The following section is typical:

[24] Ulrich, E. O., The Ordovician-Silurian boundary: Cong. Géol. Internat., Compte-Rendu, 12e Session, Canada, 1913, p. 648, 1914.

Sequatchie formation along State Highway 64, south of Lee-Wise county line

	Thickness Feet
Clinch formation	
Shale, drab, with beds of dense gray sandstone	
Sequatchie formation (135 feet)	
12. Shale, dark brown, with fracture cleavage	28
11. Sandstone, brown, dense, slabby, with shale partings	8
10. Shale, drab, with a few thin layers of blocky sandstone	8
9. Sandstone, thin bedded, dense	2
8. Shale, green, with one-inch beds of soft brown sandstone; contains marine fossils	1
7. Shale, red, with a few gray-green streaks; and sandstone, red brown, friable, blocky	20
6. Covered	20
5. Shale, yellow green, with some soft sandstone	18
4. Shale and sandstone, red	8
3. Shale, yellow green; poorly exposed	8
2. Shale, red and green	6
1. Limestone, argillaceous, nodular, rubbly, with marine fossils (projected from its occurrence behind farmhouse east of road)	8
Reedsville formation	
Sandstone, brown, thin bedded, blocky	

Fossils and correlation.—Fosils collected from the Sequatchie in this area include *Hebertella occidentalis sinuata, Platystrophia* sp., *Cyphotrypa* sp., and ramose bryozoa. These marine fossils are of especial interest because rocks of the same age as the Sequatchie are nonmarine throughout in other regions. The Sequatchie is a marine facies of the Juniata shale of the northern Appalachian region and of the Queenston shale of the Niagara gorge. It extends from southwest Virginia to Alabama. The Sequatchie is the partial equivalent of the Arnheim and Fernvale formations of the Central Tennessee Basin and of the Maquoketa shale of the upper Mississippi Valley. It is Richmond in age.

The Sequatchie is unconformably underlain by the Reedsville, due to the absence of the Oswego formation. It is succeeded conformably by the Clinch sandstone.

SILURIAN SYSTEM

MEDINAN SERIES

CLINCH FORMATION

Definition.—The Clinch formation was originally a part of the "Clinch Mountain sandstone" of Safford.[25] Later the name was shortened to Clinch sandstone and Keith[26] limited the term to use in its present sense.

Description.—In Wallen Ridge and Powell Mountain the Clinch is a light gray to white dense resistant quartzitic sandstone occurring in massive beds. In River and Poor Valley ridges on the northwest side of Powell Valley, the Clinch contains considerable drab sandy shale. Beds of dense white quartzite up to 3 feet in thickness occur interbedded with the shales. This lithology plays an important part in decreasing the formation's resistance to erosion.

A measured section of the Clinch along the main road just south of the Lee-Wise county line in Turkey Cove is included by Stose[27] in the Wise County report. As reported by him, the thickness of the formation is 150 feet, and more than 70 feet of it is either shale or interbedded shale and thin layers of quartzite. A measured section of the Clinch from farther south in the area is as follows:

Clinch formation along the trail half a mile north of Dry Branch School

	Thickness Feet
Clinton formation	
Covered; probably shale	
Clinch formation (94 feet)	
8. Quartzite, gray green	10
7. Quartzite, gray white, stained by iron oxide; in beds up to 5 feet thick; makes falls in Ely Creek	25
6. Shale, drab to brown, with layers of greenish quartzitic sandstone up to 1 foot thick; interrupted by small fold	12
5. Sandstone, gray green to white, quartzitic, in beds up to 4 feet thick	16

[25] Safford, J. M., A geological reconnaissance of the State of Tennessee: Nashville, p. 15, 1856.
[26] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Loudon folio (No. 25), p. 4, 1896.
[27] Op. cit., p. 31.

	Thickness Feet
4. Shale, brown, fissile, with beds up to 6 inches thick of greenish quartzite weathering with a coating of iron oxide; poorly exposed near top	12
3. Quartzite, greenish, in thick and thin beds with shale partings	7
2. Shale, dark brown, fissile	6
1. Sandstone, brown, dense; contains 1 foot of shale in middle part	6
Sequatchie formation	
Shale, dark brown, fissile, with fracture cleavage	

Fossils and correlation.—The Clinch sandstone is unfossiliferous except for one form, *Arthrophycus alleghaniensis* (Hall). The formation is the same as the Tuscarora quartzite of Pennsylvania. A fossiliferous limestone which occurs at the top of the Clinch equivalent at Cumberland Gap correlates it with the Brassfield of Tennessee and Ohio and the Edgewood and Kankakee formations of the Mississippi Valley. The Clinch in this area has conformable relations with beds both above and below.

NIAGARAN SERIES

CLINTON FORMATION

Definition.—The name Clinton was first applied by Vanuxem[28] to beds formerly called the Ferriferous slate and sand rock. Its type locality is the town of Clinton, Oneida County, New York.

Description.—The following measured section gives a good description of the Clinton in this area:

Clinton formation along State Highway 64 at the Lee-Wise county line

	Thickness Feet
Covered (Cayuga limestone and uppermost Clinton)	
Clinton formation (137 feet)	
20. Shale, brown to greenish, clayey, interbedded with hard greenish sandstone up to 2 inches thick	10

[28] Vanuxem, Lardner, Geology of New York, Part iii, pp. 79-90, Albany, 1842.

	Thickness Feet
19. Shale, blue gray, fissile, with some green layers; much sheared and almost talcose in places; carries poorly preserved *Anoplotheca hemispherica* (?). One-inch beds of dense green sandstone carry fucoidal marks	12
18. Shale, buff and brown, fissile when dry and clayey when wet; many fracture joints; a few thin layers of dense brownish-green sandstone	20
17. Shale, similar to preceding, with many layers of hard green-brown sandstone from 1 to 6 inches thick; whole exposure stained by iron oxide	20
16. Shale, dark brown, fissile, with some persistent thin layers of blocky sandstone	10
15. Sandstone, in beds up to 6 inches thick, separated by shale	2
14. Hematite, dark red, oolitic and pebbly, crumbly; high grade	2
13. Shale, yellow green, interbedded with 3-inch to 1-foot beds of fine-grained dark-red hematitic sandstone with fossils	4
12. Hematite, two thin beds of pebbly material separated by 3 inches of yellow-green shale	1
11. Sandstone, dark red brown, interbedded with greenish shale	2
10. Sandstone, greenish, quartzitic, interbedded with buff and blue-gray shale	6
9. Hematite, pebbly, with phosphatic nodules and some shale	1
8. Sandstone, dark red, dense, thick bedded	5
7. Shale, drab and blue gray, with lenticular thin sandstone beds	2
6. Quartzite, gray green, dense, weathers with a brownish outer layer	3
5. Shale, blue gray, and sandstone, brown and gray, in beds up to 8 inches thick	5
4. Shale, blue gray, with thin lenticular layers of sandstone	6
3. Shale, drab, with thin sandstone beds	2
2. Sandstone. thick bedded, vitreous, brown gray	4

	Thickness Feet
1. Shale, blue gray, with lenticular sandstone beds up to 10 inches thick; talcose from shearing; crumpled in a small fold	20

Thick lenticular sandstone beds which probably represent channel fillings occur locally in the Clinton shales. The Clinton is apparently somewhat thinner on the northwest side of Powell Valley than on the southeast. Stose[29] measured 400 feet of these beds in Wallen Ridge.

Fossils and relations.—The Clinton is moderately fossiliferous in this area. The ostracode *Mastigobolbina typa* and the brachiopods *Anoplotheca hemispherica* and *Brachyprion corrugatum* were collected from the upper beds of the formation.

The Clinton overlies the Clinch formation conformably. It is separated from the beds of Cayuga age by a hiatus due to the absence of the McKenzie and Bloomsburg formations of early Cayuga age.

CAYUGAN SERIES

Definition.—The term Cayuga was first used by Chapman[30] to refer to Silurian rocks of Canada. Clarke and Schuchert[31] later defined the type locality as the northern end of Cayuga Lake in central New York. In this region the term Cayuga refers to a group and not to a formation.

Description.—The formations of Cayuga age in this area consist largely of dark-blue medium granular limestone with many vugs and veinlets of calcite. Lamination due to dark organic films is characteristic. The rock gives forth an odor of petroleum when struck with a hammer. Some layers are dolomitic. At no place in the area was it possible to measure the thickness of the beds of Cayuga age. The thickness in Wise County is 227 feet, but this is probably greater than the thickness in northeastern Lee County.

Fossils and correlation.—The Cayugan group of formations in New York and Pennsylvania consists of the McKenzie, Bloomsburg, Wills Creek, and Tonoloway formations. The fossils collected in Powell Valley and the lithology indicate that most of the beds of

[29] Op. cit., p. 33.
[30] Chapman, E. J., A popular and practical exposition of the minerals and geology of Canada, p. 190, Toronto, 1864.
[31] Op. cit.

Cayuga age consist of strata of Wills Creek and Tonoloway ages. If representatives of the earlier two formations are present, their thickness is negligible. The type fossil of the Wills Creek, *Leperditia elongata* var. *willsensis,* was collected at a point a mile north of Pennington, and that of the Tonoloway, *L. alta,* was also found.

Stratigraphic relations.—The probable absence of lower Cayugan beds, equivalent to the McKenzie of Pennsylvania and Maryland, indicates a hiatus at the base of the Cayuga. The total thickness of beds missing, as represented in northern Virginia, is about 375 feet. There is an intersystemic break at the top of the Cayuga formations. In the eastern part of the area mapped they are succeeded by the Helderberg limestone, of Devonian age. On the northwestern side of the Powell Valley anticline, however, the Helderberg thins and disappears, so that southwest of Turkey Cove the beds of Cayuga age are succeeded by the Genesee shale.

DEVONIAN SYSTEM

HELDERBERG FORMATION

Definition.—The name Helderberg was first used by Mather,[32] who applied it to a series of Devonian limestones exposed in the Helderberg escarpment west of Albany, New York.

Description.—In River Ridge, the Helderberg consists of massive beds, 3 to 6 feet thick, of dark gray-blue, coarsely crystalline limestone. The upper part of the formation in this area contains some bluish to reddish fossiliferous chert. The limestone is extremely fossiliferous, brachiopods and corals predominating. The presence of considerable sand in the limestone is shown by the weathering product, a porous brown sandstone. In the valley southeast of Wallen Ridge, the Helderberg consists almost entirely of coarse crumbly sandstone, presumably derived from a calcareous sandstone by leaching of the cement.

On the northwest side of Powell Valley, the Helderberg thins toward the southwest. It is 133 feet thick at Big Stone Gap, Wise County, 38 feet thick near the Lee-Wise county line, and about 30 feet along Powell River in River Ridge. The last-named locality represents the southwesternmost exposure of the Helderberg in the northwest belt of the Appalachian region. In the valley southeast of Wallen Ridge, the thickness of the formation is probably about 100 feet.

[32] Mather, W. W., Fourth annual report of the first geological district of the State of New York: New York Geol. Survey Ann. Rept. 4, pp. 236-246, 1840.

Fossils and correlation.—The following fossils were collected from the Helderberg in this area:

Favosites sp.
Zaphrentis sp.
Plethorhyncus sp.
Rennselaeria? sp.
Spirifer sp.
Schuchertella woolworthana?
Rhipidomella oblata
Leptaena rhomboidalis
Meristella cf. symmetrica

The last-named of these fossils indicates the New Scotland age of the beds containing it. On the evidence of fossils and the predominantly sandy lithology, it is thought that most of the Helderberg of this area is of Becraft age, with a thin representative of the New Scotland at the base.

Stratigraphic relations.—In this area the Helderberg is bounded at top and bottom by unconformities. Lowermost Devonian beds are absent and the Oriskany, Onondaga, and possibly the Marcellus formations are missing between the Helderberg and the overlying black shales.

Although no evidence of a surface of relief was found between the Cayuga and the Helderberg, Stose[33] states that there is a thin bed of rock debris at the base of the Genesee in Wise County which represents the products of erosion of an old land surface in pre-Genesee time. This layer was not found in Lee County, but shale exposures are poor there and it may be present.

GENESEE FORMATION

Definition.—Vanuxem[34] first used the term Genesee for a geological formation. He named a shale in western New York the "Genesee slate," from its exposure along the Genesee River.

Description.—The entire Genesee formation in this area consists of fissile coal-black shale. The thickness is believed to be about 200 feet.

Fossils and correlation.—The black shale here discussed carries only one fossil, *Schizobolus truncatus*. Exposures of the formation are universally poor in this area, and specimens were collected from

[33] Op. cit., p. 44.
[34] Op. cit., pp. 168-169.

only a few localities. On the basis of the occurrence of *S. truncatus,* the black shale has been assigned by Stose[35] to the Genesee and described as such in the Wise County report. This correlation is followed by the writer. Butts[36] states that inasmuch as "the lowest Devonian black shale elsewhere, of probable Marcellus age, also carries *Schizobolus,* the reference to the Genesee is not without doubt." In this connection it might be pointed out that from northern Virginia southwestward the Devonian formations in general become progressively thinner, the older formations disappearing first and the younger ones last. The Genesee, being younger than the Marcellus, should extend farther to the southwest. It seems, therefore, that most of the black shale in question may be of Genesee age, overlapping the Marcellus.

The relations of the Genesee shale with the underlying formations have been discussed above. The shales of Portage age overlie the Genesee conformably.

PORTAGE FORMATION

Definition.—The term Portage was applied by Hall[37] to a group of strata in central New York.

Description.—The Portage is composed of drab and black shales. In a few places it contains thin lenticular argillaceous sandstone beds. Because of poor exposures, it was impossible to measure the thickness of the Portage. It is about 400 feet thick in Wise County.

Fossils and correlation.—No fossils were found. The beds are assigned to the Portage on the basis of their position between the Genesee and Chattanooga black shales, and also on lithology. They are practically identical lithologically with beds at Saltville, Va., which overlie the Genesee black shale and carry the typical Portage *Manticoceras* fauna. The formation in this area is conformable with the underlying Genesee beds and the overlying shales included in the Chattanooga formation.

---

[35] Op. cit., pp. 43-44.

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

[37] Op. cit., pp. 391-392, 401.

DEVONIAN AND MISSISSIPPIAN SYSTEMS

CHATTANOOGA FORMATION

Definition.—The Chattanooga black shale was so termed by Hayes[38] from the city of that name in Tennessee. Swartz[39] has shown that the black shale of Lee County is the northward continuation of the Chattanooga shale of the type area. Although the same beds have been named the Big Stone Gap shale by Stose,[40] the term Chattanooga has priority and should be used. Stose's term is used by Swartz for a member of the Chattanooga formation.

Description.—The Chattanooga shale in this area consists of two units of black shale separated by a unit of drab shale. The black shale is similar in appearance to that of the Genesee and Portage formations, and the drab shale strongly resembles that of the Portage. The thickness is estimated at about 300 feet.

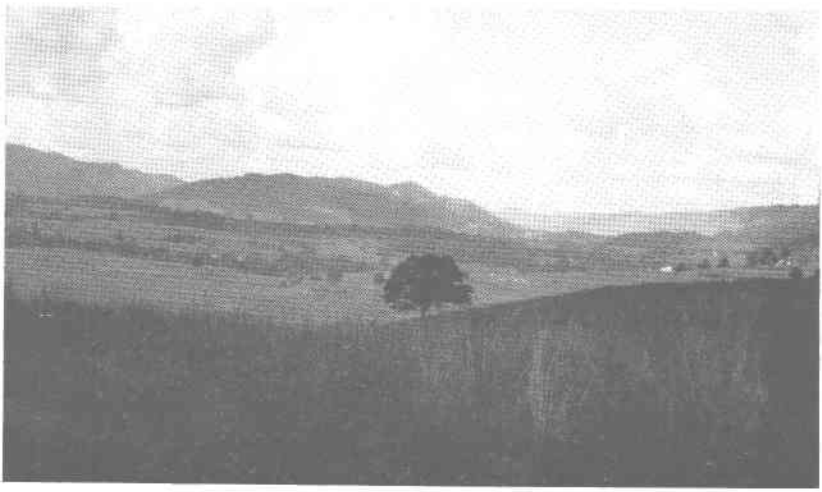
Fossils and correlation.—The Chattanooga carries a fauna of conodonts, but none were collected in this area. Specimens of *Orbiculoidea* and of a brachiopod resembling *Lingula melie* Hall were found near Olinger They are characteristic of the formation. According to Swartz,[41] the formation from Chattanooga to Big Stone Gap may be divided into three members. These are an upper black shale member, the Big Stone Gap; a middle gray shale member, the Olinger; and a lower black shale member, the Cumberland Gap. The Olinger is the same age as the upper part of the Cumberland Gap, with which it interfingers to the southwest.

It is believed that the lower part of the Cumberland Gap member is Devonian in age, inasmuch as it interfingers to the northwest with drab shales and sandstones of the Chemung formation. The remainder of the Chattanooga formation, that is, the upper part of the Cumberland Gap member with the Olinger and Big Stone Gap members, is thought to be Mississippian. The Chemung facies is not present at Chattanooga, hence the entire Chattanooga section is Mississippian. This is the conclusion which Ulrich[42] reached after a study of conodonts and small brachiopods. He correlated the Chattanooga with the Cleveland and Sunbury

[38] Hayes, C. W., The overthrust faults of the southern Appalachians: Geol. Soc. America Bull., vol. 2, p. 143, 1891.
[39] Swartz, J. H., The Chattanoogan age of the Big Stone Gap shale: Am. Jour. Sci., 5th ser., vol. 14, pp. 485-499, 1927.
[40] Op. cit., pp. 46-53.
[41] Op. cit., p. 499.
[42] Ulrich, E. O.. The Chattanooga series with special reference to the Ohio shale problem: Am. Jour. Sci., vol. 34, pp. 157-183, 1912.

A. Powell Valley northeast of Dryden. Looking northeast from State Highway 64, 2 miles southeast of Dryden. The prominent ridge to left of center is Stocker Knob. Stone Mountain on left, Wallen Ridge on right. The valley area shows remnants of the Harrisburg erosion surface.

B. Gap of Mud Creek through River Ridge. Looking northwest from a point in Turkey Cove. Stone Mountain in background.

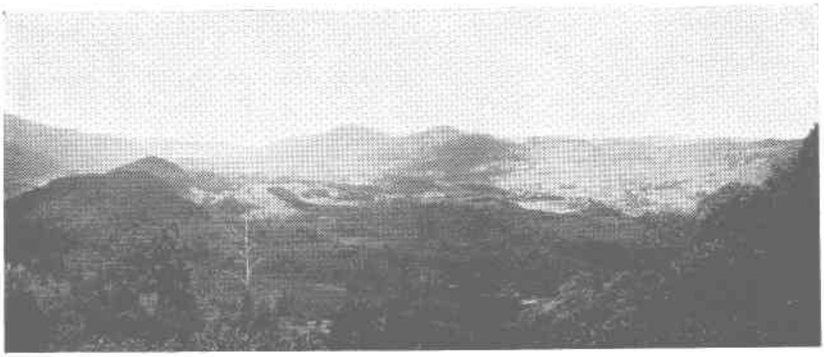


A. Powell Valley northeast of Dryden. Looking northeast from State Highway 64, 2 miles southeast of Dryden. The prominent ridge to left of center is Stocker Knob. Stone Mountain on left, Wallen Ridge on right. The valley area shows remnants of the Harrisburg erosion surface.

B. Gap of Mud Creek through River Ridge. Looking northwest from a point in Turkey Cove. Stone Mountain in background.

A. Panorama of Turkey Cove and surrounding ridges, from east slope of Stocker Knob. Stone Mountain and River Ridge on the left (northwest), Wallen Ridge and Powell Mountain on the right (southeast). The higher of the two knobs in the middle background is Elk Knob.

B. Elk Knob from the floor of Turkey Cove. Looking northeast.



A. Panorama of Turkey Cove and surrounding ridges, from east slope of Stocker Knob. Stone Mountain and River Ridge on the left (northwest), Wallen Ridge and Powell Mountain on the right (southeast). The higher of the two knobs in the middle background is Elk Knob.

B. Elk Knob from the floor of Turkey Cove. Looking northeast.

shales of Ohio, both of which he regards as Mississippian, although the Cleveland is called Devonian by the U. S. Geological Survey. Whatever the ultimate solution of the "black shale problem," one conclusion is evident, namely, that in the area studied the Devonian-Mississippian boundary is a faunal one only.

MISSISSIPPIAN SYSTEM

OSAGE SERIES

PRICE FORMATION

Definition.—The name Price was first applied by Campbell[43] to a sandstone whose type exposure is on Price Mountain, Montgomery County, Virginia. He designated this sandstone a formation some 30 years later.[44]

Description.—The following measured section gives the character and thickness of the Price formation in this area:

Price formation along Louisville and Nashville Railroad at the south end of Pennington gorge

	Thickness Feet
Covered (Newman formation)	
Price formation (243 feet)	
18. Shale and mudrock, purple red, with few layers of sandstone	25
17. Shale, purple red, fissile, with persistent layers of fine-grained red sandstone up to 1 foot thick.	20
16. Shale, buff and gray, with thin beds of blocky sandstone	40
15. Shale, gray, fissile	10
14. Shale, buff, fissile, with many layers of blocky sandstone	35
13. Sandstone, in beds up to 2 feet thick with shale partings; breaks into blocks and irregular pieces	10
12. Shale, gray, fissile, with one-inch layers of sandstone	5

[43] Campbell, M. R., Paleozoic overlaps in Montgomery and Pulaski counties, Virginia: Geol. Soc. America Bull., vol. 5, p. 177, 1894.
[44] Campbell, M. R., The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 23. 1925.

		Thickness Feet
11.	Sandstone, thick beds with shale partings	6
10.	Shale, gray, fissile, with interbedded persistent layers of gray sandstone from a fraction of an inch to 8 inches thick	8
9.	Sandstone	2
8.	Shale, buff to gray, fissile, with one 6-inch bed of sandstone	3
7.	Sandstone, buff to gray, thick bedded, with some concentric concretions ("pillow-structure")	8
6.	Shale, buff, sandy, with many layers of sandstone	12
5.	Sandstone, blocky, thick bedded, with many "pillow-structure" concretions; partings of sandy shale	25
4.	Shale, buff, fissile, and thin beds of brown sandstone	6
3.	Sandstone, buff to gray, thick bedded, with some concentric concretions	10
2.	Shale, gray, and sandstone which fractures irregularly	8
1.	Sandstone, buff to gray, thick bedded, with some concentric concretions up to 1 foot in diameter	10

Covered (probably Chattanooga shale)

The two upper units in the above section, totaling 45 feet of purple-red shale and mudrock, undoubtedly represent the Maccrady formation of Stose.[45] Red beds at this horizon are also exposed at Olinger. Because of the thinness of these beds it is not feasible to map them as a separate formation.

Fossils and correlation.—The Price is sparingly fossiliferous in this area. Fossils collected from the lower half of the formation include *Fenestralina albida?* and a species of *Productella*. On the basis of these and other fossils, and on stratigraphic evidence, the Price is correlated with the Pocono formation of northern Virginia and Pennsylvania, the New Providence formation of Indiana and Kentucky, and the Burlington of Iowa. These are all of Osage age.

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

There is a hiatus between the Price and the Chattanooga, with beds of Kinderhook age absent. As the Price and the Maccrady are both of New Providence age, they are probably conformable. The Warsaw limestone, which follows the Maccrady and underlies the basal Newman in the Greendale syncline and elsewhere in Virginia, is absent. Hence there is an unconformity between the Maccrady and the Newman in this area.

MERAMEC AND CHESTER SERIES

NEWMAN FORMATION

Definition.—The Newman formation was named by Campbell.[46] The name was taken from Newman Ridge, Hancock County, Tennessee, but the type section as measured and described by Campbell is at Big Stone Gap, Wise County, Virginia. Units have since been recognized within the Newman, corresponding to formations in other regions. Four of these are distinguishable in this area. Because the outcrop belt of the Newman is so narrow—it makes cliffs and steep mountain slopes—it is inadvisable to subdivide the formation on the map, and it is treated as a unit in the text. (See Pls. 6 and 12.)

Description.—The lower third of the Newman consists of light-gray massive pure limestone, some of whose layers are abundantly crinoidal. The upper two-thirds is composed of calcareous shale and sandstone, and shaly limestone. This upper part erodes relatively easily and hence is poorly exposed. The thickness of the Newman as measured by Campbell at Big Stone Gap is 829 feet. The writer, following in part his own measurement and in part the estimates of Butts,[47] arrives at a thickness of 750 feet for the Newman in Lee County.

The character of the lower third of the Newman formation is shown in a section exposed in an abandoned quarry at the southeast end of Pennington Gap, in Stone Mountain.

[46] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, p. 38, 1893.
[47] Op. cit., pp. 39-41.

Lower part of Newman formation at southeast end of Pennington Gap in Stone Mountain

	Thickness Feet
Covered (upper beds of Newman formation)	
Newman formation (250 feet exposed)	
31. Limestone, light gray, coarsely crystalline, pure, with thin clay partings	20
30. Limestone, dull dark brown on fresh surface, weathers light blue gray; shaly, with shelly facture	4
29. Limestone, dark blue, massive, fine grained; upper two-thirds contains dark-blue chert, on weathered surfaces only	16
28. Shale, dark gray, laminated, very calcareous	6
27. Limestone, dark colored, interbedded with laminated calcareous shale	2
26. Limestone, gray, pure, crinoidal, with oolites and black chert toward top; highly soluble as shown by dripstone; massive	60
25. Limestone, gray, massive, with rough pitted surface; somewhat argillaceous; oolitic and crinoidal toward top	8
24. Limestone, light gray, very fine grained, massive, with stem plates of *Platycrinus;* shallow solution channels and pits on bedding surfaces	10
23. Limestone, light gray to white, earthy, laminated, medium bedded	7
22. Limestone, light to medium gray, fine to medium crystalline, pure, massive; crinoids and brachiopods	18
21. Limestone, light gray; argillaceous toward bottom, oolitic in middle, subvaughanitic toward top; massive, rough surfaces, stylolitic; contains one layer of buff clayey limestone; no crinoids	6
20. Limestone, light gray, massive; so argillaceous as to be earthy or stony in appearance	6
19. Limestone, gray, pure, crinoidal, oolitic, thick bed	8

	Thickness Feet
18. Limestone, argillaceous, medium crystalline, grading upward into light-gray crinoidal granular pure limestone; poorly exposed in part	12
17. Limestone, light gray, crinoidal, crystalline, pure	8
16. Limestone, gray, argillaceous	2
15. Shale, white, calcareous, in uneven thin slabs; one bed 6 inches thick	5
14. Limestone, light gray, thin bedded, interbedded subvaughanitic and crystalline beds; pure	3
13. Limestone, gray buff, argillaceous, medium bedded, poorly exposed	3
12. Limestone, light gray, pure, crinoidal, oolitic; weathers into thick slabs in dark-brown soil; poorly exposed	7
11. Limestone, light gray, pure, crinoidal, massive bed	5
10. Limestone, light gray, pure, crinoidal, thin beds	2
9. Covered	2
8. Limestone, gray, fairly pure, crinoidal	4
7. Limestone, argillaceous, rubbly, thin bedded, poorly exposed	3
6. Limestone, gray, fine grained, with thin irregular layers (not nodules) of dark-red jasperoid chert; medium thick bedded	3
5. Limestone, gray, granular, slightly argillaceous; somewhat slabby; gray chert in rounded nodules	3
4. Limestone, buff, very argillaceous, thin bedded, hard; breaks into irregular flattish chunks	5
3. Limestone, buff to gray, contains subspherical masses of light chert up to 4 inches across	3
2. Limestone, buff, dense, thick bedded, argillaceous; many calcite veins and vugs	5
1. Limestone, buff, dense, argillaceous, in thin beds.	4

Maccrady formation

Sandstone, purple red

Fossils and correlation.—The four formations represented in the limestones and calcareous shales of the Newman are, in ascending order, the St. Louis, Ste. Genevieve, Gasper, and Glen Dean. The St. Louis consists of some 20 feet of cherty argillaceous limestone. The characteristic St. Louis fossil, *Lithostrotion canadense,* was not seen in this area, but occurs a few miles to the northeast. The St. Genevieve formation is represented by light-gray pure crinoidal limestone. Oolites are common and stem-plates of *Platycrinus penicillus* are diagnostic. Other fossils collected from the Ste. Genevieve include *Pentremites* sp., *Composita* sp., and a crinoid base. The Gasper is so similar to the Ste. Genevieve that the two can be separated only by their fossils. None of these fossils were found from horizons higher than that containing *Platycrinus,* and exposures of the Gasper and Glen Dean beds in Pennington Gap are not good enough to allow differentiation between them.

The St. Louis is Meramec in age. According to Butts,[48] the affiliations of the Ste. Genevieve, both paleontologic and lithologic, are with the Chester group of the Mississippi Valley. The Gasper and Glen Dean are also Chester in age.

Stratigraphic relations.—Due to the absence of the Warsaw limestone there is an unconformity at the base of the Newman. Within the Newman are two breaks, believed to be of the nondepositional type. The St. Louis and Ste. Genevieve are conformable, but there is a hiatus between the Ste. Genevieve and Gasper formations, due to the absence of the Bethel sandstone which intervenes between them in western Kentucky and southern Illinois. Above the Gasper and below the Glen Dean in the same region occur, in ascending order, the Cypress, Golconda, and Hardinsburg formations. None of these is present in Powell Valley. Hence, there is a hiatus between the Gasper and Glen Dean representatives. The Newman and the overlying Pennington are conformable.

CHESTER SERIES

PENNINGTON FORMATION

Definition.—The Pennington formation was named by Campbell[49] from the gap of the same name in the area discussed in this report.

Description.—The Pennington formation consists of several lithologic types. The most prominent are quartzitic sandstone and siliceous conglomerate. The sandstone is fine grained, green-

[48] Butts, Charles, The Paleozoic rocks, *in* The geology of Alabama: Geol. Survey of Alabama Spec. Rep. 14, p. 183, 1926.
[49] Op. cit., p. 37.

brown and dense. The conglomerate is composed of coarse sandstone and many rounded pebbles of white vein quartz up to 2 inches in diameter. The sandstone and conglomerate layers of the formation vary in thickness from a few feet to more than 100 feet. Sandy shale, generally poorly exposed, occurs in thick units between units of sandstone and conglomerate. The shales are varicolored and micaceous. There are a few thin beds of black coaly shale.

A measured section of the Pennington formation in Pennington Gap was made by Giles.[50] He found that the formation there has a thickness of 1,150 feet.

Fossils and correlation.—Fossils are not abundant at any horizon in the Pennington, and they are especially rare in the hard siliceous layers which give the exposures. None was collected in this area. The Pennington is correlated with the upper part of the Chester group of the Mississippi Valley. The Hinton formation, exposed near Bluefield, W. Va., is believed by Butts[51] to be the equivalent of the Pennington. Both formations carry the basal Stony Gap sandstone. The Pennington is probably a partial equivalent of the Mauch Chunk group of Pennsylvania.

The Pennington lies conformably on the Newman limestone. An erosional unconformity may separate the Pennington from the overlying basal Pennsylvanian Lee formation.

UNCONFORMITY

At the close of Mississippian sedimentation, the Appalachian geosyncline was raised. Erosion apparently took place over all the area, being most extensive along the higher, marginal parts. A surface was developed which beveled Mississippian sediments. From a source of abundant quartz, possibly quartz veins in the highlands of Appalachia, swift streams spread a thick cover of quartzose sand and gravel over a large part of the erosion surface. Locally, coal swamps developed. As a result of these conditions, in the central, lowest part of the trough, which underwent the least erosion, the youngest Mississippian rocks are overlain by the oldest Pennsylvanian rocks, with but a slight unconformity; at the edges of the geosyncline, the youngest Pennsylvanian rocks overlap the eroded edges of older Mississippian strata.[52] It is believed that Powell Valley was not very far from the center of

[50] Giles, A. W., The geology and coal resources of the coal-bearing portion of Lee County, Virginia: Virginia Geol. Survey Bull. 26, p. 19, 1925.

[51] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, pp. 45-46, 1933.

[52] Butts, Charles, The Paleozoic rocks, *in* Geology of Alabama: Geol. Survey of Alabama Spec. Rept. 14, pp. 207-208, Fig. 3, 1926.

the trough of deposition, and hence that the unconformity is not so great here as it is farther to the west. However, the difference in organisms preserved in the rocks above and below the break, as well as the change in lithology, shows that there were changes in source of material and agents of transportation and deposition.

PENNSYLVANIAN SYSTEM

POTTSVILLE SERIES

GENERAL STATEMENT

The post-Mississippian rocks in southwestern Virginia all belong in the Pottsville series. They are divided by Campbell[53] into five formations, named in ascending order the Lee, Norton, Gladeville, Wise and Harlan formations. These names were all taken from localities in this region. As the Pottsville formations contain large deposits of commercially valuable bituminous coal, they have been described at length in numerous reports.[54] Each formation is described briefly below.

LEE FORMATION

The basal part of the Lee is a massive conglomerate in which rounded white quartz pebbles are embedded in a matrix of coarse sand. This is overlain by a shale which contains thin sandstone beds and impure coal seams. The shale is succeeded by a coarse sandstone, called the Bald Rock member by Eby, and this in turn is overlain by more shale. The topmost member of the formation is a massive sandstone, locally known as the "Bee rock," which forms knife-edge ridges on Stone Mountain. The thickness of the Lee formation in Pennington Gap is about 1650 feet.

NORTON FORMATION

The Norton formation is composed of about equal parts of sandstone and shale, with interspersed coal beds. It is about 1400 feet thick. A thick persistent sandstone bed near the middle of the formation is called the McClure sandstone by Eby.

---

[53] Op. cit., pp. 31-37.

[54] Campbell, M. R., idem.
Fisher, C. A., The Pocket coal district, Virginia, in the Little Black Mountain coal field: U. S. Geol. Survey Bull. 341, pp. 409-418, 1909.
Eby, J. B., and others, The geology and mineral resources of Wise county and the coal-bearing portion of Scott county, Virginia: Virginia Geol. Survey Bull. 24, 1923.
Giles, A. W., op. cit.

GLADEVILLE FORMATION

The Gladeville is a hard gray to white extremely siliceous sandstone and conglomerate. It constitutes the best horizon marker above the "Bee rock" of the Lee formation. The thickness of this sandstone varies from 100 to 150 feet.

WISE FORMATION

The Wise formation differs little from the Norton, consisting of alternating beds of sandstone and shale with considerable coal. The formation is about 2600 feet thick. It underlies the largest part of the Lee County coal field, and contains most of the workable coal in this county. A thick persistent sandstone about 300 feet above the base of the formation, called the Addington by Eby, is a valuable horizon marker. Eby reports the finding of marine fossils, *Spirifer* and *Productus,* at two horizons in the Wise formation, indicating at least two brief invasions of the sea during the deposition of the Wise.

HARLAN FORMATION

The Harlan is a coarse-grained white sandstone with some shale and thin coal beds. It occurs on the summit and high spurs of Black Mountain, northwest of the area of this report, where the greatest thickness of the part left by erosion is 200 feet.

UNCONSOLIDATED DEPOSITS

Alluvium

Through most of its course in this area, Powell River is bordered by a narrow valley flat of unconsolidated sand, silt and mud deposited from the river during floods. One mile north of Pennington, the north fork of Powell River makes a wide bend within which is an alluvial flat. The valley bottom of the north fork of Clinch River from Oreton around the west end of Powell Mountain is underlain by alluvial materials. There are narrow strips of stream gravel along the bottoms of the smaller valleys in the area.

Older stream gravels occur on the divide just southeast of Stocker Knob, above present drainage. They are believed to be remnants of an abandoned course of Powell River.

STRUCTURAL GEOLOGY

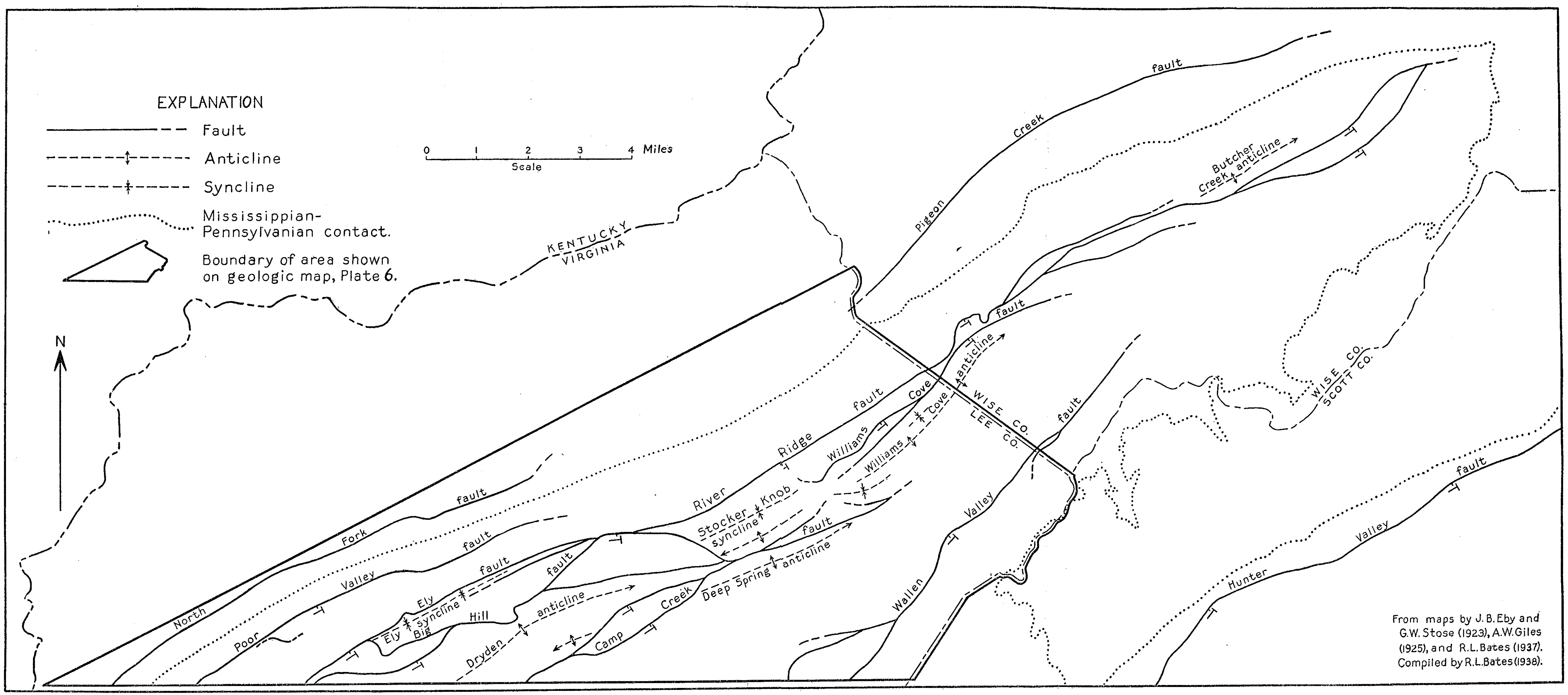
GENERAL STATEMENT

The Powell Valley anticline extends from Tennessee into southwestern Virginia and pitches northeastward in Wise County. Its length from the Jacksboro cross fault at its southwestern end to Wise County is 100 miles, and its width at the surface varies from 15 miles in Campbell County, Tennessee, to 5 miles in the area discussed in this report. The northeastern third of the Powell Valley anticline is asymmetrical in cross section. The rocks on the northwest limb dip steeply in that direction and those on the opposite side dip gently southeastward. (See Pl. 11 and Fig. 6.) The most complex structures are found at its northeastern end, in Wise County and in northeastern Lee County. They include remnants of several subsidiary folds which have been thrust faulted, one upon another.

A study of structural conditions in northeastern Powell Valley demonstrates unusually well that "competency" as applied to sedimentary strata is only a relative term. Elsewhere in the Appalachian region, the Clinch sandstone (Silurian) at many places forms open folds and is termed a competent bed. Generally it is the strongest stratum east of the Cumberland escarpment, and hence the term is applicable. In the Powell Valley anticline, however, more competent beds are involved, namely, the Pottsville sandstones and conglomerates. These formed the relatively simple broad arch of the fold, to conform to which the thin, incompetent Clinch and associated beds were thrown into a few smaller folds. The Clinch could hold up only subsidiary folds within the main fold and failed, through fracture and crumpling, to arch with the Pennsylvanian rocks. The least competent rocks in this area are the Ordovician shales and thin-bedded limestones.

The Powell Valley structure conforms admirably to a principle stressed by Nevin,[55] namely, that folds must be continually supported from below. The beds beneath the Pottsville strata, thrust faulted and squeezed into secondary plications, conformed to the lower surface of the arch-maker and supported it. Easily crumpled shales and limestones were forced to adjust themselves by smaller plications than was the Clinch sandstone. Had the Pottsville strata acted as an unsupported strut, lifting both their own weight and that of overlying beds, their crushing strength would have been far exceeded at the base of the arch on either side. No extensive crushing has been observed at these points.

[55] Nevin, C. M., Principles of structural geology, 2d ed., pp. 54-56, New York, John Wiley & Sons, Inc., 1936.



Sketch Map of the Structure of the Northeastern Part of the Powell Valley Anticline.

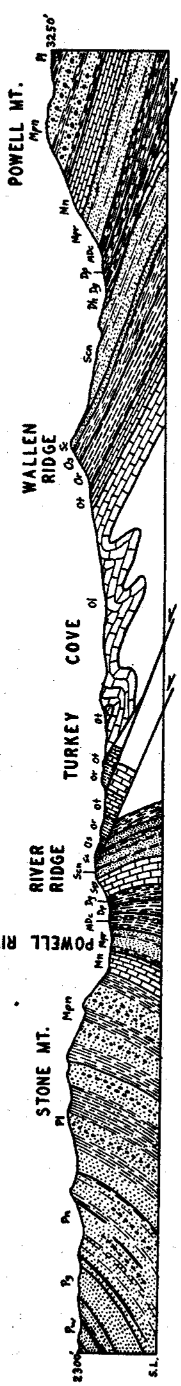


FIGURE 6.—Structure section across Powell Valley, southeast from Stone Mountain across Turkey Cove, Wallen Ridge and Powell Mountain. Pw, Wise formation; Pg, Gladeville formation; Pn, Norton formation; Pl, Lee formation; Mpn, Pennington formation; Mn, Newman formation; Mpr, Price formation; MDc, Chattanooga formation; Dp, Portage formation; Dg, Genesee formation; Dh, Helderberg formation; Scy, formations of Cayuga age; Scn, Clinton formation; Sc, Clinch formation; Os, Sequatchie formation; Or, Reedsville formation; Ot, Trenton formation; Ol, Lowville formation.

RELATION OF THE POWELL VALLEY ANTICLINE TO THE CUMBERLAND THRUST BLOCK

The entire Powell Valley anticline is a part of the Cumberland thrust block, a roughly rectangular segment of the earth's crust 125 miles long and 30 miles wide which acted as a unit during the deformation of the Appalachian region. The Cumberland block was named and described by Wentworth[56] and has been discussed by Butts[57] and by Rich.[58] Some of the conclusions reached by these writers are pertinent to an understanding of the structure of the area discussed in this report. Especially noteworthy are the manner and amount of northwestward thrusting which the Cumberland block is believed to have undergone. Wentworth recognized the northwest boundary of the block as the Pine Mountain thrust fault, and showed this fault on structure sections as dipping southeast to an unknown depth. In 1923 and 1926, Butts discovered five fensters in extreme southwestern Virginia, in which Clinton and older rocks were completely surrounded by late Cambrian limestones and dolomites which had been eroded through near the axis of the Powell Valley anticline. Butts then made the interpretation that the Pine Mountain fault does not dip indefinitely southeastward, but flattens out at a slight depth and extends more or less horizontally under the entire

[56] Wentworth, C. K., Russell Fork fault of southwest Virginia: Jour. Geol., vol. 29, pp. 351-369, 1921.

[57] Butts, Charles, Fensters in the Cumberland overthrust block in southwestern Virginia: Virginia Geol. Survey Bull. 28, 1927.

[58] Rich, J. L., Mechanics of low-angle overthrust faulting as illustrated by Cumberland thrust-block, Virginia, Kentucky, and Tennessee: Am. Assoc. Petroleum Geologists Bull., vol. 18, pp. 1584-1596, 1934.

Cumberland fault block, acting as a sole on which movement took place. Wentworth's estimate of the average amount of horizontal movement was 6 miles. Butts, using the data afforded by the fensters, arrived independently at a figure of 7 miles for that part of the block in which they lie.

Rich accepted Butt's interpretation of the sole fault underlying the block, and worked out the mechanics of thrusting to account for the formation of the Powell Valley anticline. He believes that the thrust faulting was at first dominantly horizontal, parallel with the undisturbed beds of rock, and took place along a lower bed of shale, where gliding was relatively easy; that the fault sheared across the bedding to a stratum of shale higher in the section; and that the fault finally rose again, intersecting the land surface somewhere northwest of Pine Mountain. Continued horizontal compression forced the strata to arch over the bend in the fault surface where it cut across the beds, and produced an anticline. The fact that the Powell Valley anticline is broad and has a flat top at its southwest end but is narrow and sharp at its northeast end suggests that the horizontal movement which produced the fold was greater at the southwest and diminished northeastward. That this was true is further indicated by the extensive thrusting on the Wallen Valley fault surface in the southwest part of the block and the disappearance of this fault at the northeast end of the Powell Valley anticline.

It is believed that the Pine Mountain sole fault underlies the area mapped in this report. Its depth below the surface is difficult to estimate, but perhaps is not more than a few hundred feet. Hence, the structures in the area are relatively shallow. Inasmuch as the entire Powell Valley anticline is believed to have been thrust on the sole surface, it is hardly to be expected that local structures within the anticline extend below that surface. A similarity is suggested between the structures in the southeast half of the Cumberland fault block and the imbricate structure which is so well developed in the northwest highlands of Scotland. In its typical development, imbricate structure consists of an overthrust mass above a major thrust plane, the mass being cut by minor thrusts which lie at an oblique angle to the sole fault. The minor thrusts dip in the direction from which the stress came, at an angle steeper than that of the sole thrust, and hence if projected downward they intersect it. Minor thrusts within the Powell Valley are comparable to the smaller faults of imbricate structure. Included in this group are the Poor Valley, Ely, River Ridge, Williams Cove, Big Hill and Camp Creek faults. (See Pl. 6.) The North Fork fault probably does not extend down as far as the major thrust surface. The Wallen Valley fault, especially farther to the southwest, is an independent major thrust that may parallel the Pine Mountain sole thrust at depth.

MAJOR FOLDS

It is to be understood that all the folds in the area of this report are integral parts of the main Powell Valley fold. Major folds thus are simply the larger, more prominent subsidiary folds within the regional structure.

WILLIAMS COVE ANTICLINE

That part of the Powell Valley anticline which lies between the Stocker Knob syncline on the southwest and the curve of the Clinch sandstone as it pitches to the northeast constitutes the Williams Cove anticline. It was so named by Stose[59] from the small valley just north of Elk Knob. The anticline is best exposed in Turkey Cove. (See Pls. 6 and 11.) Clinton and older rocks are involved. The dips in Wallen Ridge are gentle and their directions average S. 25° E. On the northwest side of Turkey Cove, the attitude of the rocks varies from a steep northwest dip through verticality to an overturned southeast dip of 30°. The overturned structures in Williams Cove and near the Lee-Wise county line were discussed by Stose, who demonstrated the complication of the fold by thrust faulting.

At the northeast end of Stocker Knob the Williams Cove anticline divides into two anticlines which pass on either side of the Stocker Knob syncline. The structural conditions may be well observed on the unpaved road which runs from near Deep Spring School northward toward Olinger, and on a trail which leaves this road and reaches the summit of Stocker Knob via its northern slope. The southern of the two anticlines is the larger in extent of surface outcrop. The Reedsville and Sequatchie formations have acted as the more or less plastic mass through which the single anticline of Turkey Cove changes into two anticlines separated by a syncline. In the valley of Pan Branch on the south slope of Stocker Knob, where the southern of the two anticlines pitches southwest, calcareous beds in the Reedsville shale have been so tightly compressed as to become a rubbly argillaceous limestone. Intense squeezing is indicated by the gnarled, deformed character of the rocks, their vertical position, and the distorted

[59] Stose, G. W., The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, pp. 122-124, 1923.

fossils. These exposures show the deformation of the normally soft Reedsville formation at the apex of a sharp fold.

STOCKER KNOB SYNCLINE

This syncline is named from the prominent topographic form, Stocker Knob, which it makes. In reality it is more a ridge than a knob, with the highest point at the northeast end. (See Pl. 9A.) The resistant Clinch and Clinton formations are responsible for the positive topographic expression of the syncline.

The Stocker Knob syncline is asymmetrical in cross section, as are the anticlines associated with it. Its southeast limb dips steeply northwest, and the northwest limb has a gentler dip southeastward. The southwest portion of the syncline is hidden by an overthrust mass of Ordovician limestone and shale, and hence its relations on the southwest are obscure. The continuation of the southern branch of the Williams Cove anticline, as shown by the small exposure of Clinch and Clinton beds just north of the junction of Pan Branch and Camp Creek, and the Stocker Knob syncline as now exposed are the remnants of extensive folds in the Clinch and associated beds beneath the arch of the Pottsville rocks. They demonstrate plainly that the Clinch did not conform to the primary simple fold.

DEEP SPRING ANTICLINE

Immediately southeast of the Stocker Knob and Turkey Cove areas is an anticline, here termed the Deep Spring anticline. Due to thrust faulting, only the southeast flank is now at the surface. (See Pl. 6.) The dips are uniformly to the southeast except at the pitching end 1½ miles northeast of Deep Spring School. The Wallen Ridge monocline forms the southeast limb of the Deep Spring fold and also that of the Powell Valley anticline. Hence, it is plain that the Deep Spring anticline is really a part of the regional fold—perhaps a subsidiary anticline which formed on its southeast flank—preserved in older rocks that have been brought up by thrust faulting to a position comparable to that of much younger rocks in the same regional fold. There is an unbroken succession of strata from the Copper Ridge dolomite to the Clinch sandstone, as one passes from the south foot of Stocker Knob to the crest of Wallen Ridge.

It is believed that the Deep Spring anticline is far from its original place of formation. Differential movement is suggested, in which the part of the anticline toward the south edge of the area mapped was swung northwest, with a point 2 to 3 miles northeast of Deep Spring School as a pivot. Ozarkian and Canadian rocks were thrust far over the Stocker Knob syncline and its flanking folds. It is impossible to say how much erosion has taken place since the thrusting, but it seems likely that the fault trace on the northwest side of the Deep Spring anticline has not been moved far southeastward. The northwest half of the anticline lies buried somewhere beneath the southeast half.

The connection of the Deep Spring anticline with the Dryden anticline to the west is not entirely clear, but it is believed that the transition was made through two minor folds now dislocated and in part concealed by thrust faulting southeast of Dryden.

DRYDEN ANTICLINE

The name Dryden anticline is here given to the fold revealed by outcrops southeast and southwest of the village of Dryden. (See Pl. 6.) This anticline involves rocks ranging in age from Copper Ridge, in the central part of the fold, to Reedsville, which crops out in a narrow band crossing Powell River just south of Poor Valley Ford. The northwest limb of the fold dips steeply and the southeast one more gently. The thin Mosheim formation makes a good datum for tracing the structure. Its outcrop farthest southwest is in the town of Pennington Gap, where, as at Dryden, it and the underlying Beekmantown dolomite are thrust faulted on the Lowville. Erosion has interrupted the once continuous outcrop between Pennington and Dryden. The outcrops of Mosheim southeast of Dryden show the remnant of the syncline which flanks the Dryden anticline in that direction.

It is believed that the Dryden anticline represents the Powell Valley anticline as it is expressed in Lower Ordovician, Canadian and Ozarkian rocks. The dual or even triple character of the regional fold, as expressed in the rocks of Turkey Cove and Stocker Knob, is again shown by the remnants of several folds in the rocks southeast of Dryden.

ELY SYNCLINE

The Ely syncline extends from just east of Pennington to a point 1 mile north of Dryden. (See Pl. 6.) The youngest rocks exposed are Portage shales; the oldest the Clinton formation. The syncline pitches to the northeast at a low angle. It is bounded on all sides by faults and hence is an isolated structural feature. There is a possibility that before thrusting took place the Ely syncline was connected with the Stocker Knob syncline to form a continuous fold. The strike of the axial line of the Stocker Knob syncline, projected southwestward, is parallel to that of the Ely syncline but passes a mile southeast of Ely Church. Hence, if the two synclines were formerly continuous, they were broken and offset by the thrust faulting, so that the Ely syncline was carried bodily to the northwest for approximately a mile.

The existence of an anticline adjoining the Stocker Knob syncline on the south has been pointed out. The Ely syncline also merges into an anticline in that direction. This upfold is preserved in the large area of Clinton rocks in Big Hill and in the ridge northwest of Dryden. A section showing the anticlinal structure may be observed along the railroad half a mile west of Dryden.

The Ely syncline affords evidence that the Powell Valley anticline was more intensely compressed by folding near Pennington than in the Stocker Knob segment. A comparison of altitudes shows that Silurian beds in Stocker Knob lie about 2500 feet above sea level, whereas Devonian beds at Ely lie at 1500 feet. Folding at Ely brought strata which are normally 1000 feet higher than the Clinton to an altitude 1000 feet lower than the Clinton in Stocker Knob. The vertical component of folding was evidently important in placing the rocks of the Ely syncline in their present position.

MINOR FOLDS

There are numerous folds in the area whose visible span can be measured in a few feet and which probably are not much larger at depth. The incompetent shaly limestones of the Lowville and Trenton formations and the Reedsville shale have undergone considerable crushing in Turkey Cove. (See Pls. 7B and 8B.) Close folding is also seen in Trenton limestone along the tracks of the Louisville and Nashville Railroad north of Stallard Ford. The Devonian and Mississippian black and drab shales are tightly compressed at several places, notably along U. S. Highway 23 near Jasper, and on the Lovelady Valley road which leaves that highway at Jasper. Here the shales are closely plicated.

MAJOR FAULTS

The structure of the Powell Valley anticline has been complicated not only by subsidiary folding but also by thrust faulting. Thrusts are especially numerous from the latitude of Pennington Gap northeastward. All are roughly parallel with the strike of the strata and most of them are intimately involved with the complex folding. The throws vary, the maximum stratigraphic displacement in the area studied being approximately 3000 feet. As explained on a previous page, it is believed that the faults in this area are relatively shallow and extend only to a sole fault underlying the entire anticline.

NORTH FORK FAULT

The North Fork fault parallels the northwest foot of Stone Mountain from the southwest corner of the area to a point 2 miles north of Dryden. (See Pl. 6.) Rocks involved in this fault are the Lee, Norton, Gladeville and Wise formations. The displacement varies from zero at the northeast end to a maximum of 1200-1400 feet near Purcell; it is about 1100 feet at Pennington Gap and diminishes toward the west.

The structural conditions attending the North Fork fault are obscure, due in large part to the cover of dense vegetation and the concealment of the fault trace by streams. A clue to its formation is to be had from exposures at the northwest base of Stone Mountain some 17 miles northeast of the place where the North Fork fault dies out. At this locality the Pigeon Creek fault is well exposed in a road cut. The Pigeon Creek fault is in the line of strike of the North Fork fault, involves the same formations, has approximately the same amount of throw, and is believed to represent the same type of deformation. The exposure mentioned has been described at length by Stose.[60] He believes the Pigeon Creek fault to be a "crush fault," formed when the Lee formation, rising to verticality in the Powell Valley fold, was pushed against the overlying flat massive Gladeville sandstone. The brittleness of the Gladeville caused it to break rather than to accommodate itself to the sharp curve at the base of the arch. (See Fig. 7.) The relatively soft shales of the Norton formation were crumpled and crushed severely and locally thinned between the advancing vertical plate of the Lee and the flat immovable plate of the Gladeville. It is believed that the Pigeon creek fault and the North Fork fault are both of this "crush fault" type. If so, they are probably limited to a few scores of feet in depth.

POOR VALLEY FAULT

The fault which lies at the bottom of Poor Valley and extends from the south edge of the area to a point 1½ miles north

[60] Op. cit., pp. 134-137.

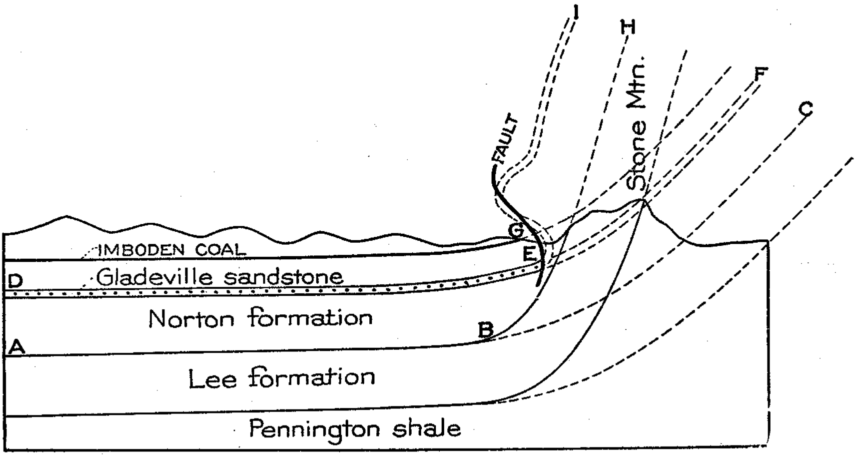


FIGURE 7.—Structure section across Pigeon Creek fault. By G. W. Stose; from Va. Geol. Survey Bull. 24, Fig. 11, 1923.

of Dryden is here named the Poor Valley fault. (See Pl. 6.) The fault surface projected downward cuts across the northwest-dipping formations on the northwest flank of the Powell Valley anticline, and on this surface Clinton and Cayuga rocks have been thrust upon Devonian and Mississippian shales. For a short distance along the trace, the overthrust mass has covered the shales entirely and the Clinton formation is in contact with the Price sandstone. Here the stratigraphic throw is about 1100 feet. The throw varies, decreasing to zero north of Dryden where the fault dies out between the Cayuga and Genesee formations. Considerable crushing occurred during the thrusting. Shale beds are contorted and dip regularly, and the Cayuga limestone is fractured and gnarled.

ELY FAULT

The name Ely fault is here given to the fracture which extends from the east environs of the town of Pennington Gap to a point three-quarters of a mile north of Dryden. (See Pl. 6.) At both extremities the Ely fault passes beneath the overthrust mass brought up by the Big Hill fault. Movement on the Ely fault has thrust Cayuga and Devonian rocks of the Ely syncline upon Ordovician and Silurian rocks to the northwest. As this syncline involves rocks as young as the Portage shales, the thrust fault has brought younger beds upon older—the reverse of the general relation. It is believed that the Ely syncline represents the remnant of a syncline which was formed at some distance to the southeast, broken across by the Ely fault, and carried to its present position on the fault surface. The maximum stratigraphic throw along this fault is thought to be about 2000 feet.

Almost directly in line with the Ely fault northeast of Dryden is the River Ridge fault, which emerges from beneath the mass brought up by the Big Hill thrust. The Ely fault block has carried the Ely syncline on its southeast side, and the River Ridge fault block has carried the Stocker Knob syncline. It is believed, however, that the two faults are not directly continuous beneath the overthrust mass. Several indications that a cross structure, now covered, exists between Dryden and Stocker Knob are: the change in strike of the formations in Stone Mountain, Wallen Ridge and Stocker Knob, from the prevailing northeast direction to a nearly east one; the offsetting of a once continuous syncline to form two separate parts, the Ely and Stocker Knob synclines; the extensive folding which took place in Beekmantown and Lower Ordovician rocks southeast of Dryden, and their subsequent faulting. Evidence that the rocks underlying the Big Hill fault surface were dragged in the thrusting along it is afforded by the westward swing of the southern spur of Stocker Knob and by the development of a minor thrust on the southeast side of the Ely syncline, paralleling the Ely fault but about one-eighth mile southeast of it near its eastern end.

RIVER RIDGE FAULT

The thrust here termed the River Ridge fault extends from Powell River just south of Poor Valley Ford to the Lee-Wise county line via the northwest slope of Stocker Knob and the crest of River Ridge. (See Pl. 6.) It breaks across the beds on the northwest limb of the Powell Valley anticline and offsets them. It serves as the surface on which the Stocker Knob syncline was carried northwestward, burying the Clinch sandstone from the northwest side of Turkey Cove to Powell River near Poor Valley Ford. Throughout its length in this area, the trace of the River Ridge fault is in contact with the outcrops of only three formations, the Sequatchie shale, the Clinch sandstone, and the Clinton formation. Its stratigraphic throw probably does not exceed 400 feet. In River Ridge where the fault lies between the Clinch and Clinton formations it is probably measured in tens of feet.

WILLIAMS COVE FAULT

The Williams Cove fault is named from the small valley immediately north of Elk Knob, in the walls of which the structural relations are well exposed. They have been studied by Stose.[61] The southwest extremity of the Williams Cove fault is on the east slope of Stocker Knob, and its eastern end is in the plunging part of the Williams Cove anticline. The part of the Williams Cove fault in Turkey Cove resembles the Ely fault, in that younger rocks occur on its southeast side and older ones on the northwest side. A similar origin is suggested for this strip of younger rocks thrust on older—a remnant of a former fold which was cross faulted. Reedsville and Trenton rocks are faulted upon Lowville and Trenton rocks. The Williams Cove fault splits just south of the Lee-Wise county line, and Lowville limestone is thrust upon Trenton beds for more than a mile along the strike of the minor thrust. The amount of stratigraphic throw along the Williams Cove fault is difficult to estimate, but it probably does not exceed a few hundred feet.

BIG HILL FAULT

The Big Hill fault extends from the town of Pennington Gap northeastward in an irregular line to the southern foot of Stocker Knob. (See Pl. 6.) It is named from its exposure along the unpaved road on Big Hill. The rocks along the fault range in age from Ozarkian to Devonian. The maximum stratigraphic throw is about 3000 feet, where the Copper Ridge dolomite is in contact with the Clinton formation on Big Hill. Where the Mosheim limestone lies against the Genesee shale in the Ely syncline, the stratigraphic throw is about 2500 feet. At the south foot of Stocker Knob, 1000 feet of strata are missing between the Trenton and Sequatchie formations which are on opposite sides of the fault.

From Stocker Knob southwestward, the Big Hill fault appears to be the major break along which the older rocks from deep within the Powell Valley anticline were brought into contact with younger rocks on the northwest limb. The remarkable salient in the Big Hill fault mass, which extends nearly to Poor Valley, shows how extensive the overthrusting may have been elsewhere before erosion. The Big Hill fault disappears on the northeast by passing under the Camp Creek fault mass. It extends out of the area southwest of the town of Pennington Gap.

CAMP CREEK FAULT

A fault enters the area 2 miles south of Dryden, follows the northwest base of Wallen Ridge and the south foot of Stocker Knob, and disappears on the slope of Wallen Ridge in Turkey Cove. (See Pl. 6.) This fault is here named from the exposures in Camp Creek. It is the

[61] Op. cit., pp. 120-124.

farthest southeast of the faults within the valley of Powell River. For some 3 miles from the south edge of the area the fault parallels the base of the Mosheim formation, which rests on the Lenoir limestone, with a stratigraphic throw of about 200 feet. On the southeast slopes of Stocker Knob, the Copper Ridge dolomite lies against the Reedsville, Sequatchie, Clinch and Clinton formations, with a maximum stratigraphic throw of about 3000 feet. The dip of the strata above the fault is about the same as the dip of the surface itself.

WALLEN VALLEY FAULT

The thrust fault which lies between Wallen Ridge and Powell Mountain is called the Wallen Valley fault. It has a total length of more than 80 miles. Only a part of the fault, near its northeast end, is present in the area under discussion. The fault enters the area at the summit of Powell Mountain 2 miles southwest of Jasper and extends northeastward into Wise County. It dies out some 3 miles northeast of the Lee-Wise county line.

The Wallen Valley fault is a major thrust farther to the southwest, but in this area the movement along the fault was not very great. In a discussion of the relations of this fault in this area, it is necessary to note the somewhat peculiar arrangement of the rocks on the southeast side of the fault. Between Jasper and the Lee-Wise county line, the Wallen Valley fault is bordered on its southeast side by the shallow syncline which complements the Powell Valley anticline to the southeast. In the area immediately surrounding Jasper this syncline terminates, and along the strike southwestward an anticline takes its place. The anticline and the syncline are in strike and both pitch northeastward, one passing into the other in the Jasper area. As movement on the Wallen Valley fault toward its end in Wise County was slight, the entire syncline remains near its place of formation. A large part of the anticline southwest of Jasper has been overthrust and then eroded away and only the southeast flank and the northeastward pitching end are left. The area of this report covers only a small fraction of the anticline, namely, that part south of Lovelady Valley.[62] From the Lee-Wise county line to Jasper the Devonian shales and the Helderberg limestone are thrust upon Clinton and Cayuga rocks. Southwest of Jasper, the Sequatchie, Clinch, and Clinton formations are thrust upon Clinton shales and sandstones.

Near the junction of Lovelady Creek and the north fork of Clinch River, the Wallen Valley fault splits. The main fault continues southwestward to the summit of Powell Mountain and the branch extends

[62] The term "Powell Mountain," as used both locally and on topographic maps, has no relation to geologic structure.

up Lovelady Valley for 2 miles. This branch swings southward out of the area and rejoins the Wallen Valley fault a short distance to the southwest. Between the two, a wedge of Clinton rocks is enclosed. The manner of emplacement of the Cayuga limestone and Genesee shale in Lovelady Valley is obscure, but it is believed that these rocks are connected, beneath the faulted wedge of Clinton, with similar rocks near Jasper.

MINOR FAULTS

Several minor dislocations of the rocks occur in this area, mostly in connection with major thrusts. Some are bifurcations of the larger faults. These include the branch of the Ely fault which parallels it about one-eighth mile to the southeast; the fault in the southern part of Turkey Cove, extending for a mile westward from the end of the Camp Creek fault; the branch of the Williams Cove fault in Turkey Cove; and the branch of the Wallen Valley fault which extends up Lovelady Valley. The contact between the Copper Ridge and Beekmantown dolomites from Pennington into Big Hill is a fault, whose displacement is probably small. The fault on which Dryden is located is thought to be a minor thrust on the northwest limb of the Dryden anticline. Another thrust, of limited linear extent and unknown displacement, is on the south flank of the Dryden anticline and crosses Powell River ¾ mile south of Stallard Ford. Finally, just northwest of Pennington, is a break affecting the outcrops of Sequatchie, Clinch and Clinton formations. The brittleness of the Clinch sandstone is shown in contrast to the relative plasticity of the shales above and below. When the Clinch snapped due to cross stresses, the shales took up the movement and it was not transmitted into other rocks.

PHYSIOGRAPHY

REMNANTS OF THE SCHOOLEY (UPLAND) EROSION SURFACE

The Schooley erosion surface is the oldest one which can be recognized in the southern part of the Appalachian Valley and Ridge province. Wright[63] states that it has been so extensively dissected that restoration on the basis of preserved remnants is difficult. It is thought that the Schooley surface is represented in northeastern Powell Valley by the summits of Stone Mountain, Stocker Knob, Elk Knob, Wallen Ridge, and the part of Powell Mountain south of Lovelady Valley. All of these have altitudes of 2750 to 3000 feet. The crests of the longer ridges are remarkably even for long distances. The placing of the Schooley surface at this altitude in this area is in agreement with Wright's statement concerning its altitude elsewhere in the southern Appalachian region. He finds that the erosion surface slopes southwestward from an altitude of 3500 feet at Wytheville, Va., to about 1000 feet near Birmingham, Ala. He gives the altitude of the Schooley level on Powell Mountain some 40 miles southwest of this area as 2100 to 2500 feet. It seems probable that the summits of the ridges mentioned above represent the Schooley surface projected into Powell Valley from its somewhat lower level to the southwest. Powell Mountain northeast of Jasper is apparently a monadnock on the Schooley surface, rising some 500 feet above it.

REMNANTS OF THE HARRISBURG (VALLEY-FLOOR) EROSION SURFACE

The approximate level of the Harrisburg (Valley-floor) erosion surface is thought to be present on the spurs between the incised meanders of Powell River southwest of Dryden. These spurs have a rather uniform altitude of approximately 1700 feet. In Turkey Cove, the Harrisburg surface was perhaps 100 feet higher. The summits of River Ridge, Poor Valley Ridge and Big Hill have altitudes between 1750 and 2000 feet and represent low ridges on the Harrisburg surface. The former difference in elevation between the valley areas at 1700 to 1800 feet, and the ridges at perhaps 2000 to 2100 feet, represents the relief on the Harrisburg surface. The unreduced remnants of the Schooley level were originally some 900 feet above the present altitude of the valley floor.

The distinct contrast between the wide rolling valley south of Stocker Knob, occupied by a stream no larger than Camp Creek, and

[63] Wright. F. J., The newer Appalachians of the south, part 2; South of the New River: Denison Univ. Bull., vol. 36, no. 6 (Sci. Lab. Jour., vol. 31, art. 3), pp. 93-142, 1936.

the narrow steep-sided valley to the north in which Powell River now flows, is an indication that during the Harrisburg cycle the master stream occupied the Camp Creek valley. (See Fig. 8.) Additional

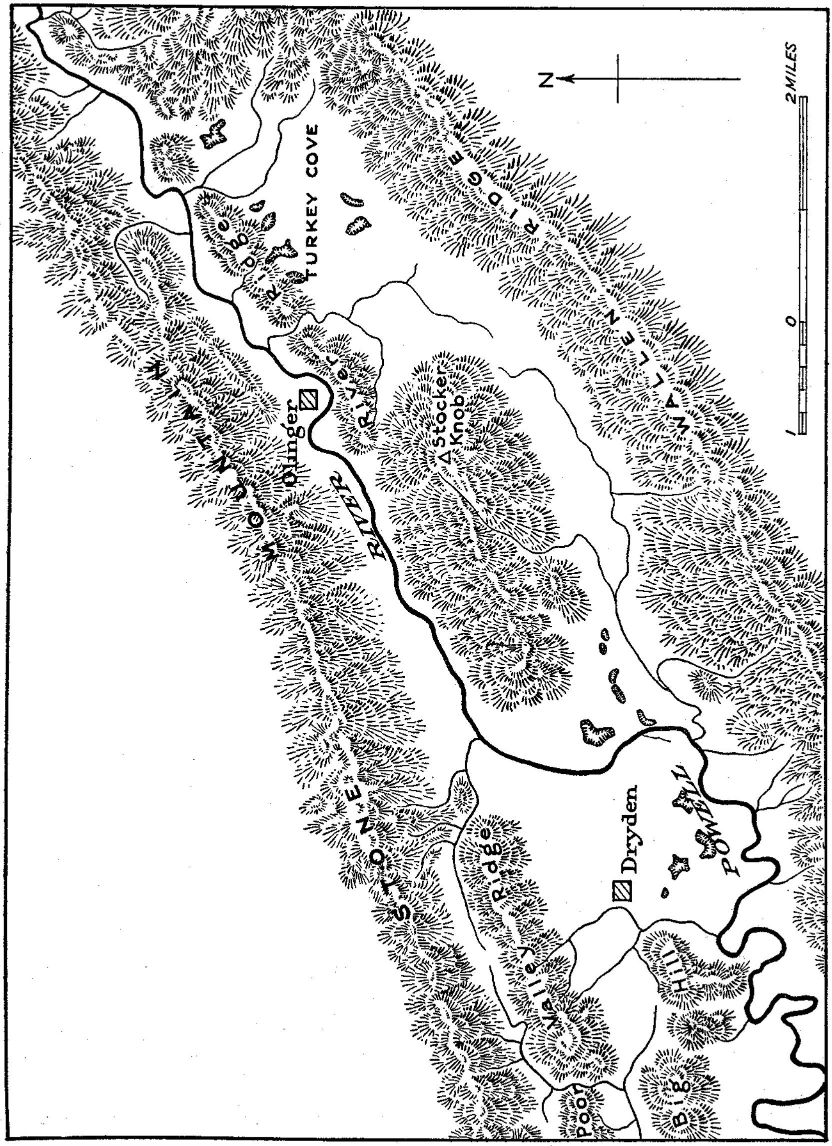


FIGURE 8.—Sketch map showing change in course of Powell River. Present drainage is shown above; earlier drainage, in Harrisburg cycle, is shown in blue.

evidence is afforded by the occurrence of stream gravels in this valley, well above the present drainage. Hence, the Harrisburg course of Powell River is believed to have extended through River Ridge, posthe narrow steep-sided valley to the north in which Powell River now flows, is an indication that during the Harrisburg cycle the master stream occupied the Camp Creek valley. (See Fig. 8.) Additional

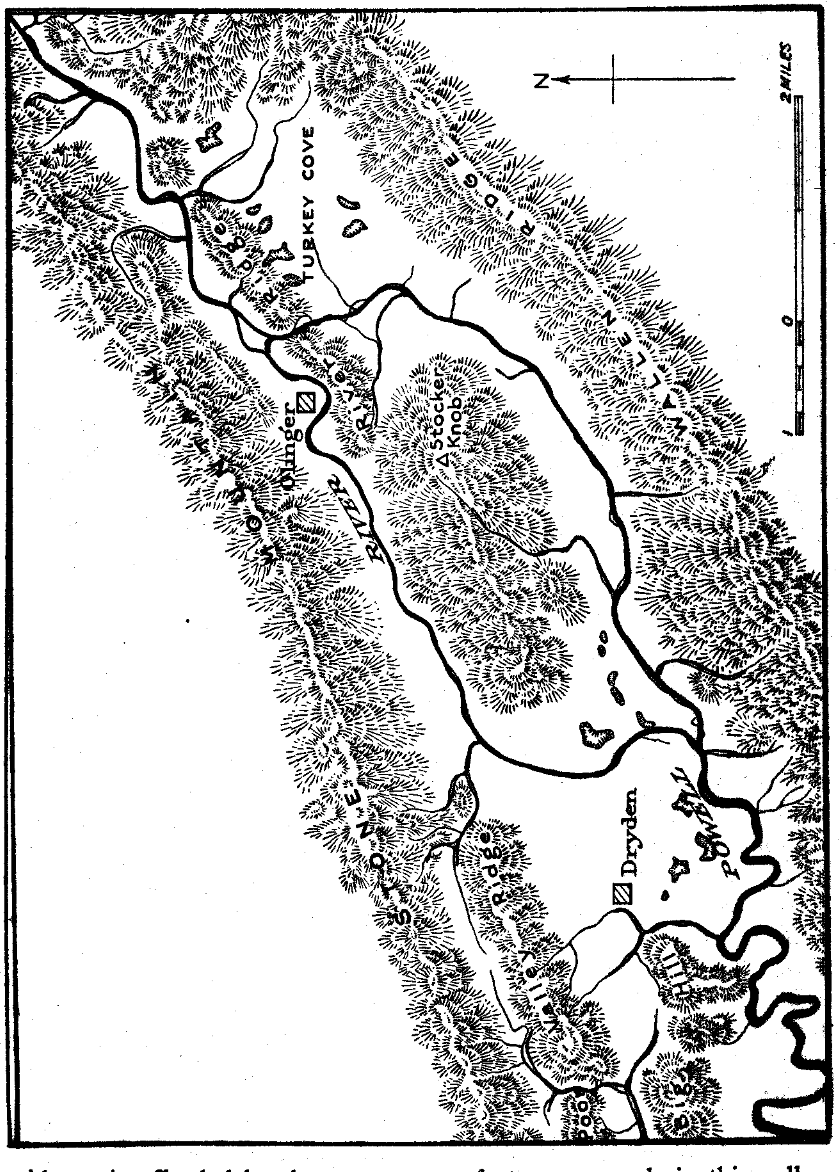


FIGURE 8.—Sketch map showing change in course of Powell River. Present drainage is shown above; earlier drainage, in Harrisburg cycle, is shown in blue.

evidence is afforded by the occurrence of stream gravels in this valley, well above the present drainage. Hence, the Harrisburg course of Powell River is believed to have extended through River Ridge, possibly at the location of the present gap of Mud Creek, and then across Turkey Cove and down the Camp Creek valley to join its present course southeast of Dryden. (See Pl. 10A.)

POST-HARRISBURG EROSION

On uplift of the Harrisburg surface and rejuvenation of drainage, a tributary which joined Powell River near Dryden lengthened by headward erosion the narrow valley between Stone Mountain and Stocker Knob. Encountering easily eroded shales and the soluble Cayuga limestone, the headwaters of this stream eroded far enough back to tap the main stream just east of Olinger and divert it to the north of Stocker Knob. Thus the Camp Creek valley was derived of through-flowing drainage. Camp Creek came into being as the much diminished stream in the old river channel. Mud Creek developed by reversal of the part of the river course in Turkey Cove.

Powell River incised itself sharply into its present course and entrenched the meanders southwest of Dryden. The Harrisburg surface in Turkey Cove was attacked by Mud Creek, Buck Creek, and the unnamed stream between them, which deepened their gaps through River Ridge in their efforts to keep pace with the downcutting of the main stream. Camp Creek, having an outlet lower than that of Mud Creek (as it joined Powell River farther downstream) had a steeper gradient and succeeded in shifting the divide between itself and Mud Creek back toward Turkey Cove.

A noteworthy feature of post-Harrisburg erosion of this area is the development of underground drainage in the parts underlain by limestone. The deepening of the gaps through River Ridge allowed Mud and Buck creeks to lower the level of ground water in the limestones underlying Turkey Cove. This permitted water in Turkey Cove to dissolve underground channels above the water table and, as a result, extensive sink drainage developed. A considerable amount of the drainage in the lower Camp Creek valley was also underground, after the rejuvenated Powell River had lowered the ground-water surface east of Dryden. The development of subsurface drainage in both these limestone areas lowered them faster than the resistant sandstones of the ridge belt or the cherty dolomite of Big Hill. Hence, the ridges and Big Hill grew in relief and the limestone areas grew in basinal character. (See Pl. 10A.)

Recent river gravels are to be seen along State Highway 64 one mile east of Pennington. These gravels are from 4 to 6 feet thick and lie some 40 feet above the present level of the north fork of Powell River. They are probably remnants of a stream terrace left in the process of entrenchment after rejuvenation in post-Harrisburg time. The undulatory, uneven character of the layer of gravel is probably due to a combination of differential solution in the underlying dolomite and slumping under the influence of gravity. The zone of residual clay which intervenes between the base of the gravel and the dolomite doubtless facilitated gravitational movement.

MINERAL RESOURCES

IRON

Beds of hematite, the red oxide of iron, in northeastern Lee County have in the past been mined for iron ore. The hematite occurs in the Clinton formation and crops out on the southeast slope of Wallen Ridge. The Lee County deposits are continuous with those of Wise County, which have been described by Eby.[64] The reader is referred to this discussion for detailed information on the occurrence, characteristics, and mining development of the Clinton ores in this area. The iron-bearing material is similar in chemical composition to the Clinton ores mined elsewhere in the Appalachian region. Metallic iron constitutes 43 per cent of each of two samples from Wallen Ridge north of Jasper.[65]

Old pits and workings are found at several places in Lee County along the southeastern slope of Wallen Ridge. Their complete abandonment since 1920, or earlier, has resulted in a heavy growth of brush and the slumping of drift entries. A few pieces of high-grade hematite may be found on the dumps. The decline of the Lee and Wise counties field has resulted not primarily from a poor grade of ore, but rather from its occurrence in thin beds so arranged that a large amount of worthless material must be handled for every ton of ore produced. Two bore-hole sections given by Eby show 12 and 19 inches of ore, respectively, in Wallen Ridge near Jasper; but in both places the ore is overlain by some 40 feet of shale and sandstone. Even the close proximity of large supplies of limestone and coal, favorable for smelting, has not compensated for the unfavorable mode of occurrence of the ore.

The Clinton formation also crops out on the northwest side of Powell Valley, but there the rocks stand vertically and have been faulted and crushed so that extraction of ore would be very difficult. A total of 4 feet of hematite was observed in the Clinton formation along State Highway 64 at the Lee-Wise county line, but the iron beds are thin and occur interbedded with barren sandstone and shale, so that even if the structure were not complex it is doubtful if these deposits could be classified as ore bodies. In conclusion, the iron resources of northeastern Lee County will not be of importance until current sources, such as the Lake Superior deposits, are exhausted, and then only if larger, more readily minable deposits are not found.

[64] Eby, J. B., and others, The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, pp. 545-569, 1923.

[65] Idem, table, p. 552.

LIMESTONE

The most important mineral resource of Powell Valley in the area studied is limestone. The uses to which it has been put include burning for agricultural lime and crushing for road metal. Some of it is pure enough for flux or to make calcined lime, but probably is not as accessible as similar limestone elsewhere. Some of the limestone might be used in the manufacture of rock wool, for heat and sound insulation.

Agricultural lime.—Limestone has been quarried on a small scale and burned in kilns by farmers at various points in the area, notably along the northwest foot of Wallen Ridge between Deep Spring School and the southern boundary of the area mapped. Here the limestone comes from the Mosheim and Lenoir formations and makes excellent lime. Small kilns have been erected in the limestone area north of Dryden, and a few are located in the vicinity of Pennington. There is a small quarry near Olinger, from which basal Newman limestone has been removed for burning.

The relative value for burning of limestones from three formations is indicated by the following analyses:

Analyses of limestones from northeastern Lee County, Virginia

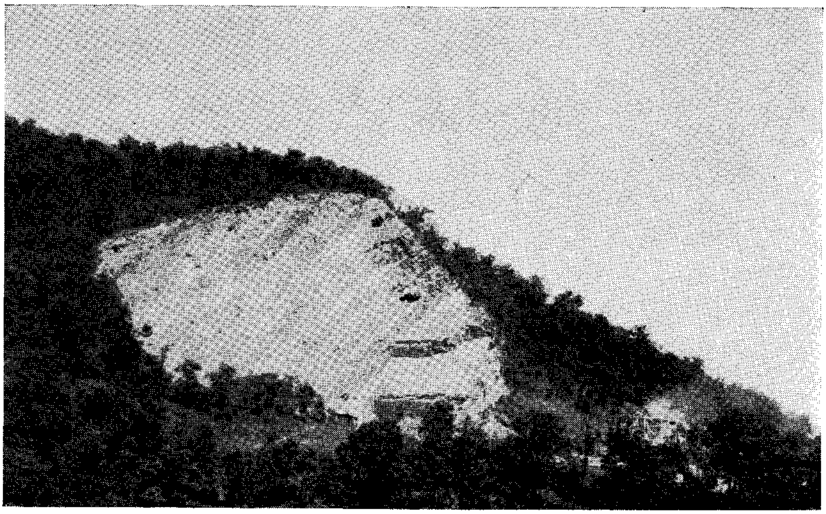
(John H. Yoe, Analyst)

	1	2	3
SiO_2	2.57	6.22	7.29
R_2O_3	.72	1.32	1.99
$CaCO_3$	93.12	90.03	85.15
$MgCO_3$	3.73	2.41	6.16
	100.14	99.98	100.59

1. Mosheim and Lenoir limestone from abandoned quarry on State Highway 64, 2 miles southeast of Dryden. Chert which occurs in the limestone is not included in the analysis. A. F. Litton Co., Owner.
2. Trenton limestone from abandoned quarry on State Highway 64, 1½ miles northeast of Deep Spring School. R. N. Reasor, Owner.
3. Lowville limestone from quarry on State Highway 64, 1 mile southwest of Lee-Wise county line. T. Q. Gilly, Owner.

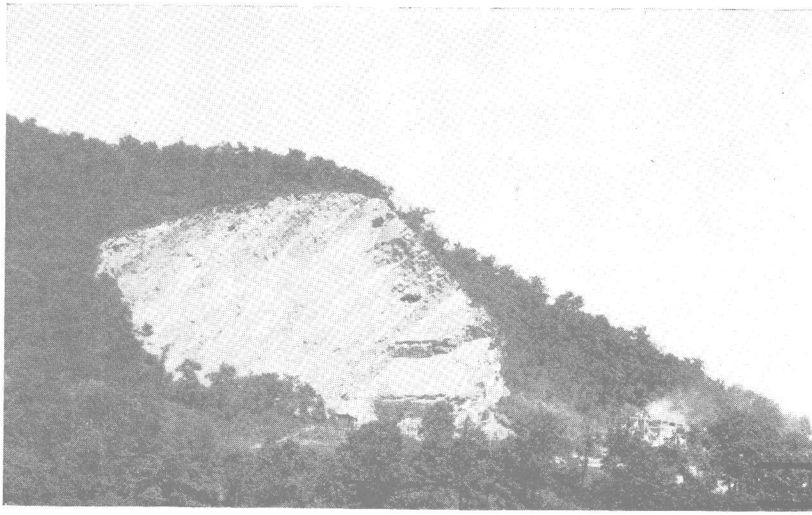
As the chemical compositions indicate, the best of these limestones for burning comes from the Mosheim and Lenoir formations. There are deposits of limestone in this area sufficient to supply the local agricultural demand for many years.

Road metal.—Crushed stone on all the paved roads in this area consists of limestone which was locally quarried. Formations which have supplied this material include the Mosheim, Lenoir, Lowville, Trenton and Newman.



A. Limestone quarry of the Stonega Coal and Coke Co., in Big Stone Gap gorge. The rock is Newman limestone dipping steeply to the west. Photograph by Arthur Bevan.

B. Loading limestone from face of quarry of the Stonega Coal and Coke Co.



A. Limestone quarry of the Stonega Coal and Coke Co., in Big Stone Gap gorge. The rock is Newman limestone dipping steeply to the west. Photograph by Arthur Bevan.

B. Loading limestone from face of quarry of the Stonega Coal and Coke Co.

State Highway 64 was first paved some 20 years ago from Big Stone Gap southwestward through the area under discussion. Road metal was supplied from small quarries which were opened as paving progressed. Two of these are in Turkey Cove and a third is near the side road to Dryden. Repaving of this road was in progress when the field work was done for this report and had extended from Big Stone Gap as far southwest as Buck Creek in Turkey Cove. All the crushed stone used in this new road came from the large quarry of the Stonega Coal and Coke Company in the gorge at Big Stone Gap. (See Pl. 12.) When the writer left the area, in September 1937, preparations were being made to continue the paving southwest from Buck Creek, and a crusher was being moved into the quarry in the Lowville formation one mile southwest of the Lee-Wise county line, in expectation of supplying road material from this source. The Lowville may not be so ideally suited to this use as the Newman, but it will probably be satisfactory. The quarries to the southwest of this one may be reopened as the rebuilt road progresses in that direction.

There is a limestone quarry, now abandoned, on the property of Mrs. Minerva Clusman in Pennington Gorge. This quarry, which is in the Newman formation, was in operation as late as 1930 and supplied road ballast for State Highway 65 and for streets in the town of Pennington Gap. This quarry is probably the most valuable single mineral property in this area. The limestone is clean, uniform, and accessible, and there is an almost inexhaustible supply, inasmuch as the limestone bed extends the entire length of Stone Mountain. On the other hand the quarry is one the east side of the north fork of Powell River, whereas the railroad is on the west side. If large operations were begun, it would be necessary to bridge the stream with a spur track. Probably such an expense would not be justified, and it is thought that this quarry will be limited to supplying the local demand for high-grade crushed stone. This it can do indefinitely.

BUILDING STONE

Sandstone for building purposes has been quarried in Wise County from the Price and Maccrady horizons. This sandstone is fine grained and compact and occurs in two colors, reddish brown and light green. According to tests made by the U. S. Bureau of Standards,[66] these sandstones possess extraordinary hardness and strength. They have not been used to any great extent in northeastern Lee County, although deposits here are as available as in Wise County. It is thought that in the future these sandstones may be of some value for local use.

[66] Eby, J. B., and others, op. cit., pp. 570-576.

So far as the writer is aware, no limestone is used for building stone in this area except very locally for foundations, retaining walls, etc. The scarcity of undisturbed rocks in the area makes it improbable that large amounts of building stone will be forthcoming.

CLAY

The occurrence of clay at four localities near Pennington has been noted by Ries and Somers.[67] On investigation, the writer found only one deposit being utilized. This is residual clay from deeply weathered Reedsville shale. The deposit occurs in a cut on the highway one-fourth mile north of Pennington, and appears to be about 20 feet thick. Its lateral extent is unknown. The material is used for fill, and so far as the writer knows has never been used for brick or tile. It is probably too impure and sandy for such use.

OIL AND GAS POSSIBILITIES

After a study of isocarbs in this region, Eby[68] concluded that the possibilities for oil and gas are slight. The ratio of fixed carbon to volatile matter in the coals of the region is so high that it is doubtful whether oil could occur. In 1923 a well was drilled in one of the fensters near Rose Hill, Lee County, some 20 miles southwest of Pennington, and a production of a few barrels was secured.[69] Commercial production has never been obtained. The occurrence of natural gas independent of oil is probably not sufficiently certain to make drilling worth while.[70]

---

[67] Ries, H., and Somers, R. E., The clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, pp. 73, 94, 104, map, 1920.

[68] Eby, J. B., The possibilities of oil and gas in southwest Virginia as inferred from isocarbs: Amer. Assoc. Petroleum Geologists Bull., vol. 7, no. 4, pp. 421 426, 1923; Oil and gas possibilities in Wise County: *in* Virginia Geol. Survey Bull. 24, pp. 578-583, 1923.

[69] Giles, A. W., An oil seep in the folded Appalachians: Amer. Assoc. Petroleum Geologists Bull., vol. 11, no. 7, pp. 757-763, 1927.

[70] See McGill, W. M., Prospecting for natural gas and petroleum in Virginia: Virginia Geol. Survey Bull. 46, pp. 11-22, 1936.

RIDGE-MAKING THIN SANDSTONE IN FREDERICK COUNTY, VIRGINIA

BY

RAYMOND S. EDMUNDSON

VIRGINIA CONSERVATION COMMISSION
VIRGINIA GEOLOGICAL SURVEY
Bulletin 51-C
UNIVERSITY, VIRGINIA
1939

CONTENTS

ILLUSTRATIONS

Ridge-Making Thin Sandstone in Frederick County, Virginia

RAYMOND S. EDMUNDSON[1]

INTRODUCTION

It is generally recognized that massive thick-bedded sandstones and relatively weak shales and soluble limestones form characteristic surface features. The uncommon effect of a thin argillaceous sandstone in producing ridges in an area in northern Virginia, in which the writer has recently done detailed field work, is briefly described in this paper. This bed, with an average thickness of 2 feet, where it crops out in a nearly vertical position, commonly forms discontinuous ridges ranging in height from a few feet to as much as 20 feet.

The areas southeast of Winchester (Fig. 9) and northwest of Stephens City (Fig. 10) were chosen as typical localities to illustrate the ridge-making influence of this sandstone on the local topography.

STRATIGRAPHY

GENERAL STATEMENT

The stratigraphic units represented on each map include a part of the Beekmantown limestone and dolomite, the Mosheim and Lenoir limestones (Stones River group), the Chambersburg limestone, and a part of the Martinsburg shale.

CHAMBERSBURG FORMATION

The Chambersburg limestone (Middle Ordovician) was named by Stose[2] in 1909, from the county seat of Franklin County, Pennsylvania, where the formation is underlain by the Lowville formation. In Frederick County, Virginia, the Lowville is not present and the Chambersburg limestone rests unconformably upon the Lenoir limestone.

The Chambersburg formation is chiefly a thin-bedded dark-blue limestone with numerous irregular clayey partings. Some layers are highly nodular and on weathering yield abundant float. This characteristic is not unlike that of the underlying Lenoir, but the texture of the Chambersburg is as a rule finer grained than that of the Lenoir.

---

[1] Associate geologist, Virginia Geological Survey.

[2] Stose, G. W., U. S. Geol. Survey Geologic Atlas, Mercersburg-Chambersburg folio (No. 170), p. 10, 1909.

In the vicinity of Vaucluse, in the southern part of Frederick County, the top part of the formation is very argillaceous and contains the brachiopod *Christiania.*

Thin beds of volcanic ash (bentonite) occur near the top of the formation along U. S. Route 11, just east of Cedar Creek and about 3 miles northeast of Strasburg. This was the only occurrence of bentonite observed in Frederick County, but elsewhere its presence seems to be a constant feature throughout the known extent of the Chambersburg.[3]

The lower part of the Chambersburg limestone in the areas here considered is characterized by an argillaceous fine-grained sandstone which averages about 2 feet in thickness. An analysis by John H. Yoe, Chemist to the Virginia Geological Survey, of a composite sample from this bed, showed 93.68 per cent insoluble matter. Along the secondary road northwest of Stephens City, about 200 yards west of the Baltimore and Ohio Railroad, the abundant sandstone float suggests that the source bed or beds are of greater thickness. In other parts of this area and in the vicinity of Winchester, measured thicknesses range from 1½ to 3 feet. It is not possible to determine whether this member is continuous throughout Frederick County, but its presence at many intermediate points from Winchester southwestward to Tumbling Run in northern Shenandoah County, suggests that, at least locally, it may be a definite horizon marker.

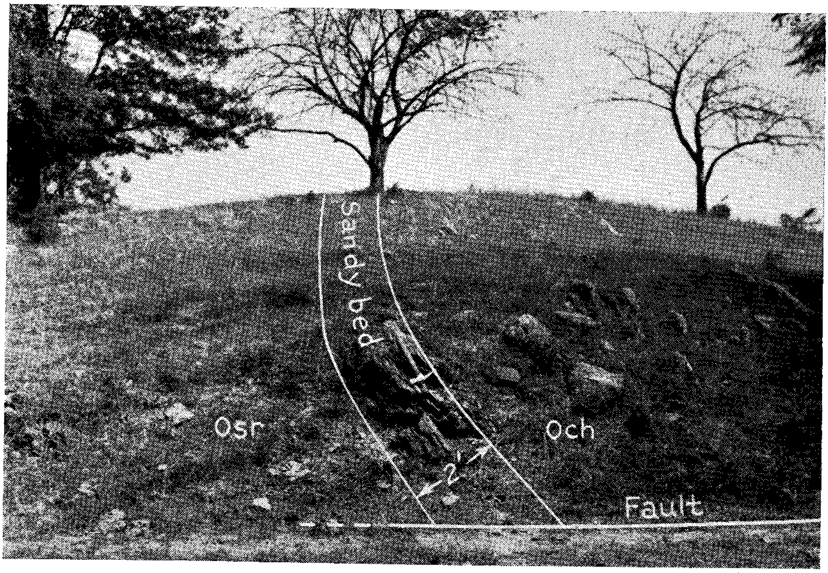
Fossils were not noted in the argillaceous sandstone, but the Chambersburg formation[4] is characterized by *Nidulites, Receptaculites,* and *Echinosphaerites.*

WINCHESTER AREA

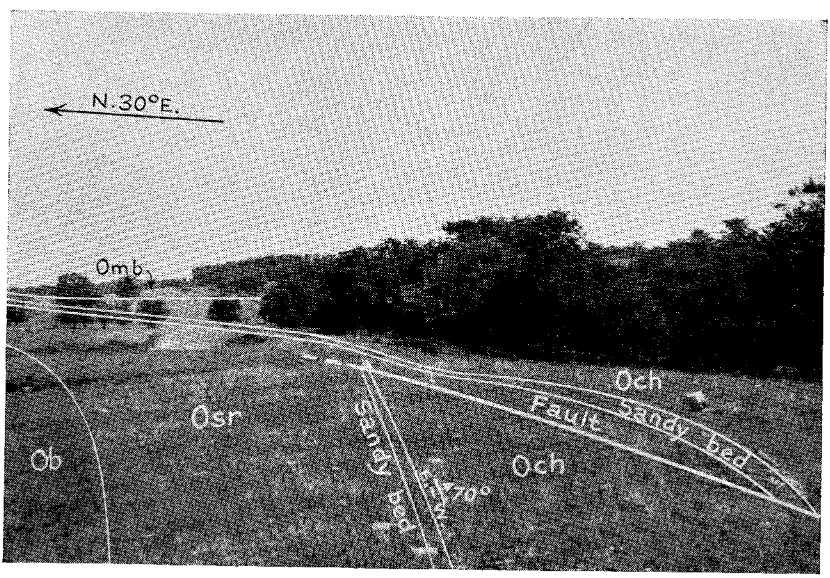
The area southeast of Winchester shown in Figure 9, is approximately one mile square. It is drained by Town Run, a tributary of Abrams Creek. The narrow valley has an average altitude of 660 feet, whereas the bordering irregular hills average about 720 feet. Rouss Spring, the source of municipal water supply for Winchester, is located along Town Run near the central part of the area.

The northeastern regional strike of the rocks is locally interrupted and offset by an oblique fault which strikes N. 25° W. This fault, about 1000 feet east of and parallel to U. S. Route 50, extends from a point near the limit of Winchester on the northwest to a point about 800 feet east of the intersection of State Highway 3 and U. S. 50 on the southeast. It passes near Rouss Spring in the central part of the area.

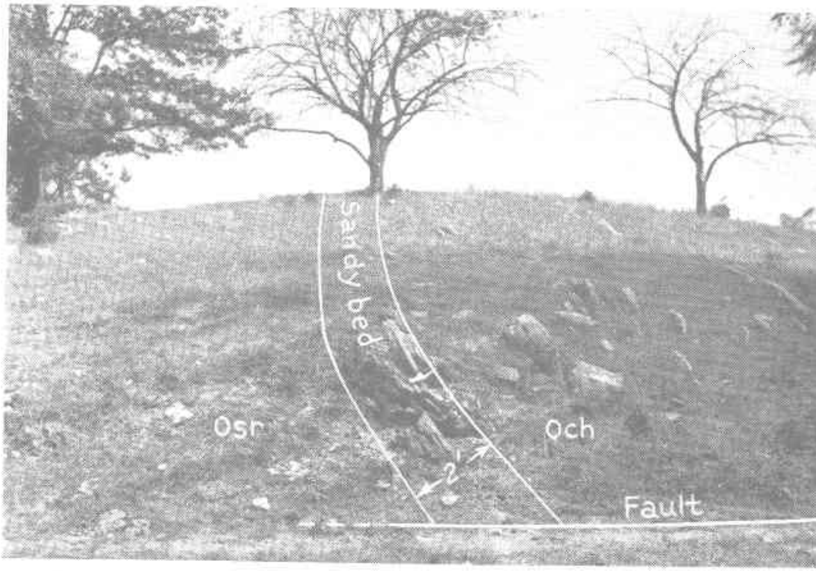
[3] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 19, 1933.
[4] Butts, Charles, op. cit., p. 20.



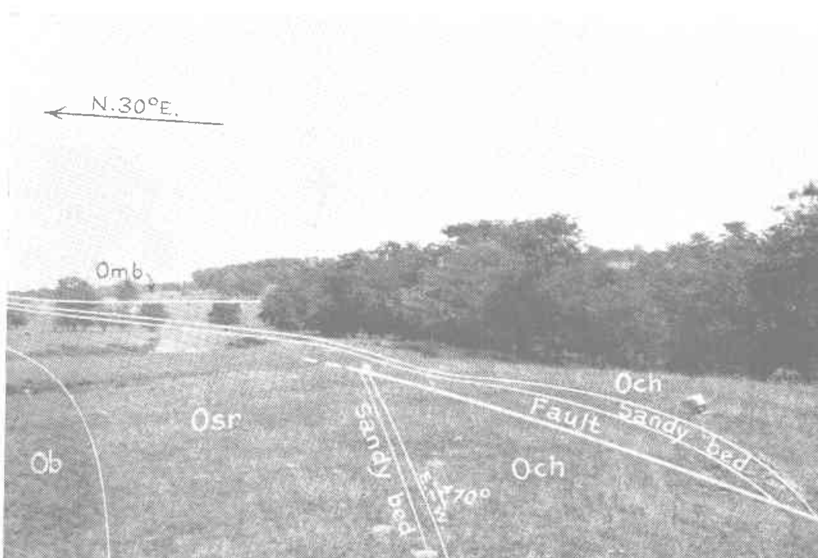
A. Argillaceous sandy bed southeast of Winchester, Frederick County, Virginia. Och, Chambersburg formation; Osr, Stones River limestone. Photograph by Arthur Bevan.



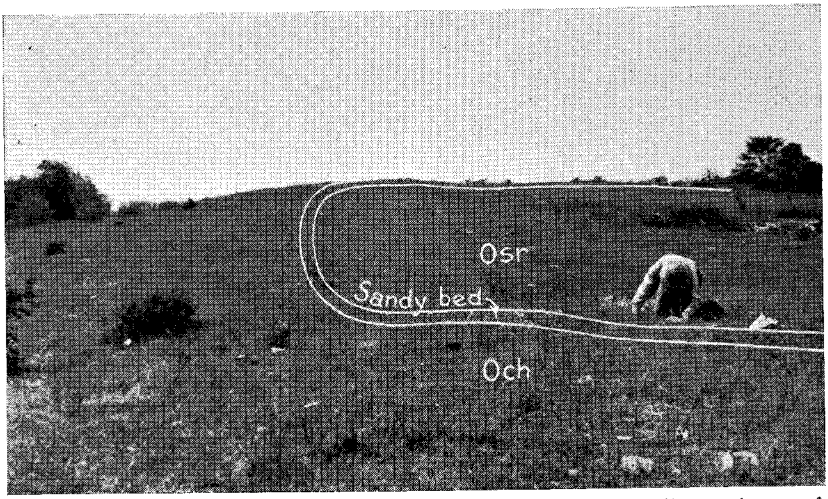
B. Ridge east along the strike, half a mile southeast of Winchester. Omb, Martinsburg shale; Och, Chambersburg limestone; Osr, Stones River limestone; Ob, Beekmantown formation. Photograph by Arthur Bevan.



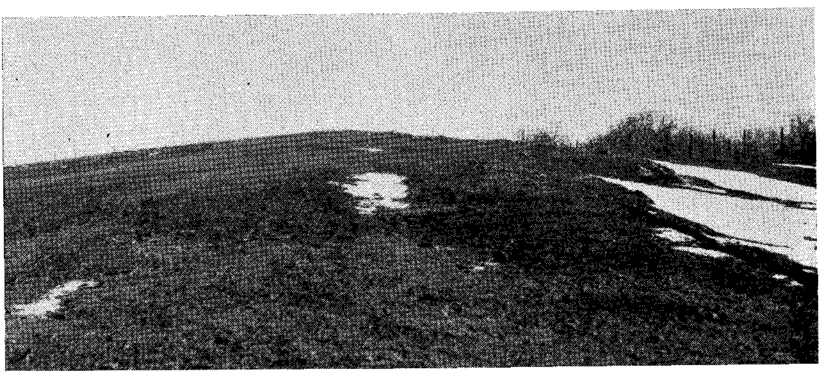
A. Argillaceous sandy bed southeast of Winchester, Frederick County, Virginia. Och, Chambersburg formation; Osr, Stones River limestone. Photograph by Arthur Bevan.



B. Ridge east along the strike, half a mile southeast of Winchester. Omb, Martinsburg shale; Och, Chambersburg limestone; Osr, Stones River limestone; Ob, Beekmantown formation. Photograph by Arthur Bevan.

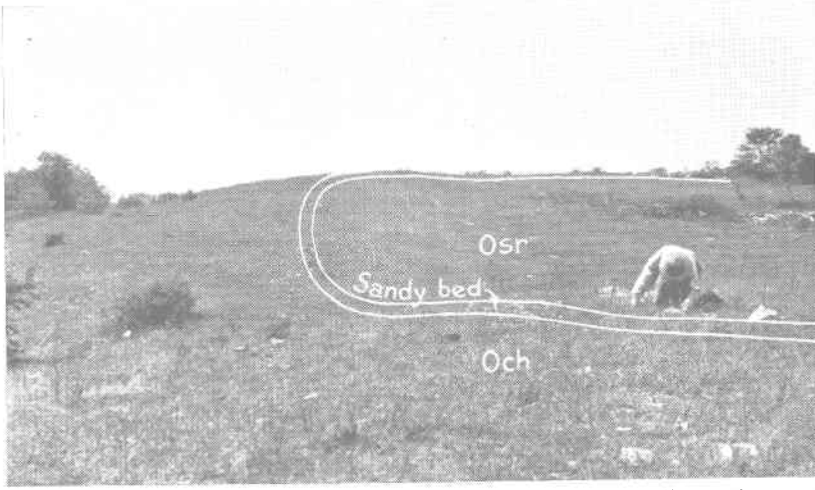


A. Ridge paralleling strike of sandy bed about half a mile southeast of Winchester. Och, Chambersburg limestone; Osr, Stones River limestone. Photograph by Arthur Bevan.



B. Ridge as seen looking northeast from road 631, half a mile northwest of Stephens City, Frederick County, Virginia.

C. Ridge three-fourths of a mile northwest of Stephens City, Frederick County, Virginia.



A. Ridge paralleling strike of sandy bed about half a mile southeast of Winchester. Och, Chambersburg limestone; Osr, Stones River limestone. Photograph by Arthur Bevan.

B. Ridge as seen looking northeast from road 631, half a mile northwest of Stephens City, Frederick County, Virginia.

C. Ridge three-fourths of a mile northwest of Stephens City, Frederick County, Virginia.

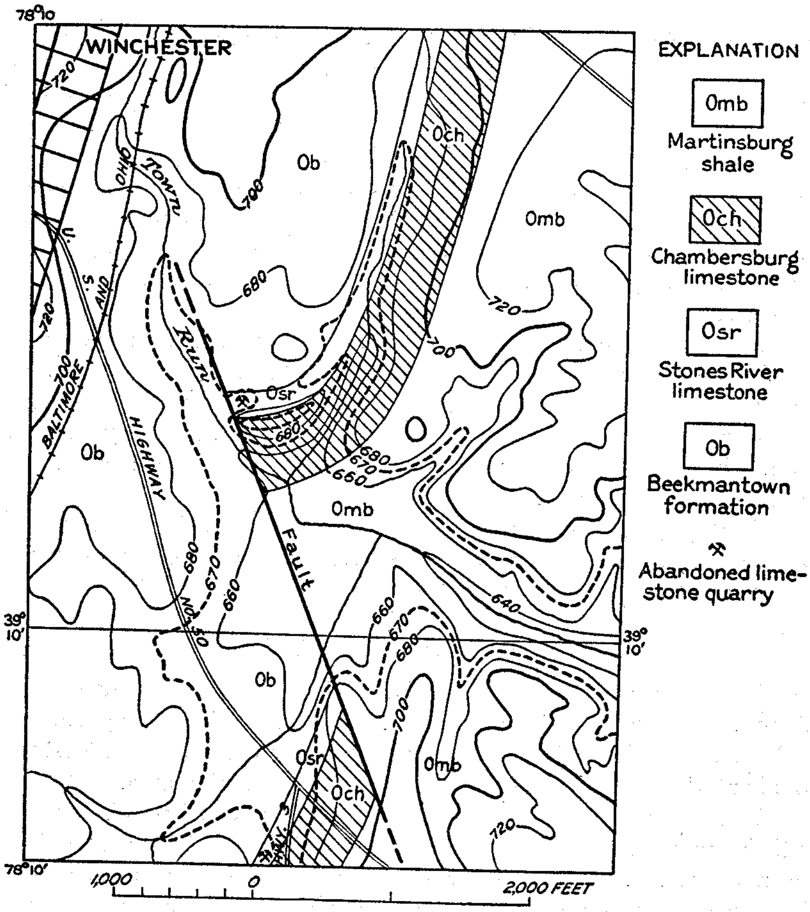


FIGURE 9.—Geologic sketch map of an area southeast of Winchester, Frederick County, Virginia. Contours based on Winchester advance sheet. (U. S. Geol. Survey.)

The formations in the northern part of the area strike N. 20° E., but on approaching the fault from the northeast, the strike trends more to the southwest and becomes west at the fault. Since drag folding along a fault always has its curvature convex toward the direction of the relative motion of the block in which it occurs, it seems that this apparent exception may be explained by faulting superimposed upon a pre-existing close flexure. The beds southwest of the trace of the fault show no evidence of distortion.

The Mosheim limestone, lower member of the Stones River group (Fig. 9), was at one time quarried for agricultural lime at an outcrop about 1000 feet north of Rouss Spring and at another locality about 300 feet west of State Highway 3. Although the limestone is of good quality, future attempts to quarry it in this area are not recommended due to local unfavorable quarrying conditions. Unlimited quantities of Beekmantown limestone and dolomite suitable for crushed stone are available here.

The argillaceous sandstone (Pl. 13A), which crops out northeast of the fault (Fig. 9), averages about 2 feet in thickness. It is responsible for a narrow ridge (Pls. 13B and 14A) that ranges from a few feet to about 20 feet in height. In the central part of the area the sandy bed is faulted against calcareous rocks of Beekmantown age. This structure is reflected topographically as a steep slope, about 20 feet in height, terminating at the fault. To the east, the ridge underlain by the sandy member maintains an even but sharp crest (Pls. 13B and 14A) for about 1000 feet. East of this point the continuity of the ridge is broken by a narrow valley formed by a tributary of Town Run, but it again becomes conspicuous near the northern end of the area shown on the map.

In the extreme southern part of the area (Fig. 9), the sandstone can be traced topographically, but its relatively low relief can not be shown by the 10 foot contours used on the map.

STEPHENS CITY AREA

The area northwest of Stephens City shown in Figure 10, is about 2 miles long and 1 mile wide. It is drained by Stephens Run and its tributaries. Altitudes range from 700 feet along the stream to about 800 feet in the northwestern part of the area.

The structure northwest of Stephens City consists of a narrow anticline plunging southwest and a corresponding parallel syncline plunging northeast. Using the thin Stones River group as an index marker, the two structures are displayed within an area approximately 1 mile long and half a mile wide. The purity of the Mosheim limestone and the favorable quarrying conditions at the southwestern end of the local anticline were responsible for the location here of one of the largest limestone quarries in northern Virginia. It appears probable that another quarry could be profitably developed at the northeastern end of the adjoining syncline.

Observations in this area indicate that the sandy bed does not form a ridge unless it is highly inclined. For example, there is no ridge on the southeastern limb of the local anticline characterized by low dips; whereas beginning at the railroad, west of the plant of the M. J. Grove Lime Co., and extending northeast for about one mile, the beds are highly inclined and there is a definite ridge (Fig. 10) that ranges from a few feet to about 20 feet in height. (See Pl. 14B and C.) The tracing of this bed topographically makes it possible to map structural details that otherwise would not be seen because of the lack of continuous exposures. The rocks comprising the northwest limb of the syncline dip about 45° SE. and do not make a conspicuous ridge. It is possible, however, to identify a low discontinuous ridge along most of the structure.

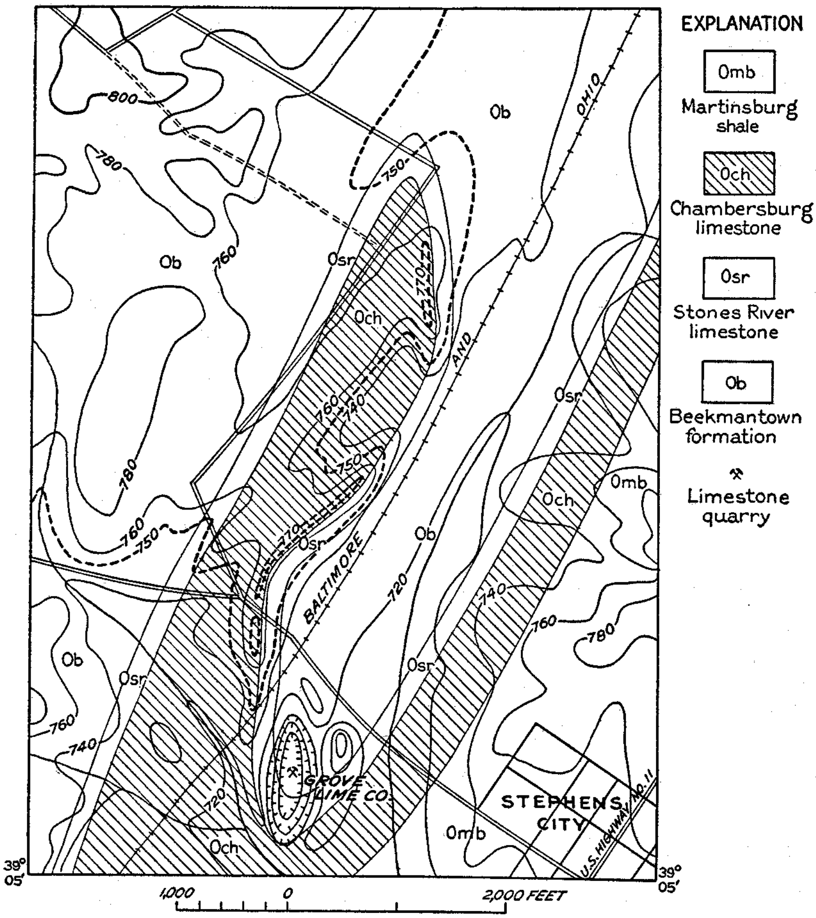


FIGURE 10.—Geologic sketch map of an area northwest of Stephens City, Frederick County, Virginia. The 770-foot contour shown by the broken line includes the crest of the sandstone ridge. Contours based on Winchester advance sheet (U. S. Geol. Survey).

CONCLUSIONS

The small discontinuous ridges, which owe their topographic expression to the thin argillaceous sandstone near the base of the Chambersburg limestone, aid in the interpretation of the structure and stratigraphy in an area of few bedrock exposures. The factors which permit this bed or any bed of similar thickness and lithology to be recognized topographically are a thin soil mantle, relatively high solubility of the enclosing rocks, and a steep dip.

VARVED SLATES IN FAUQUIER COUNTY, VIRGINIA

BY

LINCOLN R. THIESMEYER

VIRGINIA CONSERVATION COMMISSION
VIRGINIA GEOLOGICAL SURVEY
Bulletin 51-D
UNIVERSITY, VIRGINIA
1939

CONTENTS

ILLUSTRATIONS

Varved Slates in Fauquier County, Virginia[1]

By Lincoln R. Thiesmeyer

Abstract.—Finely laminated, phyllitic slates, interstratified with arkosic members of the Loudoun formation, have been found recently in Fauquier County, Virginia. They consist of regularly alternating, light- and dark-colored components, which are themselves commonly but not invariably laminated on a smaller scale. In major features and minor details these rocks are so strikingly similar to ancient and modern varved deposits that they are believed to represent seasonally banded records of Late Proterozoic or Early Cambrian time. Thickness of individual seasonal components and of intraseasonal laminae varies considerably. The average number of varves per inch in exposed parts of the deposit is about fifteen. Since the thickest continuous section is more than 280 feet, these slates may represent about 50,000 years of deposition. Pronounced diadactic structure indicates that the sediments accumulated in bodies of fresh water, subject to a regular periodic cessation of supply and freedom from agitation, such as would occur through winter freezing. No positive indicators of glaciation have yet been found associated with the slates. Nevertheless, several lines of evidence suggest that they represent lacustrine deposits, perhaps fed by the meltwaters of valley glaciers on the highlands bordering the Appalachian trough.

Introduction.—Finely laminated phyllitic slates found near the base of the Loudoun formation[2] in northwestern Fauquier County, Virginia, are of particular interest because the alternate laminae are light and dark and show many features of texture, structure and composition which make them strikingly similar to the varves of glacial clays and other seasonally banded materials. Furcron[3] observed this phenomenon in the Loudoun formation farther south in Virginia, but did not describe or discuss it. Furcron[4] noted these slates also in the Warrenton quadrangle but considered them as a unit within the late pre-Cambrian Warrenton formation. He[5] did not study details of their structure and origin but was impressed by their resemblance to varved

[1] Revised copy of paper read before the joint session of the Geological Society of America and Section E, American Association for the Advancement of Science, at Denver, June 24, 1937, under the title "Varved slates in the Lower Cambrian of Virginia."
[2] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (No. 10), 1894.
[3] Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, 1935.
[4] Furcron, A. S., Geology and mineral resources of the Warrenton quadrangle, Virginia: Virginia Geol. Survey Bull. 54. (In press.)
[5] Furcron, A. S., personal communication.

materials. Sayles[6] called attention to banded Hiwassee slates in Tennessee, and suggested that they might represent deposition under seasonal control. The writer[7] has studied similarly banded sediments near Chapel Hill, North Carolina.

The exact age of the rocks at these localities is still unknown. In each place the sediments are stratigraphically below established Lower Cambrian fossil horizons, yet are not separated from them by demonstrated major unconformities. The banded rocks likewise occur in sediments which rest with marked unconformity upon a basement complex of Late Proterozoic rocks. Hence, each group of beds is reported to be either Early Cambrian or very late Proterozoic and it is possible that the deposits may represent closely related stratigraphic horizons.

Although the slates in Fauquier County, Virginia, were found during reconnaissance traverses incident to a study of granites in northern Virginia and have not been mapped separately, preliminary investigations in the field and laboratory show that they were probably fresh-water varves, and that their deposition may have been related to glaciation. Deposits of this character may even prove fairly common in rocks of the same age through the Southern Appalachian region and elsewhere. It seems appropriate, therefore, to present details concerning these slates, as a stimulus to careful search for additional examples of the same phenomena in other Late Proterozoic and Early Cambrian rocks.

Location and thickness of the slate.—These slates appear in roadcuts and scattered field ledges between Cliff Mills, Ada, and Marshall, Virginia. (See Fig. 11.) A large, synclinorial wedge of the Loudoun formation, surrounded by a pre-Cambrian crystalline complex of metamorphic and plutonic rocks, occupies most of this area. The folding seems to be chiefly isoclinal, with slight overturning toward the northwest so that prevailing dips are steep to the southeast.

The Loudoun formation, defined and assigned to the Lower Cambrian by Keith,[8] and recently referred by Howell to the Late Proterozoic, is predominantly a medium-grained to pebbly arkose. Its thickness ranges from a few inches to more than 800 feet within short distances. In the area studied it does not include basal conglomerates, but contains a few local lenses of quartz-pebble conglomerates. The formation is locally quartzitic and includes silvery to bluish slates, but in general it has suffered only moderate metamorphism.

[6] Sayles, R. W., Preliminary notes on some regularly banded argillites which suggest seasonal deposition (abstract): Geol. Soc. America Bull., vol. 33, no. 1, p. 133, 1922.

[7] Thiesmeyer, L. R., and Storm, R. R., Features indicative of seasonal banding in silicified argillites at Chapel Hill, North Carolina (abstract): Geol. Soc. America Bull., vol. 49, p. 1964, 1938.

[8] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, pp. 285-395, 1894.

The laminated slates occur at or very near the base of the Loudoun formation. In places they rest directly on granite, greenstone, and gneiss of the basement complex; elsewhere they are separated from these rocks by several feet of coarse arkose. Beds of arkose, a few inches to several feet thick, are intercalated within the slate at several horizons, marking sudden, radical changes in the character of deposition. Several horizons of laminated slates are thus represented within the Loudoun formation. The total thickness of the laminated member (or members) is not known, but one incomplete section at Cliff Mills measured 280 feet between extremities covered by thick regolith.

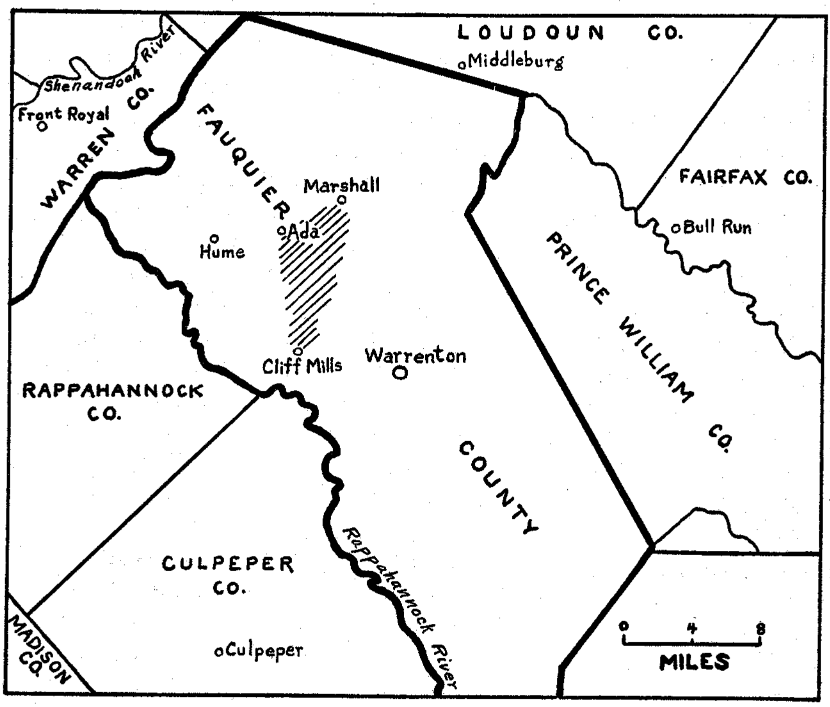


FIGURE 11.—Sketch map of northwestern Fauquier County, Virginia, showing area (shaded) in which outcrops of the laminated slates are numerous.

Nature of the lamination.—The banding is produced by the regular alternation of light- and dark-colored bands, or components, which are themselves commonly but not invariably laminated on a smaller scale. (See Pl. 15.) All of the light-colored "summer"[9] components have a coarser texture than the adjacent dark-colored "winter" ones. Similarly,

[9] For clarity in description, the seasonal designations common to descriptions of Pleistocene and other varves are employed here, in the hope that justification for applying them to the Virginia rocks will become apparent later in this paper.

thin, light-colored laminae within winter bands are coarser, and thin dark-colored laminae within summer bands are finer, respectively, in texture than the materials with which they are interstratified. Each light-colored component grades perceptibly in both texture and color into the dark-colored one on one side of it. On the other side, however, it is sharply demarcated from the dark-colored component. Scattered ripple-marks in the slate and local channeling in both the slate and the arkose indicate that the gradational side represents the top of the component,[10] that is, the summer bands grade upward into the overlying winter bands. Many of the winter bands grade upward themselves in a similar but less regular fashion, so that the finest material is at their tops. This accentuates the sudden change to the coarser material of the overlying deposit. These features are shown in Plate 16. According to the writer's interpretation, four complete varves, with parts of two others, are shown in this section. In brief, the rock has pronounced diadactic structures, a feature ascribed by Sauramo[11] and others to varves formed in fresh water.

At numerous places throughout the slate dark-colored laminae—representing periods of less turbulent water in the basin of deposition—within the light-colored, summer components are commonly thick and show an analogous gradation. Consequently, it is not always easy to distinguish how much should be considered a single, complete component—the depositional record of one season—and how much represents an intraseasonal part of a component—a record of deposition under changed conditions during only a fraction of a season.[12]

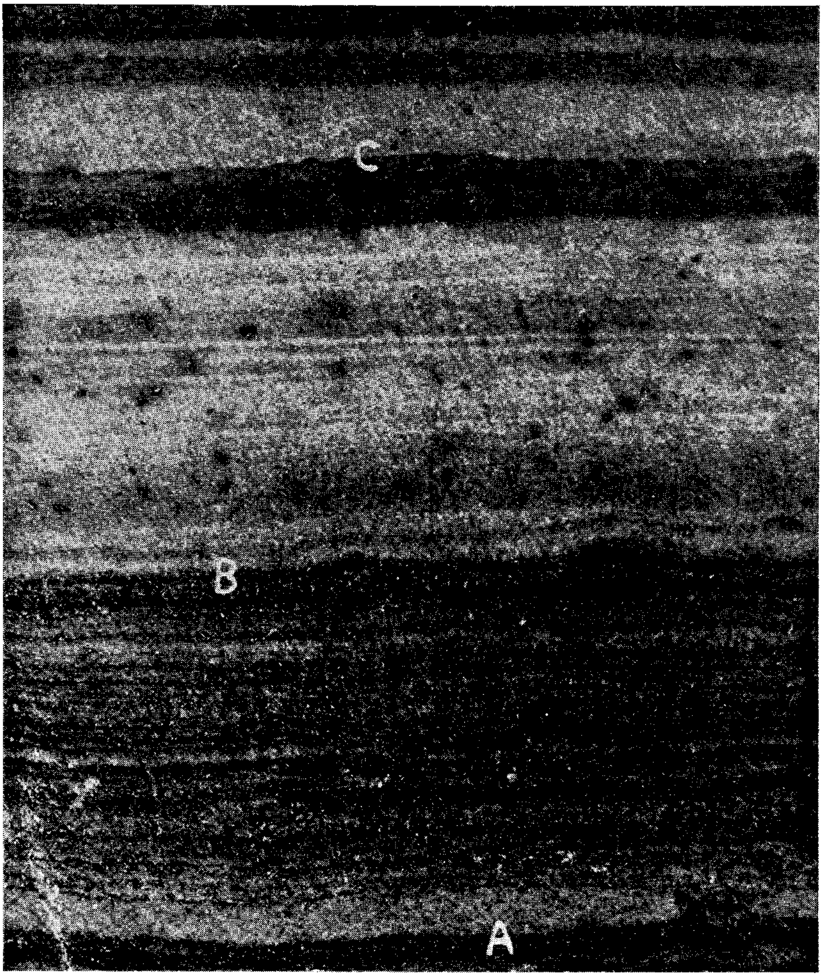
At several places narrow zones of highly contorted layers occur in the midst of undeformed ones. The crumpled layers pass downward into undisturbed horizons, but are truncated sharply by undisturbed laminae above them. (See Pl. 17A.) Such deformation must have occurred during deposition of the sediments, prior to diagenesis, and is an example of what Lahee termed "contemporaneous deformation." This phenomenon has been attributed by De Geer to slumping before diagenesis, by James Geikie, Lahee and Sayles to the grounding and drag of icebergs on a lake bottom, and by Sayles and others to readvance of glaciers over lacustrine deposits near their borders. Whatever may have been the origin of the contemporaneous deformation in these Virginia slates, the direction of overturning of the folded

---

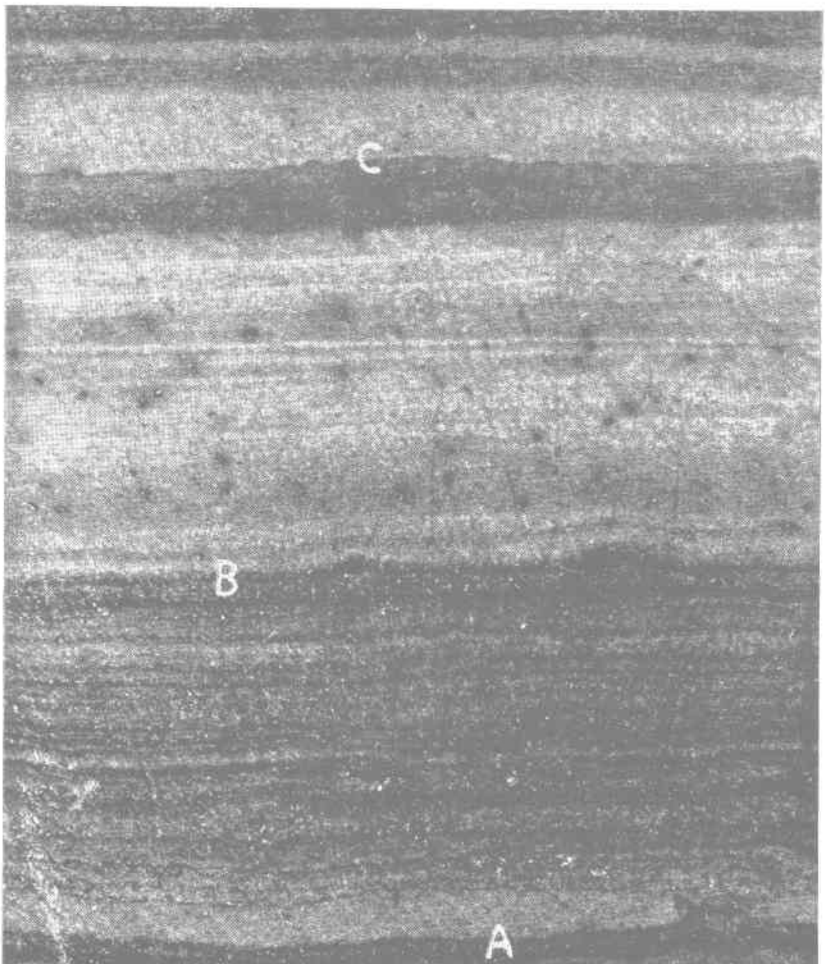
[10] This may prove very helpful in working out structures of the Loudoun formation.

[11] Sauramo, Matti, Studies on the Quaternary varve sediments in southern Finland: Commission Géologique de Finlande Bull. 60, 1923.

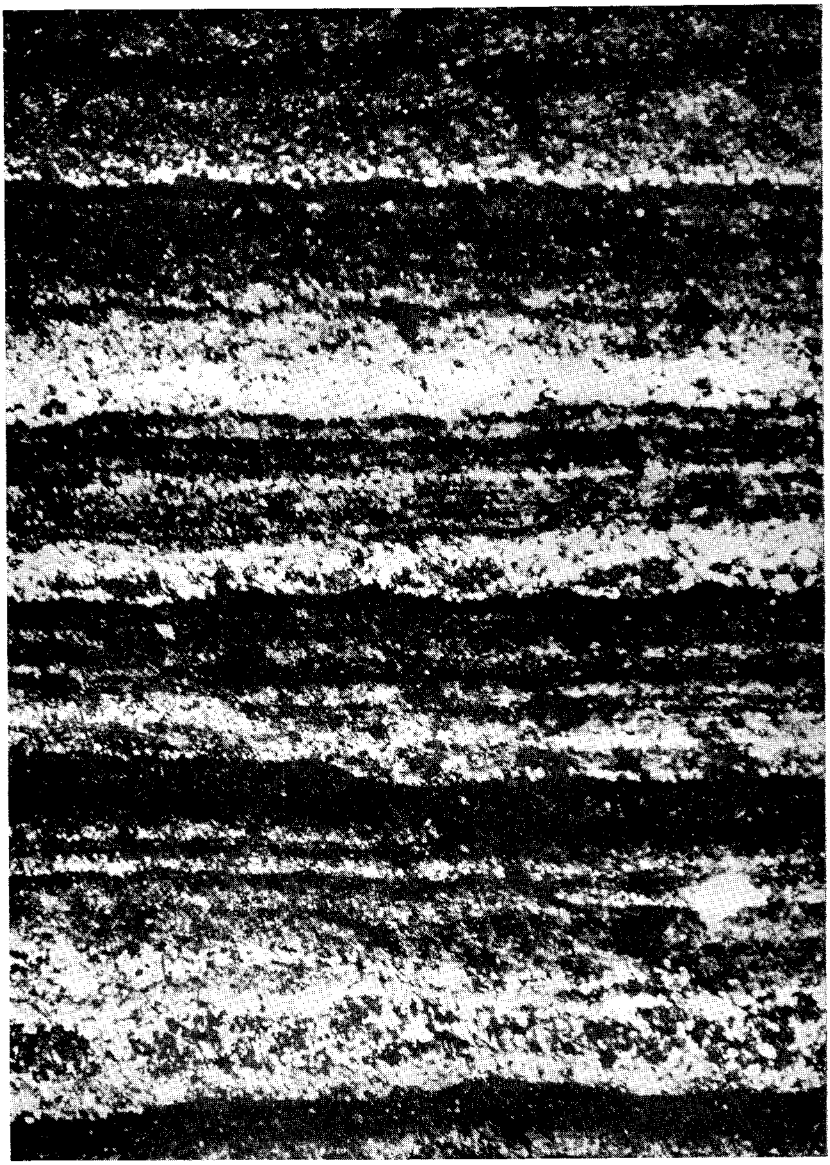
[12] This problem is especially acute near the bottom and in marginal facies of many varved deposits. Near the source of supply the intraseasonal layers may individually attain thicknesses several times those of complete varves farther away, and may duplicate most of their features. Uncertainty about interpretation in such places is a serious source of error in thickness determinations and, hence, in chronology; it renders correlations of varves from different localities doubtful, establishes false premises for certain climatologic conclusions, and casts a taint of suspicion on all systematic varve measurements.



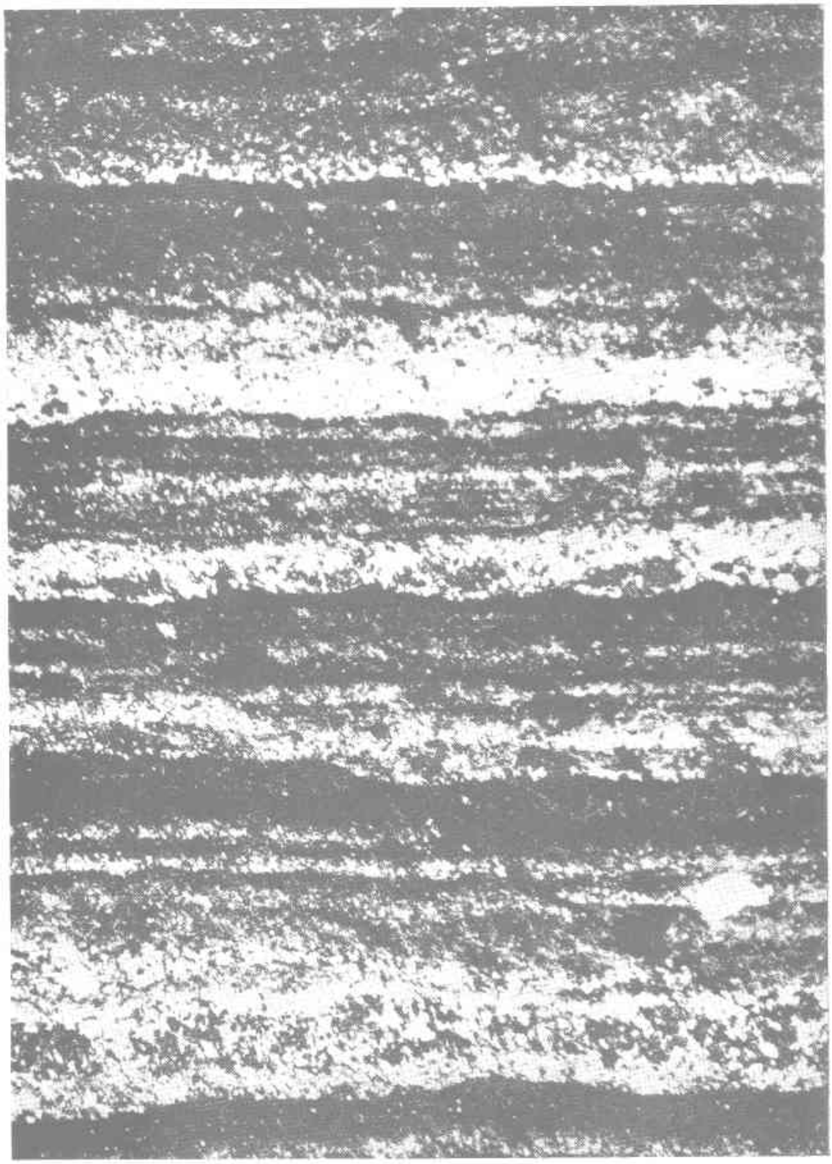
Hand specimen of Loudoun varved slate from Cliff Mills. Thickness represented is one inch. A, B, and C are tops of components.



Hand specimen of Loudoun varved slate from Cliff Mills. Thickness represented is one inch. A, B, and C are tops of components.



Photomicrograph of Loudoun varved slate. X 18.



Photomicrograph of Loudoun varved slate. X 18.

laminae in some places indicates that the compressive forces operated from the southeast. This conclusion becomes significant because several lines of evidence suggest that the source of the banded deposits was to the south and southeast.[13] It is possible, therefore, that the original clays and silts slumped periodically down a depositional slope which lay in that direction, or were dragged by ice rafts moving outward from that shore, or were overridden by ice advancing from the direction of supply of the sediment.

In parts of the slate the winter components maintain rather constant thickness, so that variations in the thickness of individual couplets or varves at such places really represent fluctuations predominantly in the summer increment of deposition. Elsewhere both components vary considerably. Nevertheless, the average number of couplets in an inch within vertical sections a few feet in length is generally uniform. This number ranges from 7 to 43 in different parts of the slate examined. An estimated general average for the whole visible part of the deposit would be about 15 in an inch. If these be truly varves, the total present thickness[14] of the measurable portion of the deposit indicates some 25,000 to 50,000 years of late Proterozoic or Early Cambrian time.

In general where there are fewer couplets to an inch, the texture of both seasonal components is coarser. Consequently, the narrowest banding occurs in the finest sediment, and the character of the slate changes vertically repeatedly from very fine-grained siltstone to dense argillite.[15] Thus in addition to the regular alternation of components, there is a broader alternation of facies, which suggests larger cyclic controls upon the deposition. Besides these changes, there is a general, less regular decrease in textural coarseness and varve thickness upward from the base through many feet of the deposit. The range of variation in couplet-thickness is also decidedly greater toward the bottom and toward the top of the slate.

The intraseasonal laminae individually comprise only a fraction of the thickness of the component in which they occur. (See Pl. 17B.) Many of them are paper-thin, but all are remarkably continuous laterally. They show no regularity in vertical distribution. A few components lack them entirely, whereas others contain more than half

[13] The northern exposures of the slate are farther from the original source of supply than the southern ones. This conclusion is supported by the direction of current ripples, general thinning of the deposit, decrease in the thickness of both components and intraseasonal laminae, less regular lamination, and marked decrease in textural coarseness of the constituent particles.

[14] Desiccation, diagenesis and changes incident to folding could account for considerable compaction in materials of this type. Originally the whole deposit must have been much thicker and the number of couplets per inch fewer than at present. According to W. H. Bradley (U. S. Geol. Survey Prof. Paper 158-E, 1929), the varved muds of the Green River formation could have been compacted as much as 90 per cent of their volume. If so, it is not unreasonable to predicate a similar or even greater compaction in these much older and more deformed materials.

[15] In using these terms, moderate metamorphism is discounted.

a dozen. They occur at any level within a couplet. In some varves they are concentrated near the bottom of each seasonal band; in others they are more common near the top. The percentage change in thickness through a series of such laminae within one couplet is generally greater than the percentage change in thickness of a series of couplets. Their textural variation is decidedly erratic except that commonly the coarsest seasonal bands contain the coarsest intraseasonal laminae. It is difficult to find a better explanation for the diversified character of these delicate laminae than that they represent weather fluctuations of variable degree, irregular periodicity, and different duration within a larger and more regular alternation of seasons.

Character in thin section.—Thin sections reveal that the clastic constituents of the slates are essentially those which would result from crushing or mechanical disintegration of the pre-Cambrian basement rocks. Angular grains of quartz predominate and show only moderate recrystallization. Grains of fresh feldspar suggest either pulverization of a feldspathic rock or mechanical weathering. Flakes of biotite altering to chlorite, broken shreds of epidotes, tiny fragments of zircon and apatite, and granules of altered titanite are minor constituents. The heavy accessory minerals are concentrated chiefly in the coarser layers. Recrystallization of much of the finest material to form sericite, which enwraps the clastic materials and forms a felted aggregate in the winter components, suggests that originally there may have been much feldspar or kaolin in the sediment. That the material was originally rock flour produced by glaciation remains unproved but plausible. No traces of organic matter or fossils could be found in the sections. Large euhedral grains of epidote and magnetite are distributed at random through the rock as secondary constituents, locally disturbing or transecting the laminae. Abundant chlorite makes the rock phyllitic. Well-defined and closely spaced foliation, responsible for the slaty cleavage of the rock, crosses the lamination, commonly at an oblique angle.

Fresh-water origin of the sediment.—In hand specimens and in thin sections it is apparent that the finest materials are largely restricted to the dark-colored, winter components. Fraser[16] showed experimentally that even slight salinity (1/50 that of sea water) of water charged with clay particles induces flocculation so that the finest materials settle and are deposited with coarser particles. Such a mixture of coarse and fine fragments is characteristic of components in *marine* and *brackish-water* varves, as has been pointed out by Pettijohn, Rubey, Sauramo and others. Restriction of the fine materials to winter

[16] Fraser, H. J., An experimental study of varve deposition: Royal Soc. Canada Trans., vol. 23, sec. 4, pp. 49-60, 1929.

components, on the other hand, is typical of *fresh-water varves,* both ancient and modern, as described by Antevs, Berkey, W. A. Johnston, Kindle, Mawson, Sayles, Wallace, Whittaker, and many others. It seems clear, therefore, that these Virginia slates were formed in a fresh-water lake (or lakes) probably located near the western margin of ancient Appalachia. Whether a seasonal cause for the banding be accepted or not, this indication that part of the Loudoun formation was of lacustrine, fresh-water origin is interesting. The similarly banded Hiwassee group farther south has for years been correlated tentatively with the Loudoun formation, and Barrell's conclusion that the Hiwassee was largely accumulated in fresh-water lakes becomes even more significant.

Cause of the banding.—So far as could be determined in these isoclinally folded rocks, the components are continuous, except for local channeling. They show no signs of partial removal suggestive of wave or current action along the lake bottom. The very thin—many almost microscopic—intraseasonal laminae are as continuous and as well preserved as the coarser bands. These sediments must, therefore, have been deposited below the depth of effective wave base and were not subjected to stirring by storms. Yet, the occasional presence of current and oscillation ripples and of local channels must mean that the water was not very deep.

The regularity in component alternations must be explained in terms of a recurring, periodic cause which continued to operate for some 20,000 to 50,000 years. The mechanism advocated by Bailey[17] in which earthquakes cause stirring of bottom muds, so that they settle differentially during the intervals between disturbances and form alternating bands of different texture and color, is wholly inadequate. It does not account for the formation and preservation of the very thin laminae within components which are so universal a feature of these and of other varved deposits. Such laminae, and any ripple-marks which might develop during the interval of quiescence, would certainly be destroyed in the stirring necessary to the production of the succeeding layers. Furthermore, no such periodicity of earthquakes has as yet been demonstrated.

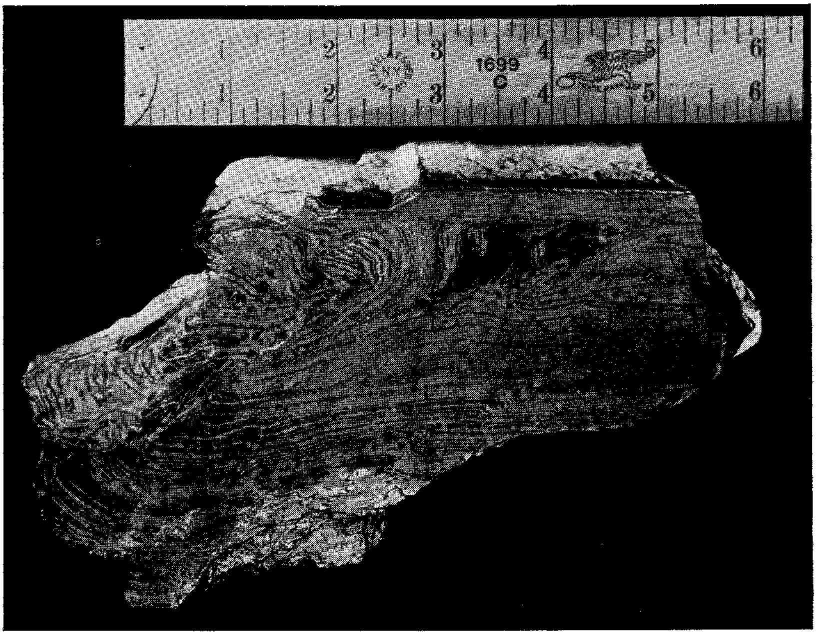
By effecting a similar stirring and subsequent differential settling, periodic storms might produce alternate banding of the character under consideration. To have produced these Virginia slates, however, such storms should have occurred with a regularity and periodicity not recognized in modern climates. Unless materials at the top of the deposit during any stage in its development had become somewhat in-

[17] Bailey, E. B., Sedimentation in relation to tectonics: Geol. Soc. America Bull., vol. 47, pp. 1713-1726, 1936.

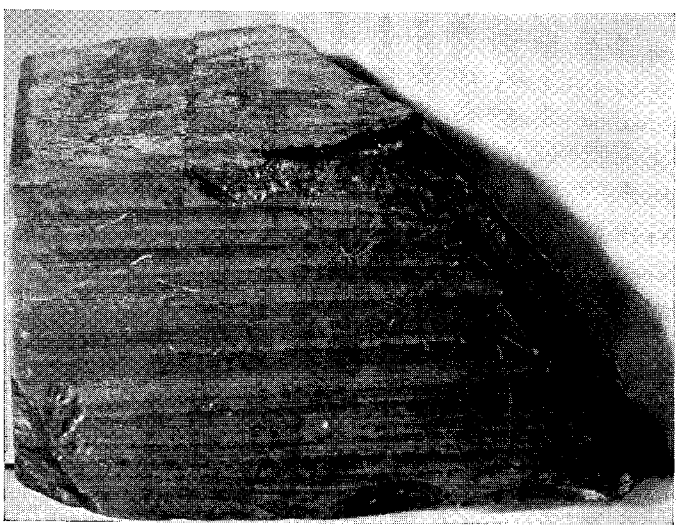
durated between disturbances, each storm capable of affecting the muds in any way other than adding to them would surely destroy laminations resulting from a previous one. To explain the slates in terms of a storm hypothesis thus requires proof of an incredible delicacy of balance between the periodicity of storms and time required for at least partial induration of each storm-evolved lamination. Furthermore, no incomplete couplets have yet been recognized in these rocks. It would be highly fortuitous if some storms destroyed only parts of couplets. It is unlikely that storms powerful enough to create whole couplets would operate without eradicating the thin laminae, some of them no more than a few grains thick, which are universal within the couplets. If the differential settling mechanism worked so effectively that each layer of fine material throughout the deposit represents the delayed settling of the smallest particles after a storm, then the coarsest material of the next succeeding layer should lie directly upon it—there should be a textural gradation upward following each fine-grained layer. But such a condition is not found in the Loudoun slates, or apparently in any deposit whose banding has been attributed to seasonal deposition.

Similar difficulties are encountered when one tries to apply to details of these slates a shifting-current hypothesis or other mechanisms to which skeptics of the explanation of seasonal banding have resorted. On the other hand, these rocks have precisely the characteristics which would be expected on purely theoretical grounds if a seasonal cause be assumed. They do not contain layers of organic debris such as Whittaker and others describe on the floors of some modern lakes, or such as Bradley found in the Green River varved shales. Nevertheless, in other respects they are so closely analogous to the varved sediments forming now under seasonal influences, that it seems wholly unnecessary to seek a more complex explanation. It must be obvious to one familiar with the literature on varved deposits that the essential features of the slates described here are likewise analogous to those of Pleistocene glacial varves, Permo-Carboniferous varved slates, and other deposits which have been called varved. Considering all these facts, the conclusion seems inescapable that deposition of the Virginia slates was controlled by alternating conditions initiated and imposed through seasonal changes, and that they are, therefore, truly varved deposits.

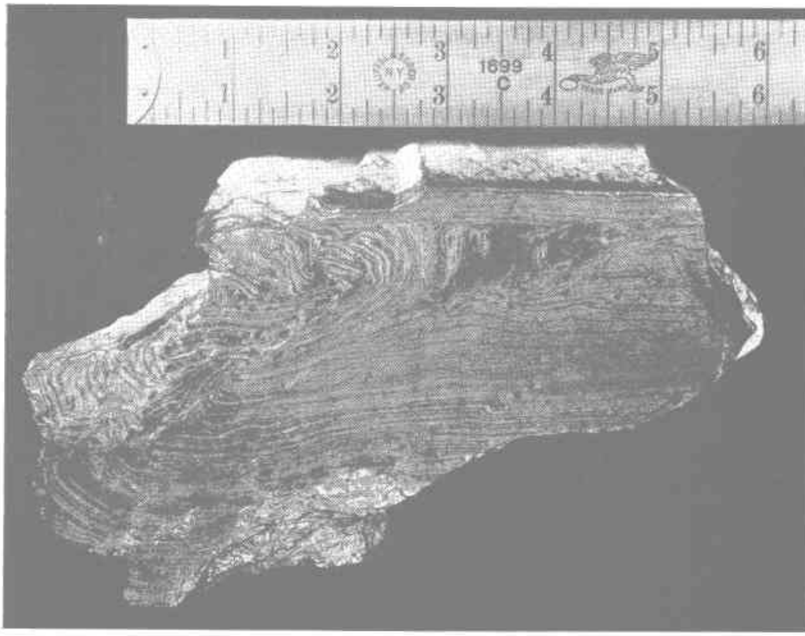
Relation to glaciation.—The sharp upper contacts of the winter components in these rocks, with the very finest material concentrated along them, must indicate a cessation of supply and a freedom of the waters from agitation, such as could best be affected by seasonal freezing of a lake. If this were the case, it stands as evidence that the climate of the Late Proterozoic or Early Cambrian in this area was



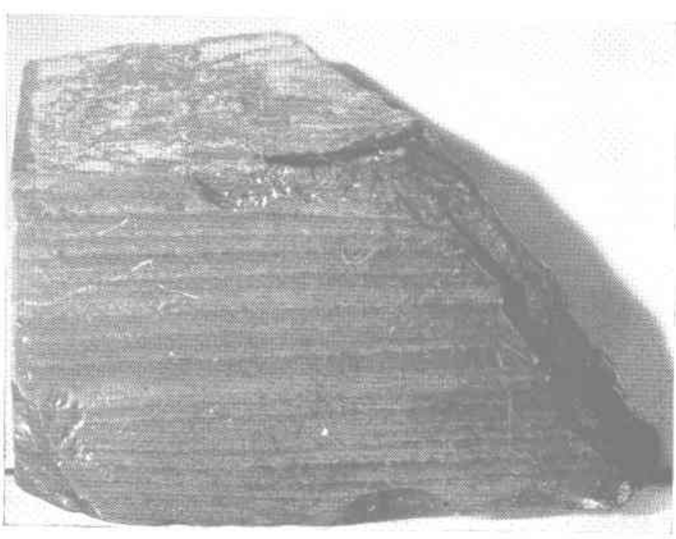
A. Contemporaneous deformation in the varved slate at Cliff Mills, Virginia. Laminae below this specimen were undisturbed and parallel to those above the crumpled zone.



B. Loudoun varved slate from Cliff Mills, Virginia. Black specks are magnetite which is concentrated along some bedding planes to form discontinuous black streaks. Surface oblique to bedding. Actual thickness represented is one inch. Diadactic structure and abundance of delicate intraseasonal laminae are notable. Photograph by R. H. Arndt.



A. Contemporaneous deformation in the varved slate at Cliff Mills, Virginia. Laminae below this specimen were undisturbed and parallel to those above the crumpled zone.



B. Loudoun varved slate from Cliff Mills, Virginia. Black specks are magnetite which is concentrated along some bedding planes to form discontinuous black streaks. Surface oblique to bedding. Actual thickness represented is one inch. Diadactic structure and abundance of delicate intraseasonal laminae are notable. Photograph by R. H. Arndt.

of a distinctly seasonal character and rather cool. Barrell reached a similar conclusion for the whole southern Appalachian region. The arkosic character of most of the Loudoun formation might well have resulted from the predominance of mechanical weathering in such a climatic environment. Coleman[18] pointed out that extensive tillites of latest pre-Cambrian or Early Cambrian age in South Africa and Australia "imply widespread refrigeration with continental ice sheets" in the southern hemisphere. Such conditions—as in the Permo-Carboniferous and Pleistocene—must have involved planetary lowering of temperatures, lowering of the snowline, and consequent glaciation of the alpine or piedmont type in other parts of the world. Indeed, he lists as evidence of such conditions at the transition between the Proterozoic and Paleozoic eras, the Nantou tillite of China, tillite on the shore of Great Salt Lake, a probable tillite in India, and similar glacial deposits reported elsewhere. Howell[19] has recently reviewed these possibilities and appealed for a more careful search for further indications of glacial phenomena in this part of the geologic record.

These considerations and the striking resemblance of the Loudoun varves to those elsewhere, whose glacial origin is unquestioned, lead to the speculation that the Virginia slates are directly related to a valley type of glaciation in highlands near the borders of ancient Appalachia. No tillites, striated pavements and fragments, berg-rafted pebbles and boulders, or other positive indicators of glaciation have yet been found associated with the rocks. Nevertheless, since the Loudoun formation is so strongly folded and deeply eroded in this Piedmont region that only patches of it remain, we must not overlook the possibility that such glacial records may lie buried beyond present observation, or may have been removed. Sayles[20] has emphasized the view that, because varved shales and slates are more likely to be preserved than are tillites, more of them will be found in the geologic records, and that almost by themselves they may prove glaciation.

The absence of conclusive evidences of glaciation, other than the varved slates, in the Loudoun formation is a strong argument against the presence of continental glaciers in this area during its deposition. But it is entirely possible that, during the general refrigeration, glaciers of the alpine or piedmont type existed on highlands near the Appalachian trough and poured their melt waters into lakes at a distance.[21] Several types of evidence indicate that such highlands were

[18] Coleman, A. P., Ice Ages: Recent and ancient, Macmillan Co., New York, 1926.

[19] Howell, B. F., Late Proterozoic and Early Cambrian climates, Compte Rendu XVII Int'l Geol. Congress, Moscow, 1937.

[20] Sayles, R. W., Banded glacial slates of Permo-Carboniferous age, showing possible seasonal variations in deposition: Nat. Acad. Sci. Proc., vol. 2, p. 170, 1916.

[21] Thinness of the banding and the very fine grain size of the constituents suggest that the muds were deposited at a distance from the source of supply.

present. Keith[22] and Barrell[23] both emphasized that the Loudoun materials were derived from lands of strong and varied relief which lay to the southeast. Because the lakes were probably located on piedmont lowlands which became submerged as the Appalachian trough sank, the varved sediments in them were buried and preserved; whereas associated glacial deposits formed in the highlands could have been eroded before induration.

It should be noted that the facts cited and the arguments presented here do not constitute proof that these slates, though varved, were of aqueo-glacial origin, but they are certainly in harmony with that interpretation. Holding this view of the origin of the Loudoun banded slates as a working hypothesis, the writer entertains the further speculation that the Hiwassee slates of Tennessee and the slates in North Carolina near Chapel Hill may belong in the same category; even may have been deposited more or less contemporaneously. He anticipates that further detailed study, with these facts in mind, will disclose many examples of varved materials in rocks of approximately the same age.

Acknowledgments.—The writer wishes to express his gratitude for many helpful suggestions in this study and for critical reading of the manuscript of this paper, to Professor Kirtley F. Mather and Mr. Robert W. Sayles, of the Department of Geology at Harvard University.

[22] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (No. 10), 1894.
[23] Barrell, Joseph, The nature and environment of the Lower Cambrian sediments of the southern Appalachians: Am. Jour. Sci., 5th ser., vol. 9, pp. 1-20, 1925.

GEOLOGY AND ARTESIAN-WATER RESOURCES OF A PART OF THE SOUTHERN VIRGINIA COASTAL PLAIN

BY

D. J. Cederstrom

Prepared in Cooperation with the United States Geological Survey

Virginia Conservation Commission

VIRGINIA GEOLOGICAL SURVEY

Bulletin 51-E

UNIVERSITY, VIRGINIA

1939

CONTENTS

ILLUSTRATIONS

Geology and Artesian-Water Resources of a Part of the Southern Virginia Coastal Plain[1]

By D. J. Cederstrom[2]

GENERAL RELATIONS

The area covered includes Sussex, Southampton, and Isle of Wight counties. It lies between James River and the North Carolina State line and extends eastward from the Fall Zone, which is roughly marked by the locations of Richmond, Petersburg, and Emporia. It is entirely within the Coastal Plain and is underlain by unconsolidated sands, clays, and marls of Cretaceous and Tertiary age which rest upon an older crystalline basement and dip gently to the southeast. As the slope of the crystalline floor is greater than the dip of the overlying sediments, the sediments form a wedge, the thin edge of which is at the Fall Zone.

STRATIGRAPHY

The sediments of the Coastal Plain in Virginia have been divided into four parts: The Potomac group, of Early Cretaceous age, which rests directly upon the crystalline basement; the Pamunkey group, of Eocene age; the Chesapeake group, of Miocene age; and the Columbia group, of Pleistocene age.

POTOMAC GROUP (LOWER CRETACEOUS)

The Potomac group is composed mostly of unconsolidated clays, sandy clays, and sands, commonly arkosic, in which iron or plant material may be present. The Potomac group may be as much as 800 feet thick where fully developed, as at Fortress Monroe, but near the Fall Zone it is nowhere more than 250 feet thick.

The plant and animal fossils found in the Potomac group indicate that these sediments were deposited on the land by streams. Because of their manner of deposition they vary greatly, and individual beds may thicken, become thinner, or pinch out in short distances.

Strata of the Potomac group are well exposed in many places along and near U. S. Route 1 between Washington and Richmond, but south of Richmond they are overlapped by younger strata.

---

[1] Published by permission of the Director, Geological Survey, U. S. Department of the Interior. The data presented in this paper represent the partial results of a study carried out as a result of cooperation between the U. S. Geological Survey and the Virginia Geological Survey. It is a preliminary report.

[2] U. S. Geological Survey, Division of Ground Water.

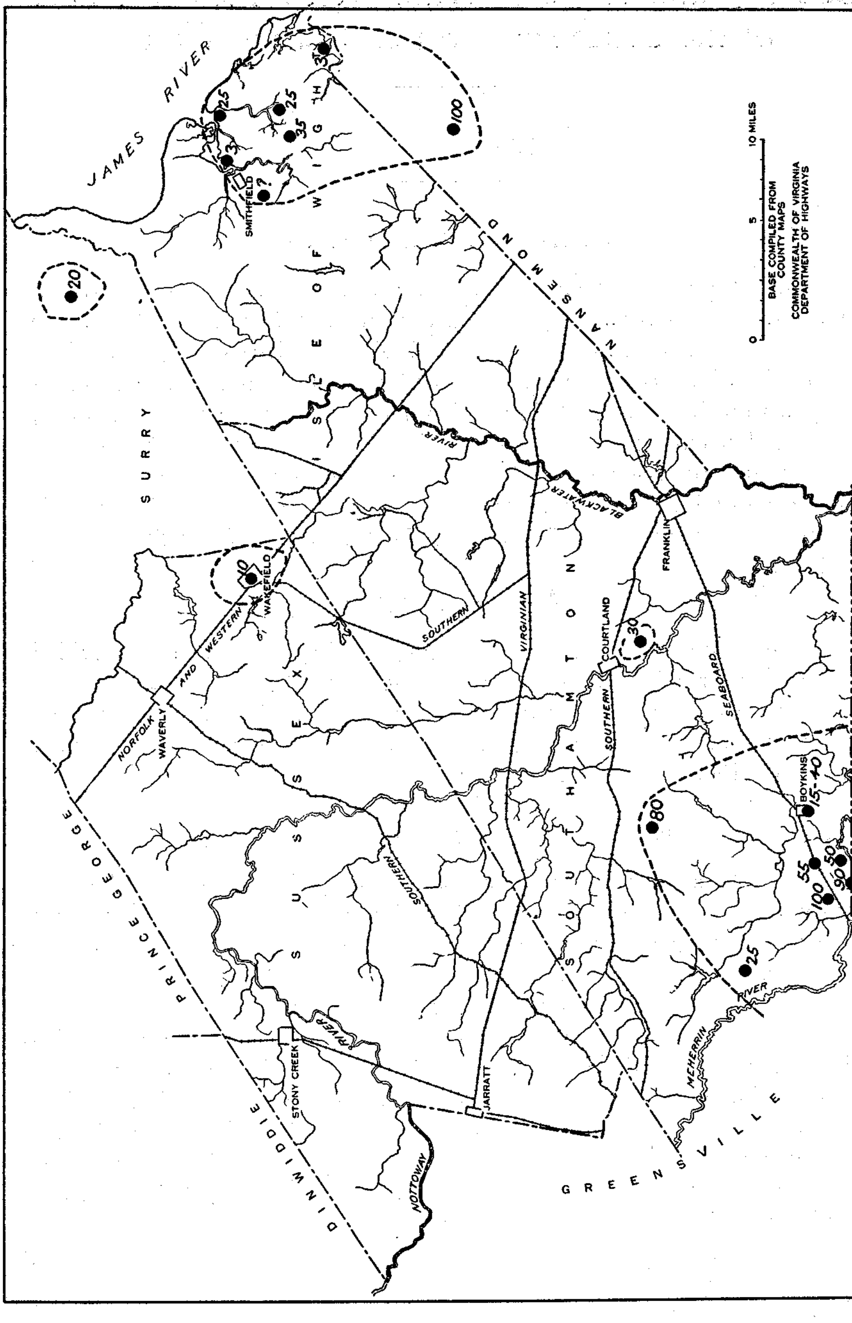


FIGURE 12.—Areas where red clay occurs at the top of the Cretaceous. Figures denote thickness in feet, encountered in wells.

The Potomac group has been subdivided in Virginia into the Patuxent and Patapsco formations. The essential differences in these formations, as noted by Clark and Miller,[3] are that the clays of the Patapsco are brighter colored and are thicker and more evenly stratified than those of the underlying Patuxent formation. Well logs from many places throughout Southampton, Sussex, and Isle of Wight counties indicate that, in general, the clays in the upper portion of the Potomac are of considerable thickness and brightly colored. Wells in the area generally go no deeper than the upper horizons of the Potomac and consequently little is known of the lower parts of the group.

Throughout a large part of these three counties a fairly clean, water-bearing, arkosic sand marks the top of the Potomac. In easternmost Isle of Wight County a thin wedge of "blood-red clay" makes its appearance and in Nansemond County, to the southeast, it thickens to 125 feet. Indications of this horizon were found in a number of the wells in the area. Figure 12 shows its distribution in the area under discussion. Darton[4] has mentioned a fairly persistent red clay member near the top of the Potomac group in the area east of Washington which may be correlated with the red clay in this area.

UPPER CRETACEOUS

Upper Cretaceous marine sediments have been identified from deep well cuttings at Norfolk but have not been recognized in this area. Their place in the local geologic column is presumably occupied by an unconformity.

PAMUNKEY GROUP (EOCENE)

Figure 13 is a contour map of the surface on which the Eocene strata rest, in large part determined by a glauconite sand that is considered to be the basal formation of the Eocene. The surface has a general eastward slope but appears to be a rather irregular surface instead of a plane. A pre-Eocene channel appears to exist in central Southampton County, trending in an east-west direction. To the north a less well defined ridge is present. The irregularity developed in southwestern Southampton County, however, has resulted from structural deformation, as will be demonstrated below.

In these three counties a "black sand" reported by the drillers is considered to be unquestionably Eocene. This material is in places almost 100 per cent dark-green to black glauconite sand rather than a glauconitic sand. In a few places it may be mixed with variable proportions of quartz sand. It everywhere includes several hard, fos-

[3] Clark, W. B., and Miller, B. L., The physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey, Bull. 4, pp. 67-68, 1912.

[4] Darton, N. H., personal communication.

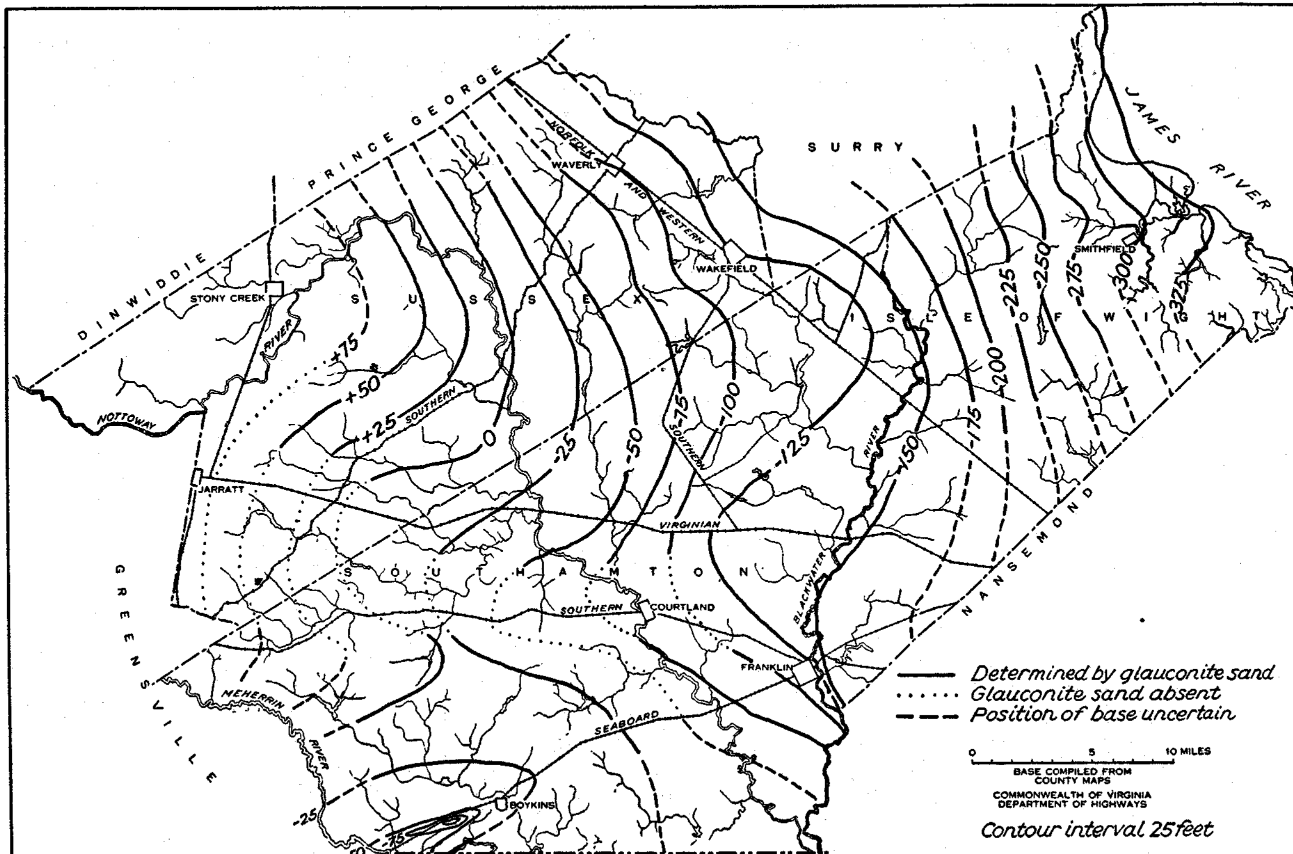


FIGURE 13.—Structural contours drawn on the base of the Eocene, in feet above (+) and below (—) sea level, in Isle of Wight, Southampton, and Sussex counties.

siliferous, limy members, from a few inches to 2 feet thick, which are called "rock" by the driller. The glauconite sand varies from a trace to 40 feet thick, as at Franklin. It appears to have been well developed throughout most of the three counties, but has been removed in several areas by post-Eocene erosion, especially near the Fall Zone.

CHESAPEAKE GROUP (MIOCENE)

The Miocene series is of marine origin. It comprises four formations—the Calvert, Choptank, St. Marys, and Yorktown, together known as the Chesapeake group. The Choptank is not recognized in this part of Virginia and its position is considered to be occupied by an unconformity. The Yorktown formation is well developed on James River near Smithfield, but it is thin elsewhere. In these three counties the Miocene consists largely of the Calvert and St. Marys formations. The Miocene is an overlapping formation, and along the Fall Zone it may rest upon the Eocene or Cretaceous sediments or upon the older granite. In the area under discussion it is variously designated by the drillers as a blue, black, or gray clay or mud, marly in places. Sand or sandy beds are uncommon. The Yorktown formation, which is more fully developed seaward, contains more sand.

COLUMBIA GROUP (PLEISTOCENE)

A large part of the area is capped by terrace sands and gravels of Pleistocene age, collectively known as the Columbia group.

STRUCTURE

GENERAL CHARACTER

Cross sections of the area, drawn entirely on the basis of well logs supplied by the drillers in the area, are shown in Figure 14. Certain members are easily recognized and correlated. The Miocene clays and marls are seen to extend continuously across the area in each of the sections. Lying beneath the marl is found the Eocene glauconite sand. It is absent in places, or very thin, probably as a result of pre-Miocene erosion rather than because of original spotty or lenticular character. The first appearance in well logs of highly colored clays is considered diagnostic of the Potomac group.

It may be noted that all of the water-bearing sands reached by wells are within the Potomac group. The great thickness of sand found at Courtland may mark the locus of Cretaceous river channels, as a great thickness of red clay is found a short distance to the south.

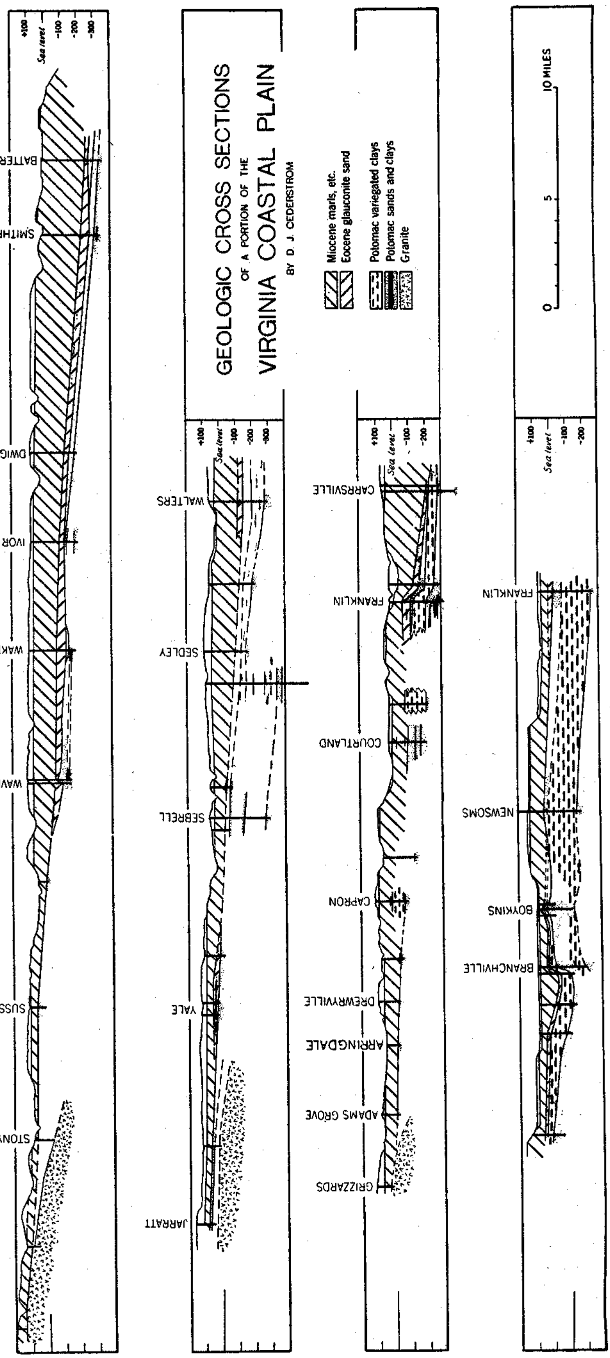


FIGURE 14.—Geologic cross sections of a portion of the southern Virginia Coastal Plain. The sections extend in general from west (left) to east (right).

Of great interest are the structural deformations which appear to have taken place. At Waverly the Eocene-Cretaceous contact rises sharply to the east. At Franklin the upper Potomac, the Eocene, and a part of the Miocene sediments form a monoclinal fold descending to the east. At Newsoms and at Boykins slight domes are present. In the vicinity of Branchville deformation has been traced over a somewhat wider area.

ORIGIN

These structures are believed to have been caused by post-Eocene or even post-Miocene faulting movements in the crystalline bedrock. It is quite possible that the structural figures here are, in reality, faults instead of folds. To the author's knowledge faults are rare in the unconsolidated sediments of the Atlantic Coastal Plain. A fault in the soft Potomac clays and sands was exposed during construction on U. S. Route 1 just south of Triangle, Va. The fault is a reverse fault with a displacement of about one foot and may have resulted from a faulting movement in the bedrock about 50 or 60 feet below. This interesting structure, however, is not unique. At Drewrys Bluff, about 6 miles south of Richmond, a similar fault is present in the unconsolidated sands of the Potomac group, possibly not more than 50 feet above the basement rock.

The structures shown in the cross sections of the southeastern Virginia Coastal Plain are of interest in that they indicate not only that movements in Cretaceous, Tertiary, and Pleistocene time took place as uplifts or depressions of large portions of the Coastal area but also that these uplifts were accompanied by faulting of the crystalline basement rocks. This faulting was then transmitted upward into the unconsolidated sediments as faults or folds, or both.

Measurements of dip were taken in places where deformation is believed to be absent. The Potomac strata in central Southampton County dip 10½ feet per mile to the east. The Eocene beds appear to dip about 7 feet per mile to the east. These dips might be somewhat greater if measured in a southeasterly direction, but even with that allowance, the dip reported here for the Potomac is considerably less than the 30 feet per mile reported by Clark and Miller who measured it in the Fall Zone. Accepting a dip of 30 feet per mile, previous writers on the area assigned much of the water-bearing strata to the Miocene, whereas they should be assigned to the Cretaceous.

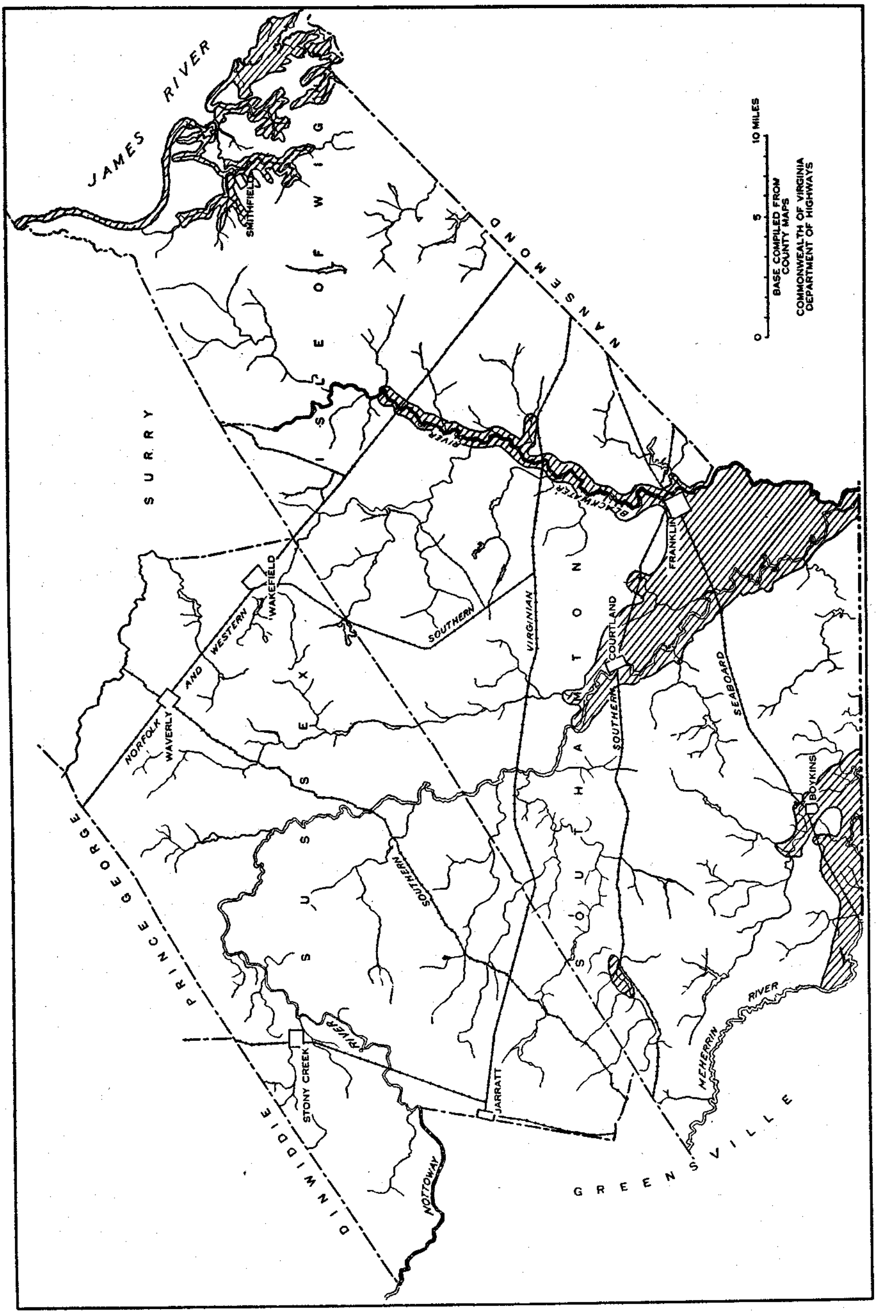


FIGURE 15.—Areas, indicated by shading, where flowing wells occur in Isle of Wight and Southampton counties.

ARTESIAN WATER

GENERAL CONDITIONS

The areas of artesian flow in these three counties are shown in Figure 15. The water contained in the sandy beds enters the formation at relatively high elevations along the Fall Zone, percolates down the dip and either discharges into the ocean where the sands may crop out on the continental shelf or is blocked by the heavier sea water. The clayey strata form the confining beds. The water will rise in wells and will overflow where the land is low.

A total of more than 200 flowing wells is found in this area, with yields ranging from very little to about 200 gallons a minute.

Figure 16 shows the piezometric surface, which indicates the height to which the artesian water will rise. The regular decline of this surface toward the east is interrupted by cones of depression which have been developed mainly by artesian discharge, especially in the Franklin-Courtland area and around Boykins and Branchville.

In an artesian aquifer that has a submarine outcrop, the fresh water will extend down to the level where the weight of sea water will balance the weight of the column of fresh water, both above and below sea level. Thus, a column of fresh water extending from 1 foot above sea level to 40 feet below sea level is balanced by 40 feet of sea water. Losses of artesian head are therefore of great significance in aquifers having submarine outcrops. The present maximum water level of 22 feet above sea level at Smithfield indicates that the salt water contact is now within 900 feet of the surface. Loss of 10 additional feet of head, which seems possible, may bring salt water within the range of some of the deeper wells.

QUALITY OF WATER

About 55 samples of water from the area were analyzed in the water laboratory of the U. S. Geological Survey. (See Fig. 17.) The diagram shows hardness, sodium, and bicarbonate that was found in water samples taken from different parts of the area. Samples taken farthest west in the area are plotted on the left side of the diagram, and samples taken farther east are plotted farther to the right.

Three types of water were found: (1) A soft water of low mineral content and low bicarbonate, some of which is objectionably high in iron. The waters along and near the Fall Zone are representative of this type. (2) A hard water of moderate mineral content in which calcium and bicarbonate predominate. Waters in the central part of the area are characteristic of this type. (3) A soft water of moderate to high mineral content in which sodium and bicarbonate predominate.

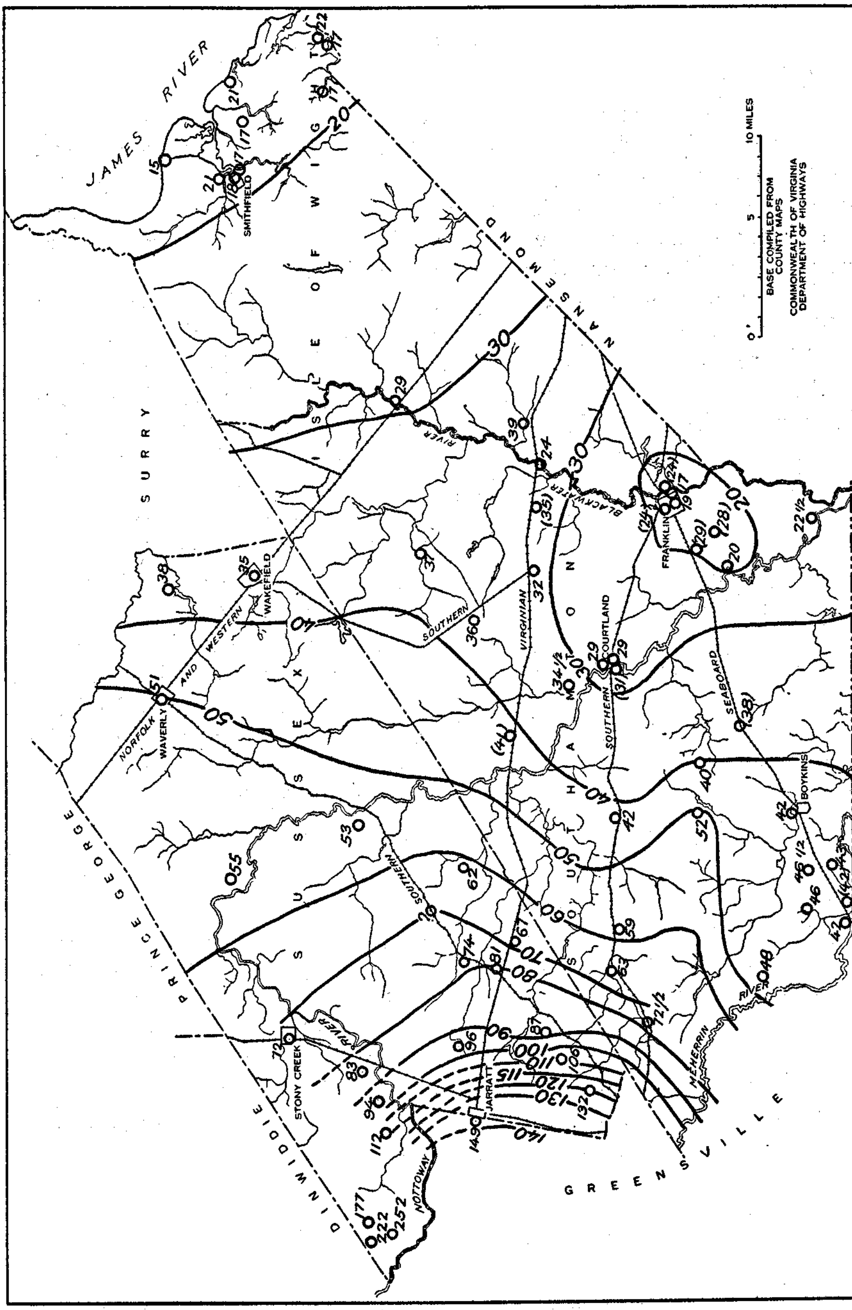


FIGURE 16.—Heights, in feet above sea level, to which water will rise in wells that enter sands of the Potomac group in Isle of Wight, Southampton, and Sussex counties.

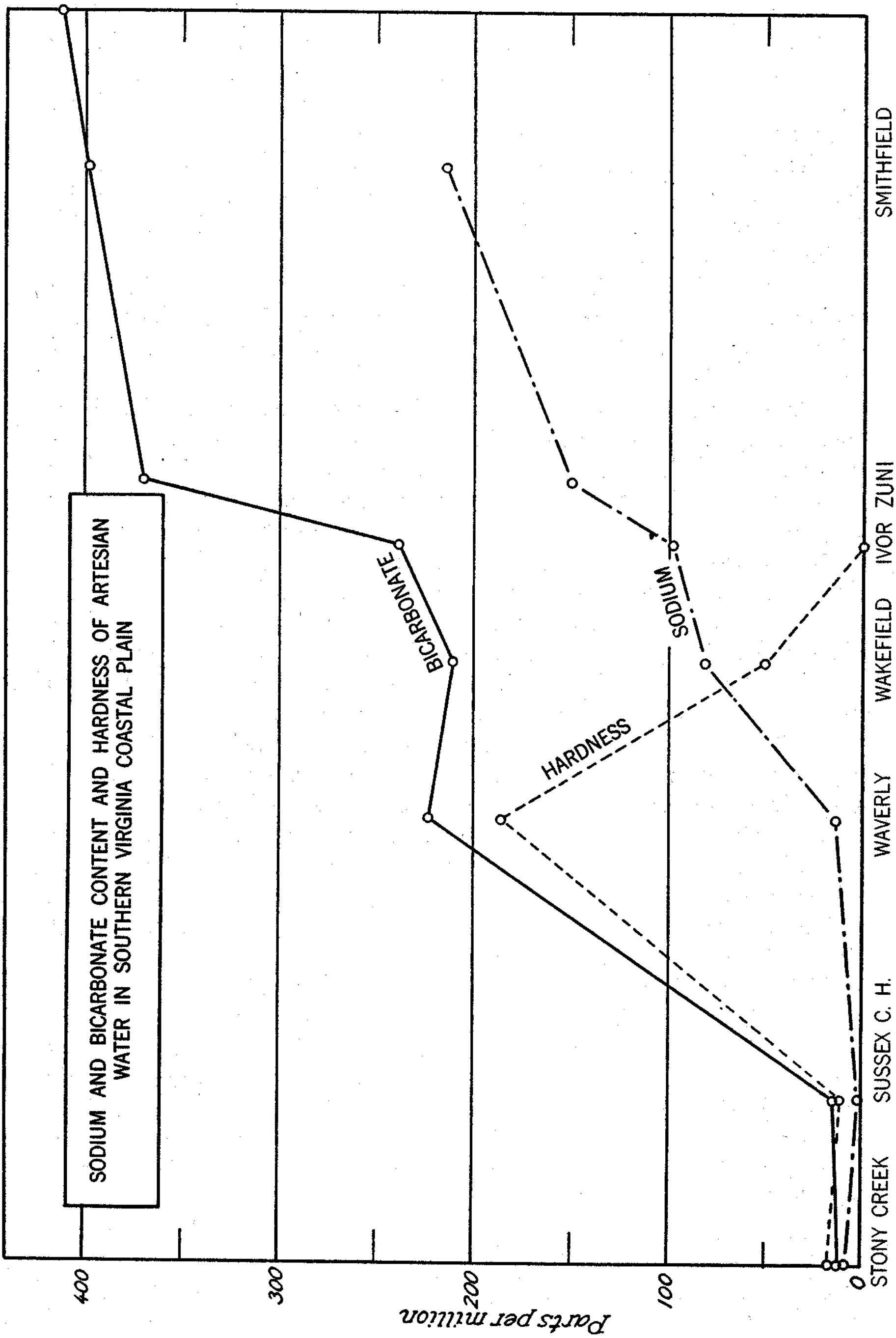


FIGURE 17.—Sodium and bicarbonate content and hardness of artesian water in the southern Virginia Coastal Plain.

In many places these soft waters contain more than 2 parts per million of fluoride or significant amounts of chloride or both. Waters in the eastern part of the area are characteristic of this type. The zones in which the three types of water are found are separated by gradational boundaries.

The lime found in the waters of the second type is apparently derived from the Eocene and Miocene marly beds, which overlie the Potomac group, and probably in part from calcite-coated sand grains within the Potomac.

East of the hard-water zone is the zone of soft water, in which sodium instead of calcium predominates, probably through the process of base exchange. This zone extends eastward beyond the limits of the area studied.

At many places in the eastern soft-water zone, fluoride has been found in sufficient quantity to injure the teeth of children who customarily drink it. On the map (Fig. 18), open circles indicate less than one part per million of fluoride; quarter-filled circles indicate 1 to 2 parts; half-filled circles indicate 2 to 3 parts; three-quarter filled circles indicate 3 to 4 parts, and completely filled circles indicate more than 4 parts. It is seen from this map that the fluoride occurrences make a broad belt extending from the Courtland and Franklin localities northeastward to James River in Isle of Wight County. Dr. Dean,[5] of the United States Public Health Service states: "From the continuous use of water containing about 1 part per million of fluoride, it is probable that the very mildest forms of mottled enamel may develop in about 10 percent of the group. At 2.5 per million an incidence of about 75 to 80 percent might be expected, with possibly 20 to 25 percent of all cases falling into the 'moderate' or a severe type. A scattering few may show the 'moderately severe' type. At 4 parts per million the incidence is, in general, in the neighborhood of 90 percent, and as a rule 35 percent or more of the children are generally classified as moderate or worse. In concentrations of 6 parts per million or higher an incidence of 100 percent is not unusual."

No data are at hand to indicate specifically the source of fluoride found in these waters. It is known that the Florida phosphate deposits contain a small amount of fluoride and that the Hawthorn, a phosphatic formation of Miocene age, yields water containing a little fluoride. The Eocene and Miocene rocks of North Carolina are phosphatic at certain horizons and phosphatic pebbles are found near the base of the Miocene in Virginia. It is therefore suspected that the Eocene and Miocene formations in the Virginia Coastal Plain may contain sediments which are the source of the fluoride. These are being investigated in coopera-

[5] Dean, H. T., Chronic endemic dental fluorosis: Jour. Am. Med. Assoc., vol. 107, pp. 1269-1272, Oct., 1936.

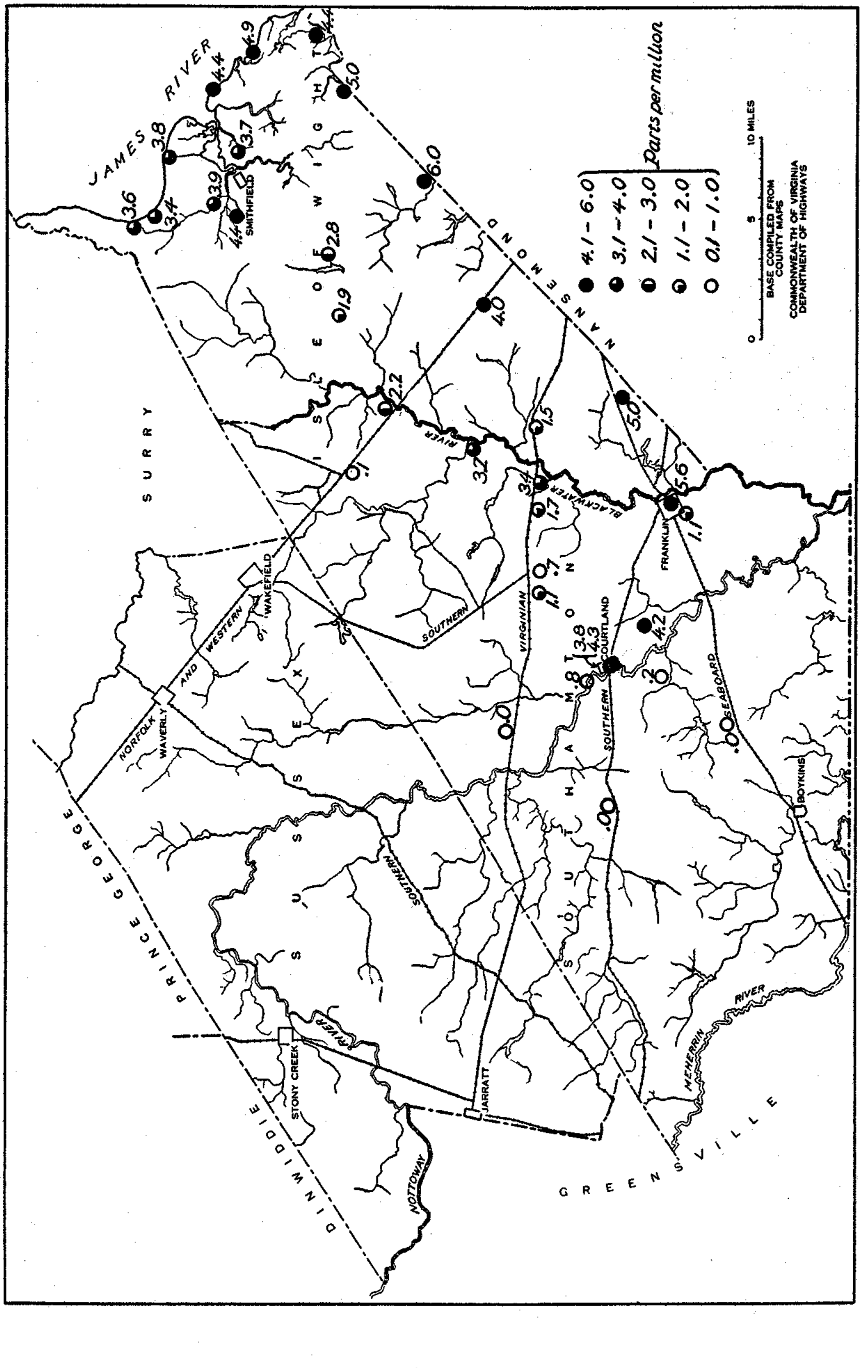


FIGURE 18.—Distribution of fluoride in ground water in Isle of Wight, Southampton, and Sussex counties.

tion with Margaret D. Foster, of the Quality of Water Division, U. S. Geological Survey. Analyses of artesian waters at Franklin show that the deeper waters, well down in the Potomac strata, carry higher fluoride concentrations than the water in the sand directly under the Eocene greensand. However, in the vicinity of Smithfield, 4 to 6 parts per million of fluoride are found in the water derived from uppermost Potomac strata.

ACKNOWLEDGMENTS

The writer is indebted to other workers on the geology of the Coastal Plain, such as Clark, Mansfield, Sanford, Stephenson and especially to Dr. N. H. Darton, whom the writer accompanied on several excursions in the Coastal Plain. He also appreciates the helpful suggestions received from Miss M. D. Foster regarding interpretation of the chemical analyses of the waters.

NOTES ON THE PETERSBURG GRANITE

BY

ROBERT O. BLOOMER

VIRGINIA CONSERVATION COMMISSION
VIRGINIA GEOLOGICAL SURVEY
Bulletin 51-F
UNIVERSITY, VIRGINIA
1939

CONTENTS

ILLUSTRATIONS

Notes on the Petersburg Granite

By Robert O. Bloomer

General features.—The Petersburg granite is a great batholithic intrusion which extends from Hanover County, Virginia, southward into North Carolina. In this paper the granite in an area bounded by Chickahominy River on the north, Appomattox River on the south, the Fall Zone on the east, and an irregular boundary from 8 to 20 miles west of the meridian of Richmond, Virginia, is discussed. Richmond is situated on the eastern edge of the area. (See Fig. 19.)

Triassic shale, sandstone, conglomerate and associated diabase dikes comprise the youngest rocks in the area, with the exception of scattered outliers of Tertiary sediments. Approximately 13 miles west of Richmond, the Triassic sediments are found in a roughly lenticular, structural basin about 33 miles long and 9 miles wide. They attain a thickness of more than 3000 feet.[1] They are underlain on the east by the Petersburg granite and on the west by the Wissahickon granitized gneiss.

Jonas[2] and Keith[3] have correlated the Petersburg granite with late Carboniferous diastrophism, on the basis of metamorphism and orogeny. In Chesterfield and Henrico counties evidence of the age of the granite, aside from lack of metamorphism, is limited to the intrusion of the granite into the Wissahickon granitized gneiss and the presence of granite boulders in the Triassic basal conglomerate. These relations are strongly indicative of a Paleozoic age. An attempt has been made to correlate the Petersburg granite with the Fredericksburg granite which intrudes Ordovician rocks. Outcrops of the two granites are separated by a relatively broad area of complex rocks classified as the Baltimore gneiss.[4] Petrographic study and analyses of the granites disclose a close similarity.

According to Jonas,[5] the oldest known rocks in the area are equivalent to the Wissahickon formation of the Glenarm series.

[1] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, p. 172, 1928.
[2] Jonas, A. I., Structure of the metamorphic belt of the southern Appalachians: Am. Jour. Sci., 5th ser., vol. 24, p. 243, 1932.
[3] Keith, Arthur, Outline of Appalachian structure: Geol. Soc. America Bull., vol. 34, pp. 321-322, 365-375, 1913.
[4] Virginia Geol. Survey, Geologic map of Virginia, 1928.
[5] Jonas, A. I., Geologic reconnaissance in the Piedmont of Virginia: Geol. Soc. America Bull., vol. 32, pp. 836-837, 1927.

In the Richmond area this formation is an intensely metamorphosed, thoroughly injected, oligoclase-biotite-hornblende gneiss in which the original characteristics have been largely obliterated. The contact of the Wissahickon with the intrusive Petersburg granite forms a zone of apophyses and is best mapped by a zone approximately one mile wide. As this zone is approached from the east xenolithic inclusions of the Wissahickon in the granite become larger and more numerous.

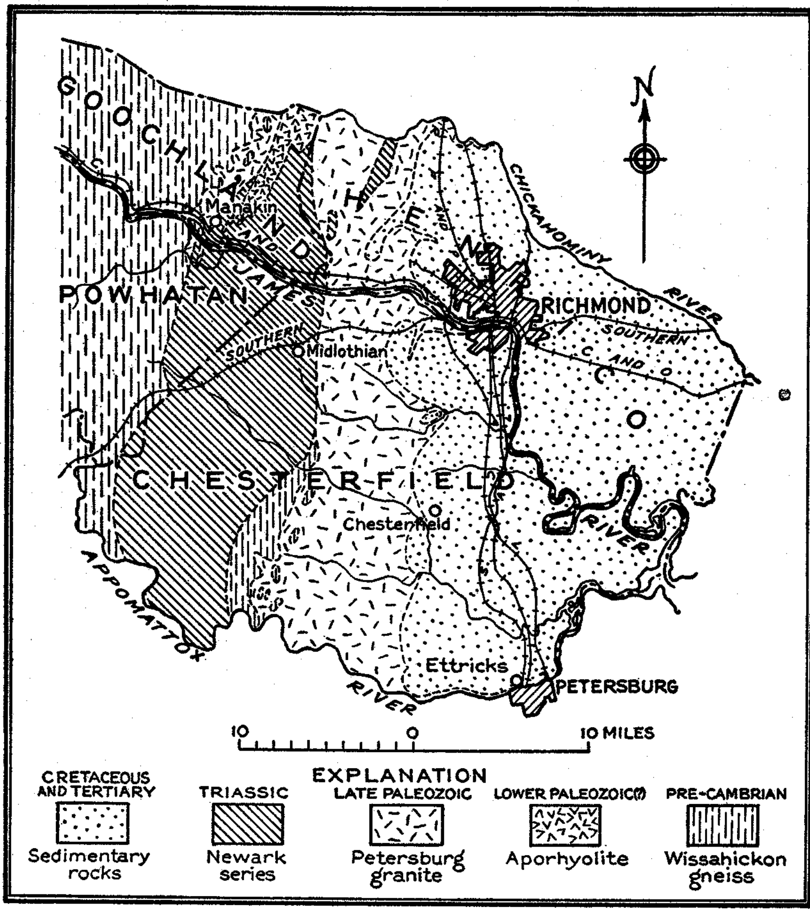


FIGURE. 19.—Sketch map showing general distribution of Petersburg granite and associated rocks in Chesterfield and Henrico counties. Based on field work by A. A. Pegau and the author, and on available maps.

Lithology.—In the Richmond area the Petersburg granite consists of three distinct facies. The most common one is a gray to pink, medium-grained granite. Just west of Richmond a blue, relatively fine-grained facies is found. A third, porphyritic, facies occurs in a belt which extends north and south along the eastern margin of the Triassic basin. Exposures of the granite are shown on Plate 18.

Watson[6] postulated a younger age for the blue, relatively fine-grained facies on the basis of its apparent intrusion into the normal Petersburg granite. It is thought from these recent studies that all facies of the granite are approximately contemporaneous and that the slightly more basic character of the blue granite is due to the assimilation of the Wissahickon gneiss. This conclusion is supported by the absence of sharp contacts between the different facies and by the gradational character of the granite around identifiable, though partially digested, xenoliths of the invaded Wissahickon.

The porphyritic facies contains phenocrysts of potash feldspar, as much as an inch or more in length, in a gray, medium-grained matrix. Indices of refraction of the feldspar phenocrysts are $\alpha = 1.518$; $\beta = 1.523$; $\gamma = 1.527$, which are indicative of orthoclase.

Watson[7] published a detailed microscopic description of the granite in the Richmond area. He found that the essential minerals are quartz, potash feldspars, oligoclase, and biotite. Myrmekite, micropegmatite, perthite, and antiperthite are common microtextures in the granite. The biotite contains numerous inclusions of zircon which are encircled by a large number of well-developed pleochroic haloes. Normal granite is shown on Plate 19A.

Fluorite appears to be a primary constituent of the granite. (See Pl. 19B.) It is included in grains of quartz which show no indication of secondary introduction. Furthermore, there appears to be no relationship between joints and fissures and the development of fluorite. The most common occurrence of the fluorite is in blebs of flesh-colored material in which the characteristic triangular cleavage fragments are noticeably absent. It is estimated that not more than one per cent of the granite is composed of fluorite. Careful examination of all phases indicates that flurorite is contemporaneous with quartz and some of the feldspar.

In the northern part of the area, near Manakin, a tongue-like area of granite about a quarter of a mile wide and approximately a mile long crops out along a fault within the Triassic basin. Megascopically the granite is a dark-gray to greenish rock so dense that

[6] Watson, T. L., Lithological characters of Virginia granites: Geol. Soc. America Bull., vol. 17, p. 534, 1906.

[7] Op. cit.

individual minerals are not distinguishable. Microscopic examination shows granitoid texture with the feldspars and femic minerals thoroughly mottled by the common alteration products and an abundance of calcite. The writer suggests[8] that movement along high-angle faults has raised the granite relative to the Triassic rocks and furnished an avenue for the invasion of solutions which have obscured the megascopic character of the granite. Elsewhere chemical metamorphism is slight although epidote, zoisite, clinozoisite, and chloritized biotite are not uncommon.

In an abandoned quarry just east of Granite Station on the Southern Railway, about 6 miles west of Richmond, stilbite was identified in well-formed radiating aggregates of crystals which reach a maximum diameter of half an inch. These aggregates encrust the granite along horizontal joints and appear to be absent along vertical joints. This relationship suggests that the horizontal system was developed and mineralized before the other systems were formed. The formation of stilbite appears to be attributable to solutions which moved along the joints from a distant source, since the granite does not display local evidences of corrosion or unusual alteration.

It is difficult to evaluate the degree of metamorphism in the Petersburg granite. Careful examinations in the field and in the laboratory indicate more foliation than is stated in previous descriptions of the rock. Evidence of strain was seen in all of the thin sections studied. The discordance between the degree of foliation and deformation of minerals is suggestive of primary gneiss although dynamic metamorphism is unquestionable in some places.

Structure.—Aside from the three systems of joints (Pl. 18A), which are evident in most exposures of the unweathered granite, structural features are vague in the area. Several major faults on the eastern edge of the Triassic basin are indicated on the geologic map of Virginia,[9] although observations in the field disclose no clear-cut evidences of displacement. The western edge of the Triassic basin offers more evidence of faulting. Roberts[10] reports the presence of breccia, slickensides, and a discordancy in the dip of the rocks as indications of these movements. In several places high-angle faults were observed in the granite, which are indicated by the offset of horizontal joints. Minor local dis-

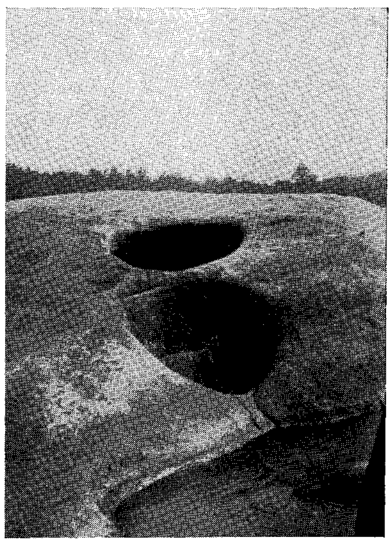
[8] Shaler, N. S., and Woodworth, J. B., Geology of the Richmond basin, Virginia: U. S. Geol. Survey 19th Ann. Rept., pt. 2, pl. 31, 1899.

[9] Virginia Geol. Survey, Geologic map of Virginia, 1928.

[10] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, p. 73, 1928.

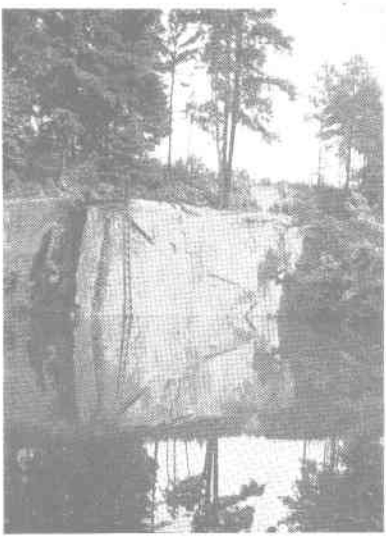
A. Sunnyside Granite Company's quarry, West Richmond, Virginia.

B. Granite exposed in abandoned quarry west of Granite Station.



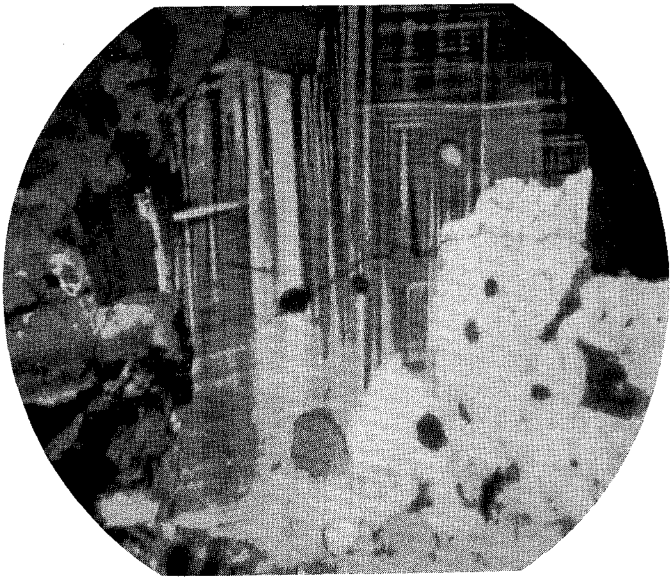
C. Potholes in granite boulder in James River, near Westham.

A. Sunnyside Granite Company's quarry, West Richmond, Virginia.

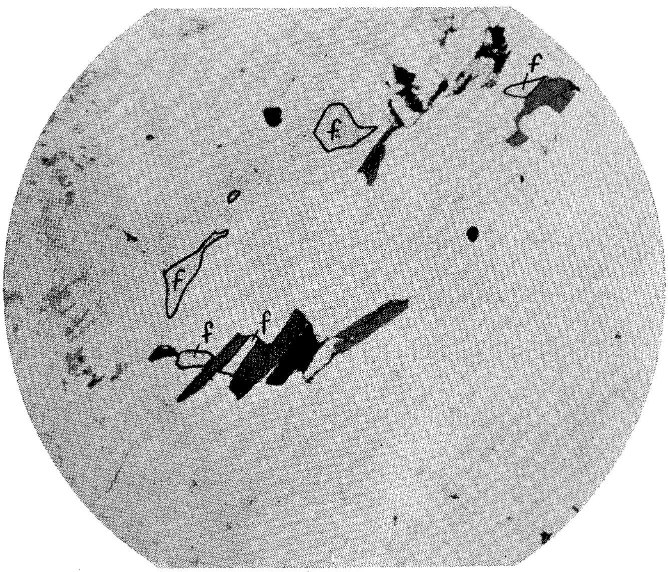


B. Granite exposed in abandoned quarry west of Granite Station.

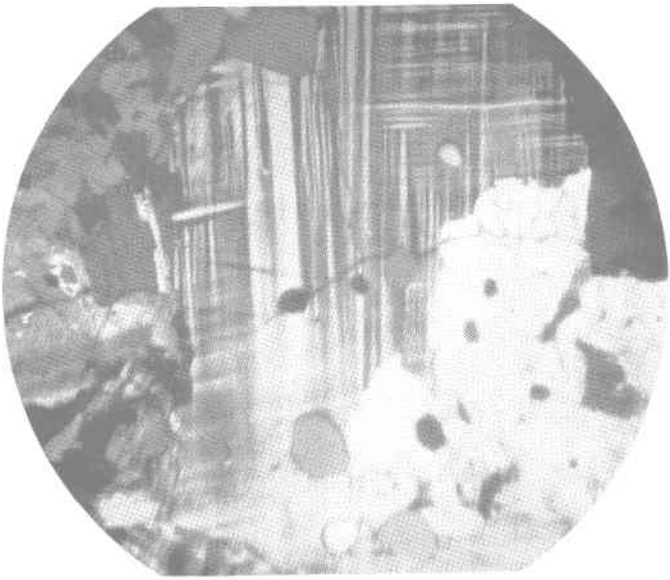
C. Potholes in granite boulder in James River, near Westham.



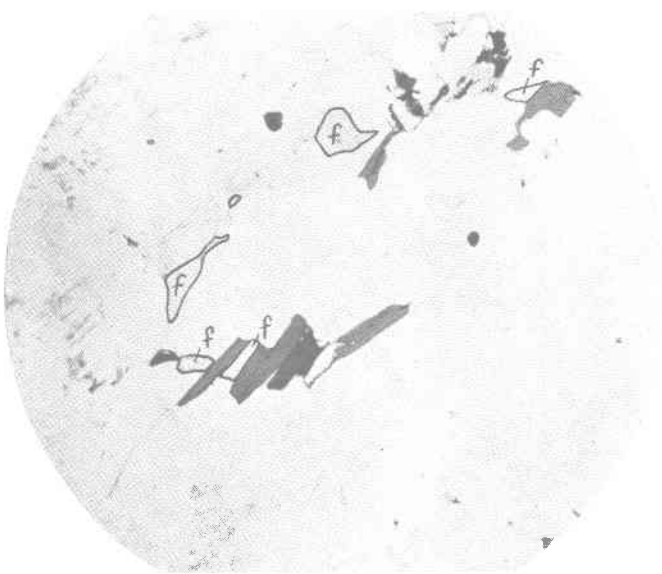
A. Normal granite showing microline, quartz and biotite. X 80. Photograph by J. K. Roberts.



B. Fluorite in Petersburg granite. f, fluorite; dark-colored laths, biotite; groundmass, quartz and feldspar. Some minute grains of magnetite are present. X 40. Photograph by J. K. Roberts.



A. Normal granite showing microline, quartz and biotite. X 80. Photograph by J. K. Roberts.



B. Fluorite in Petersburg granite. f, fluorite; dark-colored laths, biotite; groundmass, quartz and feldspar. Some minute grains of magnetite are present. X 40. Photograph by J. K. Roberts.

placements in the sediments may be seen, but the presence of basin forming faults is indicated for the most part by the great thickness of the Triassic sediments within the Petersburg granite and the Wissahickon granitized gneiss. The faults along the sides of the granite body near Manakin, mentioned above, are indicated by the depth of Triassic sediments which flank the granite and by the peculiar alteration of the granite in the narrow belt.

Conclusions.—The Petersburg granite is thought to represent only one period of granitic intrusion. Metamorphism, though not intense in the granite, has been sufficient in some localities to produce a granite gneiss. Foliation has evidently been caused both by external forces and by primary flow in the magma.

Accessory fluorite is a primary constituent of the granite. Well-formed aggregates of stilbite were secondarily developed along horizontal joint planes in at least one part of the Richmond area.

Acknowledgments.—The assistance of the Virginia Geological Survey, Professors A. A. Pegau and Joseph K. Roberts of the University of Virginia, and Professor W. H. Irwin of the University of North Carolina is gratefully acknowledged. The field work was done during the summer of 1937.

ORIGIN OF THE NARROW CAMBRIAN BELTS NORTH OF DRAPER MOUNTAIN, VIRGINIA

BY

BYRON N. COOPER

VIRGINIA CONSERVATION COMMISSION
VIRGINIA GEOLOGICAL SURVEY
Bulletin 51-G
UNIVERSITY, VIRGINIA
1939

CONTENTS

ILLUSTRATIONS

Origin of the Narrow Cambrian Belts North of Draper Mountain, Virginia

By Byron N. Cooper

Introduction.—The Cambrian belts described in this paper are in the vicinity of Pulaski, Virginia, in the Draper Mountain area. (See Fig. 20.) The conspicuous topographic features are Draper Mountain and Caseknife Ridge, which roughly outline the borders of a breached fenster in the Pulaski and Max Meadows overthrust sheets. The formations exposed in the fenster range from Ozarkian to Middle Mississippian and comprise about 13,000 feet of folded and faulted strata. The Pulaski overthrust mass in this area is composed of the Middle and Upper Cambrian Elbrook limestone, and the superjacent Max Meadows overthrust sheet is composed of the Lower and Middle Cambrian Rome formation. At the time of their formation, the Pulaski and Max Meadows faults were nearly horizontal overthrusts, but they, along with the overridden rocks beneath the Pulaski fault, have been subsequently folded and faulted.

The Pulaski overthrust sheet in this area is very thin at the most, and relatively slight irregularities or undulations on the Pulaski and Max Meadows overthrust fault surfaces cause these faults to intersect in places. Hence, locally, the Rome formation of the Max Meadows overthrust sheet lies directly upon the overridden block beneath the Pulaski overthrust sheet.

The ridges of Draper Mountain embrace a sharply overturned anticline which is the major fold of this area. Overturned Clinch sandstone (Silurian) makes the crest of this mountain between Hamilton Knob and Peak Knob. (See Pl. 21.) In descending the northwest side of Draper Mountain along the Lee Highway (U. S. 11), the following formations crop out in ascending stratigraphic order: Clinton shale (Silurian), Becraft sandstone (Devonian), Onondaga chert, Marcellus black shale, Naples buff shale, and Brallier sandstone and shale. The Brallier crops out in the northeast-trending valley between Draper Mountain to the southeast and Caseknife Ridge to the northwest. The Chemung sandstone crops out on the southeast slope of Caseknife Ridge, and the crest of this mountain is made by the lower beds of the Price formation (Middle Mississippian). South of Pulaski and also near Gunton Park, portions of the Pulaski and Max Meadows over-

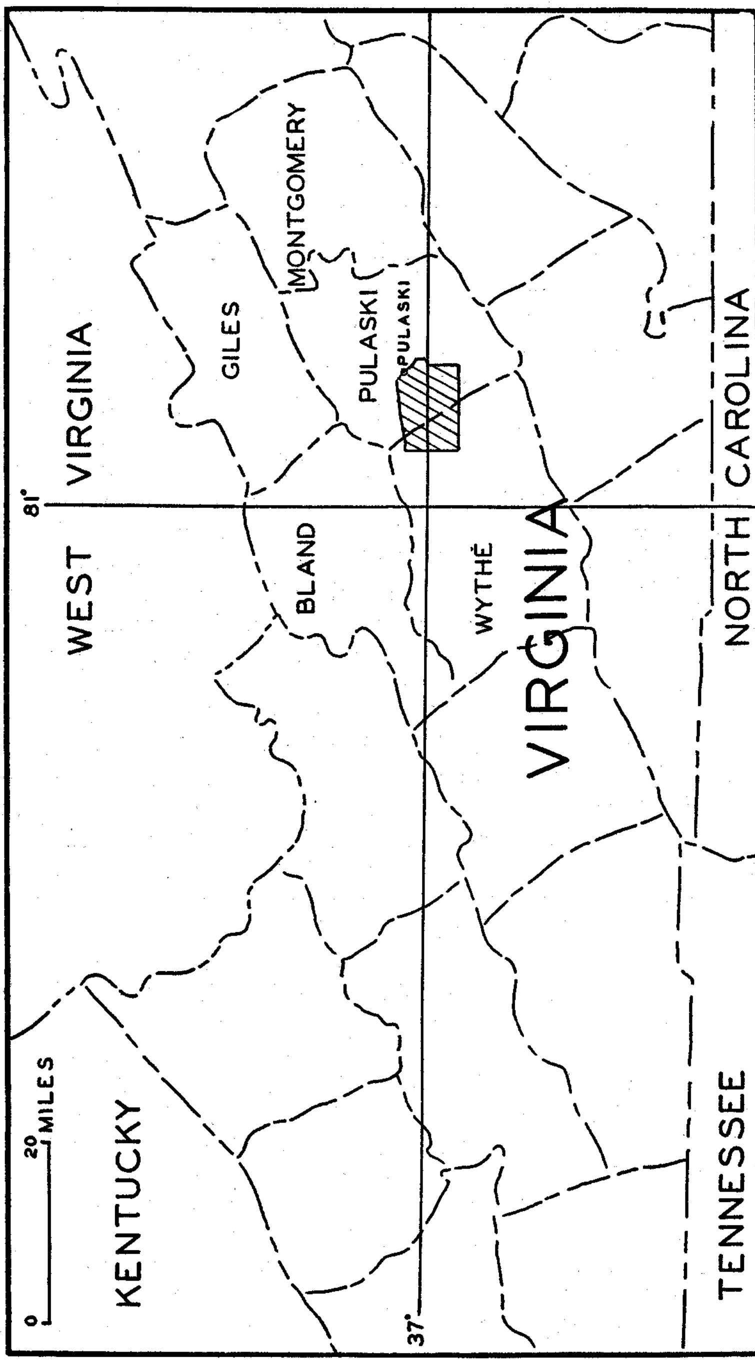
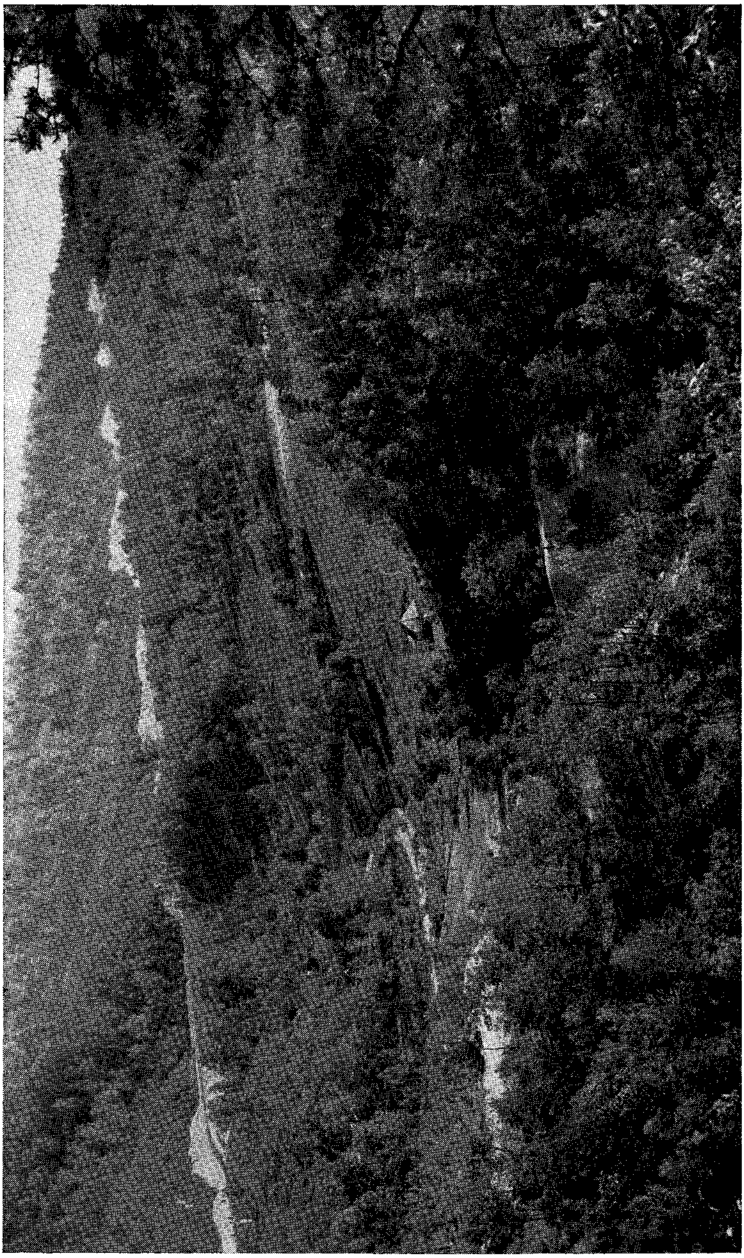
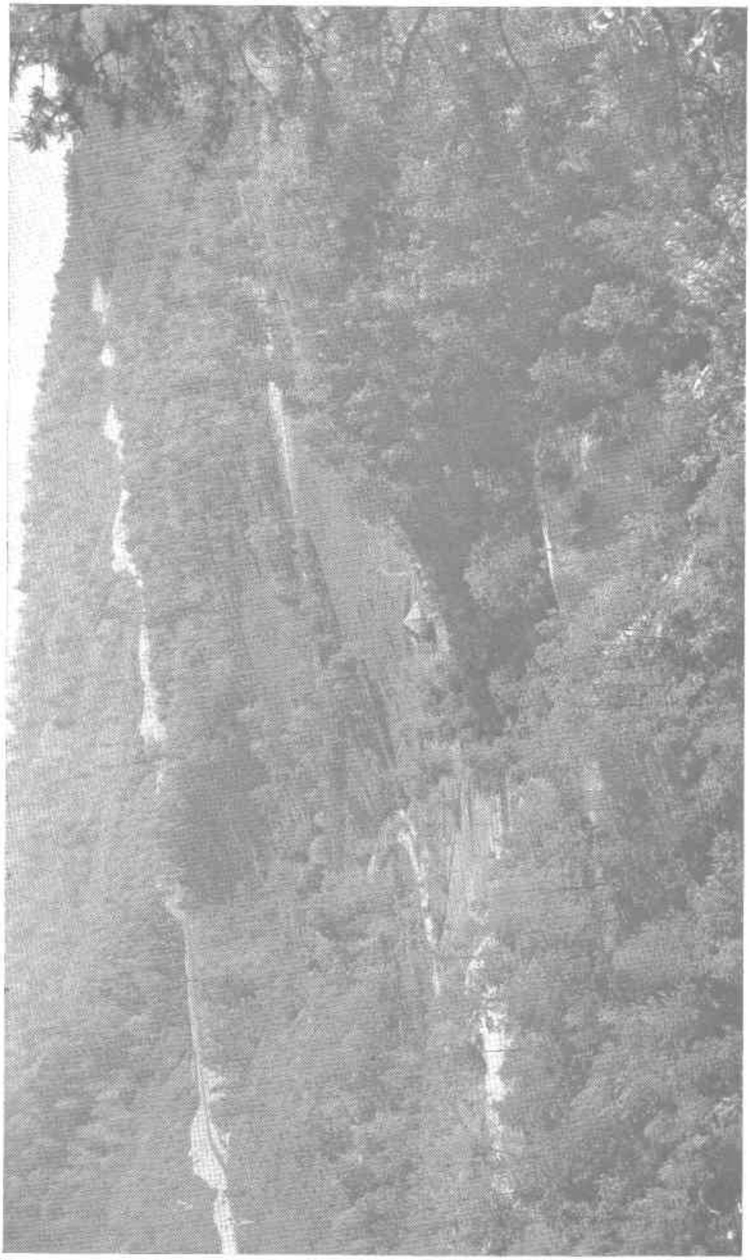


FIGURE 20.—Index map showing location of the Draper Mountain area, Virginia.



Along the Lee Highway ascending Draper Mountain. Photograph by David Kent, Pulaski.



Along the Lee Highway ascending Draper Mountain. Photograph by David Kent, Pulaski.

thrust sheets skirt the northwest base of Caseknife Ridge. (See Pl. 21.)

Character and distribution of the belts.—One of the most remarkable features of the areal geology of the Draper Mountain area is the occurrence of three more or less isolated belts of Cambrian in the valley between Caseknife Ridge and Draper Mountain. (See Pl. 21.) The northeasternmost belt extends southwest from the main body of overthrust rocks which lies to the south, east, and north of Peak Knob. It crosses the Lee Highway at the sharp bend in that road at the base of Draper Mountain and ends about 400 yards southwest of this point. The southwestern third of the belt is composed of silicified Elbrook (Cambrian) limestone and of limonite which has apparently replaced the limestone. The northeastern two-thirds is composed of Rome beds, which have also been silicified. Fault breccia, which borders the outcrop of this formation on the northwest side of the belt, has been partially replaced by limonite. It is abundant in the tailings near the old abandoned iron mines in Clayton Hollow, 2½ miles southeast of Pulaski. Silicified Rome and Elbrook fragments, limonite with small amounts of pyrolusite, and fault breccia impregnated with limonite mark the position of this belt from Clayton Hollow southwest to the abandoned Pulaski iron mines near the Lee Highway. The large excavation near the road was a source of considerable iron ore during the period of operation of the blast furnaces in Pulaski.[1] There are abundant exposures of nearly pure limonite about 150 feet north of the large excavation. So far as the writer could ascertain, the excavation marks the southern border of the belt and the limonite on the north forms the northern boundary of the belt. No limestone was seen near the highway, although the writer learned that many blocks of limestone had been taken out of the main workings of the Pulaski mines. A few small exposures of limestone, more or less silicified, are present about 350 feet east of the eastern rim of the main excavation. Other exposures of the Elbrook can be seen in the dense brush just west of the wayside park, near the western end of this belt. Another belt lies just east of the Pulaski water reservoir. (See Pl. 21.) It is well exposed in the bed of the creek which drains into the eastern end of the lake and extends northeast to the divide between this stream and Valley Branch. All of the many exposures of this belt are of silicified Elbrook, and little limonite appears to be present. The greatest width of the belt is about 400 feet.

[1] The site of crushing and washing operations is evidenced by abundant tailing piles in the wayside park just across the road.

The third Cambrian belt is located southwest of Gunton Park. (See Pl. 21.) It extends from the east fork of Brown Lick Branch southwest across a low divide into the valley of the west fork and beyond its headwaters down into the valley of Poletown Branch. The road from Gunton Park to Poletown crosses this belt, and many good exposures of dark bluish gray, laminated Elbrook limestone are present in the cleared fields on either side of the road at the headwaters of Poletown Branch. The greatest width of the Elbrook outcrop in this belt is about 450 feet.

Previous interpretation.—The isolated belt of Elbrook limestone southwest of Gunton Park and northeast of Poletown was first noted by McCreath and d'Invilliers[2] who concluded that it was of Carboniferous age and that it was conformable with the surrounding rocks. No basis for these conclusions was stated nor was any explanation given for the discordant relations of the belt with the adjacent rocks.

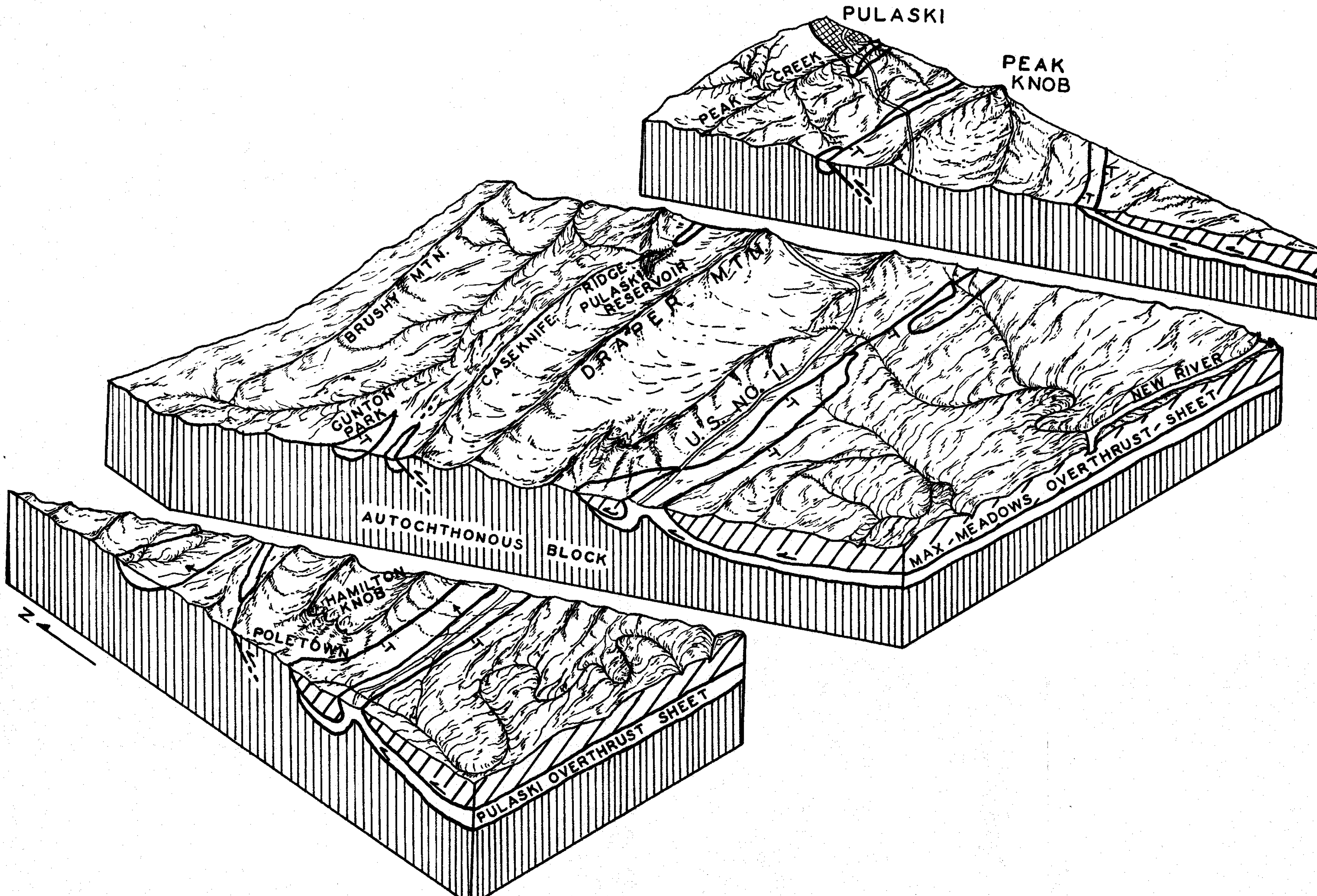
In his geological reconnaissance of this region in 1893, Campbell[3] discovered three isolated belts of limestone north of Draper Mountain and subsequently described their distribution as follows:

"(1) At the north foot of Hamilton Knob, presumably the same as that described by McCreath and d'Invilliers; (2) on Beaverdam Creek [Brown Lick Branch] near where that stream is crossed by the wagon road leading from Gunton Park to the Locust Hill Iron mine, and (3) an exposure on the old road, now abandoned, leading from Gunton Park or Clark Summit, as it was then known, to Pulaski. . . . the limestone may still be seen along the old road now overgrown with underbrush from the reservoir eastward across the summit separating this stream from the small branch that flows through the town [Pulaski], nearly to the road leading southward from Pulaski to Draper Valley. East of this road the limestone was not seen, but its position is indicated by an old iron-ore pit . . . and by red calcareous soil as far as the main Pulaski fault about one-quarter of a mile south of Peak Creek."

Campbell regarded the limestone exposures as parts of a more or less continuous belt extending from the north base of Peak Knob to the north base of Hamilton Knob and believed that the belt thence bent southward around the west base of Hamilton Knob and connected with the extensive outcrop of overthrust limestone and shale south of Poletown. On the basis of its physical

[2] McCreath, A. S., and d'Invilliers, E. V., The New River-Cripple Creek mineral region of Virginia: Harrisburg, Pa., p. 141, 1887.

[3] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 51-53, 1925.



Block diagram showing relations of the Max Meadows and Pulaski overthrust masses to the overridden strata.

appearance, he interpreted the rocks of this band as a part of the Shenandoah formation.[4]

Holden[5] first regarded the belts as of Devonian age and believed them to be conformable with the enclosing shales and sandstones, but later, apparently, he concurred with the conclusions of Campbell regarding the Shenandoah age of the strata within the belts.

Regarding the origin of the limestone belts Campbell[6] says:

> "The bed of limestone appears to dip steeply or to stand on edge and to be inclosed generally by Devonian shale . . . It is clearly bounded on both sides by a fault or faults and it certainly has no direct structural relation to the adjacent shale. It must, therefore, be regarded as something in the nature of an overthrust mass. . . . "

He believed that Cambrian rocks had been thrust over the younger rocks of this area prior to the development of the folded structures in the latter, since the overthrust fault surfaces partake of the same folds. He[7] states:

> "The conditions and movements which resulted in the engulfing of the thin band of Shenandoah 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 to-day, 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."

[4] Campbell used the term Shenandoah for the thick succession of shale, limestone, and dolomite above the Erwin quartzite (Lower Cambrian) and below the Stones River limestones which he called the Chickamauga.

[5] Idem, p. 53.

[6] Idem, p. 53.

[7] Idem, p. 84.

Woodward,[8] in his description of some of the regional features of the Pulaski overthrust block between Pulaski and Roanoke, makes the following statements regarding the structural relations of the Cambrian belts north of Draper Mountain:

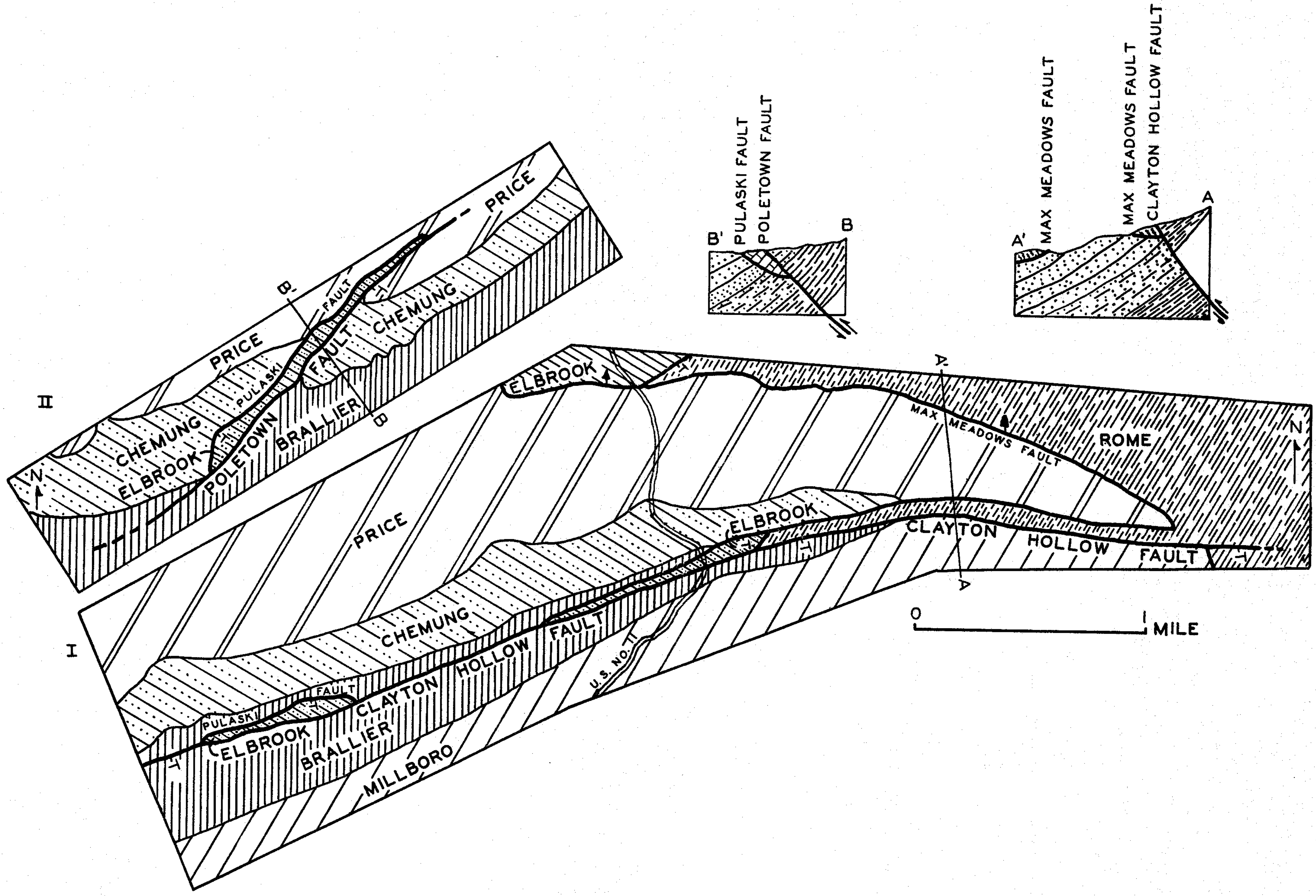
> ". . . a long narrow tongue of 'Cambro-Ordovicic' limestone has been found largely surrounded by 'Devonic' sediments just north of Draper Mountain, and its presence can scarcely be explained except as an infolded mass of an overthrust block. The presence of this band of limestone is an indication of folding and warping after overthrusting of the Pulaski fault . . ."

Origin.—In his detailed geological studies in the Draper Mountain area[9] in 1936, the writer found three belts of Cambrian rocks within Devonian and Mississippian strata, which Campbell had described, and in addition found a few isolated masses of Elbrook surrounded by Marcellus black shale just east of Poletown, in the valley of Poletown Branch. It would appear that these isolated masses of limestone east of Poletown were taken by Campbell as evidence that the Cambrian belt, or belts, north of Draper Mountain was continuous, around the base of Hamilton Knob, with the overthrust masses south of Poletown. These small masses of limestone are not adequate evidence for this hypothesis. According to the writer's interpretation, the limestone masses seen east of Poletown were once parts of the sole-rocks of the Pulaski overthrust sheet. During movements of the latter, some of the overriding Elbrook became wedged within the Devonian shale beneath the fault surface. Continued movement of the overthrust mass forced these blocks of Elbrook farther into the overridden shale below the fault, and finally the blocks of limestone were sheared off from the rest of the overthrust Elbrook.

The structural relations in the Devonian and Mississippian formations surrounding the Rome-Elbrook belts north of Draper Mountain necessitate a different explanation than has heretofore been offered for them. As shown in Plate 22, on the northwest slope of Draper Mountain along the Lee Highway, the Brallier shale, which is 1500 to 2000 feet thick west of Poletown, is not more than 500 feet thick. The lower 250 feet is exposed along the highway southwest of the Pulaski iron mine excavations, and the upper 250 feet of the Brallier is exposed along the road to

[8] Woodward, H. P., Salem block of Pulaski overthrust: Pan-Am. Geologist, vol. 63, no. 5, pp. 321-333, 1935.

[9] Cooper, B. N., Geology of the Draper Mountain area, Virginia: Virginia Geol. Survey Bull. 55, 1939.



Areal geology and structure of the Rome-Elbrook belts.

the north of the excavations. The contacts of the Brallier with the underlying Naples shale and overlying Chemung are depositional. The Cambrian belt, which passes through the old excavation east of the road, lies within the narrow outcrop belt of the Brallier. The Elbrook belt in the vicinity of the Pulaski reservoir also lies within the outcrop of the Brallier, but in this locality the width of the Brallier outcrop and the attitude of its beds indicate that the formation is about 1500 feet thick. The difference in thickness of the Brallier between the Pulaski reservoir and the Lee Highway could not be easily explained by variations of deposition.

Southeast of Pulaski in Clayton Hollow, the width of the Cambrian belt is about 300 feet. It is bordered on the north by Price sandstones, which are generally found about 500 feet above the base of that formation. On the south side, the Cambrian belt is bordered by the Naples shale. Since the lower 500 feet of the Price, 500 feet of Chemung, and 1500 feet of Brallier could not all be concealed beneath the narrow Cambrian belt in this locality, a fault which cuts out the lower Price, the Chemung, and the Brallier must cut the Devonian and Mississippian beds. Although the Naples and Price are not actually observed in contact with one another in Clayton Hollow, the trace of the fault which cuts the Devonian and Mississippian beds is probably the same as the fault contact bordering the Cambrian belts on the south. The break in the trace of the Max Meadows overthrust, as shown near the east margin of I on Plate 22, is proof of this conclusion.

The Elbrook belt northeast of Poletown lies across the trend of the Brallier, Chemung, and Price belts. (See II in Plate 22.) It is apparent that the Devonian and Mississippian strata which enclose this belt are cut by an oblique thrust fault, whereby the Brallier, Chemung, and Price south and southeast of the Elbrook belt have been thrust northward. That the trace of this oblique thrust fault is the fault contact that borders the Elbrook belt on the south and southeast is shown by the southwest and northeast extensions of this fault beyond the limits of the Elbrook belt.

The anomalous position of the three belts of Cambrian rocks and the faulted character of the enclosing Devonian and Mississippian beds suggest the following succession of geologic events. During the Appalachian revolution, Cambrian rocks were thrust over undeformed younger strata along nearly horizontal overthrust fault surfaces, the Pulaski and Max Meadows faults. Subse-

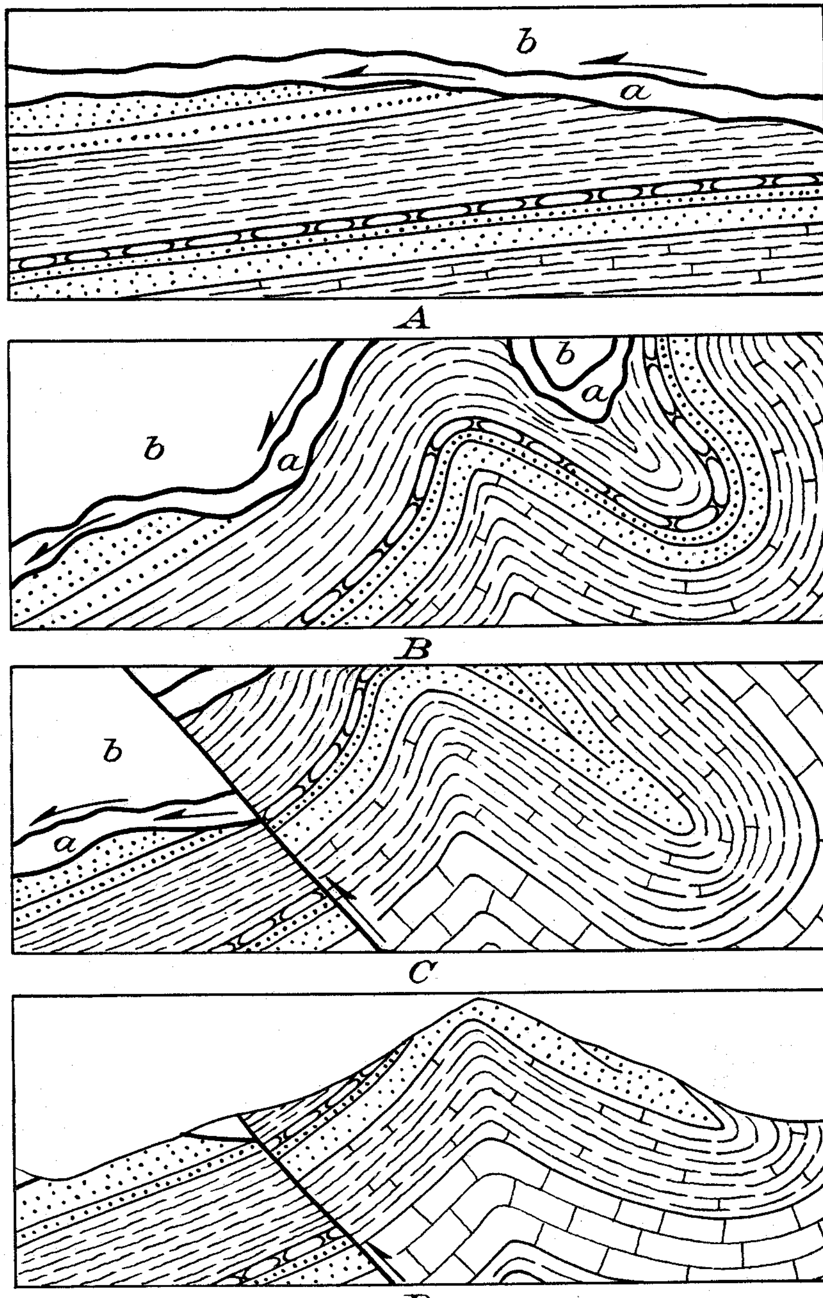


FIGURE 21.—Structure sections showing sequence of events that produced a Cambrian belt; a, Pulaski overthrust mass; b, Max Meadows overthrust mass. The present surface is shown in D.

quently, compressional stresses folded the strata beneath the overthrust masses with the resultant formation of the Draper Mountain anticline. The two overthrust fault surfaces were likewise folded. The rotational stresses which resulted in the formation of this anticline were not wholly relieved by the development of this fold or by its sharp overturning to the northwest, and, as a further relief to these stresses, the Draper Mountain anticline ruptured on its northwest flank. This fault cut through the superjacent overthrust masses, as well as the younger strata beneath the overthrust Cambrian rocks. The rocks on the south side of this rupture were pushed up and over parts of the Cambrian rocks, and wedges of the Pulaski and Max Meadows overthrust masses were thereby buried beneath Devonian strata. The Clayton Hollow and Poletown faults are the two segments of this discontinuous rupture in the northwest flank of the Draper Mountain anticline. Erosion has removed the Devonian shale cover from above these belts of Cambrian. (See Fig. 21.)

The northeast Cambrian belt is bordered on the north side by the Pulaski and Max Meadows fault traces. The Elbrook belt near the Pulaski reservoir is bordered on the north side by the trace of the Pulaski fault. Both of these belts are bordered and connected on the south by the trace of the Clayton Hollow fault. The Elbrook belt northeast of Poletown is bordered on the north by the trace of the Pulaski fault and on the south by the trace of the Poletown fault, a possible southwest extension of the Clayton Hollow fault.

This interpretation of the Cambrian belts satisfactorily explains the absence of the lower Price, the Chemung, and the Brallier formations in the vicinity of Clayton Hollow; the relative thinness of the Brallier along the Lee Highway; and the offset of the Price, Chemung, and Brallier belts of outcrop northeast of Poletown. The presence of these belts is evidence of the fact that overthrust fault surfaces of the Pulaski and Max Meadows faults have been folded and thrust faulted as though they were bedding planes. As shown in Plate 21, these belts, together with the extensive overthrust masses to the south, east, and north of the ridges of Draper Mountain, are conclusive evidence that Draper Mountain was once completely surrounded by overthrust masses and was, therefore, a true fenster.

GEOLOGY OF LITTLE NORTH MOUNTAIN IN NORTHERN VIRGINIA

BY

CHARLES BUTTS AND RAYMOND S. EDMUNDSON

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

Bulletin 51-H

UNIVERSITY, VIRGINIA

1939

CONTENTS

ILLUSTRATIONS

Geology of Little North Mountain in Northern Virginia

By Charles Butts and Raymond S. Edmundson

INTRODUCTION

Location.—Little North Mountain originates in a complex of unoriented ridges about 10 miles northwest of Lexington, Virginia. It extends northeastward for about 150 miles across Rockbridge, Augusta, Rockingham, Shenandoah, and Frederick counties, Virginia, and Berkeley County, West Virginia, to end in Bear Pond Mountains, Washington County, Maryland. Approximately 27 miles of the range is in West Virginia and Maryland.

Scope of report.—The purpose of this paper is to describe the various rock units along the mountain in Frederick and northern Shenandoah counties, including their structure, and to suggest the important role of sedimentation in the geologic history of the area. The stratigraphy and paleontology were given considerable attention during the field work, but in this preliminary report they are treated briefly.

This paper is based on a detailed geologic survey in northern Virginia made jointly by the writers for the Virginia Geological Survey. It was written by the junior author and has had the benefit of critical reading by the senior author.

TOPOGRAPHY

At many places Little North Mountain does not have the form and height of a typical mountain ridge; yet, it is a structural entity.

South of the Maryland-West Virginia boundary the mountain rises as a linear ridge from an altitude of about 400 feet at Potomac River to 1640 feet at Roundtop, Berkeley County, West Virginia. It then gradually descends to 1345 feet at the West Virginia-Virginia boundary. From Green Springs, 2½ miles southwest of the West Virginia boundary, southwestward to Cedar Creek in Frederick County, Virginia, Little North Mountain contains numerous water gaps. The interstream remnants consist of short linear ridges and isolated rounded hills, locally called mountains or knobs. Some of these interrupted parts of the mountain, with an average summit altitude of 1200 feet and a height of 350 feet above the surrounding valleys, are Babbs Mountain, Flint Ridge, Round Hill, Wisecarver Mountain, and Funkhouser Knob. In Shenandoah County the mountain increases rapidly in elevation south of Wheatfield and extends as a conspicuous ridge, although interrupted by Pontzer, Fetzer, and Scheffer wind gaps, southwestward to the vicinity of Stony Creek. The ridge is absent in southern Shenandoah County but reappears boldly in northern Rockingham County, with a maximum relief of 1200 feet. It is lacking in southwest Rockingham and northern Augusta counties. In southern Augusta County it continues as a discontinuous ridge southwestward to the complex of ridges near Goshen Pass in northwestern Rockbridge County.

One of the most interesting facts is the influence that the Tuscarora sandstone has had on the topography, especially in longitudinal profile. (See Pl. 23.) All of the water gaps are located at places where the sandstone is relatively thin or absent. The gradual ascent to higher altitudes in every place corresponds to a thickening of the Tuscarora.

STRATIGRAPHY

GENERAL STATEMENT

The stratigraphy of the Little North Mountain area includes 23 formations mapped as 19 units (Pl. 23) that range from Middle Cambrian to Upper Devonian, inclusive. Estimates based on detailed field work and measured sections in northern Virginia suggest an aggregate thickness of more than 17,000 feet.

A brief description of the lithology, thickness, and a few diagnostic guide fossils for the several formations in each geologic system are given below.

CAMBRIAN SYSTEM

Elbrook limestone.—The Elbrook limestone is bounded below by the Rome formation and above by the Conococheague limestone. Along the course of Little North Mountain it is sliced by faults at various distances above its base and thrust onto younger rocks. In northern Shenandoah County the average thickness is about 2000 feet.

The Elbrook is chiefly a thin-bedded bluish-gray argillaceous limestone with a few dolomitic layers. On weathering the rock yields a mass of platy limestone and shale fragments. These fragments are the chief criteria for its identification, since the formation is sparingly fossiliferous. The occurrence of *Glossopleura* on the east bluff of Cedar Creek, 1 mile west of Marlboro, shows the Middle Cambrian age of the lower part of the Elbrook.

Conococheague limestone.[1]—The Conococheague limestone includes all of the rocks between the Elbrook limestone and the Chepultepec limestone. Sections that could be satisfactorily measured are not found along Little North Mountain, but the width of outcrop and dip of the rocks at a locality just south of Green Springs suggest a thickness of not less than 2000 feet. Farther southwest in northern Shenandoah County, the outcrop belt is more than a mile wide and the beds are steeply inclined, but this great apparent thickness is probably due to repetition of beds by close folding.

The Conococheague is predominantly a thick-bedded blue limestone with certain beds containing laminae of siliceous and clayey material. On weathering these laminae stand out on the surface as thin, wavy or crinkly ribs. One of the most characteristic features is the occurrence of beds of coarse-grained sandstone. These beds range in thickness from a few feet to as much as 50 feet. Some of them are exposed along U. S. Route 50, west of Winchester. The sandstones apparently have no definite stratigraphic position, but are of sporadic occurrence at different horizons throughout the Conococheague. They are of great value for correlation and, so far as they can be traced on the surfaces, for interpretation of the local structure.

Fossils are very scarce, but some *Cryptozoon* and poorly preserved fragments of gastropods, brachiopods and trilobites (*Symphysurina and Tellerina*) were noted. East of this area, within the city of Winchester, one bed carries abundant specimens of *Tellerina wardi.*

ORDOVICIAN SYSTEM

Chepultepec limestone.[2]—The Chepultepec limestone, lying between the Conococheague and Beekmantown limestones, crops out as a long narrow belt about half a mile east of Nain, Cedar Grove, and Green Springs in northern Frederick County. Southeast of the area included in this report it is a persistent formation.

The Chepultepec is a thick-bedded, blue, finely crystalline limestone with an average thickness of 600 feet. Fifteen general average samples of this rock from two localities in Frederick County, analyzed by Dr. J. H. Yoe, Chemist of the Virginia Geo-

[1] Lower part of the Ozarkian system as proposed by Ulrich.
[2] Upper part of the Ozarkian system as proposed by Ulrich, and at present accepted by Butts.

logical Survey, contained about 90 per cent calcium carbonate. Differences in solubility of the relatively pure limestone of the Chepultepec and the impure limestone of the underlying Conococheague produce on weathering a marked bench or terrace along their contact. This observation is a most helpful criterion for the separation of the two formations.

The Chepultepec cannot be distinguished lithologically from the overlying Beekmantown, but characteristic fossils, such as small curved cephalopods of the genera *Dakeoceras* and *Levisoceras,* gastropods of the *Gasconadia* and *Eccyliomphalus* types, and a few silicified brachiopods of the genera *Finkelnburgia* and *Tetralobula* are fairly abundant in certain layers of the Chepultepec.

Beekmantown limestone.[3]—In Frederick County the limestone facies of the Beekmantown is well displayed, with only a slight development of chert. East of Little North Mountain it is bluish-gray and some beds, especially in the upper part, have a distinct vaughanitic texture. Where this condition prevails fossil evidence is needed for the certain separation of the Beekmantown from the overlying Mosheim limestone.

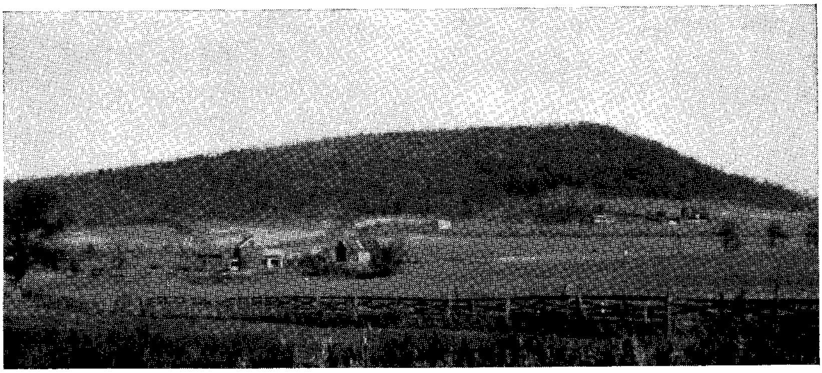
On the geologic map (Pl. 23) the Beekmantown is bounded by two faults, but more favorable exposures east of the area suggest a thickness that probably ranges between 2000 and 2500 feet.

The Beekmantown is the oldest formation in the area which is moderately fossiliferous. The lower half or less—the Nittany horizon—of the Beekmantown is characterized by such diagnostic fossils as *Roubidouxia,* and several species of the genera *Lecanospira, Ophileta, Eccyliopterus* and *Hormotoma,* whereas the upper part, or Bellefonte equivalent, has an assemblage of several species of *Ceratopea, Ophileta, Orospira,* and *Coelocaulus.*

Mosheim limestone.—The Mosheim limestone immediately overlies the Beekmantown; hence there is a small hiatus due to the absence of the Murfreesboro limestone. Just south of the West Virginia boundary (Pl. 23) the Mosheim shows this relationship, but at all other localities in the area it occurs as disconnected bodies along a fault.

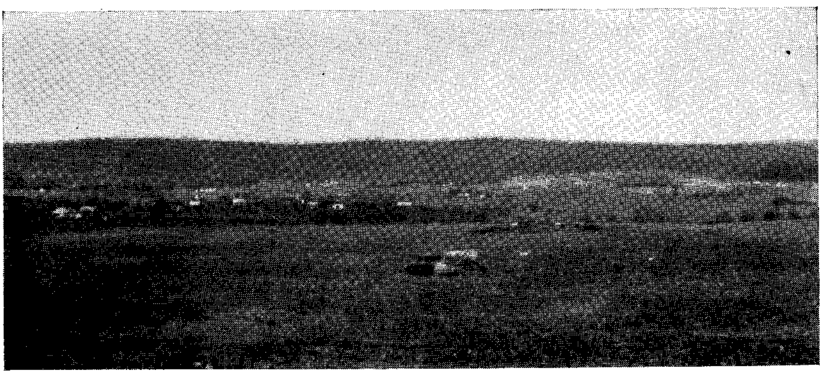
The Mosheim is a dove-colored compact limestone that generally breaks with a conchoidal fracture. Its high calcium carbonate content is not excelled by any other limestone in the Appalachian Valley. The thickness ranges from a few feet to about 50 feet in the Little North Mountain area. Important fossils for correlation are large species of *Lophospira* and *Trochonemella.*

[3] Included in the Canadian system as proposed by Ulrich.

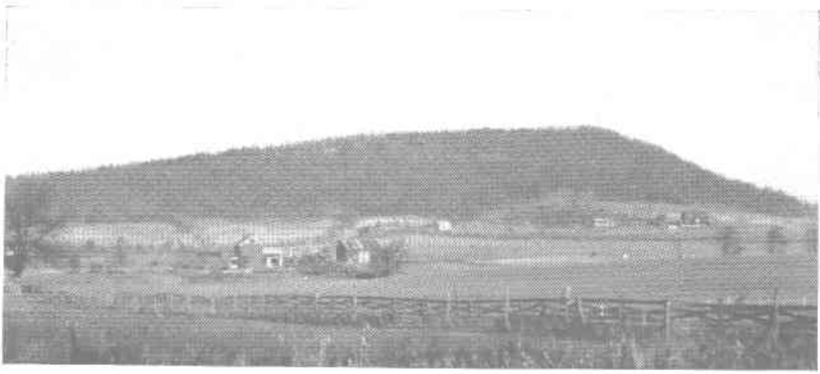


A. Round Hill on Tuscarora sandstone. The sandstone is approximately 250 feet thick at the summit of the hill and thins to about 50 feet within the limits of the photograph. Looking west from U. S. Highway 50, Frederick County, Virginia.

B. Massive sandstone about 10 feet thick near the top of the Bloomsburg formation on the north slope of Round Hill.



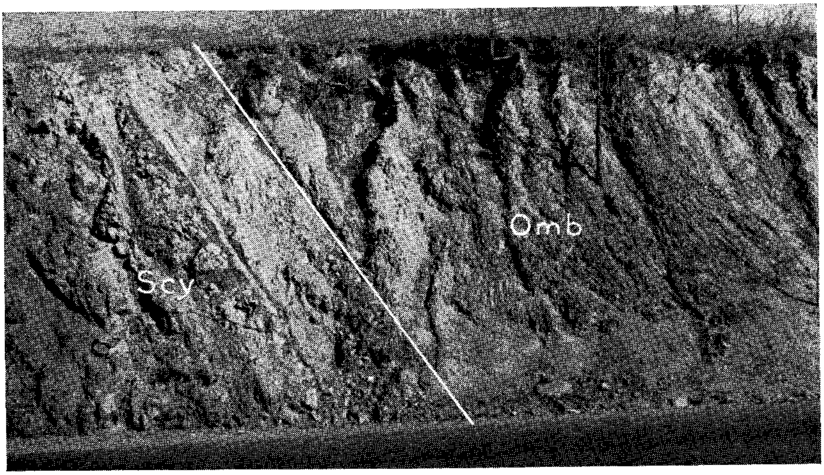
C. Even crest of Little North Mountain between Round Hill and Wisecarver Gap. The crest is on Tuscarora sandstone which forms a part of the overturned monocline with steep southeastward dips. Looking west from a point 1 mile northeast of Opequon, Frederick County, Virginia.



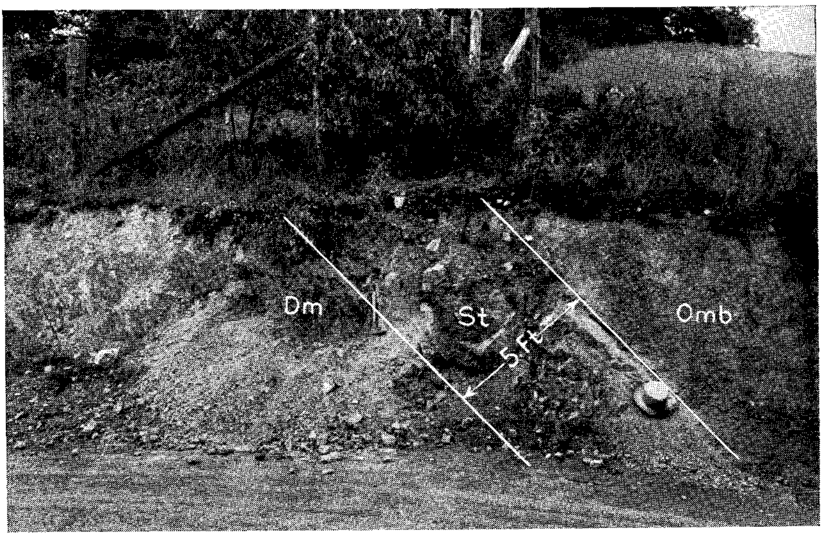
A. Round Hill on Tuscarora sandstone. The sandstone is approximately 250 feet thick at the summit of the hill and thins to about 50 feet within the limits of the photograph. Looking west from U. S. Highway 50, Frederick County, Virginia.

B. Massive sandstone about 10 feet thick near the top of the Bloomsburg formation on the north slope of Round Hill.

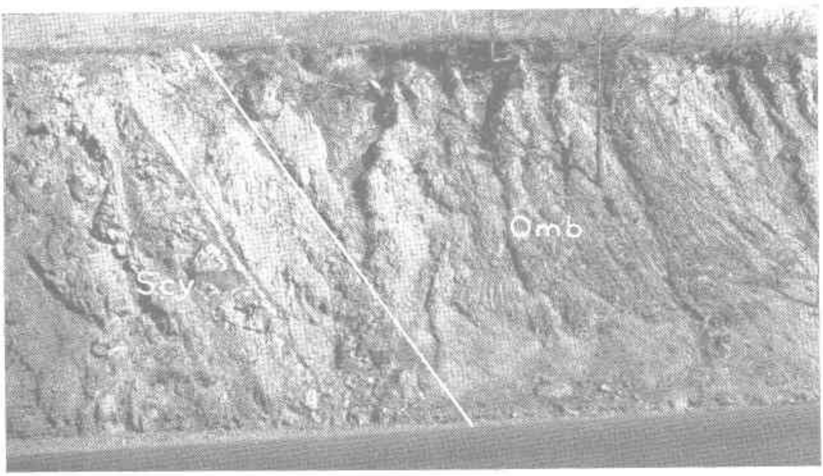
C. Even crest of Little North Mountain between Round Hill and Wisecarver Gap. The crest is on Tuscarora sandstone which forms a part of the overturned monocline with steep southeastward dips. Looking west from a point 1 mile northeast of Opequon, Frederick County, Virginia.



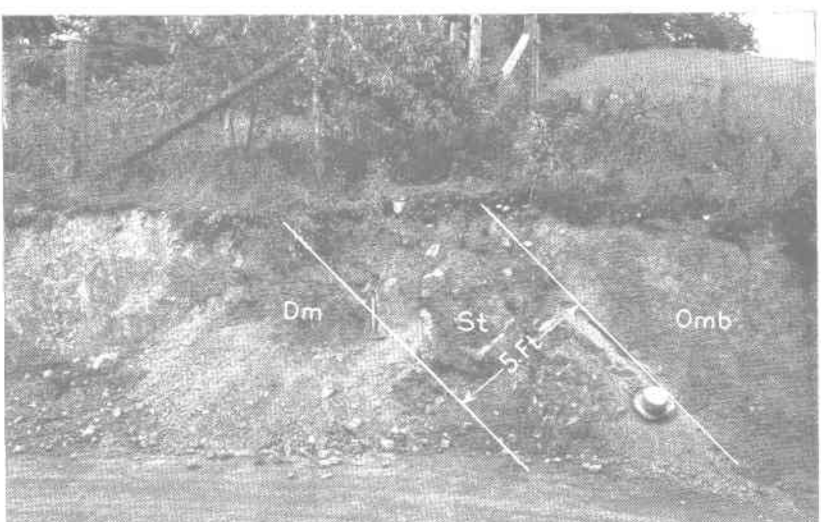
A. Martinsburg shale and Cayuga formations in Hoop Petticoat Gap, near Chambersville, along U. S. Highway 50, Frederick County, Virginia. Omb, Martinsburg shale; Scy, Cayuga shales and sandstones.



B. Silurian system in Fawcetts Gap, Frederick County, Virginia. The Silurian here is only 5 feet thick. It consists of the Tuscarora sandstone. The beds dip southeast. Omb, Martinsburg shale; St, Tuscarora sandstone; Dm, Marcellus shale. Photograph by Arthur Bevan.



A. Martinsburg shale and Cayuga formations in Hoop Petticoat Gap, near Chambersville, along U. S. Highway 50, Frederick County, Virginia. Omb, Martinsburg shale; Scy, Cayuga shales and sandstones.



B. Silurian system in Fawcetts Gap, Frederick County, Virginia. The Silurian here is only 5 feet thick. It consists of the Tuscarora sandstone. The beds dip southeast. Omb, Martinsburg shale; St, Tuscarora sandstone; Dm, Marcellus shale. Photograph by Arthur Bevan.

Lenoir limestone.—The Lenoir limestone overlies conformably the Mosheim. It is a dark-gray to black limestone with abundant nodules of black chert. The most striking characteristic is its granular texture and abundant crinoidal and bryozoan remains. *Maclurites,* which has not been found in this area, is the most diagnostic guide fossil for the Lenoir generally. No sections within the area afforded accurate measurements, but the thickness is estimated at less than 50 feet.

Chambersburg limestone.—The Lenoir limestone is overlain by the Chambersburg limestone. This sequence involves a hiatus of several thousand feet due to the absence of the Blount group and lower members of Black River group, such as the Lowville limestone. The Chambersburg is a thin-bedded dark-gray compact limestone which is commonly nodular on weathered exposures. Near the base are several thin layers of bentonite and at least one thin bed of argillaceous sandstone. The thickness ranges from about 300 feet in northern Frederick County to about 600 feet in northern Shenandoah County. Diagnostic fossils include *Christiania, Receptaculites, Nidulites, Echinosphaerites,* and abundant species of bryozoa and brachiopods.

Martinsburg shale.—The Martinsburg shale succeeds the Chambersburg limestone in normal sequence. It consists of a bluish shale, that weathers yellowish or brownish, and some layers of fine-grained sandstone. A complete section is not exposed along Little North Mountain, but the width of outcrop indicates a thickness of not less than 2000 feet.

Layers containing many species of fossils occur throughout the Martinsburg. A few of the diagnostic fossils which show in ascending order the Trenton, Eden, and Maysville ages are several species of *Cryptolithus, Prasopora,* biserial graptolites, *Dalmanella, Orthorhynchula, and Lingula.*

Oswego sandstone.—The Oswego sandstone lies between the *Orthorhynchula* zone at the top of the Martinsburg and the Juniata formation. Within the area of this report it crops out only in the northern part of Shenandoah County southwest of Wheatfield. It consists of thick-bedded, gray, iron-stained sandstone and conglomerate, A few thin shale partings are found locally. The lack of fossils suggests that this formation accumulated in a nonmarine environment. The thickness ranges from a few feet southwest of Wheatfield to about 200 feet at Pontzer Gap in Shenandoah County.

Juniata formation.—The Juniata formation is conformable on the Oswego sandstone. It consists of nonmarine red shale or mudrock and beds of brown to red sandstone. The distinctive red color makes it one of the easiest formations to recognize. Along Little North Mountain the formation occurs as discontinuous lenses ranging from a few feet to a possible maximum of about 100 feet in thickness.

SILURIAN SYSTEM

Tuscarora sandstone.—The Tuscarora sandstone, lying between the Juniata and Clinton formations, is composed of light-gray to white pure quartz sand in a siliceous matrix. It is a compact vitreous rock commonly called a quartzite. The Tuscarora occurs in Frederick and northern Shenandoah counties as lenses that range in thickness from a few feet (Pl. 25B) to approximately 300 feet. Except for a few worm burrows, *Arthrophycus,* it is not fossiliferous.

Clinton formation.—The Clinton formation is present in Little North Mountain, north of Green Springs, Frederick County, and south of Wheatfield, Shenandoah County, but is absent in every exposed section between these points. It succeeds the Tuscarora and extends upward, apparently, to the Bloomsburg member of the Cayuga formations. So far as known the Keefer sandstone member at the top of the Clinton and the McKenzie, lower Cayugan, are not present, although definitely identified west of the area considered in this report.

The Clinton is composed of yellowish shale and thin ferruginous sandstone. There are no continuously exposed sections. The distribution of fossiliferous float material indicates a thickness that probably ranges from 100 to 200 feet. Fossils include abundant species of brachiopods and ostracodes and a few pelecypods. For identification purposes, *Anoplotheca hemispherica, Liocalymene clintoni,* and several species of *Mastigobolbina* and *Zygobolba* are probably the most helpful.

Cayuga group.—The Cayuga group is especially well displayed at the northeastern end of Great North Mountain, 4 miles west of Little North Mountain. It includes, in ascending order, the McKenzie, Bloomsburg, Wills Creek and Tonoloway. Along Little North Mountain, only the Bloomsburg, Wills Creek and Tonoloway have been identified. A platy limestone which, on fossil evidence, can be referred to the Tonoloway, has been found at only one place, in Baldwins Gap, 1 mile northwest of Marlboro. The upper part of this limestone may be Keyser.

The Bloomsburg formation is composed predominately of red shale or mudrock and thin red sandstone. At a few localities in Frederick County a massive sandstone (Pl. 24B), about 10 feet thick, is a persistent marker of the upper part of the Bloomsburg. The red shales and sandstones are succeeded by yellowish shale of the Wills Creek formation. It is not possible to determine an exact boundary between the Bloomsburg and the Wills Creek. Their aggregate thickness must be about 300 feet. The Bloomsburg is unfossiliferous, whereas the Wills Creek contains a few species of fossils. *Leperditia elongata willsensis* is one of the most diagnostic forms.

DEVONIAN SYSTEM

Helderberg limestone and Oriskany sandstone.—The Keyser and New Scotland members of the Helderberg limestone and the overlying Oriskany sandstone are combined into one map unit (Pl. 23) along Little North Mountain, because of poor exposures of the limestones and the lenslike distribution of the Oriskany.

A few sections show the Keyser to be in part a thick-bedded nodular limestone. Fossils, so far as known, are rare in this area. At other localities in Frederick County and generally, the Keyser contains a large and characteristic fauna. *Chonetes jerseyensis,* a diagnostic fossil, is of common occurrence.

The Keyser is succeeded by the New Scotland limestone. Although this limestone is rarely exposed, the development of white prismatic chert fragments makes it one of the best horizon markers in Frederick County. *Spirifer macropleurus* is one of the most characteristic guide fossils. The New Scotland appears to be about 100 feet thick.

The Oriskany sandstone is not a persistent bed. In some sections it is definitely absent, whereas a few feet are represented at other localities. The best development is about 1 mile northeast of Round Hill, Frederick County, where the formation is not less than 100 feet thick. The Oriskany is a thick-bedded light-colored calcareous sandstone or conglomerate that weathers to a friable or pulverulent mass. Diagnostic fossils include *Spirifer arenosus.*

Onondaga shale.—The Onondaga shale overlies the Oriskany sandstone. It consists of dark-green shale with a few limestone layers near the base. The Onondaga does not exceed 100 feet in thickness according to the best measurements and estimates. It is abundantly fossiliferous and such fossils as *Anoplotheca acutiplicata, Bollia ungula, Amphissites? favulosa* and *Octonaria stigmata* are diagnostic guide fossils.

Marcellus shale.—The Marcellus shale is a persistent formation throughout the Little North Mountain area. It ranges in thickness from about 250 feet at certain places in Frederick County to 500 feet or more in northern Shenandoah County. Conditions of exposure and the possibility of repetition by folding in localities where there is a wide expanse of the Marcellus cause considerable uncertainty in the determinations of thickness. The lower part of the Marcellus is a black fissile shale, whereas toward the top it is a gray to yellow shale. *Leiorhynchus limitare,* which is abundant in places, is a characteristic fossil.

Hamilton formation.—The Hamilton formation succeeds the Marcellus shale and consists of about 1000 feet of green shale and interbedded green argillaceous sandstone which weathers into small hackly chips. Near the top is a massive greenish sandstone, about 50 feet thick. The entire Hamilton is characterized by exceedingly fossiliferous layers. A few of the most diagnostic fossils are *Spirifer mucronatus, Chonetes coronatus, Stropheodonta perplana, Tropidoleptus carinatus,* and several genera of pelecypods and gastropods, including *Pterinea flabellum,* and *Pleurotomaria sulcomarginata.* In addition *Taonurus* is common in the massive sandstones near the top of the formation.

Brallier shale.—The Brallier shale consists of a mass of stiff micaceous green to yellow shale and an almost equal amount of thin-bedded greenish sandstone. It is limited by the Hamilton at the base and the Chemung at the top. Along Little North Mountain its approximate thickness is 1200 to 1500 feet.

The formation is sparingly fossiliferous, but worm trails, *Pteridichnites biseriatus,* are fairly abundant throughout and very useful for correlation. The occurrence of *Spirifer mesastrialis, Spirifer mucronatus,* and *Leiorhynchus globuliformis* just west of Little North Mountain indicates the Ithaca age of the Brallier in that belt.

Chemung formation.—The base of the Chemung is placed at the lowest horizon at which large fossils occur, which, however, is not a reliable criterion where the Ithaca fossils are present in the Brallier. The upper 200-300 feet is marked by a gradational zone of alternating red shale and sandstone and gray and green shale with the ordinary Chemung fossils. On the basis of these delimiting features, the thickness in northern Virginia is approximately 2000 feet. The Chemung consists essentially of a mass of shale and interbedded thick arkosic sandstones. The sandstones generally are gray or greenish, but some beds have a distinct chocolate color. Most of the shales are green and lack the fissility of the underlying Brallier shale.

Some of the most common and typical fossils are *Spirifer disjunctus, Leiorhynchus mesicostale, Productella lachrymosa* and *Leptodesma potens.*

Hampshire formation.[4]—The Hampshire formation, limited to the syncline west of Little North Mountain, includes a mass of thick-bedded arkosic and micaceous sandstone and lumpy non-fissile mudrock. About 75 per cent of the beds are red, which is a reliable criterion for its identification. The top of the formation is not preserved in the local syncline, but observations at other localities in Frederick County indicate a thickness of about 2000 feet. The Hampshire is not fossiliferous.

STRUCTURE

GENERAL STATEMENT

The structure of Little North Mountain has been described by Giles[5] as a "faulted monocline of overturned beds with steep southeastward dip bounded on the east by closely compressed generally overturned folds affecting the Cambrian and Ordovician formations underlying the Valley, and on the west by a broad syncline developed in Devonian rocks. The faults are overthrusts from the southeast with southeastward inclination. The major overthrust presents a continuous trace on the west side of the mountain. The other faults are distributive from the major overthrust and consequently are discontinuous, merging with the major overthrust at infrequent intervals. Their traces in general lie east of the mountain crest and locally may depart some distance beyond the foot of the mountain."

The part of Little North Mountain discussed in this paper is believed by the writers to differ in many details from the structure described above. Locally, unequal sedimentation during Silurian and early Devonian times in conjunction with some minor

[4] Recent work by Chadwick has demonstrated that the Catskill formation of the type locality corresponds mainly to the Hamilton and Portage formations; hence, the younger red rocks here are described under the restored name Hampshire formation.

[5] Giles, A. W., The geology of Little North Mountain in northern Virginia and West Virginia: Jour. Geology, vol. 35, no. 1, p. 53, 1927.

faulting are proposed to explain the lenslike distribution of some of the formations shown on Plate 23.

The faulted overturned Cambrian and Ordovician beds east of the mountain and the broad Devonian syncline to the west are a reality, but the assumed low angle thrust along the west side of the mountain was not identified during the present detailed investigation.

The presence of such a fault is inevitable according to some of the stratigraphic interpretations of Giles, but it is not compatible with the present interpretation. For example, the section through Baldwins Gap, 1 mile northwest of Marlboro, Frederick County, shows in ascending order Cayuga, Helderberg, Onondaga, and Marcellus beds, whereas it was previously interpreted[6] as Cayuga thrust upon Romney shale several hundred feet above the base of that formation. Another illustration is the section through Chambersville Gap, about 4 miles west of Winchester. Here the Clinton was interpreted as thrust upon the Helderberg, but fossils show that the supposed Clinton is Cayuga and the sequence therefore is conformable.

DETAILED DESCRIPTIONS

Section A-A′ (Pl. 23) probably represents a complete stratigraphic sequence of Little North Mountain in Frederick County, whereas section J-J′ (Pl. 23) is normal for the mountain in northern Shenandoah County. So far as it is possible to determine, most of the formations thicken to the southwest and a new member, Oswego sandstone, is introduced.

Along Section A-A′ (Pl. 23), just south of the Virginia-West Virginia line, all of the formations of the mountain are overturned with steep southeastward dip. Along the same section, about half a mile east of the mountain crest, is a diagonal fault which brings upper Beekmantown in contact with Chambersburg on the west. The narrow strip of Beekmantown east of the fault is followed in normal sequence by Mosheim, Lenoir, and the lower Chambersburg which again is overridden by Beekmantown along a minor thrust fault. A few hundred feet farther to the east a second thrust fault brings Elbrook limestone in contact with Beekmantown limestone.

From Section A-A′ (Pl. 23) southwestward to a point about 1 mile south of Green Springs, the major fault nearest the mountain trends at an oblique angle to the strike of the rocks and

[6] Giles, A. W., The geology of Little North Mountain in northern Virginia and West Virginia: Jour. Geology, vol. 35, no. 1, p. 55, 1927.

brings Beekmantown, Chepultepec, Conococheague, and Elbrook limestones in contact with Martinsburg shale.

The Silurian formations diminish in thickness from the Virginia boundary to a point just north of the gap west of Green Springs. Here the Juniata, Tuscarora, Clinton, and Cayuga sandstones and shales show a rather sharp flexure to the southeast and apparently end abruptly against the underlying Martinsburg shale. It is reasonably certain that a minor fault, in conjunction with pronounced thinning, must be postulated to explain the distribution of the formations at this locality. This oblique fault apparently extends to the southwest for about 2 miles and dies out as a strike fault along the northeastern slope of Babbs Mountain. Through the Green Springs water gap the overturned formations in ascending order are Martinsburg, Helderberg-Oriskany, Onondaga, Marcellus, and Hamilton.

At Cedar Grove (Pl. 23, Sec. B-B′) the Tuscarora sandstone is about 50 feet thick. From this point it can be traced as a lens increasing in thickness to about 150 feet on Babbs Mountain and Flint Ridge. The absence of the Juniata east of the Tuscarora and of the Clinton to the west of the Tuscarora, is believed to represent interruptions in sedimentation, since the Clinton does not appear again for about 20 miles to the southwest along the mountain and the Juniata as very thin lenses is present in only a few isolated localities. In normal sequence west of the Tuscarora at Cedar Grove there is an interval of about 1100 feet occupied by the Cayuga group and the Helderberg-Oriskany formations. This apparent abnormal thickness may be explained by repetition due to folding.

The village of Nain, 4 miles northwest of Winchester, located in a wind gap of Little North Mountain, is the locus of relatively thin Tuscarora in comparison with greater thicknesses of the sandstone north and south along Flint Ridge. About 600 feet east of the ridge the Conococheague limestone is thrust upon Martinsburg shale. Farther to the east and west the structure is similar to the section at Cedar Grove.

At the southwestern end of Flint Ridge the Tuscarora sandstone thins out completely and the Martinsburg shale is in contact with the Bloomsburg member of the Cayuga group. It is not impossible that compression at this place of relative weakness, due to a thinning of the Tuscarora, may have resulted in minor faulting, but the lack of any noticeable distortion in the associated beds rather favors a sedimentary unconformity. Just south of the tributary to Pearls Run and extending for 1 mile south of the Indian Hollow Road (Pl. 23, Sec. C-C′), a thin Tuscarora and Juniata are present. Along most of this course the major fault to the east has brought Elbrook limestone in contact with Juniata shale. It should be noted here that, although the Martinsburg has been cut out, the thin Juniata and Tuscarora are in normal sequence.

West of the County Farm (Pl. 23) about 1½ miles northeast of Chambersville, there is an unusually thick development of Oriskany sandstone which is a perfect example of a lens. It is approximately 100 feet thick and thins to only a few feet in a distance of about 1 mile to the north and south. This is cited as corroborative evidence of the sedimentary environment along the course of Little North Mountain.

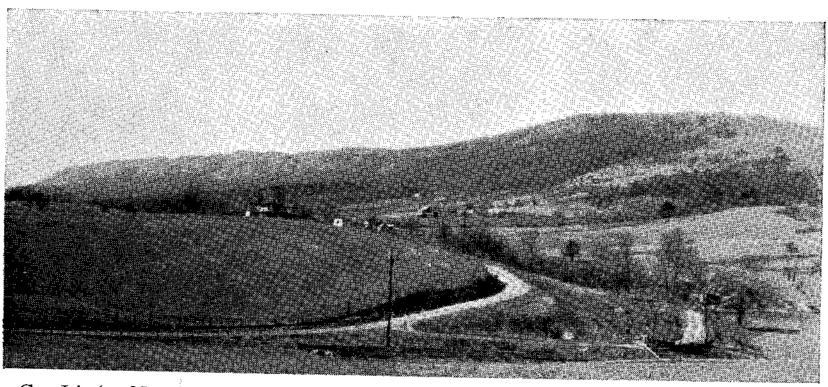
Between the County Farm and Round Hill, the Tuscarora and Juniata taper out and the Martinsburg reappears in contact with the Cayuga group. Along the northeast slope of Round Hill (Pl. 24A) the Tuscarora begins as a thin formation, rapidly increases to a maximum thickness of about 250 feet near the summit (Pl. 23, Sec. D-D′), and then gradually thins out at Hoop Petticoat Gap, west of Chambersburg along U. S. Route 50. To interpret this feature as a depositional lens seems highly speculative, yet an original local basin of deposition with an initial dip of about 5 degrees would probably explain it.

The thinning and omission of the Tuscarora sandstone near and in Hoop Petticoat Gap (Pl. 25A) may be due in part to some local readjustment in the weak zone, but the important structural feature is believed to be directly connected with primary deposition. West from the Tuscarora through the gap, the formations in ascending order are Cayuga, Helderberg-Oriskany, probably thin Onondaga, Marcellus, Hamilton, Brallier, Chemung, and Hampshire. To the east the Elbrook limestone is faulted against Martinsburg shale.

The Tuscarora sandstone crops out as a thin bed just south of U. S. Route 50 and rapidly thickens to about 200 feet. This average thickness which produces an even crest line (Pl. 24C), is maintained for 3 miles along the crest of the mountain (Pl. 23, Sec. E-E′) to the southwest. From a point about 1 mile northwest of Paxton Chapel, the sandstone gradually thins to 30 feet in Wisecarver Gap (Pl. 26A). The section through this gap (Pl. 23, Sec. F-F′) is noteworthy because of the absence of the Helderberg limestones and Onondaga shale. Exposures are not favorable to limit exactly the Helderberg and Onondaga, but chert and fossiliferous shale fragments along the road leading from Paxton Chapel to Mt. Pleasant definitely indicate that both formations extend southwest of that locality. It is believed that the

A. Wisecarver Gap, Frederick County, Virginia. The Tuscarora sandstone is approximately 30 feet thick in gap, 150 feet on the left, and 50 feet on the right. Great North Mountain in the distance.

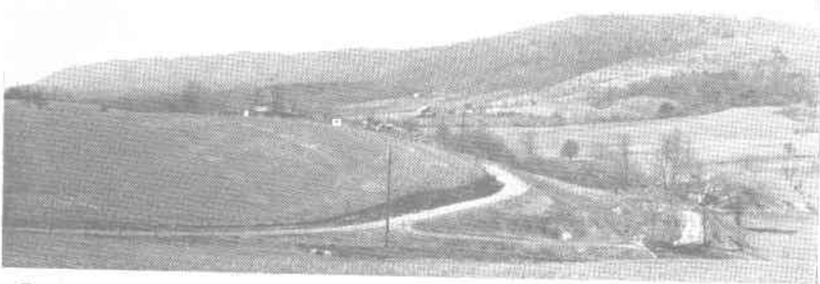
B. Funkhouser Knob southwest of Fawcetts Gap, Frederick County, Virginia. Looking southwest. The knob is underlain by a lens of Tuscarora sandstone about 250 feet thick.



C. Little North Mountain southwest of Wheatfield, northern Shenandoah County, Virginia. The ridge has an average altitude of 2000 feet.

A. Wisecarver Gap, Frederick County, Virginia. The Tuscarora sandstone is approximately 30 feet thick in gap, 150 feet on the left, and 50 feet on the right. Great North Mountain in the distance.

B. Funkhouser Knob southwest of Fawcetts Gap, Frederick County, Virginia. Looking southwest. The knob is underlain by a lens of Tuscarora sandstone about 250 feet thick.



C. Little North Mountain southwest of Wheatfield, northern Shenandoah County, Virginia. The ridge has an average altitude of 2000 feet.

lack of these two thin formations at the gap represents a stratigraphic unconformity. The prominent knob just south of Wisecarver Gap (Pl. 26A) is underlain by at least 150 feet of Tuscarora sandstone. The local thickening of the sandstone resembles the occurrence at Round Hill (Pl. 24A). From this point the Tuscarora thins gradually southwestward to about 5 feet along the road leading through Fawcetts Gap.

The section through Fawcetts Gap (Pl. 25B) includes Martinsburg, thin Tuscarora, Marcellus, Hamilton, Brallier, Chemung, and Hampshire. The absence particularly of the Cayuga, Helderberg-Oriskany, and Onondaga formations makes this section unique for the part of Little North Mountain discussed in this paper. The explanation of this phenomenon may be a matter of some conjecture, but the lack of any apparent distortion, such as drag folding and brecciation of the associated beds, and the observed gradual diminution in thickness and final disappearance of the formations north of Fawcetts Gap suggest some depositional and erosional causes rather than faulting. It should be emphasized that *the entire Silurian System is represented at this locality by a total thickness of 5 feet* (Pl. 25B). About 600 feet east of the Tuscarora, along the road leading to Quaker Hill Cemetery (Pl. 23), is a thin lenticular body of fractured Mosheim limestone, approximately 1 mile long, lying between Elbrook limestone and Martinsburg shale. There are several similar dislocated limestone slivers along the thrust fault farther to the southwest.

The area southwest of Fawcetts Gap for about one-fourth of a mile, which is mostly concealed, is mapped as a thin continuous body of Tuscarora, but it is possible instead that it occurs in a series of thin lenses. Beginning on the northeast slope of Funkhouser Knob (Pl. 26B), the sandstone increases rapidly in thickness to about 250 feet at the summit (Pl. 23, Sec. G-G′). A section through this place is similar to Fawcetts Gap, except for the thickened Tuscarora. About 1000 feet east of the summit (Pl. 23) is an ellipsoidal body of Chambersburg limestone approximately 1 mile long and a smaller lens of Mosheim limestone. These masses are bounded by Elbrook limestone on the east and Martinsburg shale on the west. On the southwest side of Funkhouser Knob is an overlap of Onondaga, Helderberg, and Cayugan upon the Tuscarora.

Through Baldwins Gap (Pl. 23, Sec. H-H′) the Elbrook limestone is thrust upon about 20 feet of Tuscarora sandstone. To the west the sequence includes Cayugan, Helderberg, Onondaga, Marcellus, Hamilton, Brallier, Chemung, and Hampshire. The

Hampshire formation rises out of the Devonian syncline just south of the Frederick County boundary west of Baldwins Gap.

From Baldwins Gap southwest to the gap east of Coalmine School the Tuscarora thickens from 50 to 175 feet, and a thin Juniata appears near the summit of the low ridge. The Juniata crops out as a lenslike body with a thickness of about 10-20 feet. Along Indian Run the Cayugan rocks have thinned to 175 feet, whereas the Helderberg is about 500 feet across the strike. It is most probable that this apparent abnormal thickness is caused by repetition due to folding. About 800 feet east of the vertical cliff of Tuscarora crossing Indian Run is another thin mass of Mosheim limestone lying between Martinsburg and Elbrook.

Discontinuous outcrops of several formations are the rule between the gap east of Coalmine School and Wheatfield. Midway between these points, Martinsburg shale is adjacent to Helderberg limestone without any visible evidence of brecciation, drag folding, or other structural features which would suggest faulting. North and south of this locality the Tuscarora crops out as a thin bed and is followed within a few hundred feet along its northwestern boundary by Cayugan shale.

The southwestern extension of the Tuscarora thins out at the secondary road 1000 feet northeast of Wheatfield (Pl. 23, Sec. I-I′); thus it forms a distinct lens with a maximum thickness of about 150 feet. Along Virginia Route 55 through Wheatfield, approximately 50 feet of Tuscarora sandstone is followed to the west by about 300 feet of Cayugan, 200 feet of Helderberg, possibly thin Onondaga, and the more or less persistent thickness of Marcellus, Hamilton, Brallier, and Chemung.

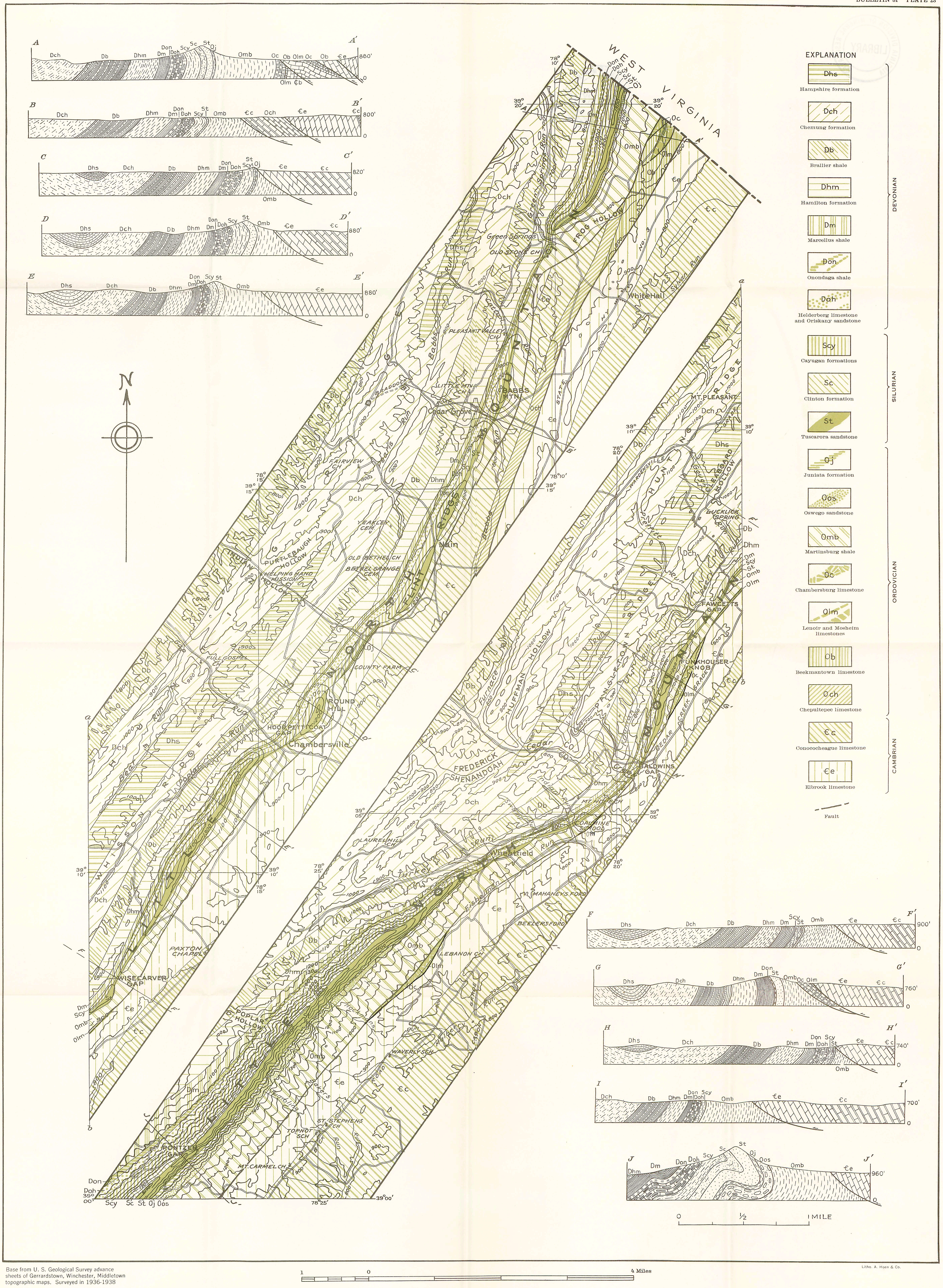
Southwest of Wheatfield (Pl. 26C), and extending to the southwestern boundary of the area mapped, all of the formations with their maximum thickness are introduced. In the vincinity of Pontzer Gap (Pl. 23, Sec. J-J′), the Tuscarora is about 300 feet thick. To the east the normal sequence includes about 100 feet of Juniata, about 200 feet of Oswego sandstone and conglomerate, and a wide expanse of Martinsburg shale in fault contact with Elbrook limestone along its eastern boundary. To the west the widths of the various outcrop belts suggest 200 feet of Clinton, 400 feet of Cayuga, 400-500 feet of Helderberg-Oriskany, 200 feet of Onondaga, and 500 feet of Marcellus. These figures are only estimates since the section is not continuously exposed. About half a mile east of the mountain and 1 mile southwest of Wheatfield is another lens of Chambersburg and Mosheim along the low angle thrust fault previously described. It was not possible to delimit accurately the northeastward extension of the Clinton, Juniata, and Oswego, but it is known that these formations extend northeast of a point 1½ miles southwest of Wheatfield and southwest of Virginia Route 55.

CONCLUSIONS

The characteristics of the formations of Little North Mountain, as described above, suggest that the discontinuities for the most part antedate Appalachian orogeny and are, therefore, directly related to an involved history of sedimentation. It is not to be denied that some displacement along certain zones of weakness, where deposition was slight, could have been a contributing factor in producing the present structures. Such an allied factor is indicated at a few places along the mountain.

All of the beds, including upper Ordovician, Silurian, and lower Devonian, are overturned steeply to the southeast. East and southeast of Little North Mountain, along the western margin of the Great Valley of Virginia, is a low-angle thrust fault which parallels the trend of the mountain through Frederick and northern Shenandoah counties.

The writers find it difficult to reconstruct the sedimentary environment, but it appears most reasonable to assume that the shallow seas from Upper Ordovician to Lower Devonian, inclusive, locally were fringed with low islands, peninsulas, straits, lagoons, and other near-shore surface features. One or more of these geographic conditions, in conjunction with oscillations of the sea and fluctuations in sedimentation, are believed to have caused the marked variations in the thickness of the formations and the stratigraphic discontinuities along Little North Mountain.



Base from U. S. Geological Survey advance sheets of Gerrardstown, Winchester, Middletown topographic maps. Surveyed in 1936-1938

Litho. A. Hoen & Co.

GEOLOGIC MAP OF LITTLE NORTH MOUNTAIN IN NORTHERN VIRGINIA

BY CHARLES BUTTS AND RAYMOND S. EDMUNDSON

Contour interval 100 feet

INDEX