COMMONWEALTH OF VIRGINIA

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 52

Geology of the Appalachian Valley in Virginia

By

CHARLES BUTTS

Part I—Geologic Text and Illustrations

PREPARED IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

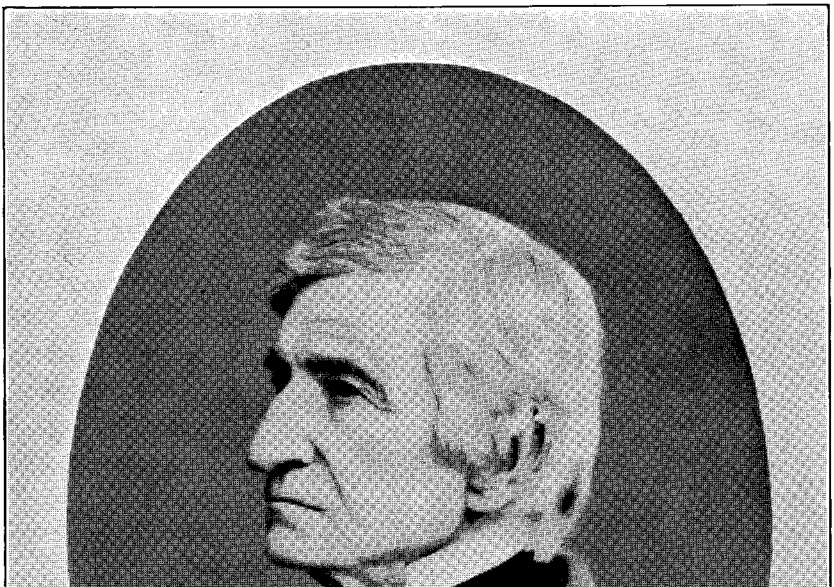
UNIVERSITY, VIRGINIA

1940

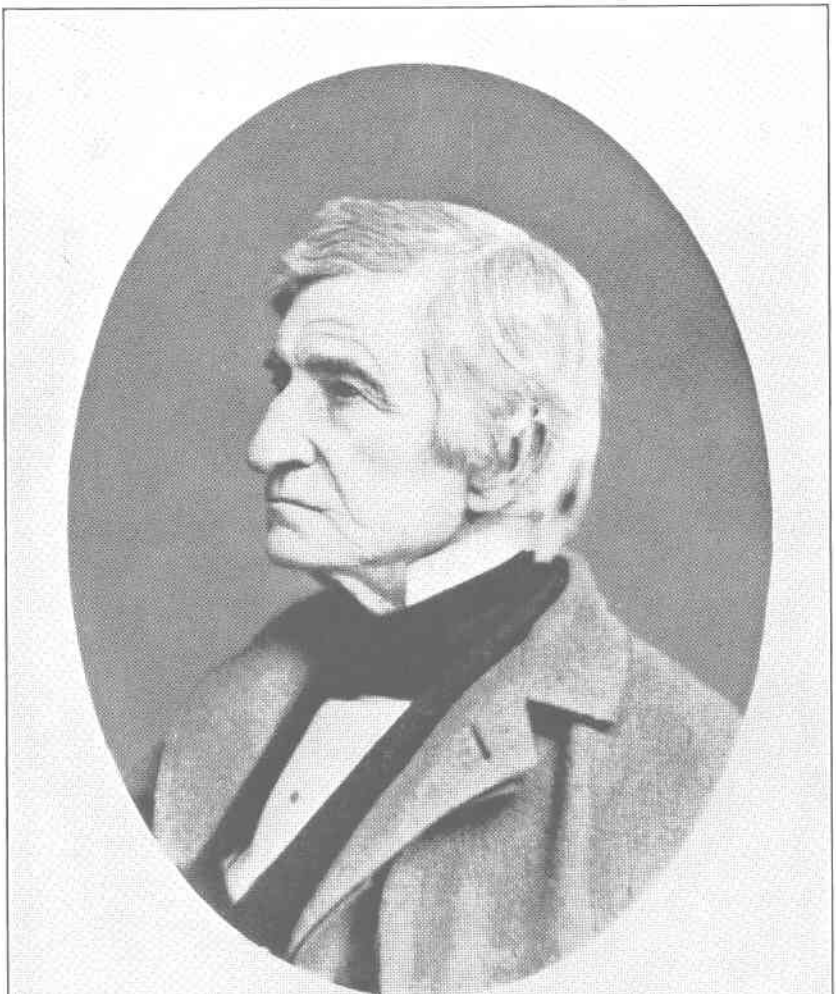
RICHMOND:

Division of Purchase and Printing

1940



William Barton Rogers



William Barton Rogers

WILLIAM BARTON ROGERS CENTENNIAL

Dedicated to the Memory

and in

Appreciation of the Fundamental Work

of

William Barton Rogers

First State Geologist of Virginia

1835-1842

ERRATA

Virginia Geological Survey, Bulletin 52, Part I

PAGE

xxiii. Plate 7B should read Clinch Mountain.

66, line 29. Insert other before genera.

153, line 10. *Raphistomina* sp. should read *Eotomaria?* sp.

174, line 22. Northwest at beginning of line should read northeast.

201, Author's note: Recent studies have cast doubt on the stratigraphic position and correlation of the Chambersburg in Virginia.

203, line 18. Route 81 should read 91.

211, line 46. *Raphistomina?* sp. should read *Eotomaria?* sp.

224, line 22. Route 81 should read 91.

244, lines 4 and 5. Author's note: Recent studies show that the ferruginous sandstone (Cacapon) extends south along Clinch Mountain into Washington County.

250, line 28. *Pentamerus oblongatus* should read *Pentamerus oblongus.*

260, line 8. Route 81 should read 91.

297, line 24.
298, line 28. } *Platyostoma* should read *Platystoma.*

311, line 38. After Route 11 insert (old location).

312, line 6.
399, line 37. } Route 81 should read 91.

477, line 40. *Homotoma* should read *Hormotoma.*

479, line 9. *Raphistomina* should read *Eotomaria?*

499, line 42.
500, line 1. } Rocky Gap sandstone should read Stony Gap sandstone.

527, line 44. Omit Rocky Gap sandstone.

529, line 2. After Stony Gap sandstone, add pages 499 and 500.

538, line 44. After *Eotomaria* sp., add pages 123, 153, 211, and 479.

540, line 10. *Homotoma* should read *Hormotoma.*

545, line 13. *Pentamerus oblongatus* should read *Pentamerus oblongus.*

546, line 37. *Platyostoma* should read *Platystoma.*

548, lines 8 and 9. Omit *Raphistomina* sp.

VIRGINIA CONSERVATION COMMISSION

N. CLARENCE SMITH, *Chairman,* Richmond

D. D. HULL, *Vice-Chairman,* Roanoke

MARSHALL B. BOOKER, Halifax

JAMES ASHBY, Stafford

L. E. LICHFORD, Lynchburg

RICHARD A. GILLIAM,
Executive Secretary and Treasurer, Richmond

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., August 1, 1939.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 52 of the Virginia Geological Survey series of reports the manuscript and illustrations of a monograph on the *Geology of the Appalachian Valley in Virginia,* by Dr. Charles Butts, formerly of the U. S. Geological Survey but retired. He is now on the staff of the Virginia Geological Survey.

The field work on which this report is based was started in Virginia in 1926 and it eventuated in part in Virginia Geological Survey Bulletin 42, "Geologic Map of the Appalachian Valley of Virginia with Explanatory Text," published in 1933. This report is complementary to that map, and contains the discussion of the characteristics of each of the formations shown thereon. Other salient and interesting features of the geology of the Valley are described and discussed, as indicated in the "Contents."

This report is in a sense the summation of the geologic studies of the author in the Appalachian Valley from New York State to Alabama, inclusive, during a lifetime of field research and surveying devoted to that vast region with its complex problems. This work has resulted in the production of maps, of which that in Bulletin 42 is one, and of descriptive texts that have advanced greatly the interpretation of the sedimentary formations of the Appalachian region and has laid the foundation for future more detailed and specialized mapping and study. This work has been invaluable in assisting the economic development of the nonmetallic mineral resources of the Valley.

This report will be issued in two parts. Part I consists of the geologic text and illustrations of the topography, stratigraphy, and structure. Part II consists of the plates of fossils from the described formations with accompanying brief explanatory text, including descriptions of some new species. By this arrangement the undue bulk of a single volume will be avoided and extra copies of Part II will thus be separately available for students and others who may have need of this comprehensive reference data.

It is appropriate that this volume should be issued in commemoration of William Barton Rogers, first State Geologist of Virginia (1835-1841), who during his residence at the University of Virginia laid so well the foundations of all later geologic work in the State.

The portrait of Professor Rogers, used as the frontispiece, is from the Account of the Memorial Meeting Held October 12, 1882, by the Society of Arts of the Massachusetts Institute of Technology.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, August 9, 1939.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

CONTENTS

ILLUSTRATIONS

TABLES

PREFACE

This description of the geology of the Appalachian Valley in Virginia is based upon field surveys begun in 1926 and continued during each field season to 1931, inclusive. Traverses were made across the Valley, throughout its length of 400 miles, and many sections showing the sequence of the formations in extensive exposures all along the Valley were studied in detail. Extensive collections of fossils were made for their bearing upon study of the stratigraphy, as the especial object in mind.

A geologic map of the Appalachian Valley in Virginia, designed to accompany this report, was published by the Virginia Geological Survey in Bulletin 42, 1933.

Use has been made of past contributions to the knowledge of the geology of the Valley. Particular mention should be made of the pioneer work of William B. Rogers while at the University of Virginia and first State Geologist of Virginia. He is still regarded as one of the foremost American geologists. Professor Rogers and his brother, H. D. Rogers, in Pennsylvania, were the first to interpret correctly the structural geology of the Valley, as much as 100 years ago. Professor Rogers' annual reports were illustrated by a series of excellent geological cross sections of the Valley that have been improved only by refinement through later detailed work. The main advance upon Rogers' work has been the subdivision of his large stratigraphic units into smaller units which have been distinguished by suitable names. Other geologists who are entitled to credit are M. R. Campbell, N. H. Darton, and Arthur Keith, the results of whose work have been published mainly in geologic folios of the U. S. Geological Survey. Some of their larger stratigraphic units, such as the Shenandoah limestone and Jennings, or Kimberling, shale, have also been subdivided in the present work in order to bring the stratigraphy and nomenclature of the rocks in the Valley in Virginia into harmony with the usage in New York and Pennsylvania.

With the exceptions named, and a few others, the subdivisions and names adopted in the folios are adequate, and the boundary lines are accurately drawn upon the geologic maps. Unfortunately, there were some errors in correlating the formations across the Valley; for example, the red Juniata formation and the Martinsburg formation on the northwest side of the Valley were correlated with the Bays sandstone and the Sevier shale (Ottosee), respectively, on the southeast side of the Valley. In fact, the Bays sandstone is the same as the Moccasin formation, and the equivalent of the Sevier was included in the Chickamauga limestone on the northwest side of the Valley. These errors, first detected by Ulrich early in 1900, have been corrected in the present work.

This work was a cooperative project by the Virginia Geological Survey and the U. S. Geological Survey, to the time of the author's retirement from the Federal Survey in 1933. From that time, the work has been continued by the Virginia Geological Survey. The project was planned by Thomas L. Watson, State Geologist. It was begun and supported by Wilbur A. Nelson as the succeeding State Geologist. Arthur Bevan, the next and present State Geologist, supported the project to its completion and planned the separate publication of the geologic map of the Valley, mentioned above. The author here expresses his appreciation for the enthusiastic and effective cooperation of these men. Especial credit is due to E. O. Ulrich who has perhaps contributed more than any one else to a knowledge of the general stratigraphy of the Valley. Charles E. Resser of the U. S. National Museum photographed the fossils illustrated in Part II. This was a laborious and valuable contribution to the investigation and to this publication. Thanks are due also to R. S. Bassler, Josiah Bridge, G. A. Cooper, and E. O. Ulrich for help in the identification of fossils, and to the National Museum for the use of storage space and facilities.

The author wishes to express here appreciation of the help of his field assistants, who were Reid P. Meacham, Wade Stafford, C. R. L. Oder, Raymond S. Edmundson, Benjamin Gildersleeve and Robert A. Laurence. The last four are now actively engaged in geologic work.

In this work, with the geologic map published in 1933 (Virginia Geol. Survey Bull. 42), available knowledge of the geology of the Appalachian Valley in Virginia has been assembled and made easily accessible to geologists and others. It is hoped that it will serve as a stepping stone to future detailed work.

CHARLES BUTTS

December 4, 1939.

Geology of the Appalachian Valley in Virginia

By Charles Butts

INTRODUCTION

The common thought of mankind is that the earth from the time of its creation has always been as it now is. People generally think the part of the earth where they live has always been the same. The mountains, valleys, plains, rivers, rocks, and soils are thought to be unchanged since creation. This assumption is commonly accepted as final and no inquiry as to causes and effects arises.

It is indispensable to substitute for this simple conception the fundamental and amply demonstrated concept that the present condition of the earth is the result of a succession of changes that have taken place through a period of time measured in hundreds of millions of years. These changes are now in progress but so slowly that they are not generally noticed. Rivulets are actively gullying the fields, and the soil and loose rock are carried in the muddy creeks and rivers to the sea where they are deposited as sediments to form the solid rocks of the future. As is well known, the delta of the Mississippi is being gradually extended in this way into the Gulf of Mexico. In some places the ocean shore lines are rising or sinking, though so very slowly as to be scarcely perceptible, yet enough in time to cover the sinking land with the sea or to drain the shallow water from the ocean floor along the shore and to change it into dry land. Extensive changes along sea coasts have taken place in historic time through the action of waves and currents, as for example around the coasts of England, the island of Helgoland, and the Mediterranean Sea.[1] Examples of another type of change are the vertical and horizontal displacements of the earth's crust which accompanied the great California earthquake of 1906, and the outpourings of molten rock (lava) by Mt. Etna and Kilauea crater in the last few years. The fact of continuous change, based upon observation, is beyond doubt, but it is not generally realized that the present features of the surface of the earth are the cumulative results of such gradual natural changes throughout long ages.

[1] These changes are discussed in most standard textbooks on geology.

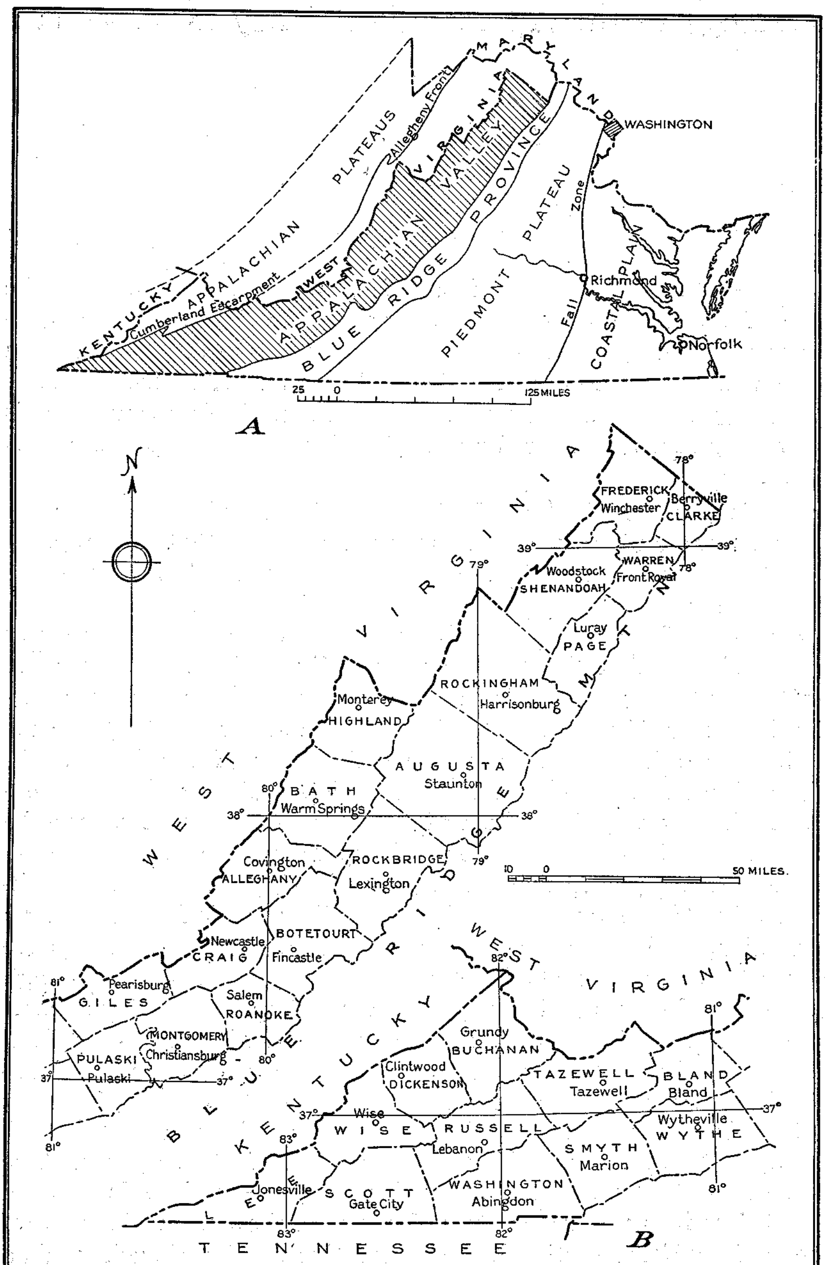


FIGURE 1.—A, Index map showing the location of the Appalachian Valley in Virginia and the physiographic divisions of the State; B, Index map showing the area and the counties described in this report.

Applying this fundamental concept of constant change to the exposition of the geology of the Appalachian Valley of Virginia, it will be helpful to a clearer understanding of the rocks and land forms to start at the beginning of the record and trace the development of the region to the present time.

According to reliable determinations of the age of the rocks recording the geologic events, about 500,000,000 years ago, when the eastern part of North America was a great plain near sea level, underlain by crumpled crystalline rocks, such as granite, gneiss, and schist, a long and comparatively narrow belt of that plain began to subside below sea level and to admit the waters of the ocean. The axis of this subsiding area extended from Newfoundland on the northeast through parts of New England, southeastern New York, east-central Pennsylvania, central and western Virginia, eastern Tennessee, and northeastern Alabama. The same or a similar axis of subsidence extended across the lower Mississippi Valley and northern Arkansas into the Arbuckle Mountain region of southern Oklahoma. This depression, or trough, affecting the solid crust of the earth to a great depth has been called the Appalachian geosyncline. As this geosyncline slowly continued to subside it was just as slowly and rather constantly filled about to water level with sediment—mud, sand, and gravel—washed in from bordering lands. In time this sediment was cemented and consolidated into the stratified shale, sandstone, and conglomerate now seen in the Valley. Much limy sediment, derived in solution from the bordering lands, was also deposited at many times throughout the trough. Upon consolidation it became the stratified limestone and dolomite of the Valley.

The formations were deposited as substantially horizontal layers or great lenticular bodies of sediment thinning out at the edges. Each later deposit was superposed upon the preceding one so that in an undisturbed sequence, or where the beds have not been tilted to the vertical, the underlying formations are always the older. Though deposition in the geosyncline was generally continuous, there were major pauses in subsidence or some reversals of movement that produced corresponding interruptions in the process. The maximum thickness of sediment in the Virginia portion of the geosyncline was 40,000 to 50,000 feet, or approximately 8 to 10 miles; the average thickness about 6 miles; and the total volume about 60,000 cubic miles. Many of these formations extended over tens of thousands square miles.

The time required to fill the Appalachian geosyncline constitutes the Paleozoic era of geologic time.[2] The length of the era

[2] The era is also delimited by other criteria, including great changes in life and great deformations of the earth's crust.

is estimated at 368,000,000 years. Since late Paleozoic the Appalachian region has been elevated high above sea level and laterally strongly compressed; the horizontal strata have been buckled and crumpled into their present inclined attitudes; and more or less continuously to the present the rocks have been eroded and the debris transported to the seas. At intervals, too, vertical uplift has maintained the elevated position of the region in spite of the great wastage by erosion. In this manner the present surface features of the Valley have been carved out of the sedimentary rocks that compose the foundations of the region.

The time required for these processes is estimated at 185,000,000 years. It is divided into the Mesozoic (oldest), Cenozoic, and Psychozoic eras.[3]

[3] See chapter on "Geologic history."

APPALACHIAN VALLEY

GENERAL RELATIONS

The Appalachian Valley in Virginia comprises the long but relatively narrow part of the State lying northwest of the Blue Ridge northeast of Roanoke and of the northwest slope of the mountainous Blue Ridge province southwest of Roanoke. (See Fig. 1.) This is but a part of the Valley as a whole which extends northeast and southwest far beyond the boundaries of Virginia. The area described in this report also includes that part of the Appalachian Plateaus marked by the coal fields of the southwestern part of the State. (See Fig. 1.)

The Appalachian Valley is a subdivision of a larger region called the Appalachian Highlands which is bounded on the southeast by the well-known Fall Zone, or "Fall Line," and on the northwest by a less definite, sinuous line drawn from northwestern Alabama to Cleveland, Ohio, and thence northeastward.

The Appalachian Highlands include four natural divisions: the Piedmont Upland at the southeast, the Blue Ridge province, the Valley and Ridge province, long also known as the Appalachian Valley, and the Appalachian Plateaus. The Piedmont Upland, a rolling surface, rises from about 200 feet above sea level at the Fall Zone to about 500 feet in the vicinity of the Potomac at the southeast base of the Blue Ridge, and about 1500 feet towards the North Carolina line. The Blue Ridge province includes besides the Blue Ridge proper the mountainous region of southern Virginia, North Carolina, South Carolina, and Georgia next west of the Piedmont Upland. This is the highest region east of the Rocky Mountains and culminates in Mt. Mitchell, North Carolina, which rises to an altitude of 6711 feet. Many other knobs range from 5000 to more than 6000 feet. The Piedmont and Blue Ridge provinces are underlain chiefly by very old rocks that comprise the crystalline basement of the Appalachian geosyncline briefly described in the Introduction.

The Appalachian Valley, or Valley and Ridge province, includes the relatively narrow belt of valley and ridge country between the northwestern ridges of the Blue Ridge province and the eastern escarpment of the Appalachian Plateaus. This escarpment extends with local interruptions from Pennsylvania to Alabama and has different names in different places. In Pennsylvania and Maryland it is called the Allegheny Front. In West Virginia it is Back Allegheny Mountain and in southwestern Virginia, northeast of Cumberland Gap, it is the Cumberland escarpment, or Cumberland Mountains. From Marlinton, West Virginia, to St. Paul, Virginia, there is no definite scarp and the boundary between the Appalachian Valley and the Appalachian Plateaus is placed along the southeast margin of the coal fields. Southwest of Big Stone Gap the Cumberland escarpment becomes a bold and striking feature which at the White Rocks 12 miles northeast of Cumberland Gap rises abruptly nearly 2000 feet above the Valley floor. The Pinnacle at Cumberland Gap, 1000 feet above valley level, marks the summit of the scarp at the southwest corner of the State.

The Appalachian Valley as a continuous physiographic feature extends from central Alabama northeastward to central Pennsylvania. Its rocks, however, extend far beyond this locality by way of the Hudson Valley, Lake Champlain, and the St. Lawrence River, to northwestern Newfoundland.

The Appalachian Plateaus include the elevated rolling and deeply dissected region northwest of the Appalachian Valley. On their southeast margin the plateaus reach an altitude of 2400 to 3000 feet on the Allegheny Front in Pennsylvania, 4800 feet in Back Allegheny Mountain of West Virginia, and 2000 to 3400 feet on the Cumberland escarpment in Virginia and Tennessee. From this high southeastern margin the plateaus slope westward to altitudes of 1000 to 1200 feet in central Ohio and Kentucky. The southeastern part coincides approximately with the Appalachian bituminous coal fields.

TOPOGRAPHY

General Character

As noted by the Virginia geologist William B. Rogers as early as 1835, the Appalachian Valley in Virginia is naturally divided longitudinally into two obviously different parts. Along the southeastern side is a belt of country of varying width and approximately flat in cross section dominated by valleys but with interspersed ridges and hills. (See Pl. 1.) Along the northwest side is a belt dominated by ridges but with interspersed valleys.

Valley Belt

The southeastern belt is best developed along Shenandoah River, where it is commonly known as Shenandoah Valley, but passes southwestward beyond the Shenandoah drainage into regions drained successively by the James, New, and Tennessee rivers. Rogers designated this belt as the Greater Appalachian Valley. It is bounded on the southeast by the Blue Ridge which for considerable distances rises abruptly above the Valley floor, as shown in Plate 2E. From West Virginia northeast of Frederick County southwest to the latitude of Lexington, Virginia, it is bounded on the northwest by Little North Mountain or by its southwestward continuation west of Lexington. It is 20 miles wide at Harrisonburg, but at Buchanan its width decreases to 2 miles between Purgatory Mountain and the Blue Ridge. Generally it is 10 miles or more wide. Its continuity is broken by Catawba and Fort Lewis mountains in Roanoke County, and elsewhere to the southwest by other ridges and hills. In Pulaski County it widens out into the Dublin plain. (See Pl. 2C.) Southwest of the Dublin plain the width of the Valley is decreased by the southeastward extension of Draper Mountain. Southwest of Draper Mountain the Valley plain is practically continuous to Tennessee. In the vicinity of Abingdon it is 18 miles wide between Grosses Mountain on the southeast, representing the Blue Ridge, and Clinch Mountain on the northwest, which stands in the same relation to the Valley plain as does Little North Mountain in northern Virginia.

To the eye the slope and inequalities of the Valley floor in many places are so slight as to be imperceptible. (See Pl. 1A.) However, from Winchester where its altitude is 700 feet, the Valley floor rises westward to 1000 feet at the base of Little North Mountain and decreases eastward to 500 feet at Shenandoah River. Southwestward the surface of this plain rises to an altitude of about 1400 feet at Harrisonburg, 1500 feet at Lexington, 2200 feet in the Dublin plain (Pls. 2C and 10A) and to its maximum altitude of 2400 to 2600 feet midway between Wytheville and Marion. Thence it descends southwestward to 2000 feet near Abingdon where the plain is nearly as flat as at Winchester. (See Pl. 2D.)

RIDGES ON THE VALLEY FLOOR

Massanutten Mountain, the most prominent of the ridges in the Valley, is in the midst of Shenandoah Valley. It extends 45 miles from Strasburg southwestward to Harrisonburg, and rises abruptly 1000 to 1500 feet above the level of the plain; hence is one of the most striking features of the entire Valley. It is a complex of several subparallel ridges enclosing Fort Valley, 2½ miles wide, drained by Passage Creek. (See Pl. 4A.) These ridges are breached at New Market Gap where the Lee Highway (U. S. 211) crosses the mountain belt. Southwest from this gap the ridges converge into a narrower belt of alternating closely spaced ridges and intervening narrow valleys or ravines and finally terminate

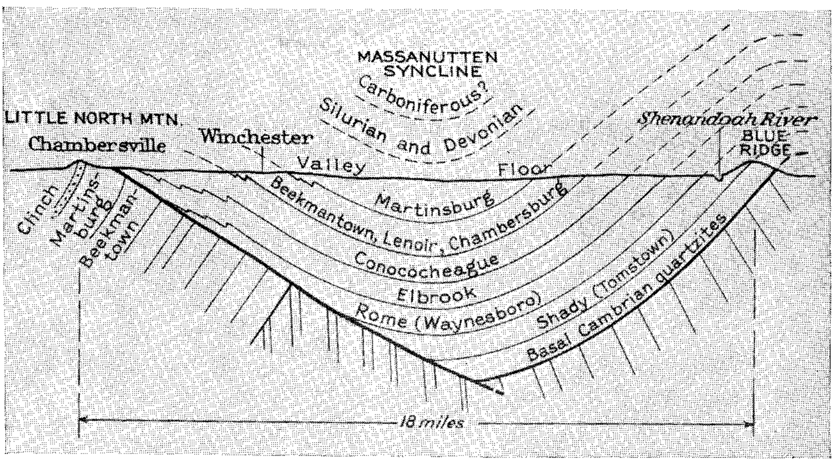
PLATE 1

A. Southeast across the Shenandoah Valley from a low ridge in the southwest environs of Winchester, Frederick County. The surface is part of the Harrisburg peneplain. The horizon is the crest of the Blue Ridge, about 15 miles to the east.

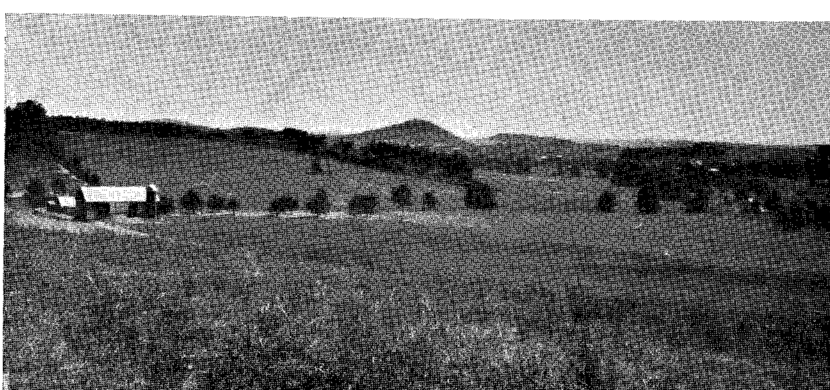
B. Sketch structure section across the Valley in the line of sight of A. The thickness of strata removed by erosion to produce the rather even valley-floor surface is roughly represented. It probably amounts to at least 25,000 feet.

C. Valley-floor surface with Mole Hill, a volcanic plug, in distance. Looking northeastward from a point 7 miles west of Harrisonburg, Rockingham County. Fragments of columnar basalt have been found on Mole Hill. The foreground is underlain by Beekmantown limestone and dolomite inclined at about 20 degrees. Owing to its greater resistance the solidified lava withstood the erosion that removed the enclosing limestone and now projects above the surrounding surface.

A



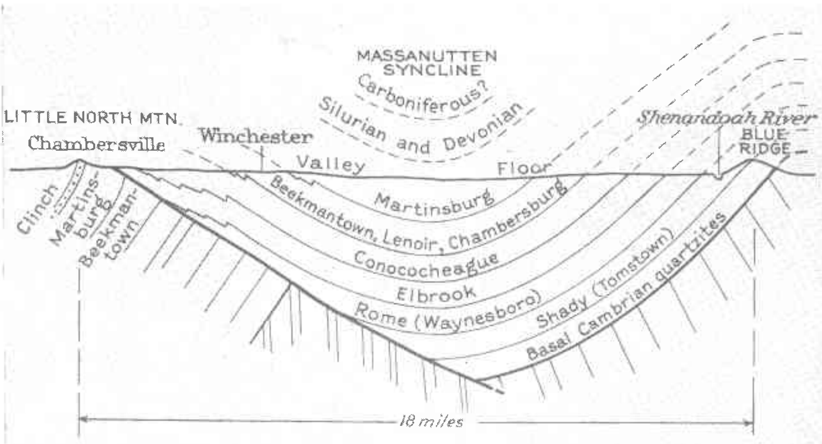
B



C

TOPOGRAPHY

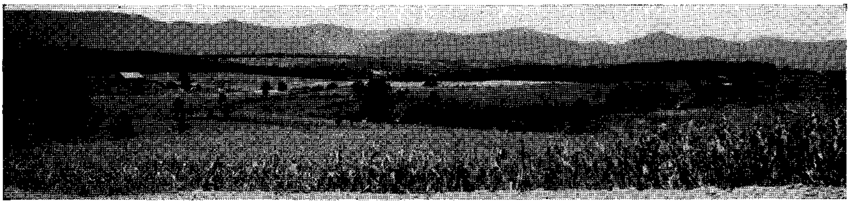
A



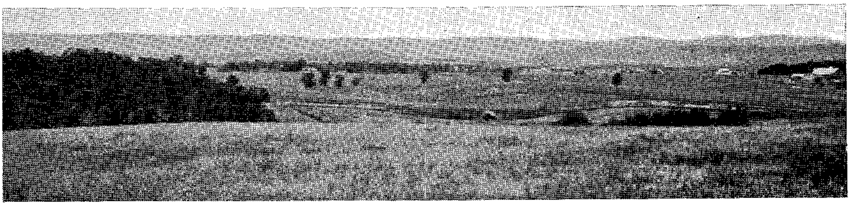
B

C

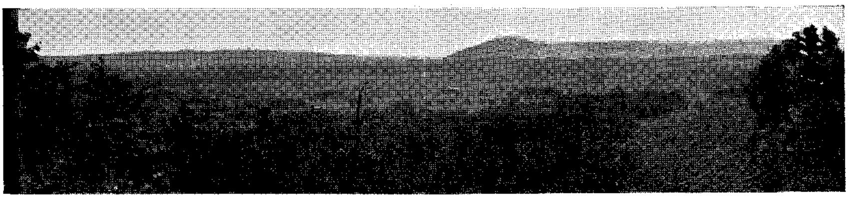
TOPOGRAPHY



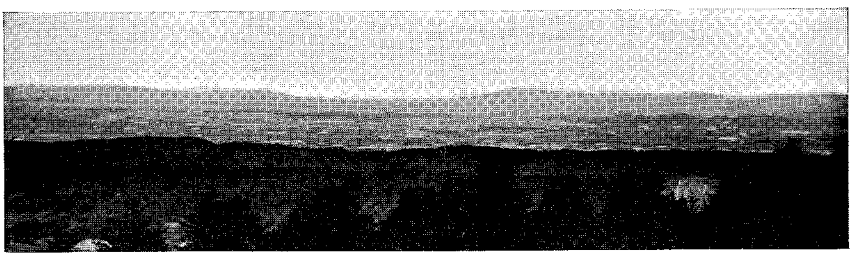
A



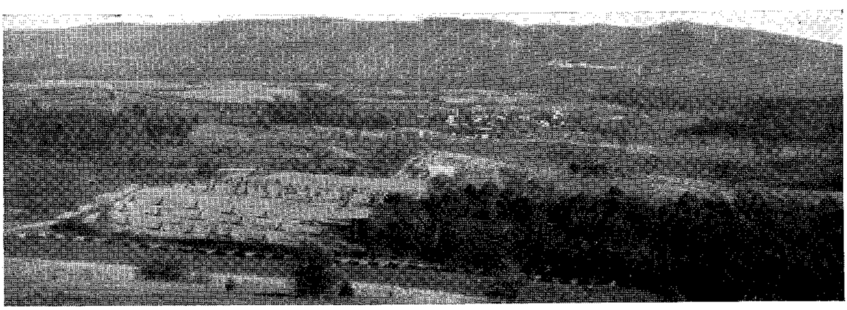
B



C

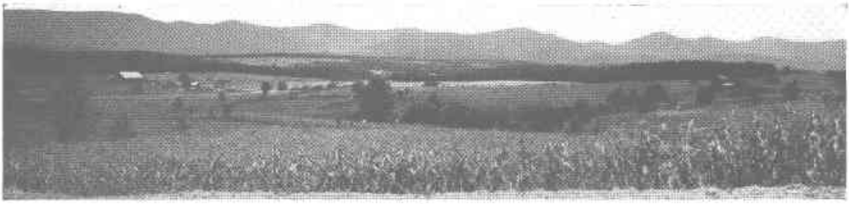


D

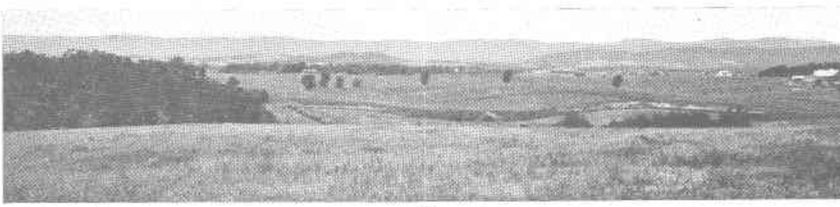


E

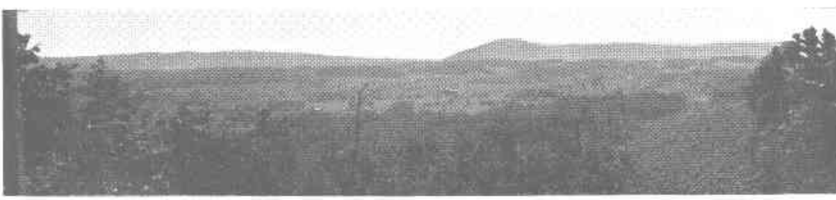
TOPOGRAPHY



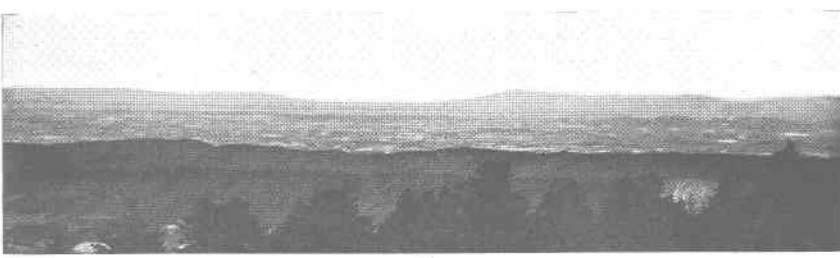
A



B



C



D

E

TOPOGRAPHY

PLATE 2

A. Across Stony Creek Valley, near Orkney Springs, Shenandoah County, to Great North Mountain. Northeast from road about 3 miles northwest of Orkney Springs. The middle ground is on Devonian shale and sandstone.

B. Northwest across the Valley to Great North Mountain from the Lee-Jackson Highway (U. S. 11), 5 miles northeast of Mount Jackson, Shenandoah County. The Harrisburg peneplain is in the foreground. The first ridge and the line of knobs to the left are Little North Mountain and its broken continuance to the southwest.

C. The Dublin plain, a part of the Harrisburg peneplain, in Pulaski County. Looking south-southeast from the summit of Little Walker Mountain near State Route 100, 6 miles northwest of Dublin. The altitude of the Dublin plain is 2100 to 2300 feet. Peak Knob at the northeast end of Draper Mountain, altitude 3376 feet, in middle distance; Macks Mountain in the Blue Ridge, altitude 3404 feet, in the extreme distance at the left. The distance to Peak Knob is 11 miles and to Macks Mountain is about 20 miles.

D. Northwest from Whitetop Mountain across the dissected Harrisburg peneplain in Washington County, to Clinch Mountain. The sag in Clinch Mountain, near the middle, shows the position of Little Moccasin Gap. The first ridge in the foreground is Straight Mountain and the second ridge is Grosses Mountain, both on the Chilhowee sandstones (Lower Cambrian). The Valley is about 18 miles wide between Clinch and Grosses mountains.

E. Northwest front of the Blue Ridge in Augusta County. Southeast across the Valley from the hills about 1 mile northwest of Greenville. The northwest escarpment of the Blue Ridge is exceptionally prominent here. Its height is about 1600 feet. The white scar on the slope is a sand pit. The valley floor is mainly on the Rome (Waynesboro) and Elbrook formations. The town of Greenville is in the middle distance.

in The Peak southeast of Harrisonburg, one of the most impressive landscape features in Virginia. It is in full view for several miles along the Spottswood trail (U. S. Route 33), and throughout the region for miles to the southwest. (See Pl. 3C.) Massanutten Mountain ends at the north in a broad curving buttress transverse to the Valley which is breached by the deep gorge of Passage Creek.

Catawba and Fort Lewis mountains northwest of Roanoke, and Draper Mountain near Pulaski, also rise conspicuously above the Valley floor. Round Hill, 1½ miles northwest of Bridgewater, Rockingham County; Mole Hill (Pl. 1C), 4½ miles west of Harrisonburg; and Buck Hill, 6 miles southwest of Edinburg, are conspicuous knobs on the Valley floor. They rise about 400 to 500 feet above the Valley level and are visible for miles. One of the best examples of isolated ridges on the Valley plain is the ridge composed of Reed (Mills) and Coyner mountains, a few miles northeast of Roanoke. Southeast of Wytheville, Lick Mountain rises 1200 feet above the Valley floor. Similarly Glade Mountain, 7 miles east of Marion, rises 1900 feet above the Valley level. Immediately southeast of Marion are rugged picturesque ridges. Still farther southwest, southeast of Abingdon, the Great Knobs and River Knobs rise abruptly 400 feet above the Valley level.

NORTHWESTERN BELT

The topography of the northwestern belt of the Valley, characterized by many high, narrow, linear northeast trending ridges and intervening narrow valleys contrasts so distinctly with that of the southeastern valley plain just described that it must forcibly impress any one who crosses the Valley anywhere. From a high observation point the crests of these ridges appear one beyond and above another as far as one can see. (See Pl. 3A.)

Clinch Mountain, one of the most conspicuous of these individual ridges, extends as a nearly straight, narrow, even-crested ridge from Little Moccasin Gap northwest of Abingdon nearly 100 miles southwest into Tennessee. Northeastward as a broader, zigzag crested mountain it presents a bold southeastern scarp and extends as far as Burkes Garden east of Tazewell, a distance of 45 miles or a total length of about 145 miles. For the whole distance it rises abruptly 1000 to 2000 feet above the Valley level and is everywhere the dominating feature of the landscape. A few knobs on the mountain are more than 4000 feet above sea level. The crest of the ridge is generally even, as shown in Plate 3D, but in places it is uneven and ragged. Good views of Clinch

Mountain from the southeast are to be had from State Route 42 between Saltville and Big Moccasin Gap near Gate City, and of its northwestern aspect from the road between Gate City and Speers Ferry. Clinch Mountain, Pine Mountain, and the intervening Poor Valley are shown in Plate 7.

Walker Mountain which extends from Newcastle, Craig County, in a nearly straight line southwest to a point 8 miles northeast of Abingdon, a distance of about 100 miles, closely resembles Clinch Mountain. Just northeast of New River, it is known as Gap Mountain, presumably on account of the gap in its summit through which the early settlers found passage from Blacksburg to Newport, and through which the highway now passes. Farther northeast to Newcastle it is named Sinking Creek Mountain. Along its entire length Walker Mountain presents a bold front on either side, rising 1000 to 1500 feet above the adjoining valleys.

Other prominent and persistent ridges are Great North Mountain in Frederick, Shenandoah, and Rockingham counties (Pl. 2A); Wolf Creek-Rich Mountain in Giles and Bland counties (Pl. 3A); Salt Pond, Doe, and Butt mountains in Giles County (Pl. 5A); Potts Mountain in Craig County with Nicholls Knob at the north end (Pl. 8C); Lantz, Monterey, and Jack mountains in Highland County; East River-Peters Mountain on the State line in the Bluefield-Narrows area; and Wallen Ridge and Powell Mountain in Lee and Scott counties.

Though an understanding of the ridge topography in the northwestern belt requires a knowledge of the geology, it may be stated here that all of the ridges are coincident with outcrops of hard rock (sandstone) which generally stands in highly inclined positions.[4]

The ridges of the northwestern, or ridge, belt are separated by deep valleys, some of which are very narrow and others broad. These valleys are drained by long creeks flowing in general parallel to the ridges but some have cut through a ridge to make a water gap, as has Little Walker Creek through Walker Mountain 1½ miles south of Poplar Hill, Giles County. (See Pl. 3B.) Sinking Creek Valley in Craig County, Hightown Valley northwest of Monterey, Highland County, and Stony Creek Valley between Orkney Springs and Liberty Furnace (Pl. 2A) are examples of the broader valleys. An example of a narrow gorge-like valley is shown in Plate 9A. The bottoms of all of these valleys descend nearly to the level of the Valley plain on the southeast, so that a

[4] The outcrop bands of hard rock, and therefore the positions of the main mountain ridges, are shown on the geologic map of the Valley (Virginia Geol. Survey Bull. 42) by the purple bands denoted by the symbol Scc. The relations of these rocks to the topography are plainly shown on the structure sections at the bottom of the map.

PLATE 3

A. Southeast across the Valley Ridges from the summit of East River Mountain on U. S. Route 21, about 2½ miles southeast of Bluefield, W. Va. Buckhorn and Wolf Creek mountains are excellent examples of the long, straight ridges that border narrow valleys. The first ridge is Buckhorn Mountain, held up by the Helderberg (Becraft) and Oriskany sandstones. The second ridge is Wolf Creek Mountain, on the Clinch sandstone (Silurian). The knob beyond Wolf Creek Mountain is Round Mountain.

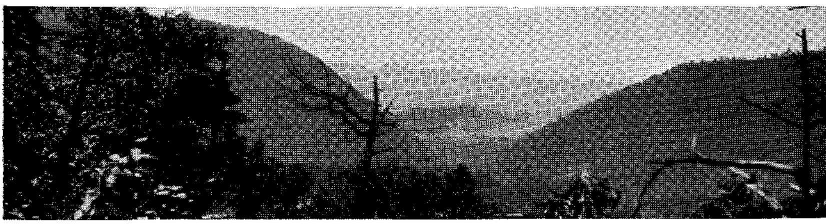
B. Gap of Little Walker Creek through Walker Mountain. On State Route 100 between Dublin, Pulaski County, and Pearisburg, Giles County, 8 miles northwest of Dublin. The gorge is about 1100 feet deep. Looking northwest.

C. The Peak at the south end of Massanutten Mountain, southeast of Harrisonburg. Looking northwest from McGaheysville, Rockingham County. The altitude of The Peak is nearly 3000 feet and the local relief is nearly 1700 feet. The northwest ridge, not visible, and the southeast ridge converge and unite here. The concave profile characteristic of mature mountain and hill slopes is exceptionally well displayed here. The high point and crest of the ridges coincide with the outcrop of the resistant Massanutten sandstone (Silurian) which dips steeply from all points toward the syncline between the ridges.

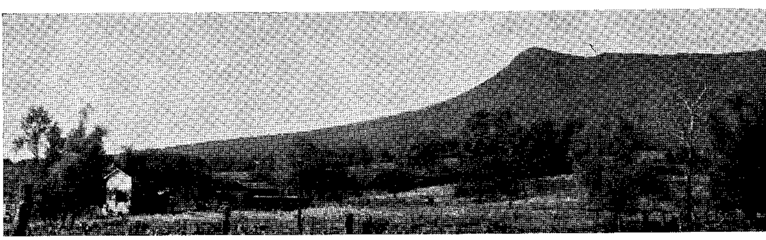
D. Even crest of Clinch Mountain, south of Speers Ferry, Scott County. Glass sand quarries are near the summit. Looking northwest from a point near Cassard, Scott County.

E. Knobs on the Rome formation northeast of Cleveland, Russell County. Looking northwest toward Clinch River from a point on State Route 82, 5 miles northwest of Lebanon, Russell County.

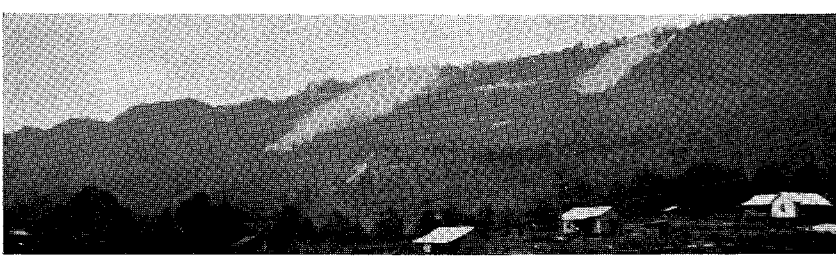
A



B



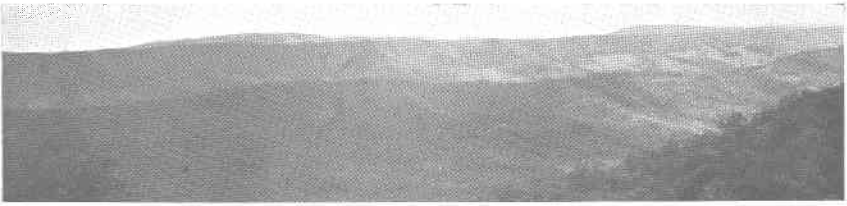
C



D

E

TOPOGRAPHY

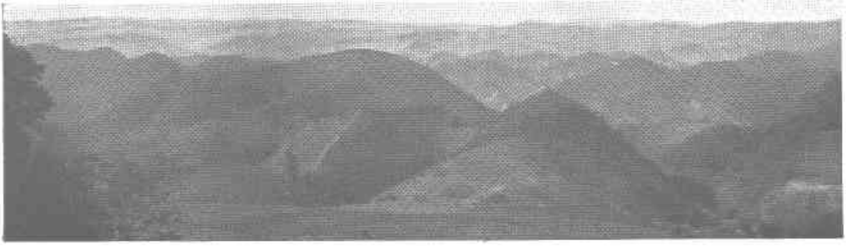


A

B

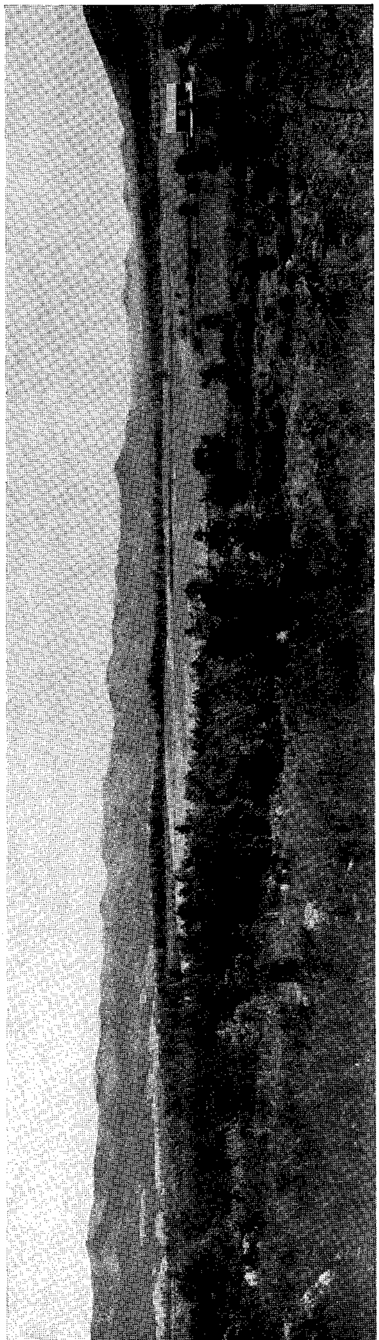
C

D



E

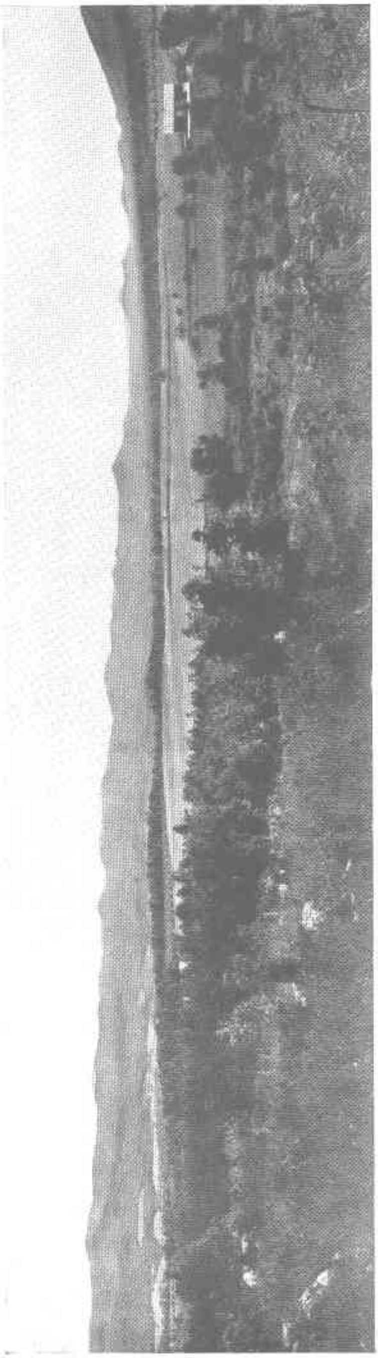
TOPOGRAPHY



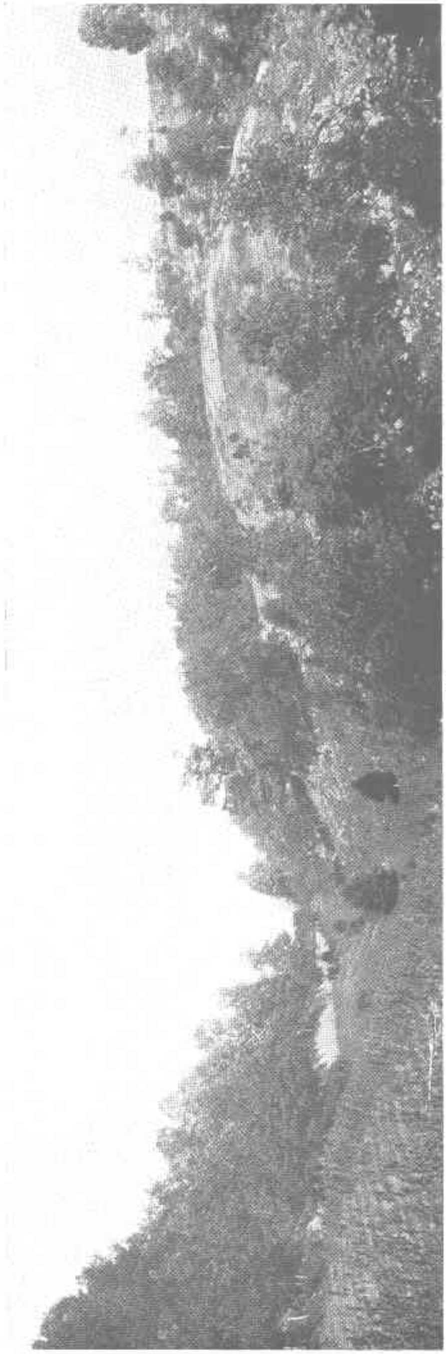
A

B

TOPOGRAPHY



A



B

TOPOGRAPHY

Plate 4

A. Fort Valley in Massanutten Mountain. Massanutten Mountain proper is on the left of the valley. Southeast slope of Powells Mountain is on the right. The floor of Fort Valley is on the Hamilton formation. Looking southward from a point about 1 mile northwest of Dietrich (Fort Cross Roads).

B. Narrow valley eroded along the St. Paul, or Hunter Valley, fault. Looking northeast 2 miles west of Dungannon, Scott County. The Cambrian Rutledge limestone (right) is thrust upon the Devonian Brallier shale (left). The Maryville limestone and the Nolichucky shale (?) crop out on the higher ground to the right.

profile connecting them makes a smooth curve departing but slightly from a level line.

Although most of the valleys are eroded in belts of soft rocks, such as shale (Pl. 7), a few are located along fault lines such as shown in Plate 4B. A longer valley evidently related to a fault extends from Greendale, Washington County, to Saltville, Smyth County, along the outcrop of the Saltville fault between the Honaker dolomite and the Mississippian rocks of the Greendale syncline.

RELIEF

The maximum relief, or difference between the highest and lowest points, in the Valley in Virginia is approximately 4224 feet. The lowest point, 380 feet above sea level, is on Shenandoah River at the State line along Clarke County. Apparently the highest point, 4604 feet above sea level, is on Beartown Mountain, Russell County, 10 miles northeast of Lebanon. (See Pl. 8B.) Summit knobs and peaks on the ridges in the Appalachian Valley in Virginia which have altitudes of 4000 feet or more are listed in Appendix A. Twenty-one of these are more than 4000 feet higher than the lowest point in the Valley. These high points are fairly well distributed throughout the Valley from Rockingham County southwestward. Other knobs which are not as high but perhaps more striking and picturesque are The Peak at the south end of Massanutten Mountain, 2900 feet (Pl. 3C); Peak Knob at the northeast end of Draper Mountain, 3374 feet (Pl. 2C); Hamilton Knob at the southwest end of Draper Mountain, 3116 feet; Angels Rest southwest of Pearisburg, 3756 feet; and Nicholls Knob, 10 miles southwest of Covington, 3573 feet (Pl. 8C). The numerous ridge crests throughout the northwestern belt of the Valley are 2500 to 3000 feet above Shenandoah River at the State line.

These variations in relief give to the Valley a considerable variety of climate and a wide range of agricultural conditions.

PENEPLAINS

The surface of the earth is being worn down gradually to lower levels by the constant removal of rock waste by running water and other agents. Given sufficient time and stability of the earth's crust this surface would be worn down nearly to sea level. Such a regional flat surface worn down chiefly by running water is called a peneplain (almost a plain).

Geographers and geologists believe that the Appalachian Highlands have been thus reduced to a peneplain at least once and that they have been partially peneplaned several times. At present extensive areas of the Appalachian Valley in Virginia, such as the Shenandoah Valley and the broad valleys in southwestern Virginia, form a partial peneplain, which would be made complete if erosion now in progress should ultimately reduce the ridges nearly to the level of the valleys. The summits above 4000 feet may mark a very old peneplain developed at or near sea level. If so, this surface was elevated 2000 feet or more and again eroded nearly to sea level, leaving the areas occupied now by the highest knobs standing above it as unreduced hills. This partial, or second, peneplain was in turn elevated and its level is now indicated by the ridges and knobs standing from 2500 to 3000 feet above sea level. Such summits are those of Clinch and Walker mountains which, viewed at a distance, are seen to approach approximately a common level. Following the second known uplift of the Appalachian region the surface has been reduced to its present form. Partial peneplains, of which the Shenandoah Valley around Winchester is the most perfect example, have been developed in the main drainage systems. The Dublin and Abingdon plains are other good examples of partial peneplains in the Valley of Virginia. It is obvious, therefore, that if the earth's crust remains static, or nearly so, and erosion is uninterrupted, peneplains are inevitable. Existing broad erosional plains, or their well-defined remnants, that bevel folded rocks afford ample evidence of the actual production of peneplains at several different periods in the earth's history. The concept of peneplains helps to explain otherwise anomalous but characteristic features of drainage and topography in the Appalachian Valley.

DRAINAGE

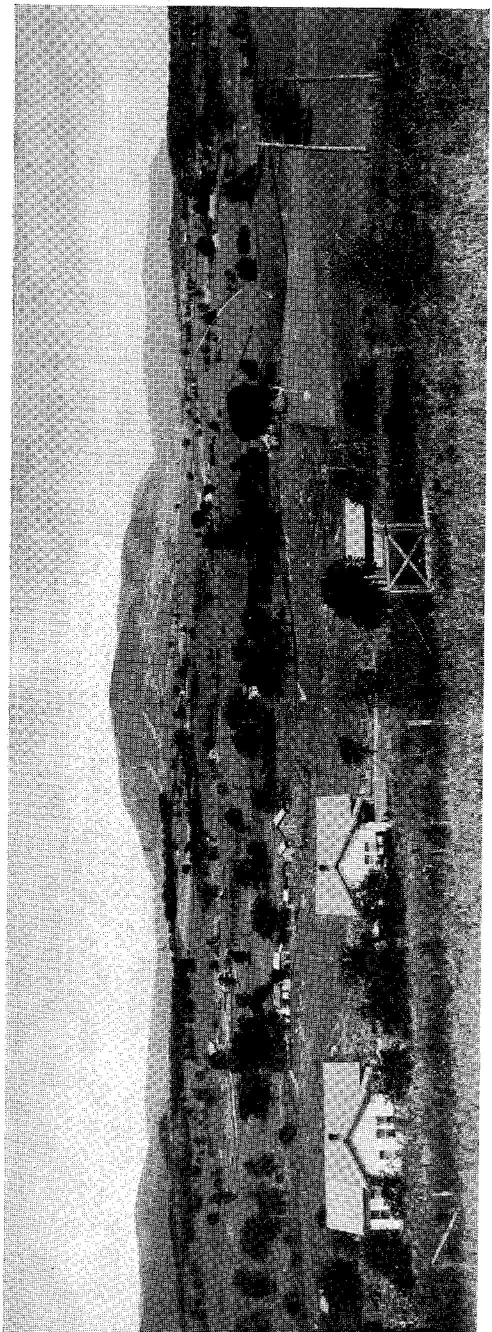
The master streams that cross the Appalachian Valley transversely are Potomac, James, New, and Tennessee rivers. Though the Tennessee is not in Virginia, it carries the drainage from the southwestern counties through Holston River and its three branches, and through Clinch and Powell rivers.

The upper courses of the Potomac lie outside of Virginia but the South Fork rises in Hightown Valley a few miles northwest of Monterey, Highland County, and flows within the State for 10 miles before entering West Virginia. The Shenandoah drainage basin tributary to the Potomac includes all of the Valley in Virginia nearly to the western boundary of Augusta County. Jack-

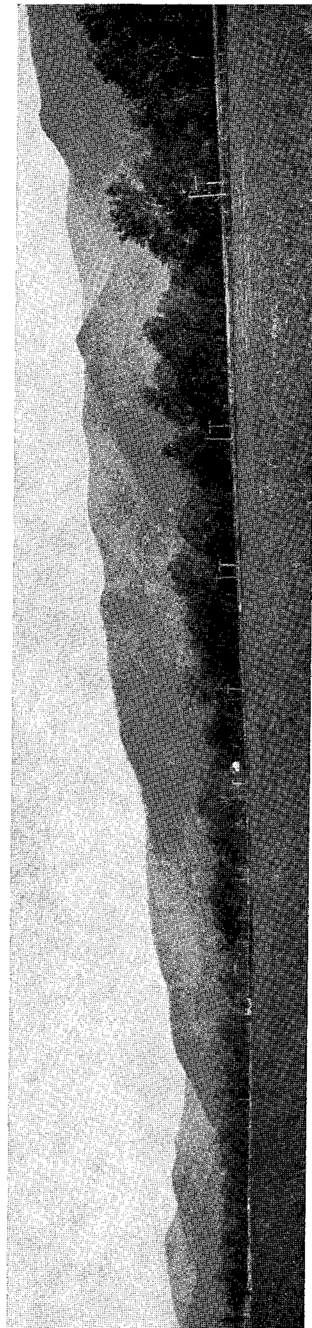
PLATE 5

A. Butt, Doe, and Salt Pond mountains northeast of Pearisburg, Giles County. Looking toward Mountain Lake. Butt Mountain is in the center, Doe and Salt Pond mountains are on the right, and Peters Mountain is on the left. Butt Mountain is 5 miles distant. The altitude of its summit is 4195 feet. The gorge of New River, 500 feet deep, crosses the middle part of the area from right to left. Mountain Lake lies in the low area between Doe and Salt Pond mountains. The foreground a part of the Harrisburg peneplain, averages about 2100 feet above sea level. It is at the same general level as the Dublin plain 15 miles to the south (Pl. 2C) and as the plain northeast of Wytheville, Wythe County (Pl. 10A).

B. Northwest front of the Blue Ridge and the flood plain of James River. Looking southeast from a point 2½ miles west of Glasgow, Rockbridge County. The front is a mile or more distant from the edge of the forest. The crest is 2500 feet or more, and the plain is about 800 feet, above sea level, making the relief here about 1700 feet.

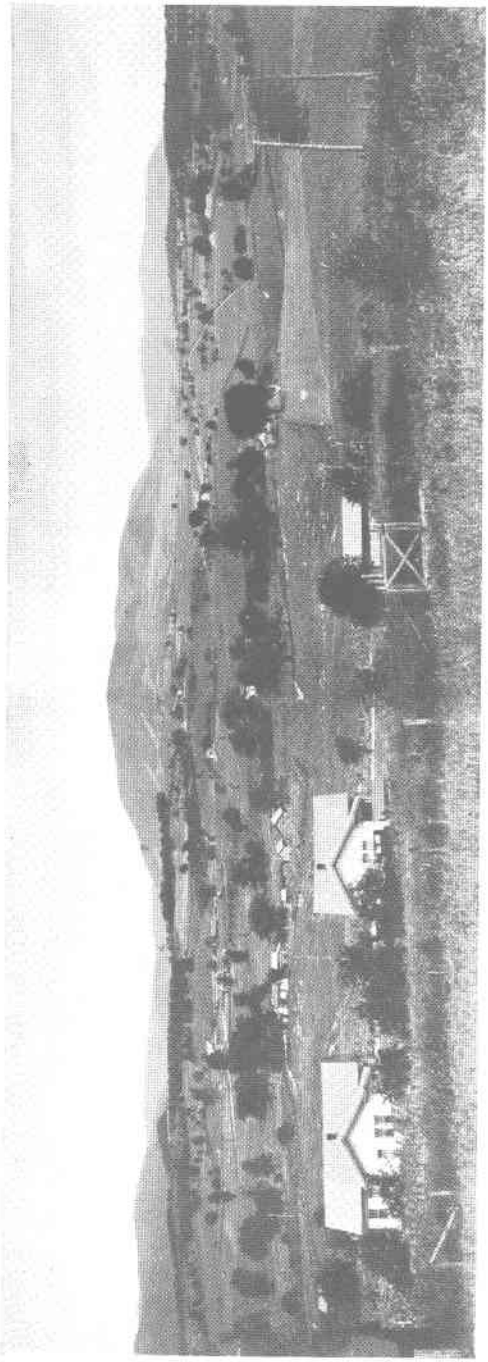


A

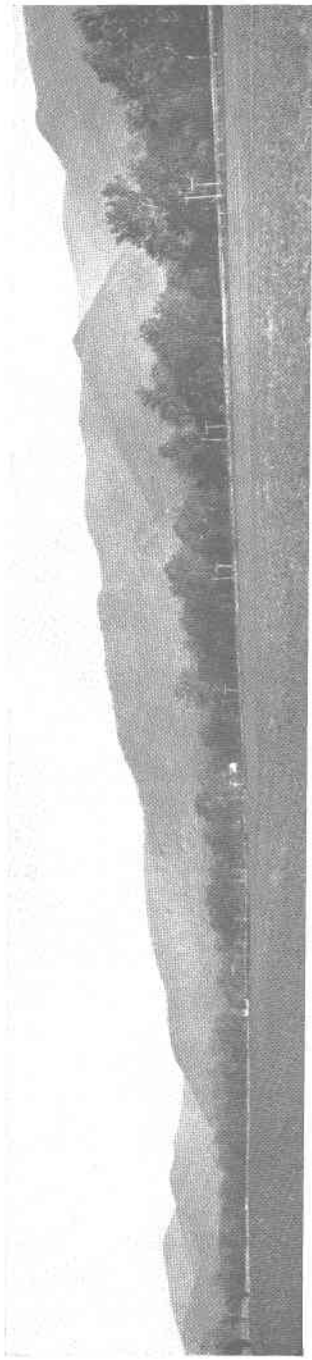


B

TOPOGRAPHY



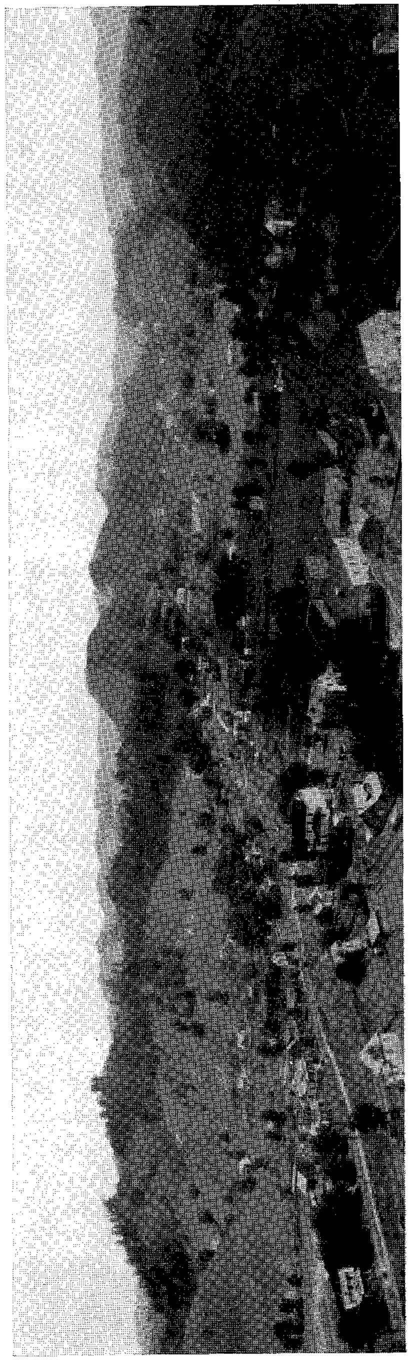
A



B

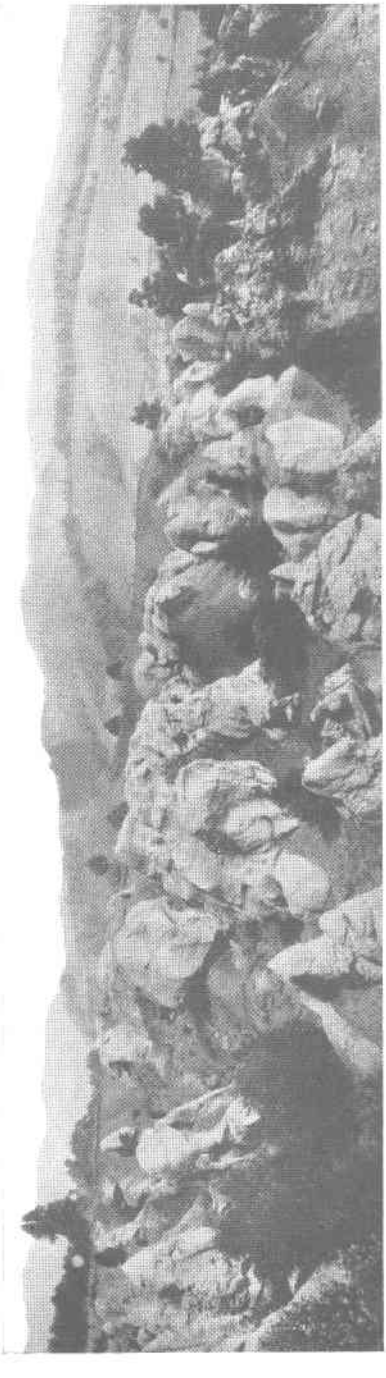
TOPOGRAPHY

A

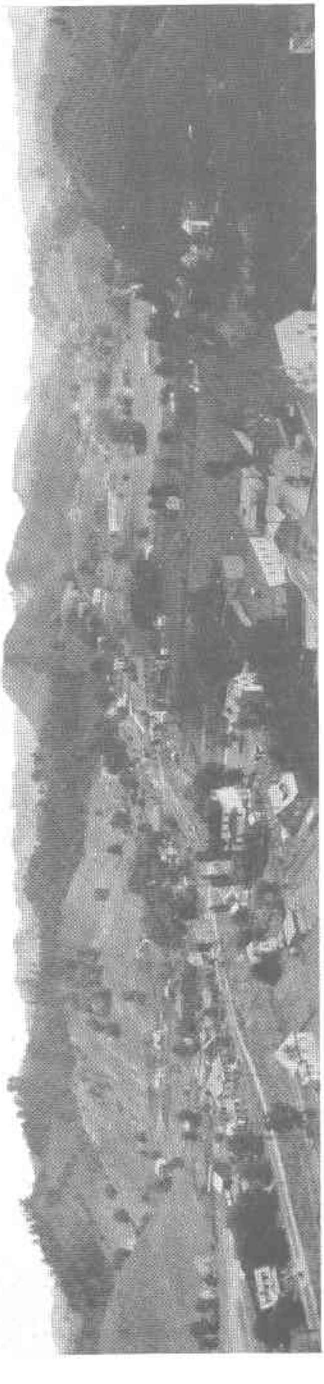


B

EROSIONAL FEATURES



A



B

EROSIONAL FEATURES

PLATE 6

A. Shady dolomite pinnacles in Pulaski County. View of an old ore pit showing the pinnacles resulting from underground differential solution. Half a mile northwest of Boom Furnace and about 2 miles southwest of Allisonia.

B. Knobby topography of the Rome formation north of Honaker, Russell County. This is an excellent example of Rome topography. The flat area is on the Honaker dolomite, which received its name from the town. Looking north.

son River also rises in Hightown Valley, Highland County, half a mile south of the head of the South Fork of the Potomac and flows southwesterly in accordance with the general trend of the drainage to a junction with Cowpasture River 4 miles southeast of Clifton Forge, Alleghany County. Southeast of this junction it is known as James River and it winds across the Valley to make its exit through the Blue Ridge in the deep water gap at Balcony Falls, or Glasgow, where it receives its principal tributary, North River. This river flows through the famous Goshen Pass—a sinuous gorge cut through North Mountain in Rockbridge County.

Roanoke River drains a comparatively small part of the Valley in Roanoke County. It flows through the Blue Ridge and thence southeast across the State and across the northeast part of North Carolina into the Atlantic. It is comparable to the James and Potomac in length and volume.

Unlike the other rivers mentioned above, New River crosses the Valley from southeast to northwest. It originates in the Blue Ridge plateau of northwestern North Carolina, flows northwest through the plateau in southern Virginia, and enters the Appalachian Valley through a deep water gap in the northwestern escarpment of the plateau 2 miles southeast of Ivanhoe, Wythe County. Thence it flows northeast along the trend of the Valley to Radford, turns northwest across the Valley, and passes from it through a picturesque gorge, the "Narrows," athwart East River-Peters Mountain in Giles County. (See Pl. 11.)

As the Tennessee River is outside Virginia, it will not be described in detail. It drains the southern part of the Appalachian Valley westward as New River does the next northern section. Holston, Clinch, and Powell rivers, tributaries of the Tennessee, rise in and drain a large area in southwestern Virginia. These head streams all flow southwestward along the strike of the Valley.

The Potomac and James flow southeastward across the Valley, whereas the New and Tennessee flow northwestward.[5] The secondary streams tributary to the master transverse rivers, almost invariably flow northeastward or southwestward along the main part of the Valley, following belts of less resistant shale and limestone.[6] Back, Walker and Little Walker creeks are examples. Back Creek in Highland and Bath counties follows for 48 miles a straight valley on an outcrop of shale. The valley is continued southwestward by Bolar Draft for another 9 miles. It is also continued northeastward in West Virginia by the valley of the North

[5] These features are explained in the section on "Geologic history."
[6] See geologic map of the Valley (Virginia Geol. Survey Bull. 42).

Fork of Potomac River for 33 miles, making the entire length of the straight valley 90 miles. The streams follow the outcrop of a single highly inclined belt of shale almost the whole distance. Walker Creek follows a limestone belt about 40 miles. About 4 miles southeast of Walker Creek and parallel to it, Little Walker Creek follows a shale belt 25 miles to a point where it turns abruptly north and, flowing through a deep gap in Walker Mountain, joins Walker Creek 1½ miles south of Poplar Hill, Giles County. This gap is a good example of the many water gaps through narrow ridges of the Valley. (See Pl. 3B.)

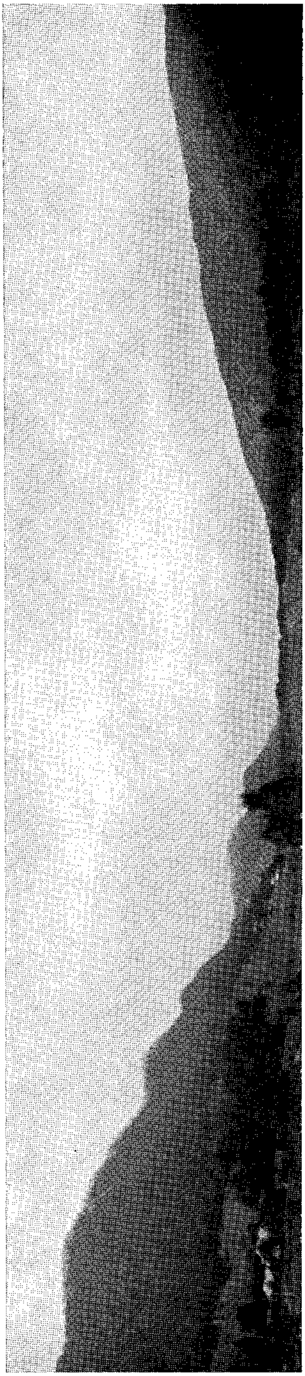
The reader may wonder why certain streams cut through the high ridges in these deep gaps instead of keeping their courses along the valleys in continuation of those in which they flow above the gaps. (See Pl. 11.) A brief explanation is that the streams established their courses in a remote time when the region was low and flat, that is, peneplained, so that the streams could meander in any direction. When the region was uplifted with respect to sea level and the slopes to the ocean were steepened, the streams flowed faster, carried more sediment, and their eroding power was increased. Those that crossed truncated belts of the hard steeply inclined rocks were forced to cut into these rocks as the region rose higher. Thus they maintained the courses assumed before the elevation of the country began, and finally carved the water gaps now seen.[7]

[7] This topic is more fully discussed in the section on "Geologic history," after the rocks and their structure have been described.

PLATE 7

A. Clinch and Pine mountains and Poor Valley, southwest of Hilton, Scott County. Clinch Mountain at the right; Pine Mountain, on the Price formation, at the left. Poor Valley is on the Brallier shale. Looking southwest. The knobs on Pine Mountain are 1800 feet above sea level. The crest of Clinch Mountain, which may not appear in this view, is 3217 feet above sea level.

B. Clinch and Pine mountains and Poor Valley 6 miles southwest of Gate City, Scott County. Clinch Mountain at right, Pine Mountain at left, and Poor Valley between. At the base of Pine mountain is a large exposure of the Price shale and sandstone which here contain marine fossils. This exposure includes beds 7 and 8 of geologic section 90. The black shale, bed 1 of geologic section 90, is a short distance beyond the curve. This view is 14 miles southwest of Hilton. Looking nearly west.



A

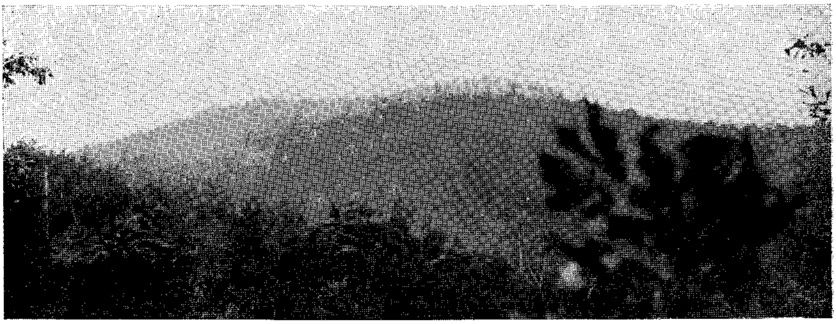
B

TOPOGRAPHY

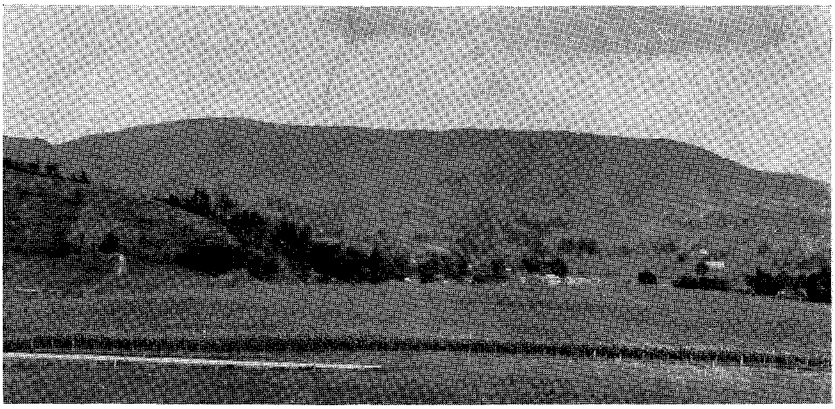
A

B

TOPOGRAPHY



A

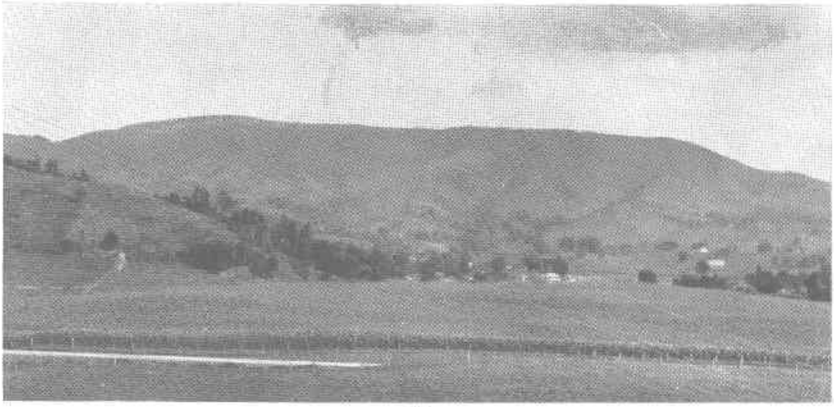


B

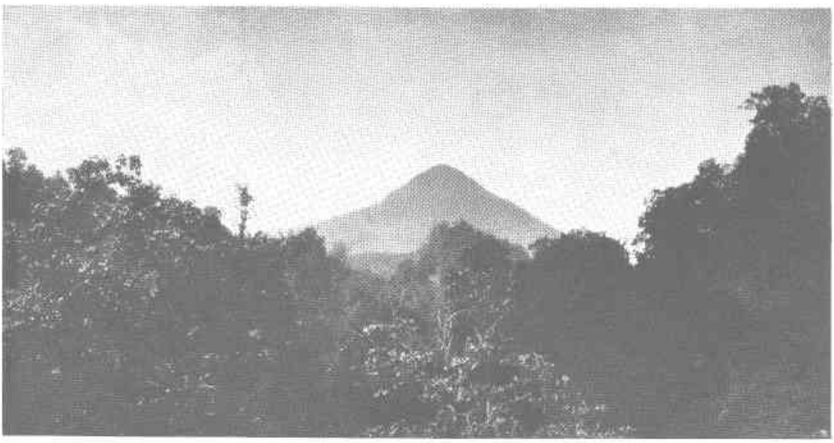
C

TOPOGRAPHY

A



B



C

TOPOGRAPHY

PLATE 8

A. North end of Short Mountain in the Massanutten Mountain complex southeast of Edinburg, Shenandoah County. Short Mountain is an outlying synclinal ridge capped with the basal part of the Massanutten sandstone, which has protected the underlying Martinsburg shale from erosion. This mountain is a good example of a synclinal mountain that is easily accessible.

B. Northwest slope of Beartown Mountain, Russell County, 10 miles northeast of Lebanon. This is one of the highest escarpments in the Appalachian Valley in Virginia. The immediate foreground is slightly more than 2300 feet above sea level. The summit of the mountain is about 4600 feet above sea level. Hence, the local relief is about 2300 feet. The summit is capped by Clinch sandstone. The slope is occupied by Martinsburg shale which makes rich grazing land. Looking southeast from a point on U. S. Route 19, 1½ miles northeast of old Rosedale.

C. Nicholls Knob, 10 miles southwest of Covington, Alleghany County. This peak is the northeast end of Potts Mountain, a synclinal or canoe-shaped mountain, capped by the Clinch sandstone. The slopes are occupied by Martinsburg shale. Looking southwest along the axial line.

STRATIGRAPHY

The successive rock units or formations in the Valley are shown in vertical sequence in the columnar section on the geologic map in Bulletin 42 of the Virginia Geological Survey. The name and position of each unit in the sequence are shown in the following table. The longest natural geologic time divisions are eras. Eras are subdivided into periods. The strata deposited in a period constitute a system. Thus the rocks of the Cambrian system were deposited in the Cambrian period, the oldest period of the Paleozoic era.

TABLE 1.—*Generalized section of the formations in the Appalachian Valley of Virginia*

Era	Period and System	Group	Formation	
Cenozoic	Quaternary		Alluvium on flood plains of existing streams. Talus slopes. Alluvial sheet deposits at foot of slopes, as locally at the foot of Blue Ridge. Travertine deposits by springs and some streams.	
Cenozoic	Tertiary		No deposits known in the Appalachian Valley of Virginia.	
Mesozoic	Cretaceous			
Mesozoic	Jurassic			
Mesozoic	Triassic			
Paleozoic	Carboniferous: Permian		No deposits now present in Virginia.	
Paleozoic	Carboniferous: Pennsylvanian	Allegheny?	Harlan sandstone.	
Paleozoic	Carboniferous: Pennsylvanian	Pottsville	Wise formation. Gladeville sandstone. Norton formation. Lee formation.	
Paleozoic	Carboniferous: Mississippian		*Southwest Virginia*	*Greendale syncline (Scott and Washington counties)*
			Bluestone formation. Princeton conglomerate. Pennington-Hinton formation. Glen Dean limestone-Bluefield shale.	No higher formations present. Pennington formation. Cove Creek limestone.
			Hiatus	Fido sandstone.
			Gasper limestone. Ste. Genevieve limestone. St. Louis limestone. Warsaw formation. Fort Payne chert. Maccrady shale. Price-Pocono formation.	Gasper limestone. Ste. Genevieve limestone. St. Louis limestone. Warsaw formation. *Hiatus* Maccrady shale. Price formation.

TABLE 1.—*Generalized section of the formations in the Appalachian Valley of Virginia*—*Continued*

Era	Period and System	Group	Formation	
Paleozoic	Devonian		*Frederick and Shenandoah counties* Hampshire formation Chemung formation. Brallier shale.	*Southwest of Shenandoah County* Hampshire formation. Chemung formation. Brallier shale.
		Romney	*Hiatus* Hamilton formation. Marcellus shale. Onondaga formation.	Millboro shale of Naples age. *Hiatus* Millboro shale. Onondaga formation.
			Oriskany sandstone.	Oriskany sandstone.
		Helderberg	*Hiatus* New Scotland limestone. Coeymans limestone? Keyser limestone.	Becraft limestone or sandstone. New Scotland limestone. Coeymans limestone. Keyser limestone.
	Silurian	Cayuga	Tonoloway limestone. Wills Creek formation. Bloomsburg formation. McKenzie limestone.	
		Niagara	Clinton formation.	
		Alexandria	Clinch-Tuscarora sandstone.	
	Ordovician	Richmond	Juniata[a]-Sequatchie formation.	
		Maysville Eden	Oswego sandstone. Martinsburg shale {Reedsville shale. Trenton limestone.	
		Black River	Chambersburg limestone=Eggleston limestone? Lowville-Moccasin limestone.	
		Blount	Ottosee limestone. *Hiatus* Athens formation. Whitesburg limestone. Holston limestone.	
		Stones River	Lenoir limestone. Mosheim limestone. Murfreesboro limestone.	
		Beekmantown	Bellefonte limestone and dolomite.[b] Nittany dolomite and limestone.[b] Stonehenge limestone.[b]	
			Chepultepec limestone.[c]	

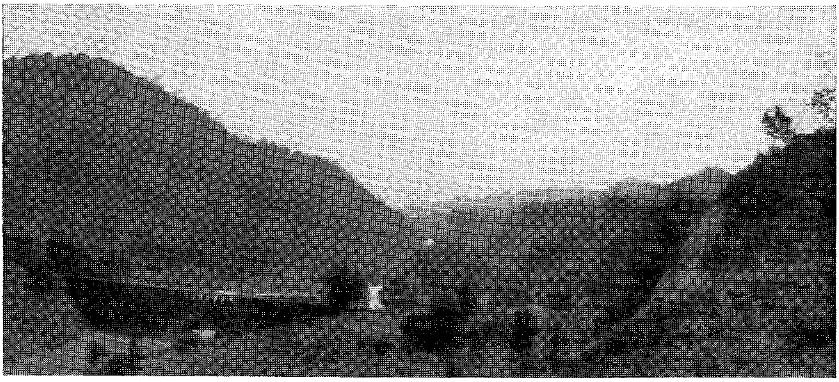
[a] Included under Silurian by Ulrich, by the New York Geological Survey, and on the Geologic map of the Appalachian Valley in Virginia (Va. Geol. Survey Bull. 42, 1933).
[b] Included in the Canadian system as proposed by Ulrich.
[c] Included in the Ozarkian system as proposed by Ulrich.

PLATE 9

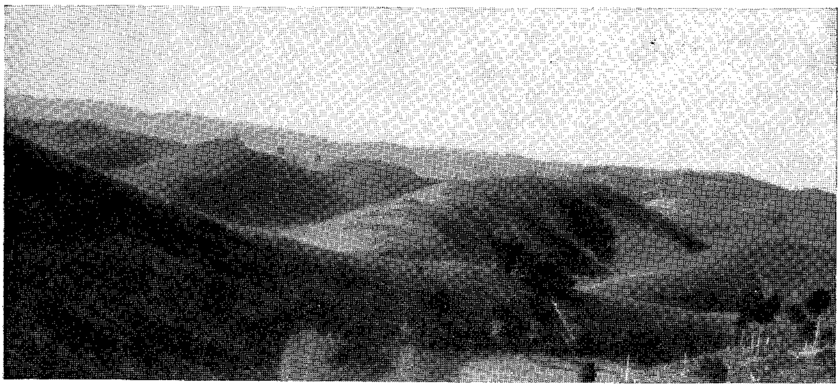
A. Valley of Clinch River below the old Speers Ferry site, Scott County. The valley is eroded in the Nolichucky shale. Hills (River Knobs) of the Rome formation are on the right and of the Copper Ridge dolomite (Copper Ridge) on the left. Looking southwest.

B. Rolling landscape eroded upon the Martinsburg shale. Looking northwest from a point on U. S. Route 19 about 1 mile southwest of Wardell, Tazewell County.

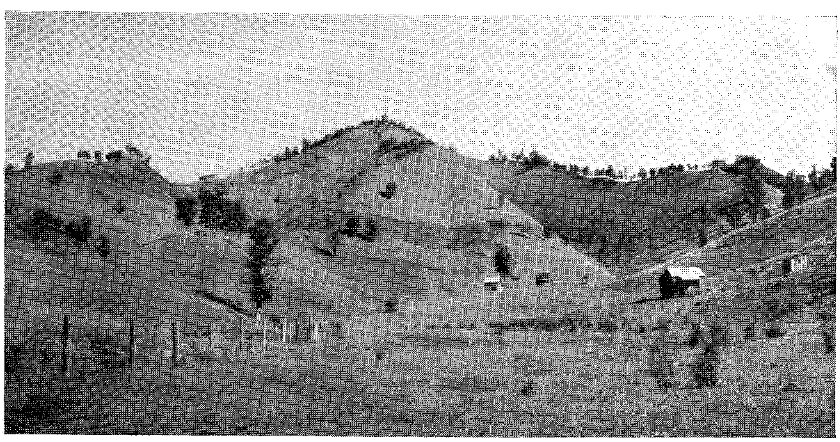
C. Conical hill on Elk Garden Ridge, 7½ miles northeast of Lebanon, Russell County. The summit is 3250 feet above sea level. The hill is on Martinsburg shale. The Clinch sandstone has recently been removed from its top. A residual mass of Clinch is present on a hill on this ridge about 1½ miles to the southwest of this knob. Looking northwest.



A



B

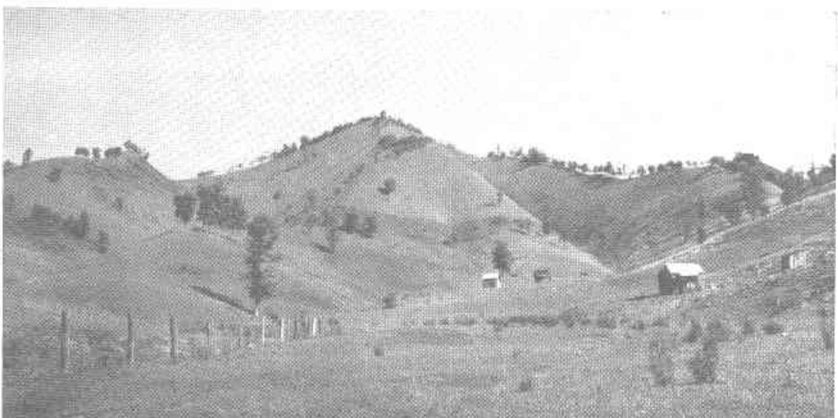


C

TOPOGRAPHY

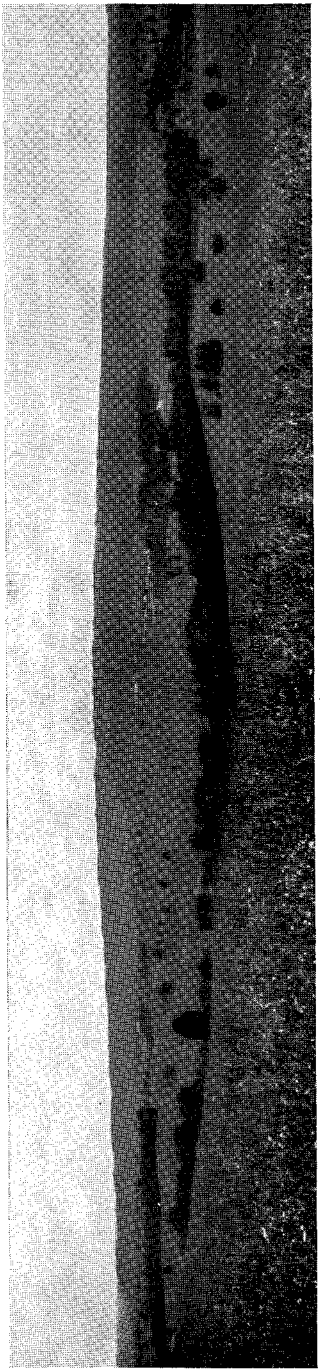
A

B

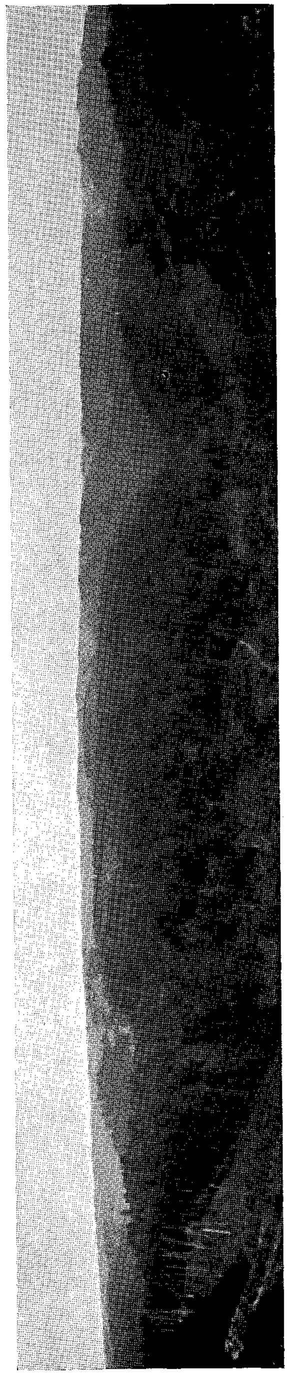


C

TOPOGRAPHY

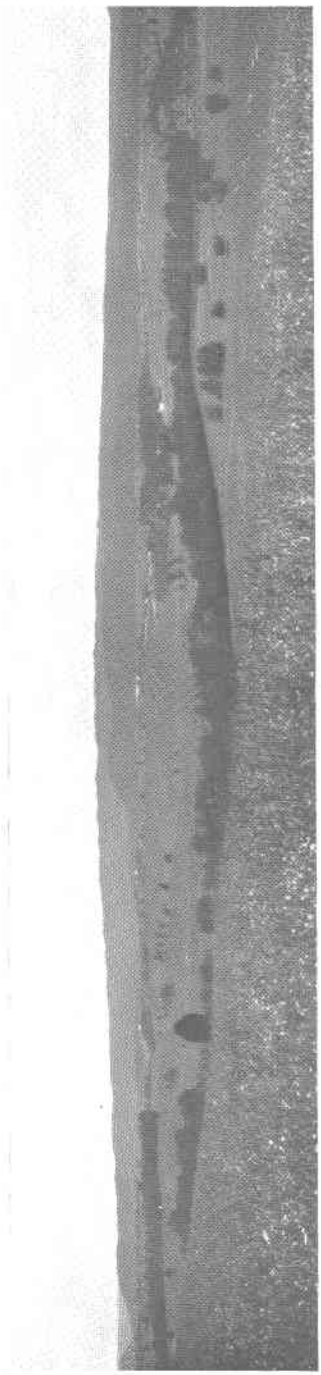


A



B

TOPOGRAPHY



A

B

TOPOGRAPHY

PLATE 10

A. Slightly dissected Harrisburg peneplain, about 5 miles east of Wytheville, Wythe County. The general altitude is 2200 feet. Looking north across the valley of Reed Creek from a point on this level about 4 miles southwest of Max Meadows. The first ridge is Little Brush Mountain, capped by the Chemung formation. The distant ridge is Cove Mountain on highly inclined Clinch sandstone. The northeast slope of Queens Knob, 3 miles north of Wytheville, shows in the left upper corner. In the extreme distance, through the gap between Queens Knob and Cove Mountain, Little Walker Mountain appears. The Rome formation underlies the upland just beyond Reed Creek. The Elbrook dolomite crops out beyond the Rome to the final emergence of the Pulaski thrust fault near the base of Little Brush Mountain. Reed Creek is entrenched in the peneplain.

B. Topography of the coal measures east of Clintwood, Dickenson County. East from Keel triangulation station 1 mile south of Clintwood. The general level is about 2200 feet above sea level. The surface appears to be the Harrisburg peneplain, as shown in A, but it has been deeply dissected, thus producing a much more rugged topography than in the limestone areas of the Valley.

TABLE 1.—*Generalized section of the formations in the Appalachian Valley of Virginia—Continued*

ERA	PERIOD AND SYSTEM	GROUP	FORMATION
	Cambrian		Cononcocheague limestone[c]—Copper Ridge dolomite.[d] Nolichucky shale. } Maryville limestone } Rogersville shale } Honaker dolomite } Elbrook dolomite. Rutledge limestone } Rome-Waynesboro formation.[e] Shady-Tomstown dolomite.[e]
		Chilhowee	Erwin quartzite-Antietam sandstone.[e] Hampton shale-Harpers shale.[e] Unicoi formation { Weverton sandstone.[e] Loudoun formation.[e]

[c] Included in the Ozarkian system as proposed by Ulrich.
[d] Ulrich regards the Copper Ridge dolomite as younger than the Conococheague limestone.
[e] Names listed first are applied to the formations southwest of Roanoke, Va.; the others are applied northeast of Roanoke, Va.

CAMBRIAN SYSTEM

CHILHOWEE GROUP

The basal Cambrian rocks of the Appalachian region are a group of three or four formations named the Chilhowee group from Chilhowee Mountain, Blount County, Tennessee. The name was first used by Safford[8] who called it the Chilhowee sandstone. The Chilhowee group is largely composed of sandstone and quartzite and has been called basal Cambrian quarztites, as designated on the geologic map of the Valley.[9]

Although the group in Virginia may not be exactly equivalent to the group in Chilhowee Mountain, Tennessee, it is so nearly the same that the extension of the name into Virginia is warranted. Unfortunately, two sets of formation names have been given to the individual members of the group in Virginia. The relations are shown in the following table:

TABLE 2.—*Names applied to Chilhowee units*

NORTH OF ROANOKE, VA.	SOUTH OF ROANOKE, VA.
Antietam sandstone	Erwin quartzite.
Harpers shale	Hampton shale.
Weverton sandstone } Loudoun formation }	Unicoi formation.

[8] Safford, J. M., A geological reconnaissance of the State of Tennessee, 1st Biennial Rept., pp. 152, 153, 1856; Geology of Tennessee, pp. 198, 203, 1869.
[9] References to the "geologic map" or the "geologic map of the Valley" are to the map in Virginia Geol. Survey Bull. 42, 1933.

Except for the Loudoun formation in the north, the character of the formations of the Chilhowee group is about the same throughout its belt of outcrop in Virginia.

Between Bristol and Mountain City, Tenn., on Tennessee Route 34, the separate units are easily distinguishable, but it is not yet possible to distinguish them with certainty throughout most of the area along the west flank of the Blue Ridge between southern Virginia and Harpers Ferry. This is due to changes in facies, lack of continuous exposures, and to structural conditions, such as minor folding and faulting. Such disturbed conditions are clearly evident in places as, for example, on U. S. Route 21, on the northwest slope of Iron Mountain south of Speedwell, Wythe County, Virginia, and on Tennessee Route 34 on the northwest slope of Iron Mountain, northwest of Mountain City, Tennessee. For these reasons the group is undifferentiated on the geologic map and is shown by a single pattern and symbol.

The general features of the several units or formations of the Chilhowee group are described below.

UNICOI FORMATION—{WEVERTON SANDSTONE / LOUDOUN FORMATION}

Names.—The Unicoi was named by Campbell[10] from Unicoi County, Tennessee. It is equivalent to the Loudoun and Weverton formations which were named by Clark and Williams[11] from Loudoun County, Virginia, and Weverton, Maryland.

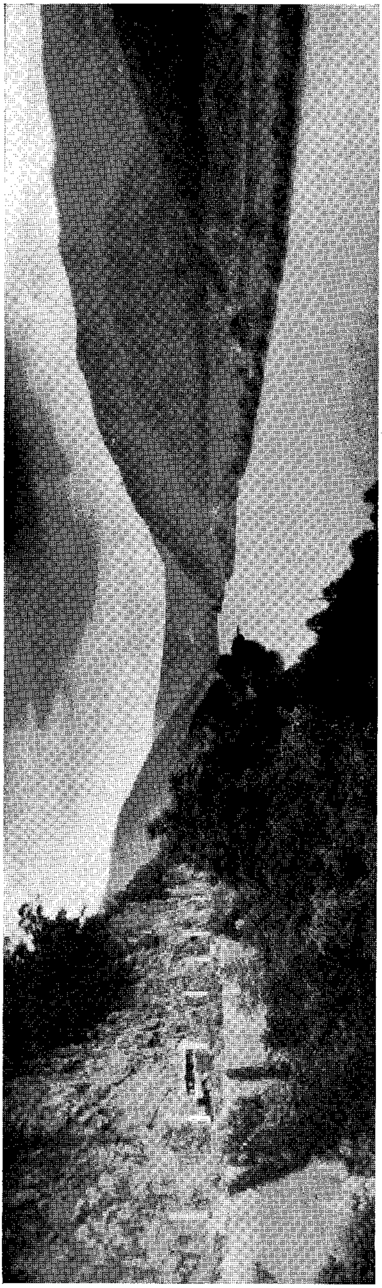
Character.—The Unicoi is predominantly a medium thick-bedded, medium coarse-grained sandstone with intercalated beds of conglomerate and shale. In places at least, it contains three distinct sheets of igneous rock of basaltic composition, called amygdaloid from the occurrence of small globular inclusions resembling almonds (Latin, *amygdalus*). The general composition of the Unicoi is well displayed along the road (geologic section 1) through the gorge of Little Laurel Creek, between Straight and Grave mountains in southern Smyth County, about 1½ miles northeast of Konnarock, Washington County.

[10] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), p. 3, 1899.
[11] Williams, G. H., and Clark, W. B., Maryland, its resources, industries, and institutions, p. 68, 1893.

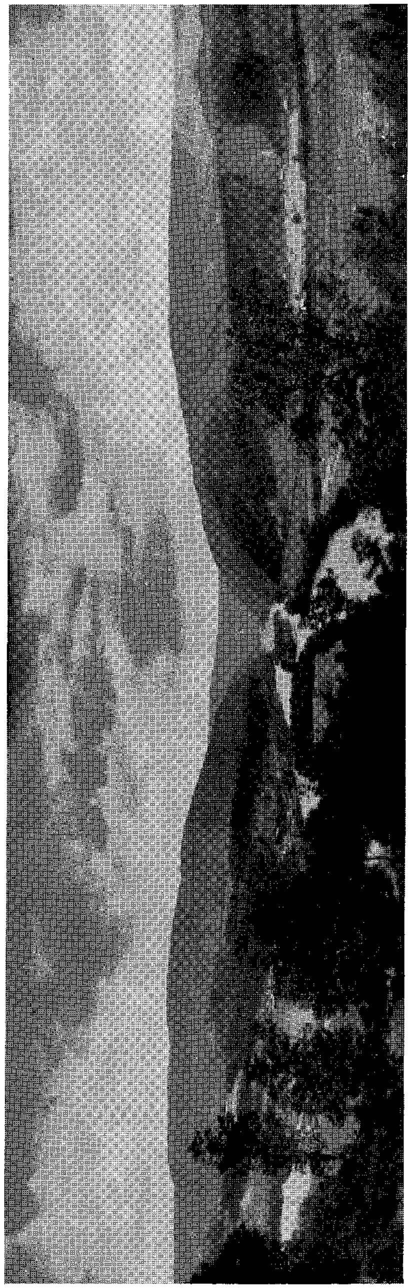
PLATE 11

A. The Narrows of New River, Giles County. Looking south from the north end of the gorge. Beekmantown dolomite is just above, and southeast of, the St. Clair fault in the left foreground near the automobile. The distant escarpment is Angels Rest southwest of Pearisburg. Photograph by Josiah Bridge.

B. A distant view of the Narrows of New River. Rich Creek, West Virginia, is on the low ground at the left. The river is 1500 feet, and the summits of East River Mountain (right) and Peters Mountain (left), are about 3300 feet above sea level. The depth of the gorge is thus 1800 feet, which is approximately the amount of down-cutting since the river was flowing on a surface now approximately represented by the crests of the mountains. That surface had probably been elevated some thousands of feet above its former position when the river took its present course. Photograph by Josiah Bridge.

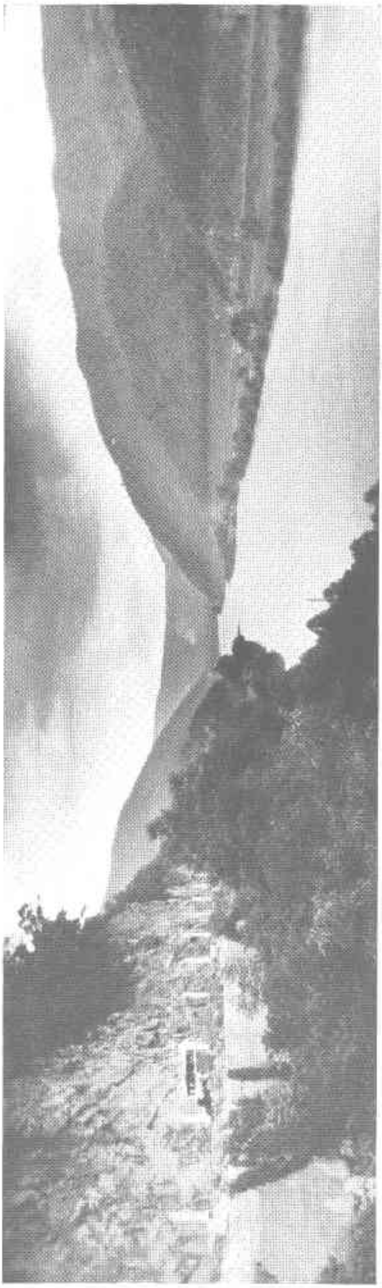


A

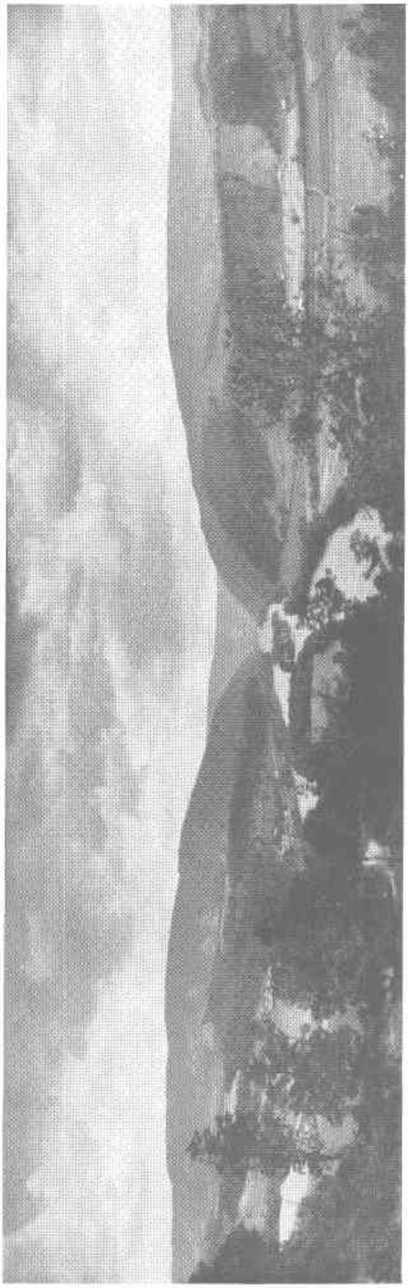


B

TOPOGRAPHY

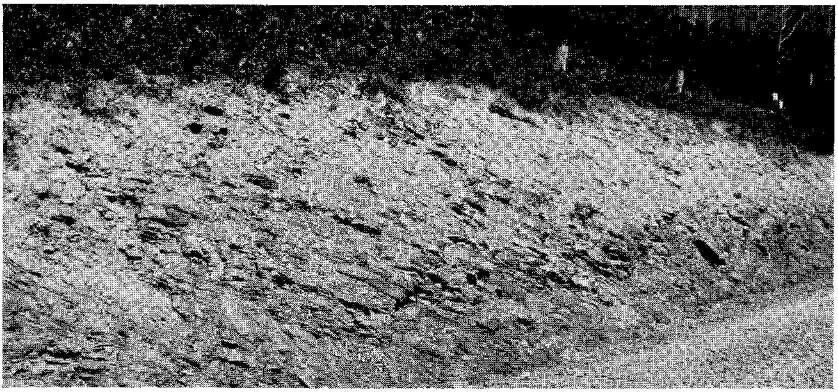


A

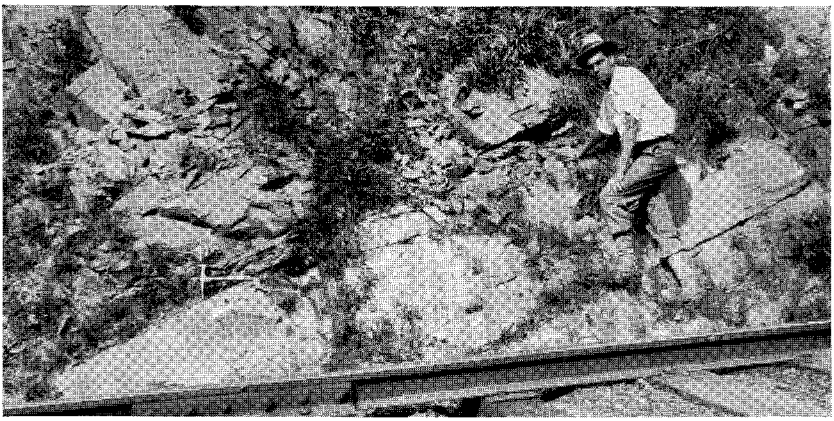


B

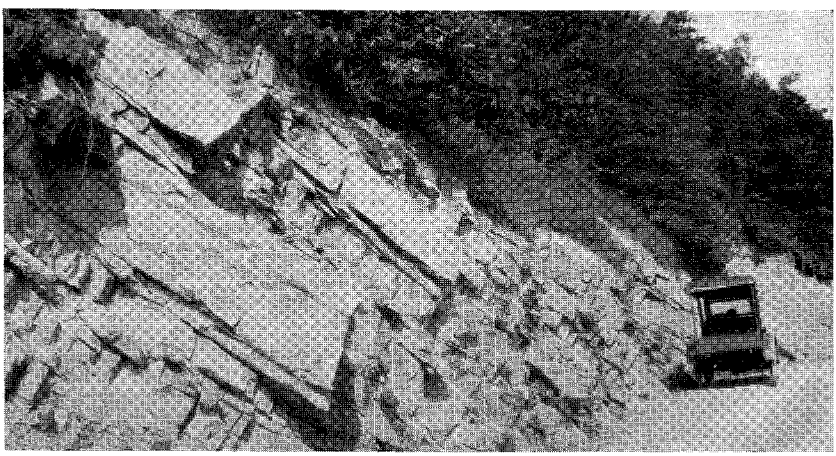
TOPOGRAPHY



A

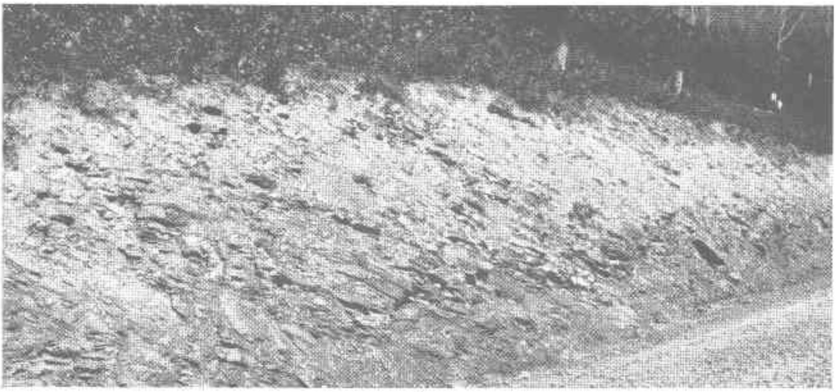


B

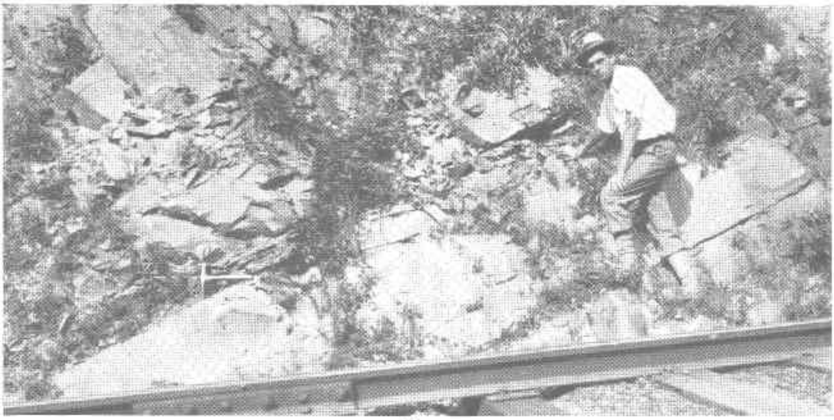


C

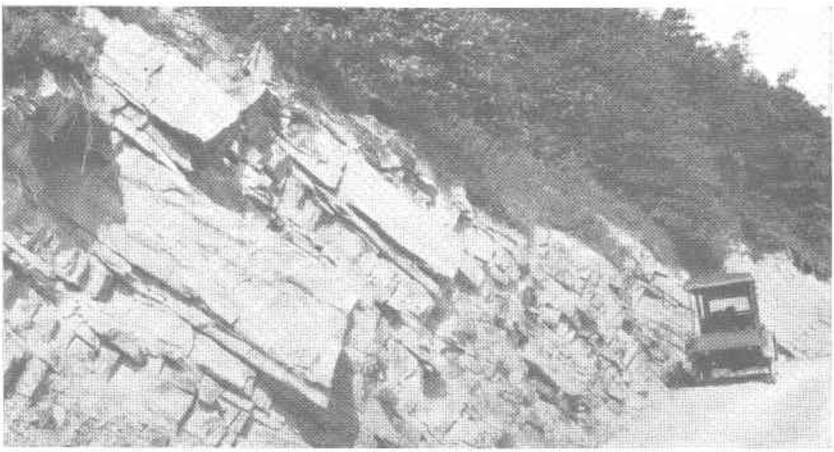
CAMBRIAN FORMATIONS



A



B



C

CAMBRIAN FORMATIONS

PLATE 12

A. Hampton shale dipping southeast into Holston Mountain. Cut on U. S. Route 421, on the northwest slope of Holston Mountain, Sullivan County, Tennessee, about half a mile northwest of the summit.

B. Lower contact of amygdaloidal lava with the Unicoi sandstone, half a mile northwest of Taylors Valley, Washington County. The man has his hand on contact, which is also marked by the hammer. The lava flowed over a smooth surface of sandstone, as is shown by the even contact. Cut on the Norfolk & Western Railroad along Whitetop Creek. (See topographic map of the Mount Rogers quadrangle.)

C. Thick-bedded sandstone of the Unicoi formation on the northwest slope of Holston Mountain. Along U. S. Route 421 at the southeast base of Delaney Knob. This sandstone is overlain by the Hampton shale, shown in A. It is thrust northwestward upon the Athens shale not far below the lowermost beds shown. This part of the Unicoi is above the amygdaloidal lava and is at least 1000 feet thick. Looking southeast.

Geologic Section 1.—Unicoi formation 1½ miles northeast of Konnarock, Virginia

	Approximate Thickness Feet
Hampton shale	
Shale and sandstone	
Unicoi formation (2604+ feet)	
24. Sandstone, medium thick bedded, coarse grained, gray; coarse-grained reddish layers at base	1000
23. Conglomerate, quartz pebbles, generally small, a few as much as half an inch in diameter, in a rusty greenish groundmass of quartz and pink feldspar grains	50
22. Shale, with thin laminae of quartz grains	2
21. Lava containing quartz pebbles, one-fourth of an inch in diameter	2½
20. Black, nongranular rock with conchoidal fracture, resembles lava	5
19. Amygdaloid, dark green, in part light green, or weathering to such; containing spherical, radiating, amber-colored inclusions	45
18. Not exposed	35
17. Sandstone, arkosic, pink feldspar and quartz	50
16. Shale, gray, with streaks of red	10
15. Amygdaloid, dark greenish rock with bands containing pink spherical inclusions, probably of pink feldspar, some half an inch in diameter. Main amygdaloid	200
14. Conglomerate, like bed 23	5
13. Sandstone, with layers of conglomerate	400
12. Sandstone, arkosic	50
11. Shale	50
10. Conglomerate and arkosic sandstone	50
9. Not exposed	55
8. Conglomerate, coarse	35
7. Not exposed	50
6. Conglomerate and arkosic sandstone, coarse conglomerate at bottom	250
5. Amygdaloid, reddish and greenish as decomposed, matrix with pink feldspar amygdules	20

	Approximate Thickness Feet
4. Sandstone, arkosic	40
3. Red rock like bed 5, with arkosic sandstone	100
2. Red rock	50
1. Sandstone, arkosic, coarse grained, light gray, loosely cemented, about two-thirds quartz and one-third feldspar grains	50

Pre-Unicoi (pre-Cambrian?)

Red rock with decayed feldspathic inclusions; occupies a wide belt of country to the southeast of the outcrop of arkosic sandstone (No. 1) next above. Probably a decomposed lava.

The general geologic character of the Unicoi throughout Virginia is similar to that described in the preceding section. Its general character is illustrated in Plate 12C. Beds of red shale as much as 5 to 10 feet thick occur sparingly throughout the formation. The conglomerate beds are commonly made up of small quartz pebbles, but on the south slope of Iron Mountain, on U. S. Route 21, south of Speedwell, there is a bed of conglomerate about 10 feet thick in which the pebbles are of quartz and quartzite, some of which are 3 inches in diameter. On the road about a mile west of Trout Dale, Grayson County, and on the road 1½ miles west of Konnarock, Washington County, granitoid pebbles and cobbles, thoroughly rounded, 6 inches or more in diameter, occur in a lava that probably was extruded upon the pre-Cambrian, or pre-Unicoi, surface where water-worn granitoid pebbles were scattered. Apparently they occur at the base of the Unicoi. This basal bed is of the same character as bed 15 of preceding section but should not be confused with it.

The reddish sandstone occurring in the lower part of bed 24 of the preceding section is composed of rather coarse quartz and feldspar grains, its reddish color being due to the feldspar and to the coating of the grains by iron oxide.

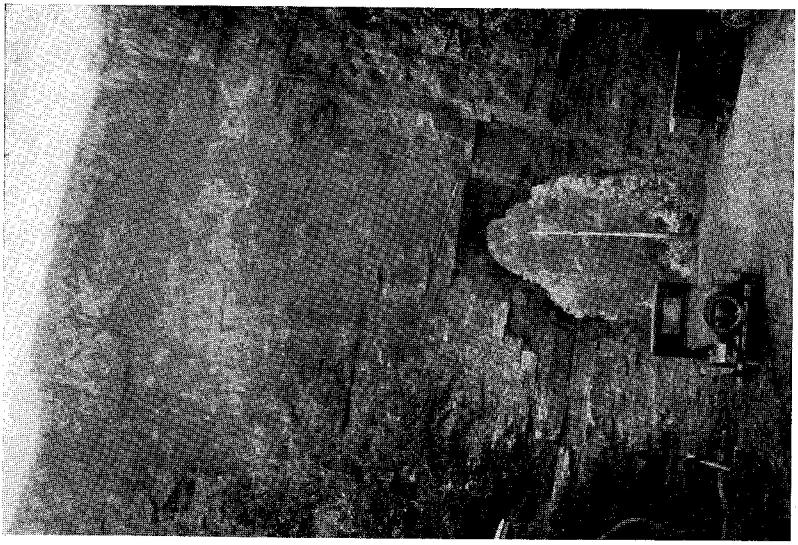
The amygdaloid rock, bed 15, is easily distinguished by its dark greenish or purplish color, its pink and greenish globular inclusions, and by its greater heaviness. These beds are conformable with the beds of sandstone both above and below, as shown in Plate 12B. This indicates that the lava flowed out on the sea bottom while the deposition of the sands was in progress.

PLATE 13

A. Chilhowee beds 4 miles east of Austinville, Wythe County. Thin-bedded sandstone and sandy shale, which look like Hampton shale, are exposed through a distance of 3500 feet along Shorts Creek through and immediately south of Poplar Camp Mountain. Looking southwest.

B. Erwin quartzite in a narrow spur, in Tennessee, 3 miles southwest of Damascus, Washington County, Virginia. The spur extends into a meander of Beaverdam Creek. The wall is about 20 feet thick. The dip is 10°-15° SE. (right).

C. Erwin quartzite at same locality as B. The tunnel was made for a lumber railroad, the abandoned grade of which is now converted into a highway. The regular bedding of the Erwin is well shown. Looking north.



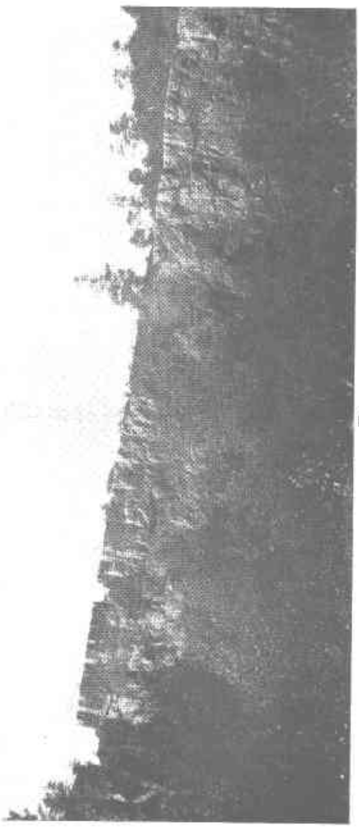
C

A

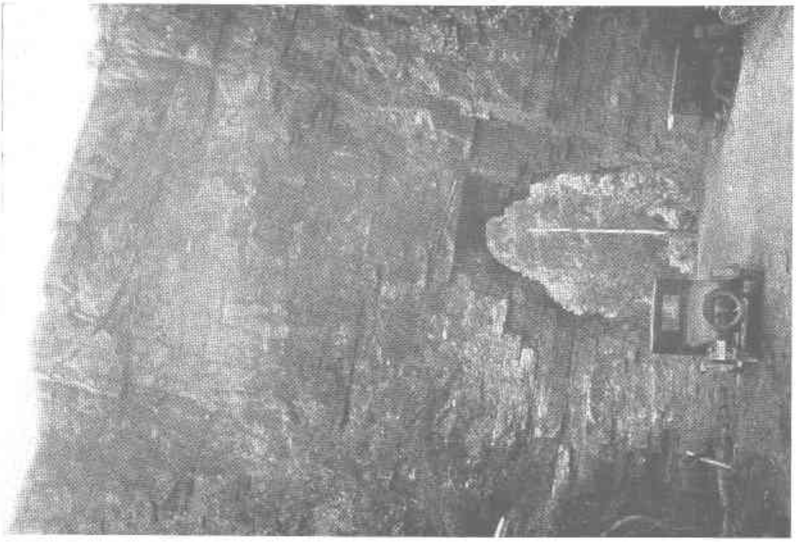
B

CAMBRIAN FORMATIONS

A

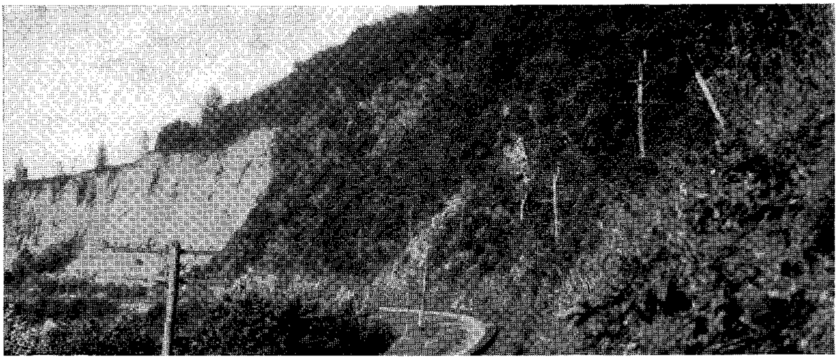


B

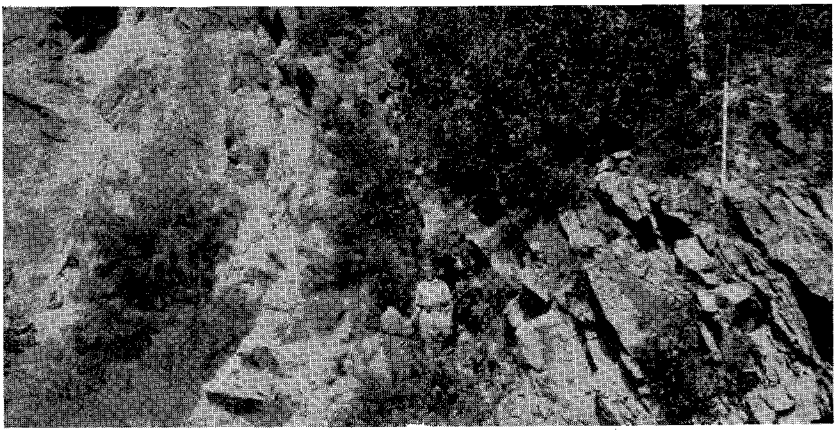


C

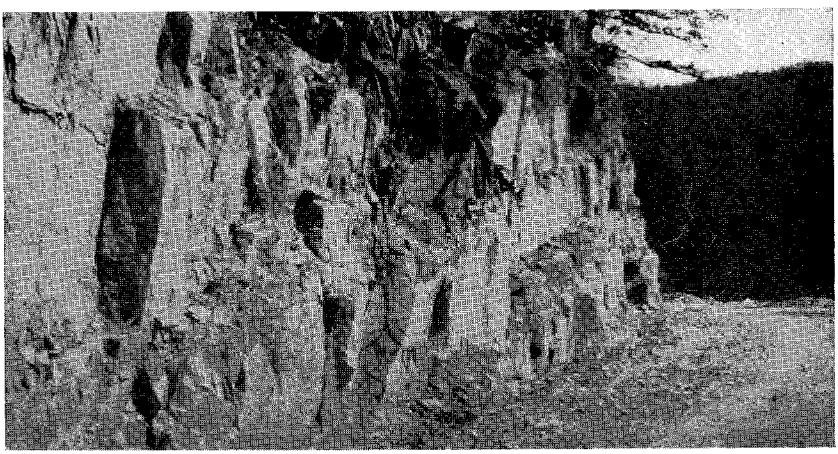
CAMBRIAN FORMATIONS



A

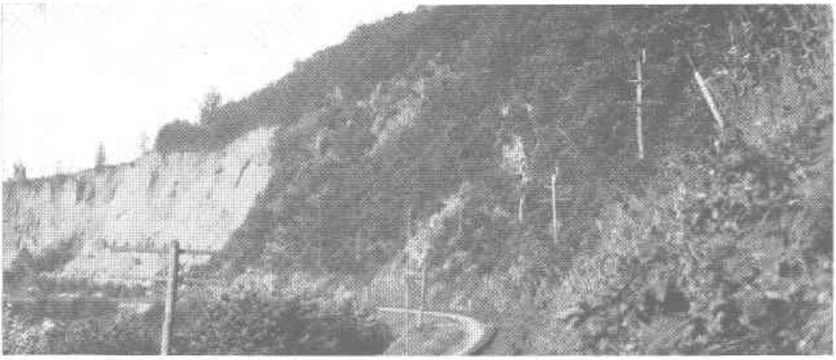


B



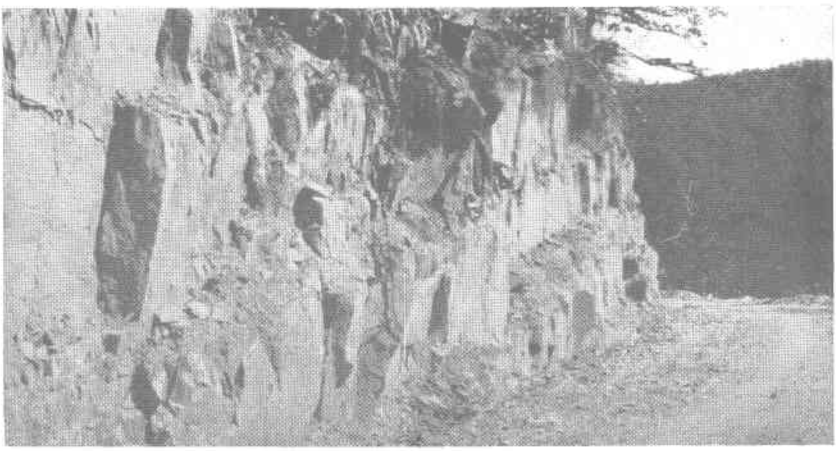
C

CAMBRIAN FORMATIONS



A

B



C

CAMBRIAN FORMATIONS

PLATE 14

A. Erwin quartzite (right) and Shady dolomite half a mile east of Buchanan, Botetourt County. The contact is at the edge of the trees. Cut on the Norfolk and Western Railroad. Looking northeast.

B. Contact of Shady and Erwin shown in A. The man stands on the contact. Several feet of the uppermost Erwin quartzite is exposed on the right. The dip is almost vertical. Looking northeast.

C. Thick-bedded Erwin quartzite east of Lexington, Rockbridge County. Cut along Jordan road through Whites Gap in the Blue Ridge at a point about 3 miles northeast of Buena Vista. This type of sandstone is exposed for about a mile along the old road, beginning on the southeast at a point about 1 mile northwest of Whites Gap. Looking southeast.

In northern Virginia the Loudoun formation, as described by Keith,[12] is composed mainly of shale, but local lenses of sandstone conglomerate and of marble are also included in its basal part. The marble is best developed on Goose Creek southwest of Leesburg. Some red shale also occurs in the Loudoun. The conglomerate is composed of the waste of the pre-Cambrian rocks upon which it rests. Where this condition exists, it is difficult to identify the base of the Loudoun and therefore of the Cambrian. In the case of the Unicoi, it is the writer's practice to regard the lowest conglomerate with granitoid pebbles or the lowest arkose that can be recognized, such as bed 1 of the preceding section, as the base of the Cambrian.

The Weverton sandstone is composed of massive beds of coarse quartz sandstone and conglomerate with almost no finer material. Many of the layers are distinctly purplish.

Distribution.—On account of folding and faulting, there are several parallel belts of Unicoi, including its amygdaloid bed, in the southern part of the Valley in Virginia. It is easily recognized in Holston and Iron mountains in Virginia as far northeast as U. S. Route 21 on the southeast slope of Iron Mountain, 3¾ miles south of Speedwell, where the amygdaloid bed, associated with sandstone and conglomerate, is well exposed. It is responsible for Grosses, Straight, and Grave mountains in southeastern Smyth and Washington counties. (See Pl. 2D.)

Apparently two main, long, narrow bands of the amygdaloid and several minor strips crop out. One band extends along the northwest flank of Grosses Mountain at least from Feather Camp Peak, about 4 miles northeast of Damascus, Washington County, to the head of Roland Branch, 8 miles south-southeast of Marion. It doubtless extends farther northeast along that line but this extension was not observed by the writer. Another belt extends along the southeast flank of Straight-Grave Mountain from U. S. Route 21, 3¾ miles south of Speedwell, southwest through the gorge of Little Laurel Creek through Straight-Grave Mountain (geologic section 1), crosses the Damascus-Mountain City highway at the State line and continues southwestward to connect with the belt of amygdaloid mapped by Keith in the northwest quarter of the Cranberry quadrangle, Tennessee. Another outcrop extends from the State line, 1 mile southeast of Taylor Valley, northeast to Green Cove Creek, and probably a greater distance in both directions.

[12] Keith, Arthur, The geologic structure of the Blue Ridge in Maryland and Virginia: Am. Geologist, vol. 10, pp. 362-368, 1892.

The Loudoun is present as a thin formation as far south as Afton, Nelson County, and the Weverton sandstone likewise is recognizable on the northwest slope of the Blue Ridge immediately northwest of Rockfish Gap near the summit, west of Afton. The Loudoun, or at least the basal sandstone of the Chilhowee group, presumably extends in disconnected patches and belts as far southeast of the Blue Ridge as Leesburg, Loudoun County, and Charlottesville, Albemarle County. The Unicoi-Weverton division has not been distinguished from the remainder of the Chilhowee group along the Blue Ridge between Rockfish Gap and U. S. Route 21, southwest of Speedwell. This is partly on account of the structural disturbance of the group in extensive areas, causing the relations of its various members to become confused, and partly due to variations in facies through which the features used for differentiating the formations have not been developed. A convincing example of this change of facies may be seen by comparing the section exposed in the gorge of Poplar Camp Creek, Carroll County, on U. S. Route 52, 2 miles southeast of Jackson Ferry, with the one exposed on Tennessee Route 34 between Bristol and Mountain City. On Poplar Camp Creek the whole Chilhowee group, approximately 3500 feet thick, appears to be represented by evenly thin-bedded sandstone, without any differentiation into formations. (See Pl. 13A.) This locality is only 17 miles northeast of the section south of Speedwell where the Unicoi, with its amygdaloid, is present. In general lithologic character, the whole Chilhowee section exposed here resembles most closely the Hampton shale.

The entire Unicoi is best exposed and most accessible on the road in the gorge through Straight-Grave Mountain, 1½ miles northeast of Konnarock (geologic section 1) and its upper part is well shown on the Bristol-Mountain City road, U. S. Route 421, on the northwest slope of Holston Mountain. (See Pl. 12C.) The amygdaloid can be seen most conveniently on the road from Damascus to Mountain City, where it crosses the State line 2 miles southeast of Damascus. An excellent and easily accessible exposure may be seen on Virginia Route 79, on the northwest slope of Grosses Mountain a mile northwest of Skull Gap, which is 3 miles northeast of Konnarock, Washington County, and at the locality of geologic section 1 in the gorge through Straight-Grave Mountain 1½ miles northeast of Konnarock. The conglomeratic amygdaloid is conspicuously shown on the road about 1½ miles southwest of Konnarock.

The Loudoun formation is generally not well exposed near the Blue Ridge in northern Virginia.

The Weverton sandstone is best displayed on Potomac River just east of the mouth of Shenandoah River and at Weverton, Maryland, 1 mile east of Harpers Ferry. A very good exposure occurs along State Route 7, half a mile northwest of Snickers Gap, Clarke County.

Thickness.—The full thickness of the Unicoi is about 2600 feet, as shown by geologic section 1. The upper 1000 feet, or the part above the amygdaloid, crops out and is fully exposed on the Bristol-Mountain City road (U. S. Route 421) on the northwest slope of Holston Mountain. The lower 1500 feet or so is not brought up by the fault on the northwestern slope of Holston Mountain that brings the Unicoi into contact with the Athens shale. The Loudoun formation ranges in thickness from only a few feet to 800 feet. The Weverton sandstone is about 800 feet thick.

Fossils and correlation.—The Unicoi is unfossiliferous. It is generally classed as lowest Cambrian, but some geologists, regarding it as older, are inclined to correlate it with the pre-Cambrian Belt series of the Rocky Mountains. They would begin the Cambrian with the oldest fossiliferous rocks, the Erwin-Antietam quartzite. Keith[13] has shown that the Unicoi sandstone is equivalent to the Snowbird sandstone and Cochran conglomerate of Tennessee. The Cochran is a member of the Chilhowee series of Hayes[14] in the type locality in Chilhowee Mountain, Tennessee. The Snowbird sandstone may be a facies of the Sandsuck shale underlying the Cochran conglomerate on Hiawassee River in northern Polk County, Tennessee. At least the Snowbird appears to occupy the same position as the Sandsuck shale.

Urry[15] determined by the helium method the age of the amygdaloid in the Unicoi as approximately 450 million years. That would imply a somewhat greater age for the beginning of Cambrian sedimentation as there are several hundred feet of the Unicoi formation beneath the amygdaloid. The sample of the amygdaloid used by Urry was collected by Bridge from the exposure at the State line 2 miles southeast of Damascus, Washington County, Virginia.

HAMPTON–HARPERS SHALE

Names.—The Hampton shale was named by Campbell[16] from Hampton, Carter County, Tennessee. The Harpers Ferry shale

[13] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranberry folio (No. 90), pp. 4-5, 1903; U. S. Geol. Survey Geol. Atlas, Roan Mountain folio (No. 151), pp. 4-5, 1907.

[14] Hayes, C. W., U. S. Geol. Survey Geol. Atlas, Cleveland folio (No. 20), p. 2, 1895.

[15] Report of the Committee on the Measurement of Geologic Time; Lane, A. C., Chairman, National Research Council, Annual meeting of the Division of Geology and Geography, p. 39, April 27, 1935.

[16] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), p. 3, 1899.

was named by Keith[17] from Harpers Ferry, Maryland. The name was subsequently modified by Keith[18] to Harpers shale.

Limits.—The lower boundary of the Hampton is distinctly marked by the thick-bedded sandstone of the Unicoi on the northwest slope of Holston Mountain. The upper boundary is about equally well marked by the appearance of thick-bedded, white to gray quartzite of the Erwin at the summit of the mountain. Both boundaries are closely determinable on the Bristol-Mountain City road (U. S. Route 421) across Holston Mountain.

Character.—The Hampton-Harpers shale is typically composed of thin-bedded, nonfissile, fine-grained, siliceous, rusty-weathering rock. (See Pl. 12A.) Near the top of the Hampton, thicker beds of sandstone come in, as shown on U. S. Route 421 near the top of Holston Mountain, Tennessee, but here the thin-bedded rock prevails. A thick sandstone occurs near the bottom of the formation on the road 1½ miles northeast of Konnarock, Va., and sporadic occurrences of thick sandstone are probable. The Harpers shale is identical in character with the Hampton as shown in Plate 12A.

Distribution.—As the Hampton shale is present in southern Virginia and the Harpers shale in northern Virginia, the formation extends along the Blue Ridge throughout the entire distance from northern Tennessee to Potomac River. The best exposure of the Hampton is on the Bristol-Mountain City road (U. S. Route 421) in Tennessee, mentioned above, where nearly the full thickness is exposed. The Hampton is partly exposed on the road on the southeast slope of Grosses Mountain from Skull Gap 3 miles northeast of Konnarock, down to Little Laurel Creek in the southeast corner of Smyth County. It comprises much of the exposure in the gorge of Poplar Camp Creek through Poplar Camp Mountain in northern Carroll County. (See Pl. 13A.) The Harpers shale is fully exposed on old State Route 13 immediately west of Whites Gap on the Blue Ridge 8 miles nearly due east of Lexington. It is nearly all exposed on U. S. Route 250 between Rockfish Gap in the Blue Ridge, and Waynesboro, Augusta County; and is fully exposed in Clarke County on State Route 7 between Snickers Gap and the bridge across Shenandoah River at Castleman Ferry. The best exposures are in the Potomac and Shenandoah rivers and on the bluffs at Harpers Ferry.

Thickness.—No exact determination of the thickness of the Hampton shale has been made by the writer. Judging from the width

[17] Keith, Arthur, as reported by Williams, G. H., and Clark, W. B., Maryland; its resources, industries, and institutions, Baltimore, p. 68, 1893.
[18] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (No. 10), p. 3, 1894.

of outcrop and the dip of the rocks, it appears to be at least 2000 feet thick on Holston Mountain. In the Roan Mountain area, Tennessee, Keith[19] makes the Hampton equivalent to the combined Nichols shale, Nebo sandstone, and Murray shale. The combined average thickness of these formations is about 1700 feet, a figure that agrees well with the estimate of 2000 feet above. On the west slope of the Blue Ridge, west of Whites Gap, as noted above, the shaly rock of Harpers type is 4000 feet thick, unless undetected repetitions due to close folding are present. About 400 feet of quartzite of the Unicoi type is present below the rock of Harpers type. This aggregate of 4400 feet or more is about the combined thickness of the Unicoi and Hampton in southern Virginia and northern Tennessee. It seems reasonable, therefore, to assume that only the upper 2000 feet of the rocks of Harpers type in the section west of Whites Gap corresponds actually to the Harpers and that the lower 2000 feet is a thin-bedded facies of the Unicoi. This section seems to repeat the one on Poplar Camp Mountain, Carroll County. At Harpers Ferry the thickness is stated by Keith[20] to be 800 to 1200 feet, but, owing to faults which may cut off part of the formation, the 1200 feet may not represent the full thickness. The Harpers is said to be as much as 2750 feet thick in the Waynesboro area in southern Pennsylvania.[21]

Fossils and correlation.—No fossils have been found in the Hampton-Harpers shale to prove its Cambrian age, but if the Unicoi is Cambrian, as generally held, the Harpers also is necessarily Cambrian. The Erwin-Antietam quartzite which overlies the Hampton-Harpers shale has yielded a few specimens of *Olenellus*, which is universally accepted as a Lower Cambrian genus; hence the Harpers is Lower Cambrian or older. Like the Unicoi, it is possibly pre-Cambrian and might be referred to the Beltian group of the Rocky Mountains.

ERWIN QUARTZITE—ANTIETAM SANDSTONE

Names.—The Erwin quartzite was named by Keith[22] from Erwin, Unicoi County, Tennessee; the Antietam sandstone by Keith[23] from Antietam Creek, Maryland.

---

[19] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Roan Mountain folio (No. 151), p. 5, 1907.

[20] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (No. 10), p. 3, 1894.

[21] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), p. 4, 1909.

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

[23] Keith, Arthur, as reported by Williams, G. H., and Clark, W. B., Maryland; its resources, industries and institutions, Baltimore, p. 68, 1893.

Limits.—The Erwin-Antietam is defined below by the Hampton-Harpers shale and above by the Shady-Tomstown limestone and dolomite. Both adjacent formations are distinctly different from the Erwin-Antietam, so that it can be easily recognized wherever the rocks are at all well exposed at or near the contact.

Character.—The Erwin-Antietam is a quartzose sandstone or quartzite, depending upon the degree of the metamorphism that has affected it from place to place. It is mainly a medium- to fine-grained, moderately thick- to massive-bedded, gray, whitish-weathering rock. The main mass of the material appears to have been a thoroughly sorted, clean, white, beach sand. The rock resembles the Clinch sandstone. Locally the grains are completely cemented with silica to form a compact quartzite, as for example, in the sandstone quarry half a mile east of Waynesboro, Augusta County, Virginia. It is more thinly bedded toward the top than in the lower parts. Weathered exposures and detached masses are commonly light gray. The uppermost part of the formation has a brownish or rusty color due to small blotches of iron oxide scattered through the rock. Thin beds of shale are reported by Keith in places in the type region in Tennessee. None were noted in the best exposures in Virginia, but their local occurrence may be suspected. Keith reports beds of conglomerate with pebbles half an inch or more in diameter in the vicinity of Elizabethton, Tenn., but no conglomerate was observed by the writer in Virginia. The general appearance of the formation is shown in Plate 13B and C.

Distribution.—The Erwin-Antietam sandstone occurs only along the northwest flank of the Blue Ridge, including Holston and Iron mountains in southern Virginia. Along this belt the formation persists from Tennessee to Potomac River and northward into eastern Pennsylvania. It extends from southern Virginia southwestward into Sevier and Blount counties, Tennessee, where it is represented by the Hesse sandstone, the highest member of the Chilhowee group. From James River northeast to Front Royal, Warren County, this formation probably is responsible for the many knobs and wide belt of rough country just to the northwest of the main crest of the Blue Ridge. The wide area of the Chilhowee rocks occupied by a great maze of knobs southeast of Greenville, Augusta County, is probably due to the presence of a thick development of Erwin-Antietam in that area and to an intricate complex of minor folds and faults. In Clarke County it caps only a few summits just to the east of Shenandoah River.

The Erwin is poorly exposed on the southeast slope of Holston Mountain on U. S. Route 421, but its limits can be closely determined. Its upper 50 feet forms an excellent exposure in the natural wall across the valley of Beaverdam Creek, Tennessee, about 4 miles south-southwest of Damascus, Virginia. (See Pl. 13B.) The most complete and thickest exposure observed by the writer is on the old State road 1 mile west of Whites Gap, Rockbridge County, and 8 miles east of Lexington. Here the formation is almost continuously exposed in road cuts for a mile. (See Pl. 14C.) On Big Run 2 miles above its mouth, and 4 miles southeast of McGaheysville, Rockingham County, it is extensively exposed but not easily accessible. Other good exposures may be seen at the sandstone quarry half a mile east of Waynesboro and just north of the manganese ore pit at Crimora, 6 miles northeast of Waynesboro.

Thickness.—The thickness of the Erwin-Antietam varies. At the exposure west of Whites Gap, it appears to be at least 1500 feet thick. The writer has found no other places in Virginia where a satisfactory determination could be made. Its thickness in Maryland is stated to be 500 feet, in Pennsylvania 500 to 800 feet, and in Tennessee 800 to 1100 feet. It apparently reaches its maximum thickness in the belt between James River and Waynesboro, Augusta County, Virginia.

Fossils and correlation.—The Erwin-Antietam has yielded a very few fossils, comprising species of *Olenellus, Hyolithes,* and *Obolella.* They are of early Cambrian age and of great interest because they are the earliest forms of life so far found in the Appalachian Valley and in the eastern United States.

SHADY-TOMSTOWN DOLOMITE

Names.—The Shady dolomite was named by Keith[24] from Shady Valley, Johnson County, Tennessee. The name Tomstown was later given to a corresponding unit by Stose[25] from Tomstown, 3 miles north of Waynesboro, Franklin County, Pa. Both authors called the formation a limestone. In Virginia it is predominantly a dolomite; hence the change in the name. The name Tomstown has been used north of Roanoke and the name Shady south of Roanoke. It is now known that both units are the same formation. The term Shady has priority. For these reasons the name Shady is used throughout this report.

[24] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranberry folio (No. 90), p. 5, 1903.
[25] Stose, G. W., The sedimentary rocks of South Mountain, Pennsylvania: Jour. Geology, vol. 14, p. 208, 1906.

Limits.—The Shady is easily distinguished from the Erwin-Antietam sandstone and, in most places at least about as easily distinguished from the red shale and other beds of the overlying Rome formation. Shaly transitional beds are reported in some localities between the Erwin-Antietam and the Shady, but none has been observed by the writer in Virginia. In one section (geologic section 2) the lower part of the Shady contains thin layers of sandstone but in all other places observed, the change from the underlying sandstone to the dolomite is abrupt. The bedding is parallel, as shown in Plate 14A and B.

There is nowhere an angular unconformity between the sandstone and the dolomite nor any direct evidence of a hiatus caused by the absence of beds, although there is some reason for assuming a hiatus. The abrupt change from quartz sand to pure calcareous material, such as dolomite, which seems to be the general rule at this horizon, suggests a considerable time without deposition, during which the change of physiographic conditions on land leading to the change in sedimentation in the sea was brought about.

Character.—The Shady is predominantly a dolomite, but in some areas it includes limestone in both the upper and lower parts. Layers of limestone, which may be more or less magnesian, are scattered through the mass. Certain beds of fossiliferous limestone in the middle of the formation appear to be lenses of small extent. In the New River district in Wythe and Pulaski counties, three members can be recognized in the Shady dolomite: the Patterson limestone member in the lower part; a saccharoidal dolomite in the middle, here named the Austinville dolomite member from the town of Austinville; and the Ivanhoe limestone member at the top. The following sections show the general character of the formation and the succession of the different members.

Geologic Section 2.—Part of Shady dolomite at the great bend of New River 1 mile west of Jackson Ferry, Virginia

	Approximate Thickness Feet
Shady dolomite (1400 feet)	
Austinville member:	
6. Dolomite, white, saccharoidal	1000
Patterson limestone member:	
5. Limestone, blue, finely laminated, banded	50
4. Not exposed	50

	Approximate Thickness Feet
3. Limestone, like bed 5, but not so pure	50
2. Dolomite and limestone	50
1. Lower part dolomite, massive, fine grained, blue, nodular in lower part and interbedded with thin layers of sandstone	200
Erwin quartzite	
Sandstone, thick and thin bedded, some coarse grained, some fine grained and bluish; exposed above railroad track; 30 to 40 feet above river	15

In this section the top bed, Austinville member, is exposed along the Norfolk and Western Railroad for about half a mile west of Jackson Ferry, but it was not examined carefully by the writer to determine its character throughout or its structure and thickness.

Another section occurs along the road at Porter, 2 miles north of Ivanhoe, Wythe County, in which the section of the formation, nearly all exposed, is as follows:

Geologic Section 3.—At Porter, 2 miles north of Ivanhoe, Wythe County, Virginia. The section begins at the top at the bridge over Cripple Creek, 1850 feet north of Porter

	Thickness Feet
Rome formation (639+ feet)	
41. Limestone	5
40. Sandstone, red	25
39. Limestone	1½
38. Sandstone and shale, interbedded, red	55
37. Limestone, mainly blue	150
36. Not exposed	120
35. Dolomite and limestone	30
34. Rusty, rotten rock, probably decalcified sandy shale	40
33. Limestone, argillaceous, weathers to rusty mealy condition	5
32. Shale, red	25

	Thickness Feet
31. Dolomite, blue, medium bedded	30
30. Shale, red	10
29. Limestone, with 4 partings of red shale	60
28. Limestone, thinly bedded	40
27. Shale, red	2
26. Limestone, thinly bedded	15
25. Shale, red	1
24. Limestone, thinly bedded, partings of red shale	25
Shady dolomite (1683 feet)	
23. Limestone, mostly thick bedded, blue	55
22. Dolomite, mostly bluish fine grained	45
21. Dolomite, shaly, sandy	1½
20. Dolomite, bluish gray, fine grained	5
19. Dolomite, shaly, sandy	1½
18. Dolomite, thick and thin bedded, mostly light bluish gray, fine grained	150
17. Dolomite, thin bedded to shaly, blue, fluorspar films	30
16. Dolomite, fine grained, light gray, compact with lithographic texture at top	100
15. Dolomite, blue, crystalline, mottled with calcite spots	100
14. Dolomite, white, crystalline	30
13. Dolomite, steely blue	30
12. Dolomite, white, crystalline as below	55
11. Dolomite	100
10. Dolomite, thick bedded, steely blue	30
9. Dolomite, light gray to white, crystalline	130
8. Dolomite, thick bedded, bluish, finely crystalline	250
7. Limestone, like bed 5, below	60
6. Dolomite	100
5. Limestone, blue, banded, peculiar checkered surface like an alligator skin, Patterson limestone member	250
4. Dolomite, thick bedded, mottled and striped, weathers dull brownish gray	160

	Thickness Feet
Fault; Shady thrust upon Rome	
Rome formation	
3. Shale, gray, weathers yellow	50
2. Shale, red	5
1. Limestone, weathers rusty	10

The Porter section of the Shady is complete except for the portion not brought up by the fault north of Porter. From the section at the bend of New River west of Jackson Ferry (geologic section 2) it is judged that the unexposed part of the Shady is small, for, in that section, the Patterson limestone is only 200 feet from the Erwin quartzite.

Another section showing a different facies of the upper beds of the Shady has been described by Currier:[26]

Geologic Section 4.—Middle and upper Shady at and near the National Carbide quarry 1 mile due east of Ivanhoe and 2½ miles southeast of Porter, Virginia

	Thickness Feet
Rome formation	
39. Covered	50
Ivanhoe limestone member (542-547 feet)	
38. Limestone, white to light dove-gray, dense	6
37. Dolomite, nearly white, finely crystalline	4
36. Limestone, dove-gray, dense and finely crystalline	12
35. Covered	8
34. Limestone, light gray, dense and slightly crystalline, evenly laminated, shows thin brecciated beds	6
33. Dolomite, light gray, finely crystalline, slightly sandy	1½
32. Sandstone, dolomitic, thin bedded, platy	3
31. Covered	3
30. Dolomite, saccharoidal	½

[26] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, p. 28, 1935.

	Thickness Feet
29. Limestone, dove-gray, dense to finely crystalline, massive	6½
28. Dolomite, light gray, fine grained, apparently lens derived from limestone by dolomitization	4
27. Limestone, dove gray, dense and slightly crystalline	13
26. Covered	5
25. Dolomite, very light gray, finely crystalline	8½
24. Covered	5
23. Limestone, as above	5
22. Covered	6
21. Limestone, as above	8
20. Covered	12
19. Limestone, dense, dove-gray, grading into bed below	5
18. Dolomite, very dark gray, crystalline	4
17. Covered	4
16. Dolomite, light gray, crystalline, partly calcareous	2½
15. Dolomite, very dark gray, fine grained	1½
14. Covered	6
13. Limestone, dove-gray, dense, massive	19
12. Covered	10
11. Limestone, as above	87
10. Covered	10
9. Limestone, nearly white, dense	40
8. Covered, includes near top several feet of dark gray, brecciated dolomite, bearing streaks of coarse grained white dolomite and a sphalerite prospect	65
7. Dolomite, sandy and argillaceous	2
6. Covered	6
5. Limestone, dove-gray, dense to finely crystalline, massive	13
4. Covered	15
3. Dolomite, light gray, crystalline	7

	Thickness Feet
2. Covered	9
1. Limestone, chiefly dove-colored and medium gray, dense, massive; includes very thin reddish sandy and shaly partings; dolomitized and streaked with coarse white dolomite at base	125–130
Austinville ("saccharoidal") member	600

The amount of limestone in the upper part of the Shady here gives it a facies strongly contrasting with the upper 500 feet of the Porter section and warrants constituting it a distinct member of the Shady. This was named the Ivanhoe member by Currier.[27] The thick bed of limestone at the base of the Ivanhoe, which is relatively pure, has been extensively quarried for the manufacture of calcium carbide at Ivanhoe which give it economic importance. If the Porter section is considered to be more nearly the normal section of the Shady in southwestern Virginia, the Ivanhoe section shows a striking departure in the strong development of limestone in the upper 500 feet. An apparently continuous section of beds of almost uniform southeast dip, made from exposures along Clear Creek from the Norfolk and Western Railroad to the vicinity of Bethany and thence to the assumed contact with the Chilhowee rocks near the crest of Poplar Camp Mountain, is given below. If the section is really continuous, the Shady is extraordinarily thick here. So far as observed, only a small anticline and a small fault, inferred by Currier, cross the section near its middle part.

Geologic Section 5.—Shady dolomite along Clear Creek, 1 mile east of Austinville, Virginia, from the Norfolk and Western Railroad to Poplar Camp Mountain

	Thickness Feet
Chilhowee rocks (near crest of Poplar Camp Mountain)	
Fault	
Shady dolomite (5040 feet)	
13. Not exposed, probably limestone and dolomite; estimated	500±
12. Limestone with oolitic, brecciated, and sandy layers	300

[27] Currier, L. W., op. cit., p. 16.

		Thickness Feet
11.	Dolomite, partly crystalline, layers with clastic impurities	400
10.	Dolomite and limestone interbedded, brecciated layers with clastic impurities	600
9.	Limestone, partly exposed, black, medium coarse-grained, crystalline, contains *Kootenia* and *Nisusia*	80
8.	Shale, or laminated dark-colored sandy, argillaceous, and calcareous rock interbedded with limestone and dolomite; contains *Ptychoparella* and *Amecephalina*	400
7.	Dolomite	1200
6.	Dolomite, argillaceous, slightly sandy with very fine quartz sand and fossils; *Nisusia* bed, contains *Nisusia* and *Bonnia*	20
5.	Dolomite	400
4.	Limestone (reef), white and dark-colored, locally splotched with pink, contains *Archaeocyathus, Nisusia, Kutorgina, Stenotheca, Helcionella* (Fossil Point limestone)	20±
3.	Dolomite	350
2.	Limestone, fossiliferous; contains *Kutorgina* and *Prozacanthoides*	20±
1.	Dolomite, Austinville member with *Archaeocyathus;* possibly Patterson limestone in the lower part; bottom not exposed	750±

In the above section beds 10 to 12, inclusive, are from a section published by Currier.[28]

The remainder of the section, including bed 13 at the top, is based on the writer's field notes. There is plainly a great difference in the lithologic character and thickness from the section at Porter 5 miles west-northwest. Porter, however, is in another belt of outcrop which is separated by an overthrust fault from the belt south of Austinville.

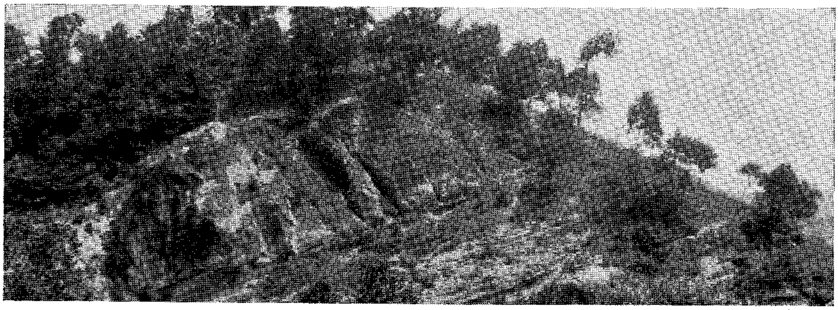
[28] Op. cit., p. 33.

PLATE 15

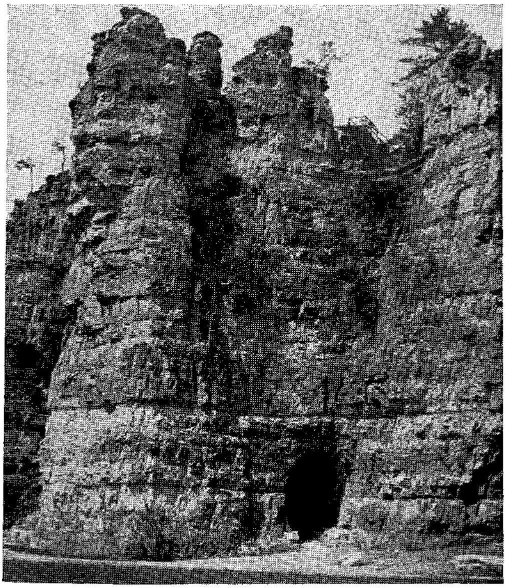
A. Massive bed of dolomite in shale of the Rome formation, 3 miles east of Wytheville, Wythe County. Cut on the Norfolk and Western Railroad. Looking north.

B. Cyclopean Towers, in Elbrook limestone along the east side of the valley of North River north of Mt. Solon, Augusta County. Produced by erosion of horizontal beds, intersected by vertical joints. A view of a small part of a much more extensive cliff. Photograph by J. K. Roberts.

C. Thin-bedded sandstone and shale in the Rome formation, along State Route 121, about 3 miles south of Fort Chiswell, Wythe County. Looking northeast in the direction of strike.



A

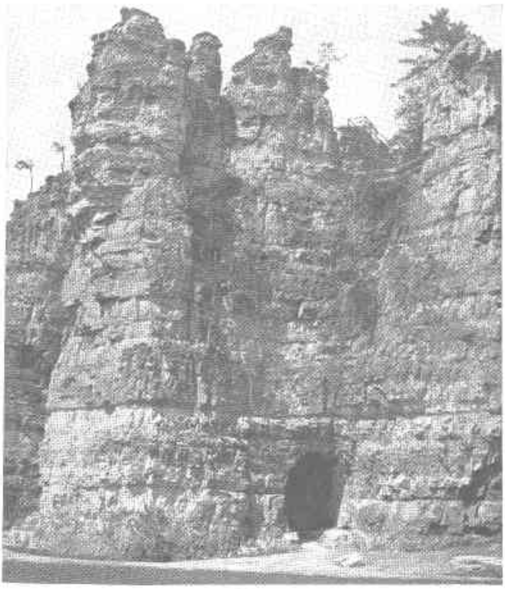


B

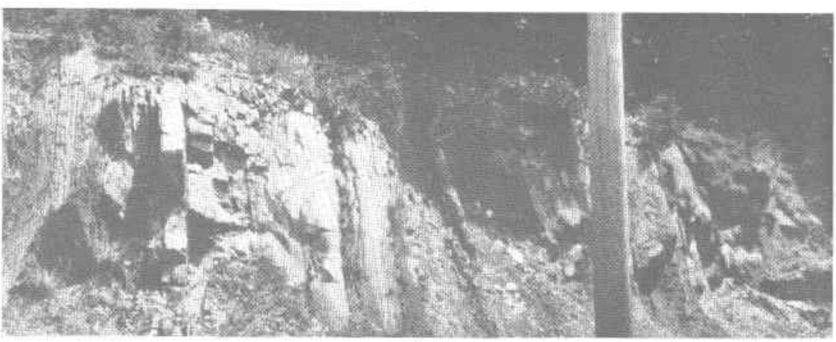
C

CAMBRIAN FORMATIONS

A



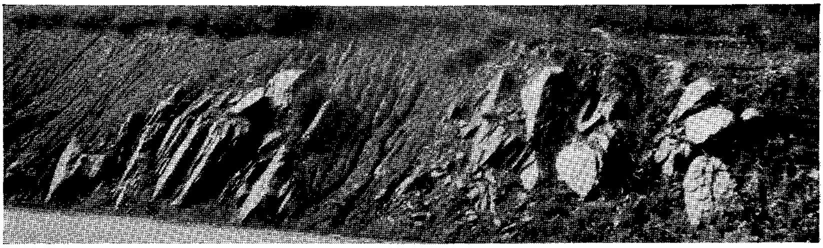
B



C

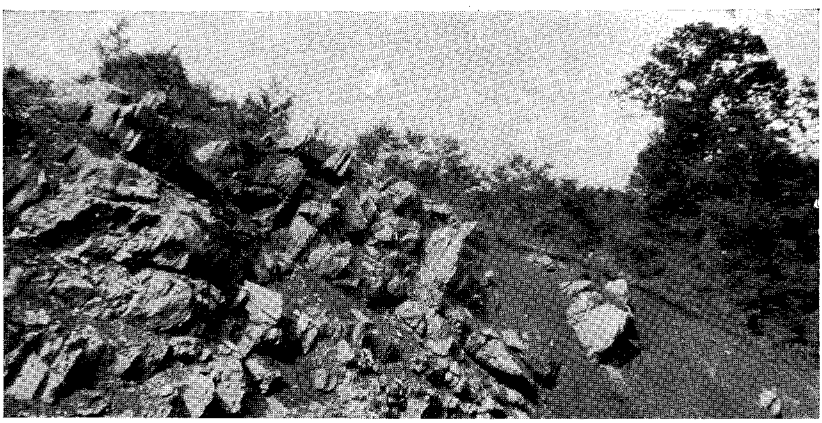
CAMBRIAN FORMATIONS

A



B

C



D

CAMBRIAN FORMATIONS

A

B

C

D

CAMBRIAN FORMATIONS

PLATE 16

A. Upper part of the Rome formation, southeast of Brookside Inn, Russell County. About 1100 feet of the Rome is exposed. The base of the Rutledge limestone (D below) shows at the extreme left end of the view. The Copper Creek fault crops out just to the right of the view. The bottom bed of limestone is about 25 feet from the fault. Fossils occur throughout the thin argillaceous limestone layers. The Moccasin red limestone is exposed 100 feet to the right. Along State Route 71, looking southeast from a point 550 feet southeast of Brookside Inn.

B. Limestone in the Rome formation with red shale above and below. Along State Route 71, 2000 feet southeast of Brookside Inn. Looking southeast.

C. Shale and thin limestone in the Rome formation, about half a mile southeast of Brookside Inn. Looking southeast.

D. Rutledge limestone (left) in contact with the Rome formation (right), southeast of Brookside Inn. Shown in the extreme left of A. The shale bed is 60 feet thick. Looking northeast.

Geologic Section 6.—Part of Shady dolomite along Short Creek, east and north of Poplar Camp, Virginia

	Thickness Feet
Chilhowee group	
Fault	
Shady dolomite (1550± feet)	
2. Dolomite and limestone, generally rather thin bedded, some thin sandy and some brecciated layers, exposed on the northwest slope of Poplar Camp Mountain east of Poplar Camp village	700±
1. Dolomite, partly coarsely crystalline, dark and light gray	850±

The great difference in character and thickness of the Shady in the Austinville district as compared with the Shady elsewhere has been a problem.

Some geologists, including Currier, have suggested the correlation of the fossiliferous limestone beds 2 and 4 of the Clear Creek section (geologic section 5) with the Ivanhoe limestone, because of lithologic similarity. Structurally the correlation is plausible, for the Ivanhoe occurs on the northwest limb of an anticline just above the Austinville (saccharoidal) member, and the fossiliferous limestone beds occur in the same position above the Austinville member on what appears to be the south limb of the same anticline. But no fossils have been found in the Ivanhoe, and thus the suggested correlation seems doubtful. Other geologists have thought that the part of the section above the fossiliferous limestone beds, extending upward to include the semiclastic blackish stratum, bed 8, represents the Rome formation in a changed facies, but this explanation seems untenable for two reasons: The beds in question lack all the characteristic lithologic features of the Rome, including its most characteristic type of rock, red shale, whereas 2 miles to the northwest the Rome is present with its characteristic lithology; furthermore the black limestone, bed 9, carries *Nisusia* and the same genera of trilobites as bed 4, the species of bed 9 differing but slightly, if at all, from the species of bed 4. No such fossils are known in the Rome. The evidence then is decidedly against correlating any part of the Austinville section with the Rome formation.

The explanation of the seeming, and probably actual, abnormal thickness of the limestone in this area by assuming that it is in part Rome has been carried further by assuming that the upper beds, including beds 10-12 and probably bed 13 of the Clear Creek section, are in the succeeding Elbrook limestone. But, if the beds tentatively referred to the Rome are actually Shady, as the fossils of the black limestone (bed 9) indicate, then there are no grounds for regarding the upper beds, which apparently normally succeed the black limestone, as Elbrook. Currier[29] has postulated a fault or a number of minor faults to explain the situation. On this hypothesis the beds above the black limestone (bed 9) are lower Shady of a changed facies thrust up and over higher Shady beds by a fault passing near the intersection of Clear Creek with the road from Austinville to Bethany. But no structural evidence of such a fault is evident. Moreover, beds 10-12 and the apparently still higher beds of the upper part of the Poplar Camp section, bear no resemblance to the lower part of the Shady, and especially no resemblance to the Austinville saccharoidal member, although a few layers of saccharoidal dolomite occur in those beds.

Since the preceding discussion was written, the Austinville area has been studied in detail by Stose and Jonas.[29a] Their interpretation postulates several faults by which the Shady has been repeated in part, and if correct, that interpretation will explain the apparently greater thickness of the formation here.

The Patterson limestone is a thin-bedded, pure, blue limestone, apparently about 200 feet thick, along the Norfolk and Western Railroad 1 mile west of Jackson Ferry, Wythe County, where geologic section 2 was measured. About 200 feet of dolomite with thin sandstone layers is present below the Patterson in this section. Currier[30] has included these layers in the Patterson, extending it to the Erwin quartzite below. From this it follows that the lower part of the Shady has different facies from place to place in and near the Austinville area. The old iron ore pits on the ridge about 1 mile northwest of Laswell, Wythe County, appear to be on an outcrop of the Patterson limestone.

The Austinville, or saccharoidal, member is composed of characteristic, thick-bedded, rather coarsely crystalline, nearly white, light-gray, to cream-colored dolomite. This type of rock characterizes the Shady from north of Riverton, Warren County, Virginia, to Alabama. Analyses of specimens collected through a thickness

[29] Op. cit., p. 30.

[29a] Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll counties, Virginia: Virginia Geol. Survey Bull. 51-A, 1938 (published 1939).

[30] Op. cit., p. 21.

of about 100 feet at Thomas Bridge on the South Fork of Holston River 6 miles southwest of Marion, Smyth County, show the rock to be practically a normal dolomite with not more than 2 per cent of insoluble impurities, 43 per cent magnesium carbonate, and 54 per cent calcium carbonate. The crystalline texture of the rock is plainly evident under a hand lens. The rhombic crystals show a decided uniformity in size. The rock takes a good polish and probably would make a suitable building stone, but it is too much checked by cracks and small pits for use as an ornamental marble. The zinc ores now mined at Austinville are in this Austinville member, and the open pit workings for zinc carbonate at Bertha, Wythe County, and vicinity are probably located on its outcrop. The subsurface erosion of the rock through solution, probably because of its purity, is shown in one of the open workings in the Bertha district. (See Pl. 6A.) Iron ore (limonite) and manganese ore have both been obtained in considerable quantities at different localities in the Shady dolomite in Virginia. Extensive diggings were made on the top of a flat bench or spur 1 mile west of Ivanhoe.

The Ivanhoe limestone member is composed predominantly of thick-bedded, gray limestone interbedded with layers of dolomite which make only a small proportion of the whole. With the exception of the members just described, the Shady is composed of bluish-gray dolomite or to a less extent of ordinary blue limestone. Some of the layers in the Austinville area, especially in the upper beds (geologic section 5, beds 10-12), are oolitic, others sandy, and others strongly brecciated, being largely composed of angular fragments of blue limestone indiscriminately mixed. In a few places in the Austinville area rather large bodies of fissile, greenish clay shale occur. One such place is just northwest of the highway 1 mile due south of Austinville, and another and more extensive area is about 1½ miles south-southwest of Austinville.

Distribution.—The Shady dolomite crops out only in one belt in Virginia. This belt lies along the northwest foot of the Blue Ridge for the full length of the Valley and is continuous, except where locally covered by the overthrust Chilhowee rocks. None of the other faults or anticlines in the Valley bring the Shady to the surface. The distribution of the Shady is shown on the geologic map of the Valley (Virginia Geol. Survey Bull. 42).

From Damascus, Washington County, near the southern boundary of Virginia the Shady crops out almost continuously, to a point midway between Allisonia and Hiwassee, Pulaski County.

From a point east of Steeles Tavern, Augusta County, to the northern end of the belt of outcrop, the area is so deeply covered by an apron of detritus washed down from the slopes of the Blue Ridge, that it is not possible to be sure that the Shady is present everywhere. About 2 to 3 miles east of Front Royal it again emerges from beneath the overthrust mass of the Blue Ridge and is traceable to Harpers Ferry.

One of the best exposures of the Shady is in a quarry on the Norfolk and Western Railroad half a mile east of Buchanan, Botetourt County (Pl. 14A and B), and another, almost as good, is found at Porter, Wythe County. (See geologic section 3.) Excellent exposures mark the east bank of New River for a mile just south of Ivanhoe and the north bank of the river about 1 mile east of Ivanhoe. Many beds are well exposed on Laurel Creek in Damascus, Washington County; on the South Fork of Holston River at Thomas Bridge, 6 miles southwest of Marion; in the vicinity of Quebec, Smyth County; and at Cedar Springs, Smyth County. In the northern area good exposures are available in the vicinity of Sherwood, a few miles east of Natural Bridge, Rockbridge County. Campbell[31] proposed the name Sherwood limestone for these exposures, but the term Shady has priority. In Shenandoah River, at the great bend 4 miles east of Riverton, Warren County, the Shady is extensively displayed and makes a long riffle at low stages of the river. On the bluffs of the great meanders of the river south of Berryville, Clarke County, the Shady is extensively exposed at several points. A very large exposure of characteristic dolomite is 1½ miles northeast of Castlemans Ferry and 1000 feet west of Shenandoah River, Clarke County. A good exposure is just below Boyds Ferry on Shenandoah River, Jefferson County, West Virginia. The Shady is extensively quarried at Millville, West Virginia, 3 miles southwest of Harpers Ferry, where it has many specimens of *Salterella* in the top beds of the quarry.

Thickness.—The best determination of the thickness of the Shady is that of the Porter section (geologic section 3), in which 1683 feet is exposed. Allowing 100 feet or more for the lowermost beds not brought up by the fault at the bottom of the section, the total thickness is here about 1800 feet. The thickness of more than 5000 feet derived from the exposures in the Austinville area (geologic section 5), is so abnormal and subject to so many possible sources of error that it should be regarded with suspicion. At

[31] Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., vol. 20, pp. 445-447, 1905.

the quarry half a mile east of Buchanan, Botetourt County, the only other place that seems to offer a satisfactory condition for measurement, no measurement was made. A thickness comparable with that at Porter is suggested at Sherwood, Rockbridge County, where Campbell[32] reported a thickness between 1600 and 1800 feet. Near Tomstown, Franklin County, Pennsylvania, Stose[33] reported it to be about 1000 feet thick.

Fossils and correlation.—Throughout most of its extent from Pennsylvania to Alabama the Shady dolomite is very sparingly fossiliferous. Representatives of the genus *Salterella* were reported by Walcott from outcrops near Waynesboro, Franklin County, Pennsylvania, and by Henry McCalley in the Shady ("Aldrich") limestone in the vicinity of Anniston, Alabama.[34] As noted above, *Salterella* occurs at Millville, West Virginia. Within the last five or six years, several fossiliferous localities have been discovered in the Austinville area in Wythe County. This discovery was made by the geologists of the Bertha Mineral Company at Austinville, and to them, especially to W. H. Brown, should go the credit for the discovery. The fossils occur at several points and in several beds, mostly within an area 2 miles east and southeast of Austinville. Other localities are one-fourth of a mile due east of Jackson Ferry, 2 miles southwest of Fosters Falls, and at a point probably not far east of Fosters Falls, where a specimen of an olenelloid trilobite was recently found in what is probably the Patterson limestone member. This is the oldest fossil so far found in the Shady. The main collections have been made from a blue-gray, white-weathering limestone exposed on the point of a spur between Clear Creek and Huddle Branch, almost 1 mile east of Austinville. This is bed 4 of the Clear Creek section (geologic section 5), and this locality for convenience is called Fossil Point. Other fossiliferous horizons which yield the fauna found at Fossil Point are shown in the detailed section. (See geologic section 5.) Several other localities have yielded fossils. The limestone at Fossil Point appears to be a reef resulting from the deposition of limy sediments through the activities of the animals that lived in abundance upon it. The fossils collected from these localities have been studied and described by Resser.[35]. Most of the fossils that he has identified and named are listed below:

[32] Op. cit.

[33] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), p. 5, 1909.

[34] McCalley, Henry, Report on the Valley regions, Alabama: Part 2, p. 41, 1897.

[35] Resser, C. E., Cambrian system of the southern United States: Geol. Soc. America Special Paper No. 15, 1938.

Fossils from the Shady dolomite

Sponge or coral
- Archaeocyathus sp.

Brachiopods
- Kutorgina sp.
- Nisusia cf. N. festinata (Billings)
- Paterina swantonensis (Walcott)
- Yorkia sp.

Gastropods
- Helcionella buttsi Resser
- Helcionella callahani Resser
- Hyolithellus sp.
- Hyolithes sp.
- Scenella virginica Resser

Trilobites
- Amecephalina poulseni Resser
- Austinvillia virginica Resser
- Bicaspis austinvillensis Resser
- Bonnia crassa Resser
- Bonnia tenuis Resser
- Bonniella minor Resser
- Bonniella virginica Resser
- Kootenia currieri Resser
- Kootenia browni Resser
- Kootenia virginiana Resser
- Olenellus austinvillensis Resser
- Olenoides hybridus Resser
- Proliostracus goodwini Resser
- Proliostracus granulatus Resser
- Prozacanthoides excavatus Resser
- Prozacanthoides expansus Resser
- Prozacanthoides virginicus Resser
- Ptychoparella michaeli Resser
- Zacanthoides nitidus Resser
- Zacanthopsis virginica Resser

A number are new genera, and most, if not all, are new species and are of uncertain value for correlation. *Kutorgina* sp. and *Nisusia festinata?* are possible exceptions. Either one or both of these fossils occur in the Forteau limestone of Labrador along the Straits of Belle Isle, and across the straits along the northwest side of Newfoundland; at Bic harbor on St. Lawrence River, Canada; and in northwestern Vermont. *Nisusia festinata* is rather common in the vicinity of Emigsville, York County, Pennsylvania. Species of *Bonnia* occur in the Forteau limestone on the Straits of Belle Isle; at Bic Harbor, Quebec; in northwestern Vermont; in the Schodack formation of the Hudson Valley, New York; in the Kinzers shale near Emigsville north of York, York County, Pennsylvania; and in the Mount White formation in the Canadian Rocky Mountains. *Archaeocyathus* reefs are known in Labrador, Vermont, the Hudson Valley, Pennsylvania, and from southern Virginia to northern Georgia. The Archaeocyathae are of uncertain zoological affinities but generally regarded as related to the sponges and corals. They are widespread at this general horizon (Lower Cambrian) throughout the world and are especially abundant and varied in southern Australia. They occur in the Austinville dolomite member, in the limestone at Fossil Point, and in other beds far below the horizon of this limestone. Large chunks of dolomite crowded with the contorted cups of this fossil have been found in the zinc mine at Austinville. This fossil occurs also in the Shady on the old railroad three-fourths of a mile west of Teas in the Rural Retreat quadrangle, and has also been collected at a barite mine and at other localities in northwest Georgia.

Wherever it is possible to determine the stratigraphic position of the formations that carry these fossils they are found to lie a short distance above pre-Cambrian crystalline rocks.

ROME-WAYNESBORO FORMATION

Names.—The name Rome was introduced by Hayes[36] from Rome, Georgia, which is located upon an outcrop of the formation. The name Montevallo[37] was published about one month earlier, and thus has a slight priority over Rome, but the latter has obtained such currency that it seems to the best interest of geologic science to retain it. The name Watauga has been extensively applied and is still in use in Tennessee. The names Russell and Buena Vista have also been applied to the same formation in different localities in Virginia, but have been abandoned as synonyms. The name Waynesboro introduced by Stose[38] is in the same category, but it has been retained for the present and, like the northern names of the formations of the Chilhowee group, applied to the formation as far south as Roanoke, Virginia. The formation, however, is a single unit and it is thought best to apply the name Rome throughout.

---

[36] Hayes, C. W., The overthrust faults of the southern Appalachians: Geol. Soc. America Bull., vol. 2, p. 143, 1891.

[37] Smith, E. A., Report on Cahaba coal field: Alabama Geol. Survey, p. 148, 1890.

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

Limits.—The Rome is a lithologic unit. Its base is commonly marked by red shale as is shown in the continuous exposure across the contact in the Porter section (geologic section 3), and also in the Buchanan section (geologic section 8). Its top is defined by the contact between the uppermost clastic beds and the succeeding continuous sequence of dolomite or limestone, whether Rutledge and Maryville as in Scott County, or Honaker dolomite farther northeast, or Elbrook dolomite along the southeast side of the Valley. All of the clastic rock of the Rome type is here included in the Rome, although the uppermost 200 to 300 feet, or even 600 feet, as in geologic section 7, may contain Middle Cambrian fossils. The Rome is so distinct from the overlying and underlying formations that there is little difficulty in recognizing it everywhere and in determining its boundaries where they are exposed.

Character.—The Rome-Waynesboro is an extremely heterogeneous formation, being composed of red and green shale, sandstone, dolomite, and pure limestone, all of which vary greatly in proportion and distribution throughout the formation in different areas of its outcrop. (See Pls. 15A and C.) The red shale is the most impressive feature of the formation throughout Virginia, as well as in the Appalachian Valley from Pennsylvania to Alabama. It not only attracts attention in exposures of the bed rock itself, but generally colors the soil, above parts of the formation in which it is present, a bright red. Such soil is a reliable index of the underlying Rome formation because no significant beds of red rock are present in the formations underlying the Rome and none in those overlying it for a thickness of several thousand feet. The next red rocks above the Rome are those in the Moccasin limestone of Ordovician age. The outcrop of the Moccasin is generally so far from the outcrops of the Rome that there is slight chance of confusing the two formations because of the red color. Actually, red shale forms a minor proportion of the Rome. The gray or greenish shale portion commonly has a silky luster, due to a high sericite content, and is nearly as good an index of the Rome as the red shale. Beds of dolomite reaching a thickness of 50 to 100 feet occur locally. In the vicinity of Roanoke, they are so prominent and so coarsely crystalline that they can be mistaken for Shady dolomite. Such a bed, intercalated in the gray and red shale, is shown in Plate 15A. Beds of pure, blue-banded limestone, similar to those making up much of the overlying Rutledge and Maryville limestones of Scott County, and of limestone beds in the Nolichucky shale, are found in the Rome throughout the

Valley, but such limestones are neither numerous nor thick. Thin beds of argillaceous limestone are common in the sequence but constitute only a small part of the formation. They commonly weather to a reddish or tawny colored ocher somewhat resembling tripoli. This rock is also very characteristic of the Rome, though somewhat similar rock occurs in small amounts in the overlying Elbrook dolomite or limestone. This type of rock is well displayed on the Lee Highway (U. S. Route 11) in the bend of Reed Creek about midway between Wytheville and Draper. The reddish ocher is exposed on the road between Hiwassee and Snowville, a mile or so northeast of Hiwassee. Trilobites, such as *Olenellus,* are commonly found in these beds in an excellent state of preservation. Beds of medium- to fine-grained, rusty, to reddish brown sandstone are of common occurrence. In some sections the sandstone beds are thin and comprise a small proportion of the formation. Some of these beds are ripple-marked. The Rome as described above extends as far north as Waynesboro, Augusta County, where considerable red shale is present. Northeast of Waynesboro there are but few exposures and the character of the Rome is not well known. In Clarke County thin beds of red shale have been seen in a few places. A few other exposures show rusty argillaceous limestone or dolomite and more or less ferruginous shale and thin sandstone.

The character of the formation is shown by the upper part of the Porter section (geologic section 3), and by the following sections:

Geologic Section 7.—Rome formation along State Route 71, just south of Brookside Inn, Washington County, Virginia

	Thickness Feet
Honaker dolomite (Rutledge limestone equivalent at base)	
Limestone, blue banded, thick bedded (Pl. 16D), trilobites rare	175
Rome formation (1282 feet)	
52. Shale, green, thin limestones (Pl. 16D), trilobites, *Elrathiella buttsi, Solenopleurella minor*	60
51. Limestone, blue, banded	5
50. Limestone, thin bedded, shale partings, fossils in basal part	70
49. Shale, red	5

		Thickness Feet
48.	Shale, green	15
47.	Shale, red	5
46.	Shale, green, thin limestone layers, trilobites, *Glossopleura* sp.	70
45.	Limestone, blue, banded	20
44.	Shale and thin layers of argillaceous limestone	20
43.	Shale, red	20
42.	Limestone, partly oolitic	20
41.	Shale, red, with thin limestone, *Anoria bantius,* in base	90
40.	Limestone, thick bedded, ferruginous, weathers to ocher, trilobites	20
39.	Shale, red	40
38.	Shale, green	10
37.	Shale, red	40
36.	Limestone	30
35.	Shale, red	5
34.	Not exposed	40
33.	Shale, red	10
32.	Shale, green, contorted	10±
31.	Shale, red	10±
30.	Limestone, thin bedded, argillaceous, trilobites, *Elrathiella buttsi*	10
29.	Not exposed	12
28.	Shale, red	30
27.	Shale, green	20
26.	Shale, red	80
25.	Shale, mostly red, a few layers green	80
24.	Shale, green, with thin layers of limestone	30
23.	Limestone crowded with fragments of trilobites	5
22.	Shale, red	30
21.	Shale and thin limestone	20
20.	Limestone, thin bedded, argillaceous, compact, blue, ripplemarked	20
19.	Shale, red	15
18.	Limestone, weathers to ocher	5
17.	Shale, red	10

	Thickness Feet
16. Shale, green, thin layer of argillaceous limestone in lower part with trilobites	90
15. Shale, red	45
14. Shale, green	10
13. Not exposed	15
12. Limestone	5
11. Not exposed	20
10. Shale, mostly green	35
9. Limestone, oolitic	5
8. Shale, red	5
7. Limestone	5
6. Shale, red	10
5. Limestone	5
4. Shale, green	5
3. Limestone, argillaceous, sandy, banded	25
2. Shale with calcareous layers, trilobites, *Periommella*	10
1. Limestone, sandy, ferruginous	10

Fault; Rome thrust over Moccasin limestone.

The character of the Rome here is well shown on Plate 16A, B, and C.

The fault at the base of this section is not of sufficient throw to expose the bottom of the Rome. This condition also characterizes every belt of Rome, except the one just northwest of the Blue Ridge, as every other belt is bounded along its northwest side by a thrust fault. The underlying Shady dolomite is nowhere brought to the surface, and there remains an unexposed lower part of the Rome of considerable thickness and of unknown character.

Another section of the Rome is almost fully exposed along the Chesapeake and Ohio Railroad on the north side of James River about 1 mile east of Buchanan, Botetourt County.

Geologic Section 8.—Rome-Waynesboro formation on the Chesapeake and Ohio railroad just east of Buchanan, Virginia

	Thickness Feet
Elbrook limestone	
20. Not exposed, includes Elbrook-Rome contact	
Rome formation (1886 feet)	
19. Shale, partly exposed, probably extends nearly to the top of the Rome	300
18. Limestone, drab, weathering white, partly exposed	180
17. Shale	500
16. Shale, with a few layers of limestone and dolomite 5 to 6 feet thick	230
15. Limestone, thick bedded, weathers white; a layer of pearl gray compact limestone (vaughanite)[a] at top	20
14. Limestone, blue, ribbony	165
13. Partly exposed, a few beds of limestone showing	100
12. Limestone	100
11. Dolomite, mottled	30
10. Shale, red streaks and thin layers of limestone and dolomite	100
9. Limestone or dolomite, compact	5
8. Limestone and dolomite, some argillaceous, weathers yellow, partly thin bedded and ribbony	100
7. Shale, red	2
6. Shale, green	10
5. Shale, red	2
4. Shale, green	15
3. Shale, red	2
2. Dolomite, shaly, gray	25
Shady dolomite	
1. Dolomite, thick bedded, exposed	500

[a] Compact, very fine-grained limestone that breaks with a conchoidal fracture.

This section is notable for the small amount of red shale. The Rome probably extends higher into the covered interval at the top of the section and the total thickness may reasonably be assumed to be 2000 feet. In a broad belt extending from Blacksburg southwest to the meridian of Pulaski, the Rome seems to be composed largely of shale or at least of soft rocks that are very poorly exposed. Small scattered exposures of green shale, thin layers of red and pink shale, and layers of dolomite are found in this belt. A wide exposure in the great bend of New River west of Blacksburg shows a jumbled mass of green shale and dolomite, due to crumpling of the soft beds, and similar conditions probably prevail the entire length of this broad belt. The scarcity of exposures affords little information about the character and structure of the rocks in this belt, but such information as can be obtained suggests that these beds are a facies of the Rome formation. In all other areas of the Rome shown on the geologic map, the typical facies shown in geologic sections 3 and 7 prevails.

Distribution.—The Rome formation has many areas of outcrop, large and small. The principal area is the first belt northwest of the Blue Ridge which, with varying width and with adjacent small outlying areas, is nearly continuous from the State line northeast of Berryville, Clarke County, to Tennessee in the vicinity of Damascus, Washington County. This belt is covered by overthrust pre-Cambrian rocks for several miles southwest of Front Royal and for a shorter distance 2 miles southwest of Stanley, Page County. The belt is of moderate width northeast of Roanoke. Southwest of Roanoke, because of folding, its width is doubled or trebled, and so maintained for most of the distance southwest to a point south of Marion. It reaches its greatest width, about 8 miles, between Max Meadows and Jackson Ferry, Wythe County. Perhaps, the best exposure in the whole southeastern belt is on U. S. Route 21, north of Speedwell, Wythe County, beginning just north of Cripple Creek and extending north 1½ miles. The semi-fenster north of Villamont and Montvale, Bedford County, several miles east of the outcrop belt along the northwest foot of the Blue Ridge, indicates the wide extension of the Rome to the southeast of its outcrop belt, that is, beneath the overthrust mass of the pre-Cambrian rocks of the Piedmont province. The best exposure of the Rome seen in the north is on West Virginia Route 9 immediately southeast of Mechanicsburg and 2½ miles southeast of Charlestown, Jefferson County, West Virginia.

Another area of unusual width is west of Blacksburg. Still another belt, having great width in the vicinity of Wood and Fort

Blackmore, Scott County, extends from Honaker, Russell County, to the Tennessee line, south of which it widens still more. Besides these larger areas the map shows many smaller occurrences which do not require special description.

The outcrop belt of the Rome is commonly marked by a highly characteristic topography of knobs and ridges, as shown in Plates 3E and 6B.

Thickness.—The Rome is about 2000 feet thick in the section east of Buchanan. (See geologic section 8.) This is the most complete section examined by the writer in which the succession is not greatly disarranged and duplicated by faulting and minor folding. The section just south of Brookside Inn (geologic section 7) is also undisturbed and the thickness is accurate for the portion exposed but, as the basal part is concealed, the full thickness can not be determined. It can be safely estimated that the Rome in the southwestern part of the Valley in Virginia reaches a maximum thickness of at least 2000 feet. Judging from the width of outcrop north of Damascus, Washington County, it is not so thick in that area. Campbell[39] gave the thickness of the Rome (Russell) formation as more than 1000 feet in the Estillville, Va.-Tenn., quadrangle; Keith[40] estimated the thickness at 1300 feet in the Morristown, Tenn., quadrangle; and 1100 feet for the Rome (Watauga) in the Roan Mountain, Tenn., quadrangle. Northeast of Buchanan the thickness of the Rome can not be measured. According to Stose[41] the correlative Waynesboro formation is 1000 feet thick in the vicinity of Waynesboro, Franklin County, Pennsylvania.

Fossils and correlation.—The Rome is a scantily fossiliferous formation in Virginia and its fauna consists of only a few genera and species. The known fossil localities are widely scattered between Buchanan, Botetourt County, and Blackwater, Lee County. Owing to the heterogeneous composition of the formation and to its structural complexities, the exact horizon of the fossils in most localities is uncertain, and definite correlation of the fossiliferous beds and horizons is not yet possible. From the meager data at hand it appears that the fossiliferous horizons are distributed throughout the full thickness of the formation, but, so far as can be judged, most occurrences are in the upper half of the formation. The few species that have been obtained are listed below. The Middle Cambrian species are designated by (M) and the Lower Cambrian by (L) following the names.

[39] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), p. 2, 1894.
[40] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Morristown folio (No. 27), columnar section, 1896.
[41] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), p. 5, 1909.

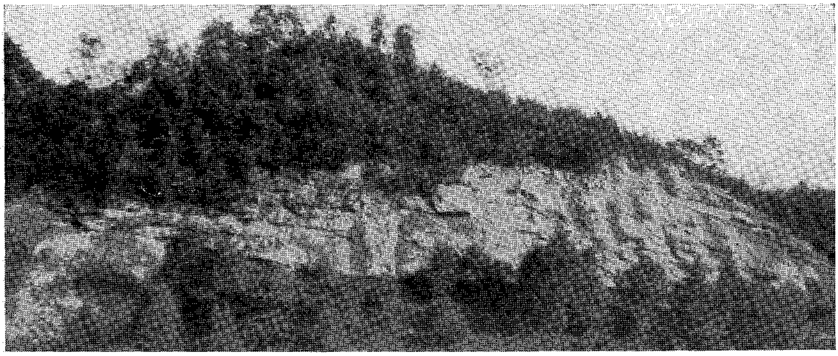
PLATE 17

A. Rutledge, Rogersville, and Maryville formations 3 miles northeast of Clinchport, Scott County. Looking east-northeast across Clinch River in the vicinity of Carter Ferry. The limestone at the bottom is Rutledge, the scar next above is in the Rogersville shale, and the slope above the Rogersville is on the Maryville limestone. The knob is probably occupied by the Nolichucky shale.

B. Rutledge limestone, 3 miles northeast of Clinchport. Cut on the Clinchfield Railroad on Clinch River. Looking southward from a point near Carter Ferry.

C. Upper part of the Rome formation, 1 mile southeast of Cleveland, Russell County. The beds are shale with thin limestone. The Rutledge limestone is to right of the bend in the road. *Glossopleura* is abundant in a thin bed of yellow argillaceous limestone in the shale about 200 feet below the base of the Rutledge. Looking southeast.

A

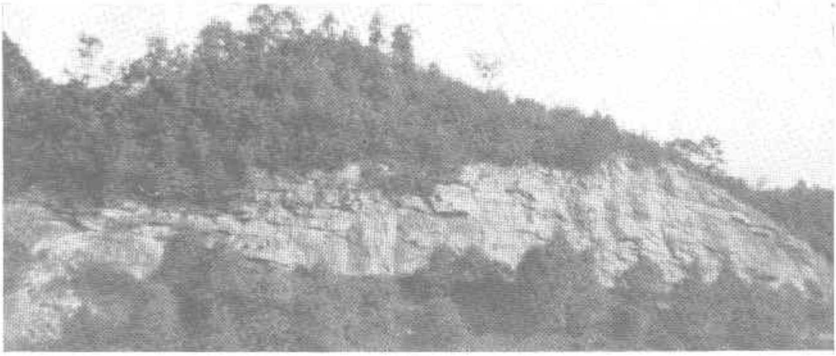


B

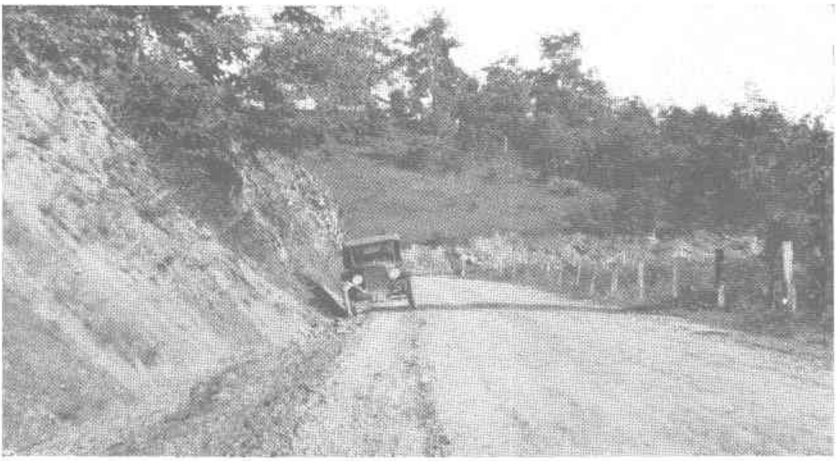
C

CAMBRIAN FORMATIONS

A



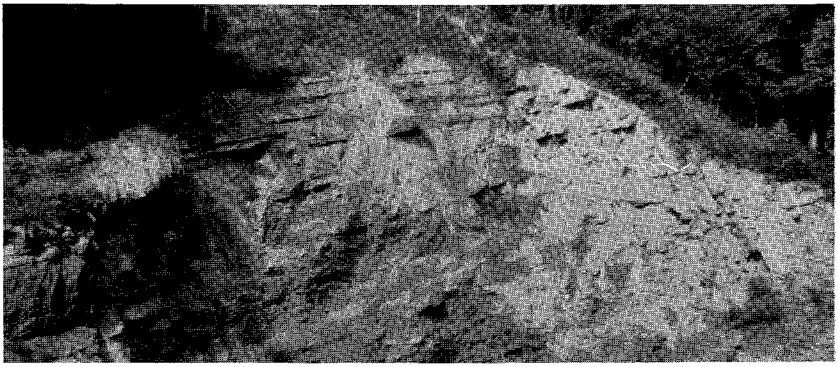
B



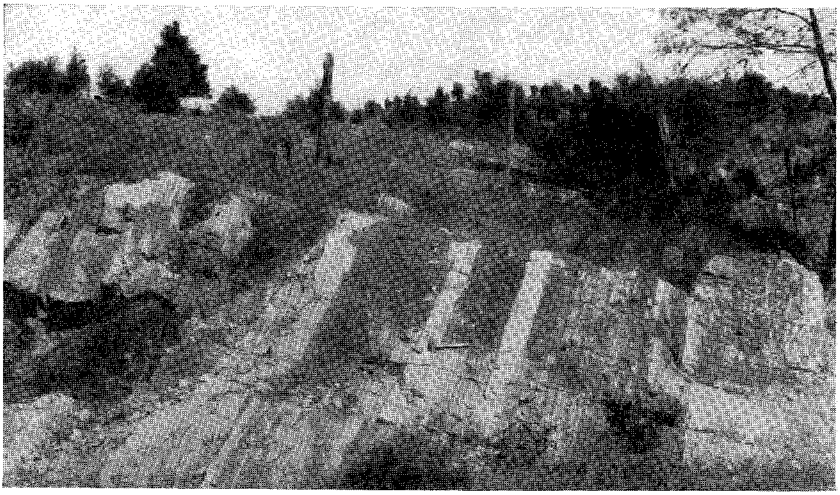
C

Cambrian Formations

A



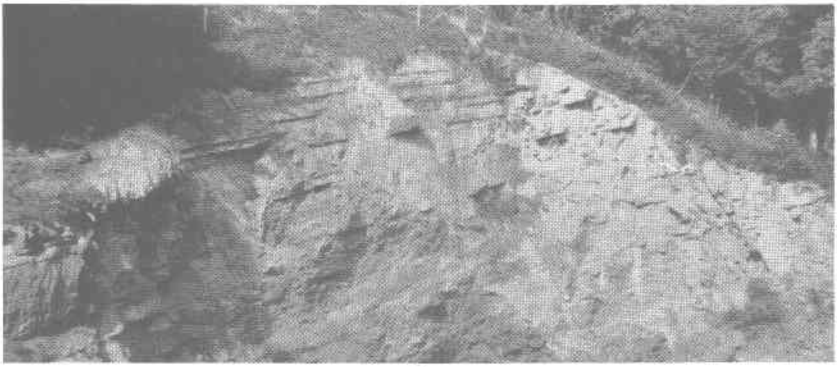
B



C

CAMBRIAN FORMATIONS

A



B

C

CAMBRIAN FORMATIONS

PLATE 18

A. Elbrook limestone in a quarry 2 miles northeast of Moffett Creek and 10 miles southwest of Staunton, Augusta County. Looking northeast.

B. Maryville limestone in a quarry on State Route 71, 1 mile southeast of Brookside Inn, Russell County. Looking southwest.

C. Elbrook dolomite with layers of blue, compact limestone (white) in cut on U. S. Route 21, in the southeast environs of Wytheville, Wythe County. Looking northeast.

Fossils from the Rome formation in Virginia

Brachiopods
- Acrotreta buttsi Resser (L)

Pteropods
- Hyolithes wanneri Resser and Howell (L)

Trilobites
- Acrocephalops exigua Resser (M)
- Acrocephalops teres Resser (M)
- Alokistocare virginicum Resser (M)
- Alokistocarella typicalis Resser (M)
- Amecephalina poulseni Resser (L)
- Anoria bantius (Walcott) (M)
- Elrathiella buttsi Resser (M)
- Glossopleura buttsi Resser (M)
- Glossopleura virginica Resser (M)
- Kootenia sp.
- Olenellus romensis Resser and Howell (L)
- Periommella sp. (L)
- Ptychoparella buttsi Resser (L)
- Solenopleurella minor Resser (M)
- Solenopleurella virginica Resser (L)

Of these fossils the genera *Alokistocarella, Anoria, Elrathiella, Glossopleura,* and *Solenopleurella* occur, so far as known, only in formations regarded as of Middle Cambrian age, as in Greenland, the Rocky Mountains, and elsewhere in the Appalachian Valley. The genus *Olenellus* is universally accepted as of Lower Cambrian age. Neither it nor any of the other genera of trilobites marked (L) in the preceding list occur in association in the same beds with any of the genera named above.

From the facts and assumptions set forth above, it appears that at least the upper 600 feet of the Rome in geologic section 8 is of Middle Cambrian age. As neither *Olenellus* nor any of the Lower Cambrian fossils listed, except *Periommella,* has been found in section 8, it is not possible to locate the boundary between the Lower and Middle Cambrian in that section. The only locality in Virginia where a lower limit to the Middle Cambrian can be recognized is on the Chesapeake and Ohio Railroad about half a mile southeast of Indian Rock, Botetourt County, where *Olenellus* occurs 350 feet below the base of the Honaker dolomite, which corresponds to the base of the Rutledge limestone. This, of course, indicates a variation of 250 feet in the thickness of the Middle

Cambrian part of the Rome. These provisional determinations are subject to revision with the acquisition of additional data.

Olenellus, of one or more species, a few other trilobites, and a few species of brachiopods occur in the Rome of Alabama, but in general the formation in that State is scarcely more fossiliferous than in Virginia.

MIDDLE AND UPPER CAMBRIAN

EQUIVALENCE OF FORMATIONS

The formations overlying the Rome differ in character and have different names in various parts of the Appalachian Valley in Virginia, as shown in Table 3.

TABLE 3.—*Nomenclature of post-Rome, pre-Beekmantown formations in the Appalachian Valley in Virginia*

SOUTHWEST VIRGINIA SCOTT AND RUSSELL COUNTIES	NORTHWEST SIDE OF VALLEY WASHINGTON TO CRAIG COUNTIES	SOUTHEAST SIDE OF VALLEY WASHINGTON TO CLARKE COUNTIES
Copper Ridge dolomite	Conococheague limestone	Conococheague limestone
Nolichucky shale	Nolichucky shale	Elbrook dolomite
Maryville limestone Rogersville shale Rutledge limestone	Honaker dolomite	Elbrook dolomite

Two of the main features of the changing facies of these equivalent formations are the disappearance northeastward of the Rogersville shale in Russell County and the change of the combined Rutledge and Maryville limestones to dolomite, which becomes the Honaker dolomite. The Nolichucky shale continues unchanged above the Honaker. Another feature is that in the southeastern belts the Nolichucky disappears as a shale. It becomes the top part of the dolomite which is equivalent to the Honaker and Nolichucky and which is named the Elbrook dolomite. In southern Tennessee, northwestern Georgia and northeastern Alabama, all of these formations lose their distinctive character and merge into a unit named the Conasauga shale.

RUTLEDGE LIMESTONE

Name.—The Rutledge limestone was named by Keith for Rutledge, Grainger County, Tennessee, but was first reported by Campbell.[42]

[42] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), p. 2, 1894.

Limits.—The Rutledge limestone is limited below by shale with thin limestones included in the upper part of the Rome formation (Pls. 16D and 17C), and at the top by the persistent and characteristic Rogersville shale. It is easily identified in every complete sequence.

Character.—The Rutledge is a rather thick-bedded, blue to gray, and, in part, somewhat magnesian limestone. Its lower part contains thin partings of siliceous shale. Some layers locally contain trilobites but fossils are generally scarce.

Distribution.—In the northwestern belt the Rutledge limestone extends nearly as far northeast as Honaker, Russell County. In the most southeastern belt, not far northeast of a point 6 miles northeast of Gate City, Scott County, the change to Honaker dolomite takes place.

The best exposures of the Rutledge are on the Clinchfield Railroad between a point northeast of Clinchport and Hill Station, Scott County, at the base of the southeast bluff of Clinch River. (See Pl. 17A and B.) Good exposures occur along the foot of the northwest bluff of Big Ridge southwest of Clinchport, and are visible along much of the road following the valley. A nearly complete exposure, with fossiliferous layers, is present along State Route 72, 1 mile east of Dungannon, Scott County.

Thickness.—The Rutledge limestone is about 250 feet thick.

Fossils and correlation.—Fossils are rare in the Rutledge limestone. The only form collected and described is *Solenopleurella buttsi* Resser. (See Part II, plates of fossils.)

ROGERSVILLE SHALE

Name.—The Rogersville shale was named by Campbell[43] from Rogersville, Hawkins County, Tennessee.

Limits.—The Rogersville shale is limited by the Rutledge limestone below and the Maryville limestone above.

Character.—The Rogersville shale is predominantly greenish-gray, rather fissile shale within which are layers of sandstone one inch thick or less. Both shale and sandstone are in places fossiliferous.

[43] Campbell, M. R., op. cit., p. 2.

Distribution.—The Rogersville shale gives rise to a bench directly above the Rutledge limestone on the slopes along which they both crop out. (See Pl. 17A.) The geographic distribution is the same as the Rutledge limestone. It is well exposed in places on the bluff above Clinch River northeast of Clinchport and on the northwest slope of Big Ridge southwest of Clinchport, Scott County. It is to be seen in places along the road southwest of Bickley Mill, 2 miles south of St. Paul, Russell County, and again at Locust Lane, on State Route 72, about 2 miles east-southeast of Dungannon. At this exposure it contains highly fossiliferous layers, with trilobites and brachiopods.

Thickness.—The Rogersville ranges in thickness from 80 to 120 feet, and averages about 100 feet.

Fossils and correlation.—The following fossils have been collected from the Rogersville in Virginia and identified by Walcott and Resser.

Acrotreta rudis Walcott
Ehmaniella walcotti Resser
Hyolithes sp.
Iphidella virginica Resser
Obolus rogersvillensis Resser

MARYVILLE LIMESTONE

Name.—The Maryville was named by Campbell[44] from Maryville, Blount County, Tennessee.

Limits.—The Maryville is sharply limited below by the Rogersville shale and above throughout most of its extent, perhaps, by shale in the base of the Nolichucky formation. In places the passage to the Nolichucky appears to be limestone of similar character and there is no sharply defined lithologic boundary between them.

Character.—The Maryville is a thick-bedded, dark-blue, somewhat banded limestone. (See Pl. 18B.) It is comparatively free from earthy impurities and is but slightly magnesian. Together with the Rutledge, it is sufficiently resistant to erosion to form bluff-like slopes along the northwest side of Copper Ridge, as shown in Plate 17A and B, and on the steep northwest slope of Moccasin Ridge, Scott County.

Distribution.—The Maryville limestone has the same distribution as the Rutledge limestone and the Rogersville shale.

Thickness.—The Maryville is 500 to 600 feet thick.

---

[44] Campbell, M. R., op. cit., p. 2.

Fossils and correlation.—Walcott[45] assumed that some of the Cambrian trilobites and brachiopods that he described from the Appalachian Valley in Tennessee came from the Maryville limestone, but later studies have shown that these fossils came from limestones in the Nolichucky shale. Fossils are very rare in the Maryville, and have been found in it in only one place in Virginia. The Maryville is assumed to be of Middle Cambrian age. This assumption is based upon the fact that the overlying Nolichucky shale contains the oldest Upper Cambrian fauna.

HONAKER DOLOMITE

Name.—The Honaker dolomite was named by Campbell[46] from the town of Honaker, Russell County, Virginia. The reasons for the name have been stated above, but it is uncertain where the three formations just described merge into the Honaker. According to Campbell[47] the change takes place somewhere southeast of a line passing through Jessees Mills, 2 miles south of Cleveland, Russell County, and Big Branch, Scott County, 3 miles northwest of Hilton. The Rogersville shale, however, occurs on Copper Creek, 2 miles north of Fugates Hill, Russell County, and within 2 miles southwest of Honaker, Russell County. On the geologic map,[47a] the Rutledge, Rogersville, and Maryville, and their equivalent, the Honaker, are shown by the same pattern and no effort is made to indicate the exact limits of the equivalents.

Limits.—The Honaker is limited below by the distinctive shale of the Rome and above by fossiliferous shale and limestone of the Nolichucky.

Character.—The Honaker in the transitional areas from the Rutledge-Rogersville-Maryville units partakes somewhat of the limestone characteristics of those formations, but as the distance from the transitional areas increases, the Honaker becomes more and more magnesian and finally becomes almost entirely a thick-bedded, dark bluish gray dolomite. The lithologic composition of the Honaker near the transitional area is shown in the following approximate section on State Route 71, half a mile south of Brookside Inn, Russell County.

[45] Walcott, C. D., Cambrian Brachiopoda: U. S. Geol. Survey Mon. 51, 1912.
[46] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Tazewell folio (No. 44), p. 2, 1897.
[47] Campbell, M. R., U. S. Geol Survey Geol. Atlas, Bristol folio (No. 59), p. 3, 1899.
[47a] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, 1933.

Geologic Section 9.—Honaker dolomite south of Brookside Inn, Russell County, Virginia

	Thickness Feet
Nolichucky shale	
Limestone, thin bedded, and shale; contains *Agnostus, Norwoodella,* and cystid plates	
Honaker dolomite (1120 feet)	
5. Limestone, medium thick bedded, dark bluish, finely crystalline, banded; tongue of Maryville limestone	80
4. Dolomite, thick bedded, rather fine grained, bluish gray	550
3. Not exposed; may include a thin Rogersville shale	250
2. Dolomite, thick bedded, fine grained, bluish	65
1. Limestone, thick bedded, blue banded, trilobites in bottom; represents Rutledge limestone	175
Rome formation	

This section shows limestone of Rutledge type at the bottom and of Maryville type at the top, but dolomite comprises the greater part of the formation between the limestones. Farther from the transition area, southeast of Greendale on U. S. Route 19, the Honaker consists of medium thick-bedded, fine-grained, blue dolomite 1000 feet thick. This change from a limestone facies on the northwest to a dolomite facies on the southeast is the reverse of the change of the Copper Ridge dolomite on the northwest to the Conococheague limestone on the southeast, or of the change in the Beekmantown from a dolomite facies on the northwest to a limestone facies on the southeast. In the broad flat region between Wyndale and U. S. Route 19, north of Abingdon, the belts of Honaker are largely composed of argillaceous dolomite which, on the leaching of the calcareous content, becomes a coarse-grained, lumpy, mealy, ferruginous clay, as for example, along U. S. Route 19, 1½ miles northwest of Abingdon. The Honaker in the belt lying about 3 to 5 miles northwest of Abingdon yields in places a profusion of cryptozoan chert. Massive chert also occurs along U. S. Route 421, 5 miles northwest of Bristol. As a general rule chert is relatively rare in the Honaker.

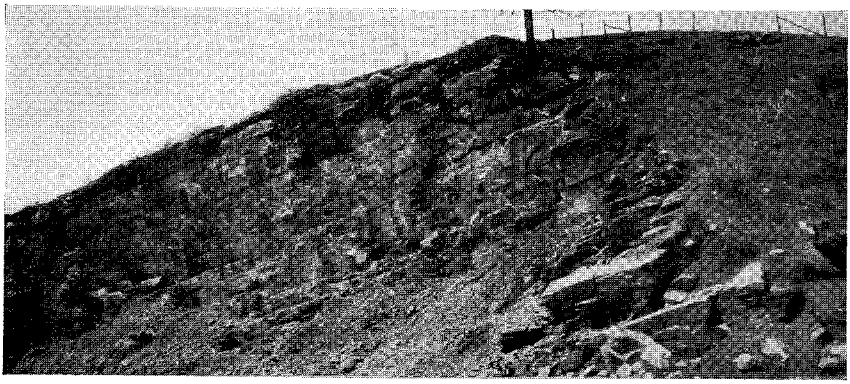
Distribution.—The Honaker dolomite crops out in seven belts in the area between Bristol and Big A Mountain along the 82nd meridian. In all of these belts the Honaker is overlain by the Nolichucky shale, except in the belt on which the town of Honaker is located, where the

PLATE 19

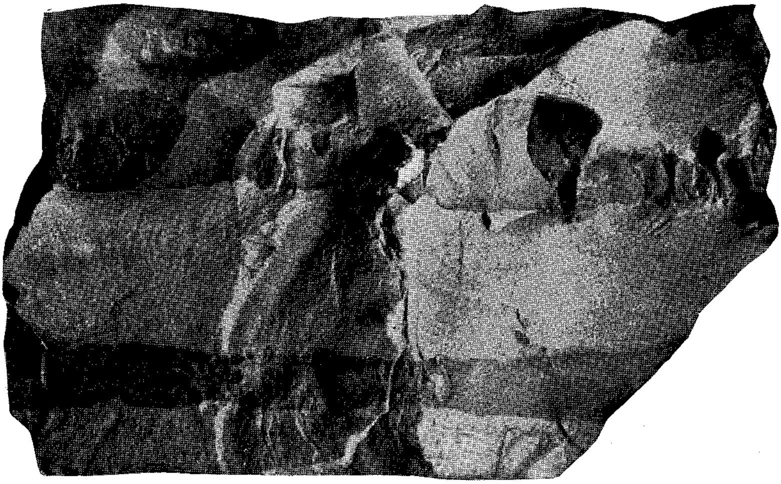
A. Conococheague limestone in a quarry along the Lee Highway (U. S. 11) at the crossing of the Norfolk and Western Railroad 5 miles northeast of Dublin, Pulaski County. Looking west.

B. Limestone from the Nolichucky formation showing the characteristic banding. About three-fifths natural size. Along State Route 71, about 1 mile south of Brookside Inn, Russell County.

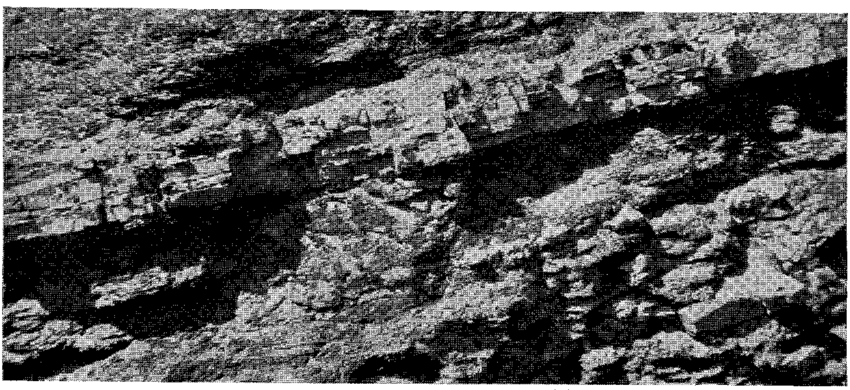
C. Nolichucky shale showing the common interbedding of shale and thin layers of limestone. Cut along State Route 64 on the northwest slope of Copper Ridge 2 miles south of Castlewood, Russell County. Looking southwest.



A



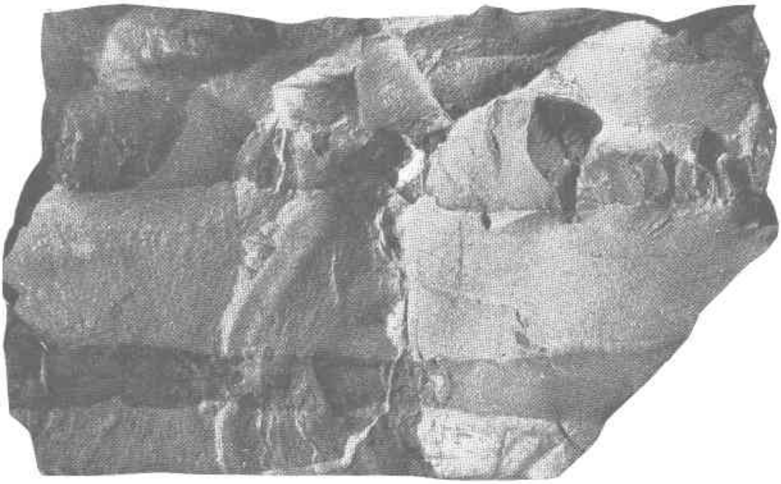
B



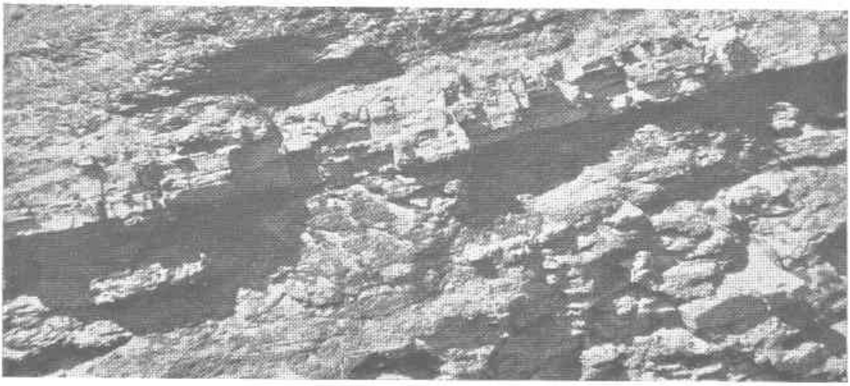
C

CAMBRIAN FORMATIONS

A

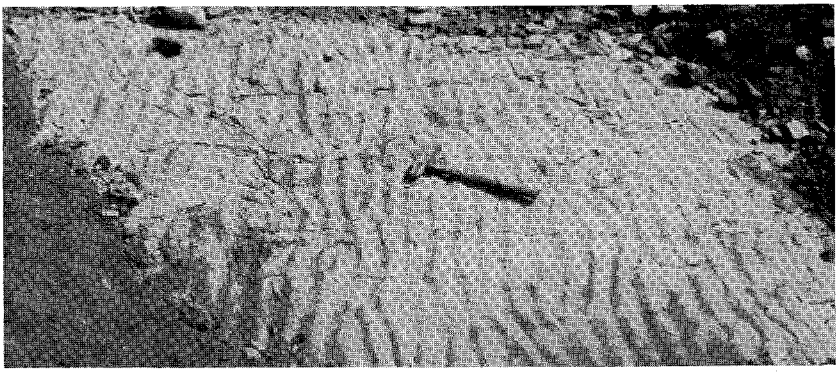


B

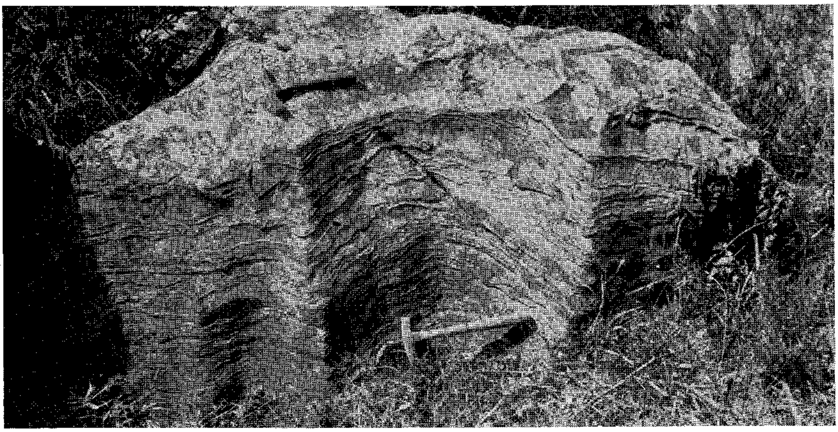


C

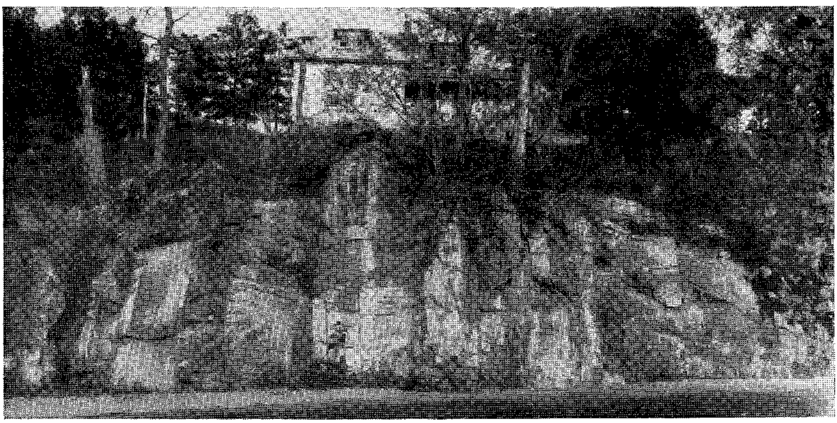
Cambrian Formations



A

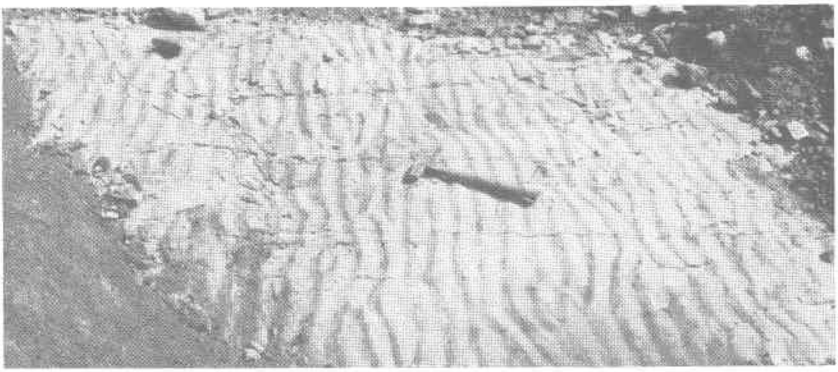


B

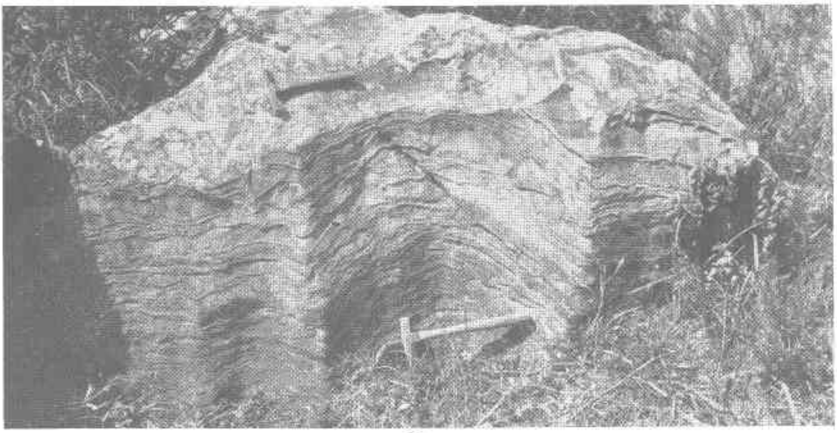


C

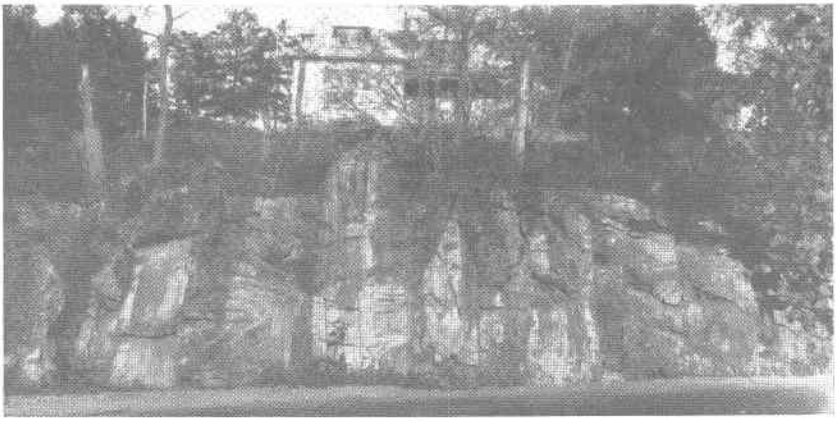
CAMBRIAN SANDSTONE AND LIMESTONE



A



B



C

CAMBRIAN SANDSTONE AND LIMESTONE

PLATE 20

A. Ripple-marked sandstone in the Conococheague limestone. Along the road to Valley Church 3 miles northeast of the railroad station at Abingdon, Washington County.

B. Layer of Conococheague limestone with characteristic projecting, crinkley, clayey laminae. Near Swover Creek on road to Columbia Furnace, 1 mile northeast of Conicville (Cabin Hill), Shenandoah County.

C. Conococheague limestone containing characteristic sandstone beds. A thickness of about 50 feet contains 4 layers of sandstone. Along Lee Highway (U. S. 11) in front of Cedar Hill school, 3 miles east of Wytheville, Wythe County.

Nolichucky is faulted out. The Honaker dolomite is southwest of New River, and with the exception of one narrow, local belt, it is northwest of a line approximately marked by Bristol, Marion, Wytheville, and Goodwins Ferry in Giles County.

Among the best outcrops of the Honaker are the following: Along U. S. Route 19 at and southeast of Greendale, Washington County; on State Route 71 southeast of Brookside Inn; on State Route 80 southeast of Honaker; and along Walker Creek where it crosses the Bane anticline in Giles County.

Fossils and correlation.—The Honaker is unfossiliferous except for local occurrences of *Cryptozoon*. Either few organisms existed in the Honaker seas in Virginia or their remains have been destroyed. It is equivalent to the Rutledge-Maryville limestone, and, therefore, is of Middle Cambrian age, at least in part. It is equivalent to the lower and larger part of the Elbrook dolomite into which it passes through the disappearance or merging of the Nolichucky shale.

ELBROOK DOLOMITE

Name.—The Elbrook was named by Stose[48] from Elbrook, Franklin County, Pennsylvania.

Limits.—The Elbrook is bounded above by the Conococheague limestone and below by the Rome-Waynesboro formation, both of which, as a general rule, are easily distinguishable from it.

Character.—The Elbrook closely resembles the Honaker dolomite, but differs locally in having a considerable amount of thin-bedded argillaceous limestone or dolomite (Pl. 18A), and elsewhere relatively thin layers of pure, light gray to white limestone. (See Pl. 18C.) The most satisfactory section showing the typical features of the Elbrook in southwestern Virginia is exposed on U. S. Route 21 in the southeast environs of Wytheville, as follows:

Geologic Section 10.—Elbrook dolomite at Wytheville, Virginia

	Thickness Feet
Conococheague limestone	
Dolomite with several thin layers of sandstone	
Elbrook dolomite (1910 feet)	
8. Dolomite, thick bedded	200
7. Not exposed, at Norfolk and Western Railroad	100

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

	Thickness Feet
6. Dolomite, thick bedded	280
5. Dolomite, thick bedded, many layers of dove-colored limestone weathering white	450
4. Dolomite, thick bedded, some layers of limestone; contains *Cryptozoon*	550
3. Dolomite, shaly	200
2. Dolomite, thin bedded	65
1. Dolomite, thick bedded, near bottom of Elbrook	65

The Elbrook generally displays much the same character throughout the Valley in Virginia. Below are three other sections representative of the Elbrook in different localities.

Geologic Section 11.—Near the head of Widner Branch, 4 miles southwest of Cole, Washington County, Virginia

	Thickness Feet
Conococheague dolomite	
13. Dolomite, a few layers of limestone	250
Elbrook dolomite (1380 feet)	
12. Shale, yellow, Nolichucky type	25±
11. Limestone; contains trilobites, *Crepicephalus, Coosia, Kingstonia,* and *Blountia,* in upper 50 feet	125
10. Not well exposed, shows some slabby and thick-bedded, light bluish-gray dolomite	125
9. Dolomite, thick bedded, yields some black scraggy chert; contains *Cryptozoon* like *C. proliferum*	200
8. Dolomite, a few thin layers of limestone	300
7. Limestone, blue, compact, largely ribbony, with layers of light-gray, fine-grained dolomite	275
6. Not exposed	60
5. Limestone	20
4. Not exposed	250
Rome formation (1010 feet)	
3. Shale, yellow	10
2. Not exposed	500
1. Shale, red and yellow	500

Geologic Section 12.[49]*—Northwest of Holston Mill, 6 miles southwest of Marion, Smyth County, Virginia*

	Thickness Feet
Conococheague formation	
22. Chert and sandstone debris on slope	
Elbrook formation (1795 feet)	
21. Limestone, argillaceous, thin crust of clay on weathering; small trilobites (*Terranovella buttsi*) rare	15
20. Dolomite, yields some chert	150
19. Dolomite	225
18. Dolomite, argillaceous, thin bedded, thicker bedded at top	225
17. Limestone, rather pure, ribbony or banded	15
16. Not exposed	20
15. Limestone like bed 17	60
14. Not exposed	30
13. Limestone like bed 17, *Lingulepis*	100
12. Shale	10
11. Limestone like bed 17	60
10. Shale, yellow, decomposed argillaceous dolomite, a few thin layers of dolomite	160
9. Limestone, banded	10
8. Shale, like bed 10	75
7. Dolomite, thin bedded, yields some chert	50
6. Not exposed, thin layers of chert in road bank	50
5. Dolomite	5
4. Not exposed	450
3. Dolomite, thin bedded to shaly	15
2. Not exposed; includes contact	70
Rome formation	
1. Shale, green and red	200

This section is about 300 feet thicker than the section on Widners Branch, and about 100 feet less than that at Wytheville, which suggests a thickening to the northeast. Part of the difference is doubtless due to the lack of precise determinations of the boundaries because

[49] This section is on the same belt as the preceding section.

of poor exposures. In a section on the road south of Newbern, Pulaski County, the Elbrook is continuously exposed from Newbern south to Peak Creek, a distance of 2 miles, as follows:

Geologic Section 13.—Elbrook dolomite south of Newbern, Virginia

	Thickness Feet
Elbrook dolomite (1455 feet)	
12. Limestone and dolomite, formation uncertain	70
11. Dolomite, with scattered layers of pure blue limestone	100
10. Dolomite, more or less argillaceous, shaly	60
9. Dolomite, shaly, some limestone	70
8. Partly exposed on slopes above road, probably all shaly dolomite	160
7. Dolomite or magnesian limestone, nodules and stringers of chert	140
6. Dolomite and limestone, few layers of blue limestone weathering white	180
5. Dolomite and limestone	200
4. Dolomite and limestone; dolomite, medium thick bedded, predominating	90
3. Dolomite, shaly, some compact layers of dolomite and limestone 6 inches to 1 foot thick	80
2. Shale, red	5
1. Dolomite, thick bedded	300
Rome formation	
Red shale	

As the upper limit of the Elbrook was not determined in this section the thickness obtained may be a few hundred feet short. The section exhibits excellently the lower 1455 feet of the formation. Besides the rock types shown in the sections, a few pale red layers occur in the broad area south of Fincastle; a small thickness of this rock is exposed on the former route of the Lee Highway (U. S. Route 11) 2 miles northeast of Pulaski; and a pink band has been traced over a considerable area west of New River southwest of Radford. The thin-bedded argillaceous layers commonly weather into thin yellowish-gray slabs. Such layers on long weathering and loss of their lime, break down into yellow shale which resembles the Martinsburg shale. Good examples of this feature occur on low ridges half a mile west of Marlboro, Frederick County.

Distribution.—The Elbrook crops out in normal sequence along the southeast side of the Valley northeastward from Damascus, Washington County, to the vicinity of Atkins, Smyth County, where it is cut out by a thrust fault. The same belt reappears to the north of Snowville, Pulaski County, and continues to Limeton, Warren County. From Limeton to a point 2 miles southeast of Front Royal it is covered by the Blue Ridge overthrust mass. From Front Royal it continues northeastward to the Potomac. Northwest of the southeastern belt, the Elbrook covers large areas from southwestern Wythe County northeastward to the Potomac River. The Cyclopean Towers near Mount Solon are in the Elbrook. (See Pl. 15B.) One of the most extensive exposures is along Jennings Branch, beginning 1½ miles northwest of Churchville, Augusta County. In Frederick County there is a fairly good exposure 1 mile north of Opequon; also 4 miles southwest of Winchester, and at White Hall and along the ridge road northeast of White Hall. In Clarke County the Elbrook is partly exposed on a road about 3 miles southeast of White Post, approaching Shenandoah River.

Thickness.—The thickness of the Elbrook ranges from about 1400 to about 2000 feet in the southwestern part of the Valley, that is, from Washington County to Pulaski County. No measurements have been made in the northeastern part, but it is reasonable to assume a thickness of at least 2000 feet, since, according to Stose,[50] the formation is 3000 feet thick near Elbrook, Franklin County, Pennsylvania, the type locality.

Fossils and correlation.—Except for the Nolichucky fossils in the Widner Branch section (geologic section 11), and in the Holston Mill section (geologic section 12), the Elbrook has yielded few fossils in Virginia except a few specimens of *Cryptozoon.* The most notable occurrence of these forms is in the Jennings Branch section, Augusta County, where several layers crowded with *Cryptozoon undulatum* are exposed on the south side of U. S. Route 250, 1 mile south of Jennings Gap. *Cryptozoon* has also been noted at Wytheville, Wythe County; Burketown, Augusta County; near the river 3 miles southeast of Long Glade, Augusta County; and 1 mile east of Summerdean, Augusta County. Half a mile west of Marlboro, Frederick County, a species of *Glossopleura* occurs near the bottom of the fault block and probably near the bottom of the formation. *Glossopleura* is a Middle Cambrian fossil of Rutledge age and on the basis of its occurrence in

[50] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), p. 5, 1909.

the basal part of the Elbrook in Virginia and at Waynesboro, Pennsylvania, the entire thickness of 3000 feet in the type region has been assigned to the Middle Cambrian. If, however, the Nolichucky element present in the top of the Elbrook in southwestern Virginia persists to southern Pennsylvania, the Elbrook includes beds of Upper Cambrian age which would correspond to the Warrior limestone of central Pennsylvania.

NOLICHUCKY SHALE

Name.—The Nolichucky shale was named from the Nolichucky River, 4 miles southeast of Greeneville, Greene County, Tennessee, along which the formation is extensively exposed. The name was first published by Campbell.[51] The lithological designation, shale, is misleading, for in some areas the formation contains as much limestone as shale.

Limits.—The lower boundary of the Nolichucky is commonly marked by the appearance of thin-bedded limestones and shales containing trilobites. In both of these features the formation differs plainly from the underlying Maryville limestone or Honaker dolomite. In places, however, the boundary lies within a continuous mass of limestone, and its position can not be easily located. The top of the Nolichucky is also clearly marked by the appearance of dolomite of the Copper Ridge or Conococheague formations, which is so obviously different from the shale or banded blue limestone of the Nolichucky as to mark unmistakably the boundary between the two. In Scott and Russell counties the basal layers of the dolomite are thinly laminated and the edges of the layers look like a pile of thin cardboard.

Character.—The Nolichucky is composed of more or less alternating beds of shale and limestone which vary in relative amount and proportion in different areas, but with the shale greatly predominating. This heterogeneous composition is well shown in Plate 19C. The shale is commonly grayish, greenish, yellowish, or drab, and soft and fissile. The limestone is generally thin bedded or moderately thick bedded. In places there are massive beds of limestone 100 feet or more in thickness. The limestone is commonly banded with clayey impurities, as shown in Plate 19B. There is no regularity in the distribution of shale and limestone either geographically or vertically. The thicker masses of limestone occur in any part of the formation. The general gross composition is shown in the following detailed sections:

[51] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), p. 2, 1894.

Geologic Section 14.—Along Mumpower Creek at the reservoir of the Bristol waterworks, 3 miles north of Bristol, Virginia

	Thickness Feet
Copper Ridge dolomite (682± feet)	
16. Dolomite, faulted at top	450±
15. Dolomite and limestone	40±
14. Dolomite with several thin layers of sandstone	40±
13. Dolomite	40±
12. Sandstone	2
11. Dolomite	100
10. Dolomite finely straticulate, widespread at base of Copper Ridge	10±
Nolichucky formation (575 feet)	
9. Limestone, thick bedded, banded; contains *Blountia bristolensis and Maryvillia bristolensis*	180
8. Limestone, shaly; contains *Blountia bristolensis* and *Maryvillia bristolensis*	25
7. Limestone, thin bedded; contains *Aphelaspis* and *Crepicephalus greendalensis*	50
6. Shale, thin layers of limestone; probably leached argillaceous limestone; contains *Aphelaspis* and *Crepicephalus greendalensis*	75
5. Limestone and shale, some limestone in thin layers in shale, mostly limestone with shale partings; contains *Agnostus, Dicellomus* cf. *D. appalachia, Coosia* and *Tricrepicephalus*	150
4. Shale	25
3. Limestone, shaly	5
2. Not exposed; includes contact	65
Honaker dolomite	
1. Dolomite, thick bedded; exposed	300

Geologic Section 15.—Along State Route 71, about 1.2 miles southeast of Brookside Inn, Russell County, Virginia

	Thickness Feet
Copper Ridge dolomite (1305± feet)	
25. Dolomite	1300
24. Dolomite, straticulate, same as bed 10 of Mumpower Creek section	5±
Nolichucky formation (459 feet)	
23. Limestone, blue, banded	45
22. Not exposed	20
21. Shale, soft, greenish	5
20. Not exposed	10
19. Limestone, banded	5
18. Not exposed	20
17. Shale, soft, greenish; contains *Lingulepis walcotti* and *Aphelaspis*	10
16. Not exposed	40
15. Shale, soft, greenish	25
14. Limestone, thick bedded	15
13. Shale, soft, greenish; thin layers of limestone; some beds of edgewise conglomerate	45
12. Shale, soft, green; contains thin layers of limestone; some beds of edgewise conglomerate	30
11. Limestone, glauconitic; contains *Coosia, Oedorhachis boltonensis* and *Tricrepicephalus*	2
10. Not exposed	15
9. Limestone	2
8. Shale	5
7. Limestone, thin and thick bedded, argillaceous, banded, sandy	30
6. Sandstone as in bed 4, more thinly laminated and with thin layers of limestone	45
5. Not exposed	15
4. Sandstone thin bedded, fine grained, fucoidal (?) stems	25
3. Shale, finely fissile, greenish; *Agnostus, Norwoodella saffordi* and cystid plates	25
2. Limestone, thin bedded, clay banded, blue	25

Honaker dolomite

1. Limestone, evenly bedded, blue banded (Maryville) in quarry (See Pl. 18B)

Geologic Section 16.—Along U. S. Route 19, beginning at bottom about 1100 feet southeast of Greendale, Washington County, Virginia

	Thickness Feet
Copper Ridge dolomite	
11. Dolomite, several hundred feet thick	
10. Sandstone	20
Nolichucky formation (725 feet)	
9. Limestone and shale, alternating beds; contains *Acrotreta, Aphelaspis* and *Crepicephalus greendalensis*	150
8. Not exposed	50
7. Shale, soft, greenish, fissile, includes a thin layer of ferruginous, very fine-grained fossiliferous sandstone; contains cystid plates (abundant) and *Crepicephalus greendalensis*	150
6. Limestone, thick bedded, coarse, glauconitic, ledge maker; yields rusty soil; contains *Tricrepicephalus* sp.	30
5. Shale, soft, greenish, like bed 7	65
4. Limestone, thin bedded	15
3. Shale, like bed 7	65
2. Limestones, thin bedded, shale partings, fragments of trilobites	200
Honaker dolomite	
1. Dolomite; see geologic section 9.	

In this section the sandstone in the bottom of the Copper Ridge dolomite is found close above the Nolichucky. This succession is repeated in many sections throughout the entire area in which the Nolichucky crops out. The sections show the variations in the occurrence of limestone and shale in the Nolichucky. The character shown holds throughout the area of outcrop in the Appalachian Valley in Virginia. In Carter Valley, Hawkins County, Tennessee, west of Kingsport, it is stated[52] that the middle 400 to 500 feet of the formation is massive

[52] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), p. 2, 1894.

blue limestone. A few layers of very fine-grained micaceous and calcareous, gray, fossiliferous sandstone occur, but no pure, coarse-grained quartz sandstone has been observed. Much of the full thickness, 100 feet or less, toward the northeastern limits of the formation, is composed of sandy or clayey rock. In the vicinity of Abingdon and at the head of Widner Branch, 4 miles southwest of Cole, Washington County, the formation contains thick-bedded, coarse-grained, fossiliferous layers in which water-worn pebbles of limestone one-eighth of an inch to one inch in diameter are common. Such conglomerates seem to be most prevalent in the upper 50 to 100 feet of the formation, or, stated otherwise, these conglomeratic layers seem to be within the section 100 feet below the basal sandstone beds of the Conococheague, which are especially thick and persistent north and northwest of Abingdon. The banded limestone (Pl. 19B), though not confined to the Nolichucky, is better developed, more prevalent and more widely distributed in the Nolichucky than in the underlying formations, and is characteristic of the Nolichucky. The banding is due to alternate deposition of pure calcareous sediment and of clayey sediment, apparently after floods when much clay and silt were discharged into the sea and held in suspension, drifted far and wide, and slowly settled to form thin clayey layers in the calcareous sediments. These alternating layers can scarcely be seen on freshly broken surfaces of the limestone but become conspicuous on weathered ones where the lime is leached out and thin films of the insoluble clay form gray bands on the surface of the rock.

Distribution.—The outcrop of Nolichucky shale is almost confined to the area southwest of New River, but the central belt crosses New River in the vicinity of Pembroke, Giles County. The most northwestern belt appears to thin out to the west of Tazewell, Tazewell County. The Crocketts Cove belt north of Wytheville ends in that area. No Nolichucky has been detected in the Dublin area where the horizon of its outcrop is widely exposed. The southeastern belts, offset by faults that extend from Abingdon through the vicinity of Marion, terminate at Groseclose and southeast of Marion. Fossils occur in the Nolichucky for several miles northeast of Marion and also in the southern offset belt in the vicinity of Abingdon. This belt, mapped on the basis of lithology, extends to a point 4 miles southwest of Marion. No paleontologic evidence of its extension farther to the northeast has been obtained. In the extreme southeastern belt this formation is exposed on the head of Widner Branch 4 miles southwest of Cole, Washington County, where it is included in the Elbrook dolomite. Nolichucky fossils, *Crepicephalus* and others, occur in somewhat banded limestone immediately below 25 feet or so of shale, all of Nolichucky lithologic type, which forms the top of the Elbrook. Half a mile north of Holston Mill and 6 miles southwest of Marion, Smyth County (geologic section 12), a few small trilobites (*Terranovella*) were found in the clayey crust adhering to and resulting from the leaching of the lime from an argillaceous thick-bedded limestone. This locality is on the same belt of Elbrook as that southwest of Cole. This is the most northeastern point at which any Upper Cambrian fossils have been found in the Elbrook in Virginia. South of Virginia, Keith[53] has recognized the Nolichucky as persistent in this belt of outcrop and has mapped the Elbrook equivalent as including Nolichucky and Honaker. The indication that the Nolichucky passes into the top of the Elbrook dolomite in southern Virginia and persists northward as an unrecognizable constituent, is the basis for the use of the name Elbrook dolomite in Virginia.

A good exposure appears on U. S. Route 19, 2½ miles southeast of Lebanon, Russell County, and a nearly full exposure on the same road 4 miles northeast of Lebanon. Good exposures may be seen on Wolf Creek above the mill in Abingdon, where the two very prominent beds of sandstone in the base of the Conococheague are also excellently exposed. It is finely exposed below a thick sandstone on a hill just west of Hungry Mother Creek and 2 miles north-northwest of Marion. The formation is fully exposed on a secondary road 1½ miles east-southeast of Cedar Branch, Smyth County, where it is 500 feet thick and is composed of alternating thick beds of shale and limestone. It is nearly all exposed on the North Fork of Holston River about 1 mile east of Chatham Hill, Smyth County, where it is about 150 feet thick and is immediately overlain by a bed of coarse friable sandstone, 20 to 50 feet thick, in the base of the Copper Ridge dolomite. A fair exposure appears on the Bane anticline at Prospectdale, Giles County, where the rock is green shale and limestone with *Dicellomus, Crepicephalus,* and cystid plates.

Thickness.—The thickest section of the Nolichucky measured, about 700 feet, is along U. S. Route 19, southeast of Greendale, Washington County. (See geologic section 16.) About 450 to 500 feet seems to be the prevailing thickness in Washington, Scott, and western Smyth counties. It thins to 200 feet or less in eastern Smyth and Russell counties, to 100 feet or less in Wythe and Bland counties, and thins out and disappears in Giles County. The Nolichucky appears to thin out north of Tazewell, Tazewell County. It has been assumed that the Nolichucky shale in this most southeastern belt persists in a changed nonfossiliferous character in the top of the dolomite mass named Elbrook. But it is an open question whether the Nolichucky really does not disappear as it does north of Tazewell, so that the Elbrook in most of its extent actually corresponds to the Honaker.

[53] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Roan Mountain folio (No. 151), 1907.

Fossils and correlation.—Unlike the underlying and overlying formations, the Nolichucky formation is rather fossiliferous, trilobites being the most abundant in both species and individuals. A few species of brachiopods occur but, except for *Dicellomus,* they are rare. Because of its fossils and the fact that the adjacent strata are nearly barren, and because of its distinctive lithology and relative thinness, the Nolichucky is easily recognizable, and thus is an invaluable stratigraphic marker throughout the area of its occurrence.

Some of the most characteristic species found in the Nolichucky are as follows:

Aphelaspis simulans Resser
Aphelaspis walcotti Resser
Blountia bristolensis Resser
Blountiella buttsi Resser
Coosia calanus (Walcott)
Coosia latilimbata Resser
Crepicephalus buttsi Resser
Crepicephalus goodwinensis Resser
Crepicephalus greendalensis Resser
Crepicephalus petilus Resser
Crepicephalus rectus Resser
Crinoid plates
Dendrograptus edwardsi major Ruedemann
Dicellomus appalachia Walcott
Dicellomus sp.
Dresbachia appalachia Resser
Genevievella blandensis Resser
Genevievella buttsi Resser
Genevievella campbelli Resser
Genevievella marionensis Resser
Genevievella virginica Resser
Genevievella wallacensis Resser
Holstonia holstonensis Resser
Kingstonia virginica Resser
Lingulepis walcotti Resser
Maryvillia bristolensis Resser
Maryvillia masadensis Resser
Maryvillia virginica Resser
Maryvillia widnerensis Resser
Norwoodella saffordi (Walcott)
Obolus sp.
Oedorhachis boltonensis Resser

Oedorhachis greendalensis Resser
Stenochilina? anceps Resser
Terranovella bristolensis Resser
Terranovella buttsi Resser
Tricrepicephalus walcotti Lochman
Tricrepicephalus sp.

The standard Upper Cambrian section of the eastern United States is in Wisconsin. The major subdivisions of this Upper Cambrian that have been commonly accepted are in descending order Trempealeau formation, Franconia formation, Dresbach sandstone, Eau Claire shale, and Mount Simon sandstone.

By comparison of fossils it has been found that the Nolichucky corresponds in the main to the Eau Claire shale in the lower half of the Wisconsin section. The Mt. Simon and Dresbach are unfossiliferous. The uppermost Upper Cambrian formations of Wisconsin, the Franconia and Trempealeau, are either absent in Virginia or are represented by the Copper Ridge dolomite and the Conococheague limestone. The correlation of the Nolichucky with the Upper Cambrian of Wisconsin and Missouri indicates that the Nolichucky corresponds approximately to the lower half of the Upper Cambrian of those states. The upper half of the Upper Cambrian in those states, namely, the Trempealeau and Franconia of Wisconsin and the Elvins of Missouri may be represented by a hiatus in the Appalachian Valley. This conclusion is in agreement with the geologic map of the Valley, with the descriptions in Bulletin 42 of the Virginia Geological Survey, and, in general, with the classification proposed by Ulrich.[54] It must be stated, however, that this classification is not accepted by most American geologists who believe that in Virginia and Tennessee the uppermost Upper Cambrian is represented by either the Copper Ridge dolomite or the Conococheague limestone, according to locality, and this belief is supported by a substantial amount of paleontologic evidence.

CONOCOCHEAGUE LIMESTONE[55]

Name.—The Conococheague limestone was named by Stose[56] from Conococheague Creek in Franklin County, Pennsylvania.

[54] Ulrich, E. O., Revision of the Paleozoic formations: Geol. Soc. America Bull., vol. 22, pp. 281-680, 1911.

[55] The Ozarkian system proposed by Ulrich (op. cit.) is defined by him to include all the rocks that are younger than the Nolichucky shale of the Appalachian Valley and older than the Stonehenge limestone of Pennsylvania. While this system has not been accepted by most American geologists, the present writer has been favorable to it and on the geologic map of the Appalachian Valley in Virginia, and, in the explanatory text (Virginia Geol. Survey Bull. 42, 1933), has referred the Conococheague limestone, Copper Ridge dolomite, and Chepultepec limestone in Virginia to the Ozarkian system of Ulrich. The first two formations named are generally considered by other stratigraphers to be Upper Cambrian and the Chepultepec is considered by some authors to be in the basal part of the Ordovician.

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

Limits.—In Virginia the Conococheague limestone includes all the strata between the Elbrook dolomite, or the fossiliferous Nolichucky, below and the Chepultepec limestone above. It is commonly distinguishable with little uncertainty from the Elbrook or Nolichucky but not so easily from the blue limestone of the Chepultepec, which, however, can be recognized nearly everywhere by its rare but characteristic fossils.

Character.—The predominant characteristic of the Conococheague is thick-bedded blue limestone which forms about 75 per cent of the formation. Most of the remainder is dolomite. (See Pl. 19A.) Its most diagnostic features are beds of coarse-grained sandstone and laminae of siliceous and clayey material in many of the layers of the limestone. On weathering, these laminae stand out on the limestone beds as thin, wavy or crinkly ribs. (See Pl. 20B.) This feature was emphasized by Stose[57] as one of the distinguishing characters of the typical Conococheague. The sandstone beds are composed of relatively large, well-rounded grains of quartz cemented by calcite; and as the calcite is dissolved a porous, friable sandstone is left. The thickness of these sandstones ranges from 1 foot to possibly 100 feet but is generally less than 20 feet. Some beds are ripple-marked. (See Pl. 20A.) One example of mudcrack fillings on the lower surface of a layer of sandstone was found. The beds of sandstone are lenses irregularly distributed vertically and horizontally through the formation. In some localities hardly any sandstone appears; in others, several layers, or groups, occur through a thickness of as much as 200 feet. Some of the thicker sandstone beds, where steeply inclined, make low, long and narrow ridges. In new road cuts and quarries, the beds of gray sandstone can be distinguished only by close examination from the similarly colored layers of limestone; in well-weathered exposures they are made conspicuous by their brown color, projecting edges, or persistence of fragments in the residual earth resulting from the decay of the enclosing limestone. As no sandstone occurs in the Elbrook, or any resistant sandstone in the Nolichucky, and as such beds are exceedingly rare in the Chepultepec and Beekmantown, this feature becomes an almost infallible criterion for the identification of the Conococheague limestone, or its equivalent, the Copper Ridge dolomite. The Conococheague contains a very small amount of chert, which occurs as black nodules, or as thin residual ferruginous plates.

Distribution.—The Conococheague crops out only in the southeastern half of the Valley in Virginia, through which it extends in one or more belts from Tennessee to the Potomac. Just northeast of Buchanan its outcrop is restricted to a narrow belt faulted on the

[57] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), p. 6, 1909.

northeast and southwest. Two of the belts continue northeastward through Maryland into the type locality in Franklin County, Pennsylvania. Southwest of Virginia the Conococheague persists, perhaps, as far as Morristown, Tennessee, where it has been given other names.

One of the best exposures of the Conococheague is on Widner Branch, 13 miles east of Abingdon, Washington County, where the formation, in a vertical attitude, is continuously exposed through its full thickness. It is almost fully exposed along Wolf Creek below the mill at Abingdon, and here also two thick beds of sandstone in the base are exposed. Another fine exposure is along Buffalo Creek south of Lexington, Rockbridge County. Some of the best displays of the sandstone in the Conococheague are in road cuts between Winchester and Chambersville; near the mill on Wolf Creek, Abingdon; on Hogthief Creek midway between the Lee Highway (U. S. Route 11) and the road to Meadowview along the Norfolk and Western Railway, 8 miles northeast of Abingdon, where the sandstone beds occur at intervals through a thickness of about 300 feet. A persistent bed of sandstone makes a pronounced ridge extending from the vicinity of Chrisman to Cherry Grove, Shenandoah County, and a ridge farther northeast, on which Conicville is located, is probably made by the outcrop of the same sandstone. Another such ridge, at least 4 miles long, extends from a point a mile west of Harriston on the Norfolk and Western Railroad, 11 miles north of Waynesboro, Augusta County, to Grand Caverns.

Thickness.—The most reliable determination of the thickness of the Conococheague was made on Widner Branch, where the section is as follows:

HENRY WIDENER BR.

Geologic Section 17.—Conococheague limestone on Widner Branch, 13 miles due east of Abingdon, Washington County, Virginia

	Thickness Feet
Chepultepec limestone	
7. Limestone, contains large flat gastropods and curved cephalopods	400±
Conococheague limestone (2013 feet)	
6. Limestone, thick bedded, a few ripple-marked beds	660
5. Sandstone	3
4. Limestone like bed 7; lower 560 feet is thick bedded (some beds 5 feet thick), thin banded or ribbony; layers of dolomite throughout making a small pro-	

	Thickness Feet
portion of the whole; fossils rare, trilobites and *Lingulepis,* 125 feet above the bottom	1100
3. Dolomite, thick bedded, some layers of limestone	250
Elbrook formation (upper 150 feet)	
2. Shale, yellow, of Nolichucky type	25
1. Limestone, fossils in top part (See geologic section 12, bed 8)	125±

The thickness of substantially 2000 feet here may be taken as the approximate thickness of the Conococheague throughout Virginia. Stose[58] determined the thickness as 1635 feet at Scotland, 5 miles northeast of Chambersburg, Pennsylvania. Bassler[59] estimated 1650 feet as the average thickness in Maryland, but suggests that the formation is thicker because discontinuous exposures and structural irregularities prevent accurate determination.

Fossils and correlation.—The Conococheague is sparingly fossiliferous. An occasional layer of limestone is crowded with fragments of trilobites, but they are generally so tightly held in the matrix that identifiable specimens can not be obtained. An exception to the general rule is an occurrence along the old route of the Lee Highway (U. S. Route 11) 1 mile northeast of Natural Bridge. Here a good collection of *Tellerina wardi* (Walcott) was made from a compact yellow decalcified limestone just beneath 10 to 20 feet of sandstone and estimated to be about 150 feet below the top of the Conococheague. The same species has been found under similar conditions in Winchester. A cheek of a Saukian trilobite and a few poor specimens of a linguloid brachiopod were found on Widner Branch (geologic section 17, bed 4) about 400 feet above the base of the Conococheague. A few chips of limestone covered with cheek spines of trilobites, and a few specimens of an oboloid brachiopod were found in an old quarry 1¾ miles N. 20° E. of the railroad station at Abingdon, but this material may have been derived from the top part of the Nolichucky. A boss of limestone in the cemetery at Abingdon shows sections of trilobite carapaces. On Virginia Route 81, 2 miles south of Glade Spring and three-fourths of a mile south of U. S. Route 11, a layer of coarsely crystalline or fragmental blue limestone, thought to be about 500 feet below the top of the Conococheague, is literally packed with fragmentary carapaces of trilobites. A species of *Symphysurina* occurs 500 feet slightly southeast of

[58] Stose, G. W., op. cit., p. 6.
[59] Bassler, R. S., Cambrian and Ordovician: Maryland Geol. Survey, p. 78, 1919.

Relief Church 3½ miles northeast of Marlboro, Frederick County, Virginia. It is, therefore, evident that trilobites flourished at times and in places in the Conococheague seas in Virginia. Besides trilobites, a very few poorly preserved specimens of gastropods and brachiopods have been observed. *Cryptozoon proliferum* Hall and *C.* cf. *C. undulatum* Bassler occur. The former is well displayed beside the Lee Highway 2 miles northeast of Buchanan, Botetourt County. (See Pl. 21C.) A trilobite, *Saukia stosei* Walcott, occurs in the Conococheague at Scotland, Franklin County, Pennsylvania, and *Plethopeltis?* sp. occurs at Greenville, Tennessee. *Saukia* and *Tellerina* occur in the Upper Cambrian of Wisconsin, and *Plethopeltis* occurs in Upper Cambrian rocks elsewhere.

In addition to the correlation of the Conococheague of Virginia with that of Pennsylvania and Tennessee by actual tracing of outcrops, it is correlated by the author with the Gatesburg dolomite of central Pennsylvania. The Conococheague is also correlated with the Copper Ridge dolomite of the northwestern belts of the Valley in Virginia on the basis of identical stratigraphic relations, of certain similarities in lithological character, such as the occurrence of sandstone beds, and by actual continuity of outcrop from one into the other around the northeast end of Tinker Mountain, 10 miles north of Roanoke.

COPPER RIDGE DOLOMITE

Name.—The Copper Ridge dolomite was named by Ulrich[60] in 1911 from Copper Ridge, a prominent ridge in Tennessee and Virginia, along which the formation crops out. The type locality is the gorge of Forked Deer Creek through Copper Ridge 1 mile northwest of Thorn Hill, Grainger County, Tennessee, and 13 miles northwest of Morristown.

Limits.—The Copper Ridge overlies the Nolichucky shale and extends upward to the Chepultepec limestone. Northwest of the Greendale syncline, in Washington County, Virginia, the Copper Ridge and Beekmantown form a continuous vertical mass of dolomite 2400 feet thick with no recognizable boundary between them. The occurrence of Chepultepec fossils at, or very near, the middle of a similar section in Tennessee 3½ miles southeast of Cumberland Gap, proves that the mass is about equally Copper Ridge and Beekmantown. On this basis the upper boundary of the Copper Ridge is drawn at about the middle of the combined mass. The Chepultepec in this northwest belt probably persists northeastward into Virginia but

[60] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 548, 635-636, 1911.

in a dolomitic facies, and hence is not easily distinguished from the Copper Ridge.

Character.—In all of its outcrops northwest of the Greendale syncline or of Sinking Creek Valley northeast of New River, the Copper Ridge is composed almost entirely of pure dolomite which is thick bedded, medium coarse-grained, and bluish gray. The base is widely marked by a finely straticulate and highly distinctive bed 5 to 10 feet thick. In the belt southeast of the Greendale syncline some layers of limestone, reaching a thickness of 10 to 15 feet, appear in the greatly predominant mass of dolomite. A suite of samples taken at intervals through a thickness of 1200 feet, across Copper Ridge, just north of Speers Ferry, Scott County, contains no limestone. The appearance of limestone in the belt southeast of the Greendale syncline, where the Copper Ridge is nearest to the Conococheague, may be reasonably interpreted to signify the beginning of the transition from the Copper Ridge dolomite facies to the Conococheague limestone facies of this common stratigraphic unit.

The Copper Ridge and its equivalent, the Conococheague, contains diagnostic sandstone beds. In the Copper Ridge they are equally numerous and the same in composition, distribution, and thickness, as in the Conococheague. No such sandstone occurs in the Honaker or Nolichucky below, and with very rare exceptions, none has been noted in the Beekmantown above. Residual chert, though extremely abundant in large dense and gnarly masses, in the Copper Ridge of southern Tennessee and northeastern Alabama, is relatively much less abundant and in smaller masses in Virginia.

Distribution.—The Copper Ridge dolomite crops out in one long, narrow belt southeast of the Greendale syncline extending from Tennessee nearly to Newcastle, Craig County, and in two long belts northwest of the Greendale syncline, as shown on the geologic map. The southeastern of these belts coincides with the ridge from which its name is taken and extends from Tennessee through Scott County to Belfast Mills in Russell County.

The Copper Ridge dolomite is clearly exposed in full thickness on Buchanan Branch 2½ miles southwest of Saltville, Smyth County, and on the highway along Troublesome Creek and on the Clinchfield Railroad, just north of Speers Ferry, Scott County. A section on Buchanan Branch is given below:

Geologic Section 18.—Nolichucky formation to the Athens shale on Buchanan Branch, southwest of Saltville, Virginia

	Thickness Feet
Athens shale	
65. Shale, exposed at bottom	20+
Holston limestone (65 feet)	
64. Not exposed	30
63. Limestone	15
62. Not exposed	20
Lenoir limestone (65 feet)	
61. Limestone, dark-colored, fossiliferous	65
Hiatus—Mosheim and Murfreesboro limestones absent	
Beekmantown formation (1329 feet)	
60. Dolomite	20
59. Not exposed	50
58. Dolomite	165
57. Partly exposed, dolomite	100
56. Dolomite, cavernous chert with persistent assemblage of *Coelocaulus* sp.? and *Orospira* sp. in top	300
55. Chert, interbedded layer	1
54. Dolomite	35
53. Limestone	10
52. Dolomite	10
51. Limestone	30
50. Dolomite	20
49. Limestone, contains *Hormotoma, Lecanospira?, Chiton?*	20
48. Dolomite	10
47. Limestone	3
46. Dolomite, contains *Bathyurus, Roubidouxia, Ophileta*	180
45. Partly exposed, some dolomite	100
44. Limestone, contains fragments of cystids, crinoids, and brachiopods	10
43. Dolomite	35
42. Limestone	2

	Thickness Feet
41. Dolomite	15
40. Limestone, blue	2
39. Dolomite	10
38. Chert, partly silicified calcareous edgewise conglomerate, in a distinct ledge	5
37. Not exposed	40
36. Dolomite	30
35. Limestone	5
34. Dolomite	30
33. Limestone	5
32. Dolomite	65
31. Limestone	1
30. Dolomite, thick bedded, blue	20
Chepultepec formation (36 feet)	
29. Limestone, thick bedded, dark blue, banded, contains gastropods and curved cephalopods of *Levisoceras* or *Dakeoceras* types	18
28. Dolomite	5
27. Limestone	11
26. Dolomite	2
Copper Ridge dolomite (1336± feet)	
25. Sandstone	3
24. Dolomite, thick to medium thick bedded, light blue gray	130
23. Sandstone	2
22. Dolomite	70
21. Sandstone	4
20. Dolomite	15
19. Sandstone, mainly	18
18. Dolomite	50
17. Limestone, oolitic, dark blue	10
16. Limestone, dolomite, and layers of sandstone interbedded in thin beds; one bed of sandstone about 4½ feet thick	47±
15. Dolomite, thick bedded; medium bedded, fine grained below	350

		Thickness Feet
14.	Dolomite with scattered plates and nodules of black chert	45
13.	Dolomite, thick bedded	140
12.	Dolomite, thick bedded to massive, nodules of black chert in top part	25
11.	Dolomite, medium thick bedded, some massive layers, blue and light bluish, medium coarse grained	350
10.	Sandstone	1½
9.	Dolomite	10
8.	Sandstone	1½
7.	Dolomite	30
6.	Sandstone	2
5.	Dolomite	20
4.	Sandstone	2
3.	Dolomite, straticulate, prevalent basal bed of Copper Ridge. (See geologic sections 14 and 15.)	10±
Nolichucky formation (150± feet)		
2.	Limestone, blue, banded, thin bedded	100±
1.	Shale, lenses of limestone, contains *Crepicephalus* and *Coosia;* the bottom of this section is in the railroad cut just northeast of the "Tin Bridge" over Buchanan Branch, 1 mile southwest of Plasterco and 3 miles southwest of Saltville	50+

On Mumpower Creek north of Bristol another good section is exposed. (See geologic section 14.) Still another good exposure is along State Route 71 between Bolton and Brookside Inn. On both Mumpower Creek and Buchanan Branch sandstone beds at or near the bottom of the Copper Ridge and close above the Nolichucky are exposed.

Excellent examples of sandstones in the Copper Ridge are to be seen in the following places: On Holston River 1 mile east of Chatham Hill, Smyth County, a bed about 50 feet thick and just above the Nolichucky; State Route 88 just south of Maiden Spring Creek about 1 mile south of Thompson Valley, Tazewell County, a thick bed near the top of the Copper Ridge; at the intersection of State Route 42 with 87, about half a mile west of Sharon Springs, Bland County, a bed 50 to 100 feet thick and near the top of the Copper Ridge; in the south environs of Bland, Bland County, just above the Nolichucky; and in

Crocketts Cove, 5 miles north of Wytheville, along the north road to Bland. A sandstone several feet thick is exposed for several hundred feet along U. S. Route 23, one-third of a mile southwest of the Natural Tunnel, Scott County. In Lee County the presence of sandstone in the Copper Ridge is plainly shown by much sandstone debris along State Route 64, on the ridge between Jonesville and Powell River. Scarcely a single large exposure of the Copper Ridge throughout Virginia fails to show one or more beds of sandstone, which are distributed as lenses throughout the full thickness and entire areal extent of the formation in the State.

Thickness.—On Buchanan Branch (geologic section 18), the Copper Ridge is 1336 feet thick. In Lee and Scott counties, the best determinations give a thickness of approximately 1200 feet. On State Route 71, south of Brookside Inn, Russell County, the thickness is 1353 feet. The thickness is about 1400 feet in the type section in the gorge of Forked Deer Creek through Copper Ridge, Grainger County, Tennessee. It probably ranges from 1200 to 1400 feet in Virginia.

Fossils and correlation.—The only fossils that have been found in the Copper Ridge in Virginia are occasional specimens of *Cryptozoon* and a few specimens of *Hemithecella* at two places. The horizon of the *Hemithecella* is high in the Copper Ridge and may mean that some of the Chepultepec has been locally included in the Copper Ridge. A few fossils have been found in Tennessee and Alabama. *Scaevogyra* cf. *S. swezeyi* Whitfield, has recently been found about 500 feet below the top of the Copper Ridge in the vicinity of Norris Dam, Tennessee, and the same, or a closely similar species has been found in Alabama. *Scaevogyra swezeyi* occurs in the Upper Cambrian (St. Lawrence dolomite) of Wisconsin. If the Tennessee and Alabama specimens are *S. swezeyi,* they would suggest that the Copper Ridge[61] is Upper Cambrian.

ORDOVICIAN SYSTEM

CHEPULTEPEC LIMESTONE[62]

Name.—The Chepultepec limestone was named by Ulrich[63] from the village of Chepultepec, Blount County, Alabama, just west of which the formation crops out and is highly fossiliferous. It makes the upper

[61] Subsequently this zone had been found in the Potosi of Missouri and the basal Ellenburger of Texas. (See U. S. Geol. Survey Prof. Paper 186-L.) Against this evidence may be cited the occurrence of two species of a small, curved cephalopod, *Shelbyoceras*, in the Copper Ridge of Alabama. No such cephalopod is reported from the Upper Cambrian elsewhere. Ulrich bases his proposal for the Ozarkian system on the belief that the included body of rocks is later in age than the Upper Cambrian of Wisconsin.

[62] Upper Ozarkian of Ulrich and the author. The provisional reference of the Chepultepec to the Ordovician here is based upon recent paleontological studies by Josiah Bridge of the U. S. Geological Survey and of G. A. Cooper of the U. S. National Museum.

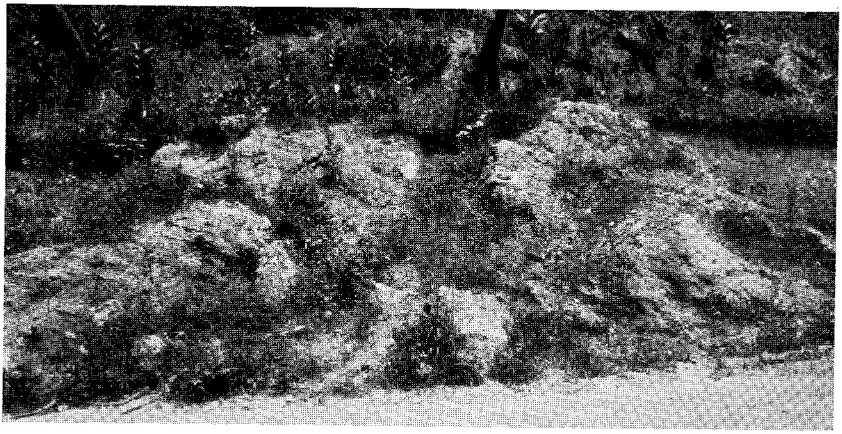
[63] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull. 22, p. 638, 1911.

PLATE 21

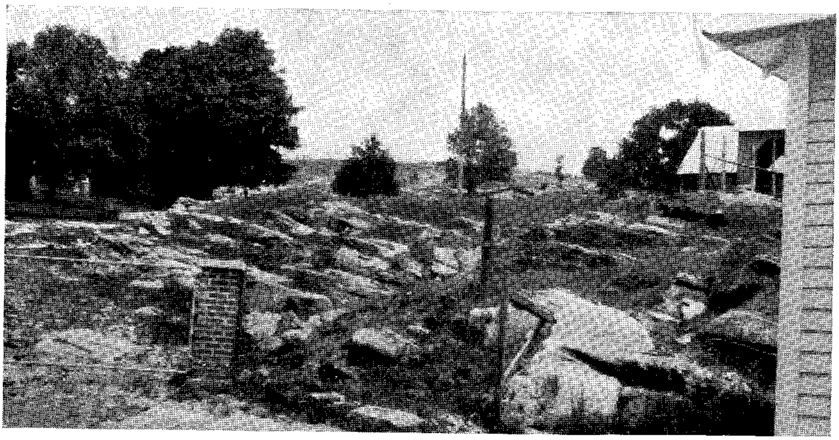
A. Rough, gnarly dolomite at the base of the Beekmantown formation. It lies upon the Chepultepec limestone shown in B. Near De Busk Mill on the Middle Fork of Holston River, 12 miles east-northeast of Abingdon, Washington County. Looking northeast.

B. Chepultepec limestone near De Busk Mill. Only the upper part of the formation, 500-600 feet thick here, is shown. The dolomite shown in A is a short distance to the right of the view. Looking northeast.

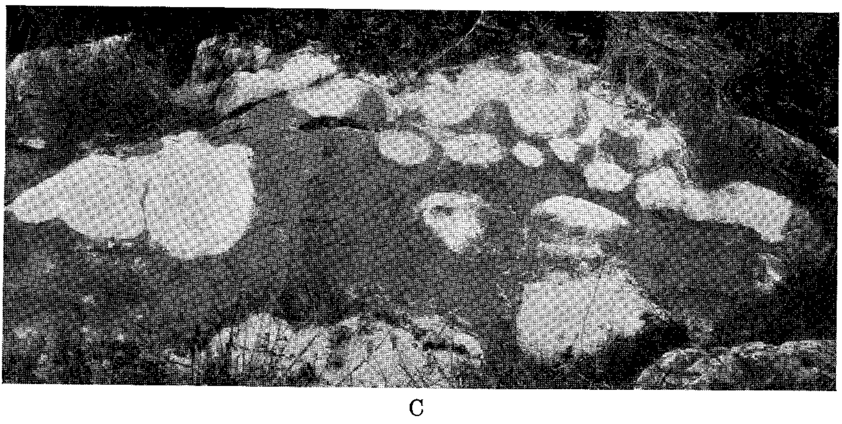
C. Large heads of *Cryptozoon* in Conococheague limestone. They have become white on weathering. Along the Lee Highway (U. S. 11) 2 miles northeast of Buchanan, Botetourt County, a short distance southwest of the intersection of the road on Purgatory Creek.



A

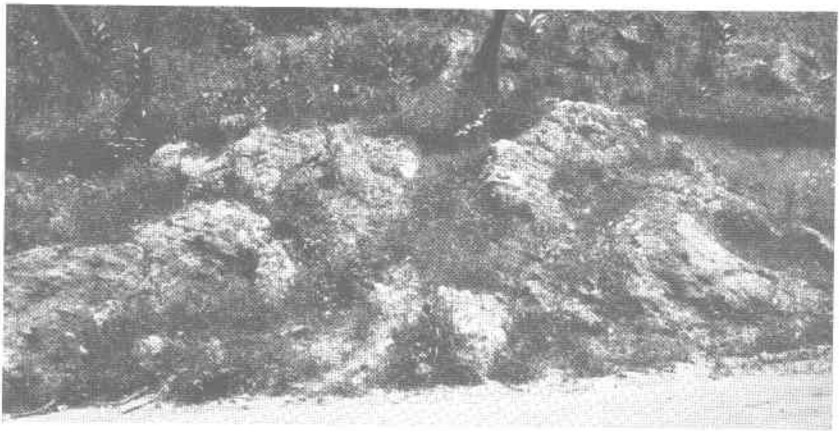


B



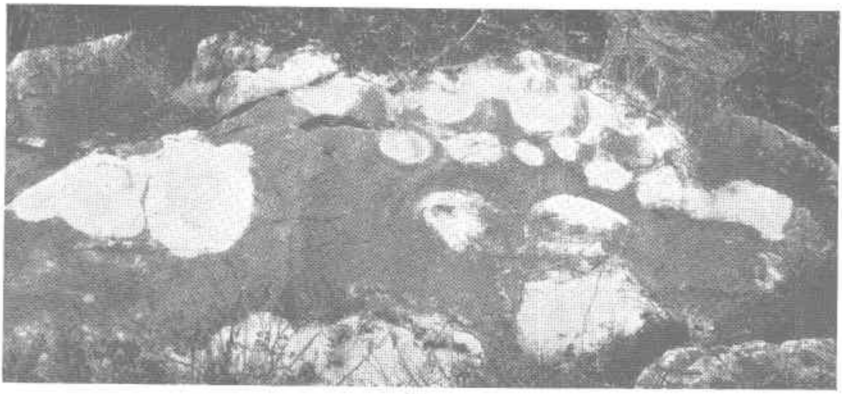
C

CAMBRIAN AND ORDOVICIAN FORMATIONS



A

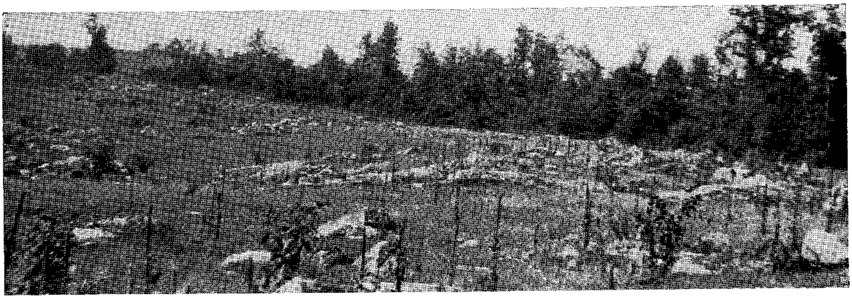
B



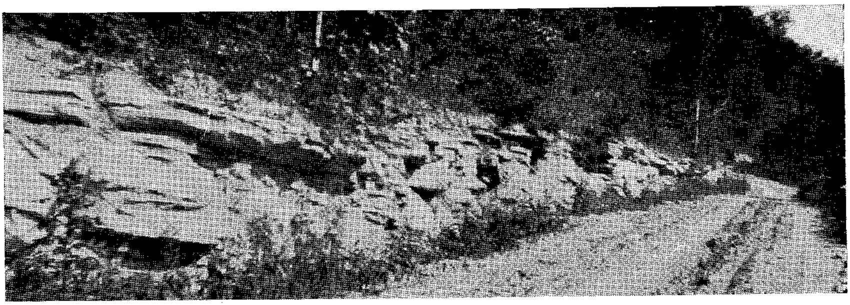
C

Cambrian and Ordovician Formations

A



B



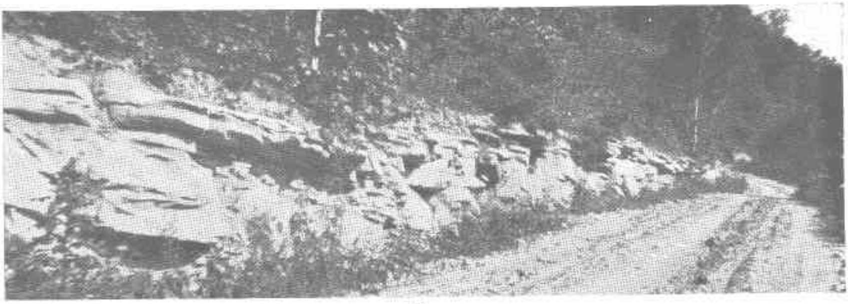
C

D

ORDOVICIAN LIMESTONE AND DOLOMITE

A

B



C

D

ORDOVICIAN LIMESTONE AND DOLOMITE

PLATE 22

A. Vertical beds of Beekmantown limestone, in Clarke County, 4 miles northwest of Berryville. Looking southeast.

B. Beekmantown limestone. Same locality and in the same field as A. Looking southeast. Extensive tracts with such displays of limestone are found in the area surrounding Berryville.

C. Beekmantown dolomite on Yellow Branch, 5½ miles southeast of Rose Hill, Lee County. It belongs in part, if not wholly, to the post-*Lecanospira*, or *Ceratopea*, zone beginning at the top about 100 feet beneath the Murfreesboro limestone shown on Pl. 24C. The contact is at the bend of the road in the distance. Looking southeast.

D. Beekmantown limestone in quarry north of Riverton, Warren County. Looking north.

few hundred feet of the Knox dolomite at Chepultepec, as mapped in the Birmingham quadrangle.[64]

Limits.—In Virginia the Chepultepec succeeds the Conococheague limestone or the Copper Ridge dolomite without known unconformity and is overlain by the basal member of the Beekmantown group described beyond. In Frederick County the top bed of the Conococheague is distinctively marked by the clayey laminae which are characteristic of the Conococheague. This bed crops out across the county. Its top is commonly marked by a terrace 50 feet or so wide, on which the fossiliferous basal beds of the Chepultepec crop out. It is one of the best marked contact zones in the State.

Character.—The Chepultepec is predominantly a rather pure limestone with intercalated beds of more or less magnesian limestone and dolomite. The limestone is commonly thick bedded, blue, and finely crystalline. In Frederick County the basal 40 feet are in many places massive and stand up conspicuously on their outcrop. Its general aspect is shown in Plate 21B. Of 18 consecutive samples taken on Glade Creek, 2 miles southwest of Glade Spring, Washington County, through about 400 feet of rock, each representing about 20 feet, 12 samples contained 90 per cent or more $CaCO_3$ and one sample contained 97.42 per cent; 3 samples contained 4, 5, and 6.52 per cent $MgCO_3$. Most of the remainder ranged from about 2 to 4 per cent $MgCO_3$. The formation is evidently a low magnesian limestone in the southeastern belts of the Valley, where it overlies the Conococheague limestone. In the first belt of the Copper Ridge south of the Greendale syncline, the Chepultepec is composed of alternating beds of blue limestone and dolomite, as shown in the section on Buchanan Branch (geologic section 18). On U. S. Route 19, 1¼ miles southeast of Greendale, the Chepultepec is associated with sandstone in the top of the Conococheague, and a thin sandstone occurs within the Chepultepec. This is the only sandstone that has been observed in the formation. In northern Tennessee, 3½ miles southeast of Cumberland Gap, on U. S. Route 25E, the Chepultepec is known only by residual chalky chert with *Helicotoma uniangulata* (Hall), that may be derived either from limestone or dolomite.

Distribution.—The Chepultepec is present along the southeast side of the Valley from Tennessee to West Virginia, as shown on the geologic map. It has been observed as far northeast as Winchester, Virginia, and Hagerstown, Maryland, and has recently been identified in Page Valley east of the Massanutten syncline and northward along the strike of that belt to West Virginia. West of the Massanutten syncline it is a persistent bed through Frederick County. In the Copper Ridge belt

[64] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Birmingham folio (No. 175), 1910.

next southeast of the Greendale syncline, it has been observed nearly as far northeast as Chatham Hill, Smyth County, and is believed to persist to the northeast end of that belt in Sinking Creek Valley, 8 miles southwest of Newcastle, Craig County. No certain Chepultepec fossils in any beds that could be identified as Chepultepec have been observed in the Valley northwest of the Greendale syncline or the Saltville-Bland fault. At two and perhaps three places in the area under consideration, a few specimens of *Hemithecella* (see Part II) have been found near the top of the dolomite referred to the Copper Ridge and, as representatives of that genus occur in the Chepultepec, the beds in Virginia containing them may be Chepultepec. *Hemithecella* is especially plentiful at the Natural Tunnel, Scott County, where it occurs along the path to the top of the tunnel on the west side of the southern portal. Another possible occurrence of the Chepultepec is suggested by a single specimen of *Syntrophina campbelli* (Walcott), supposed to be a Chepultepec fossil, in residual chert associated with *Hystricurus conicus* (Billings) and *Lecanospira* at the base of a steep slope southeast of State Route 71, one-third of a mile east of Bolton, Russell County. It is possible that the Chepultepec is present here and that its chert is mixed with chert from the *Lecanospira* zone of the Beekmantown. But as *Syntrophina campbelli* (Walcott) has been found elsewhere in chert piles in which chert with *Lecanospira* also occurs, there is reason to suspect that it occurs in the lower Beekmantown too.

The Chepultepec is extensively exposed in a wide area crossed by Barron Creek and Sharp Branch just north of the State line 1 to 2 miles south of Alvarado, Washington County. The best exposure is just north of De Busk Mill 3 miles south of Glade Spring, Washington County (See Pl. 21B). An equally extensive exposure may be seen in Frederick County, 2½ miles west southwest of Stephens City, and it is well exposed just north of U. S. Route 11 through the city of Winchester. It is also well exposed along the former course of the Lee Highway (U. S. Route 11),[65] half a mile west of Glade Creek and 1 mile south of Emory, Washington County. The location of the road has been changed and it now passes a few hundred feet south of the good exposure. The samples whose composition is summarized above were taken along Glade Creek just north of the Lee Highway. The thin Chepultepec in the belt south of the Greendale syncline may be seen on Buchanan Branch (geologic section 18), along State Route 81, at the junction, 2 miles south of Saltville, on the northeast road to the old quarries of the Mathieson Alkali Works. On this belt also, the Chepultepec, containing cephalopods, is exposed at the road intersection

[65] The road is not accurately located on the geologic map for the former highway passes through this area instead of north of it.

1 mile southeast of Glenford, Washington County; and, farther south, on U. S. Route 19, at a church about 1¼ miles southeast of Greendale. Northeast of Saltville, the Chepultepec is exposed on Holston River 3 miles southwest of Chatham Hill; on a road 1 mile nearly south of Chatham Hill; and on another road three-fourths of a mile southeast of Chatham Hill. Another good exhibit of the Chepultepec and one that can easily be seen is at Natural Bridge, Rockbridge County. The Natural Bridge is in the Chepultepec limestone near the southern end of a long narrow syncline extending northeast to a point south of Fairfield, Rockbridge County. The limestone, with cephalopods and large gastropods, is well exposed along the relocated highway about half a mile north of Natural Bridge. Another good partial exposure of blue limestone, with the common curved cephalopods, is east of the road northeast of Lacey Spring, 2 miles southwest of Marland, Shenandoah County. A mile northwest of Fishers Hill and 2 miles nearly west of Strasburg is a fine exposure of a thick-bedded limestone from which a specimen of *Levisoceras* sp. was obtained. (See Part II.) Here also, the common large flat gastropods occur in the top part. Three miles northwest of Middletown and 1 mile southeast of Marlboro, Frederick County, a massive ledge of limestone containing cephalopods and gastropods crosses the road. *Ophileta complanata* Vanuxem and *Eccyliomphalus* sp. were collected here.

Thickness.—The Chepultepec is 600 feet thick at De Busk Mill in the southeastern part of the Valley. It is estimated to be at least 500 feet thick south of Alvarado, Washington County, at Natural Bridge, and in Frederick and Shenandoah counties. In the section on Buchanan Branch, Washington County (geologic section 18), the Chepultepec is 36 feet thick. Throughout this belt, which is next southwest of the Greendale syncline, all observations indicate a thickness of less than 50 feet.

Fossils and correlation.—The Chepultepec carries a sparse but very characteristic fauna composed almost exclusively of cephalopods and gastropods. The cephalopods are small curved forms one to two inches high with very closely spaced septa. These most commonly appear as longitudinal sections on the smooth weathered faces of the limestone layers, and are to be seen only on close examination. Good examples are illustrated in Part II. In some places a silicified specimen is partly exposed on weathering and stands out on the surface. The gastropods are exposed in the same way but are commonly easier to see than the cephalopods. A few nearly complete specimens of one type, *Gasconadia* (see Plates in Part II), and a few species of brachiopods have been found. Both cephalopods and gastropods occur along the Valley from Tennessee to the Potomac. The species, mostly imperfectly preserved, as provisionally identified by Ulrich, Bridge, and Cooper are listed below:

Conocerina sp.
Dakeoceras sp.
Eccyliomphalus sp.
Ectenoceras sp.
Finkelnburgia buttsi Ulrich and Cooper, and 2 other species
Gasconadia putilla (Sardeson) and two other species
Helicotoma uniangulata (Hall)
Hemithecella expansa Ulrich and Bridge,
  n. gen and sp.
Levisoceras, 2 sp.
Ophileta, cf. O. complanata Vanuxem
Ophileta, a large form, possibly O. grandis Ulrich
Ozarkispira subelevata Ulrich and Bridge, n. sp.
Robsonoceras? sp.
Sinuopea, 2 sp.
Tetralobula delicatula Ulrich and Cooper

In the chert of the Chepultepec in Tennessee, mentioned above, the following fossils were collected: *Finkelnburgia?* sp., *Helicotoma uniangulata* (Hall), *Ophileta?* sp., and *Clarkoceras* sp. This locality in Tennessee is just east of U. S. Route 25E, 3½ miles southeast of Cumberland Gap village and in a shallow ravine at the west foot of Gobblers Knob.[66] The same zone, just above the Conococheague, with some of the same species, occurs at Funkstown in the south environs of Hagerstown, Maryland; at Le Gore northeast of Frederick, Maryland; and in the Nittany Valley of central Pennsylvania, 2 miles due south of Buffalo Run Post Office, and 13 miles southwest of Bellefonte, Pennsylvania. *Helicotoma uniangulata* (Hall) (see plates in Part II) is the chief guide fossil for the Chepultepec of Alabama, Gasconade of Missouri, Oneota of Wisconsin, and a cherty zone referred to the top of the Little Falls dolomite in the Mohawk Valley of New York. The occurrence of *Eccyliomphalus,* perhaps *E. multiseptarius* Cleland, and *Ophileta complanata* Vanuxem in the top of the limestone where referred wholly to the Chepultepec, indicates that the Stonehenge limestone of central Pennsylvania and the Tribes Hill limestone of New York, in which both of these species occur, are represented in the top of the Chepultepec. The occurrence of several common species in the Chepultepec, Stonehenge, and Tribes Hill of New York has led some geologists to the tentative conclusion that those formations are all the same.

66 As shown on the topographic map of the Middlesboro quadrangle.

BEEKMANTOWN GROUP[67]

Name.—The name Beekmantown was proposed by Clarke and Schuchert[68] in order to supplant the old descriptive name Calciferous Sandrock with a geographic name. The type locality is Beekmantown Township, Clinton County, New York. As originally proposed the Beekmantown included all of the strata lying above the Potsdam sandstone (Upper Cambrian) and the Chazy limestone. This group was originally divided into five sections, A-E, by Brainerd and Seely.[69] At the present time the greater part of Division A is correlated with the Little Falls dolomite of the Mohawk Valley, New York, and placed in the Cambrian or Ozarkian. The name Beekmantown is restricted to the uppermost portion of Division A and Divisions B-E.

The Beekmantown is well represented in central Pennsylvania where it has been divided into four formations which are, in ascending order, the Stonehenge limestone, Nittany dolomite, Axemann limestone and Bellefonte dolomite. Here, as in New York, the Beekmantown is overlain by limestones of Chazyan age. In Virginia it is underlain by the Chepultepec limestone which may be the approximate equivalent of the cherty zone in the top of the Little Falls dolomite.

As these beds are traced southwestward across Maryland and into Virginia the four formations become difficult to distinguish and map separately, and on the geologic map[69a] they are combined under the convenient designation, Beekmantown group. Where they can be distinguished they are treated as members or zones.

Limits.—In the southeastern half of the Valley where the Chepultepec is well developed, as already described, the base of the Beekmantown group (Stongehenge limestone) is believed to be somewhere in the upper part of the limestone included in the Chepultepec. This provisional location of the base of the Beekmantown is indicated in the "Explanation" of the geologic map by the line drawn through the block showing the pattern and symbol of the Chepultepec-Stonehenge limestone.

In the belt of Copper Ridge and Beekmantown next southeast of the Greendale syncline, the Beekmantown is separated from the Copper

---

[67] The beds described under this heading comprise the Canadian system of Ulrich who proposed it to include the group of formations lying between the Little Falls dolomite (Ozarkian) of the Champlain region, New York, and the Chazy limestone. This group has its best development in the vicinity of Bellefonte, Pennsylvania, where it occupies a stratigraphic position corresponding to that of the Lake Champlain region.

[68] Clarke, J. M. and Schuchert Charles, The nomenclature of the New York series of geological formations: Science, new ser., vol. 10, pp. 874-878, 1899.

[69] Brainerd, Ezra, and Seely, H. M., The Calciferous formation in the Champlain Valley: Am. Mus. Nat. Hist. Bull. 3, pp. 1-23, 1890.

[69a] Butts, Charles, Geologic map of the Appalachian Valley with explanatory text: Virginia Geol. Survey Bull. 42, 1933.

Ridge by the thin Chepultepec limestone, shown in geologic section 18. For reasons given below under "Character," the separation of the Beekmantown from the Copper Ridge generally is difficult to make on lithologic criteria in any of the belts northwest of the Greendale syncline or in any of the other northwestern belts of the Valley. In a few places the boundary can be drawn at the top of a bed of sandstone in an exposed section, for sandstone beds are persistent in the Copper Ridge at this horizon and practically absent from the Beekmantown. Where lithologic criteria are wanting, the location of the boundary is based upon the occurrence of Chepultepec fossils, such as those in the middle of the Beekmantown-Copper Ridge mass southeast of Cumberland Gap, Tennessee. In other parts of the Valley it has been determined by the occurrence of Beekmantown fossils such as *Lecanospira* and *Roubidouxia* in residual chert in such position as to indicate that they were derived from about the middle of the combined mass of Copper Ridge and Beekmantown. These fossils indicate that the dolomite of these belts and areas, such as the area in Lee County, around Rye Cove, Scott County, and the two broad belts in Scott and Russell counties next northwest of the Greendale syncline, is about equally divided between the Copper Ridge and Beekmantown. Therefore, as a general practice, in this region where exposed beds and fossils are scarce, the boundary has been drawn through the middle of each combined belt.

In Virginia the Beekmantown group is everywhere overlain by Chazyan rocks. In southwestern Virginia it is succeeded by the Murfreesboro limestone, in the middle portion of the Valley it is followed by the Mosheim limestone, and in the southeastern belts it is followed by the Lenoir limestone.

Character.—The Beekmantown has three distinct lithologic facies in Virginia, namely, dolomite in the area southwest of Lexington and in the northwestern belts from Lee County to Highland County; dolomite and limestone southwest of Frederick County; and a dominantly limestone facies in Frederick and Clarke counties. The dolomite is thick bedded, bluish gray, and finely to medium coarsely crystalline. Locally the massive beds weather to a very rough gnarly surface, as shown in Plate 21A. A suite of more than 100 samples, collected through the entire 2400 feet of Copper Ridge and Beekmantown dolomites exposed in a continuous section along the Clinchfield Railroad immediately north of Speers Ferry Station, and along U. S. Route 58 below the tunnel immediately southeast of the bridge across Clinch River at old Speers Ferry, Scott County, shows no differences between the specimens from the Copper Ridge and those from the Beekmantown. Less than a dozen specimens gave an appreciable effervescence when treated with dilute hydrochloric acid. No limestone corresponding to

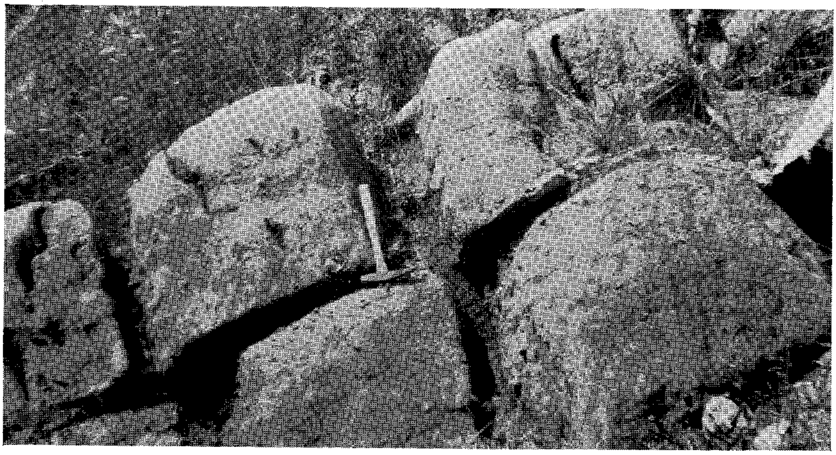
PLATE 23

A. Upper Beekmantown and the overlying Blackford facies of the Murfreesboro limestone, near Gate City, Scott County. At the base of the Murfreesboro, marked by the man, is a calcareous muddy conglomerate sprinkled with angular fragments of chert, evidently residual from the underlying Beekmantown. Above the conglomerate is gray shale with thin layers of fossiliferous limestone which here, as elsewhere, contain more or less chert. Along Templeton Branch, 4 miles northwest of Gate City, on road from Gate City to Hill Station. Looking west.

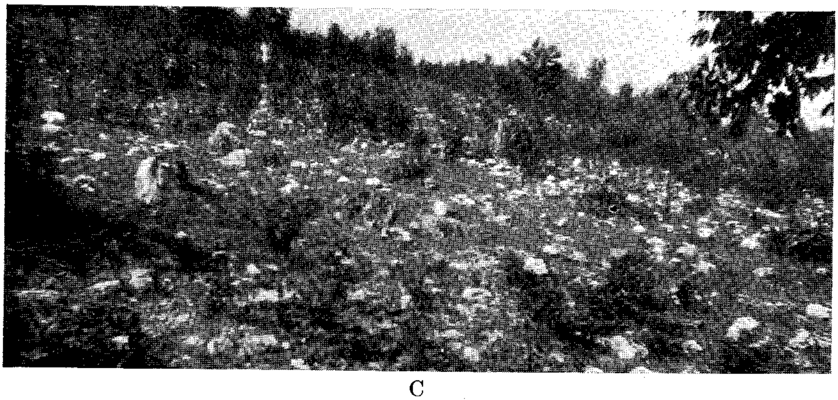
B. Basal conglomerate in the Murfreesboro; near view of bed shown in A.

C. Slope covered with chert from the *Lecanospira* zone of the Beekmantown, near Abingdon, Washington County. Such occurrences are common in southwest Virginia. This view is in a ravine about 3 miles north of Abingdon and 1 mile south of Whites Mill.

A

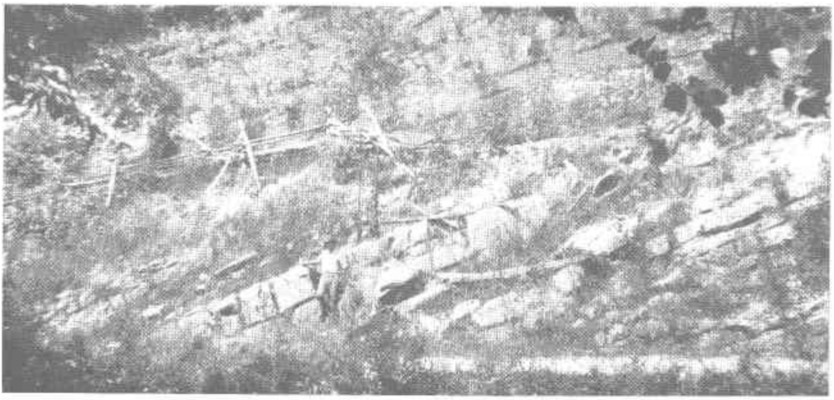


B

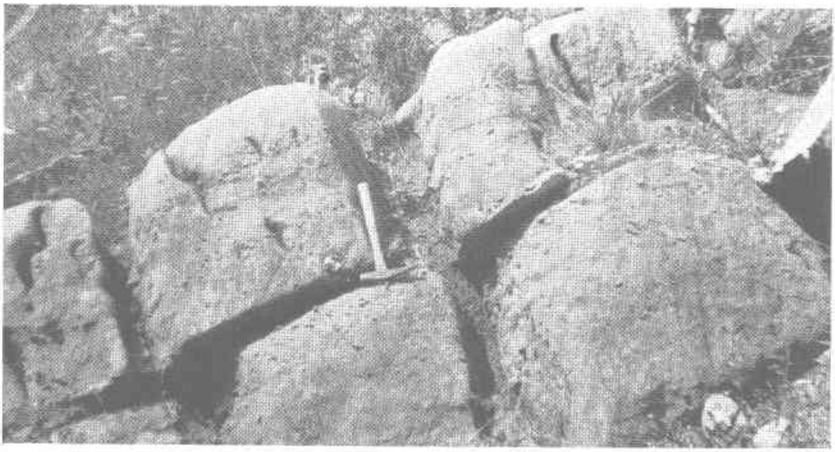


C

ORDOVICIAN FORMATIONS



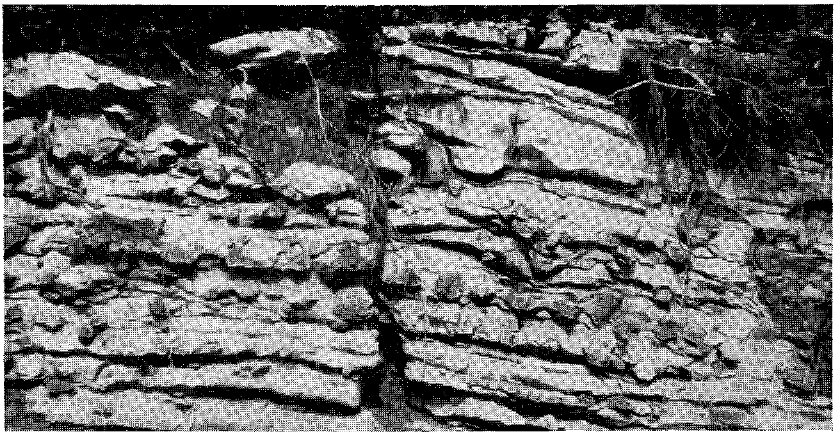
A



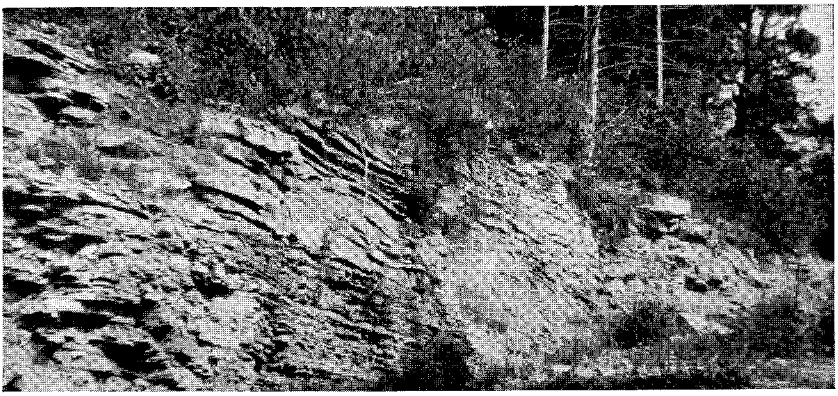
B

C

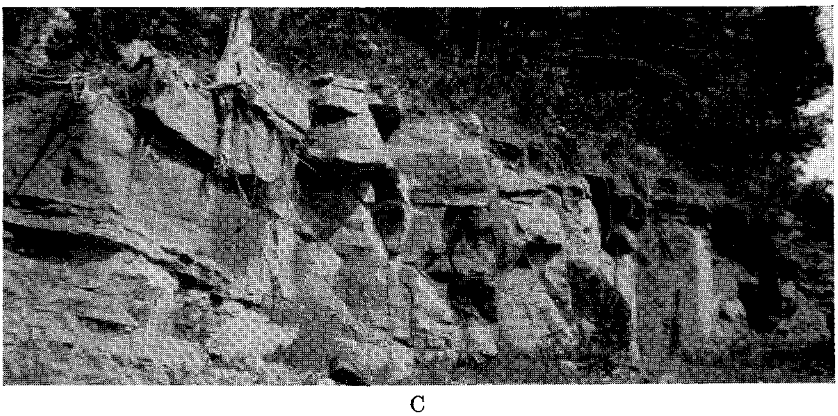
ORDOVICIAN FORMATIONS



A

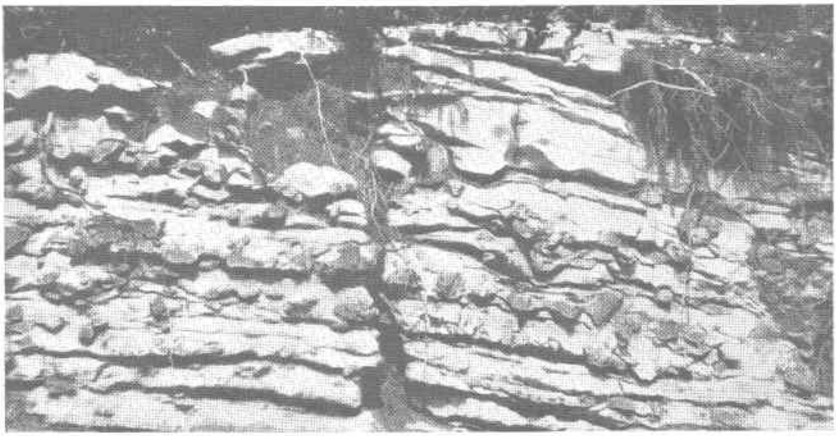


B

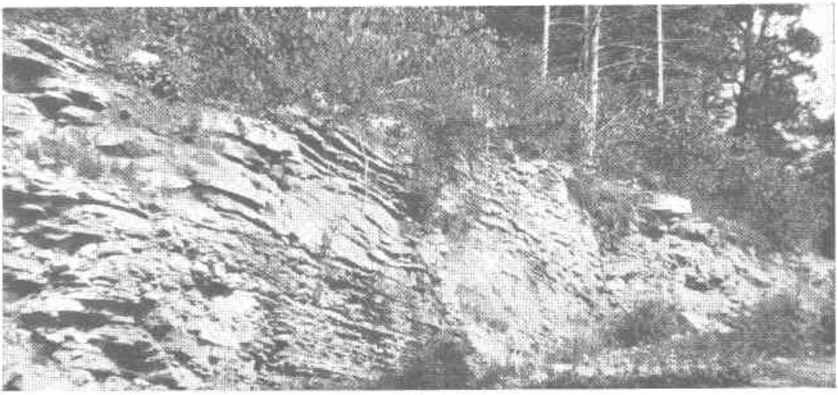


C

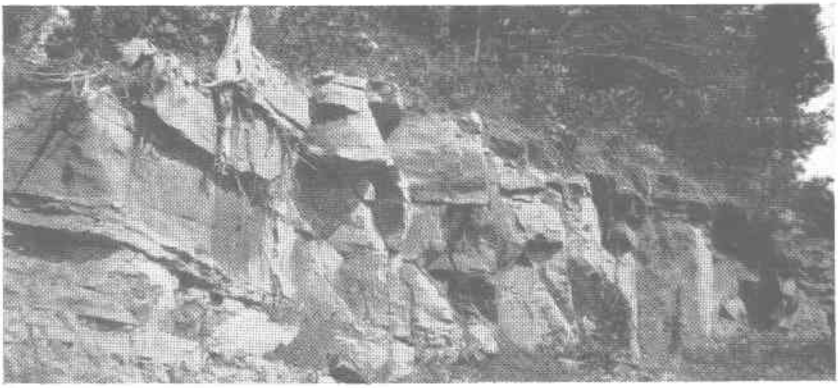
ORDOVICIAN LIMESTONE



A



B



C

ORDOVICIAN LIMESTONE

PLATE 24

A. Murfreesboro limestone, bed about 8 feet thick, with nodules of black chert. Immediately beneath the limestone and shale shown in Pl. 25C. On Yellow Branch, Lee County, 5½ miles southeast of Rose Hill. Looking southeast.

B. Limestone just below the cherty bed shown in A.

C. Thick-bedded granular limestone just beneath the limestone shown in B. It resembles closely the Lenoir limestone shown in Pl. 25D.

the Chepultepec of the southeastern belts was recognized, although the horizon is probably represented in the dolomites. Here and there a layer of limestone, generally only a foot or two thick, occurs between the dolomite layers. Dolomite of this type is illustrated in Plate 22C. In the section just northwest of Blackford, Russell County (geologic section 19), this facies contains more limestone than seen at any other locality. These scattered layers of limestone are of compact texture (vaughanitic), blue or dove-colored, and commonly fossiliferous. They resemble the Mosheim limestone so closely that where they are immediately succeeded by the Mosheim, as near Cedar Grove Church 2 miles east of Harrisonburg, Rockingham County, the boundary between the Beekmantown and Mosheim is not easily determined. In the dolomite and limestone facies, thin beds of limestone occur promiscuously throughout the full thickness of the formation. They are more abundant in the belts southeast of the Greendale syncline and in the southeastern belts. In Augusta, Rockingham, Shenandoah, and Frederick counties, limestone beds become still more abundant, and in some localities predominate in the upper two-thirds of the formation, constituting the limestone facies of the formation. (See Pl. 22A, B, and D.) In other words, the Beekmantown becomes increasingly calcareous from the northwest side of the Valley to the southeast side. It is also more calcareous at the northeast end of the Valley, as in Frederick County, than in the southwest end of the Valley, as in Scott County.

On weathering, the formation in southwestern Virginia yields an immense quantity of chert, masses of which strew the surface above its outcrop (See Pl. 23C.) In Tennessee and Alabama the Copper Ridge dolomite is extremely cherty and the Beekmantown only moderately so, but in southwestern Virginia, this characteristic of the two formations is completely reversed. The section of the Beekmantown at Speers Ferry contains only three or four thin layers of bedded chert. At one horizon a few layers of dolomite an inch or so thick, contain many well rounded grains of quartz, the largest being about half a millimeter in diameter. These grains are isolated and imbedded in a dolomitic matrix, in solution of which the quartz grains fall apart instead of cohering to form a layer of sandstone. Such quartzose layers are very rare. The bedded chert in unweathered rock that might be considered original is equally rare as compared with the profusion of residual chert on the surface, as shown in Plate 23C. The chert is almost all of secondary origin through replacement of limestone or dolomite by silica.

The character of the Beekmantown is given more fully in the following detailed sections and in geologic section 18:

Geologic Section 19.—Along State Route 80, northwest of Blackford, Russell County, Virginia

	Thickness Ft.	In.
Murfreesboro limestone		
Shale and dolomite, partly red		
Beekmantown formation (1152± feet)		
21. Dolomite, thick bedded, gray, cherty	300	
20. Limestone (vaughanite), thick bedded, blue; contains *Lecanospira, Roubidouxia*	100	
19. Not exposed	50±	
18. Limestone and dolomite	10±	
17. Chert with *Lecanospira*	0	4
16. Limestone with *Lecanospira*	2	
15. Limestone and dolomite interbedded, about half and half	90±	
14. Dolomite, gray; chert, 18 inches, 75 feet below top; chert, 1 foot, at bottom	300	
13. Dolomite; thin layers of sandstone 100 feet below top	300	
Copper Ridge dolomite (1099± feet)		
12. Sandstone	4	
11. Not exposed	10	
10. Sandstone	2±	
9. Dolomite	20	
8. Sandstone	8	
7. Dolomite	20±	
6. Sandstone	1	
5. Dolomite	30	
4. Sandstone	1	
3. Dolomite	2	
2. Sandstone	1	
1. Dolomite	1000±	

The most notable features of this section are the limestone with *Lecanospira* 300 feet below the top and the beds of sandstone just below the base of the Beekmantown. The occurrence of these layers of sandstone is the basis of the separation of the Beekmantown from the Copper Ridge in this section.

The section given below, which is southeast of the Greendale syncline, includes more beds of limestone but apparently at a lower horizon below the middle of the formation.

Geologic Section 20.—Along State Route 81, two miles south of Saltville, Smyth County, Virginia

	Thickness Feet
Lenoir limestone	
Beekmantown formation (1250± feet)	
28. Dolomite	250
27. Chert, spongy, *Orospira* fairly plentiful	5±
26. Dolomite, blue gray	425
25. Limestone, argillaceous, banded; contains *Ophileta, Hormotoma, Bathyurus?*	32
24. Dolomite	4
23. Limestone	16
22. Dolomite, gray band	2
21. Limestone	28
20. Dolomite, gray band	2
19. Limestone, shale parting of 7 inches; contains gastropods	18
18. Dolomite, gray, crystalline	10
17. Limestone	3
16. Dolomite	3
15. Limestone	9
14. Dolomite	75
13. Dolomite, cherty, fossiliferous	45
12. Chert, dense, jagged, soft, cavernous	5
11. Dolomite	175
10. Limestone	8
9. Dolomite	25
8. Limestone	7
7. Dolomite	5
6. Limestone	2
5. Dolomite	20
4. Limestone	1
3. Dolomite	75

	Thickness Feet
Chepultepec limestone	
2. Limestone with curved cephalopods, at road intersection; 2 miles nearly due south of railroad station at Saltville, contains *Dakeoceras*, small sp.	20–30
Copper Ridge dolomite	
1. Dolomite with several beds of sandstone	100

The next two sections show the limestone in the upper part of the formation.

Geologic Section 21.—Near Vance Mill, 2 miles south of Abingdon, Washington County, Virginia

	Thickness Feet
Athens shale	
Lenoir limestone	35
Hiatus: Mosheim limestone absent	
Beekmantown formation (577 feet)	
8. Dolomite	10
7. Limestone, coarse grained	2
6. Dolomite	20
5. Limestone, light gray, compact, like Mosheim (vaughanite)	35
4. Dolomite, mainly, with layers of limestone up to 4 feet thick	60
3. Dolomite, thin layers of limestone distributed throughout	100
2. Dolomite, thick bedded, fine grained, bluish	250
1. Not exposed	100
Chepultepec limestone, blue, thick bedded	450

Even if bed 1 of the above section is Beekmantown, the formation is only 577 feet thick, about half its thickness in the belts to the northwest.

Another section is of especial interest because of the occurrence of *Ceratopea*, a post-*Lecanospira* fossil in the limestone very near the top.

Geologic Section 22.—Along Denton Creek, three-fourths of a mile above its mouth, 7 miles nearly south of Abingdon, Virginia

	Thickness Feet
Athens shale	
Lenoir limestone	35
Hiatus: Mosheim limestone absent	
Beekmantown formation (292 feet)	
12. Limestone, blue	10
11. Dolomite	10
10. Limestone, contains *Ceratopea keithi* Ulrich	6
9. Limestone, cherty	1
8. Dolomite	30
7. Limestone, blue, contains gastropods	2
6. Unexposed and dolomite	15
5. Limestone, blue, pure	3
4. Dolomite	50
3. Not exposed	60
2. Limestone, blue	5
1. Dolomite (full thickness not determined)	100+

Besides the limestone in the top, the important feature of this section is the occurrence of *Ceratopea,* one of the most diagnostic of the post-*Lecanospira* fossils of the Beekmantown.[70]

The character of the Beekmantown in the northeastern part of the Valley is illustrated by the following three sections:

Geologic Section 23.—Just northeast of Middle River, 5½ miles northeast of Staunton, Augusta County, Virginia

	Thickness Feet
Athens shale, graptolites abundant	
Lenoir limestone, cherty, full of black nodules	200
Mosheim limestone, thick bedded, dark-colored (in quarry)	150
Beekmantown formation (1640-2140 feet)	
9. Dolomite, thin layers of limestone, *Hormotoma* at bottom	150

[70] See page 117.

	Thickness Feet
8. Dolomite, mainly, thin beds of cavernous chert in middle	400
7. Dolomite, gray, finely crystalline, cavernous chert with fossils	30
6. Dolomite	150
5. Dolomite with layers of limestone	200
4. Limestone, contains *Ceratopea tennesseensis* Oder, *Lophonema* 2 sp., *Hormotoma, Eccyliopterus, Coelocaulus*	10±
3. Limestone and dolomite, interbedded; conspicuous beds of white limestone on weathered exposures	200
2. Not exposed; ridge covered with chert with *Lecanospira* (estimated)	500-1000?
Conococheague formation	
1. Dolomite with much sandstone	

The significant features of this section are the prevailing dolomite in the upper 700 to 800 feet, the presence of conspicuous layers of limestone in the lower 200 to 300 feet down to the cherty horizon with *Lecanospira,* and the post-*Lecanospira,* fossils at least 950 feet below the top. The part of the Beekmantown above the *Lecanospira* zone has become the thicker part of the formation going northward from Tennessee to the latitude of Staunton.

A complete change of facies appears in the upper part of the Beekmantown, 2 miles east of Harrisonburg, as shown in the following partial section:

Geologic Section 24.—Just southeast of Cedar Grove church, 2 miles east of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Athens shale, contains graptolites	
Whitesburg limestone, fossils abundant	
Lenoir limestone	
Mosheim limestone, pure, compact, dove-colored to bluish, 94 to 98 per cent calcium carbonate	189
Beekmantown formation (upper 348 feet measured)	
7. Limestone, pure, blue, 92 to 94 per cent calcium carbonate	37

PLATE 25

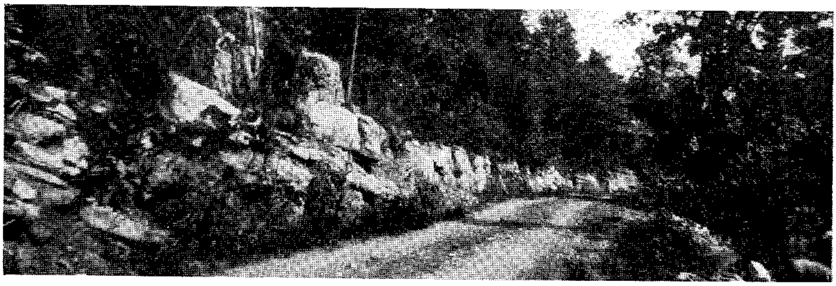
A. Evenly bedded limestone in the Murfreesboro limestone in Lee County. Along U. S. Route 58, about 3 miles west of Jonesville. Looking east.

B. Mosheim and Murfreesboro limestones on Yellow Branch 5 miles southeast of Rose Hill, Lee County. The upper bed (light gray) is Mosheim, which is underlain by upper Murfreesboro limestone. Looking southeast.

C. Uppermost part of the Murfreesboro limestone, on Yellow Branch 5 miles southeast of Rose Hill. It consists of thin-bedded limestone and shale, just below the Mosheim limestone shown in B. Looking southeast.

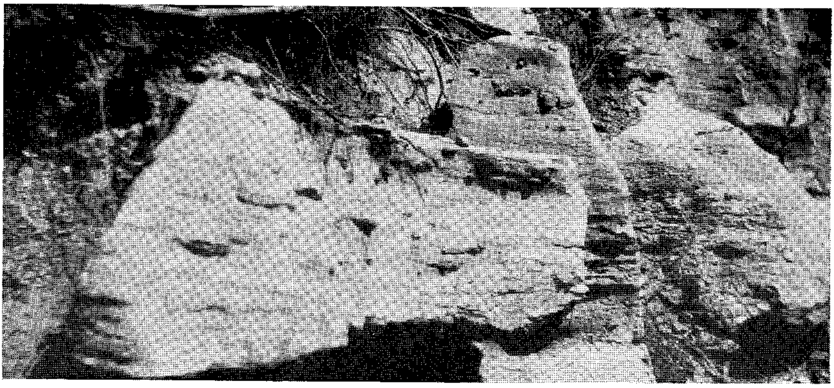
D. Lenoir limestone on Yellow Branch 5 miles southeast of Rose Hill. It lies just above the Mosheim limestone shown in B. The nodular and cherty character is well shown. Looking southeast.

A



B

C

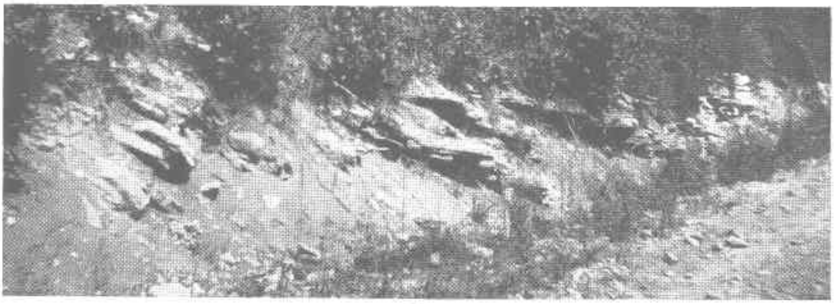


D

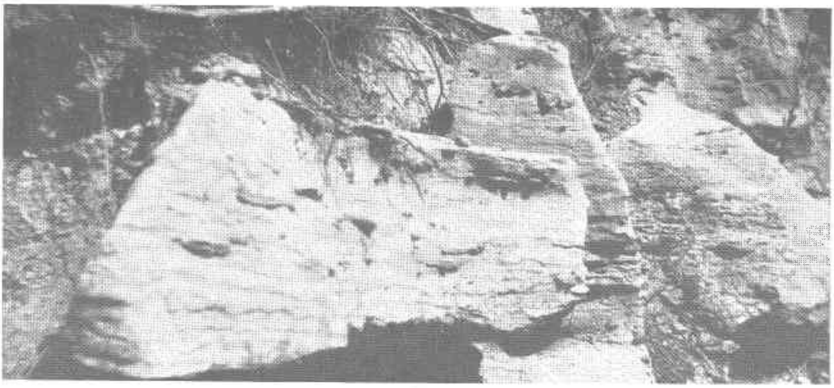
ORDOVICIAN LIMESTONES

A

B

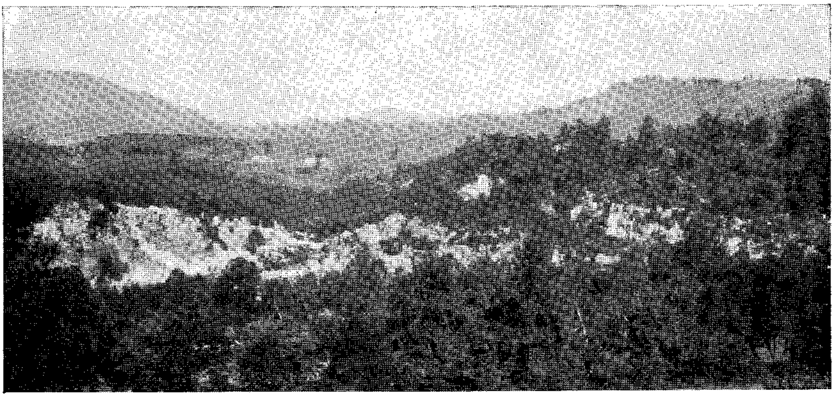


C

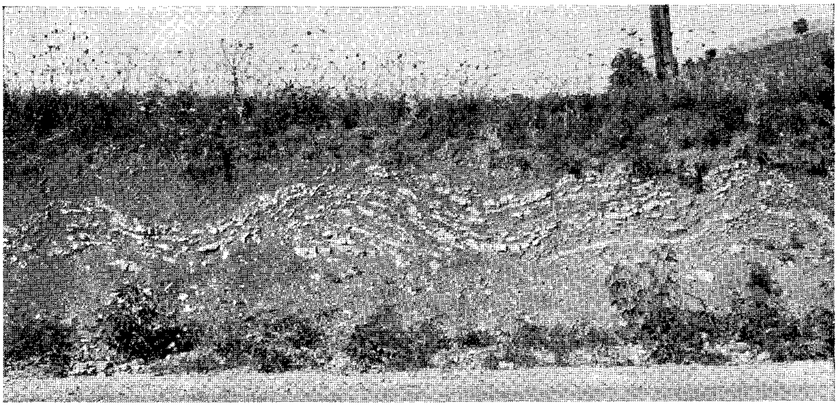


D

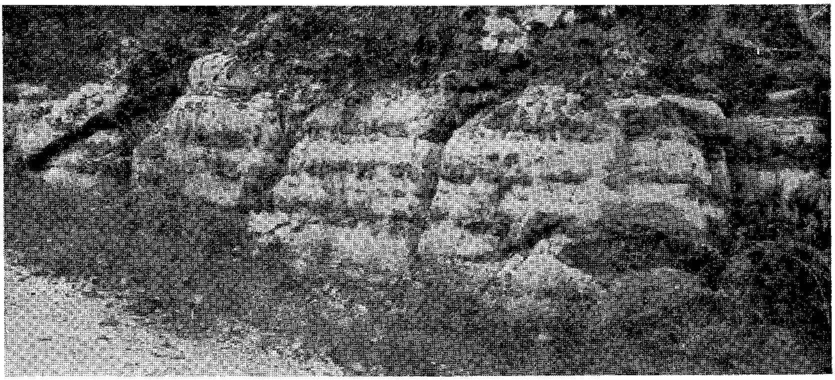
ORDOVICIAN LIMESTONES



A

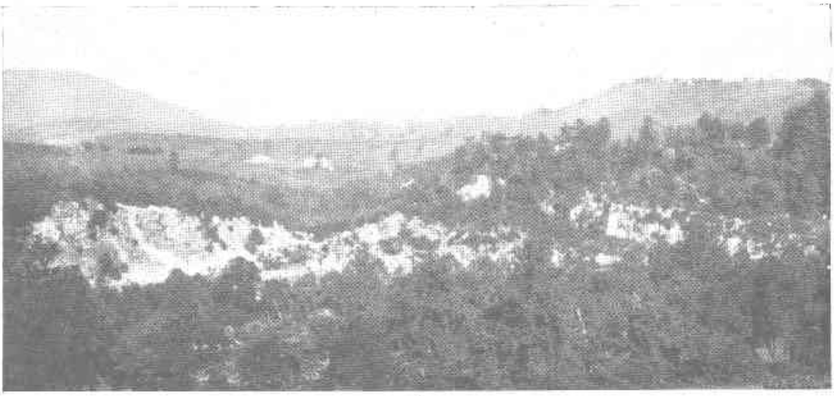


B

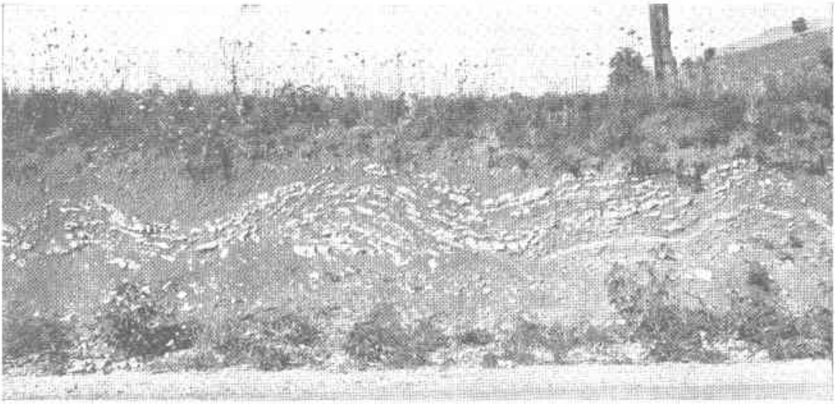


C

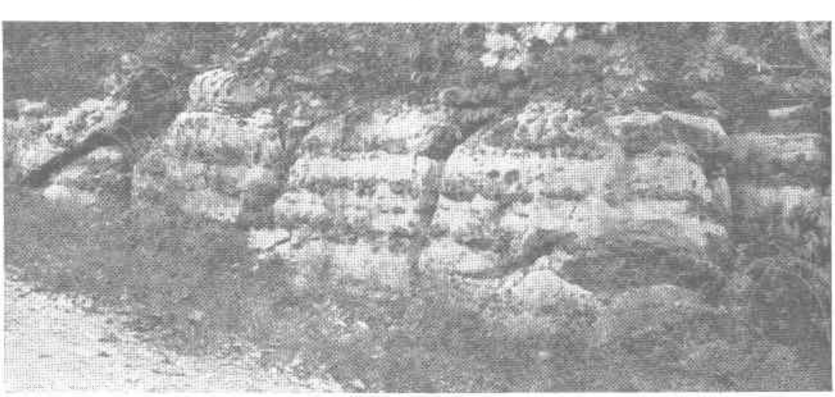
ORDOVICIAN LIMESTONES



A



B



C

ORDOVICIAN LIMESTONES

PLATE 26

A. Murfreesboro and Mosheim limestone near Ripplemead, Giles County. The thick stratum at the top (right) is Mosheim, 40 feet thick. It contains large gastropods common to the Mosheim. The rest of the limestone is Murfreesboro, which is in contact below with the Beekmantown (at railroad level). Looking east from the west bank of New River just north of Ripplemead.

B. Slightly folded chert in the Murfreesboro in Russell County. The chert was formed by silicification of thin layers of limestone and still preserves the bedding. It is slightly fossiliferous. This is part of the Blackford facies which is widespread in Russell County. Along State Route 80, three-fourths of a mile east of Elk Garden. Looking east.

C. Cherty limestone in the Murfreesboro (?). The dark-colored projecting bodies are chert. The parallel arrangement of the cherty bands indicates that the locus of accumulation was determined by the bedding planes of the limestone. Along State Route 251, 6 miles due west of Lexington, Rockbridge County. Looking northeast.

	Thickness Feet
6. Limestone, 16 to 22 per cent magnesium carbonate	45
5. Limestone, 3 to 9 per cent magnesium carbonate	45
4. Dolomite, 20 to 40 per cent magnesium carbonate	11
3. Dolomite and limestone interbedded	158
2. Dolomite, 26 to 40 per cent magnesium carbonate	22
1. Limestone, 94 to 98 per cent calcium carbonate	30

At this locality the uppermost part of the Beekmantown contains a large proportion of high-calcium limestone, in striking contrast to the section on Middle River near Staunton, which is on a belt lying southeast of the belt containing the above section. The limestone makes a striking display in extensive exposures to the northeast and southwest of Cedar Grove church. At this locality, the boundary between the Beekmantown and Mosheim is uncertain, and it is possible that the lower part of the limestone referred to the Mosheim is Beekmantown. In the general vicinity of Cedar Grove church and at other points are exposures of Beekmantown composed of limestone and dolomite similar to the beds of the preceding section but underlying them. On the road from Middletown to Marlboro, Frederick County, a partly exposed section appears to be roughly as follows:

Geologic Section 25.—Approximate section along the road in the space 2 to 3 miles northwest of Middletown, Frederick County, Virginia

	Thickness Feet
Mosheim limestone	
Beekmantown formation (3100± feet)	
6. Dolomite, partly exposed	1000±
5. Not exposed, surface with much chert, *Ceratopea* at base	500±
4. Not exposed, across low valley	250±
3. Limestone; contains *Lecanospira* and *Finkelnburgia*	500±
2. Not exposed, chert debris in lower part	850±
Chepultepec and Stonehenge limestones	
1. Massive limestone; contains *Ophileta* cf. *O. complanata* Vanuxem and curved cephalopods	200

While no accuracy is claimed for this section, it shows clearly the presence of a thick limestone with *Lecanospira* abundant in the lower part and extending to 1350 feet above the base, and *Ceratopea* of the post-*Lecanospira* beds not to exceed 250 feet above the beds with *Lecanospira.*

Throughout Frederick and Clarke counties, the Beekmantown appears to be predominantly thick-bedded limestone yielding but little chert. It appears to be a southwest continuation of the limestone facies of the Beekmantown[71] of Franklin County, Pennsylvania. The belt on which Winchester, Virginia, is located, lying northwest of the Massanutten syncline, continues northeastward into Franklin County, Pennsylvania, and crosses Licking Creek 4 miles southeast of Mercersburg, where the most important of the Beekmantown sections described in the folio is exposed. The formation in this exposure is said to be all limestone. A progressive change from predominating dolomite in the vicinity of Staunton, Virginia, to limestone in the Mercersburg, Pennsylvania, area takes place in practically the same belts of outcrop. In the south end of the Nittany anticline in Bedford County, Pennsylvania, 40 miles northwest of Mercersburg and across the strike of the formations the Beekmantown is again exposed, and is all dolomite. It plunges below the surface in the south end of the Nittany arch in Bedford County and reappears along the strike in Hightown Valley, Highland County, Virginia, where it is also all dolomite. A notable change of facies from limestone to dolomite occurs in the 40 miles or so intervening between the two belts; that is, between the Winchester-Mercersburg belt and the Nittany Valley belt extending from Bedford County into Center County, Pennsylvania.

Distribution.—The Beekmantown was once universally distributed throughout the length and breadth of the Valley in Virginia and is still everywhere present either in outcrop or beneath the synclines but it has been eroded from the highest anticlines and from a wide strip on the southeast bordering the Blue Ridge, as shown on the geologic map of the Valley.

Besides the localities of the geologic sections 19 to 25 and the sections along the Clinchfield Railroad north of Speers Ferry, Scott County, already described, some of the best places to examine the Beekmantown are along U. S. Route 21, within half a mile south of Rocky Gap; along State Route 8, between Pearisburg and Narrows; and for 2 miles across the fields 3 miles east-northeast of Harrisonburg where the full section from high in the Athens limestone at the Lee Highway (U. S. Route 11) to the bottom of the Beekmantown is exposed. The formation is also fully exposed along the road for a mile northwest of Fishers Hill, which is northwest of Strasburg,

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

Shenandoah County. A large part of the Beekmantown crops out along U. S. Route 50 in the southeast part of Winchester; on State Route 277, for 1½ miles west of White Post, Clarke County; at the quarries of the Riverton Lime Co., at Riverton, Warren County; and along U. S. Route 50 between Opequon Creek and Boyce, where the more or less compressed, contorted, and steeply inclined limestone is well exposed in the fields to the north of the road through a distance of 2 miles northwest of Boyce. There are very extensive and striking exposures of highly tilted Beekmantown limestone across Clarke County, along a belt about 3 miles wide, east of the Massanutten syncline.

Thickness.—The dolomitic facies of the Beekmantown in southwestern Virginia is 1200 feet thick, whereas in the Knobs area southeast of Abingdon, Washington County, the thickness does not appear to be more than 500 to 700 feet. On Middle River northeast of Staunton, Augusta County, the thickness down to the approximate top of the cherty zone with *Lecanospira* is 1140 feet, and adding the estimated thickness of the *Lecanospira* zone makes the total thickness 1640 feet. The thickness increases northeastward. On the road northwest from Fishers Hill and west of Strasburg, Shenandoah County, it is 2500 feet. Still farther northwest, on the road northwest of Middletown, the thickness appears to be 3000 feet but may be less on account of minor folds. The thickness in this belt on Licking Creek southeast of Mercersburg, Pennsylvania, was computed by Stose[72] and Ulrich to be 2310 feet. These determinations agree closely enough to warrant the general statement that the thickness of the Beekmantown in northeastern Virginia is between 2500 and 3000 feet.

Fossils and correlation.—The Beekmantown group, though not richly fosiliferous, has enough diagnostic species of fossils for wide correlation. The fossils occur in a lower and an upper zone. Among those of the lower zone the following are most significant: *Lecanospira,* several species, all confined to this zone, and *Roubidouxia,* two species, one of which appears to be *R. umbilicata* Ulrich and Bridge. Described species of *Lecanospira* occurring in Virginia are *L. salteri* Ulrich and Bridge, *L. sigmoidea,* and probably *L. conferta* Ulrich and *L. compacta* (Salter). A mass of chert, 18 by 24 inches, collected near Narrows, Giles County, shows on the surface 40 specimens of *Lecanospira* belonging to two or more species. (See Pt. II.) Commonly the two forms, *Lecanospira* and *Roubidouxia,* occur together in the same piece of chert. They are generally found only in the residual chert, but both have been found in one or another of the

[72] Stose, G. W., op. cit., p. 7.

intercalated beds of limestone, as bed 20 of the section northwest of Blackford. (See geologic section 19.) It is surmised that some, or possibly most, of the residual chert carrying *Lecanospira* is derived from the beds of limestone. In addition to the fossils named, various undescribed species of *Ophileta, Hormotoma,* and *Eccyliopterus* are common. *Finkelnburgia virginica* Ulrich and Cooper and a species of a syntrophoid brachiopod, *Xenelasma syntrophioides* Ulrich and Cooper, that has been erroneously identified as *Syntrophina campbelli* (Walcott), a Chepultepec species, occur sparingly but are widely distributed and diagnostic fossils. Trilobites are rare. A few specimens of *Hystricurus conicus* (Billings) and of *Bathyurus* have been found.

In the upper zone of the Beekmantown, fossils are more plentiful and varied. The fauna is almost wholly composed of gastropods and coiled cephalopods, the latter being represented among living animals by the well-known chambered Nautilus. Most characteristic are several species of *Ceratopea,* which is the operculum of a gastropod. Described species from Virginia are *Ceratopea keithi* Ulrich, *C. subconica* Oder, and *C. tennesseensis* Oder. Other species occur in Virginia but are as yet undescribed.

The principal gastropods are species of *Lophonema,* six species; *Ophileta,* several species including *O. solida* Butts, and *O. canadensis* (Billings); *Orospira,* several species; *Hormotoma,* several species, including *H. gracilens* (Whitfield) and *H. artemesia* (Billings); *Coelocaulus,* including *Coelocaulus* cf. *C. linearis* (Billings); *Turritoma acrea* (Billings); *Plethospira,* two species; *Fusispira obesa* (Whitfield); *Maclurites affinis* (Billings), *M. oceanus* (Billings), and *M.* cf. *M. crenulatus* (Billings). The straight, or orthoceroid, cephalopods are represented by species of *Cameroceras.* Other genera are found, but they are undescribed. The coiled cephalopods are represented by *Campbelloceras virginianum* (Hyatt) emend. Foerste, by undescribed species of *Eurystomites, Centrotarphyceras,* and *Trocholites,* and by an undescribed genus and species (see Part II), all of which occur near the top of the upper or *Ceratopea* zone in Bolar Valley, 1½ miles north of Bolar Springs, Highland County. Some of these species also occur in Warm Springs Valley, Alleghany and Bath counties, in the Brushy Hills, 2 miles west of Lexington, Rockbridge County, and at other localities. Brachiopods and trilobites are very rare in the upper part of the Beekmantown in Virginia. Imperfect specimens of brachiopods are provisionally referred to *Finkelnburgia* and a very few specimens of *Diparalasma* have been found at two places near the top of the formation. A trilobite referred to *Bolbocephalus* occurs at the very top of the formation in Bolar Valley, Highland County. Other rare and interesting forms are the large bivalve crustaceans, *Euchasma* and

Eopteria, both occurring together with the coiled cephalopods in Bolar Valley, 1½ miles north of Bolar Springs, and in the Brushy Hills west of Lexington. Nearly all the fossils occurring in the *Ceratopea* zone are confined to that zone, as those of the *Lecanospira* zone are confined to that zone. As shown by the section northwest of Middletown, Frederick County (geologic section 25), the boundary between the two zones must lie within a thickness of 200 to 300 feet of beds about 1000 to 1200 feet above the bottom of the Beekmantown of that area, for *Lecanospira* and *Ceratopea* occur in that section not more than 250 feet apart, which makes it appear that the boundary between the two zones here lies near, but below, the middle of the Beekmantown, which is 2500 to 3000 feet thick here. In southwestern Virginia the *Ceratopea* zone is present, but its thickness is indeterminate. Judging from the distribution of *Lecanospira* and of either *Ceratopea* or some of its accompanying fossils, all found in residual chert, the *Ceratopea* zone is probably not more than 200 feet thick and the *Lecanospira* zone may be about 1000 feet thick in that part of the State, where the total thickness of the Beekmantown is about 1200 feet. The presence of *Lecanospira* (wrongly identified as *Ophileta complanata* Vanuxem) near Beekmantown, N. Y., the type locality of the Beekmantown group, and also at different localities in Quebec, Canada, shows the continuity of the *Lecanospira* zone between northeastern New York and Quebec, and the Appalachian Valley. *Lecanospira* also occurs in a division of the Durness limestone of northwest Scotland. The *Lecanospira* zone, with *Lecanospira* common in it, is widely distributed in the Nittany dolomite of Blair, Huntingdon, and Center counties of central Pennsylvania, from which it is believed that the lower, or *Lecanospira,* zone of Virginia, corresponds closely to the Nittany dolomite. Hence, that name has been used in a formational sense for the *Lecanospira* zone of Virginia. Some of the genera of coiled cephalopods and *Fusispira obesa* occur in the uppermost division of the Beekmantown at Fort Cassin, Vermont, and in New York, and indicate the approximate equivalence of that division with the upper zone of the Beekmantown of Virginia. *Euchasma* and *Ceratopea* occur in the northwest part of Scotland, above the beds carrying *Lecanospira,* from which it is inferred that the uppermost beds of the Durness limestone are represented in the upper zone of the Beekmantown of Virginia. A rare occurrence of *Ceratopea* in the Bellefonte dolomite of central Pennsylvania suggests the correlation of the upper zone of the Beekmantown in Virginia with the Bellefonte. *Maclurites affinis* (Billings) is common in the Axemann limestone, between the Nittany and Bellefonte, and as far as known the occurrence of that fossil in Virginia can be reasonably referred to the Axemann horizon, which is not lithologically or formationally distinguishable in the Appalachian Valley of Virginia. The upper and lower, or *Ceratopea* and *Lecanospira* zones, are continuous from Virginia across Tennessee into northeastern Alabama, where they are formationally represented in the Newala and Longview limestones, respectively. The presence of *Diparalasma* in the uppermost beds of the Beekmantown of Virginia may indicate that the Odenville limestone is represented in those beds, for the type species of that genus occurs in the Odenville. *Lecanospira* and *Roubidouxia* are the most characteristic fossils of the Roubidoux formation of Missouri, while *Ceratopea, Lophonema* and *Orospira* are the dominant fossils of the Jefferson City, Cotter, and Powell dolomites of Missouri and Arkansas, which there succeed the Roubidoux formation. It thus appears that the same vertical distribution of the fossil faunas of the Beekmantown prevails from the northwest Highlands of Scotland through Newfoundland, Quebec, Champlain Valley, central Pennsylvania, Virginia and Tennessee, to Alabama, and thence beneath the Mississippi Valley into Misouri and Arkansas. The same fossils and distributions also occur in the Arbuckle limestone of the Arbuckle Mountains of Oklahoma and in the Ellenburger limestone of the Llano area of central Texas.

HIATUS

Possibly in those areas where the St. Clair facies (p. 126) of the Murfreesboro limestone is present, the succession from the Beekmantown to the Chazyan is continuous or but slightly interrupted. But where the Blackford facies of the Murfreesboro prevails, the basal conglomerate is evidence of a pre-Chazy land surface. This coarse material was washed by streams from land and deposited on the sea bottom before the deposition of the shale and limestone of the Murfreesboro. Such conditions necessarily involve a break in sedimentation resulting in a stratigraphic gap between the beds below and the beds above. This hiatus is even greater along the southeast side of the Valley where the Murfreesboro limestone is universally absent and the Beekmantown is succeeded above by the Mosheim limestone or, as in the Knobs area southeast of Abingdon, even by the Lenoir limestone.

CHAZYAN SERIES[73]

STONES RIVER GROUP

Name.—The Stones River group was named from Stones River in the Nashville Basin of Central Tennessee.[74]

[73] Beginning of the Ordovician system according to E. O. Ulrich.
[74] Safford, J. M., Stones River beds: Am. Jour. Sci., 2nd ser., vol. 12, p. 354, 1851.

Limits.—The Stones River group in Virginia unconformably succeeds the Beekmantown and extends up to the Holston limestone. Where most fully represented it is composed, in ascending order, of the Murfreesboro limestone, Mosheim limestone, and Lenoir limestone. Throughout most of the Valley in Virginia southeast of Clinch Mountain the Murfreesboro is not present and the Stones River group is represented only by the Mosheim and Lenoir limestones. Although the Stones River limestone is shown on the geologic map as a single unit, each of its divisions is here separately described. There are areas, however, where the Mosheim has not been recognized and some areas where neither the Mosheim nor the Lenoir has been recognized; in such areas the whole thickness of the unit is included under the name Stones River. In some areas, as, for example, in the vicinity of old Collierstown, Rockbridge County, the entire thickness is described under the Murfreesboro limestone.

MURFREESBORO LIMESTONE

Name.—The Murfreesboro was named[74a] from Murfreesboro, Rutherford County, Tennessee, in the Nashville Basin. It extends eastward beneath the Cumberland Plateau and crops out in the western belts of the Appalachian Valley.

Character.—In Lee County the Murfreesboro is almost completely exposed on Yellow Branch, 5½ miles southeast of Rose Hill, and its general character in that area is shown in the following section:[75]

Geologic Section 26.—Stones River limestone group on Yellow Branch, 5½ miles southeast of Rose Hill, Lee County, Virginia

	Thickness Ft.	In.
Lowville limestone, *Cryptophragmus antiquatus* Raymond in lower part	1000±	
Not exposed—small space		
Lenoir limestone (132 feet)		
43. Limestone, thick bedded, fossiliferous, cherty; contains silicified Bryozoa, *Archaeocrinus?, Dekayella?, Monotrypa?, Rhinidictya, Mesotrypa, Camarella, Glyptorthis bellarugosa* (Conrad), *Mimella*	20	
42. Not exposed	80	

[74a] Safford, J. M., and Killebrew, J. B., Elements of geology of Tennessee: pp. 105, 125, 1900.
[75] Beds 41-43 have been compiled from exposures near each other and the relations probably are nearly as shown.

	Thickness Ft.	In.
41. Limestone, like bed 43 (Pl. 25D); contains *Hindia sphaeroidalis* Duncan, *Carabocrinus* sp., *Batostoma* sp., *Crepipora* cf. *C. perampla* Ulrich, *Nicholsonella pulchra* Ulrich, *Camarella varians* Billings, *Glyptorthis bellarugosa* (Conrad), *Mimella*, *Rafinesquina* cf. *R. champlainensis* Raymond, *Sowerbyella*	32	
Mosheim limestone		
40. Limestone, compact, dove-colored, weathers with white chalky crust (vaughanite), (Pl. 25B); contains *Trochonemella*	27	
Murfreesboro limestone (208± feet)		
39. Limestone, compact	2	6
38. Limestone, medium bedded, blue	4	6
37. Limestone, medium bedded, blue	1	
36. Shale	2	
35. Shale	4	
34. Limestone	6	
33. Limestone	3	6
32. Limestone, chert bands; with *Tetradium syringoporoides* Ulrich	2	6
31. Shale	4	
30. Shale and argillaceous limestone; contains *Pterygometopus* sp.?, *Leperditella mundula* (Ulrich), *Isochilina* two species and probably *Hemicistites eckeli* Cullison and Prouty	4	
29. Limestone	4	
28. Limestone; contains *Helicotoma tennesseensis* Ulrich and Scofield, *Oxydiscus catilloides* (Raymond), *Polylopia* (*Salterella*) *billingsi* (Safford)?, *Oncoceras* aff. *O. constrictum* Hall, *Pterygometopus troosti* (Safford)?, *Leperditella* cf. *L. inflata* (Ulrich), *L.* cf. *L. mundula* (Ulrich)	4	
[a]27. Limestone	3	6
26. Limestone, chert nodules	3	
25. Shale and limestone, argillaceous, cherty	3	

[a] Beds 17-27 are shown on Plate 25C.

	Thickness Ft.	In.
24. Limestone, black chert bands	1	
23. Limestone, argillaceous, shaly	3	
22. Limestone	2	6
21. Limestone, shaly	2	
20. Limestone, black chert nodules	1	3
19. Limestone, argillaceous, shaly	4	
18. Limestone, argillaceous, shaly	4	
[a]17. Limestone, argillaceous, shaly	2	
16. Limestone, irregular nodules of black chert (Pl. 24A)	8	
15. Limestone, thin bedded (Pl. 24B)	6	6
14. Limestone, thick bedded, dark blue, full of silicified fossils (Pl. 24C)	9	
13. Limestone, compact (vaughanite)	10	6
12. Limestone, argillaceous	3	6
11. Limestone, evenly thick bedded (vaughanite)	12	
10. Limestone, argillaceous, thick bedded, compact	8	
9. Limestone	4	
8. Limestone, argillaceous	4	
7. Limestone, banded, pure and argillaceous	6	
6. Limestone, argillaceous	4	
5. Limestone	3	
4. Shale	2	
3. Limestone; contains *Isochilina* sp., *Primitia* sp?	1	
2. Limestone, mainly argillaceous, and shale	55	
Beekmantown formation		
1. Dolomite (Pl. 22C)	1200±	

The Murfreesboro limestone in this section is composed predominantly of thin-bedded, blue limestone with interbedded shale in layers 4 feet or less thick. Near the middle are thicker beds of cherty, coarse-grained, fossiliferous, or compact dove-colored, limestone (beds 10-16). All these types are illustrated by Plates 23 and 24. Flaggy limestone in the lower part of the Murfreesboro, probably belonging in bed 2 of the above section, is exposed on the road west of Jonesville. (See Pl. 25A.) All of the Murfreesboro is limestone in the small

[a] Beds 17-27 are shown on Plate 25C.

area south and west of Bluefield, Virginia, where the following section, exposed on U. S. Route 19, for half a mile south of St. Clair railroad station, 2½ miles west of Bluefield, Virginia, was measured:

Geologic Section 27.—Just south of St. Clair railroad station, 2½ miles west of Bluefield, Virginia

	Thickness Ft.	In.
Lowville limestone		
Lenoir limestone		
32. Limestone, nodular	100	
Mosheim limestone (?)		
31. Limestone, thick bedded, compact, calcite veins, dove-colored, with *Lophospira*	70	
Murfreesboro limestone (1152 feet)		
30. Limestone, partly exposed	75	
29. Limestone, partly exposed, dark-colored, shaly; contains *Rafinesquina* sp.?, *Rhinidictya* sp.?, *Isochilina* sp.	70	
28. Limestone, mainly thick bedded, compact, veined with calcite, dove-colored; contains *Lophospira, Maclurites,* or *Eotomaria*	105	
27. Limestone, thick bedded, mainly dark dove-colored, a little is pure, dove-colored, compact	85	
26. Limestone, thick bedded to medium thick bedded, mainly compact, dove-colored	55	
25. Limestone, mainly compact, dark dove-colored, a few argillaceous layers	40	
24. Limestone, dark dove-colored	50	
23. Limestone, compact or subcrystalline, dark dove-colored; slightly compact	20	
22. Limestone, finely crystalline, thinly laminated	25	
21. Not exposed	20	
20. Limestone, finely crystalline, dark- to dove-colored, with bryozoa	22	
19. Limestone, thick and thin bedded, some shaly, a little chert, dove-colored and dark dove-colored with *Helicotoma tennesseensis* Ulrich and Scofield	45	
18. Limestone, thick bedded, mostly compact, dove-colored and dark dove-colored, with *Lophospira* and other gastropods	65	

	Thickness Ft.	In.
17. Limestone, variable, thick and thin bedded, dove-colored and dark dove-colored, argillaceous streaks, lower 2½ feet shaly, with *Tetradium syringoporoides* Ulrich	20	
16. Limestone, medium thick bedded, mainly dark dove-colored, ostracodes abundant in some layers	16	
15. Limestone, argillaceous	4	
14. Limestone, medium bedded, mainly compact, dove-colored	14	
13. Limestone, argillaceous	2	
12. Limestone, medium bedded, compact, dove-colored	6	
11. Limestone, fossiliferous; contains *Tetradium syringoporoides* Ulrich	4	
10. Limestone, thick bedded, compact, light gray with ostracodes	19	
9. Limestone, as above with calcite eyes; *Zygospira?* cf. *Z. acutirostris* (Hall)	21	
8. Limestone, as above, cherty below	20	
7. Limestone, bluish gray, finely striped, nodules and plates of black chert, with *Tetradium* sp.	8	
6. Limestone, bluish gray, fine grained, finely striped	7	
5. Limestone, thick bedded, light colored, rather dense	13	
4. Limestone, medium bedded, fine grained, dark drab-colored, a few fossils	40	
3. Limestone, compact, pearl-gray	1	
2. Limestone, partly exposed across low ground, apparently all fine grained	280	
Beekmantown formation		
1. Dolomite	1000±	

Although the lower 280 feet of the above section is not fully exposed, it is probably all limestone. In the Narrows of New River, 25 miles northeast of Bluefield, Virginia, the Stones River is all limestone with nodular, ropy layers, cherty layers, and scattered layers of compact dove-colored vaughanitic rock like the Mosheim. It is about 400 feet thick there. All but about 25 feet at the top is exposed on the

Virginian Railroad on the east side of New River. The upper 25 feet of the exposed section is coarse grained, nodular, ropy, cherty, fossiliferous limestone. *Maclurites magnus* Lesueur is reported. The beds containing this fossil are probably Lenoir.

At Ripplemead, Giles County, 8 miles east of the Narrows, the Murfreesboro is about 230 feet thick and is composed predominantly of thick- and thin-bedded limestone, including cherty layers and a bed of shale about 10 feet thick in the lower part. There is a bed in which *Helicotoma tennesseensis* Ulrich and Scofield is abundant and a layer in the lower 50 feet contains a species of *Lophospira*. The layers just above the Beekmantown dolomite contain small ostracodes. In sharp contrast with the Narrows section, the Mosheim, a thick-bedded, compact, dove-colored limestone, is 40 to 50 feet thick here and contains a few large gastropods, as the Mosheim commonly does. (See Pl. 26A.) The quarry above the highway west of New River and just north of Ripplemead is in the Mosheim.

In Warm Springs Valley, Bath County, and in Bolar Valley, Highland County, the Murfreesboro is the lower undefined part of the Stones River group, which in those valleys is almost wholly composed of thick to medium thick-bedded, compact, dove-colored, white-weathering vaughanitic limestone, of Mosheim type. At Healing Springs it is several hundred feet thick and about 1 mile north of Bolar, on the southeast side of the valley, it is about 350 feet thick. The Lenoir is recognizable here, but the Murfreesboro and Mosheim are not readily separable, although about 50 feet of limestone below the Lenoir is distinctly of Mosheim character.

In Hightown Valley, 2 miles northwest of Monterey, Highland County, and about 100 miles northeast of the Narrows, all of the Stones River is also limestone about 700 feet thick. It is thick bedded, compact, light gray to dove-colored, and nearly free of chert. The Mosheim and Lenoir are locally recognizable at the top.

In the large area east and southeast of Collierstown and northwest of Brownsburg, Rockbridge County, the same limestone facies of the Stones River occurs. It is fully exposed along Colliers Creek between old Collierstown postoffice and the mouth of Toad Run. It is mostly thick bedded, coarse grained, and partly nodular. Much of it here contains an abundance of chert nodules and plates. (See Pl. 26C.) It also contains layers of compact dove-colored limestone, and layers of very coarse-grained, bluish gray rock of the Holston type. At the base, in contact with the underlying dolomite, are a few feet of rock with angular fragments of residual chert. The Stones River here is definitely bounded by the Beekmantown dolomite below and by the Athens limestone above. Its thickness, though not precisely determined, is at least 400 feet. The Lenoir and the Mosheim were not recognized in this section.[76] This Rockbridge County occurrence is the only one known of Murfreesboro or lower Stones River southeast of the strike line of Clinch Mountain.

This purely limestone facies of the Murfreesboro is here designated the St. Clair facies from its best development just south of the St. Clair railroad station, as shown in geologic section 27.

Over extensive areas, lying in general southeast of the belt in which the St. Clair facies is found, the Murfreesboro occurs in a very different facies, which, for reasons that will appear beyond, is named the Blackford facies. In this facies the basal bed is in places a massive layer or two, as much as 5 feet thick, of dull gray dolomitic rock containing many angular fragments of residual chert generally half an inch or less in diameter. One of the best exhibits of this layer is on Templeton Branch, 4¼ miles northwest of Gate City, Scott County, as shown on Plate 23A and B. (See also geologic section 31, beds 13 and 15.) Another equally good example is three-fourths of a mile east of Elk Garden, Russell County.

The Blackford facies of the Murfreesboro is commonly composed, in the lower 70 feet or less, of a heterogeneous sequence of red shale, red mottled argillaceous dolomite, gray shale, gray clay, and gray, magnesian, crumbly limestone which probably in part weathers to the gray clay. Some of these dolomitic layers contain fragments of chert. The red rock makes a striking display where extensively exposed. The Blackford facies of the formation is illustrated by the following sections:

Geologic Section 28.—Murfreesboro formation on Templeton Branch, 4¼ miles northwest of Gate City, Scott County, Virginia

	Thickness Feet
Holston limestone	
Murfreesboro limestone (245 feet)	
6. Limestone, thick bedded, nodules of black chert throughout	140
5. Limestone, thin bedded, nodules of black chert	50
4. Not exposed	25±
3. Limestone, pure, gray shaly layers; contains ostracodes, *Pterygometopus* sp.	25±
2. Limestone, magnesian, conglomeratic, with angular chert fragments (Pl. 23A and B)	5

[76] Although the limestone here is described under the Murfreesboro, and is in large part most probably equivalent to the Murfreesboro, it is only certainly known to be Stones River.

	Thickness Feet
Hiatus	
Beekmantown formation	
1. Dolomite	1200±

Geologic Section 29.—Stones River group at Blackford, 2 miles southeast of Honaker, Russell County, Virginia

	Thickness Feet
Holston limestone	
Lenoir limestone	
14. Limestone, coarse grained, nodules of black chert	15
Mosheim (?) limestone	
13. Limestone, compact, dove-colored	40
Murfreesboro formation (160 feet)	
12. Limestone, cherty	50
11. Shale and limestone, shale partly purple	42
10. Shale, purple	10
9. Dolomite, gray	5
8. Dolomite, purple shale partings	5
7. Dolomite, purple	20
6. Dolomite, gray	5
5. Dolomite, purple	2
4. Shale, purple	15
3. Dolomite, purple and gray	4
2. Shale, yellow	2
Hiatus	
Beekmantown formation	
1. Dolomite and limestone (see geologic section 19)	1152±

Geologic Section 30.—Murfreesboro limestone in a ravine 1 mile due east of Elway, Russell County, Virginia

	Thickness Ft.	In.
Holston limestone		
Lenoir and Mosheim, not exposed	100±	

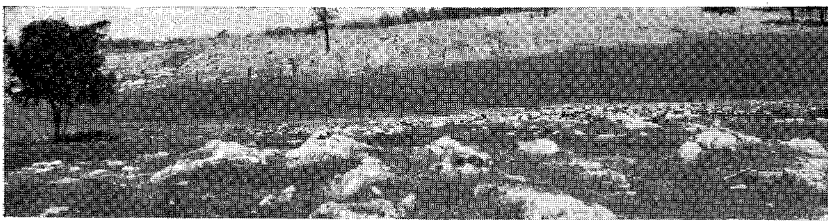
PLATE 27

A. Athens limestone near Harrisonburg, Rockingham County. This exposure is in a wide expanse of outcrop of the limestone facies of the Athens, 2 miles northwest of Harrisonburg. Looking northeast.

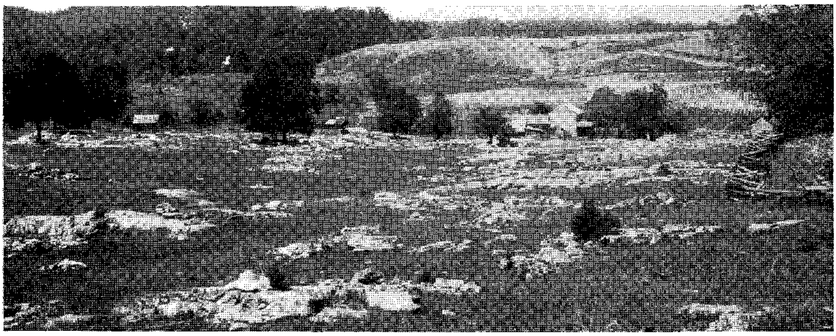
B. Mosheim limestone in Washington County. The beds dip at a low angle to the northeast (away from the observer). The Lenoir limestone occurs just beyond the buildings and the Athens shale crops out in cleared fields in the distance. About 3 miles north of Alvarado and 6 miles southeast of Abingdon.

C. Mosheim (light) and Lenoir (dark) limestones near Staunton, Augusta County. This view shows the slightly undulating contact between them. Abandoned quarry just north of the Lee Highway (U. S. 11), 2 miles northeast of Staunton. Looking northwest.

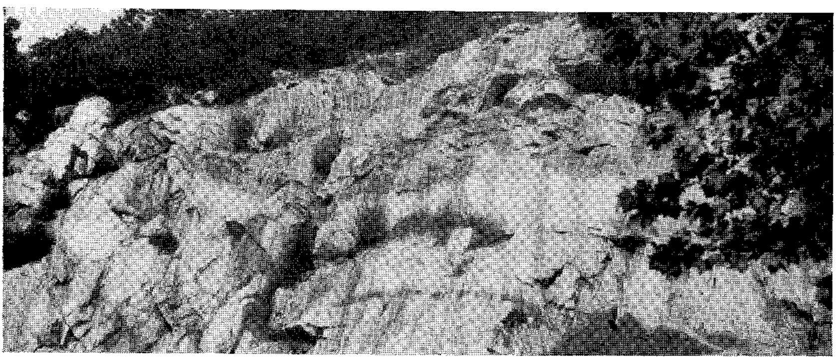
D. Mosheim and Lenoir (above) sequence in old quarry in the southeast environs of Martinsburg, West Virginia. This is probably the best exposure of this sequence and the best expression of the Mosheim in the Valley. The Mosheim is estimated to be at least 200 feet thick in this area. The lower part of the quarry is filled with water. Looking southeast.



A



B



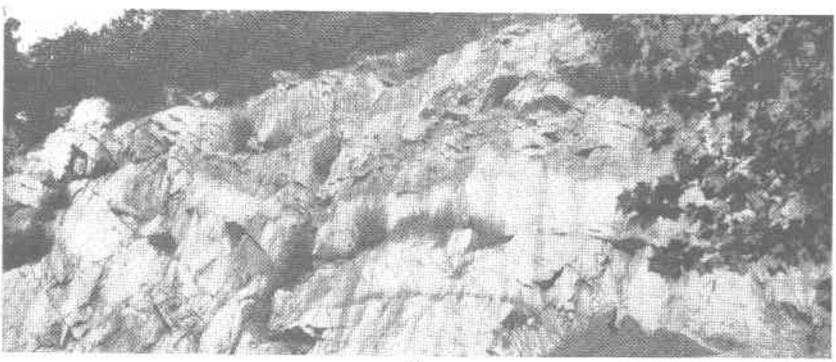
C

D

ORDOVICIAN LIMESTONES

A

B

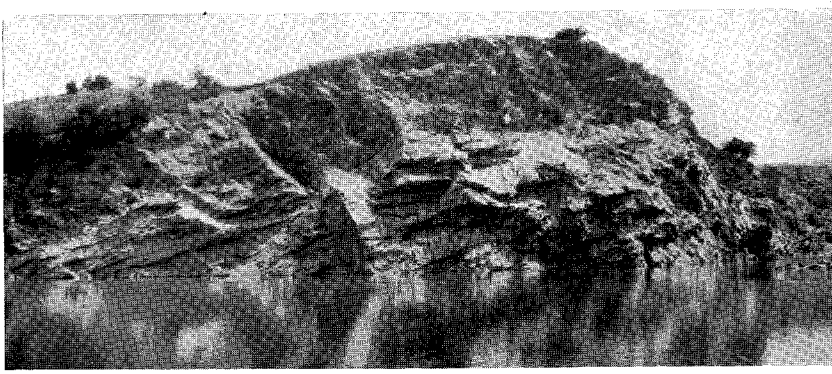


C

D

Ordovician Limestones

A

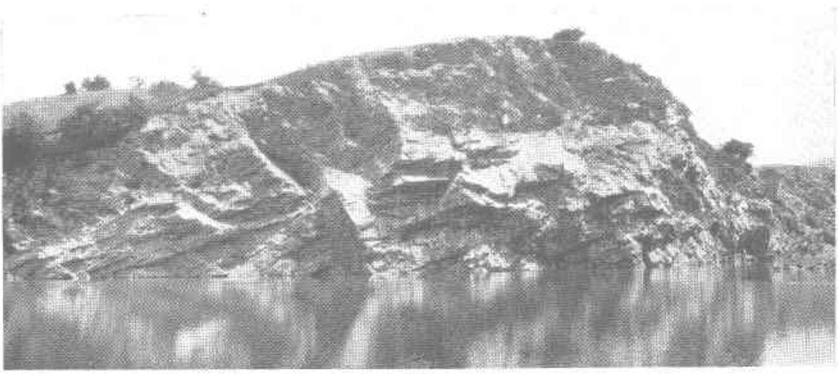


B

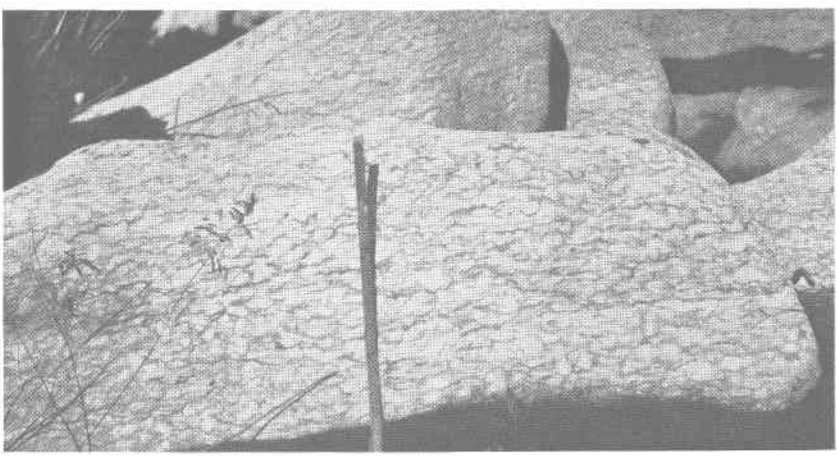
C

ORDOVICIAN FORMATIONS

A



B



C

Ordovician Formations

PLATE 28

A. Conglomerate in Athens shale, near Fincastle, Botetourt County. It is about 50 feet thick. The pebbles are generally gray quartzite, some as much as 6 inches in diameter. It occurs in a small area in the Pine Hills north of Fincastle. This exposure is along U. S. Route 220, 1 mile north of Fincastle. The geologist is E. O. Uulrich.

B. Lenoir limestone overlain by Athens shale, near Saltville, Smyth County. The Holston limestone, nearly everywhere present between the two, is absent here. Old quarry of Mathieson Alkali Works 3 miles southeast of Saltville. Looking southeast.

C. Nodular limestone in the Lenoir limestone in Smyth County. In the northwest end of the quarry of the Mathieson Alkali Works at Porterfield, 5 miles east of Saltville. An extreme example of a type of rock which is common in the Lenoir from northern Virginia to Alabama.

	Thickness Ft.	In.
Murfreesboro limestone (485± feet)		
14. Limestone with blocky chert, slightly exposed, with *Helicotoma tennesseensis* Ulrich and Scofield near top	300±	
13. Shale, purple	5	
12. Limestone	15	
11. Limestone, white, and dolomite as below; partly exposed	15	
10. Limestone, white, a few purple layers	25	
9. Dolomite, purple	2	
8. Dolomite, gray, purple shale partings	10	
7. Dolomite, yellow gray, weathers smooth and yellowish	3	
6. Dolomite, pink, angular fragments of chert	1	
5. Dolomite, gray, angular fragments of chert	1	
4. Shale, purple	5	
3. Dolomite, pink		6
2. Not exposed	2	
Beekmantown formation		
1. Dolomite	1000±	

Geologic Section 31.—Murfreesboro limestone in the bluff of New River just above Klotz quarry, 1 mile north of Ripplemead, Giles County, Virginia

	Thickness Ft.	In.
Murfreesboro limestone, basal part (27+ feet)		
21. Limestone with chert; contains *Pterygometopus* sp.; thickness estimated	2+	
20. Limestone, white	2	
19. Dolomite, argillaceous	6	
18. Dolomite, massive, argillaceous, angular chert fragments	3	
17. Limestone, compact, pearl-gray		8
16. Marl		3
15. Dolomite, angular chert fragments	1	3
14. Shale, gray	1	

	Thickness Ft.	In.
13. Dolomite, purplish, angular chert fragments	3	
12. Shale, green		3
11. Shale, purple	1	
10. Dolomite, argillaceous, shaly, gray	1	
9. Dolomite	1	3
8. Shale, green		6
7. Shale, purple		10
6. Shale, green		4
5. Dolomite, purplish	1	6
4. Shale		8
3. Dolomite		5
2. Shale		2
Beekmantown formation		
1. Dolomite, exposed in Klotz quarry	200	

Geologic Section 32.—Stones River group 2½ miles southwest of Stinson, Russell County, Virginia

	Thickness Feet
Holston limestone	
Lenoir limestone	
5. Limestone, dark-colored, nodular, black chert nodules	5
Mosheim limestone	
4. Limestone, compact, light dove-colored	10
Murfreesboro limestone (176 feet)	
3. Limestone, thin bedded, becomes chert on weathering (utilized for road material); contains ostracodes, *Dinorthis* sp.	75
2. Limestone, argillaceous, gray, crumbles to small pieces	100
1. Dolomite, purple	1
Beekmantown dolomite	

The variegated lower part of the Blackford facies is 20 to 70 feet thick. Above it is 100 to 300 feet with layers of chert which is derived from thin-bedded limestone through silicification on weathering. This bedded chert is exposed along Virginia Route 80, three-fourths of a mile east of Elk Garden, Russell County. (See Pl. 26B.) This chert has been utilized locally for road metal and some pits show a mass of thin-bedded chert 15 to 20 feet thick. One of the best examples of this chert is to be seen on the northwest side of a knoll 1 mile west of old Rosedale, Russell County. Other sections show comparable thicknesses of these variable beds which differ somewhat in composition from place to place, but still preserve the general character of the facies. The chert has yielded rare specimens of *Dinorthis* sp., *Helicotoma tennesseensis* Ulrich and Scofield, *Holopea scrutator* Raymond, *Pterygometopus,* and ostracodes (*Leperditia* and others). On Sinking Creek at the junction of the road to Mountain Lake, 1½ miles northwest of Newport, Giles County, *Dinorthis* sp. is especially abundant.

Although no fossils have been found in the variegated part of the Blackford facies, it is referred to the Stones River group on account of the basal conglomerate with angular chert fragments. The chert fragments, as well as their magnesian matrix, are residual from the weathering of the underlying Beekmantown cherty dolomite during the interval represented by the hiatus preceding the deposition of the Stones River. In places, as 1000 feet east of old Collierstown, Rockbridge County, and on the Martins Creek road to Powell River, 5 miles southeast of Rose Hill, Lee County, the conglomeratic layers were observed at the base of the St. Clair facies of the Murfreesboro. Presumably, they are generally present at the base of that facies.

Distribution.—The distribution of the Murfreesboro limestone has been indicated partly by the preceding detailed sections. In general it comprises the greater part of the thickness of the Stones River group northwest of Clinch Mountain and northwest of the prolongation of that line northeast of Burkes Garden in Tazewell County. It extends from Tennessee to the northern boundary of Highland County. An exception to that general distribution is the area in the vicinity of old Collierstown in Rockbridge County and northwest of Brownsburg, which is southeast of the line of Clinch Mountain. Within the Murfreesboro belt the St. Clair facies is mainly confined to the northwest side and the Blackford facies to the southeast side. It is to be borne in mind, however, that in this area the top of the Murfreesboro can be certainly identified only in those localities where the Mosheim limestone is present and distinctly recognizable, as on Yellow Branch (geologic section 26), and in the vicinity of Ripplemead, Giles County. (See Pl. 26A.)

Investigation since the completion of the geologic map of the Valley has led to a clearer understanding and a more precise discrimination of the Stones River units in various areas. It is now known that most of the thickness of rock designated as Olm on the map in Tazewell, Russell, and Scott counties from Thompsons Valley on the northeast through Elk Garden, Lebanon, Nickelsville, Gate City, and Speers Ferry on the southwest, is really composed of the Blackford facies of the Murfreesboro and should have been designated by the symbol Osr. (See geologic sections 28-32.)

The best exhibits of the St. Clair facies of the Murfreesboro are on Yellow Branch, 5½ miles southeast of Rose Hill, Lee County (geologic section 26); at St. Clair station, Tazewell County (geologic section 27); in the Narrows of New River and at Ripplemead, Giles County; at Healing Springs, Bath County; at localities 1 mile northeast of Bolar, Highland County; and 1 mile west of Crabbottom, Highland County.

Good exposures of the Blackford facies are 1 mile south of Nickelsville, Scott County, and at the road intersection 1¼ miles west of Dickensonville, Russell County. The upper cherty beds are shown along State Route 80, 1 mile east of Elk Garden (Pl. 26B); along U. S. Route 19, between Claypool Hill, 1 mile south of Cedar Bluff, and Pounding Mill, Tazewell County. All through the area of the Blackford facies, the outcrop of the cherty beds is marked in the fields by narrow strips covered abundantly with fragments of white chert.

The red shale and red dolomite of the Blackford facies are best displayed at Blackford. Red soil from this bed is well displayed in a field a short distance north of the road at the northwest base of East River Mountain about 2½ miles east of Bluefield, West Virginia. This red rock is present throughout the area of the Blackford facies. It was also noted at the base of the Stones River in the road near Ewing, Lee County, and it is well displayed on the top of a spur 5 miles southwest of Rose Hill, Lee County, about half a mile east of Martin Creek.

Thickness.—The thickness of the St. Clair facies of the Murfreesboro is 271 feet in Lee County; 1142 feet near Bluefield, Tazewell County; about 400 feet in the Narrows of New River, Giles County; 300 to 400 feet in Warm Springs and Bolar valleys in Bath County; and 650 feet in Hightown Valley, Highland County. The thickness of the Blackford facies is about 245 feet on Templeton Branch 4¼ miles northwest of Gate City, Scott County; about 380 feet, 3 miles northeast of Elk Garden, Russell County; 160 feet at Blackford, Russell County; and about 176 feet, 2 miles west of Stinson, Russell County. The Stones River in Rockbridge County is 400 feet thick. The thickness varies within these limits from place to place throughout southwest Virginia.

Fossils and correlation.—The Murfreesboro is moderately fossiliferous. Small ostracodes are perhaps the most abundant and most widely distributed fossils, both geographically and stratigraphically. Most of the ostracodes are minute species and difficult to clean from the matrix and identify. Fossils occur both in the limestone of the St. Clair facies and in the chert of the Blackford facies. Generally they are scarce and poorly preserved; collections have been few and small. Better collections could doubtless be obtained with more extended search, especially in the wide area of the well-exposed Stones River southwest of Jonesville, Lee County. A list of the species identified, some rather uncertainly, follows:

- Calcareous algae
  - Girvanella sp.
  - Solenopora sp.
- Corals
  - Tetradium syringoporoides Ulrich
- Bryozoa
  - Batostoma? sp.
  - Dekayella? sp.
  - Rhinidictya? sp.
- Brachiopods
  - Dinorthis sp.
  - Glyptorthis bellarugosa (Conrad)
  - Rafinesquina sp.; flat dorsal valve
  - Zygospira? cf. Z. acutirostris (Hall)
- Pelecypods
  - Ctenodonta sp.
  - Cyrtodonta sp.?
  - Modiolopsis cf. M. consimilis Ulrich
- Gastropods
  - Helicotoma tennesseensis Ulrich and Scofield
  - Holopea scrutator Raymond
  - Lophospira bicincta (Hall)
  - Lophospira centralis Ulrich
  - Lophospira perangulata (Hall)
  - Oxydiscus catilloides (Raymond)?
  - Eotomaria? sp.
- Pteropods
  - Polylopia (Salterella) billingsi (Safford)?
- Trilobites
  - Bathyurus sp.
  - Homotelus? sp.
  - Pterygometopus, 2 sp.
  - Pterygometopus troosti (Safford)?

Ostracodes
- Aparchites sp.
- Eurychilina sp.
- Isochilina, 3 sp.
- Leperditella inflata (Ulrich)
- Leperditella mundula (Ulrich)
- Leperditella sp.
- Leperditia fabulites pinguis Butts
- Leperditia sp.

Of the species listed *Tetradium syringoporoides, Modiolopsis* cf. *M. consimilis, Helicotoma tennesseensis, Lophospira centralis, L. perangulata, Eotomaria?* sp., *Polylopia* (*Salterella*) *billingsi?, Pterygometopus troosti?* and *Leperditia fabulites pinguis,* are among the common fossils of the Murfreesboro limestone of the Nashville basin of central Tennessee. *Tetradium syringoporoides, Helicotoma tennesseensis,* and small ostracodes identical or closely similar to those of Virginia occur in the Carlim or lower Stones River limestone of the Nittany Valley, central Pennsylvania. The Carlim has the Lemont member at the top with *Maclurites magnus* and other middle Chazy (Crown Point) fossils. The Murfreesboro of Virginia is directly overlain by the Mosheim limestone, followed by the Lenoir limestone which also carries *Maclurites magnus* and other middle Chazy fossils. The Lenoir, Lemont, and Crown Point limestones are thus believed to be about equivalent. *Zygospira acutirostris* is a common fossil of the basal member of the Chazy limestone of Champlain Valley, and *Holopea scrutator* also occurs in that member. On the basis of its fossils and stratigraphic position and relations, the Murfreesboro limestone of Virginia is therefore, correlated with the Murfreesboro limestone of Tennessee, the Carlim limestone of central Pennsylvania, and the basal member of the Chazy of the Lake Champlain area. (See Table 5.)

MOSHEIM LIMESTONE

Name.—The Mosheim limestone was named by Ulrich[77] in 1911 from Mosheim, a station on the Southern Railway 7 miles northwest of Greeneville, Green County, Tennessee.

Limits.—The Mosheim limestone immediately overlies the Murfreesboro limestone in southwestern Virginia wherever the Murfreesboro is present as described above. In belts southeast of Clinch Mountain, where the Murfreesboro is generally absent, the Mosheim rests upon the Beekmantown dolomite. Wherever the Mosheim succeeds the

[77] Ulrich, E. O., Revision of the Paleozoic systems, Geol. Soc. America Bull., vol. 22, pp. 413, 414, 538, 543, 544, 557, 636, pl. 27, 1911.

Beekmantown directly, a hiatus exists due to the absence of the Murfreesboro limestone. This hiatus is marked locally by an erosional unconformity. At the southwest end of the long channel quarry about 1 mile east of Staunton, the basal Mosheim occupies a rather deep depression in the Beekmantown. On Whistle Creek, 2½ miles northwest of Lexington, a slight angular unconformity seems to appear between the Beekmantown and Mosheim. This, if true, is an unusual feature in the Appalachian Valley. The quarry at Marion, Smyth County, shows a pronounced erosional unconformity. The Mosheim is everywhere succeeded by and limited above by the Lenoir limestone, which in some places overlies the Mosheim with an irregular contact due to moderate erosion. (See Pl. 33B.)

Character.—The Mosheim is distinctively characterized by a compact or glassy texture—a rock type designated as "vaughanite,"[78] and by a prevailing bluish-gray, light-gray, or dove color. Locally, as at the quarry on Middle River 5 miles northeast of Staunton, the lower part is nearly black. It is constantly thick bedded. These features make it easily distinguishable in most places. Its appearance in exposed sections is clearly shown by Plates 25B; 26A; 27B, C, and D. It is a very pure limestone and is preeminently suitable for high-grade chemical lime.

Distribution.—The Mosheim is generally present in the belts designated on the geologic map. It is locally absent or thin, as in the Knobs area, south of Abingdon, Washington County, where as a rule only the Lenoir is present. Even in this general area it is locally well developed three miles north of Alvarado, Washington County. (See Pl. 27B.) Northwest of Clinch Mountain it is commonly present and recognizable just above the Murfreesboro. It may be included within the upper 100 feet of limestone designated the Murfreesboro in places where it is not readily distinguishable from limestone of similar aspect in the Murfreesboro, as in the section exposed along the Virginian Railroad in the Narrows of New River. From its irregular distribution, it appears that the Mosheim was not uniformly deposited throughout the Valley area.

The Mosheim is well exposed at the top of the Blackford facies of the Murfreesboro limestone in the road 600 feet southeast of the bridge over Clinch River at Blackford, where its thickness is 30 feet, and at a chert pit on the secondary road 2½ miles southwest of Stinson, Russell County, where its thickness is 10 feet. It is well exposed at the railroad crossing at the freight station and in the quarries at Marion where it is 50 to 75 feet thick. One of the abandoned quarries 200

[78] Kindle, E. M., Nomenclature and genetic relations of certain calcareous rocks: Pan-Am. Geologist, vol. 39, p. 370, 1923.

yards or so northeast of the present active quarry at Marion, exhibits well the thick-bedded limestone which has weathered to a conspicuous white color. An excellent exposure of the Mosheim, 50 feet thick, is one-fourth of a mile southeast of Fairview and 4 miles northwest of Wytheville. A few miles northeast of Fairview, in Crocketts Cove, Wythe County, on the Cove road three-fourths of a mile east-northeast of its intersection with State Route 98 from Wytheville to Bland, the Mosheim is well exposed on the same belt of outcrop that passes through Fairview. One of the best exposures of Mosheim is on the South Fork of Buffalo Creek, 4½ miles northeast of Rapps Mill, Rockbridge County, where the following section was measured:

Geologic Section 33.—Mosheim limestone on South Fork of Buffalo Creek, Rockbridge County, Virginia

	Thickness Ft.	In.
Lenoir limestone		
15. Slope covered with chert debris		
Mosheim limestone (102+ feet)		
14. Limestone, compact, vaughanitic, with much chert	30	
13. Limestone, thick bedded, compact, vaughanitic, bluish gray	60	
12. Limestone, thin bedded, curly limestone partings	6	
11. Limestone, thick bedded, argillaceous; a layer 2 inches thick, 2 feet above the bottom crowded with gastropods; scattered angular fragments of chert in basal bed	6	
Murfreesboro (?) limestone (28+ feet)		
10. Limestone, blue	2	6
9. Limestone, argillaceous	1	8
8. Limestone, blue	3	
7. Limestone, argillaceous, many angular chert fragments in basal bed	9	
6. Limestone, argillaceous	8	
5. Shale	4	
Beekmantown formation		
4. Dolomite, argillaceous	2	2
3. Not exposed		6±
2. Chert, cavernous	1±	
1. Dolomite, exposed	50±	

In this section bed 13 is most typical of the Mosheim and the expression of it most frequently seen.

It could be reasonably thought that beds 5 to 12 represent the thinned Murfreesboro in view of the fact that about 400 feet of limestone southeast of old Collierstown, only 3 miles to the north, is provisionally referred to the Murfreesboro. It appears probable that an embayment of the Murfreesboro sea extended into this general area. The occurrence of the beds with angular fragments of chert, like those at the base of the Murfreesboro, and necessarily derived from the underlying Beekmantown, strongly suggests this conclusion.

The Mosheim is well displayed 2 miles northeast of Staunton (Pl. 27C) and at the large old quarry 1 mile east of town. The Mosheim is fully exposed, and is about 50 feet thick, on Tumbling Run 1½ miles southwest of Strasburg, Shenandoah County. Still farther northeast a long synclinal area extends from Strasburg to a point 1½ miles northwest of Middletown. At Stephens City the Mosheim is extensively quarried for lime burning. It is also fully exposed in the quarries at Riverton, Warren County. The very best display of the Mosheim is in old quarries in the southeast environs of Martinsburg, West Virginia. (See Pl. 27D.)

Thickness.—The maximum thickness of the Mosheim is known to be about 100 feet. This is its thickness on the South Fork of Buffalo Creek (geologic section 33) if all the beds of that section are included in it. The Mosheim also appears to be 100 feet thick at the quarry of the National Lime Co., about three-fourths of a mile southwest of Meadow Mills, Frederick County. Elsewhere the maximum thickness ranges from 50 to 75 feet. In many places the formation is only a few feet thick and it disappears over large areas.

Fossils and correlation.—The Mosheim fauna is almost entirely composed of gastropods. The most noteworthy are large species of *Lophospira,* such as *L. grandis* Butts and *L. superba* Butts. Such fossils occur at only a few places in Virginia where they are sufficiently freed from the rock to be distinguishable. The best collections were obtained at the type locality, Mosheim, Tennessee, and in the vicinity of Odenville, Alabama. On Yellow Branch, 5½ miles southeast of Rose Hill, Lee County, and on U. S. Route 58 at the curve 5 miles northeast of Rose Hill, Virginia, *Trochonemella trochonemoides* (Ulrich) was obtained. (Illustrated on Fossil Plates, Part II.) Three other species were also recognized at that point but not identified. A large *Lophospira,* like *L. superba,* was seen in the rock high up on the south side of the quarry at Marion, Smyth County. Numbers of gastropods were seen in a cut on the Virginian Railroad just below the east end of the old bridge at Ripplemead, Giles County. *Trochonemella trochonemoides* and *Tetradium syringoporoides* were obtained in the Mosheim 1¾ miles northwest of Middletown, Frederick County, and gastropods were noted as abundant elsewhere in this area.

The Mosheim extends southward along the southeast side of the Appalachian Valley to the vicinity of Shelby, Alabama. The formation is known at Bunker Hill and Martinsburg, Berkeley County, West Virginia, but is not present in central Pennsylvania.

Ulrich believes that the Mosheim was deposited in a sea connected with the Atlantic and probably not extending westward as far as central Tennessee. The characteristic Mosheim has not been recognized between the Murfreesboro and the younger Ridley limestone which there corresponds to the Lenoir limestone. The Lenoir overlies the Mosheim in the Appalachian Valley. This opinion is based upon the distinctive gastropod fauna which does not occur in the typical Murfreesboro. On the other hand, the occurrence of beds of limestone, as much as 10 feet thick, of strictly Mosheim lithology at several horizons in the Murfreesboro in Virginia, such as those in the section in the Narrows of New River, suggests the possibility that the Mosheim is a specially developed regional facies of the upper part of the Murfreesboro and that its horizon in the true Murfreesboro is occupied by rock of different character.

Before the discovery in 1926 of the section on Yellow Branch, Lee County (geologic section 26), Ulrich was inclined to assign the Mosheim to a position below the Murfreesboro. Its true position in the general succession was definitely established, however, by the Yellow Branch sequence. This conclusion is accepted by Ulrich.

LENOIR LIMESTONE[79]

Name.—The Lenoir limestone was named by Safford and Killebrew[80] from Lenoir City southwest of Knoxville, Tennessee.

Limits.—The Lenoir succeeds the Mosheim limestone or the Murfreesboro limestone, or the Beekmantown dolomite where the Mosheim is absent, as in the Knobs area south of Abingdon, Washington County. A hiatus of some magnitude thus appears between the Lenoir and the formation which underlies it in parts of the Valley. Even where the Lenoir succeeds the Mosheim the irregular contact surface of the Mosheim, caused by pre-Lenoir erosion which resulted from pre-Lenoir emergence, indicates a considerable hiatus in some areas. (See Pl. 33B.) These irregularities suggest subaerial rill marks or channels caused by rainwater trickling over a rounded surface of lime-

[79] Ulrich now questions the identification of this limestone as Lenoir.
[80] Safford, J. M., and Killebrew, J. M., The elements of the geology of Tennessee, pp. 130-131, Nashville, 1876.

stone, which are common on any exposed surface of limestone at present. Examples of this irregularity have been seen as far southwest as Mosheim, Tennessee. Commonly, however, the Mosheim-Lenoir contact is regular.

Locally, as in the vicinity of Draper, Pulaski County, the Lenoir appears to be absent and the Beekmantown is succeeded by the Holston limestone of a local embayment or by the Athens shale. The Lenoir is normally succeeded by the Holston limestone, that is, no formation is known between the Holston and Lenoir. This sequence prevails in the intermediate belts next northwest of Clinch Mountain. Southeast of Clinch Mountain, the Holston is absent, except in the area west of Lexington, Rockbridge County, and the Lenoir is succeeded by the Athens shale. (See Pl. 28B.) In Rye Cove, Scott County, the Holston and Athens are absent and the Lenoir is directly overlain by the Ottosee limestone. In Lee County the Holston, Athens, and Ottosee are absent and the Stones River is overlain by the Lowville limestone.

Character.—Most of the Lenoir is thick-bedded, medium coarsely crystalline, dark-gray to black limestone. It commonly contains rather abundant nodules of black chert, most of which are 2 to 4 inches in diameter. (See Pl. 25D.) The black nodules are generally sprinkled through the rock rather indiscriminately but in some places are not at all common. One of the best displays of the chert nodules may be seen at the quarry on Middle River, 5½ miles northeast of Staunton, Augusta County, and a few hundred feet northwest of the Lee Highway (U. S. Route 11); also at the Marcem quarry, 2½ miles west of Gate City, Scott County. The thick layers commonly consist of limestone nodules, a feature that characterizes the Lenoir from Virginia to Alabama. (See Pl. 28C.) Much of the limestone is fossiliferous, crinoidal remains predominating. These fossils, either entire or fragmental, stand out in relief on weathered surfaces and give the rock an extremely, though minutely, rough surface. Silicified bryozoa, both ramose and massive types, are abundant on weathered surfaces. These features are so persistent and characteristic that there is generally no difficulty in recognizing the Lenoir.

Distribution.—With the exception noted above, the Lenoir, so far as known, is universally present throughout the Valley in the belts of outcrop shown on the geologic map. It has been recognized at the top of the Stones River at a number of places and probably is everywhere present at that horizon whether recognized or not. The Lenoir sea probably spread all over the Valley area so that the Lenoir limestone was deposited over all of it.

Some of the best exposures of the Lenoir at the top of the St. Clair facies of the Murfreesboro limestone are the following: Yellow

Branch, 5½ miles southeast of Rose Hill, Lee County (geologic section 26 and Pl. 25D); top of limestone, bed 32 of geologic section 27; half a mile southeast of St. Clair Station, 2½ miles west of Bluefield, Virginia; about 1 mile northeast of Bolar, Bath County, on the southeast side and about 200 feet above the valley floor; and at the west edge of the town of Crabbottom, Highland County.

Where the Blackford facies of the Murfreesboro is present, the Lenoir is not obviously recognizable but is probably present above the Mosheim limestone. Exposures of rock that is probably Lenoir may be seen at the following places: At the chert pit 2½ miles southwest of Stinson, Russell County, where it is about 5 feet thick (geologic section 32); at the Marcem quarry, 2½ miles west of Gate City, Scott County; along the roads on the east bluff of New River opposite Ripplemead, 3 miles east of Pearisburg, Giles County; and near Sinking Creek, Giles County, on the road to Mountain Lake just north of its intersection with State Route 8.

Southeast of Clinch Mountain, the Lenoir is well exposed at Vance Mill, 1¾ miles south of Abingdon, Washington County; on State Route 77 at the southeast base of the Great Knobs, south of Abingdon; at Avens Ford on the South Fork of Holston River, 6 miles south of Abingdon; and on Denton Branch at the road intersection just southeast of the school house 7 miles south of Abingdon. At the above localities it is about 30 feet thick and rests on the Beekmantown dolomite and is overlain by the Athens shale. Fine exposures of the Lenoir may be seen in the vicinity of Marion, Smyth County, in the active quarry and in the abandoned quarries one-fourth of a mile northeast of the active quarry; also in an old quarry on Umbarger Creek just northwest of the railroad and old Lee Highway 3 miles southwest of Marion. At this place in a bed showing on the southeast bank of the old road are numbers of fine specimens of *Maclurites magnus* Lesueur. Five miles due west of Marion the formation is well exposed at the road intersection and just above the junction of Wassum and Walker creeks. *Maclurites magnus* is also common here. The Lenoir is exposed along Reed Creek 3 miles west of Wytheville, and is well exhibited in Crocketts Cove, 5 miles northeast of Wytheville, on the Cove road three-fourths of a mile east-northeast of its intersection with the road crossing the Cove northward from Wytheville to Bland. The contact with the Beekmantown in a full exposure is included in the large quarry on New River just above its junction with Little River about 4 miles south of Radford, Montgomery County. It is fully exposed at Lusters Gate 3 miles east-northeast of Blacksburg, Montgomery County, and at a point 1 mile north of Ellett on the Virginian Railroad 3 miles southeast of Blacksburg. It shows well for a mile or more northeastward from the main road beginning just southeast of Galena, Augusta County, and is completely exposed on Middle River near the quarry just northwest of the Lee Highway, 5 miles northeast of Staunton. The Lenoir is exposed in the quarry at Riverton, Warren County. There are complete exposures at the bridge over North River 1¼ miles east of Edinburg, Shenandoah County, and on Tumbling Run 1½ miles southwest of Strasburg. There are numerous good exposures in the area extending from a point northwest of Harrisonburg to a point northwest of Strasburg.

Thickness.—The Lenoir ranges from 5 feet or less at places in the area of the Blackford facies northwest of Clinch Mountain to 30 feet in the Knobs area southeast of Abingdon and commonly to as much as 50 feet throughout most of the Valley.

It has a possible maximum thickness of 200 feet on Sinking Creek, 1 mile northwest of Newport, Giles County, but it is not certain that all the limestone referred to the Lenoir here is really Lenoir.

Fossils and correlation.—The Lenoir limestone is moderately fossiliferous. Approximately 150 different species have been recognized. The fossils are generally firmly embedded in the rock and fairly good specimens have been obtained at only a few places. The best collections have been made at the following localities: Whistle Creek, 2½ miles northwest of Lexington, Rockbridge County; North Fork of Roanoke River, 3 miles southeast of Blacksburg and 1 mile north of Ellett, Montgomery County; vicinity of Pearisburg, Giles County; Marion, Smyth County; and Marcem quarry 2½ miles west of Gate City, Scott County. Many of the fossils, especially the bryozoa, have not been described. The trilobites are poorly preserved; therefore the determination of genera and species is difficult and uncertain. The brachiopods are the best preserved and best known forms. The best determined of the species, including those known outside of Virginia and serviceable for correlation, are listed below:

TABLE 4.—*Fossils from the Lenoir limestone*

	1	2	3	4	5	6	7	8
Sponges:								
cf. Anthaspidella or Zittelella, common and widespread	x							
Hindia parva Ulrich	x	x						
Nidulites ovoides Butts, n. sp.			x					
Receptaculites sp.	x							

1. At Marion, Smyth County.
2. Along Whistle Creek, 2½ miles northwest of Lexington, Rockbridge County.
3. Along North Fork of Roanoke River, 3 miles southeast of Blacksburg, Montgomery County.
4. Along Yellow Branch, 5½ miles southeast of Rose Hill, Lee County.
5. Porterfield quarry, 5 miles east of Saltville, Smyth County.
6. Marcem quarry, 2½ miles west of Gate City, Scott County.
7. In Rye Cove, Scott County.
8. Near Pearisburg, Giles County.

TABLE 4.—*Fossils from the Lenoir limestone—Continued*

	1	2	3	4	5	6	7	8
Corals:								
Stylaraea parva (Billings) rare		x						
Bryozoa:								
Batostoma sp				x				
Batostoma several sp		x			x	x		
Constellaria sp						x		
Crepipora cf. C. perampla Ulrich				x				
Cyphotrypa sp		x				x		
Dekayella ? 2 sp	x	x				x		
Glauconome sp	x							
Mesotrypa sp		x		x		x		
Monotrypa 2 sp	x					x		
Nicholsonella pulchra Ulrich		x		x				
Nicholsonella sp				x				
Pachydictya cf. P. robusta Ulrich				x		x		
Rhinidictya trentonensis (Ulrich)				x		x		
Brachiopods:								
Camarella varians Billings				x				
Camarella sp		x						
Camarotoechia plena (Hall) ?						x		
Christiania ? cf. C. lamellosa Bassler	x							
Dinorthis sp						x		
Dinorthis sp								
Glyptorthis bellarugosa (Conrad)	x					x		
Hesperorthis cf. H. ignicula (Raymond)		x				x		
Hesperorthis sp								
Mimella sp	x	x		x		x		
Multicostella platys (Billings)	x	x				x		
Oxoplecia cf. O. occidentalis (Butts)			x			x		
Paurorthis sp							x	
Plectorthis exfoliata (Raymond)?	x							
Productorthis sp	x							
Rafinesquina champlainensis Raymond		x		x				
Rafinesquina cf. R. minnesotensis (Winchell)								x
Sowerbyella sp		x			x	x		
Sowerbyites sp								
Valcourea strophomenoides (Raymond)		x			x	x		
Pelecypods:								
Ctenodonta gibberula Salter					x			
Gastropods:								
Helicotoma cf. H. tennesseensis Ulrich and Scofield		x				x		
Holopea sp								
Kokenospira virginiana Butts, n. sp						x		
Liospira cf. L. decipiens Ulrich						x		
Maclurites magnus Lesueur	x				x			x
Sinuites sp						x		
Tetranota? sp						x		
Trochonema? sp						x		
Cephalopods:								
Protocycloceras sp		x						

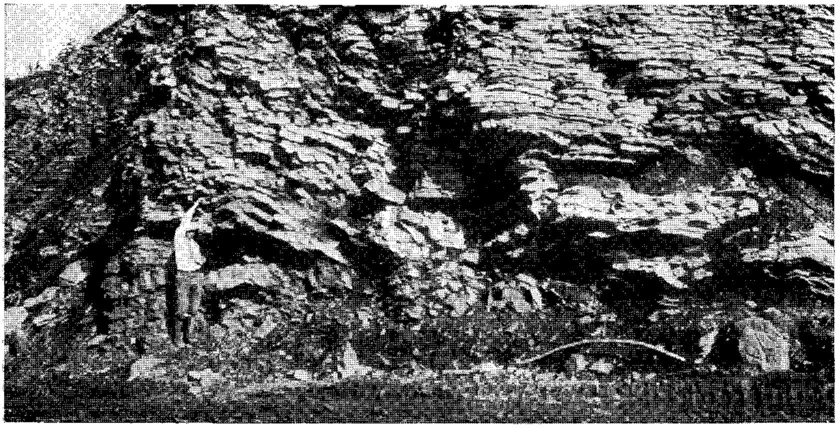
1. At Marion, Smyth County.
2. Along Whistle Creek, 2½ miles northwest of Lexington, Rockbridge County.
3. Along North Fork of Roanoke River, 3 miles southeast of Blacksburg, Montgomery County.
4. Along Yellow Branch, 5½ miles southeast of Rose Hill, Lee County.
5. Porterfield quarry, 5 miles east of Saltville, Smyth County.
6. Marcem quarry, 2½ miles west of Gate City, Scott County.
7. In Rye Cove, Scott County.
8. Near Pearisburg, Giles County.

PLATE 29

A. Athens limestone in the Porterfield quarry near Saltville, Smyth County. (See Pl. 31B.) The man stands on Whitesburg limestone and his hand is on the contact. Note the even, thin, and compact beds which characterize the Athens limestone. Looking southeast.

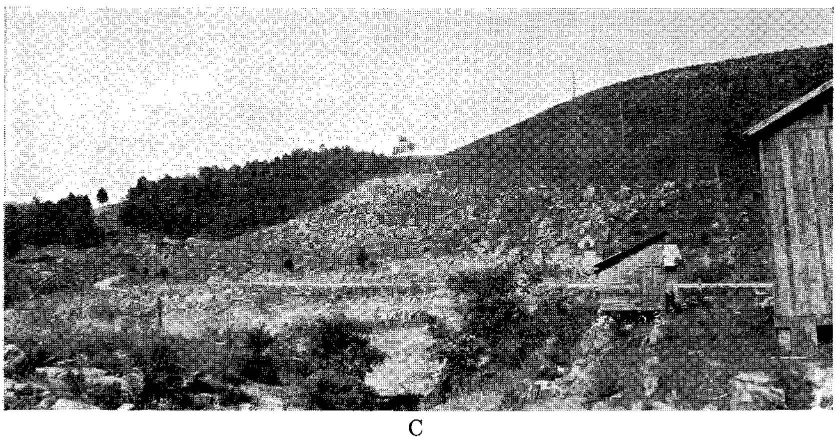
B. Characteristic exposure of limestone of Holston type. One mile northwest of the northeast entrance to Ward Cove, Tazewell County, and about three-fourths of a mile west of Snapp. Looking southwest.

C. Holston limestone and Ottosee limestone near Blackford, Russell County. The thick-bedded rock, about 50 feet thick, next below the smooth space marked by the telephone poles, is a coarse-grained, pink marble with *Nidulites* cf. *N. pyriformis* at the base. This fossil has been found elsewhere at the base of the Ottosee limestone, and the pink marble is regarded as probably Ottosee. Similar beds occur in the Ottosee elsewhere in Virginia and Tennessee. In Clinch Valley, 3½ miles southwest of Blackford. Looking northeast.



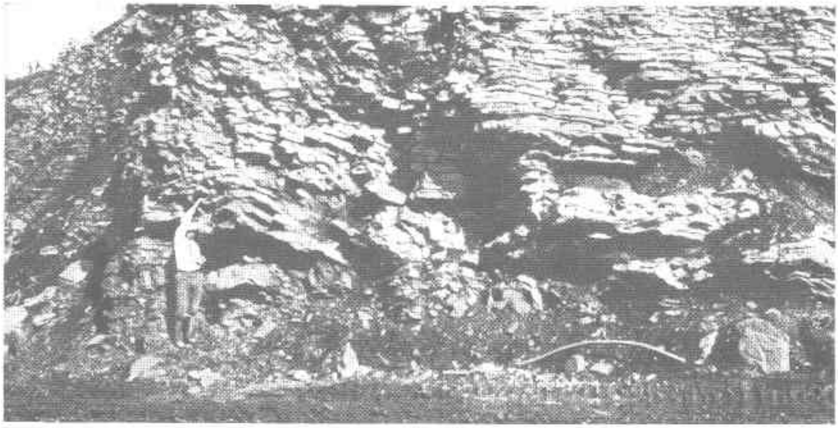
A

B

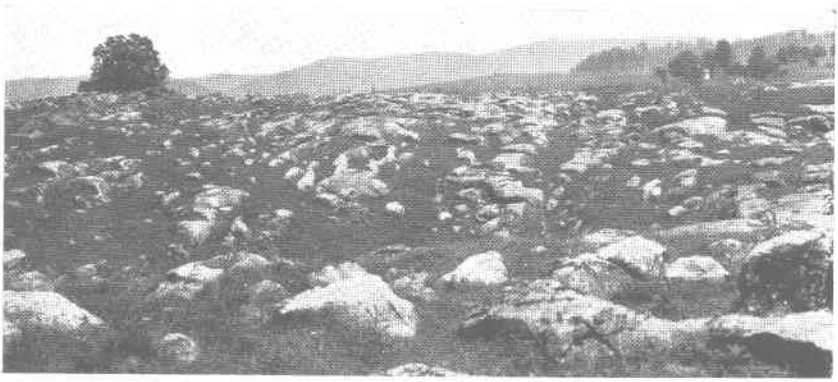


C

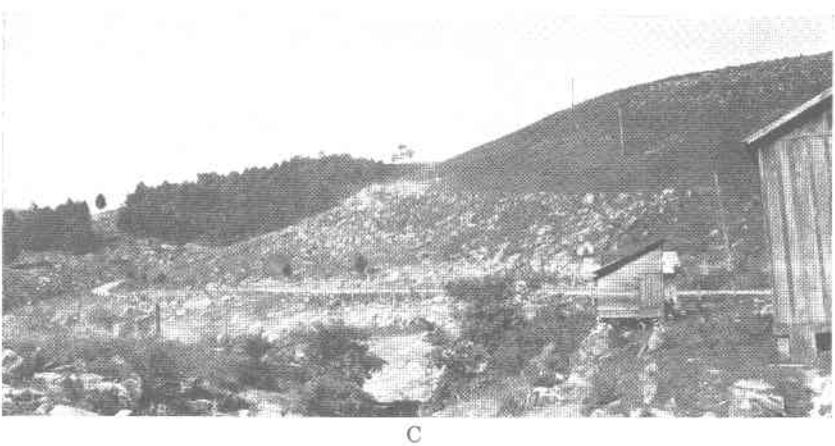
ORDOVICIAN LIMESTONES



A



B

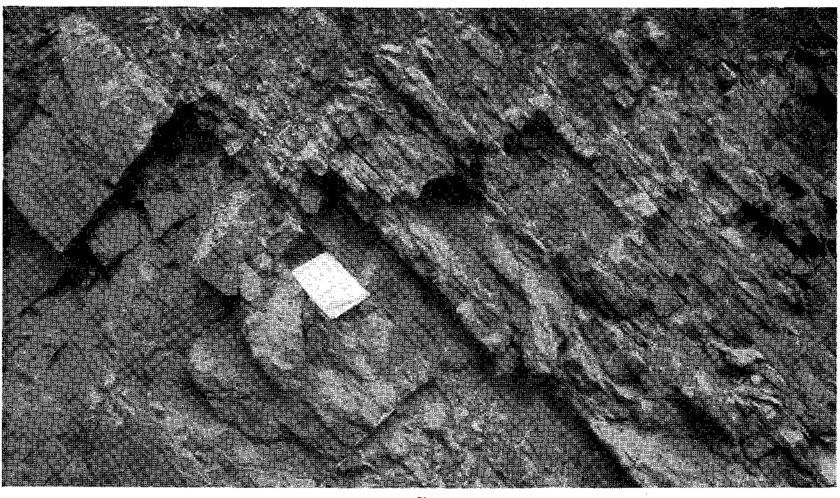


C

ORDOVICIAN LIMESTONES

A

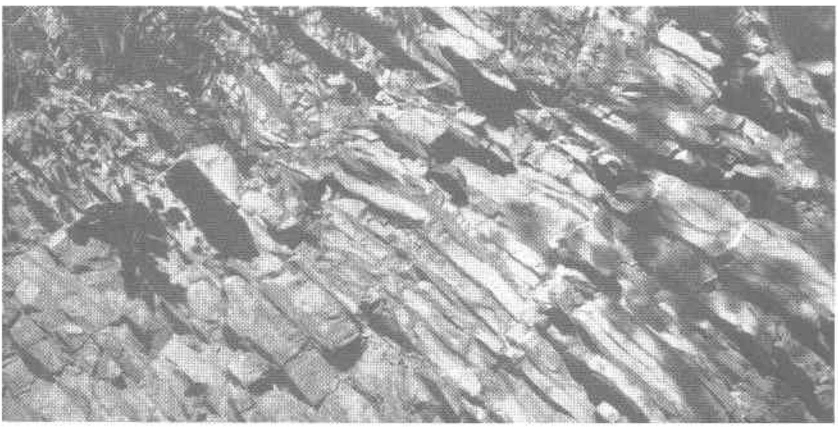
B



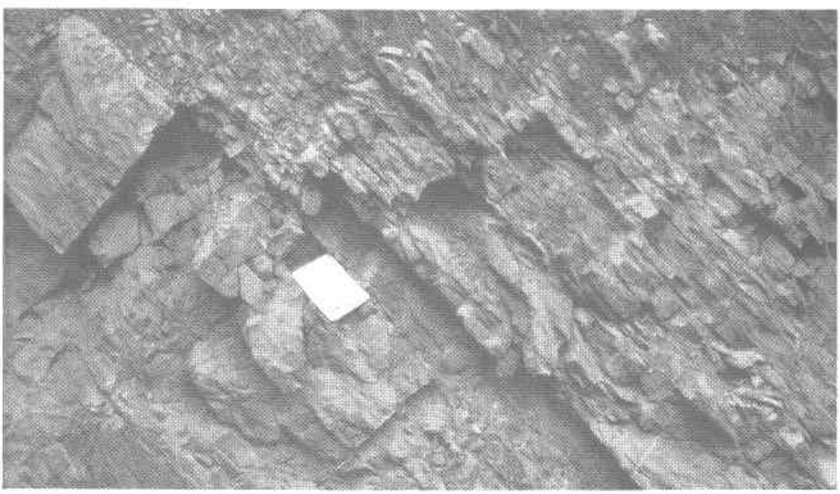
C

ORDOVICIAN FORMATIONS

A



B



C

ORDOVICIAN FORMATIONS

PLATE 30

A. Thick-bedded sandstone in Athens shale. *Dicellograptus* and other graptolites occur in the shale partings. Along State Route 77, through the Great Knobs, 2½ miles south of Abingdon, Washington County. Looking northeast.

B. Athens limestone in Rockbridge County. Even-bedded, pure limestone showing faint traces of dark banding. Along State Route 251, on Collier Creek about 7 miles southwest of Lexington. Looking northeast.

C. Athens limestone (below) and Chambersburg limestone in Rockbridge County. The contact is at the upper edge of the notebook. The hiatus at this contact is indicated by the absence of the Tellico sandstone, Ottosee limestone (Sevier shale in Tennessee), and Lowville limestone, having a maximum thickness of 5000 feet. Along State Route 251, 7 miles southwest of Lexington, near the locality of B. Looking northeast.

TABLE 4—*Fossils from the Lenoir limestone—Continued*

	1	2	3	4	5	6	7	8
Trilobites:								
Ceraurinus ? sp	x							
Encrinurus sp	x							
Homotelus sp								
Pliomerops canadensis (Billings)	x							
Pterygometopus annulatus Raymond ?							x	
Pterygometopus sp	x							
Remopleurides sp	x							
Sphaerexochus sp	x							

1. At Marion, Smyth County.
2. Along Whistle Creek, 2½ miles northwest of Lexington, Rockbridge County.
3. Along North Fork of Roanoke River, 3 miles southeast of Blacksburg, Montgomery County.
4. Along Yellow Branch, 5½ miles southeast of Rose Hill, Lee County.
5. Porterfield quarry, 5 miles east of Saltville, Smyth County.
6. Marcem quarry, 2½ miles west of Gate City, Scott County.
7. In Rye Cove, Scott County.
8. Near Pearisburg, Giles County.

A few of the species of the preceding list may be used with reasonable certainty for correlating the Lenoir with the Ridley limestone of central Tennessee, the Lemont member of the Carlim limestone of central Pennsylvania, and the Crown Point limestone or middle member of the Chazy limestone of the Champlain Valley, northeastern New York. The species common to the Lenoir and the Ridley are *Nicholsonella pulchra* and *Maclurites magnus* Lesueur; those common to the Lenoir and Lemont are *Rafinesquina champlainensis* and *Maclurites magnus* Lesueur. The fossils of the Lenoir which correlate it with the Crown Point (Middle Chazy) limestone are *Valcourea strophomenoides* and *Maclurites magnus* Lesueur. Both are confined to the Crown Point limestone. *Stylaraea parva, Camarella varians,* and *Multicostella platys* are common in the Crown Point but occur also in higher beds. *Pliomerops canadensis* is most abundant in the Crown Point but occurs also in higher and lower beds. *Rafinesquina champlainensis* is present throughout the Crown Point. It also occurs in lower but not higher beds. *Camarotoechia plena* is recorded only in the Valcour limestone, next above the Crown Point limestone in the Lake Champlain region. It was found in Virginia at only one point—at the northeast base of Big A Mountain, Russell County, close beneath the Ottosee limestone and thus presumably at a higher horizon in the Lenoir than any of the other fossils listed. The Lenoir there may include a representative of the Valcour to which *Camarotoechia plena* is confined in the Champlain Valley. The occurrence of *Sowerbyella* in the Lenoir is worthy of note as being possibly its earliest known occurrence.

This list of correlative species is small, but, together with the stratigraphic relations of the Lenoir, it affords satisfactory grounds for correlation and it has been widely accepted by most geologists for many years.

The Lenoir of Virginia continues into Alabama as shown by the common occurrence of *Maclurites magnus* in Cahaba Valley and by *Paurorthis stonensis* (Hall and Clarke) and *Oxoplecia occidentalis* in the Birmingham Valley.[81]

The general correlation of the Stones River group of Virginia is shown in Table 5:

TABLE 5.—*Correlation of the Stones River group*

APPALACHIAN VALLEY IN VIRGINIA	CENTRAL TENNESSEE	CENTRAL PENNSYLVANIA	CHAMPLAIN VALLEY, N. Y.
Lenoir limestone	Lebanon limestone Ridley limestone Pierce limestone	Lemont member of Carlim limestone	Valcour limestone Crown Point limestone
Mosheim limestone Murfreesboro limestone	Hiatus ? Murfreesboro limestone	Hiatus ? Carlim limestone	Hiatus ? Basal member of Chazy

The full geographic extension of the Lebanon, Pierce, and Mosheim limestones is unknown. It should not be assumed that the correlated units of the above table are exactly equivalent in all the regions cited, but it is reasonably certain that they all occupy approximately the same chronologic and stratigraphic level.

Such forms as *Paurorthis, Productorthis,* and *Glauconome,* rare in American strata, occur in the Baltic region of Europe and indicate direct marine connections in Lenoir time. The Lenoir sea was continuous with the Atlantic Ocean and derived its inhabitants therefrom, which explains the probably simultaneous presence of common species in North America and the Baltic region.

HIATUS (?)

The Lebanon limestone of central Tennessee has been recognized at only a few places in Virginia. The Valcour limestone, upper member of the Chazy of the Champlain Valley, has not been recognized; if represented in Virginia, it must be very thin. Thus a hiatus may intervene between the Lenoir limestone and the next overlying formation, the Holston limestone.

BLOUNT GROUP

The Blount group was named by Ulrich[82] from Blount County, Tennessee. A complete sequence of the Blount group is as follows:

[81] Butts, Charles, Geology of Alabama: The Paleozoic rocks: Alabama Geol. Survey Spec. Rept. 14, Pls. 22 and 31, 1926.

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

Lowville-Moccasin limestone
Blount group
    Ottosee limestone—Sevier shale
    Tellico sandstone
    Athens shale
    Whitesburg limestone
    Holston limestone
Lenoir limestone

Nowhere, so far as known, are all these formations present in a continuous vertical section, but this sequence is fully established. In the Athens belt in the vicinity of Athens, Tennessee, the sequence is as follows:

No higher rocks present
Blount group
    Ottosee limestone—Sevier shale[83]
    Tellico sandstone
    Athens shale
    Hiatus; Holston absent
Lenoir limestone

In Rich Valley, from Saltville to Bland, Virginia, the sequence is as follows:

Lowville-Moccasin
Blount group
    Ottosee limestone
    Hiatus; Tellico absent
    Athens shale
    Whitesburg limestone
    Holston limestone
Lenoir limestone

From these two sections the full sequence is plainly determinable.

HOLSTON LIMESTONE

Name.—The Holston limestone was named from Holston River in the vicinity of Knoxville, Tennessee. It is the famous Holston, or Tennessee, red marble so commonly used in public buildings. The name was first published by Keith.[84] Bassler[85] used the name in 1909 but did

[83] Of the type area southeast of Knoxville, Tenn., but not of the U. S. Geological Survey folios in general.
[84] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Knoxville folio (No. 16), map, 1895.
[85] Bassler, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, 1909. In the section at Speers Ferry, Scott County (p. 164), it comprises beds b to i; in the Walker Mountain section (p. 217), it is bed c of the Stones River formation.

not clearly define it. The name has since been used by Gordon[86] and by Butts.[87] H. D. Campbell applied the name Murat to the Holston in the area 1½ miles west of Lexington, Virginia, before its identity with the earlier named Holston limestone had been determined. It is called a limestone in Virginia, because in this State the formation commonly lacks the red color that makes it desirable as a commercial marble, although in some localities the formation contains some reddish layers.

Limits.—With a single known exception, the Holston, wherever present in Virginia, succeeds the Lenoir limestone. Northwest of Clinch Mountain the Holston is directly overlain by the Ottosee limestone, with a large hiatus between, resulting from the absence of the Athens and Whitesburg. Southeast of Clinch Mountain, the Holston, where present, is overlain by the Whitesburg limestone or Athens shale.

Character.—The Holston limestone is a coarsely crystalline rock composed largely of fragments of fossils which give it a notably crystalline texture. It is prevailingly thick bedded, but some layers are somewhat nodular or shelly. The color is generally dark gray, but in the southern part of the Valley, as at Gate City, Scott County, some layers are light gray and strongly tinted pink to reddish, resembling the typical Holston or Tennessee marble. At the Porterfield quarry, 5 miles east of Saltville, Smyth County, and elsewhere in Rich Valley, the rock is light bluish gray. (See Pl. 31B.) Almost everywhere in Virginia the rock is essentially homogeneous, showing no significant variations in character from top to bottom. The only exceptions that have been noted are in the Porterfield quarry and in Catawba Valley, Botetourt and Roanoke counties. In the Porterfield quarry a 30-foot bed is composed of black graptolitiferous shale and of small lenses of limestone of ordinary Holston type so coated with carbonaceous films that the entire bed stands out distinctly in the middle part of the Holston in the face of the quarry. The section of the Holston at the Porterfield quarry is as follows:

Geologic Section 34.—Holston limestone in the Porterfield quarry, 5 miles east of Saltville, Virginia

	Thickness Feet
Whitesburg limestone	
4. Limestone and shale, black	50
Holston limestone (280 feet)	
3. Limestone, thick bedded, coarsely crystalline, light gray	125

[86] Gordon, C. H., History, occurrence and distribution of the marbles of east Tennessee: Tennessee Dept. Education, Div. Geology, Bull. 28, pp. 37-38, 1924.

[87] Butts, Charles, and others, Southern Appalachian region: XVI Internat. Geol. Cong., United States, 1933, Guidebook 3, Excursion A-3, 1932; Geologic map of the Appalachian Valley in Virginia with explanatory text: Virginia Geol. Survey Bull. 42, 1933.

	Thickness Feet
2. Shale, black, with small lenses of limestone coated with a carbonaceous film; contains graptolites	30
1. Limestone like bed 3	125

Lenoir limestone

The Holston is a very pure high-grade limestone. At the present time it is extensively used by the Mathieson Alkali Works at Saltville, which obtains its rock from the Porterfield quarry, and by the cement plant at Kingsport, Tennessee, which operates the Marcem quarry 2½ miles west of Gate City.

Distribution.—The Holston crops out in the northwest half of each of the two belts northwest of Clinch Mountain, shown on the geologic map, which extend from the Tennessee line northeastward to North Tazewell and Burkes Garden. It has not been certainly identified farther northeast but is probably represented by about 10 feet of limestone at its horizon in the section on Wolf Creek slightly more than a mile south of the town of Rocky Gap, Bland County. In Rich Valley, which lies between Clinch and Walker mountains, the Holston is generally present. In this belt it is known to extend from State Route 81, 3 miles south of Saltville, northeastward to New River at a point 1¼ miles south of Goodwin Ferry, or 2200 feet south of Berton Station. It is absent for some distance along this outcrop at the old quarries of the Mathieson Alkali Works, 3 miles southeast of Saltville, where the Athens shale lies directly upon the Lenoir limestone. (See Pl. 28B.) It is possibly represented by a 5-foot bed of coarse-grained limestone full of the coral *Lichenaria* exposed in Sinking Creek Valley 1 mile northwest of Newport, Giles County, and by the same bed at a point on the road to Mountain Lake, State Route 112, on the southeast slope of Johns Creek Mountain, 1¼ miles northwest of the locality just mentioned. It is equally possible that this bed is Ottosee. It continues northeast of Newport to a point in Craig County on the northwest slope of Gap Mountain, 1 mile northeast of the county line and 5 miles southwest of Simmonsville, where it is 1 foot thick. One-third of a mile northeast of Draper, Pulaski County, a bed of Holston type, coarse grained, partly reddish, and fossiliferous, immediately succeeds the Beekmantown dolomite and is overlain by the Athens shale. This is the only known exception to the rule that the Holston, where present, succeeds the Lenoir limestone. Its outcrop here is small. In Crocketts Cove north of Wytheville, and directly beween Draper and Burkes Garden, the Holston is absent. A coarse-grained bed 10 feet thick between the Lenoir and Athens on the North

Fork of Roanoke River, between Lusters Gate and Ellett, 3 miles southeast of Blacksburg may be Whitesburg but is probably Holston. In Catawba Valley, a black argillaceous, fossiliferous, limestone between the Lenoir and Athens is thought by Ulrich to represent the Holston. This is a distinctly different facies from any known in the Holston, and more closely resembles the Whitesburg limestone. A considerable thickness of Holston is exposed in an active quarry at Eagle Rock, Botetourt County. In Rockbridge County, typical Holston extends for 12 miles northeast of Murat and west of Lexington.

Among the best exposures of the Holston is that at Gate City and westward along U. S. Route 58 in Scott County; that at the Marcem quarry west of Gate City; and the one at the quarry at Porterfield, Smyth County (Pl. 31B). It is finely displayed in natural exposures between Dickensonville and Lebanon; just southeast of U. S. Route 19, 1 mile north of Hansonville; on the foothills at the southwest end of Beartown Mountain, 1 mile northeast of Elk Garden; and just northwest of the entrance to Ward Cove 1 mile west of Snapp, Tazewell County. (See Pl. 29B.) There are extensive exposures in the Clinch Valley southwest of Blackford, Russell County. (See Pl. 29C.) One of the best exposures is 1 mile west of Lexington where the display of the Holston is comparable to that shown in Plate 29B.

Thickness.—The thickness of the Holston generally ranges between 100 and 200 feet. Near North Tazewell it is only 8 feet and in Sinking Creek Valley on the northwest face of Gap (Walker) Mountain only 1 foot thick. At the Porterfield quarry, northeast of Saltville, it is apparently 280 feet thick but a fault may cause some repetition here. In the area west of Lexington the thickness, based upon the width of outcrop and the dip, may be about 350 feet but this estimate may be too high because of repetition by unobserved faults or folds.

Fossils and correlation.—The Holston is a highly fossiliferous limestone, being largely composed of fragmentary remains of fossils, especially crinoids. In the belts northwest of Clinch Mountain very few specimens well enough preserved for satisfactory identification have been collected, but in the Rich Valley belt good material is fairly abundant and varied. The best collections have been made at the Porterfield quarry, Smyth County; Tilsons Mill, Wythe County; the McNutt quarry 1½ miles southeast of Sharon Springs; the John Grayson farm 5 miles southwest of Bland; and at the Hogue and Waddle farms between the Grayson farm and McNutt quarry. The last five localities are in Bland County.

The Holston fossils are largely undescribed, and most of the published descriptions are by Raymond[88] and by Willard.[89] Most of the extensive collections in the U. S. National Museum have been studied by Ulrich and provisionally identified and named. The following list is compiled from the sources named above.

TABLE 6.—*Provisional list of Holston fossils from Virginia*

	1	2	3	4	5	6	7
Cystids:							
Echinosphaerites sp.?							x
Bryozoa:							
Anolotichia sp.?							
Chasmatopora sp					x		
Crepipora? sp					x		
Graptodictya sp.?					x		
Homotrypella sp					x		
Pachydictya sp.?		x					
Rhinidictya sp.?		x					
Brachiopods:							
Acrosaccus panneus Willard						x	
Acrosaccus shuleri Willard						x	
Camarella, 3 sp						x	
Christiania sp							x
Clitambonites? sp. rare					x		
Crania (Petrocrania) sp							x
Dinorthis atavoides Willard						x	
Dinorthis? sp							x
Doleroides? sp						x	
Hallina? sp						x	
Hebertella? sp						x	
Leptaena prona Willard			x				
Leptaena sp						x	
Lingula lyelli Billings						x	
Mimella sp					x		x
Multicostella cf. M. platys (Billings)					x		
Oxoplecia holstonensis Willard						x	
Oxoplecia, 2 sp., common							
Palaeoglossa gibbosa Willard					x		
Paurorthis sp. (rare, at several places)							
Plectorthis holdeni Willard							
Productorthis agilera (Willard)						x	
Ptychoglyptus virginiensis Willard						x	x
Ptychoglyptus?, 1 or more sp							x
Rafinesquina grandistriata Willard						x	
Sowerbyella crassus (Willard)						x	
Sowerbyella triseptatus (Willard)			x				
Strophomena tenuitesta Willard							

1. Thomas farm, 3 miles northeast of Blacksburg, Montgomery County.
2. Catawba Valley, Roanoke County.
3. Along New River, 1½ miles southwest of Goodwins Ferry, Giles County.
4. Hogue farm, 6 miles southeast of Bland, Bland County.
5. Locality 1½ miles west of Lexington, Rockbridge County.
6. McNutt quarry, 1½ miles southeast of Sharon Springs, Bland County.
7. Porterfield quarry, 5 miles east of Saltville, Smyth County.

[88] Raymond, P. E., Some trilobites of the lower Middle Ordovician of eastern North America: Harvard Coll., Mus. Comp. Zoology Bull., vol. 67, no. 1, pp. 1-180, 1925; The brachiopods of the Lenoir and Athens formations of Tennessee and Virginia: idem, vol. 68, no. 6, pp. 293-309, 1928.

[89] Willard, Bradford, The brachiopods of the Ottosee and Holston formations of Tennessee and Virginia: Harvard Coll., Mus. Comp. Zoology Bull., vol. 68, no. 6, pp. 255-292, 1928.

TABLE 6.—*Provisional list of Holston fossils from Virginia—Continued*

	1	2	3	4	5	6	7
Pelecypods:							
Clionychia sp., widely distributed					x	x	
Cyrtodonta sp.							
Gastropods:							
Bucania sp.					x		
Cyclonema sp.					x		
Holopea cf. H. obliqua Hall							
Raphistomina sp.					x		
Scenella sp.					x		
Subulites? sp.							x
Tetranota sp.						x	
Trochonema sp.							x
Cephalopods:							
Cameroceras, 3 sp.							x
Spyroceras sp.							x
Trilobites:							
Acrolichas minganensis (Billings)		x				x	
Acrolichas prominulus Raymond		x		x		x	
Amphilichas sp.					x		
Amphilichas, several other sp.					x		x
Basilicus laeviculus Raymond (very rare)						x	
Bronteopsis gregaria Raymond				x			
Bumastus lioderma Raymond		x			x	x	
Bumastus longiops Raymond				x		x	
Ceraurus hudsoni Raymond		x		x			
Glaphurina brevicula Ulrich		x			x		
Glaphurus sp.							x
Hyboaspis shuleri Raymond						x	x
Illaenus fieldi Raymond		x		x		x	
Illaenus lautus Raymond		x					
Illaenus valvulus Raymond		x					
Onchaspis confraga Raymond, rare	x						
Remopleurides canadensis Billings		x					
Ostracodes:							
Several genera and species							

1. Thomas farm, 3 miles northeast of Blacksburg, Montgomery County.
2. Catawba Valley, Roanoke County.
3. Along New River, 1½ miles southwest of Goodwins Ferry, Giles County.
4. Hogue farm, 6 miles southeast of Bland, Bland County.
5. Locality 1½ miles west of Lexington, Rockbridge County.
6. McNutt quarry, 1½ miles southeast of Sharon Springs, Bland County.
7. Porterfield quarry, 5 miles east of Saltville, Smyth County.

A few of the fossils of the list have correlative value. *Bumastus lioderma, B. longiops, Glaphurina brevicula, Illaenus fieldi, I. lautus,* and *Clionychia* sp. occur in the Holston of both Virginia and Tennessee and confirm the identification of the limestone of Virginia with the typical Holston of Tennessee. A peculiar species of *Amphilichas,* characterized by an extremely long proboscis, occurs in the Holston, both near Meadow, Tennessee, and 1½ miles west of Lexington, Virginia. *Acrolichas prominulus* occurs at the McNutt quarry in the Rich Valley belt and in the dark-colored limestone of Catawba Valley, and it is largely upon its presence that that limestone is identified as Holston. On the whole, the Holston fauna is unique and its species mostly confined to itself. The generic types, however, continue into and through the Blount group as a whole and they constitute a considerable element of the Chazy fauna of northeastern New York, Quebec, and the Mingan Islands of the St. Lawrence Valley. Though the Holston fauna is distinctly Chazyan, there are no specific identities to afford any evidence for its correlations with any of the divisions of the typical Chazy of the Champlain Valley. If the correlation of the Lenoir and Crown Point is correct, the Holston could only be correlated with the Valcour limestone. Most probably the Holston, as well as the rest of the Blount group, is not represented in the Champlain Valley where, as in central Pennsylvania and along the northwestern side of the Appalachian Valley in Virginia, the Chazy is immediately succeeded by the Lowville limestone.

Such rare fossils as *Paurorthis, Productorthis,* and *Cyrtonotella* prove the continuity of the Holston sea with the sea of the Baltic or Leningrad region of Russia of the time and suggest the contemporaniety of the Holston with the Russian deposits of that region bearing those genera.

WHITESBURG LIMESTONE

Name.—The Whitesburg limestone was named by Ulrich[90] from Whitesburg, Hamblen County, Tennessee, 10 miles northeast of Morristown. The type section is 2 miles southeast of Whitesburg in the road and fields 1 mile due west of the town of Bulls Gap, or Rogersville Junction. It is the basal fossiliferous 50-75 feet of the Liberty Hall (Athens) limestone of H. D. Campbell.[91]

Limits.—The Whitesburg generally succeeds the Holston limestone, apparently in continuous sequence. In places, as at Whitesburg, Tennessee, and in Crocketts Cove northeast of Wytheville, Virginia, it lies upon the Lenoir limestone, the Holston being absent. It is directly overlain by the Athens, of which it at one time was considered the basal limestone member. (See Pl. 31B.)

Character.—The Whitesburg throughout most of its extent in Virginia is a dark-gray, medium coarsely crystalline, or mostly fragmental, generally somewhat thin-bedded to shaly limestone. It includes some dark-colored to black shale. Locally it contains, or is perhaps largely composed of, highly earthy rock that weathers to a reddish or tawny shale or clay. This red residual rock occurs in the vicinity

[90] Ulrich, E. O., Ordovician trilobites of the family Telephidae and concerned stratigraphic correlations: U. S. Nat. Mus. Proc., vol. 76, art. 21, 1930.

[91] Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, pp. 445-447, 1905.

of Harrisonburg where it is exposed in a cut on the Lee Highway (U. S. Route 11) 1 mile northeast of town. It stains the soil conspicuously red in the fields within a radius of 2 or 3 miles around Harrisonburg. The rotten tawny rock occurs in the belt mapped as Athens extending from Kerrs Creek, northeast to Zack, Rockbridge County. At Whitesburg, Tennessee, highly nodular layers appear in the lower part and very compact, drabbish, fossiliferous layers, each a few inches thick, occur in the upper part. The Whitesburg is highly fossiliferous in places, having yielded about 175 species of fossils. Some layers could be regarded as almost a coquina, being composed of fragments of trilobites, crinoids, and bryozoans, with entire specimens of brachiopod shells and carapaces of ostracodes. Its general appearance and its relations to, and its striking contrast with, the Holston limestone are illustrated in Plate 31B.

Distribution.—The best development of the Whitesburg in Virginia is in the Rich Valley belt between Clinch and Walker mountains, Smyth and Bland counties, and 1 mile west of Lexington, Rockbridge County. It is best known at the Porterfield quarry and at the Grayson farm 4 miles southwest of Bland, and is supposed to be continuous between those points. It is well developed and highly fossiliferous near the old Liberty Hall, 1 mile west of Lexington.[92] The maximum development of Whitesburg evidently took place along a belt extending southwest in the strike of Rich Valley. Its northernmost known occurrence is in the vicinity of Harrisonburg, but a bed of Whitesburg character occurs near the mouth of Narrow Passage Creek, 3 miles south of Woodstock, and it probably occurs in the strips of Athens west of Woodstock and southwest, near Broadway, Rockingham County. So far as known, the Whitesburg does not extend into the region northwest of Clinch Mountain.

The entire distance from Whitesburg, Tennessee, to Harrisonburg, Virginia, through which the Whitesburg limestone is known, is about 300 miles. From Whitesburg to Pratts Ferry, Bibb County, Alabama, the Whitesburg has not been recognized. It probably occurs at places, but has not been recognized through lack of search in that area.

Thickness.—At Whitesburg, Tennessee, the type locality, the Whitesburg has its maximum known thickness of 500 feet.[93] Its greatest known thickness in Virginia is 75 feet at the Grayson farm. At the Porterfield quarry, it is about 50 feet thick and at Cedar Grove Church, 2 miles east of Harrisonburg, it is 20 feet thick. Elsewhere in Virginia its thickness ranges from 10 to 50 feet.

---

[92] Bassler, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. II-A, p. 110, 1909.
[93] Ulrich, E. O., op. cit., p. 2.

Fossils and correlation.—According to Ulrich the fauna of the Whitesburg consists of about 175 species, but only a few have been described and published. A number of brachiopods have been described by Willard[94] and the genus of trilobites, *Telephus,* has been fully described by Ulrich.[95] Bassler published a list of fossils from the bed 1 mile west of Lexington.[96] Ulrich has worked over all the extensive collections in the National Museum and distinguished all the different forms. A partial list comprising the most diagnostic genera and species so far as published follows:

TABLE 7.—*Partial list of fossils of the Whitesburg limestone*

	1	2	3	4	5	6
Sponges:						
Receptaculites sp		x				
Cystids:						
Echinosphaerites cf. E. aurantium (Gyllenhal)			x			
[a]Bryozoa:	x	x	x	x	x	x
Arthroclema						
Chasmatopora						
Eridotrypa						
Glauconome						
Graptodictya						
Mesotrypa						
Nicholsonella						
Pachydictya						
Rhinidictya						
Brachiopods:						
Camarella, 2 or 3 sp	x	x	x			
Conotreta, 2 sp	x	x	x	x	x	x
Dinorthis, aff. D. pectinella? (Emmons)			x			
Glyptorthis cf. G. bellarugosa (Conrad)		x				
Hebertella, several sp	x	x	x	x	x	x
Leptaenisca? 2 sp	x	x	x	x	x	x
Leptellina elegantula Butts, n. sp						
Lingula, 2 sp	x	x	x	x	x	x
Multicostella whitesburgensis Butts, n. sp			x			
Orbiculoidea, 2 sp			x	x		
Oxoplecia, 2 sp	x	x	x	x	x	x
Pseudocrania? sp			x			
[b]Ptychoglyptus, aff. P. virginiensis Willard						
Ptychoglyptus pulchrus (Butts)				x		

1. Albany, Greene County, Tenn.
2. Grayson farm, 4 miles southwest of Bland, Bland County, Va.
3. 1 mile west of Lexington, Rockbridge County, Va.
4. Pratts Ferry, Bibb County, on Cahaba River, 37 miles south-southwest of Birmingham, Ala.
5. Thomas farm, 3 miles northeast of Blacksburg, Montgomery County, Va.
6. Whitesburg, Hamblen County, Tenn.

[a] Several species of each genus at all localities.
[b] At several localities in Virginia.

[94] Willard, Bradford, The brachiopods of the Ottosee and Holston formations of Tennessee and Virginia: Harvard Coll., Mus. Comp. Zoology Bull., vol. 68, no. 6, 1928.

[95] Ulrich, E. O., Ordovician trilobites of the family Telephidae and concerned stratigraphic correlations: U. S. Nat. Mus. Proc., vol. 76, art. 21, 101 pp., 1930.

[96] Bassler, R. S., Cement resources of Virginia: Virginia Geol. Survey Bull. II-A, p. 119, 1909.

TABLE 7.—*Partial list of fossils of the Whitesburg limestone—Continued*

	1	2	3	4	5	6
Rafinesquina aff. R. alternata (Emmons)	x	x	x	x	x	x
Rafinesquina aff. R. minnesotensis (Winchell)	x	x	x	x	x	x
Rafinesquina 2 other species	x	x	x	x	x	x
Scenidium? 3 sp		x				
[c]Schizambon sp		x				
Sowerbyella?, 5 sp	x	x	x	x	x	x
Strophomena, sp	x	x	x	x	x	x
Trematis aff. T. terminalis (Emmons)		x		x		
Valcourea, 4 sp.?			x			
Pelecypods:						
Clionychia sp			x			
Conocardium sp		x				
Ctenodonta, 2 sp		x	x			
Cyrtodonta sp						
Vanuxemia sp						
Gastropods:						
Archinacella, 4 sp		x	x		x	
Bucania sp		x	x			
Clisiospira, 3 sp						
Holopea, 2 sp		x	x			
Liospira sp		x	x		x	
Oxydiscus sp		x				
Scenella, 2 sp		x	x			
Sinuites sp		x	x			
Tetranota, 2 sp		x	x			
Cephalopods:						
Cameroceras sp						
Dawsonoceras sp		x				
Endoceroids, 2 sp			x			
Orthoceras sp		x				
Trilobites:						
Acrolichas aff. A. minganensis (Billings)			x			
Amphilichas, fragments of other sp						
Ampyx camurus Raymond		x	x		x	
Ampyxina sp			x	x		
Arthrorhachis elspethi Raymond	x	x	x	x	x	x
Bronteopsis gregaria Raymond	x	x	x	x	x	x
Bumastus longiops Raymond					x	
Bumastus, several other sp						
Ceratocephala sp		x	x	x		
Ceraurinus glabrus Butts			x	x		x
Ceraurus granulosus Raymond and Barton			x		x	
Ceraurus, 2 other sp						
Cybeloides sp						
Cyphaspis sp		x	x			
Glaphurus latior Ulrich		x		x		
Heliomera sp		x		x		
Homotelus obtusus (Hall)			x		x	

1. Albany, Greene County, Tenn.
2. Grayson farm, 4 miles southwest of Bland, Bland County, Va.
3. 1 mile west of Lexington, Rockbridge County, Va.
4. Pratts Ferry, Bibb County, on Cahaba River, 37 miles south-southwest of Birmingham, Ala.
5. Thomas farm, 3 miles northeast of Blacksburg, Montgomery County, Va.
6. Whitesburg, Hamblen County, Tenn.

[c] Also at several other localities.

TABLE 7—*Partial list of fossils of the Whitesburg limestone—Continued*

	1	2	3	4	5	6
Homotelus, several other sp.						
Illaenus protuberans Raymond					x	
Proetus, 4 sp.		x				
Pseudosphaerexochus, 2 sp.		x	x	x		
Pterygometopus cf. P. annulatus Raymond	x	x	x	x	x	x
Pterygometopus, several other sp.?						
Remopleurides aff. R. canadensis Billings		x	x	x		
Sphaerexochus parvus Billings	x	x	x	x	x	x
Sphaerocoryphe sp.		x	x			
Telephus bicornis Ulrich		x				
Telephus bilunatus Ulrich	x					
Telephus bipunctatus Ulrich			x	x		
Telephus gelasinosus Butts				x		
Telephus impunctatus Ulrich	x			x		
Telephus prattensis Ulrich				x		x
Telephus pustulatus Ulrich	x		x			
Telephus sinuatus Ulrich		x	x			
Ostracodes:						
Aparchites, 6 sp.	x	x	x	x	x	x
Eurychilina, 5 sp.	x	x	x	x	x	x
Leperditella sp.						
Leperditia sp.	x	x	x	x	x	x
Primitia, 4 sp.		x				
Schmidtella? sp.		x				

1. Albany, Greene County, Tenn.
2. Grayson farm, 4 miles southwest of Bland, Bland County, Va.
3. 1 mile west of Lexington, Rockbridge County, Va.
4. Pratts Ferry, Bibb County, on Cahaba River, 37 miles south-southwest of Birmingham, Ala.
5. Thomas farm, 3 miles northeast of Blacksburg, Montgomery County, Va.
6. Whitesburg, Hamblen County, Tenn.

It is to be noted that so far the genus *Telephus* is unknown in the Holston limestone and makes its appearance in the Whitesburg and, through the wide distribution of its species, indicates the continuity of the Whitesburg sea and deposits from Harrisonburg, Virginia, to Pratts Ferry, Alabama. The same is true of such species as *Arthrorhachis elspethi, Ceraurinus glabrus, Glaphurus latior, Bronteopsis gregaria, Trematis* aff. *T. terminalis,* the unnamed species of *Conotreta,* species of the genus compared with *Leptaenisca,* and species of the highly characteristic genus *Ptychoglyptus.* The species of *Telephus* may be regarded as index fossils of the Whitesburg, and *Arthrorhachis elspethi* and *Bronteopsis gregaria* are highly characteristic of it. One or more of them can be found at nearly every exposure of the formation in Virginia; however, an agnostid similar to *A. elspethi,* or identical with it, has been etched from the Chambersburg limestone collected near Strasburg, Shenandoah County.

ATHENS FORMATION

Name.—The Athens shale was named by Hayes[97] from Athens, McMinn County, Tennessee.

Limits.—In all areas in Virginia where the Holston limestone and Athens are both present the Athens shale, so far as known, is underlain by the Whitesburg limestone. (See Pl. 29A.) In Rich Valley, 3 miles southeast of Saltville, the Athens lies upon the Lenoir limestone for an unknown distance but certainly for only a few miles. (See Pl. 28B.) Southeast of Walker Mountain, except in a few known small areas where a thin Whitesburg is present, the Athens immediately succeeds the Lenoir limestone. In Rich Valley the Athens is overlain by the Ottosee limestone, and the Tellico sandstone which normally succeeds the Athens in Tennessee is absent. In Shenandoah, Rockingham, Montgomery, and Pulaski counties, the Athens is overlain by the Chambersburg limestone. (See Pls. 30C and 32A.)

Character.—The Athens formation has three distinct facies in Virginia; gray to black shale, sandstone, and limestone. The name Athens shale, though not at all applicable to this variable unit, is widely used for this formation because it is predominantly a shale and because through long use the name has become firmly established.

Even in areas where the limestone or sandstone facies prevails, a greater or less thickness of black shale comprises the lower part of the Athens. In the vicinity of Harrisonburg, where the limestone facies is at a maximum, a thin shale with limestone layers occurs at the bottom. At, and northeast of Galena, Augusta County, a large area of pink-banded gray shale comprises the lower 500 feet of the Athens. This banding is parallel to the bedding and represents original differences in sedimentation. The upper 500 feet of the Athens on the North Fork of Roanoke River, on the west base of Paris Mountain east of Blacksburg, consists of another type of shale—a bluish-gray, compact clay rock weathering to a rusty, yellowish to silvery gray color. Another extraordinary local feature of the shale facies of the Athens is a coarse conglomerate in the black shale which occurs 1 mile north of Fincastle, Botetourt County. The bed appears to be about 50 feet thick. The pebbles are of well-rounded quartzite, some of which are 6 inches in diameter. (See Pl. 28A.) This conglomerate is of comparatively small extent in the Pine Hills north of Fincastle. Stow[98] has recently described it as an alluvial cone deposited on the bottom of the Athens sea off the mouth of a river with steep gradient and torrential current which

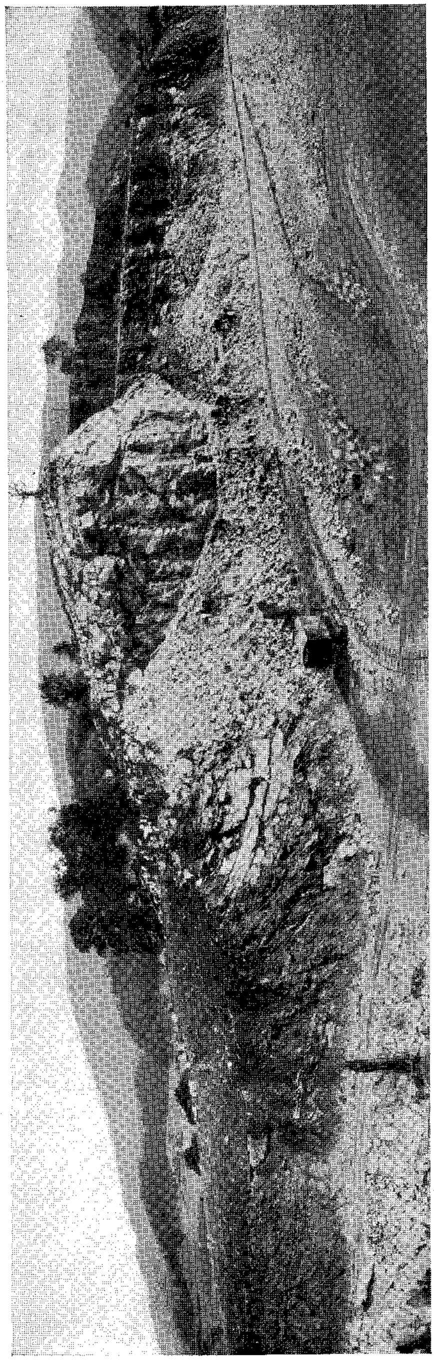
[97] Hayes, C. W., U. S. Geol. Survey Geol. Atlas, Kingston folio (No. 4), p. 2, 1894.
[98] Stow, M. H., and Bierer, J. C., Some significance of an Athens conglomerate near Fincastle, Virginia (abstract): Virginia Acad. Sci. Proc., 1936-1937, p. 71, 1937.

PLATE 31

A. Chambersburg limestone (left) and Martinsburg shale near Strasburg, Shenandoah County. The upper thick beds of limestone carry *Christiania trentonensis* and constitute the *Christiania* zone of the Chambersburg. Just below the *Christiania* bed is the rubbly and blocky limestone of the ordinary Chambersburg. The occurrence of *Cryptolithus tessellatus* and *Diplograptus amplexicaulis* in the shale above the uppermost layer of limestone proves the Trenton age of the shale. There are several thin layers of bentonite in the *Christiania* bed and in the Trenton beds. Along the Lee-Jackson Highway (U. S. 11) at the curve about one-fourth of a mile southwest of Tumbling Run, and 1½ miles southwest of Strasburg. Looking northeast.

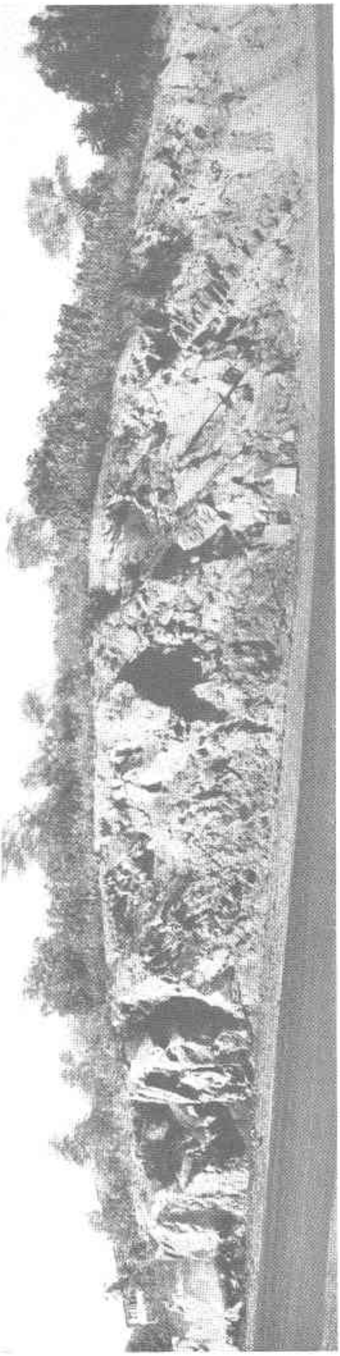
B. Holston, Whitesburg, and Athens formations in the quarry of the Mathieson Alkali Works at Porterfield, 5 miles east of Saltville, Smyth County. Photograph taken in 1932. Looking southeast. The limestone (white) in the middle is the Holston used in the Alkali Works. This limestone dips to the right beneath the Whitesburg dark-colored shale and limestone. Just beyond the steam shovel is a transverse fault on which the Holston is thrust up against and above Whitesburg at the left of the steam shovel. In the lower left corner the Holston dips beneath this body of Whitesburg. The outcrops are repeated as a consequence of the fault. The Athens limestone is exposed in the face above the bench at the right. (See Pl. 29A.)

A

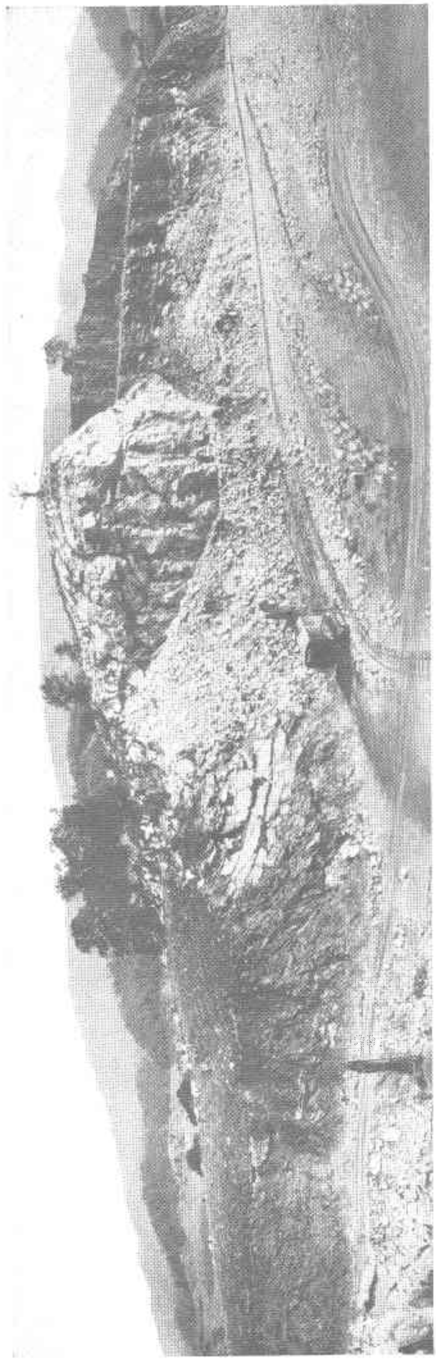


B

ORDOVICIAN FORMATIONS

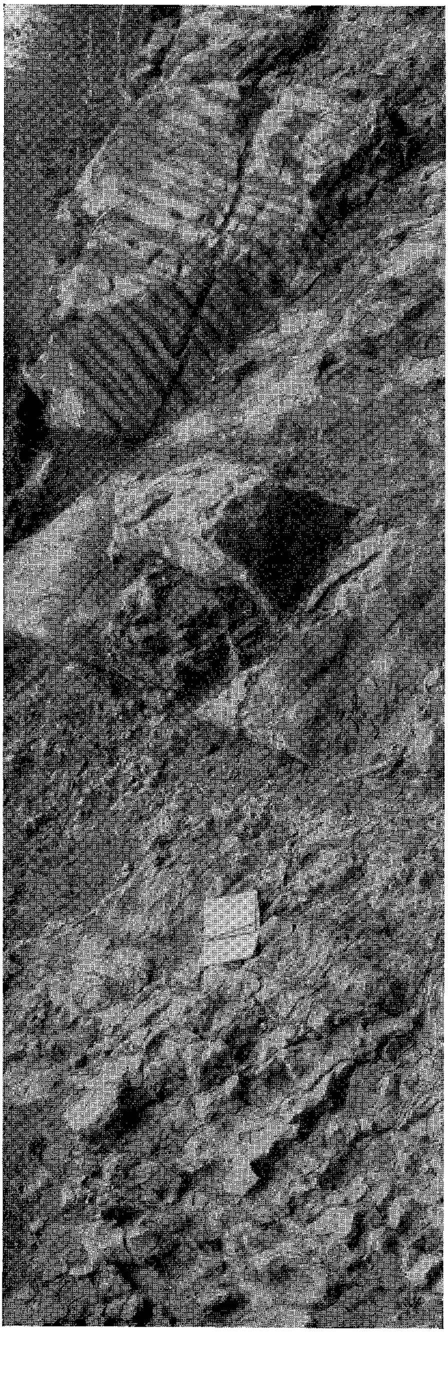


A

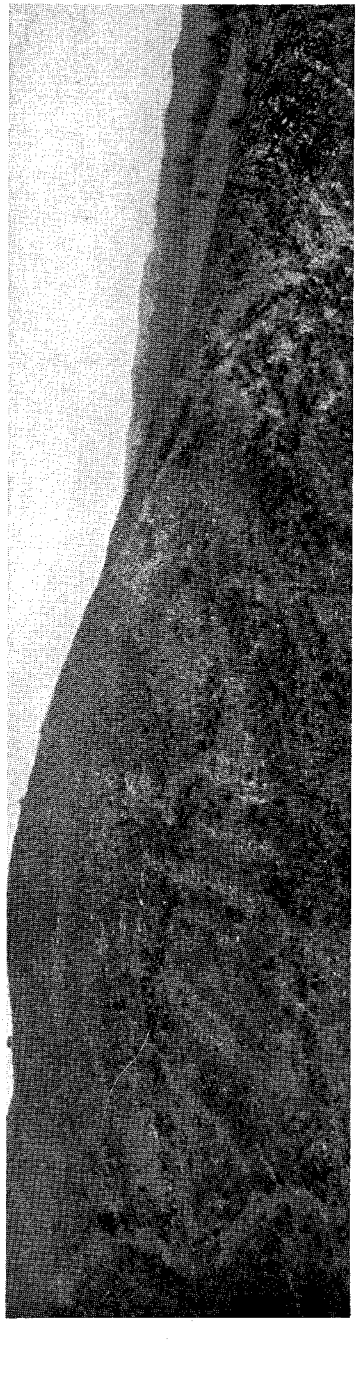


B

ORDOVICIAN FORMATIONS

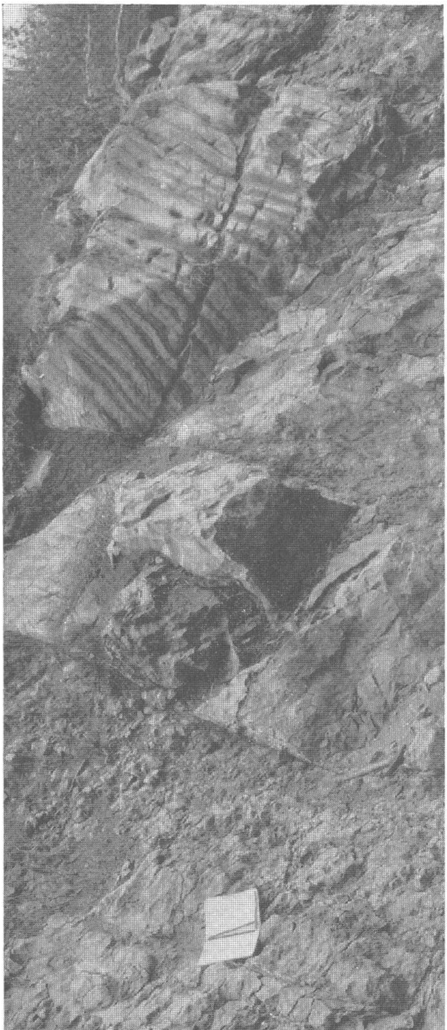


A

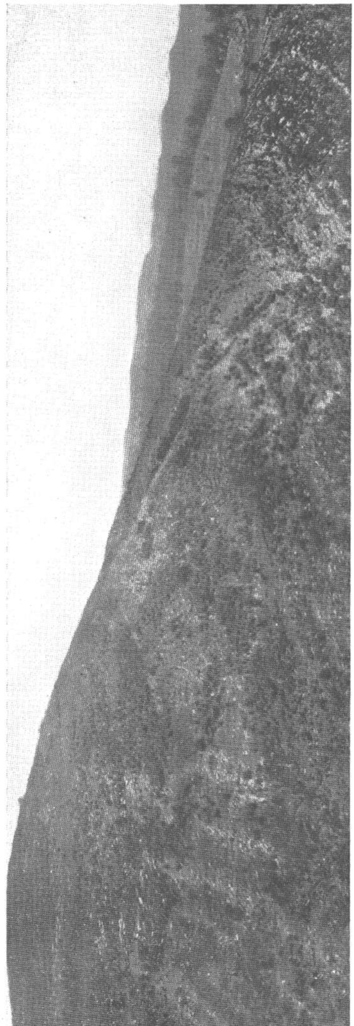


B

ORDOVICIAN LIMESTONES



A



B

ORDOVICIAN LIMESTONES

PLATE 32

A. Chambersburg cobbly limestone (left) underlain by banded Athens limestone in Rockbridge County. The hammer is on the contact. The dip is to the northwest on the southeast limb of a minor syncline. The hiatus at this contact is the same as that indicated on Pl. 30C. Cut along State Route 251, on Collier Creek, 6 miles southwest of Lexington.

B. Lowville limestone southeast of Rose Hill, Lee County. On the northwest slope of Wallen Ridge 6 miles southeast of Rose Hill, just south of Powell River in Tennessee. Looking southwest.

had its headwaters to the southeast where only was there a source of the quartzite gravel.

On long-weathered outcrop the black color of the Athens shale fades to dark gray, pale gray, and finally to yellow or reddish. The unweathered shale is firm, moderately fissile, and generally cleaves into good-sized plates or slabs. Though mainly composed of clay, the shale contains a small amount of lime as shown by feeble effervescence with acid. At Lexington the Athens shale is calcareous and contains beds of limestone of considerable thickness. It there seems to be transitional between the shale and the limestone facies, for on Colliers Creek, 7 miles southwest of Lexington, only the limestone is present. (See Pls. 30B and C, and 32A.) Probably the shale facies grades laterally into the limestone facies seaward (west) and into the sandstone facies toward the ancient shores.

The limestone facies where completely developed and prevailing through nearly the full thickness of the Athens is composed of a rock of very distinctive and unmistakable characters. It is densely black, very fine grained, and breaks with a conchoidal fracture. It is commonly evenly thin bedded and in layers 2 to 6 inches thick (Pls. 29A and 30B), but in some areas, as in the vicinity of Harrisonburg, layers as much as 2 feet thick are common. (See Pl. 27A.) In some areas the limestone is very evenly interbedded with black shale and on weathering presents a strikingly banded appearance as shown in Plate 32A. Locally the limestone and shale facies of the Athens are interbedded, as illustrated by the following section:

Geologic Section 35.—West base of Paris Mountain, 3½ miles due east of Blacksburg, Virginia

	Thickness Feet
Lowville-Moccasin formation	
8. Red shale	
7. Sandstone	50
Athens formation (1650 feet)	
6. Shale, bluish, weathering yellowish and silvery; graptolites rare	500
5. Not exposed	100
4. Limestone, black, compact, conchoidal fracture, typical limestone facies	220
3. Shale, black, with graptolites	160
2. Not exposed, probably all black shale	450
1. Shale, black; graptolites abundant	220

Whitesburg limestone?
May be present and thin.

Lenoir limestone
Limestone

The only other limestone in the Valley in Virginia that at all resembles that of the Athens is the Chambersburg, and where the two are in contact, as they are in large areas, their separation is difficult except where the contact is well exposed. (See Plates 30C and 32A.)

The sandstone facies of the Athens is a combination of shale and sandstone without limestone, with shale both below and interbedded with the sandstone. A good display of this facies is in the Great Knobs along State Route 77, 2½ miles south of Abingdon. An approximate section is as follows:

Geologic Section 36.—Sandstone facies of the Athens formation, south of Abingdon, Virginia

	Thickness Feet
Athens formation (1595 feet)	
7. Sandstone, thick bedded, coarse grained, arkosic, gray; shale partings with graptolites, *Dicellograptus* common (Pl. 30A) estimated	500
6. Not well exposed; only shale showing; probably all shale	400
5. Sandstone as in bed 7	275
4. Not exposed	60
3. Sandstone and shale with graptolites; sandstone medium grained, bluish gray, weathering greenish brown	90
2. Shale, black, with graptolites	270
Lenoir limestone	
1. Limestone	20

The shale of this section is of the same character as that of the shale facies of the Athens generally. The sandstone is really an arkose, being composed in large part of quartz and feldspar. The larger quartz grains are well rounded and rather uniformly about 1 millimeter in diameter. The feldspars are angular and some are larger than the quartz grains. Sandstone of this facies of the Athens collected in the wide area east of Bristol[99] is identical in character with that in the Great Knobs, except that some layers are conglomeratic, containing subangular to lenticular pebbles of limestone, quartz, and sandstone. Some pebbles of limestone are more than an inch in diameter. The matrix seems to be arkosic. In this area the essential features of the sequence are the same as in the Great Knobs area—shale with little or no limestone below and shale and sandstone above, but the formation is much thicker here.

Distribution.—The Athens does not extend northwest of Clinch Mountain nor of the line of Clinch Mountain northeast of Burkes Garden, Tazewell County. It is present southeast of this line as far north as Woodstock. Southeast of the Massanutten syncline the Athens extends northward to the West Virginia line. Its outcrop everywhere comprises most of the width of the belts mapped under the symbols Oa, Ooa, and Oawh.[100] In Rich Valley the shale facies of the Athens persists from the small area 4 miles west of Meadow View, Washington County, northeastward to the Porterfield quarry where the lower 50 feet at least consists of limestone. (See Pl. 29A.) At the Grayson farm (4 miles southwest of Bland), it is mainly limestone. Its northeastern extent in this belt is unknown, but it is not present on New River and must thin out beyond Bland. In the belt southeast of Walker Mountain, it persists northeastward at least to Broadway, Rockingham County.[101] On the belt next northwest of Massanutten Mountain, the Athens certainly is present as far north as New Market and probably thins out between New Market and Narrow Passage Creek 3 miles south of Woodstock, where apparently the Whitesburg limestone is immediately overlain by the Chambersburg limestone.

The shale facies of the Athens prevails in the Catawba belt; in the wide area north of Fincastle, Botetourt County; in the belt north of Roanoke; at Lexington; and in the belt a mile east of Staunton. Virtually all of the wide area of Athens north of Harrisonburg is underlain by the limestone facies. (See Pl. 27A.)

The limestone facies seems to prevail in Crocketts Cove north of Wytheville, in the Draper Mountain area south of Pulaski, and on Colliers Creek 7 miles southwest of Lexington. Limestone and

[99] Mapped as Tellico sandstone by Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), 1899.

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

[101] It is shown on the geologic map as extending to Fairview 4 miles northwest of Woodstock, but in the general area northeast of Broadway, the Chambersburg limestone is present and possibly its lower part has been mistaken for Athens which has not been positively identified north of Broadway.

shale are about equal constituents of the formation in the Marion area; in the fenster between Wytheville and Max Meadows; in the vicinity of Broadway; and on the southeast flank of Massanutten Mountain.

The sandstone facies of the Athens occurs only in the Great Knobs south of Abingdon and in all the synclinal areas in southern Washington County and southward into northern Tennessee. The only other area of this facies is that of Pine Ridge extending from Wytheville southwest to a point about north of Rural Retreat. In this strip the sequence is the same as in the Great Knobs—thick-bedded arkosic sandstone above and black graptolitic shale below.

The best exposures of the shale facies are in the southern part of Rich Valley in the vicinity of Gieslers Mill; at the old quarries of the Mathieson Alkali Works, 3 miles southeast of Saltville (Pl. 28B); in the valley of the North Fork of Roanoke River east of Blacksburg; in the vicinity of Hollins College and Cloverdale north of Roanoke; in a large area north of Fincastle; at Lexington; and in the vicinity of Staunton.

The limestone facies is well shown in the Porterfield quarry (Pl. 29A); at the Grayson farm southeast of Bland; along the Lee Highway for 2 miles southwest of Marion; in Crocketts Cove along the road from Wytheville to Bland; at the Collier Creek locality (Pl. 30B and C); and northward from Harrisonburg where, in an area 6 miles wide, the crumpled Athens is largely exposed in one of the largest and finest exposures of limestone in the State.

The best exposures of the sandstone facies are in the Great Knobs on State Route 77, 3 miles southeast of Abingdon; and just south of the State line in Tennessee on U. S. Route 421, where the Athens is almost continuously exposed across the strike for a distance of 4 miles.

The areal distribution of the different facies of the Athens indicates that they are roughly aligned so that the limestone facies lies to the northwest, the sandstone facies to the southeast, and the shale and part-shale facies lies between the other two facies. This would be the natural arrangement of the depositional facies of sediments derived from the Piedmont areas to the southeast.

Thickness.—The thickness of the Athens varies from a few feet on its western margins to perhaps 5000 to 10,000 feet in the large area in southern Washington County, Virginia, and northern Sullivan County, Tennessee. It must thin out in Rich Valley between Bland and New River and on its northwestern margin generally. In the general area covered by this report the thickness seems to range from 200 feet or less to about 4000 feet.

Fossils and correlation.—The fossils of the Athens are mainly graptolites, brachiopods, and trilobites. The graptolites have been described by Ruedemann.[102] Though Ruedemann's descriptions were mainly of material from New York, many of the same species occur in Virginia and in Alabama, and some specimens from Alabama are figured. Several species of Athens trilobites from Virginia have been described by Raymond[103] and by Ulrich.[104] The brachiopods, which are scarce, have not been described.

The more important forms are listed below.

Partial list of fossils of the Athens formation

Sponges
- Receptaculites sp.

Cystids
- Echinosphaerites cf. E. aurantium (Gyllenhal)

Graptolites
- Climacograptus bicornis (Hall)
- Climacograptus parvus Hall
- Climacograptus scharenbergi Lapworth
- Dicellograptus divaricatus (Hall)
- Dicellograptus moffatensis alabamensis Ruedemann
- Dicellograptus sextans (Hall)
- Dicellograptus smithi Ruedemann
- Dicranograptus nicholsoni var. parvangulus Gurley
- Dicranograptus ramosus (Hall)
- Diplograptus foliaceus (Murchison)
- Glossograptus ciliatus Emmons
- Nemagraptus gracilis (Hall)

Brachiopods
- Clitambonites? sp.
- Dalmanella or Paurorthis sp.
- Dinorthis or Hebertella sp.
- Leptobolus sp.
- Lingula, 2 sp.
- Oxoplecia? sp.
- Ptychoglyptus sp.
- Trematis? sp.

---

[102] Ruedemann, Rudolph, Graptolites of New York, pt. 1, Graptolites of the lowest beds: New York State Museum Mem. 7, 1904; Graptolites of New York, pt. 2, Graptolites of the higher beds: idem, Mem. 11, 1908.

[103] Raymond, P. E., Some trilobites of the lower middle Ordovician of eastern North America: Harvard Coll. Mus. Comp. Zoology, vol. 67, no. 1, 1925.

[104] Ulrich, E. O., Ordovician trilobites of the family Telephidae and concerned stratigraphic correlations: U. S. Nat. Mus. Proc., vol. 76, art. 21, 101 pp., 1930.

Gastropods
- Eccyliopterus sp.
- Lophospira sp.
- Sinuites sp.

Trilobites
- Ampyx americanus Safford and Vogdes
- Ampyx, 2 sp.
- Ampyxina scarabeus Butts, n. sp.
- Arthrorhachis? sp.
- Ceraurus cf. C. tenuicornis Raymond
- Dionide contrita Raymond
- Dionide holdeni Raymond
- Encrinurus sp.
- Pterygometopus sp.
- Raphiophorus powelli Raymond
- Robergia major Raymond
- Telephus latus Ulrich
- Telephus spiniferus Ulrich
- Tretaspis reticulata Ruedemann
- Triarthrus caecigenus Raymond

The most important fossils of this list for correlation are the graptolites. Nearly every species listed occurs in the Normanskill shale of the Albany district, New York, and in black shale in the Cahaba Valley in Shelby and Bibb counties, Alabama, at the south end of the Appalachian Valley. Many or most of them occur in Quebec, Wales (Rorrington black flags), Scotland (Glenkiln shale), Scandinavia, and Australia. Being floating animals they were transported almost simultaneously to all parts of the earth so that their presence is regarded as one of the best evidences of contemporaneous deposition and of formational correlation. The Athens shale is substantially of the same age as the Normanskill shale of New York and the Glenkiln shale of southern Scotland. These widespead contemporaneous graptolitic beds are known as the *Nemagraptus* zone because of the ubiquitous presence of the characteristic graptolite *Nemagraptus gracilis*.[104a]

Too little is known about the brachiopods and gastropods of the Athens to justify any further statements about them. The trilobites listed are confined to the Athens in Virginia and, so far as known, have not been recorded elsewhere, although other species of *Telephus* occur in the Athens of Alabama and doubtless some or all of those listed occur in the Athens of Tennessee. As with

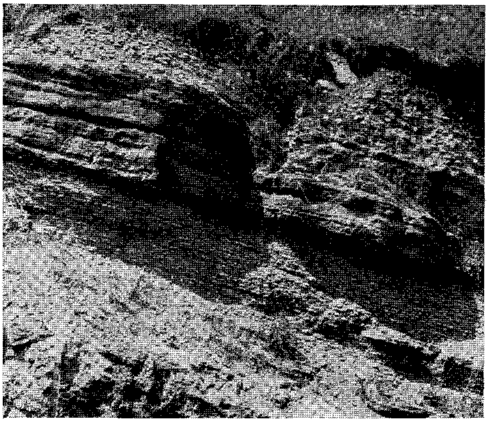
[104a] Diagnostic species are illustrated in Part II.

PLATE 33

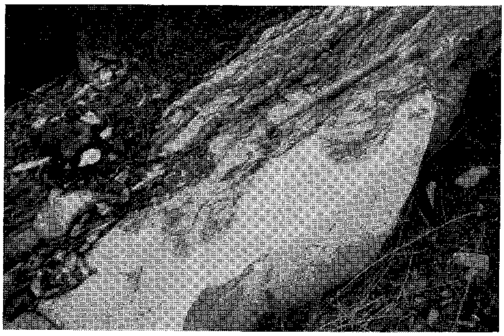
A. Nodular Ottosee limestone in Russell County. Such nodular beds are especially characteristic of the Ottosee. Along U. S. Route 19 on Little Indian Creek, about 1 mile north of Belfast Mills. Looking northeast.

B. Irregular contact of the Mosheim limestone (below) and the nodular Lenoir limestone. This kind of contact of the two formations has been observed at several places in the Valley through a distance of several hundred miles. In a quarry about 1 mile east of Staunton, Augusta County.

C. Contact, shown by hammer, of the Martinsburg shale (right) with the Wills Creek shale and sandstone (Silurian). The Tuscarora sandstone, Clinton formation, McKenzie shale, and Bloomsburg sandstone are absent. Along U. S. Route 50 near Chambersville, 4½ miles west of Winchester, Frederick County. Looking north. (See Plate 35A.)



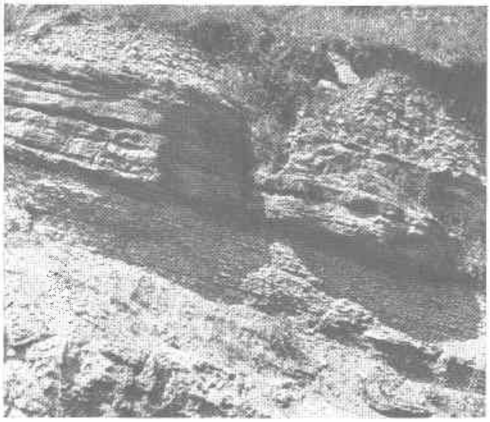
A



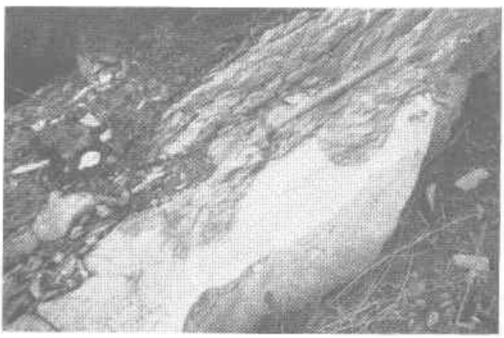
B

C

ORDOVICIAN AND SILURIAN FORMATIONS



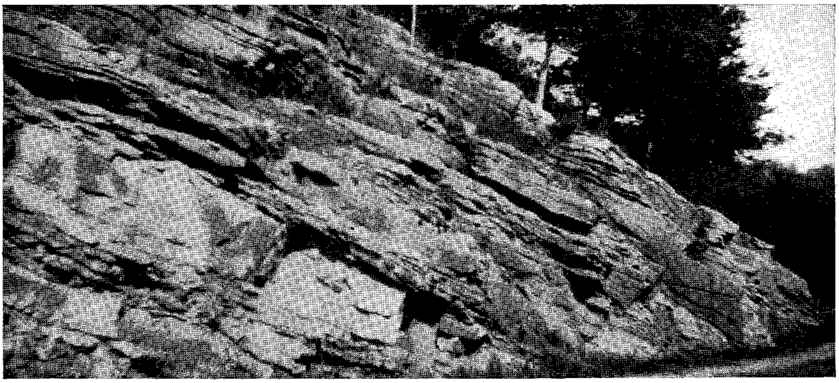
A



B

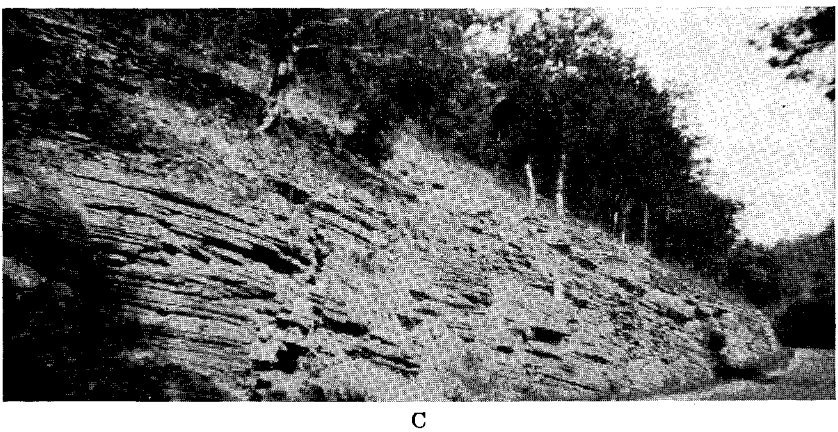
C

Ordovician and Silurian Formations



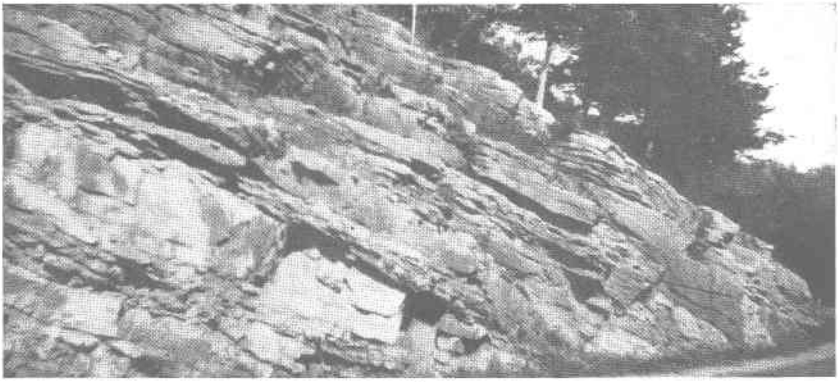
A

B

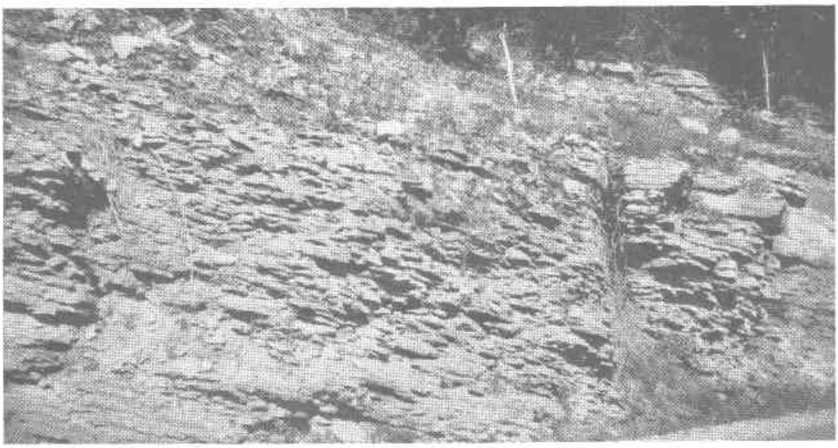


C

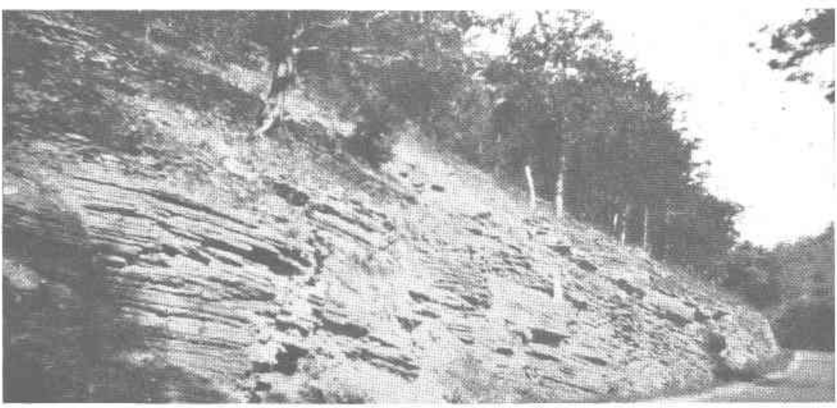
ORDOVICIAN LIMESTONE



A



B



C

ORDOVICIAN LIMESTONE

PLATE 34

A. Limestone in the upper part of the Ottosee; an alternation of thin and thick beds. Along U. S. Route 19, about one-fourth of a mile northwest of Little Moccasin Gap, through Clinch Mountain, Russell County. Looking northeast.

B. Ottosee limestone. Thin-bedded limestone between that shown in A and that shown in C. Looking northeast.

C. Lower part of the Ottosee, consisting of evenly thin-bedded limestone. Same locality as A. Looking northeast.

the graptolites, any of the diagnostic trilobites figured are likely to be found in either the shale or limestone facies of the Athens and are equally good indices of that formation. *Robergia, Dionide,* and *Ampyxina* are especially diagnostic.

HIATUS

In the type region of the Blount group, in Blount County, Tennessee, the Athens is absent. The next formation in the sequence is the Tellico sandstone. Farther southwest, in McMinn and Bradley counties, and at the type locality, the Athens is directly overlain by the Tellico, so that the normal sequence is established. In these areas the Sevier shale, which is partly represented by the Ottosee limestone in Virginia, everywhere succeeds the Tellico. As the Tellico is absent in Virginia its place in the stratigraphic sequence is represented by a hiatus between the Athens and Ottosee.

OTTOSEE LIMESTONE

Name.—The Ottosee was named by Ulrich[105] from Lake Ottosee in Chilhowee Park, Knoxville, Tennessee. The name was first published by Ulrich, though without definition, in 1911. Ottosee was proposed to obviate the confusion resulting from misidentification of formations and misuse of the name Sevier in the northwestern half of the Appalachian Valley. The Sevier of the type locality in Tennessee is actually Ottosee, but the name had been misapplied in many publications, such as folios of the U. S. Geological Survey and State reports and maps, to the Martinsburg shale which is a much younger formation than the Ottosee (Sevier). In Virginia the so-called Sevier shale of the Estillville, Bristol, Tazewell, and Pocahontas folios is really the Martinsburg shale, and the Ottosee, or true Sevier, is included in the Chickamauga limestone of those folios. The same is true of the belts northwest of Clinch Mountain in the Morristown, Maynardville and Knoxville quadrangles, Tennessee, where the Martinsburg shale is mapped as Sevier and the true Sevier (Ottosee) is included in the Chickamauga. In the area southeast of Clinch Mountain in these same folios, the Sevier is the Ottosee, and the name Sevier has thus been given to two different formations on these maps.

Limits.—Normally the Ottosee is limited below by the Tellico sandstone and above by the Lowville-Moccasin (Bays) lime-

[105] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 453, 551, 1911.

stone, but in Virginia the Ottosee is bounded below by the Athens shale in Rich Valley and generally southeast of Clinch Mountain; by the Holston limestone in the two belts next northwest of Clinch Mountain; and by the Lenoir limestone still farther northwest, as in Rye Cove, Scott County, and at the south base of Big A Mountain in Russell County. Locally the boundary between the Holston and Ottosee is difficult to detect owing to the lithological similarity of the basal Ottosee to the typical Holston. The best example of such a sequence is in Clinch Valley 2 miles southwest of Blackford, Russell County, where the lower 50 feet of the Ottosee is a thick-bedded, reddish marble closely simulating typical Holston marble, and lies upon the thick-bedded gray Holston which prevails in Virginia. (See Pl. 29C.) The criterion for separating the two formations in such occurrences is the general occurrence of a peculiar fossil, *Nidulites* cf. *N. pyriformis* Bassler, in the base of the Ottosee in many places where the boundary is plainly marked by a change in lithology. An example of the sequence marked by the occurrence of the *Nidulites* is shown in Plate 35D. It is therefore believed that the occurrence of the *Nidulites* at the base of the marble in Clinch Valley also indicates that the marble is in the Ottosee formation.

Character.—The Ottosee is composed of limestone in beds of rather diverse character. The limestones are rather thin bedded, bluish, coarse grained, shelly, or fragmental, composed largely of the fragments of shells but including many entire fossils. Its general character in its unweathered condition is shown on Plate 34. Massive beds that are essentially of the same composition, texture, and thickness as the Holston limestone occur over extensive areas. (See Pl. 36C.) Such a bed, about in the middle of the formation, is of wide extent but is not coextensive with the formation. (See geologic section 37.) At least four localities have beds of reddish marble similar to the Holston marble of Tennessee. (See Pl. 29C.) The most characteristic beds of the Ottosee, however, are composed of an infinite number of small nodules of limestone, an inch or two in diameter, loosely held together by a matrix of yellow clayey material that coats the nodules. (See Pl. 33A.) These nodules seem to result from the jointing and weathering of thin layers of limestone with thin partings of calcareous shale. Some of the beds which appear to be massive are essentially nodular, as revealed on weathering. In places the horizon of a nodular bed is conspicuously revealed by a smooth strip of surface in the midst of a wide area with exposed edges of the more massively bedded limestone, as shown in Plate 29C.

The general character of the Ottosee northwest of Clinch Mountain is illustrated by the following sections:

Geologic Section 37.—Ottosee limestone on State Route 80 on the northwest slope of Clinch Mountain, 1 mile south of Rockdell, Russell County, Virginia

	Thickness Feet
Lowville-Moccasin formation	
5. Limestone, blue	
Ottosee limestone (595 feet)	
4. Limestone, yellow, shaly, and nodular, some layers of pure blue limestone 5 feet thick	180
3. Limestone, thick bedded to massive	285
2. Limestone, very nodular	50
1. Limestone, thin bedded	80
Holston limestone	

Geologic Section 38.—Ottosee limestone along U. S. Route 19, just west of Little Moccasin Gap, 10 miles northwest of Abingdon, Virginia

	Thickness Feet
Lowville-Moccasin formation	
8. Limestone, argillaceous, red, several hundred feet	
7. Limestone, pure blue	75
6. Shale, red, thin	2–5
Ottosee limestone (590 feet)	
5. Limestone, evenly thin bedded	185
4. Limestone, thin bedded, nodular	90
3. Limestone, thick and thin bedded (Pl. 34A)	50
2. Limestone, irregularly thin bedded, and shelly above (Pl. 34B), and evenly thin bedded below (Pl. 34C)	215
1. Limestone, shaly, nodular	50
Holston limestone	

Geologic Section 39.—Approximate section of the Ottosee limestone in Rye Cove, 8 miles northwest of Gate City, Scott County, Virginia

	Thickness Feet
Lowville limestone	
8. Limestone, pure blue, *Cryptophragmus antiquatus* Raymond, near bottom.	
Ottosee limestone (280 feet)	
7. Limestone shaly, thin layers of limestone	25
6. Limestone, thick bedded	5
5. Limestone, shaly	5
4. Not exposed	30
3. Limestone, rather thick bedded and shaly in alternating layers, estimated	120
2. Limestone, shaly	20
1. Limestone, rather pure, medium thick bedded	75
Lenoir limestone	

In Rich Valley and southeast of Walker Mountain, the lithology is apparently about the same as northwest of Clinch Mountain, as shown in the following section:

Geologic Section 40.—Ottosee limestone in Rich Valley on the northwest slope of Walker Mountain, near U. S. Route 88, 2 miles due south of Chatham Hill, Virginia

	Thickness Feet
Lowville formation	
6. Limestone, blue	
Ottosee limestone (555 feet)	
5. Limestone, thin bedded, shaly, weathers yellow	75
4. Marble, coarsely crystalline, reddish	25
3. Limestone, coarsely crystalline, gray (marble?)	25
2. Limestone, thick bedded, coarsely crystalline, gray	110
1. Limestone, medium bedded	320
Athens shale	

No good sections were found southeast of Walker Mountain.

Distribution.—The most northwestern outliers of the Ottosee limestone are those in Rye Cove 8 miles northwest of Gate City, Scott County, and at the southeast base of Big A Mountain, Russell County. A bed of granular limestone on the northwest slope of Wallen Ridge above the big bend in the road, 6 miles southwest of Big Stone Gap, is also referred to the Ottosee because it carries the Ottosee brachiopod *Oligorhynchia* sp. (See Fossil Plates, Part II.) Northwest of these localities the Blount Group has no representative, and the Lowville limestone directly overlies the Lenoir limestone of the Stones River group.

In the two belts of Holston and Ottosee next northwest of Clinch Mountain, the Ottosee occupies somewhat more than the southeast half of each belt and extends from the Tennessee line as far northeast as Tazewell. It disappears by gradual thinning out between Tazewell and New River and is not known anywhere north of New River. In Rich Valley the Ottosee occupies approximately the southeast half of the mapped belt and is known to extend from the south end of Walker Mountain, marked by Giesler Mill, 1½ miles north of Meadowview, as far north as the Grayson farm 4 miles southwest of Bland. At the Grayson farm it is of considerable thickness and must extend much farther northwest but, like the Ottosee northwest of Clinch Mountain, it does not extend to New River. Southeast of Walker Mountain, the Ottosee is known only on the north side of the Marion anticlinal area and in Crocketts Cove. Five or six miles across the strike east of Crocketts Cove, in the area south of Draper Mountain and south of Pulaski where the horizon of the Ottosee is exposed, the formation is absent and the Athens is directly overlain by the Chambersburg limestone. In the Great Knobs area of Washington County, southeast of Abingdon, the horizon of the Ottosee has been removed by erosion and no evidence as to its southeastward extent exists.

The red marble layers in the Ottosee are known in Clinch Valley 2 miles southwest of Blackford, Russell County; at Rockdell, Russell County; 2 miles south of Chatham Hill, Smyth County; and in Wassum Valley, 4 miles northwest of Marion. The marble is at no constant horizon. In Clinch Valley it is in the bottom part; at Rockdell it is in the middle, being a facies of the thick limestone (geologic section 37, bed 3); 2 miles south of Chatham Hill it is 75 feet below the top (geologic section 40, bed 4); and in Wassum Valley it is about at the top. The local development of such beds of marble is characteristic of the Ottosee throughout Tennessee and many examples could be cited.

The best exposures of the Ottosee are at the localities of the preceding sections, the best being that of geologic section 38.

Thickness.—The thickness of the Ottosee, where best determined, ranges from 280 feet in Rye Cove to 595 feet south of Rockdell. In Clinch Valley 2 miles southwest of Blackford, and in Ward Cove southwest of Snapp, Tazewell County, the thickness is about 400 feet. In Wassum Valley, in the area north of Marion, and in Crocketts Cove, it is about 100 feet thick.

Fossils and correlation.—The Ottosee is very fossiliferous, brachiopods and bryozoa being the most abundant in species and individuals. Algae or sponges (*Receptaculites*), sponges (*Anthaspidella?* and *Zittelella*), corals (*Tetradium* and *Lichenaria*), and cystids (*Platycystites, Echinosphaerites*) are common. The formation is everywhere crowded with fossils in a more or less fragmentary condition, but good collections can be made at only a few localities. The best locality is at Rye Cove, 8 miles northwest of Gate City, Scott County, where the outcrop of the Ottosee, lying nearly flat, occupies several square miles of surface thickly strewn with fragments of limestone and fossils. Fossils are also fairly abundant with fairly good specimens at Speers Ferry railroad station and Gate City. Many places on the general outcrop may be found where the beds are exposed or the surface is strewed with debris, including fossils. Areas underlain by the nodular layers usually yield the most free specimens and afford the best collecting. Fossils are generally abundant in the shelly beds but are so firmly held in the rock that they can not be extracted in a satisfactory condition.

Not many of the Ottosee fossils have been described. In the following list, the most common forms are referred to their genera and a few new specific names are proposed, but it is not within the scope of the present work to describe many new species.

Fossils of the Ottosee limestone, mainly from Rye Cove, Scott County, Virginia[a]

Sponges
- *Anthaspidella? sp.
- Dystactospongia sp.
- Hindia parva? Ulrich
- *Receptaculites sp.
- Receptaculites cf. R. elegantulus Billings
- Receptaculites, 1 or more other species

[a] The more common and diagnostic species are designated by an *.

*Zittelella cf. Z. varians (Billings)

Corals
- Lichenaria cf. L. carterensis (Safford)
- Streptelasma sp.
- *Tetradium sp.

Cystids
- Echinosphaerites cf. E. aurantium (Gyllenhal)
- Platycystites faberi Miller
- Several other species of cystids

Crinoids
- Diabolcrinus asperatus (Miller and Gurley)
- Diabolocrinus perplexus Wachsmuth and Springer
- Palaeocrinus aff. P. striatus Billings

Bryozoa
- *Anolotichia sp.
- Arthroclema sp.
- *Batostoma sevieri Bassler
- Batostoma, 2 other species
- Berenicea sp.
- Bythopora sp.
- Chasmatopora? sp.
- Corynotrypa inflata (Hall)
- Dekayella? sp.
- Eridotrypa sp.
- Escharopora sp.
- Graptodictya sp.
- Mesotrypa sp.
- Mitoclema sp.
- *Monotrypa, 2 sp.
- Pachydictya sp.
- Phaenopora sp.
- *Scenellopora radiata Ulrich
- Stromatotrypa sp.

Brachiopods
- Camarotoechia aff. C. plena (Hall)
- Dinorthis aff. D. pectinella (Emmons)
- *Glyptorthis aff. G. bellarugosa (Conrad)
- Hebertella sp.
- *Hesperorthis aff. H. tricenaria (Conrad)
- *Mimella sp.

*Multicostella aff. M. platys (Billings)
Pionodema sp.
Rafinesquina aff. R. champlainensis Raymond
Rafinesquina aff. R. minnesotensis (N. H. Winchell)
*Rafinesquina magna Butts, n. sp.
Schizambon cuneatus Willard
*Sowerbyella, 2 sp.
*Strophomena amploides Butts, n. sp.
*Strophomena medialis Butts, n. sp.
Valcourea magna Schuchert and Cooper?

Gastropods
Bucania sp.
Cyclonema sp.
Gyronema sp.
Lophospira aff. L. perangulata (Hall)
*Maclurites aff. M. bigsbyi (Hall)
Trochonema sp.

Cephalopods
*Gonioceras sp.
Orthoceras sp.

Trilobites
Amphilichas sp.
*Eoharpes sp.
*Illaenus fieldi Raymond
*Pliomerops canadensis (Billings)
*Pseudosphaerexochus sp.
Pterygometopus sp.
*Sphaerexochus sp.

Many of the species of the preceding list are common in the Ottosee at a fine exposure in a glade on the Morristown-Cumberland Gap road, 1 mile southeast of the bridge over Clinch River (Evans Ferry), Tennessee, and also at Lake Ottosee, Chilhowee Park, Knoxville, Tennessee, the type locality of the Ottosee.

The Ottosee at Lake Ottosee has been recognized by both Keith and Ulrich as belonging in the Sevier shale of the Knoxville, Tennessee, folio, the type locality of which is in Sevier County, 22 miles east of Knoxville. The Sevier has been recognized as far southwest as Charleston, McMinn County, Tennessee, but its extreme southwestern limit has not been determined. It does not occur in Alabama unless it is represented by the Little Oak limestone, but the Little Oak carries no Ottosee fossils although its rather abundant fauna is still distinctly Chazyan in its affinities. Ulrich regards it as younger than the Ottosee. If these correlations are true the Ottosee is confined to the middle belts of Ordovician rocks in northern Tennessee and southern Virginia. However, there is some basis for correlating the Ottosee with the Lebanon limestone of middle Tennessee. That problem is under investigation at present.

HIATUS

In Lee and Highland counties and presumably along the intermediate area in the belt bordering the northwest side of the Valley in Virginia, the Lowville rests upon the Lenoir limestone with an intervening hiatus due to the absence of the Blount group. In Catawba Valley and the vicinity of Roanoke the Lowville rests upon the Athens shale and the hiatus is less. In Frederick County the Lowville itself, in addition to the Blount group, is absent west of the Massanutten syncline and the Chambersburg limestone succeeds the Lenoir limestone. East of the syncline the Athens is present but is thin to the north in Clarke County. Only in the Rye Cove area and in Rich Valley between Walker and Clinch mountains does the Lowville succeed the Ottosee limestone, apparently without a break. No formation is known anywhere to intervene between the Ottosee and the Lowville.

BLACK RIVER GROUP

The Black River group, which received its name[106] from Black River in Jefferson and Lewis counties, New York, comprises in that region the following units named in ascending order: Lowville limestone, including the Leray limestone member at top; Watertown limestone; and, in Montgomery County, N. Y., the Amsterdam limestone. In Virginia only the Lowville-Moccasin and the Chambersburg limestones can be definitely recognized as members of the Black River group, but at the top of the Lowville-Moccasin along the northwest side of the Valley from Lee County to New River, is a persistent bed of argillaceous, shelly, gray limestone that may correspond to the Watertown and Amsterdam limestones and also to the Chambersburg limestone. For this bed the name Eggleston limestone has been proposed by A. A. L. Mathews[107] from its exposure on the east bluff of New River midway between Eggleston and Goodwins Ferry, Giles County.

---

[106] Vanuxem, Lardner, Geology of New York, pt. 3, comprising the geology of the third geological district, p. 38, Albany, 1842.
Hartnagle, C. A., Classification of the geologic formations of the State of New York: New York State Museum Handbook 19, p. 36, 1912.

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

LOWVILLE-MOCCASIN LIMESTONE

Names.—The name Lowville was proposed by Clarke and Schuchert[108] as a geographic substitute for the "Birdseye" limestone, a descriptive name used by the geologists of New York and other states from 1824 to 1900. The hyphenated name, Lowville-Moccasin, is used here because the equivalent of the upper three-fourths of the Lowville in the middle belts of the Valley, as shown on the geologic map, is a red argillaceous limestone or calcareous mudrock facies, which has received the name Moccasin limestone,[109] a name extensively used in southwestern Virginia and northern Tennessee.

Limits.—The Lowville is bounded below by the Lenoir limestone, or by Athens shale, or Ottosee limestone, or locally, by the Holston limestone. It is overlain in some places by the Eggleston limestone; in others by the Trenton limestone or by the Trenton division of the Martinsburg shale. In parts of the Valley a hiatus exists between the Lowville-Moccasin and the Trenton, due to the absence of the Chambersburg limestone which in Franklin County, Pennsylvania, immediately overlies the Lowville. The Chambersburg is present in Virginia, but not in the same regions where the Lowville occurs, unless it is represented by the Eggleston limestone.

Character.—Along the northwestern side of the Valley the Lowville is composed entirely of medium- to thin-bedded, compact, bluish to dove-colored limestone, without any red beds. Locally a few scattered layers of gray, clayey crumbly limestone are found, texturally similar to the red argillaceous layers of the Moccasin facies. This dove-colored limestone, the Lowville limestone proper, constitutes the limestone facies of the Lowville-Moccasin unit. The general character of the Lowville along the northwest side of the Valley in Virginia is illustrated by Plate 35C.

The Moccasin facies is composed of thin- to thick-bedded, red, argillaceous limestone or mudrock. Much of it seems to be wholly clastic and destitute of calcareous matter. Some layers preserve mud cracks and strong rectangular joints. (See Plates 54C and D.) Much of the exposed rock is bright red. Beneath the bright red layers is about 50 to 100 feet of dove-colored limestone in all respects like the limestone facies. This basal dove-colored limestone is absent in Catawba Valley and the Salem-Roanoke areas. Where it is present there is commonly a few feet of the red

[108] Clarke, J. M., and Schuchert, Charles, The nomenclature of the New York series of geological formations: Science, new ser., vol. 10, pp. 874-878, 1899.
[109] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), p. 2, 1894.

argillaceous limestone of the Moccasin facies below it and at some localities scattered red layers within it. This is shown on U. S. Route 19 in Little Moccasin Gap, Russell County. (See geologic sections 38 and 41.)

The composite character of the Moccasin facies in places is illustrated by the following section:

Geologic Section 41.—Moccasin formation on a long northwest spur of Beartown Mountain, 2 miles southwest of Stinson, Russell County, Virginia

	Thickness Feet
Trenton limestone	
9. Limestone, highly fossiliferous.	
Eggleston formation	
8. Limestone (?), argillaceous, crumbly, gray and yellow	30±
Moccasin formation (790 feet)	
7. Limestone or red mudrock	240
6. Limestone, blue and gray, crumbly red layers in middle; contains orthoceroids, gastropods, and ostracodes	70
5. Limestone or red mudrock	150
4. Limestone, blue	120
3. Partly exposed, shows of red mudrock throughout	190
2. Sandstone	20
Ottosee limestone	
1. Limestone, shaly	

The Lowville not only undergoes a change of facies regionally from northwest to southeast, but also vertically from the dove-colored limestone at the base into the overlying red Moccasin, through a transition zone 20 to 50 feet thick. This condition is shown in the following section:

Geologic Section 42.—North side of Angels Rest peak just west of Pearisburg, Giles County, Virginia

		Thickness Feet
Moccasin limestone (195 feet exposed)		
	(Top not shown)	
4.	Mudrock, red	70
3.	Limestone, fine grained, variegated pink, yellow and gray (marble)	25
2.	Limestone, dove-colored, medium bedded to slabby; gastropods abundant	100±
Hiatus; Blount group absent		
Lenoir limestone		
1.	Limestone, dark-colored, crystalline, streaked with clay, weathers nodular	100±

The variegated transitional limestone, of variable thickness, is widely, if not universally, present in Virginia. It is of interest as an ornamental marble because it takes a high polish and the combination of reddish, pink, yellow, tan, and gray veinings and mottlings gives the polished surfaces a pleasing ornamental effect that should make the rock highly desirable for decorative purposes. The possible use of this rock as a decorative marble was first recognized by A. A. L. Mathews,[110] as a result of detailed studies in Giles County.

The continuance of limestone to the top of the Lowville-Moccasin unit is shown in the following section:

Geologic Section 43.—Lowville-Moccasin formation at Speers Ferry railroad station, Scott County, Virginia

		Thickness Feet
Martinsburg shale		
6.	Shale and limestone, highly fossiliferous	
Lowville-Moccasin (700 feet)		
5.	Limestone, argillaceous, red	285
4.	Not well exposed, only red rock showing	145
3.	Limestone, blue or dove-colored, fossils abundant	240
2.	Limestone, red	10
1.	Limestone, blue	20

[110] Mathews, A. A. L., and Pegau, A. A., Marble prospects in Giles County, Virginia: Virginia Geol. Survey Bull. 40, 1934.

Ottosee formation

The top bed, No. 5, of this section which is freshly exposed in the railroad cut, shows that the Moccasin is essentially a red argillaceous limestone which is reduced to a red mud rock through the leaching out of the lime content on weathering.

The basal dove-colored limestone of the Moccasin facies contains some of the distinctive Lowville fossils, including the main guide fossil, *Cryptophragmus antiquatus* Raymond. Intercalated in the red mass are layers of dove-colored limestone from 1 to 20 feet thick. *Tetradium cellulosum* (Hall), another guide fossil of the Lowville, and ostracodes are found at places in some of these layers. In still other places, as at Thorn Hill, Tennessee, and 2 miles to the northwest, *Cryptophragmus* also occurs in dove-colored layers intercalated in the red. The equivalence of the Moccasin and typical Lowville is satisfactorily established by such paleontologic evidence, as well as by the stratigraphic relations. One aspect of the basal dove-colored limestone is shown in Plate 36A, and of the red limestone of the Moccasin in Plate 36B.

At the base of the Moccasin locally is a thin-bedded, fine-grained, bluish-gray, brown-weathering sandstone 5 to 20 feet thick. This is persistent in northeastern Russell and southwestern Tazewell counties; in the limestone valley northwest of Beartown and Clinch mountains; and in Ward Cove southwest of Snapp, Tazewell County. This bed is especially serviceable in locating the boundary between the Ottosee and Moccasin. In Sinking Creek Valley half a mile north of Newport, Giles County, and in Rich Valley on the northwest slope of Walker Mountain, two beds of sandstone or fine conglomerate 5 feet or more thick generally occur in the Moccasin. In the strip of Moccasin at the south end of Walker Mountain, between the Saltville branch of the Norfolk and Western Railroad and Giesler Mill, this sandstone becomes a hard white quartzite 15 feet or more thick that makes a conspicuous display along its outcrop. This sandstone is thickest at the south end of Paris Mountain 6 miles southeast of Blacksburg, Montgomery County, where the following section is nearly all exposed:

Geologic Section 44.—Moccasin formation on the North Fork of Roanoke River, 6 miles southeast of Blacksburg, Virginia

	Thickness Feet
Martinsburg shale	
24. Shale and limestone with abundant fossils	
Moccasin formation (830 feet)	
23. Sandstone and shale; sandstone thin bedded, shale partings	25
22. Sandstone, massive	25
21. Shale, red	25
20. Sandstone, green, fine grained	5
19. Shale, red	5
18. Sandstone, green, fine grained	5
17. Shale, red	20
16. Sandstone	5
15. Shale, red	5
14. Sandstone, rather thick bedded, fine grained, hard, greenish	250
13. Shale, red	80
12. Sandstone and shale, alternating layers 5 feet or so thick, green sandstone and mudrock	50
11. Sandstone like bed 14	30
10. Shale	30
9. Sandstone	5
8. Shale, red mudrock	50
7. Sandstone	15
6. Shale	15
5. Shale, red	5
4. Sandstone with partings of green mudrock	65
3. Sandstone, thin bedded, greenish	80
2. Not exposed	30
1. Sandstone; probably base of Moccasin	5
Athens shale (?)	
Not exposed to fossiliferous shale below	165

This sandstone facies persists northeastward around Catawba and Tinker mountains into the area north of Roanoke and Salem.

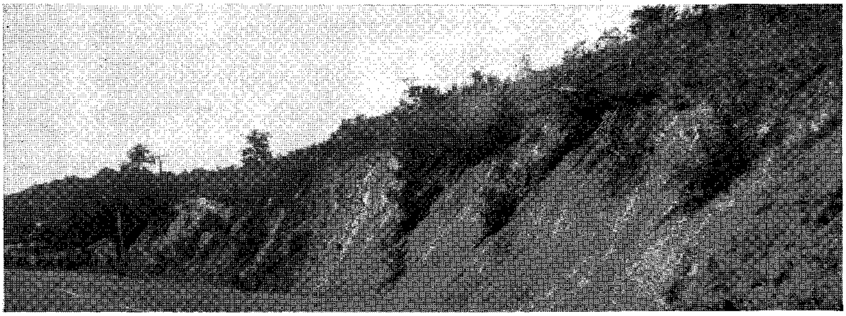
PLATE 35

A. Martinsburg shale (foreground) and Wills Creek shale in Petticoat Gap through Little North Mountain, Frederick County. The Martinsburg contains *Cryptolithus* and the Wills Creek contains *Leperditia elongata willsensis*. The contact is the projecting bed of sandstone (in middle just below the large bush). The Tuscarora, Clinton, McKenzie, and Bloomsburg formations are absent; probably a hiatus. The Tuscarora is over 100 feet thick on Round Hill, 1 mile north of the road, and it decreases to a foot or two in thickness on the slope 200-300 feet north of the road. It is present in normal thickness on the south slope of the gap, half a mile south of the road. Along U. S. Route 50, at Chambersville, 4 miles west of Winchester. Looking west.

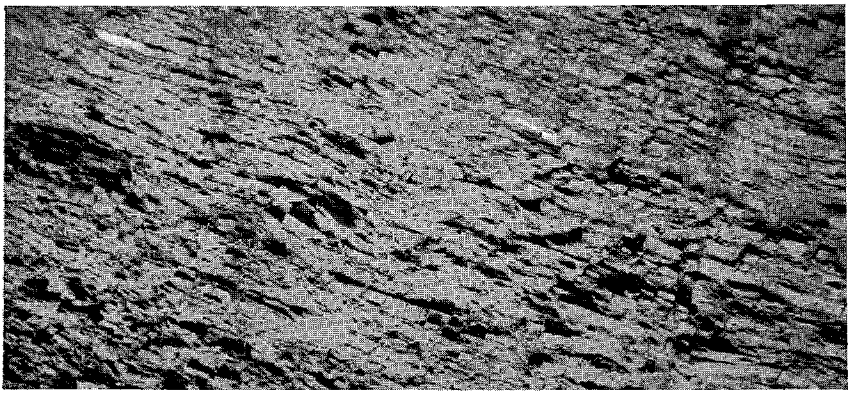
B. Limestone in the Trenton zone of the Martinsburg shale. Along State Route 8, through the Narrows of New River, 2 miles north of the town of Narrows, Giles County. This is in the transition belt from the shale facies of the Trenton zone in the southeastern belts to the limestone facies, Trenton limestone proper, in the northwestern belts in Lee and Wise counties. Looking northeast.

C. Lowville limestone in Lee County. This character persists through its thousand feet of thickness in the county. In the Wheeler quarry half a mile northwest of Wheeler, Virginia, and 7 miles northeast of Cumberland Gap, Tenn. Looking northwest.

D. Holston-Ottosee sequence in Russell County. The Holston is on the slope beyond the ravine and the contact is in the bottom of the ravine. The dip is toward the observer. *Nidulites* cf. *N. pyriformis* occurs in the shelly limestone in the base of the Ottosee. On Indian Creek near U. S. Route 19, about 2 miles northeast of Belfast Mills. Looking east.

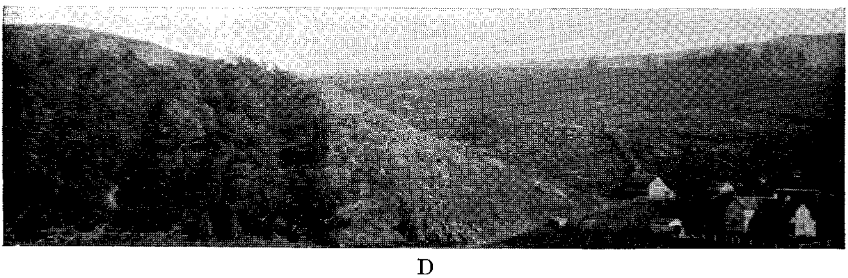


A



B

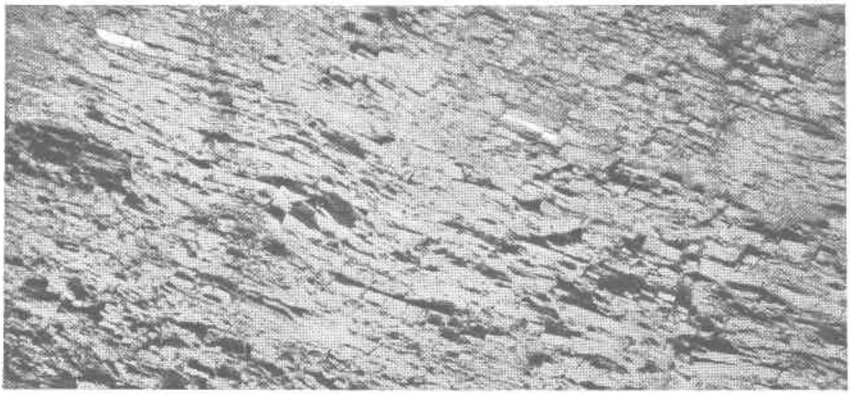
C



D

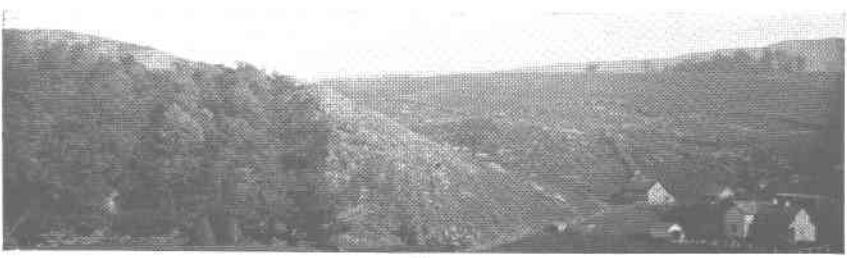
ORDOVICIAN FORMATIONS

A



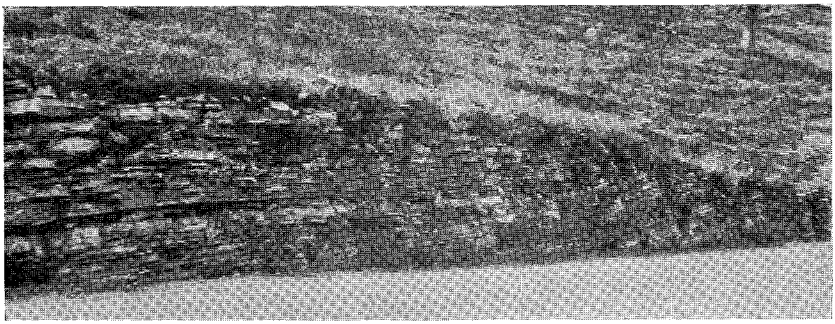
B

C

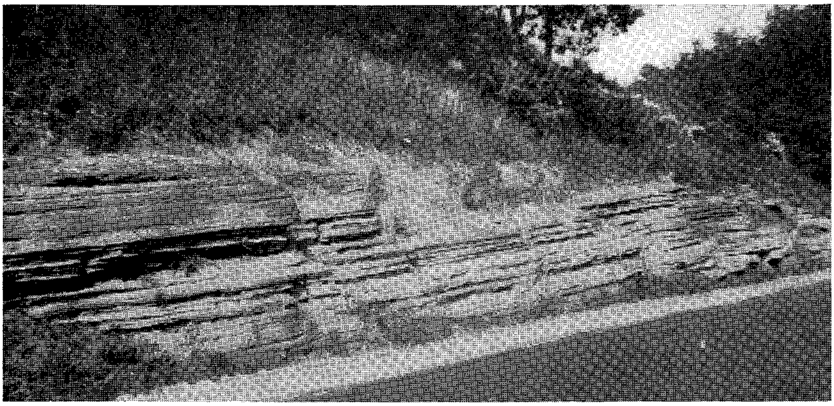


D

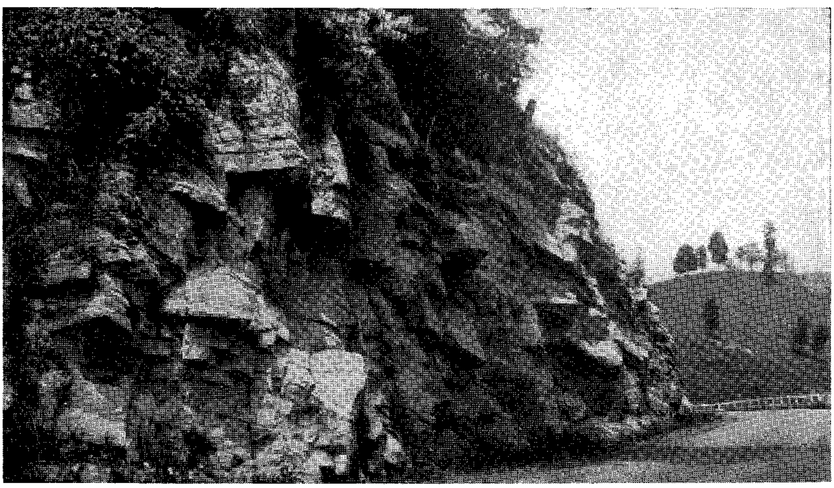
ORDOVICIAN FORMATIONS



A

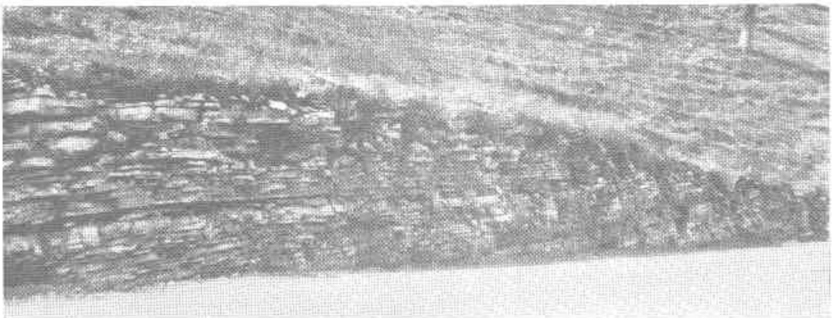


B



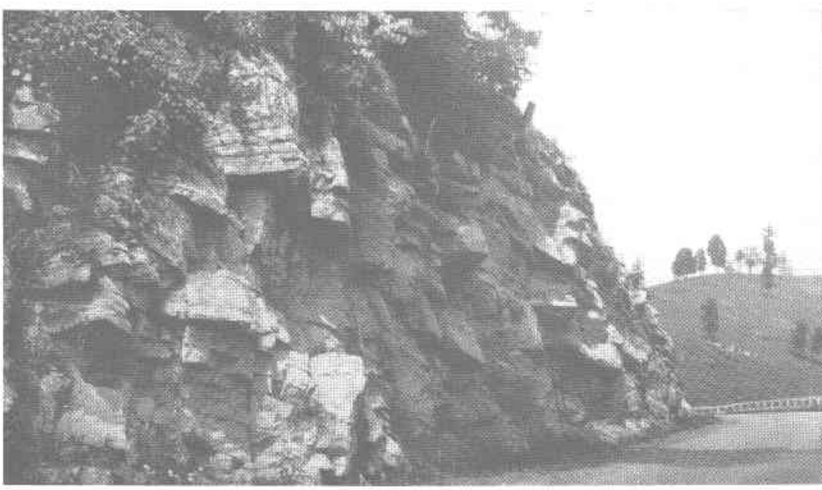
C

ORDOVICIAN LIMESTONES



A

B



C

Ordovician Limestones

PLATE 36

A. Lowville limestone in Russell County. Bed of dove-colored limestone underlying the argillaceous, yellow-gray and red limestone of the Moccasin facies of the Lowville. Along U. S. Route 19, half a mile east of Dickensonville. Looking southwest.

B. Evenly thin-bedded, red, argillaceous Moccasin limestone. Along U. S. Route 19, just east of Little Moccasin Gap, Washington County. On the summit of Little Moccasin Gap, a short distance west of this road cut, the underlying dove-colored limestone of the same bed as shown in A is well exposed in a quarry. Looking southwest.

C. Massively bedded, gray limestone of Holston aspect. It is thought to be lowermost Ottosee, like the lower marble beds in Clinch Valley. Along U. S. Route 19, on Little Indian Creek about 2½ miles northeast of Belfast Mills, Russell County. Looking northwest.

The knobby spurs forming a scalloped fringe along the northwest base of Catawba Mountain, shown on the Salem topographic map, are caused by the outcrop of this sandstone. The occurrences in the Roanoke-Salem and Crocketts Cove areas and those north of Marion mark the known southeastern extent of the Moccasin in Virginia, for in the Draper Mountain area south of Pulaski the Moccasin is absent and the next younger formation, Chambersburg limestone, directly overlies the Athens shale.

Distribution.—The limestone, or true Lowville, facies of the Lowville-Moccasin unit occupies a wide belt in Lee County, as shown on the geologic map. Other outcrops are shown on the map, of which the following are the more extensive: Along most of the length of Warm Springs Valley; in Bolar Valley between Bolar and Trimble; and along nearly the entire length of Hightown Valley in Highland County. It crops out extensively in Franklin County, and in the Nittany Valley of Cambria, Huntingdon, and Center counties, Pennsylvania. The Lowville extends as far south as Birmingham, Alabama.

The Moccasin facies begins to appear within a few miles southeast of the limestone belt (Lowville facies). The Lowville of the south end of Warm Springs Valley is of the pure limestone facies. The Moccasin near Sweet Springs, West Virginia, and in the Narrows of New River, between 5 and 10 miles southeast of the strike of Warm Springs Valley, is mainly of the limestone facies but has a few intercalated layers of pink limestone, or at the Narrows, a bed of red mudrock at top. These areas are in the zone of transition from the Lowville limestone proper to the Moccasin facies of red argillaceous limestone or mudrock. The areas next southeast across the strike from Sweet Springs and the Narrows have the Moccasin facies fully developed.

The most northeastern known occurrence of the Moccasin is in Rich Patch Valley, 6 miles southeast of Covington and southeast of the strike of Warm Springs Valley. The Moccasin persists in this belt, parallel to the belt of the pure limestone facies on the northwest, to the vicinity of Odenville, Alabama, 25 miles northeast of Birmingham. The sandy facies at the south end of Walker Mountain, Washington County, Virginia, is more fully developed in the Bays Mountain syncline southwest of Kingsport, Tennessee, and extends southwest to Bulls Gap. The sandstone identified as Clinch in Bays Mountain is probably a thicker development of the sandstone in the Moccasin at the south end of Walker Mountain.

From the distribution of the Lowville-Moccasin unit it is evident that it was a widely transgressing deposit covering all the members of the Blount group and on its northwestern extent at least, resting unconformably upon the Lenoir limestone. The relations are shown in Figure 4.

The best display of the Lowville limestone is at the southwest base of Elk Knob, midway between Stickleyville and Pennington Gap in Lee County. The exposures are nearly as good along the northwest base of Wallen Ridge from this locality northeast nearly to Big Stone Gap. Another excellent exposure is at the northeast end of Hightown Valley northwest of Crabbottom. There are abundant exposures of the Moccasin everywhere on its outcrop, especially where it is crossed by roads. It is one of the best exposed formations in the Valley and everywhere identifiable by its red color and stratigraphic position. It can be easily distinguished from the Juniata, the only other red formation with which it might be confused, by the universal occurrence above the Juniata of the white Clinch quartzitic sandstone, whereas the Moccasin is overlain by Martinsburg shale and limestone.

Thickness.—The Lowville is about 1000 feet thick in the Powell Valley and on the northwest slope of Wallen Ridge near the Tennessee line at the bend 6 miles southeast of Rose Hill. Just southeast of Harrogate, Tennessee, it is more than 900 feet thick and it is reported to be thick near Cumberland Gap. This is the greatest thickness known for the true Lowville. At a locality 1 mile southeast of Hightown the thickness is only 250 feet. These figures indicate the actual range in thickness of the Lowville proper in Virginia.

The Moccasin facies in the Narrows of New River, Giles County, is about 300 feet thick. It is about 350 feet on the northwest slope of East River Mountain directly south of Bluefield, West Virginia. At Tazewell, each facies of the Lowville-Moccasin unit—limestone and mudrock—is about 400 feet thick. In Ward Cove, Tazewell County, the Moccasin is about 550 feet thick. At Speers Ferry railroad station, Scott County, an accurately measured section shows the Moccasin to be 700 feet thick. (See geologic section 43.)

At the south end of Paris Mountain (geologic section 44) the Moccasin apparently reaches its maximum thickness. On Catawba Creek, 1 mile southeast of Catawba Sanatorium, the Moccasin, all sandstone with partings of green mudrock, is only 110 feet thick. At this place the red sandstone contains a species of *Lingula,* the only fossil found in the sandstone facies of the Moccasin. (See

Fossil Plates, Part II.) This is a great diminution in thickness from that on the same outcrop belt at the south end of Paris Mountain. The absence of red shale is also notable. The thickness of about 100 feet appears to be constant around Catawba and Tinker mountains and in the area north of Roanoke and Salem. It contains some red shale here.

Fossils and correlation.—The limestone facies of the Lowville-Moccasin is generally moderately fossiliferous. The fossils generally show only in sections on weathered surfaces and do not separate from the rock on breaking. That is especially true of the gastropods, which are abundant. Brachiopods are common but of few species. They separate fairly well from the rock. Bryozoa are also rather plentiful and some species weather out. The Lowville fossils of Virginia have not all been identified and described. No fossils occur in the red beds of the Moccasin facies, but a few, including rare *Tetradium cellulosum* and *Leperditella,* occur in the occasional intercalated layers of blue limestone. A list of the best determined species is given below.

Fossils from the Lowville-Moccasin formation

Algae
- Phytopsis tubulosa Hall

Sponges
- Cryptophragmus antiquatus Raymond

Corals
- Columnaria alveolata Goldfuss
- Streptelasma profundum (Conrad)
- Tetradium cellulosum (Hall)
- Tetradium columnare (Hall)
- Tetradium racemosum Raymond

Bryozoa
- Batostoma cf. B. magnopora Ulrich
- Batostoma type of B. minnesotense Ulrich or B. winchelli (Ulrich)
- Escharopora confluens Ulrich
- Escharopora aff. E. ramosa (Ulrich)
- Escharopora subrecta (Ulrich)
- Escharopora, 2 other sp.
- Nematopora sp.
- Pachydictya sp.
- Rhinidictya nicholsoni Ulrich

Brachiopods
- Camarotoechia cf. C. plena (Hall)
- Dalmanella? sp., rare
- Glyptorthis cf. G. bellarugosa (Conrad), very rare
- Oxoplecia sp., rare
- Pionodema subaequata (Conrad)
- Rafinesquina minnesotensis (N. H. Winchell)
- Strophomena incurvata (Shepard)
- Strophomena sp.
- Zygospira recurvirostris (Hall)

Pelecypods
- Clionychia sp.
- Cyrtodonta aff. C. janesvillensis Ulrich
- Cyrtodonta sp.?

Gastropods
- Conradella sp.
- Eotomaria sp.
- Helicotoma? sp.
- Lophospira oweni Ulrich and Scofield
- Subulites regularis Ulrich and Scofield
- Trochonema umbilicatum (Hall)

Cephalopods
- Centrocyrtoceras subannulatus (D'Orbigny)
- Orthoceras multicameratum Emmons

Trilobites
- Bathyurus cf. B. johnstoni Raymond
- Calliops (Pterygometopus) callicephala (Hall)?
- Ceraurus pleurexanthemus Green
- Illaenus sp., rare

Ostracodes
- Drepanella aff. D. crassinoda Ulrich
- Isochilina armata (Walcott)
- Isochilina sp.
- Leperditella sulcata (Ulrich)
- Leperditella tumida (Ulrich)
- Leperditia fabulites (Conrad)

The most significant fossils of the above list for correlation are *Cryptophragmus antiquatus*, *Tetradium cellulosum*, *T. racemosum*, *Rhinidictya nicholsoni*, *Isochilina armata*, *Leperditella sulcata*, and *Leperditia fabulites*. The best guide fossil is *Cryptophragmus antiquatus* which occurs, rather rarely, near the bottom of the formation from Canada to Alabama. It is as common in the dove-colored member at the base of the Moccasin facies as in the pure limestone of the Lowville facies. In a few places, such as the locality 2 miles northwest of Belfast Mills and at Thorn Hill, Tennessee, it has been found in limestone interbedded with the red beds of the Moccasin. In Lee County *Cryptophragmus antiquatus* occurs in Lowville that rests upon the Lenoir limestone; likewise in Rye Cove, Scott County, it occurs near the bottom of the basal blue limestone of the Moccasin, only a short distance above the Ottosee limestone. (See Fossil Plates, Part II.) Thus the identity of the Lowville in Virginia is established and its position in the general time scale and in the stratigraphic sequence in the Appalachian Valley is demonstrated.

The relations of the Lowville in Lee County are shown in the section on Yellow Branch (geologic section 26); those in Rye Cove are shown in the following section:

Geologic Section 45.—Lowville-Moccasin formation, 2 miles northeast of Rye Cove postoffice, Scott County, Virginia

	Thickness Feet
Trenton limestone	
5. Limestone, thin bedded (to top of knob)	200±
Lowville-Moccasin formation (350-400± feet)	
4. Limestone and mudrock, mainly red	200±
3. Limestone, blue; contains *Cryptophragmus antiquatus*, *Clionychia* sp., *Calliops callicephala*, *Bathyurus* sp.	100±
2. Interval	50-100?
Ottosee formation	
1. Limestone, thin bedded, highly fossiliferous; contains some fossils that occur in the vicinity of Knoxville, Tennessee	280

Here the Lowville with its main guide fossil is directly superposed upon the Ottosee limestone, the uppermost formation of the Blount group. *Tetradium cellulosum* is an associate of *Cryptophragmus antiquatus* from New York to Alabama. The type specimens of *T. cellulosum* came from the Lowville of New York, where, together with *Phytopsis tubulosa,* it is very plentiful. The Lowville was originally called the Birdseye limestone because the cross sections of these fossils made spot or "eyes" on the weathered surface of the rock. *Leperditia fabulites* and *Isochilina armata* occur in the Lowville of New York and in its equivalent, the Tyrone limestone, in the gorge of Kentucky River at High Bridge, Kentucky. A blue fossiliferous limestone of Lowville character occurs at the base of the red "Bays" of Bays Mountain southeast of Knoxville, Tennessee. The relations and character of the basal limestone and red "Bays" here are precisely the same as those of the red Moccasin and its basal blue limestone member. *Tetradium cellulosum* also occurs in an impure limestone 2 feet thick at the top of the red mudrock in Beaver Creek Mountain 1 mile southeast of Odenville, Alabama. *Cryptophragmus antiquatus* occurs also in the Auburn chert, associated with the Plattin limestone of eastern Missouri. *Pionodema subaequata, Leperditella sulcata, Subulites regularis,* and *Centrocyrtoceras subannulatus* occur in the Lowville of New York. *Rafinesquina minnesotensis, Pionodema subaequata, Leperditia fabulites,* and *Calliops callicephala* occur in the Platteville limestone of Wisconsin. Apparently all of these species are confined to beds which are correlated with the Lowville of Virginia.

The Lowville is perhaps the most widespread limestone in the eastern United States. It extends southward into Alabama and westward into the Nashville area, Tennessee, where it is named the Carter and Tyrone limestones, and still farther west into Missouri where it is called the Plattin limestone. It was deposited during one of the most extensive, if not actually the most extensive, submergences of the eastern part of North America in the Ordovician period.

EGGLESTON LIMESTONE

Name.—The name Eggleston was proposed by A. A. L. Mathews[111] for beds that are well exposed along the road on the east bluff of New River about 1 mile southeast of Eggleston and half a mile north of Goodwins Ferry, Giles County.

Limits.—The Eggleston is bounded below by the Lowville-Moccasin and above by the highly fossiliferous basal limestone of the Martinsburg shale, which is of Trenton age.

Character.—The Eggleston is most generally a rather thick-bedded, coarse-grained, gray, argillaceous limestone which on weathering crumbles to angular bits or decalcifies to a soft, mealy, yellow to brown shale. In Wallen Ridge, Lee County, it is a thin-bedded, shaly, gray argillaceous limestone weathering in part to shale. Some of the limestone is compact and becomes silicified to a pale bluish, brittle, finely jointed, fossiliferous chert that breaks into cubical chunks which are very characteristic. This is especially true of the facies on Wallen Ridge. Though immediately underlain by the Moccasin red beds in

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

areas where the Moccasin occurs, it nowhere contains any red rock. Its characters are so distinctive and its stratigraphic relations so well defined that it can be easily distinguished everywhere. It contains several beds of bentonite,[112] another distinguishing feature, as shown by the following sections:

Geologic Section 46.—Beds containing bentonite along State Route 8, in the Narrows of New River, Giles County, Virginia

	Thickness Ft.	In.
Trenton formation (basal 28 feet)		
14. Limestone, thick bedded, flaggy		
13. Bentonite	2	6
12. Limestone, thin bedded, shale partings, bottom 1 foot highly fossiliferous, *Dalmanella*	17	
11. Bentonite, with thin limy layers	3	6
10. Limestone, argillaceous, fossiliferous	5	
Eggleston formation (138+ feet)		
9. Bentonite	2	
8. Limestone, argillaceous, even bedded, blocky, some shale partings	12	
7. Shale	1	6
6. Bentonite	1	
5. Limestone, argillaceous, weathers to soft, brown, mealy rock	30	
4. Bentonite, limestone in midst	6	
3. Limestone, argillaceous, weathers to soft, yellowish, mealy rock	45	
2. Bentonite	1	
1. Limestone, argillaceous, weathers to soft, mealy rock	40	
Moccasin formation		
Limestone, argillaceous, or red mudrock		

[112] Bentonite is an altered volcanic ash named from the Fort Benton formation of Cretaceous age, in Montana, in which it occurs. It originates as a finely pulverized rock or dust from explosive volcanic eruptions, which is transported by air currents and distributed over large areas as a relatively thin layer. In the course of time the ash undergoes chemical and physical changes, converting it to a substance called bentonite. Through a longer time it is further changed, such as the altered volcanic dust of the Paleozoic rocks in the Appalachian region. This rock is called metabentonite by some geologists. The main interest of the Appalachian bentonite beds lies in their evidence of volcanic activity in Black River time, in areas from which the dust could be transported into the Appalachian Valley. The location of the volcanoes which were the source of the dust is unknown.

Geologic Section 47.—Eggleston formation on State Route 80, about half a mile northwest of old Rosedale, Russell County, Virginia

		Thickness Ft.	In.
Trenton limestone			
15. Limestone, 1 to 4 inch layers, highly fossiliferous, with *Dalmanella fertilis* Bassler in very bottom. (Basal Martinsburg)			
Eggleston formation (87-92± feet)			
14. Shale		5	
13. Bentonite		8-10	
12. Limestone, rather thick bedded, argillaceous		8	
11. Bentonite		1±	
10. Limestone, argillaceous, thin bedded		18	
9. Bentonite (Pl. 37B)		5-8	
8. Limestone, argillaceous		40	
7. Bentonite	(Pl. 37C)		8
6. Shale and limestone parting	(Pl. 37C)		10
5. Bentonite	(Pl. 37C)	1	
Moccasin formation (550 feet)			
4. Limestone, or calcareous mudrock, red		200	
3. Limestone, blue		20	
2. Limestone, or calcareous mudrock, red		180	
1. Limestone, dove colored, fossiliferous		150	

In both of the preceding sections the base of the Trenton is marked by limestone crowded with the shells of *Dalmanella* and *Sowerbyella* in striking contrast with the comparatively barren beds of the Eggleston. That sequence is constant through the entire area in which the Eggleston is present.

Distribution.—The Eggleston is present along the northwest slope of Wallen Ridge from Tennessee nearly to Big Stone Gap, Virginia. It is probably present at the top of the Lowville-Moccasin throughout the entire area between Russell and Giles counties. It is extensively exposed around the base of Elk Garden Ridge, Russell County, around the base of Beartown Mountain northeast of Elk Garden and Rockdell, and in Ward Cove, Tazewell County. It is also well exposed at the type locality on the road on the east bluff of New River, 1 mile southeast of Eggleston; on State Route 8, 1 mile northwest of Newport;

and on the northwest slope of Peters Mountain in West Virginia, 5 miles southeast of Gap Mills on the road to Waiteville.

Thickness.—The thickness of the Eggleston appears to be about 100 feet. Exact determinations are difficult.

Fossils and correlation.—The Eggleston is only sparingly fossiliferous, but fossiliferous layers occur here and there, and collections rather hastily made have yielded the fossils of the following list:

Fossils from the Eggleston limestone

Corals
- Lichenaria sp.?
- Streptelasma profundum (Conrad)?

Worms
- Cornulites sp.

Bryozoa
- Escharopora subrecta (Ulrich)
- Hallopora multitabulata (Ulrich)
- Rhinidictya nicholsoni Ulrich

Brachiopods
- Dalmanella rogata (Sardeson)?
- Pholidops sp.
- Rafinesquina alternata (Emmons)
- Rafinesquina minnesotensis (N. H. Winchell)
- Strophomena incurvata (Shepard)
- Zygospira recurvirostris (Hall)

Pelecypods
- Cyrtodonta, small sp.
- Modiolopsis sp.
- Vanuxemia sp.

Gastropods
- Hormotoma gracilis (Hall)
- Lophospira oweni Ulrich and Scofield
- Lophospira perangulata (Hall)

Trilobites
- Calliops (Pterygometopus) sp.
- Homotelus sp.

Ostracodes
- Eurychilina reticulata Ulrich
- Eurychilina subradiata Ulrich

Haploprimitia minutissima (Ulrich)
Isochilina large sp.
Isochilina, smaller, probably another sp.
Leperditella sulcata (Ulrich)
Leperditella tumida (Ulrich)
Leperditia sp.

Except for the *Dalmanella rogata* and *Rafinesquina alternata,* all the fossils of the above list are Black River forms, most of which occur in the underlying Lowville or in beds of Black River age elsewhere. *Haploprimitia minutissima* occurs in the Black River (Decorah) shale of Minnesota. The decayed rock of Eggleston aspect yielding *Dalmanella* and *Rafinesquina alternata* may be of Trenton age, above the horizon of the basal shell limestone layers which are absent at the localities of collection.

Though it would be reasonable to suppose that the Eggleston may occupy a place in the general sequence near that of the Watertown limestone or of the Amsterdam limestone of New York, or of the Chambersburg limestone of Pennsylvania and Virginia, as described beyond, precise correlations are not justified by the evidence in hand.

CHAMBERSBURG LIMESTONE (EMENDED)

Name.—The Chambersburg limestone was named by Stose and Ulrich[113] from Chambersburg, Franklin County, Pennsylvania.

Limits.—In the Chambersburg area the Chambersburg limestone, as the name originally applied, included all the limestone between the Stones River limestone and the Martinsburg shale, thus including the Lowville limestone in the lower part. The Lowville part was definitely distinguished, however, in the description as the 150 feet at the base carrying the distinctive Lowville fossils *Cryptophragmus antiquatus* Raymond (*Beatricea gracilis* Ulrich), and *Tetradium cellulosum* (Hall). At present only the part of the original Chambersburg above the Lowville is included by Ulrich in the Chambersburg; hence, the Chambersburg is herewith redefined to apply only to the part of the original Chambersburg limestone overlying the part of Lowville age. The Chambersburg is overlain by the Martinsburg shale which contains a distinctive Trenton fauna in its lower part.

Character.—The Chambersburg is a black compact limestone which in texture and color so closely resembles the limestone facies of the Athens that the two can hardly be distinguished from each other by their lithology. The Chambersburg is thinner bedded, generally minutely cross-joined into cubical blocks, and commonly contains layers composed

[113] Stose, G. W., The sedimentary rocks of South Mountain, Pennsylvania: Jour. Geology, vol. 14, p. 211, 1906.

of small nodules or small irregular lenticular pieces, a feature absent in the Athens. The cubical jointing of the Chambersburg and the even bedding and the dark banding of the Athens are shown on Plates 30 and 32A. In clean exposures little uncertainty exists about the boundary between the two formations and wherever the Athens is absent the Chambersburg is easily recognizable.

In the vicinity of Strasburg, Shenandoah County, and northeast to Stephens City at least, the Chambersburg contains at its base, or very low in the formation, a bed of sandy shale or fine-grained sandstone 5-10 feet thick. In the 8 to 10 feet of limestone below the sandy bed are found at least four layers of bentonite, each about 1 inch thick. Below the limestone with bentonite and extending down to the Lenoir limestone, appears a limestone about 50 feet thick, the age of which is uncertain. It can not be referred certainly on a lithologic or faunal basis to either the Lowville limestone or Athens shale. The Lowville underlies the Chambersburg in Pennsylvania, and the Athens comes in below the Chambersburg to the southwest of Strasburg, probably in the vicinity of Edinburg, where the Lowville is absent. This 50 feet of limestone is here provisionally included in the Chambersburg, but it may be a facies of the Whitesburg limestone. In the vicinity of Strasburg and southwest as far as Edinburg, the top of the Chambersburg is a rather massively bedded, dark-colored, impure, limestone, 25 feet thick, which for convenience is called the *Christiania* bed (Pl. 31A) from its most distinctive fossil, a species of *Christiania*. Immediately beneath the *Christiania* bed are two beds of bentonite each about 1 inch thick. Bentonite occurs at other horizons in the Chambersburg. It has been described by Whitcomb and by Rosenkrans.[114]

Distribution.—The Chambersburg limestone in Virginia, cropping out continuously from Pennsylvania through Maryland and West Virginia, extends in narrow strips on each side of the Massanutten syncline; on the southeast side as far south as Newport, Page County; on the northwest to a point 10 miles southwest of Endless Caverns. On the southeast, however, it has not been identified along a belt from a point about due east of Winchester southwest to Overall, Page County. In northern Clarke County it is present in several small synclinal outliers east of the main belt. It is present in the long syncline northeast of Harrisonburg from Fairview nearly to the latitude of Harrisonburg; also in the syncline extending from Harrisonburg to Long Glade. It is present in the wedge northwest of Fairview and in the narrow syncline 1 mile northwest of Mount Jackson, extending northeast to a point west of Edinburg, Shenandoah County. Elongate areas both east and west of Lexington are in strike with the outcrops in the Massanutten

[114] Whitcomb, Lawrence, and Rosenkrans, R. R., Bentonite beds in the Lower Chambersburg: Geol. Soc. America Bull., vol. 46, pp. 1251-1254, 1935.

syncline already mentioned. Northwest of the North Mountain fault it appears in detached strips, as west of Singers Glen, southwest of Rawley Springs, and east of Jennings Gap. Along this general belt it extends nearly to the latitude of Buchanan, its outcrop expanding into its largest areas at the southwest base of Big House and Little House mountains, 10 miles west of Lexington, and in a wide belt 2 miles west of Natural Bridge, Rockbridge County. Southwest of Buchanan it is unknown throughout the distance to Draper Mountain, Pulaski County. Along the southeast base of Draper Mountain it crops out for several miles in characteristic form with its distinctive fossil, *Nidulites pyriformis*. Southwest of Draper Mountain it is unknown in the Appalachian Valley.

The best section of the Chambersburg in Virginia is exposed on Tumbling Run, 1½ miles southwest of Strasburg, Shenandoah County, and northwest of U. S. Route 11, where the following section is exposed.

Geologic Section 48.—Chambersburg limestone on Tumbling Run, 1½ miles southwest of Strasburg, Virginia

	Thickness Feet
Martinsburg shale (Trenton member)	
12. Shale, slaty, black, calcareous, thin layers of bentonite; contains *Diplograptus amplexicaulis* (Hall) and *Cryptolithus tessellatus* Green in bottom part	
Chambersburg limestone (563 feet)	
[a]11. Limestone, massively bedded, argillaceous, dark-colored, compact; *Christiania* bed	25
[a]10. Limestone, dark-colored, compact, much jointed or nodular; several thin layers of bentonite	10
9. Limestone, thick bedded black	50
8. Limestone, layers 24 inches thick, compact, black, jointed into cubical blocks or nodular, with *Nidulites pyriformis* Bassler	400
7. Shale, sandy, and fine-grained sandstone	3
6. Limestone, irregularly medium and thin bedded, nodular, 4 thin layers of bentonite	20
5. Limestone, irregularly medium and thin bedded, dark-colored to black; a little chert, fossiliferous, *Sowerbyites*	40

[a] Beds 10 and 11 are exposed on the Lee Highway (U. S. Route 11), about one-fourth of a mile southwest of Tumbling Run (See Pl. 29B).

	Thickness Feet
4. Limestone, apparently thick bedded but weathers to irregular thin layers and imbricating lenses, black, partly compact, in part finely crystalline; a little chert, very similar to bed 5	20
Lenoir limestone	
3. Limestone, black, crystalline, full of nodules of black chert, fossiliferous	100
Mosheim limestone	
2. Limestone, dove-colored, compact, thick bedded, vaughanitic	50
Beekmantown formation	
1. Dolomite	

In this section, the age of beds 4 and 5 is uncertain, but they are included in the Chambersburg at present. The *Christiania* bed is fully exposed in a sloping wall beginning about half a mile southwest of Strasburg and extending along the west side of U. S. Route 11 for a short distance.

Another fine exposure of well-weathered Chambersburg is on the railroad between Strasburg and the limestone quarry about 1 mile west of town. The main *Nidulites* bed is best exposed in the abandoned part of U. S. Route 11 at the abrupt bend just southwest of Tumbling Run. These exposures in the vicinity of Strasburg afford the best opportunities for the study of the Chambersburg and its fossils. The fossiliferous *Christiania* bed yields abundant fossils along the road about 6 miles northwest of Harrisonburg and half a mile northwest of Green Mount Church. There are excellent exposures about 8 miles west of Lexington on the road along Collier Creek 1 mile or so southeast of old Collierstown. (See Pls. 30C and 32A.)

Thickness.—The only accurate determination of the thickness of the Chambersburg is that of approximately 568 feet made on Tumbling Run. A thickness of about 100 feet is estimated in the belts on the southeast side of Massanutten Mountain. It will probably vary from 300 to 500 feet in most of its outcrops northwest of Massanutten Mountain. The thickness seems to be at least 300 feet south of Draper Mountain. In Franklin County, Pennsylvania,[115] the Chambersburg varies in thickness from about 100 to about 750 feet.

[115] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), p. 8, 1909.

Fossils and correlation.—The Chambersburg limestone is abundantly fossiliferous. Several of the common species have been provisionally identified by Ulrich whose lists have been published.[116] Ulrich has also given much study to the Chambersburg fossils collected in the vicinity of Strasburg, Virginia, and has provisionally identified a considerable number of species. The fauna awaits critical study, classification, and description. The following list is compiled from Ulrich's manuscript lists, somewhat amplified by the writer.

Fossils from the Chambersburg limestone

Plants?
- Solenopora sp.

Sponges?
- Nidulites pyriformis Bassler
- Receptaculites sp.

Hydroids
- Dendrograptus sp.

Corals
- Bolboporites americanus Billings?
- Streptelasma profundum (Conrad)?
- Tetradium sp.

Echinoderms
- Cystid plates
- Echinosphaerites aurantium (Gyllenhal)?

Bryozoa
- Batostoma fertile Ulrich
- Batostoma winchelli (Ulrich)
- Ceramoporella sp.
- Chasmatopora aff. C. corticosa (Ulrich)
- Chasmatopora aff. C. reticulata (Hall)
- Corynotrypa delicatula (James)
- Glauconome sp.
- Helopora sp.
- Mesotrypa, small discoid sp.
- Monotrypa sp. (large massive zoarium)
- Nematopora sp.
- Pachydictya sp. (foliate form)
- Rhinidictya cf. R. mutabilis Ulrich

[116] Stose, G. W., op. cit., p. 9.

Brachiopods
- Camarella sp.?
- Christiania lamellosa Bassler
- Christiania cf. C. trentonensis Ruedemann
- Christiania trentonensis brevis Butts, n. var.
- Dalmanella edsoni Bassler
- Dinorthis pectinella (Emmons)
- Hesperorthis tricenaria (Conrad)
- Leptaena homostriata Butts, n. sp.
- Leptobolus walcotti Ruedemann
- Nicolella strasburgensis Butts, n. sp.
- Orbiculoidea sp. (large form)
- Oxoplecia sp.
- Ptychoglyptus sculpturatus (Bassler)
- Schizambon cf. S. dodgei Winchell and Schuchert
- Sowerbyella alternata Butts, n. sp.
- Sowerbyella cf. S. pisum (Ruedemann)
- Sowerbyella platys Butts, n. sp.

Pelecypods
- Cyrtodonta sp.

Gastropods
- Bucania sp.
- Maclurites sp.

Cephalopods
- Orthoceras sp.
- Spyroceras sp.

Trilobites
- Arthrorhachis cf. A. elspethi Raymond
- Ascidaspis sp.
- Bronteopsis gregaria Raymond
- Eoharpes sp.
- Homotelus simplex (Raymond and Narraway)
- Illaenus americanus (Billings)
- Lonchodomas hastatus (Ruedemann)
- Pterygometopus sp.
- Sphaerexochus sp.
- Sphaerocoryphe sp.
- Tretaspis sp.

The most important fossil for the identification of the Chambersburg is *Nidulites pyriformis* Bassler. (See Fossil Plates, Part II.) This form occurs through nearly the full thickness of the formation below the *Christiania* bed and is distributed throughout the entire geographic extent of the formation from Pennsylvania to Draper Mountain, Virginia. It is of such characteristic appearance that there can be little difficulty in its recognition. It is also present in nearly every exposure of the Chambersburg and commonly can be found in cross section even on the weathered and smoothly polished surfaces of the limestone. The three species of *Christiania* and *Sowerbyella* cf. *S. pisum,* if not also the other three species of *Sowerbyella,* figured on the same Plate in Part II, apparently occur only in the *Christiania* bed, as do also *Dalmanella edsoni* Bassler; *Ptychoglyptus sculpturatus* (Bassler), *Nicollella,* and *Lonchodomas hastatus.* Though not confined to the Chambersburg, the *Echinosphaerites* and *Bolboporites* are highly characteristic in their association with the other forms listed.

Most of the diagnostic species of the list occur also in the typical Chambersburg of Pennsylvania where the formation is immediately underlain by the Lowville limestone with its diagnostic fossils *Cryptophragmus antiquatus* and *Tetradium cellulosum.* As the Lowville is of early Black River age, the late Black River age of the Chambersburg may be reasonably inferred. The Chambersburg is also correlated with beds near Highgate Falls, Vermont, through the common occurrence of *Dalmanella edsoni.* Some of the pebbles of black limestone[117] in the Rysedorph Hill conglomerate near Albany, New York, may have been derived from beds of Chambersburg age, as they contain *Christiania trentonensis, Sowerbyella pisum, Lonchodomas hastatus,* and other species. The *Christiania* bed of Virginia is correlated with the *Christiania* bed of Ulrich[118] at Greencastle, Franklin County, Pennsylvania.

MARTINSBURG SHALE

Name.—The Martinsburg shale was named[119] from Martinsburg, West Virginia, which is located just west of a wide belt of the shale.

Limits.—At Martinsburg, West Virginia; in Massanutten Mountain; at Strasburg, Shenandoah County (Pl. 31A); and just south of Draper Mountain, in Wythe and Pulaski counties, the Martinsburg overlies the Chambersburg limestone with no known break, or hiatus, between them. Where the Chambersburg is absent, as northwest of Walker and Clinch mountains in southwest Virginia, the Martinsburg lies upon the Lowville-Moccasin limestone. The Martinsburg is not known to rest on any formation older than the Lowville. Around the south end of the Massanutten syncline, the geologic map shows the Martinsburg

[117] Ruedemann, Rudolph, Trenton conglomerate of Rysedorph Hill, Rensselaer County, N. Y., and its fauna: New York State Mus. Bull. 49, pp. 3-114, 1901.

[118] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 322 and fig. 3, 1911.

[119] Geiger, H. R., and Keith, Arthur, The structure of the Blue Ridge near Harpers Ferry, Maryland-West Virginia: Geol. Soc. America Bull., vol. 2, p. 161, 1891.

resting upon the Athens shale, but there is reason to believe that the Chambersburg limestone, or shale of about equivalent age, is there included in the base of the Martinsburg. In central Pennsylvania and for long distances, but not everywhere, along the line of Little North Mountain in Virginia as far south as Brocks Gap, Rockingham County, and perhaps as far as Rawley Springs, the *Orthorhynchula* zone in the top of the Martinsburg is succeeded by the Oswego sandstone. (See Pl. 38A and B.) In Walker and Clinch mountains and throughout the entire northwest part of the Valley in Virginia, the *Orthorhynchula* zone of the Martinsburg is invariably overlain by the Juniata formation, with intervening hiatus due to the absence of the Oswego sandstone. In Massanutten Mountain both the Oswego and Juniata are absent and the Martinsburg is succeeded by the Massanutten sandstone, the basal part of which is possibly the Clinch or equivalent Tuscarora. (See Pl. 8A.)

Character.—The Martinsburg is predominantly shale. The unweathered shale is bluish, but on weathering it becomes yellowish to brownish. The main body of the formation is a thin-bedded calcareous mudrock, but layers largely composed of very fine quartz sand, and many thin layers of fossiliferous limestone are scattered through the mass from bottom to top. (See Pl. 39C.) Thick beds of clay shale occur locally as, for example, on the northwest slope of Clinch Mountain. A thick body of very fine-grained, bluish-green sandstone occurs in the middle of the formation on the east side of Massanutten Mountain and is well exposed along the Lee Highway (U. S. 211) on both sides of the Rockingham-Page county line. The basal part of the formation on the west side of the Massanutten syncline contains a considerable thickness of black slaty calcareous shale, which is well displayed along the Lee Highway 1½ miles southwest of Strasburg. In the more northwestern belts, as northwest of Clinch and East River mountains in the belt extending from the Narrows of New River to Lebanon, Russell County, the formation is more largely composed of limestone in the lower, or Trenton, part. (See Pl. 35B.) In the Draper Mountain belt south of Pulaski, the beds in contact with the Chambersburg limestone are rather coarse-grained brown sandstone.

In passing northwestward across the Valley from the Massanutten syncline, or from its line of strike southwestward, the Trenton part of the Martinsburg becomes more calcareous and undergoes a transition from a calcareous shale to a pure thin-bedded limestone. The calcareous shale facies is typical of the Massanutten syncline. The limestone facies is well developed in the Big Stone Gap area in Lee and Wise counties. This transition seems to be complete in the vicinity of the Narrows of New River. (See geologic section 51 and Pl. 35B.) Nowhere southeast of a line from the Narrows to the south boundary of

Lee County, along the line of Wallen Ridge, is this limestone so predominant as to be readily distinguished by its lithologic character from the overlying beds of Eden and Maysville age. Even in the syncline of Elk Garden Ridge in Russell County, the Trenton part of the Martinsburg, as proved by its fossils, includes so much shale and thin-bedded argillaceous limestone that it does not differ noticeably from the Eden and Maysville parts of the formation. By detailed stratigraphic and paleontological work these constituents of the Martinsburg can be ultimately separated into independent stratigraphic units.

In Lee and Wise counties, where the Trenton limestone is clearly differentiated, it is treated as a separate formation and represented on the geologic map by a distinct pattern and symbol. The overlying shale, corresponding to the Eden and Maysville parts of the Martinsburg, is likewise made a distinct formation, named the Reedsville shale.[120]

The general character of the Martinsburg in different areas is shown by the following sections:

Geologic Section 49.—Martinsburg shale in Rich Valley northwest of Walker Mountain, on State Route 81 in Washington County, midway between Saltville and Glade Springs

	Thickness Feet
Juniata formation	
12. Red shale	300
Martinsburg shale (1617± feet)	
11. Sandstone, fine grained, ferruginous, and shale; a few feet of reddish argillaceous limestone with *Orthorhynchula linneyi* (James) and *Lingula nicklesi* Bassler, in the top; *Orthorhynchula* in sandstone throughout; *Orthorhynchula* bed	75
10. Not exposed	150
9. Shale, thin fine grained sandstone, thin layers of fossiliferous limestone	1000
8. Not exposed	75
7. Shale	10
6. Not exposed	40
5. Shale and thin limestone	40
4. Not exposed	75
3. Shale, *Dalmanella* abundant at base	150
2. Bentonite	2±
Moccasin limestone	
1. Red argillaceous limestone and red mudrock	

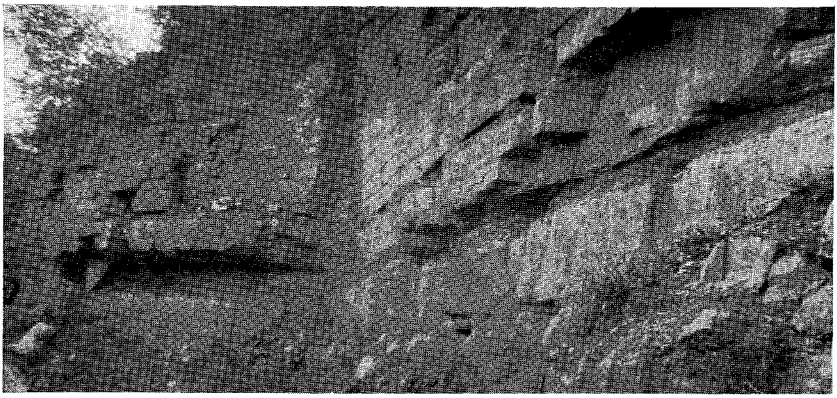
[120] Ulrich, E. O., op. cit., Plate 27.

PLATE 37

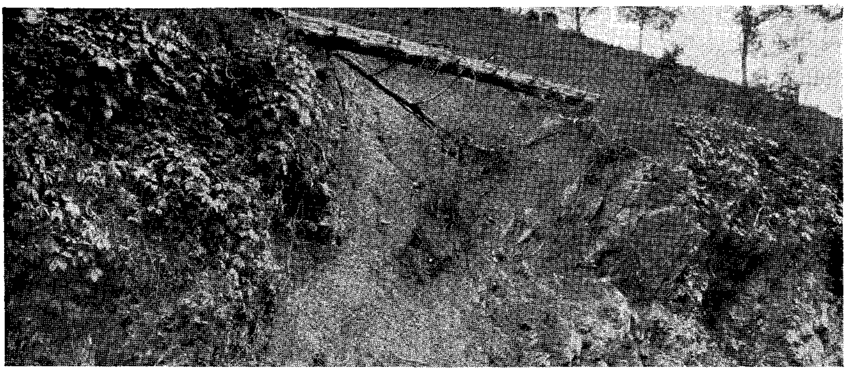
A. Basal Trenton, or upper Black River, limestone with a bed of bentonite. The bentonite (in recess) is 14 to 18 inches thick. A 2-inch layer of bentonite occurs 2 feet above the main bed. A little red shale and pink limestone indicative of Moccasin limestone occur just below the bentonite. In old quarry on southeast side of U. S. Route 19, about 1 mile southeast of Little Moccasin Gap, Washington County. Looking southeast.

B. Bed of bentonite, about 8 feet thick, in Black River (Eggleston) limestone. This is the second of four beds in about 90 feet of limestone at this locality. Along State Route 80, about half a mile north of old Rosedale, Russell County. Looking northeast.

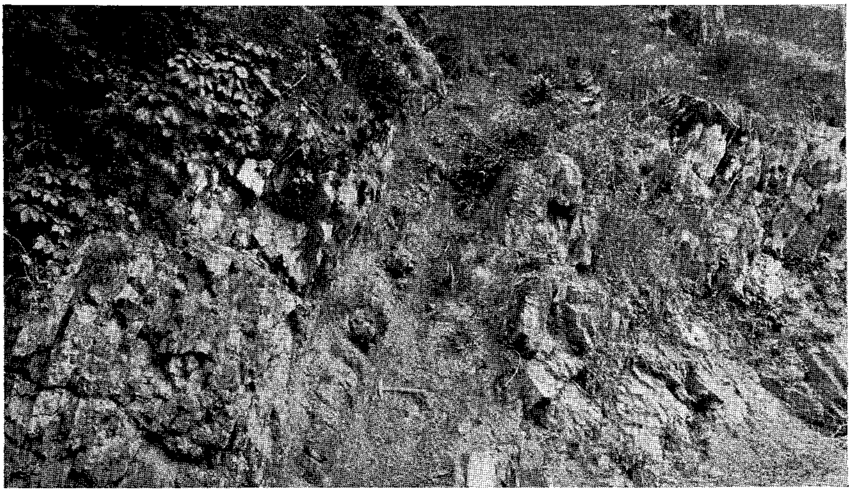
C. Bed of bentonite, 2½ feet thick, with a layer of shale or argillaceous limestone, 10 inches thick, in the middle. Same locality as B. Red and green argillaceous limestone of the Moccasin limestone is just below. This is the lowest of four beds of bentonite in this section. The bed shown in B is about 40 feet above this one. The beds dip to the northwest.



A



B



C

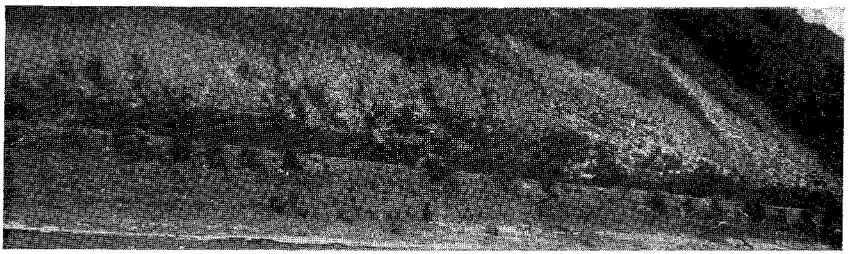
ORDOVICIAN BENTONITE

A

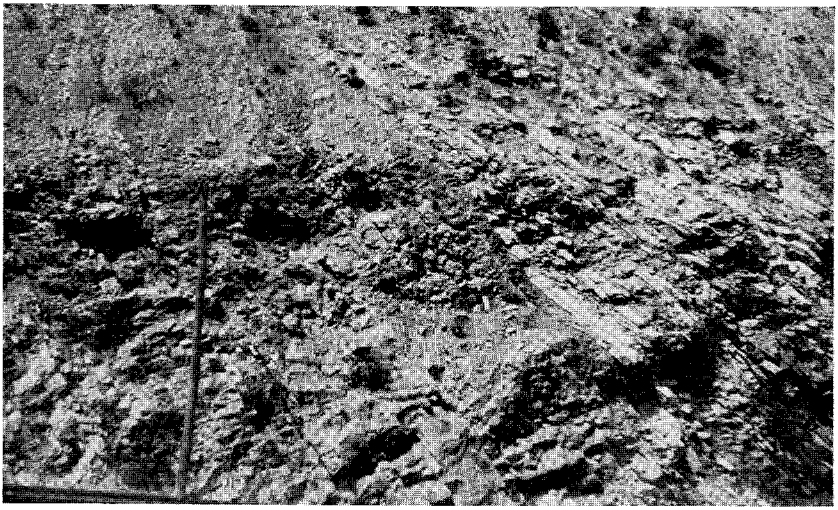
B

C

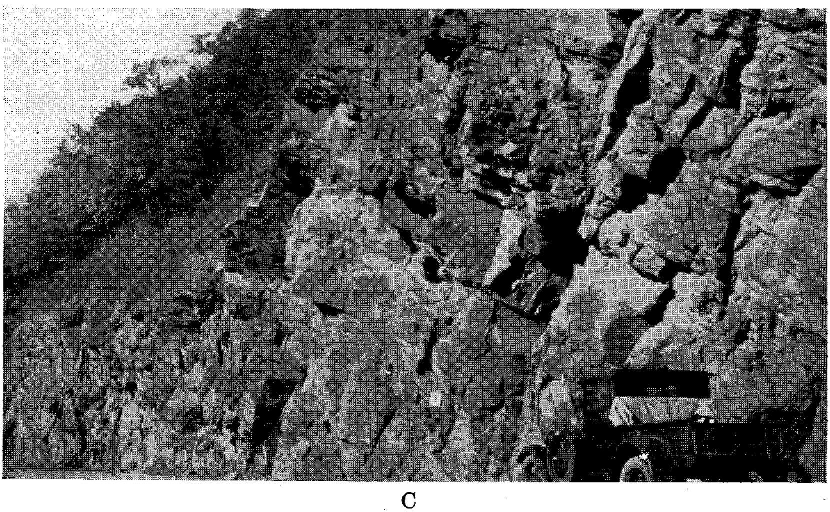
Ordovician Bentonite



A



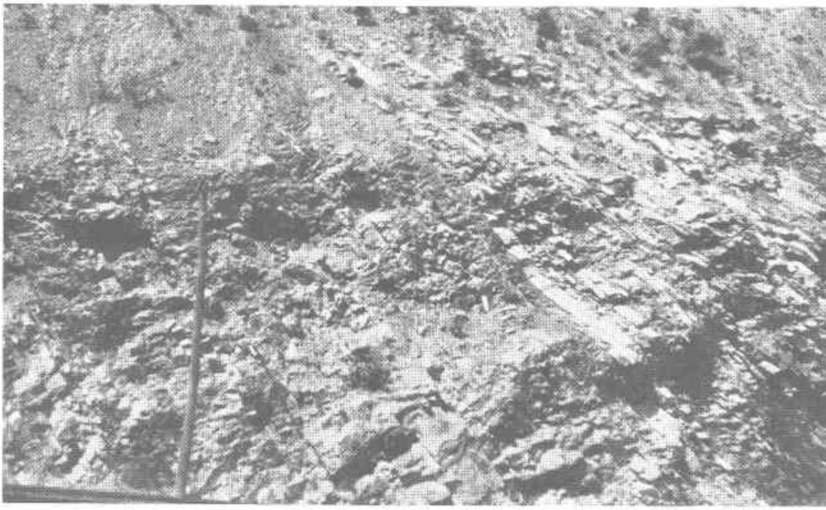
B



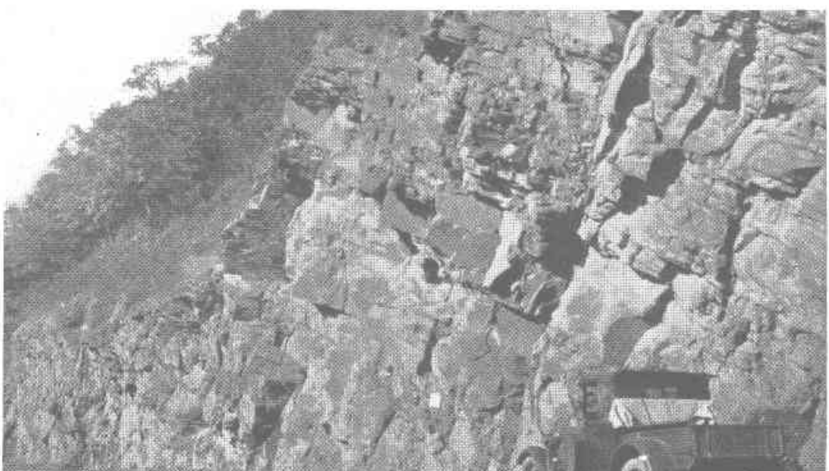
C

ORDOVICIAN FORMATIONS

A



B



C

ORDOVICIAN FORMATIONS

PLATE 38

A. Reedsville shale (left) and Oswego sandstone. This section includes the beds and contact shown in B. The Juniata red shale and sandstone are beyond the Oswego sandstone to the right. Along the Petersburg Branch of the Pennsylvania Railroad midway between Ganister and Point View Station, Blair County, Pennsylvania. Looking northwest.

B. Reedsville shale and Oswego sandstone. Detail of section shown in A. The contact is at the bottom of the lower layer of sandstone (white). *Orthorhynchula linneyi* is rather plentiful in the thick-bedded stratum just to the right of the pole.

C. *Orthorhynchula* bed at the top of the Martinsburg shale in the Narrows of New River. The Martinsburg-Juniata contact is at the top of the thick-bedded limestone. Lower edge of notebook is on layer containing *Orthorhynchula linneyi.* Along State Route 8, 1¼ miles north of the town of Narrows, Giles County. Looking west.

Geologic Section 50.—Martinsburg formation on State Route 80, on northwest slope of Clinch Mountain in Russell County, Virginia, immediately north of the Hayter wind gap

	Thickness Feet
Juniata formation	
19. Red shale and sandstone	400
Martinsburg formation (1313± feet)	
18. Limestone, dark-colored, sandy or calcareous sandstone, with *Orthorhynchula linneyi* (James)	40±
17. Not exposed	110
16. Limestone, 2-6 inch layers alternating with layers of green shale, about half and half of each; contains *Dekayella* sp.?, *Rafinesquina alternata* (Emmons), *Dalmanella emacerata* (Hall), and *Orthorhynchula linneyi* (James), the last at top	145
15. Limestone, thin bedded, shale partings	105
14. Clay	1½
13. Shale, very fine-grained sandstone, micaceous and thin sandy limestone; contains *Hallopora sigillarioides* (Nicholson), *Zygospira recurvirostris* (Hall) var., and *Cryptolithus bellulus* (Ulrich)? (Eden)	70
12. Limestone, thick and thin bedded; fossils 50 feet below the *Cryptolithus* bed; *Hallopora ampla* (Ulrich)?, *Dalmanella fertilis* Bassler, *Zygospira recurvirostris* (Hall) var. tending toward *Z. kentuckiensis* James, and *Sinuites cancellatus* (Hall)	200
11. Limestone; fossils at bottom; *Hallopora ampla* (Ulrich)?, *Prasopora simulatrix* Ulrich, *Hebertella sinuata* Hall and Clarke, *Plectorthis*? sp., *Orthorhynchula linneyi* (James), *Sowerbyella rugosa* (Meek), *Zygospira recurvirostris* (Hall) var., and *Sinuites cancellatus* (Hall)	160
10. Limestone, even bedded, argillaceous, shale partings; contains *Hallopora ampla* (Ulrich)?, *Mesotrypa* cf. *M. quebecensis* (Ami), *Prasopora simulatrix* Ulrich, *Schizocrania filosa* Hall, and *Sinuites cancellatus* Hall	85

	Thickness Feet
9. Shale and limestone	65
8. Shale with layers of limestone; bentonite 40 feet above bottom; contains *Hallopora ampla* (Ulrich)?, *Mesotrypa quebecensis* (Ami)?, *Lingula* sp.?, *Sowerbyella rugosa* (Meek), *Liospira* sp., and *Sinuites cancellatus* Hall	200
7. Shale, with *Dalmanella fertilis* Bassler	65
6. Not exposed	35
5. Bentonite	1
4. Limestone	25
3. Bentonite	1
2. Limestone	5

Hiatus, slight; Eggleston limestone or Chambersburg limestone absent

Lowville-Moccasin limestone

1. Limestone, red, argillaceous

Geologic Section 51.—Martinsburg formation at the Narrows of New River, Giles County, Virginia

	Thickness Feet
Juniata formation	
5. Sandstone and shale, all red	200
Hiatus; Oswego sandstone absent.	
Martinsburg formation (1380 feet)	
4. Sandstone, massively bedded, very fine grained, bluish green, weathering rusty, slightly calcareous; contains *Orthorhynchula linneyi* (James) and *Byssonychia radiata* (Hall); *Orthorhynchula* bed (Pl. 38C)	80±
3. Shale, and thin layers of very fine-grained sandstone of shaly character; thin layers of fossiliferous limestone; of Eden and Maysville age	600

	Thickness Feet
2. Limestone, evenly thin bedded, mainly 1-4 inch beds (Pl. 35B); layers as much as 1 foot thick near bottom crowded with fossils, mainly *Dalmanella* and *Sowerbyella;* several thin beds of bentonite in lower 50 feet; of Trenton age	700
Eggleston limestone	
1. Limestone, argillaceous, with several thin layers of bentonite	

The top member of the Martinsburg is the same in all these sections. It is known as the *Orthorhynchula* bed, from the large brachiopod, *Orthorhynchula linneyi,* universally present and abundant in these beds from central Pennsylvania to the south end of Clinch Mountain east of Morristown, Tennessee. (See Fossil Plates in Part II.) The *Orthorhynchula* bed is a slightly calcareous, generally fine-grained, bluish-gray, thick or massively bedded sandstone. Some of its layers commonly contain a few small black pebbles which are possibly phosphatic. On loss of its calcareous matter through weathering, the rock is reduced to a dark-brown friable mass that can be easily recognized. The *Orthorhynchula* bed is probably the best horizon marker in the entire Appalachian Valley. It has been found present wherever its horizon is exposed and open to examination from Tyrone, Pennsylvania, to west of Morristown, Tennessee, where it occurs on the top of Clinch Mountain just below the Clinch sandstone on the Morristown-Cumberland Gap road.

The Martinsburg, wherever it is not protected by the overlying Tuscarora-Clinch sandstone, makes a rolling and very pleasing topography, as shown in Plate 9B and C. On long-continued erosion it is worn down to a flat surface. (See Pl. 1A and B.) On the flanks of the anticlines, as northwest of Clinch and Walker mountains, the Martinsburg crops out on the steep northwestern slopes and extends to the mountain crests occupied by the Clinch sandstone. As these slopes are fairly free from stones and the soil is of good fertility, they are generally cleared and tilled or in pasture nearly to the crests. (See Pls. 8B and 9C.) Some of the best grazing land in the State, as in Russell and Tazewell counties, is on these slopes.

Distribution.—The Martinsburg shale is widely distributed throughout the Valley in Virginia as shown on the geologic map. The largest area is that of the Massanutten syncline, which is a belt 3 to 10 miles wide extending from the Potomac River to a point south of Staunton, a distance of 100 miles. This belt continues northeastward without a break to the Albany district, New York, and thence westward along the Mohawk Valley to Lake Ontario and southern Canada. In New York other names are applied to the formation, such as Trenton limestone for the lower part and Lorraine shale for the upper part. Some belts occupy the flanks of anticlines like those of Hightown, Bolar, and Warm Springs valleys, in Highland and Bath counties, and those flanking the northwest slopes of Walker, Clinch, and East River mountains southwest of New River.

Among the best exposures of the Martinsburg are those on Virginia Route 7 between Winchester and Berryville; on U. S. Route 50 for 4 miles southeast of Winchester; on the Lee Highway (U. S. Route 211) between Newmarket and the Shenandoah River; on Route U. S. 250 between Fishersville and Staunton; and on Virginia Route 80, between old Rosedale and Blackford. Good exposures are to be seen on almost every road crossing the Martinsburg synclines or any of the main ridges, as Clinch, Walker, and East River mountains.

Thickness.—No good determinations of the thickness of the Martinsburg have been made. This is because of the crumpling of the relatively weak layers of limestone and shale in the folding of the Valley strata, and the possibility of hidden faults, which repeat portions of the section. The thicknesses obtained in the detailed sections are as good as can be given at present. They are 1617 feet for the section between Saltville and Glade Springs, 1313 feet for the section north of Hayter Gap on Virginia Route 80, and 1380 feet for the section at the Narrows of New River. On the northwest slope of Catawba Mountain, on State Route 311, the thickness is estimated at 1300 feet, assuming that there are neither minor folds nor faults to vitiate the estimate. These figures are believed to be close approximations to the thickness throughout the Valley northwest of the Massanutten syncline. The great width of outcrop and high dip suggest a greater thickness of the Martinsburg in the Massanutten syncline. In the area just south of the Endless Caverns, where the outcrop of the Martinsburg is narrowest, the thickness can not exceed 4000 feet even if the rocks are vertical and regular across the whole width of outcrop. The greater width of outcrop in other parts of the syncline is largely the result of folding.

Fossils and correlation.—The Martinsburg is moderately fossiliferous. The fauna needs critical study and the identifications in the lists herewith are subject to revision. The species collected in the progress of the present investigation and also made at other times by Ulrich and Bassler, and identified by them, are listed below.

TABLE 8.—*Fossils from the Martinsburg shale*

	1	2	3	4
Graptolites:				
Climacograptus sp	x			
Diplograptus amplexicaulis (Hall)	x			
Bryozoa:				
Amplexopora cingulata Ulrich				
Amplexopora pustulosa Ulrich				
Arthroclema sp	x			
Atactopora cf. A. maculata Ulrich			x	
Bythopora gracilis (Nicholson)			x	
Chasmatopora fenestrata (Hall)?	x			
Constellaria teres Ulrich and Bassler	x			
Dekayella sp				x
Dekayia cf. D. aspera Milne-Edwards and Haime			x	
Eridotrypa? sp	x			
Hallopora ampla (Ulrich)	x			
Hallopora andrewsi (Nicholson)			x	
Hallopora sigillarioides (Nicholson)		x		
Mesotrypa angularis Ulrich and Bassler?	x			
Mesotrypa quebecensis (Ami) ?	x			
Mesotrypa, 3 sp	x			
Prasopora cf. P. orientalis Ulrich	x			
Prasopora simulatrix Ulrich	x			
Rhinidictya nicholsoni Ulrich	x			
Brachiopods:				
Catazyga sp			?	
Dalmanella bassleri Foerste	x			
Dalmanella emacerata (Hall)	x			
Dalmanella fairmountensis Foerste			x	
Dalmanella fertilis Bassler	x			
Dalmanella multisecta (Meek)		x		
Dalmanella rogata (Sardeson)	x			
Dinorthis pectinella (Emmons)	x			
Hebertella sinuata Hall and Clarke	x		x	
Leptaena rhomboidalis (Wilckens)	x			
Lingula nicklesi Bassler				x
Orthorhynchula linneyi (James)	x			x
Pholidops cincinnatiensis Hall		x		
Pholidops subtruncata (Hall)			x	
Pholidops trentonensis Hall	x			
Plectorthis cf. P. plicatella (Hall)				x
Plectorthis? sp				
Rafinesquina alternata (Emmons)	x		x	
Rafinesquina cf. R. fracta (Meek)			x	
Schizocrania filosa Hall	x			
Sowerbyella cf. S. curdsvillensis (Foerste)	x			
Sowerbyella rugosa (Meek)	x	x	x	
Sowerbyella rugosa triradiatus Butts, n. var				
Strophomena sp	x			
Trematis millepunctata Hall				x
Zygospira kentuckiensis James (small)			x	
Zygospira modesta Hall		x		
Zygospira recurvirostris (Hall) var. tending toward Z. kentuckiensis James	x			
Pelecypods:				
Byssonychia praecursa Ulrich				x
Byssonychia radiata (Hall)				x
Byssonychia vera Ulrich				x

1. Trenton; 2. Eden; 3. Maysville; 4. *Orthorhynchula* bed in the top of the Maysville.

TABLE 8.—*Fossils from the Martinsburg shale—Continued*

	1	2	3	4
Clidophorus cf. C. ellipticus (Ulrich)			x	
Clidophorus sp				x
Colpomya sp				x
Ctenodonta aff. C. levata (Hall)	x		x	
Ctenodonta cf. C. nitida (Ulrich)			x	
Ctenodonta pectunculoides (Hall)			x	
Ctenodonta aff. C. pectunculoides (Hall)	x			
Cuneamya cf. C. neglecta (Meek)			x	
Cuneamya sp. (small)	x			
Cycloconcha sp			x	
Cymatonota, 2 sp			x	
Cyrtodonta sp	x			
Goniophora ? sp	x			
Lyrodesma cf. L. poststriatum (Emmons)			x	
Lyrodesma, 2 sp			x	
Modiodesma modiolare (Conrad)				x
Modiolodon obtusus Ulrich				x
Modiolodon cf. M. truncatus (Hall)				x
Modiolopsis milleri Ulrich				x
Modiolopsis sp	x			x
Orthodesma contractum (Hall)				x
Orthodesma rectum Hall and Whitfield				x
Psiloconcha sp			x	
Pterinea demissa (Conrad)				x
Pterinea? sp. (small)	x			
Pterinea sp				x
Rhytimya sp				x
Whiteavesia sp				x
Whitella sp				
Gastropods:				
Carinaropsis sp			x	
Cyclonema sp				x
Cyrtolites ornatus Conrad			x	
Hormotoma gracilis (Hall)	x			
Liospira aff. L. micula (Hall)	x			
Liospira aff. L. mundula Ulrich	x			
Liospira cf. L. vitruvia (Billings)				x
Lophospira aff. L. bicincta (Hall)			x	
Lophospira aff. L. medialis Ulrich and Scofield			x	
Lophospira aff. L. perangulata (Hall)			x	
Lophospira? aff. L. uniangulata (Hall)				x
Oxydiscus? sp				x
Patelloid shell, genus undetermined	x			
Raphistomina? sp	x			
Sinuites cancellatus (Hall)	x			
Tetranota sp				x
Cephalopods:				
Beloitoceras sp			x	
Orthoceras, several sp. (one annulated)	x		x	
Wetherbyoceras conoidale (Wetherby)			x	
Trilobites:				
Calliops callicephalus (Hall)?	x			
Calymene granulosa (Foerste)			x	
Calymene meeki Foerste			x	
Calymene, 2 sp	x			
Ceraurus pleurexanthemus Green	x			

1. Trenton; 2. Eden; 3. Maysville; 4. *Orthorhynchula* bed in the top of the Maysville.

TABLE 8.—*Fossils from the Martinsburg shale—Continued*

	1	2	3	4
Cryptolithus bellulus (Ulrich)?		x		
Cryptolithus tessellatus Green	x			
Homotelus? sp				
Isotelus covingtonensis Ulrich			x	
Isotelus gigas deKay	x			
Isotelus cf. I. latus Raymond	x			
Odontopleura cf. O. crosota (Locke)			x	
Pterygometopus cf. P. eboraceus Clarke	x			
Ostracodes:				
Aechmina sp	x			
Aparchites minutissimus (Hall)		x		
Bythocypris cylindrica (Hall)		x		
Ceratopsis chambersi (Miller)	x			
Ceratopsis intermedia Ulrich	x			
Ctenobolbina bispinosa Ulrich	x	x		
Ctenobolbina aff. C. bispinosa Ulrich	x			
Ctenobolbina ciliata (Emmons)	x	x		
Dicranella cf. D. bivertex (Ulrich)	x	x		
Jonesella sp	x			
Leperditia sp	x			
Primitia sp. (very small)		x		
Primitiella unicornis (Ulrich)	x			
Primitiella sp	x			
Tetradella aff. T. quadrilirata Hall and Whitfield	x			
Other Crustacea:				
Eurypterus sp. (fragments)	x			
Lepidocoleus aff. L. jamesi (Hall and Whitfield)				

1. Trenton; 2. Eden; 3. Maysville; 4. *Orthorhynchula* bed in the top of the Maysville.

The species *Diplograptus amplexicaulis, Prasopora simulatrix, Mesotrypa quebecensis, Hallopora ampla, Sinuites cancellatus, Ceratopsis intermedia,* and *Tetradella quadrilirata* are strictly of Trenton age and clearly define the lower third or so of the Martinsburg as Trenton, corresponding in general to the Trenton limestone at Trenton Falls, New York, and to the Canajoharie shale and part, at least, of the overlying Schenectady formation, both occurring in the Albany district, New York. A few species, such as *Hallopora sigillarioides* and *Cryptolithus bellulus,* seem to be of Eden age and the part of the Martinsburg containing them is thus of the age of the Eden formation at Cincinnati, Ohio. That zone is represented also in the midst of the Lorraine formation of New York east of Lake Ontario. The species *Hallopora andrewsi, Byssonychia radiata, Calymene granulosa,* and *Calymene meeki* serve to correlate the upper beds of the Martinsburg with the Maysville of Ohio, and the upper part of the Lorraine (Pulaski) of New York. *Orthorhynchula linneyi* and *Lingula nicklesi* are sure indices of the *Orthorhynchula* zone. The species of *Dalmanella,* though easily recognizable generically, are difficult to distinguish from each other. Taken altogether, however, in connection with their constant association with *Sowerbyella curdsvillensis* ? and *S. rugosa,* also easily recognizable generically or even specifically, they make the identification of the Martinsburg, including the Trenton equivalent in the lower part, a simple matter.

TRENTON LIMESTONE

Name.—The Trenton limestone was so named from Trenton Falls on West Canada Creek, Herkimer and Oneida counties, New York.[121]

Limits.—In the type region in New York, the Trenton rests either upon the Lowville or the upper Black River limestone. In Lee County along the northwest base of Wallen Ridge, the Trenton lies upon the Eggleston or upper Black River limestone. In the type region, the Trenton is succeeded by the Utica shale and the Utica by the Lorraine shale. The Trenton in Lee County and adjacent areas is succeeded by the Reedsville shale which corresponds approximately to the Lorraine shale.

Character.—The Trenton is composed of a mass of thin- to medium thick-bedded, rather coarsely crystalline, bluish-gray to light-gray limestone. Shale partings occur at some horizons and are associated with irregular thin layers or small irregular lenticular slabs of limestone. The limestone is commonly highly fossiliferous. Two sections measured by Stose[122] on the northwest slope of Wallen Ridge, 2 miles southwest of Big Stone Gap, are combined and given below:

Geologic Section 52.—Composite section of the Trenton limestone near Big Stone Gap. Wise County, Virginia

	Thickness Feet
Reedsville shale	
Trenton (Catheys) limestone (225 feet)	
7. Not exposed	100
6. Limestone, gray, granular, with some irregular impure laminations which weather in relief; contains cephalopods, gastropods, and brachiopods	75

[121] Vanuxem, Lardner, Second annual report . . . of the geological survey of the third district of the State of New York: New York Geol. Survey, 2nd Ann. Rept., pp. 257, 276, 283, 1838.

[122] Stose, G. W., *in* Eby, James B., 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.

	Thickness Feet
5. Limestone, light gray, rather thick bedded, granular, spotted white by many bryozoa, and containing many brachiopods and *Stromatocerium pustulosum* (Safford)	50
Trenton (Cannon) limestone (375 feet)	
4. Limestone, chiefly impure, which weathers dull and contains few fossils; some harder, purer beds	140
3. Limestone, blue; contains numerous cephalopods and brachiopods	10
2. Limestone, like bed 4	215
1. Limestone, gray, crinoidal; contains numerous brachiopods	10
Lowville limestone	
Limestone, dark drab to pink, fine grained; probably includes some Eggleston limestone in the upper part.	

From beds 5 and 6, Stose lists the following fossils which were identified by Ulrich:

Byssonychia sp.
Hebertella sinuata Hall and Clarke (Trenton var.)
Lophospira? sp.
Orthorhynchula linneyi (James)?
Platystrophia sp.
Pterinea sp.

From beds 1 to 4, the following forms have been identified by Ulrich:

Cyrtodonta grandis (Ulrich)
Cyrtodonta saffordi (Hall)
Hebertella frankfortensis Foerste
Hormotoma sp.
Lophospira sp.
Rafinesquina sp.
Rhynchotrema increbescens (Hall)
Zygospira recurvirostris (Hall)

A section of the lower 350 feet of the Trenton examined by the writer on the northwest slope of Wallen Ridge southeast of

Rose Hill, Lee County, is composed of medium thick-bedded, blue-gray, granular limestone, with large *Dalmanella* at the bottom, *Cyrtodonta grandis* in middle, and *Hebertella frankfortensis* and *Rhynchotrema increbescens* at the top.

Beds of bentonite are widely distributed in the lower part of the Trenton or in the equivalent of the Trenton in the basal Martinsburg shale, as shown in Plate 37A.

Distribution.—The Trenton as a distinct lithologic unit occurs only in Lee and Wise counties and is so designated on the geologic map. It crops out in three belts: one along the southeast base of the Cumberland escarpment, a second along the northwest base of Wallen Ridge from Big Stone Gap to the Tennessee line, and a third along the northwest base of Powell Mountain from the east base of Elk Knob, 4 miles northeast of Stickleyville, to the Tennessee line. Outlying small areas occur on Big A Mountain, Russell County, and on the top of a high knob in Rye Cove, Scott County, 2 miles northeast of Rye Cove school.

The best exposures of the Trenton are along U. S. Route 58, on the northwest slopes of Powell Mountain and Wallen Ridge; in Williams Cove, 2 miles southwest of Big Stone Gap (geologic section 52); and on the northwest slope of Powell Mountain along Virginia Route 64 south of Jonesville, Lee County, half a mile southeast of the bridge at the former Dickerson ford.

Thickness.—The best measurements give a thickness of 600 feet for the Trenton on the northwest slope of Wallen Ridge, 2 miles southwest of Big Stone Gap, and on State Route 64, south of Jonesville. The thickness probably does not vary much elsewhere. The Trenton part of the Martinsburg in the Narrows of New River is 700 feet thick.

Fossils and correlation.—The Trenton is highly fossiliferous, but only a comparatively few species have been collected and identified. A short list of the fossils is given below:

Bryozoa
- Constellaria teres Ulrich and Bassler
- Eridotrypa? sp.
- Escharopora? sp.
- Hallopora multitabulata (Ulrich)
- Mesotrypa, 2 sp.
- Monotrypa? sp.
- Prasopora? sp.
- Rhinidictya nicholsoni Ulrich
- Rhinidictya, 2 or 3 other sp.

Brachiopods
- Dalmanella fertilis Bassler
- Dalmanella rogata (Sardeson)
- Hebertella frankfortensis Foerste
- Hebertella sinuata Hall and Clarke
- Rafinesquina alternata (Emmons)
- Rhynchotrema increbescens (Hall)
- Sowerbyella curdsvillensis Foerste?
- Sowerbyella rugosa? (Meek)
- Zygospira recurvirostris (Hall)

Pelecypods
- Byssonychia sp?
- Ctenodonta hartsvillensis (Safford)
- Ctenodonta, rather large sp?
- Cyrtodonta grandis (Ulrich)

Gastropods
- Bucania sp.
- Cyclonema cf. C. varicosum Hall
- Hormotoma? sp.
- Liospira micula (Hall)
- Lophospira medialis Ulrich and Scofield

The most significant fossils for correlation are *Constellaria teres, Hebertella frankfortensis, Rhynchotrema increbescens,* and *Cyrtodonta grandis,* which indicate without doubt the continuity of the Trenton sea of southwest Virginia with that which covered the Nashville dome in central Tennessee and Kentucky, where these fossils occur abundantly in certain limestones. None of these forms migrated far enough eastward to intermingle with the Atlantic fauna of the southeast valley belts characterized by *Cryptolithus tessellatus,* which has been found only in the lower third of the Martinsburg shale of the southeastern belts in Virginia. A few specimens of *Rhynchotrema increbescens* were found in the basal Martinsburg on the northwest side of the Elk Garden Ridge syncline about a mile south of Blackford, Russell County. Other forms, such as the species of *Dalmanella,* seem to have spread freely through both parts of the Trenton sea, indicating at least intermittent, if not permanent, connection.

REEDSVILLE SHALE

Name.—The Reedsville received its name from Reedsville, Mifflin County, Pennsylvania,[123] where it is well displayed and lies between the Trenton limestone and the Juniata formation.

[123] Ulrich, E. O., op. cit., plate 27.

Limits.—In Virginia the Reedsville is recognized as a distinct formation only in Lee and Wise counties, where it lies between the Trenton limestone and the Sequatchie formation.

Character.—The Reedsville shale is identical in character with and fully equivalent to the post-Trenton part of the Martinsburg shale in the southeastern belts of the Valley. The *Orthorhynchula* zone has the same position in the Reedsville as in the Martinsburg, but at Cumberland Gap it appears to be a thin-bedded limestone rather than a massively bedded argillaceous and arenaceous limestone as in the Martinsburg. The general appearance of the *Orthorhynchula* bed is shown in Plate 38B and C. A section partly exposed on the highway and partly on the Louisville and Nashville Railroad, 1 mile southeast of Cumberland Gap village, shows the general character of the Reedsville in Lee County. Neither the top nor the bottom of this section was precisely located, but it is approximately correct.

Geologic Section 53.—Reedsville shale southeast of the village of Cumberland Gap, Tennessee

	Thickness Feet
Sequatchie-Juniata	
Limestone and shale with pink or red limestone; *Drepanella richardsoni* Miller	
Hiatus; Oswego sandstone and probably the lower Sequatchie absent	
Reedsville shale (416 feet)	
7. Limestone, flaggy to shaly, dark blue, argillaceous, partly stained pink on surface; contains *Amplexopora cingulata* Ulrich, *Cyphotrypa semipilaris* (Ulrich), *Hebertella sinuata* Hall and Clarke, *Platystrophia laticosta* (Meek), *Zygospira kentuckiensis* James, *Byssonychia* sp., *Modiolodon truncatus* (Hall), *Pterinea demissa* (Conrad), *Bellerophon* sp., *Lophospira? sp.*	70
6. Limestone, gray, flaggy; contains *Cyphotrypa semipilaris* (Ulrich), *Platystrophia* sp., *Byssonychia* sp., *Modiodesma modiolare* (Conrad), *Modiolodon truncatus* (Hall)	8
5. Limestone, shaly, pink	8

	Thickness Feet
4. Limestone, dark-colored, argillaceous, shaly; contains *Cyphotrypa semipilaris* (Ulrich), *Eridotrypa* sp., *Hebertella sinuata* Hall and Clarke, *Orthorhynchula linneyi* (James), *Platystrophia laticosta* (Meek), *Rafinesquina alternata* (Emmons)?, *Zygospira kentuckiensis* James, *Byssonychia* sp., *Bellerophon* sp.	40±
3. Limestone, cobbly, with shale partings; contains *Amplexopora cingulata* Ulrich, *A. pustulosa* Ulrich, *Batostoma?* sp., *Constellaria florida* Ulrich, *Escharopora hilli* (James), *Monotrypa* sp., *Monticulopora molesta* Nicholson, *Hebertella sinuata* Hall and Clarke, *Orthorhynchula linneyi* (James), *Zygospira kentuckiensis* James, *Lophospira* sp.	20
2. Shale, layers of limestone, few fossils	20
1. Shale with thin layers of very fine-grained soft sandstone	250

Distribution.—The Reedsville, like the Trenton, crops out in three belts, one on the northwest slope of Powell Mountain, one on the northwest slope of Wallen Ridge, and the third along the southeast base of the Cumberland escarpment, all in Lee County except the northeast end of the Wallen Ridge belt which is in Wise County.

Thickness.—As given by Stose,[124] the Reedsville shale is 460 feet thick at the northeast end of Wallen Ridge a few miles southwest of Big Stone Gap. As shown by geologic section 53, its thickness at Cumberland Gap is 416 feet or slightly more. It probably ranges from 400 to 500 feet.

Fossils and correlation.—The Reedsville is fossiliferous, but only a few small collections have been made, and those only in the upper 100 feet or so of the Maysville part. These forms are listed in geologic section 53. *Modiodesma modiolare* and *Modiolodon truncatus* occur in the Maysville at Cincinnati and in the equivalent Pulaski (upper Lorraine) of north-central New York and of Quebec, Canada. The bryozoa are all Maysville species of the Cincinnati area. *Orthorhynchula linneyi, Hebertella sinuata,* and possibly *Zygospira kentuckiensis,* are known to occur also in the southeastern belts of the Martinsburg in Virginia. The occurrence of this fauna at Cumberland Gap connects the two extreme ends of the middle Maysville areas, that at Cincinnati with that of central New York. The upper

[124] Stose, G. W., op. cit., p. 28.

part of the Maysville in southwest Ohio is believed to be represented by the Oswego sandstone in Virginia and Pennsylvania. It is believed that the part of the Reedsville below the lowest zone represented by the fossil lists in the preceding section contains an Eden fauna, but the fact has not been established by determined fossils.

OSWEGO SANDSTONE

Name.—The Oswego sandstone is named from Oswego, New York, where it crops out and was described by Vanuxem[125] in 1842 as the gray sandstone of Oswego. It was later specifically named by Prosser[126] as Oswego. It is conspicuously displayed in Bald Eagle Mountain of Center and Blair counties, Pennsylvania, on account of which it was named Bald Eagle sandstone by Grabau.[127] As Oswego sandstone has clear priority that name is accepted.

Limits.—The Oswego sandstone occupies the space between the *Orthorhynchula* zone of the Martinsburg shale and the Juniata-Sequatchie formation.

Character.—The Oswego is a thick-bedded greenish or bluish-gray, iron-speckled sandstone with some layers of red shale and red sandstone. It is very uniform in character from central Pennsylvania into Virginia. The following section in Brocks Gap, Rockingham County, shows its character:

Geologic Section 54.—Oswego sandstone in Brocks Gap, Rockingham County, Virginia

	Thickness Feet
Tuscarora quartzite	
11. Quartzite, white	30
Juniata formation (?)	
10. Not exposed, probably Juniata	300
Oswego sandstone (507 feet)	
9. Sandstone, hard, quartzitic, partings of green shale	130

[125] Vanuxem, Lardner, Fourth annual report of the geological survey of the third district: New York Geol. Survey 4th Ann. Rept., p. 67, 1842.
[126] Prosser, Charles, The thickness of the Devonian and Silurian rocks of western central New York: Am. Geologist, vol. 6, pp. 199-211, 1890.
[127] Grabau, A. W., Physical and faunal evolutions of North America during Ordovicic, Siluric, and early Devonic time: Jour. Geology, vol. 17, p. 235, 1909.

		Thickness Feet
8.	Sandstone, bluish gray, medium thick bedded, quartzitic, cross laminated	165
7.	Sandstone, red	10
6.	Sandstone, bluish gray	50
5.	Sandstone and shale, red	10
4.	Sandstone, bluish gray	7
3.	Shale, red	5
2.	Sandstone, bluish gray	130

Martinsburg shale

1. Sandstone and sandy shale, with *Orthorhynchula linneyi* (James)

Except for thickness, the section here is a duplicate of the section in Bald Eagle Mountain at Tyrone, Pennsylvania, and in Lock Mountain three-fourths of a mile northwest of Ganister, Blair County, Pennsylvania. (See Pl. 38A and B.)

Distribution.—In Virginia the Oswego crops out in three discontinuous strips along the southeast slope of Little North Mountain: one beginning on the north probably about 1 mile south of Wheatfield, Shenandoah County, and extending southwest to a point 6 miles northwest of Edinburg, Shenandoah County, where its outcrop is cut off by the Little North Mountain fault; another extending from a point 3 miles northeast of Brocks Gap to a point 2½ miles east of Rawley Springs, Rockingham County, where its outcrop is also cut off for a short distance by the Little North Mountain fault; and a third, about 2 miles long, in continuation of the same strike 2 miles south of Rawley Springs where it is apparently of unusual thickness and makes the conspicuous knob known as the Giants Grave, which marks its southern limit in Virginia. The Oswego also appears in the gorges of Duck Run and Paddy Run and on the flanks of the North Mountain anticline along the valley of Paddy Run in southwestern Frederick County. In these localities the Oswego includes beds of a very coarse and characteristic conglomerate with pebbles 2 inches in diameter. It extends southwest along both flanks of Great North Mountain to a point 5 miles north of Fulks Run, Rockingham County, where it dips beneath the surface on the pitching axis of the Fulks Run anticline. It is thin on Lantz Mountain in northwestern Highland County.

Thickness.—As shown by the preceding section, the maximum known thickness of the Oswego sandstone in Virginia is about 500 feet. Its thickness is apparently much less along the Little North Mountain belt.

Fossils and correlation.—The Oswego sandstone is devoid of fossils in Pennsylvania and Virginia, from which it is inferred that it accumulated in a body of fresh water or on a wide sea beach. The depositional area may have been occasionally overflowed by the sea with distribution of the fine mud of the shale beds and shale partings in the sandstone, but the inundations apparently never lasted long enough to permit the incursion of marine animals. If invertebrate remains accumulated in these beach sands they have apparently been destroyed throughout the area of the Oswego sandstone in Virginia.

The correlation of this sandstone in Virginia with the Oswego sandstone in the type locality rests upon its similarity to the Oswego both in lithologic character and in stratigraphic position. In Virginia, as in New York, it lies between beds with characteristic upper Maysville fossils below and the equally highly characteristic Juniata red shale above. In New York the Maysville fossils are in the upper part of the Lorraine shale, in Virginia they are in the corresponding upper part of the Martinsburg shale or the Reedsville shale, according to locality. The Oswego is correlated with the McMillan formation, the upper division of the Maysville group of the Cincinnati area of Ohio.

HIATUS (?)

If the Oswego sandstone horizon is absent in Virginia southwest of Augusta and Highland counties, there is a hiatus between the Martinsburg, or Reedsville, shale and the Juniata, or Sequatchie, formation in the southwestern part of the state.

JUNIATA-SEQUATCHIE FORMATION[128]

Names.—The Juniata formation was named from Juniata River, Pennsylvania,[129] because of its extensive outcrop crossed by the river. The name Sequatchie, applied to the same unit in its transition to a marine facies in southwest Virginia, is from Se-

[128] As most geologists and many geological surveys, including the U. S. Geological Survey and numerous state geological surveys, place the Juniata and Sequatchie formations of Richmond age in the Ordovician system, they are so included in this report. That procedure has also recently been followed by the correlation subcommittees of the National Research Council, Division of Geology and Geography. Those formations were included, however, in the Silurian system as delineated on the geologic map of the Appalachian Valley in Virginia (Virginia Geol. Survey Bull. 42), published in 1933, in order to indicate the opinion of some geologists, including the author of this report.

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

quatchie Valley, Tennessee, where that facies was first observed.[130] The Juniata corresponds to the lower and much the thicker part of the original Medina sandstone of Vanuxem and Hall in New York.[131] Included in the top of the original Medina was about 100 feet of sandstone and shale which has been made a distinct formation, the Albion sandstone.[132] The name Queenston shale is now applied in New York to the remaining nine-tenths of the original Medina sandstone. The Queenston corresponds to the Juniata of Pennsylvania and Virginia and the Albion sandstone corresponds to the Tuscarora-Clinch[133] sandstone of those states, which overlies the Juniata just as the Albion overlies the Queenston of New York. It is regrettable that the name Medina was not retained with appropriate redefinition for the greater part of the original Medina and used everywhere instead of Queenston and Juniata.[134]

Limits.—The Juniata formation occupies the space between the Oswego sandstone below and the Tuscarora sandstone above in the northern end of the Appalachian Valley in Virginia; farther southwest it is overlain by the Clinch sandstone and rests everywhere upon the *Orthorhynchula* zone of the Martinsburg shale. In Lee County the equivalent Sequatchie formation also succeeds the *Orthorhynchula* zone.

Character.—The Juniata formation is composed mainly of bright red shale or mudrock and beds of brown to red sandstone. A few layers of gray sandstone occur in places near the top. Its distinctive feature is the red color. It is one of five red formations in the Valley, the first two being the older Rome and Moccasin formations already described, and the fourth and fifth the younger Bloomsburg and Pennington or Hinton formations.

One of the best sections of the Juniata in Virginia is exposed on the east slope and crest of Lantz Mountain[135] along U. S. Route 250 northwest of Monterey, Highland County. It is as follows:

---

[130] Ulrich, E. O., The Ordovician-Silurian boundary: Compte-Rendu International Geological Congress, XII Session, Canada, p. 651 and correlation chart, 1913.

[131] Vanuxem, Lardner, Fourth annual report of the geological survey of the third district: New York Geol. Survey, 4th Ann. Rept., 1840.

Hall, James, Fourth annual report of the survey of the fourth geological district: New York Geol. Survey, 4th Ann. Rept., pp. 453-455, 1840.

[132] Kindle, E. M., U. S. Geol. Survey Geol. Atlas, Niagara folio (No. 190), p. 6, Aug. 17, 1913; also mentioned by Ulrich, E. O., *op. cit.*, pp. 26, 27, 30, 36, and 49, in advance copy issued before preceding reference.

[133] The Tuscarora and Clinch sandstones are identical formations. See section on Silurian system.

[134] In a number of the U. S. Geological Survey folios of southwest Virginia and eastern Tennessee, the Juniata was called Bays formation from its mistaken identification with the Bays formation of Tennessee which is the same as the Moccasin. This identification was evidently suggested by the red color of the Juniata.

[135] Called Little Mountain on early editions of the topographic map of the Monterey quadrangle.

Geologic Section 55.—Juniata formation, 4 miles northwest of Monterey, Highland County, Virginia

	Thickness Feet
Tuscarora sandstone	
Juniata formation (725± feet)	
8. Not exposed, probably Juniata	100±
7. Mudrock, red, with thin layers of red sandstone	200
6. Sandstone, mainly	100
5. Mudrock, red, with thin layers of sandstone	160
4. Sandstone and shale	100
3. Shale, red, and sandstone, medium thick bedded, red and gray	65
Oswego sandstone (?)	
2. Sandstone, rather thick bedded, greenish gray	40
Martinsburg formation	
1. Sandstone, rusty, leached sandy limestone; contains *Orthorhynchula linneyi* (James) and *Byssonychia radiata* (Hall); exposed	100±

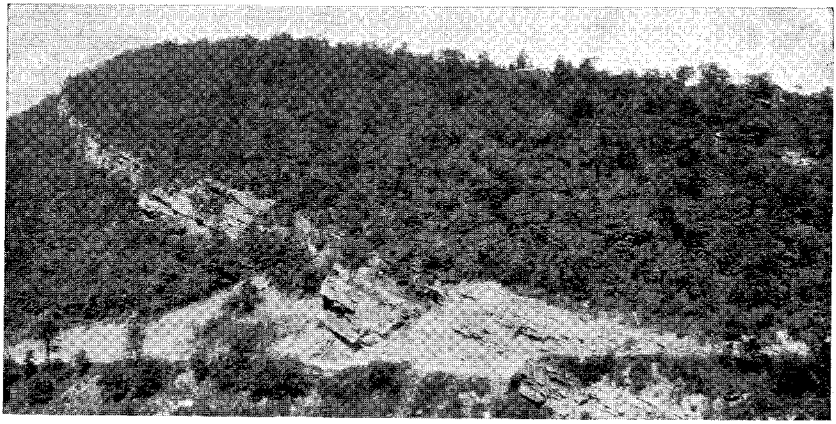
The Juniata anywhere else in the Valley would not differ in character essentially from this section, except in Lee County, in the extreme southwestern part of Virginia, where it passes into a marine calcareous and fossiliferous facies to which the name Sequatchie is applied. This part of the state approaches the meridian of the Cincinnatian area where the Richmond formations are fully developed. As Lee County lies in the transition zone from the nonmarine Juniata to the marine Richmond, the Sequatchie formation there partakes of the characteristics of both of these formations. This transitional zone also crops out at the western end of Lake Ontario, where limestone with some of the same fossils as those in the Sequatchie at Cumberland Gap also occurs in the Queenston red shale of Richmond age. These fossils are listed in the following section which is exposed on U. S. Route 25 E., half a mile southeast of Cumberland Gap, Tennessee:

PLATE 39

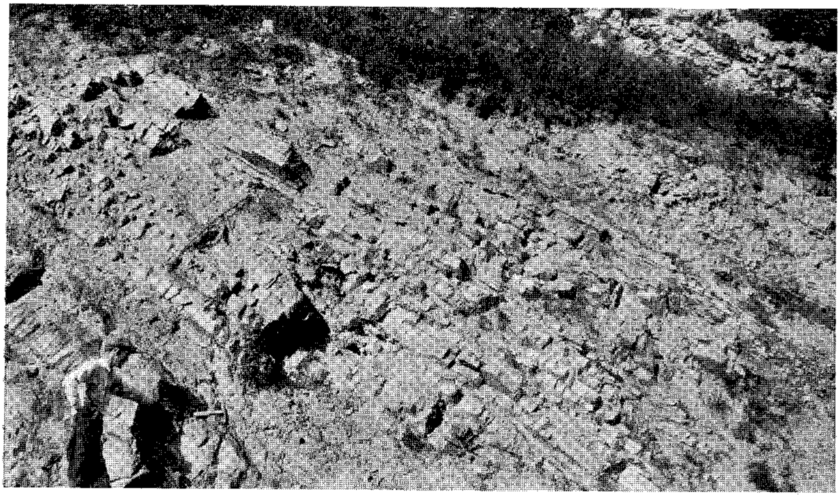
A. Clinch sandstone on the southwest end of Peters Mountain, Giles County. It dips to the southeast and rises northwestward to make the crest of the mountain. The crests of most of the high, generally straight, northeast-southwest ridges of the Valley coincide with the outcrop of the steeply dipping Clinch sandstone. In the Narrows of New River about 1 mile north of the village of Narrows.

B. Clinch sandstone, about 18 feet thick, in McCall Gap, Washington County. The man is pointing to the contact with the underlying Juniata shale. The top is at the uppermost thin layer of sandstone. The Clinch is overlain by about 6 inches of brown, ferruginous, crumbly sandstone with *Spirifer arenosus*, which represents the Oriskany sandstone. The Clinton formation, normally overlying the Clinch, is absent here but is present a few miles to the northeast along the strike. Overlying the Oriskany here, is Onondaga shale and limestone from which a single specimen of *Amphigenia elongata* was obtained. Other Onondaga fossils occur. In the upper right corner is the massive, gnarly chert almost universally present in the Onondaga in the southwestern counties of the Valley. Road cut in McCall Gap on State Route 81 midway between Glade Spring and Saltville. Looking northeast.

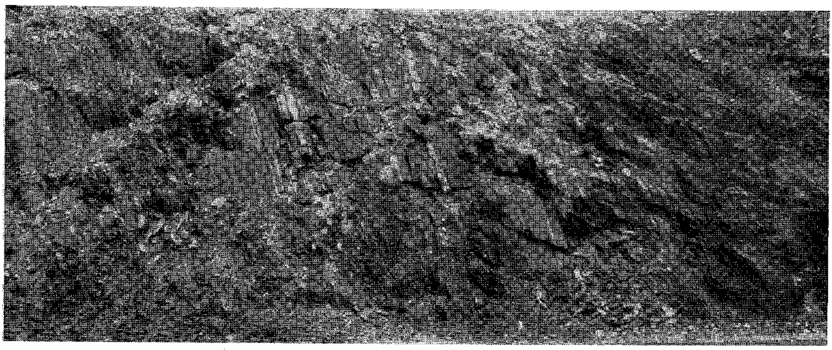
C. Martinsburg shale near Staunton, Augusta County. It dips about 70° SE. The joint planes dip to the southeast at a low angle and resemble bedding planes. These beds contain graptolites, including *Diplograptus amplexicaulis*. Along U. S. 250, 3 miles southeast of Staunton.



A

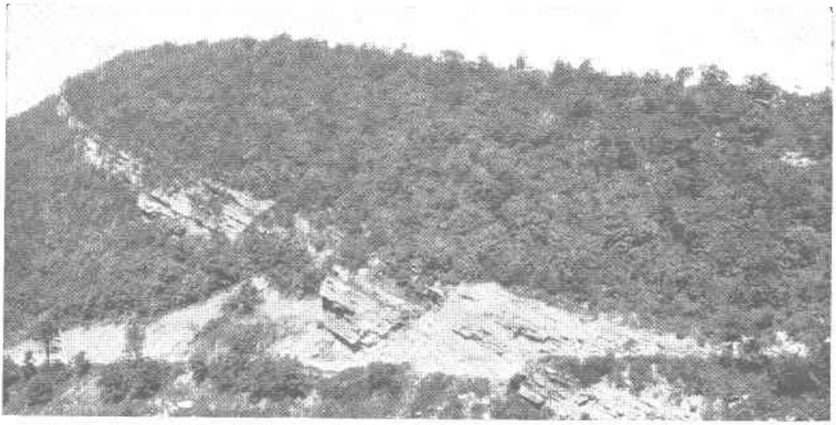


B

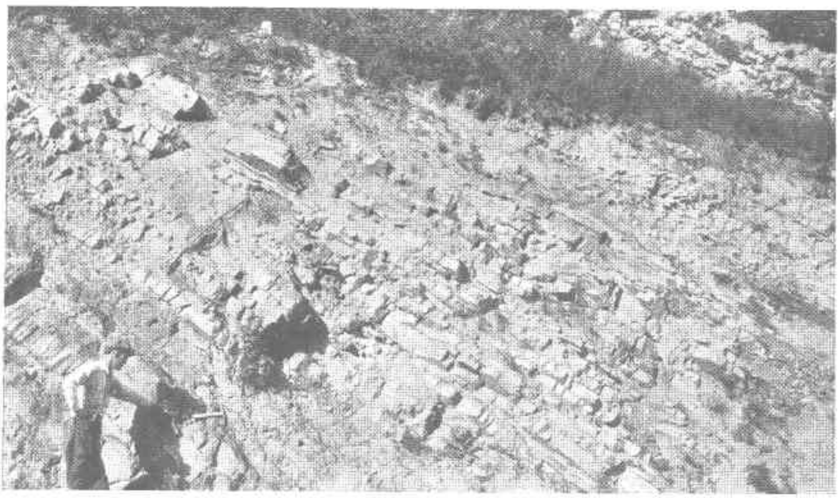


C

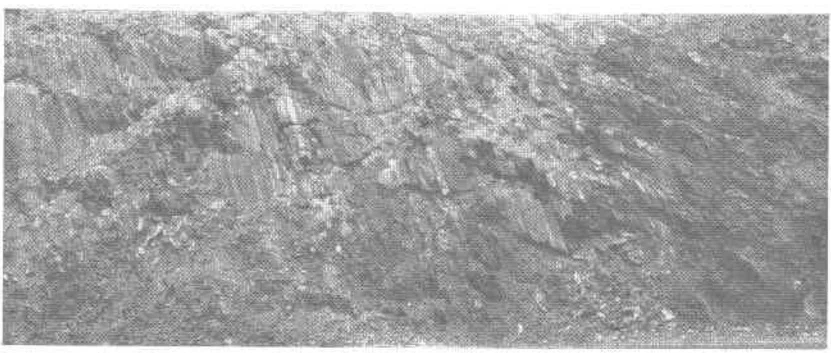
ORDOVICIAN AND SILURIAN FORMATIONS



A

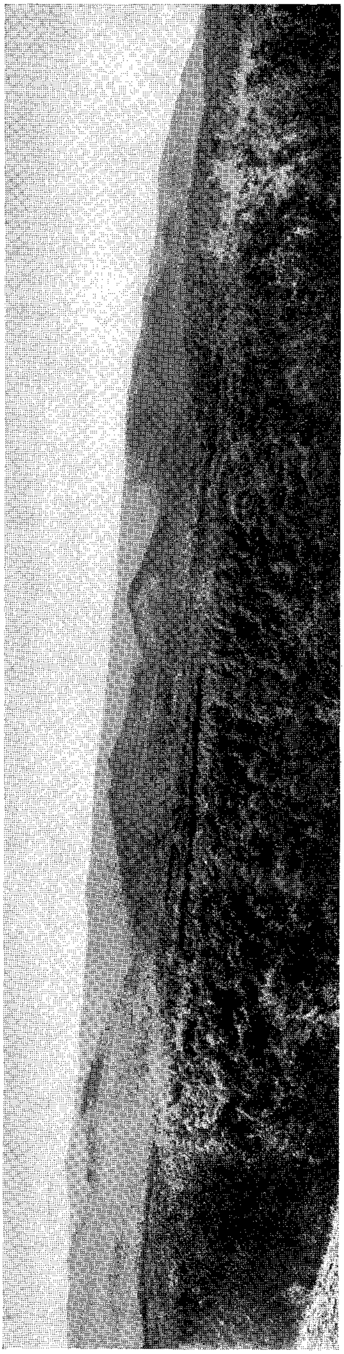


B

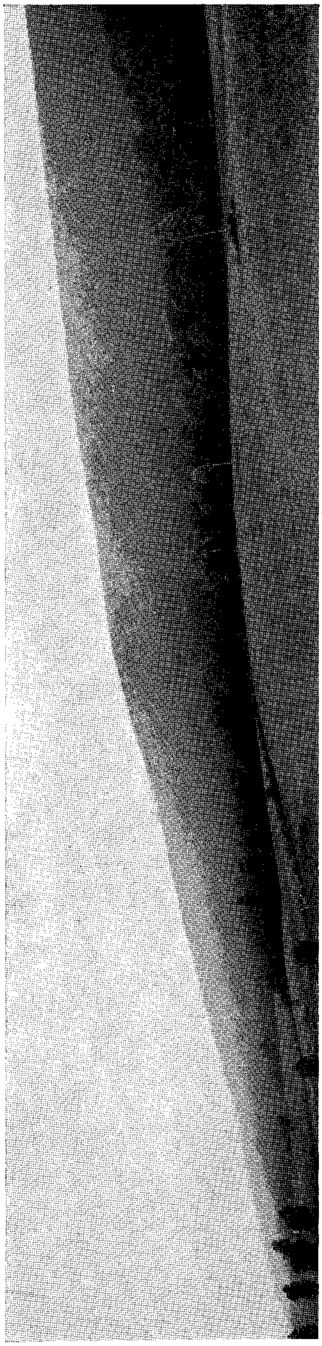


C

ORDOVICIAN AND SILURIAN FORMATIONS

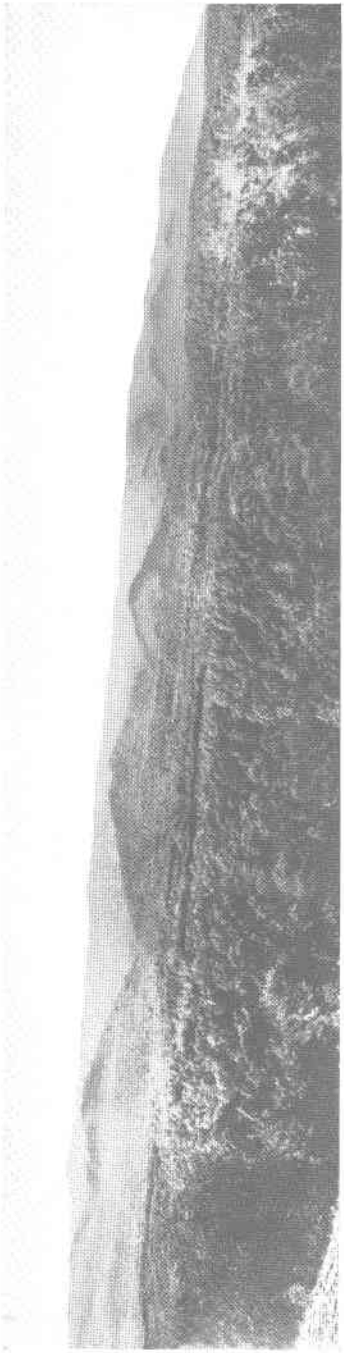


A

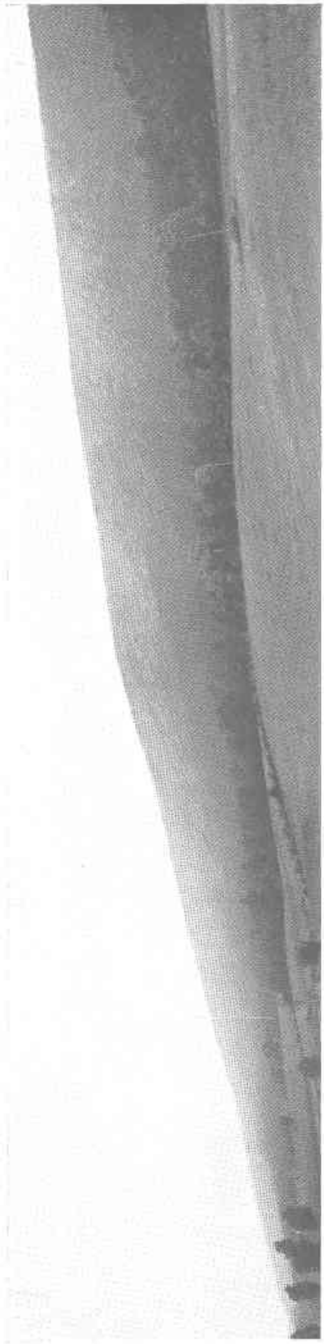


B

SILURIAN QUARTZITE TOPOGRAPHY



A



B

SILURIAN QUARTZITE TOPOGRAPHY

PLATE 40

A. Tuscarora quartzite on the southeast slope of Paddy Mountain. The line of knobs is a dissected hogback on beds which dip toward the observer (southeast). In the distance is the main ridge of Paddy Mountain, which is synclinal. The Juniata formation is on the crest. The lower area back of the hogback is an anticlinal valley in the Martinsburg shale. Looking northwest from a point about 2 miles northeast of Van Buren Furnace, Shenandoah County.

B. Walkers Mountain in Augusta County. Note the remarkably even crest line. This is an anticlinal mountain, the crest of which is occupied by Tuscarora quartzite (Clinch sandstone). The even crest is 3100 feet above sea level, 1000 feet above the base, and 6 miles long. The apparent northeast slope of the crest is due to perspective. The county line southwest of Deerfield follows the crest for 4 miles. Looking northeast from a point on the road northwest of the mountain, about 7 miles southwest of Deerfield.

Geologic Section 56.—Sequatchie formation southeast of Cumberland Gap, Tennessee

	Thickness Feet
Clinch sandstone	
5. Sandstone, flaggy, fine grained, hard, green; layers of fossiliferous grit with *Helopora* and *Pterinea*....	20±
Sequatchie formation (295 feet)	
4. Poorly exposed; scattered small exposures of shale	125±
3. Limestone, argillaceous, rather thick bedded, with red layers; contains *Zygospira kentuckiensis* James near top; slender species of bryozoa (abundant), *Platystrophia annieana* Foerste, or *P. moritura* (Cummings), *Cyrtodonta halli* (Nettelroth), *Bellerophon* or *Bucania* sp., *Kloedenella*?, *Drepanella richardsoni* (Miller), and *Primitia lativia* Ulrich....	75
2. Limestone, thin bedded, shale partings, thin layers of red shale and limestone	45±
1. Limestone, medium bedded	50
Reedsville formation, Maysville horizon	
Limestone, thin bedded, shale partings, with *Orthorhynchula* and other fossils.	

On the northwest slope of Wallen Ridge at the head of Turkey Cove, 4 miles southwest of Big Stone Gap, is a considerable thickness of red limestone and green shale with layers of impure limestone weathering to a rotten ferruginous rock. From these beds, including the rotten limestone, the following fossils were collected: Slender bryozoa (same as in bed 3 of the section at Cumberland Gap), *Hebertella sinuata* Hall and Clarke, *Zygospira kentuckiensis* James, *Z. modesta* (Hall), *Cyrtodonta*? sp., *Bellerophon* or *Bucania* sp., and *Kloedenella?* sp. This faunule is the same as that at Cumberland Gap.

On the northwest slope of Powell Mountain, 2 miles east of Stickleyville, Lee County, the following section is exposed on U. S. Route 58.

Geologic Section 57.—Sequatchie formation 2 miles east of Stickleyville, Lee County, Virginia

	Thickness Ft.	In.
Clinch sandstone		
18. Sandstone	50±	
Sequatchie formation (295± feet)		
17. Shale, sandy, green, and clay, blue	15	
16. Sandstone	1	
15. Shale, like bed 17	15	
14. Sandstone		6
13. Shale, soft, yellow green	5±	
12. Sandstone		3
11. Shale, clay, soft, pale green; thin sandstone layers with fossils including *Dalmanella* sp.	40	
10. Conglomerate	2±	
9. Shale, red	20	
8. Sandstone, *Lingula rectilateralis* (Emmons)?		6
7. Shale, red	10	
6. Sandstone		2
5. Shale, red, some green layers	60	
4. Shale, clay, thin layers of sandstone and of nodular fossiliferous limestone containing *Hebertella sinuata* Hall and Clarke, *Zygospira kentuckiensis* James, and *Byssonychia* sp.	30	
3. Shale, red, sandy, calcareous (?), resembles sandstone in fresh condition	40	
2. Not exposed, red shale (?)	50	
1. Shale, red	5	

The preceding sections, through their few fossils, illustrate clearly that the Sequatchie of Lee County was deposited in the same sea as the marine Richmond formations of the Cincinnati area. The Richmond and Juniata facies interfinger in Lee County to make the Sequatchie formation, and the zone of transition extends beneath the Appalachian Plateaus northward from southwestern Virginia to the west end of Lake Ontario.

Distribution.—The Juniata is absent in Massanutten Mountain, in northern Virginia. It is present in Catawba Mountain only as a thin bed for an undetermined distance along the summit northwest of Bradshaw, Roanoke County. It occurs in several detached strips along Little North Mountain in Frederick and Shenandoah counties; also in Draper Mountain south of Pulaski, and in Cove Mountain, 3 to 4 miles north of Wytheville, Wythe County. It crops out along or near the crests of all the mountain ridges northwest of Little North Mountain, as shown on the geologic map. The Sequatchie facies is present in Powell Mountain, Wallen Ridge, and along the southeast base of the Cumberland escarpment in Lee County. The present distribution shows that probably the Juniata-Sequatchie originally extended over all of the Valley northwest of the Massanutten syncline.

The typical nonmarine Juniata continues southward along Clinch Mountain to the latitude of Morristown, Tennessee. It is absent in Bays Mountain northeast of Morristown. The original southeastern limit of the Juniata would be roughly indicated by a line drawn from the south end of Walker Mountain, 2 miles northwest of Emory, Washington County, Virginia, to Clinch Mountain west of Morristown, Tennessee, and passing to the northwest of Bays Mountain in Tennessee.

It is also of interest that the Juniata formation and the Oswego sandstone are absent in eastern Pennsylvania where the Shawangunk sandstone, possibly the partial equivalent of the Tuscarora in that region, rests upon the Martinsburg shale.

The maximum thickness and the coarsest material of the Juniata, including conglomerate with quartz pebbles several inches in diameter, are in the vicinity of Lewistown and Orbisonia, central Pennsylvania, which indicate that the sediment was derived from land to the east. It may have been discharged by large rivers upon extensive mud flats and distributed widely by flood waters.

Thickness.—The greatest known thickness of the Juniata in Virginia is 725 feet in the section in Highland County. It does not appear to exceed 200 feet in any of the Little North Mountain belts, or in Draper and Cove mountains. It is 200 feet thick on Wolf Creek south of Rocky Gap, Bland County; 175 feet in the Narrows of New River; 275 feet in McCall Gap between Saltville and Glade Spring, Washington County; and 370 feet on Clinch Mountain at Hayter Gap, Russell County. Thickness of the Sequatchie is 293 feet on Powell Mountain, Lee County, and 295 feet at Cumberland Gap.

Fossils and correlation.—The typical Juniata is nonmarine and unfossiliferous. The Sequatchie facies has yielded a few fossils, but the search has been inadequate. They are listed in geologic sections 56 and 57. All are species that occur in the Richmond formations of Ohio and Indiana. *Drepanella richardsoni* (see Part II) is a characteristic form from the Whitewater beds near the top of the Richmond in Indiana and in limestone intercalated in the red Queenston shale in Ontario, west of Lake Ontario. *Primitia lativia* occurs in the same beds with the *Drepanella* in Ontario. The *Platystrophia* occurring at Cumberland Gap has certain characters allying it with the late Richmond species *P. annieana* or *P. moritura*. The *Cyrtodonta* seems to be the same as, or very near to, the *C. halli* which also occurs high in the Richmond of Oldham County, Kentucky. The very small number of fossils of the Sequatchie point only to its late Richmond age. The Juniata is of the same age. Hence, the approximate equivalence of the Sequatchie with the upper Richmond Whitewater formation of Ohio and Indiana is indicated. The typical Juniata is correlated with the Queenston red shale and sandstone of western New York and of Ontario, and thus with the lower nine-tenths of the original Medina sandstone of New York.

SILURIAN SYSTEM

The Silurian system in the Valley in Virginia comprises the following formations, named in ascending order: Clinch-Tuscarora sandstone, Clinton formation, McKenzie limestone, Bloomsburg formation, Wills Creek shale and sandstone, and the Tonoloway limestone. The McKenzie, Bloomsburg, Wills Creek, and Tonoloway constitute the Cayuga group, and as they could not be conveniently shown separately on the geologic map they were mapped together as the Cayuga formation. Likewise the Tuscarora-Clinch and Clinton formation were combined on the map.

CLINCH–TUSCARORA SANDSTONE

Names.—The name Clinch was taken from Clinch Mountain,[136] Tennessee, and the name Tuscarora[137] was derived from Tuscarora Mountain, Pennsylvania. Both names apply to the same formation; Tuscarora being used in Pennsylvania, Maryland and the northern part of the Appalachian Valley in Virginia; Clinch in southern Virginia and northern Tennessee.

As the name Clinch Mountain sandstone was first used in 1856, and the name Tuscarora was first used in 1896, the term Clinch has priority. In order to promote uniformity of stratigraphic usage, it would be desirable to discard the name Tusca-

[136] Safford, James, Geology of Tennessee, p. 292, Nashville, 1869.
[137] Darton, N. H., op. cit., p. 2.

rora and use only the name Clinch throughout the Valley, because the use of two names suggests two formations, whereas only one is present. In deference to established usage, however, the name Tuscarora is applied south to the parallel of 38 degrees to include the Staunton and Monterey quadrangles, described in the corresponding folios of the U. S. Geological Survey. These are the southernmost areas in which the name Tuscarora has been used.

Limits.—The Clinch-Tuscarora occupies a position between the Juniata-Sequatchie below and the Clinton formation above. The lower boundary is everywhere distinct. The upper boundary is clearly marked where the lower part of the Clinton includes characteristic red ferruginous sandstone, as in the middle portion of the Valley in Virginia. In the southern part of the Valley, as in Bland and Wythe counties and southwestward, where the red sandstone does not occur, the boundary is less easily determined or can not be drawn with certainty.

Character.—The Clinch-Tuscarora throughout most of Virginia is composed almost entirely of pure quartz sand, is generally light gray to white, and is very hard. The quartz grains are commonly cemented and partly rebuilt into crystals by silica deposited from circulating water, thus producing a compact vitreous rock called quartzite. The formation is locally a friable sandstone, as on Clinch Mountain southwest of Burkes Garden where it disintegrates into pure white sand. In places, for example on East River Mountain southeast of Bluefield, West Virginia, the basal 50 feet contains conglomerate layers with quartz pebbles ranging in size up to half an inch in diameter. Such layers are not common and no coarse conglomerate has been noted anywhere in the formation. It contains only small amounts of impurities, such as clay or iron oxide. Its general appearance is shown on Plates 41B and C and 55A.

A section on U. S. Route 19, 8 miles northwest of Abingdon, Washington County, and half a mile north of the North Fork of Holston River, shows an apparent merging of the Clinch and Clinton.

Geologic Section 58.—Clinch and Clinton formations, 8 miles northwest of Abingdon, Washington County, Virginia

	Thickness Feet
Onondaga formation	
15. Chert fragments	
Clinton formation (361 feet)	
14. Not exposed, except 2 feet of sandstone	50±
13. Shale, purple and green, soft, fragile, thin layers of sandstone, red and greenish gray, red layers with small white clay balls and fine quartz pebbles; contains fossils	75
12. Sandstone, fine grained, greenish	20
11. Shale, soft, green, with thin layers of sandstone	30
10. Sandstone, fine grained, gray; conspicuous bed	5
9. Lumpy mottled red and green rock with thin layers of sandstone; persistent in this region	50
8. Sandstone, thick bedded, greenish, shaly partings, tends to break down to thin layers	30
7. Sandstone, thin bedded	10
6. Shale, greenish, clay	1
5. Sandstone, thick bedded, white	15
4. Sandstone, thick and thin bedded	10
3. Sandstone, thick bedded, resembles Clinch	15
2. Sandstone, thin bedded, gray, stained with iron oxide or manganese oxide	50
Clinch sandstone	
1. Sandstone, evenly bedded, white	125
Juniata formation	
Shale, red	

In this section bed 1 is Clinch and as bed 3 is of distinctly Clinch character it might be included in the Clinch. It seems, however, that the rocks of bed 2 stained with iron and manganese are more indicative of Clinton, so the boundary is drawn as indicated. This section should be compared with the section of the Clinton on New River (geologic section 61), where the boundary between the Clinch and Clinton is clearly defined.

In Lee County the Clinch-Tuscarora undergoes a change to a thin-bedded, gritty, rusty, fossiliferous sandstone with layers of fossiliferous limestone. This change is well displayed on the Louisville and Nashville Railroad half a mile southeast of Cumberland Gap village, Tennessee. A section of the formation here, as nearly as it can be determined from partial exposures, is as follows:

Geologic Section 59.—Clinch and Clinton formations, half a mile southeast of Cumberland Gap, Tennessee

	Thickness Feet
Clinton formation	
12. Shale and sandstone, with a 2-foot bed of iron ore near middle	540±
Clinch-Brassfield formation[a] (250 feet)	
11. Sandstone, shaly, very fine grained, green layer with abundant *Clidophorus*	30
10. Limestone, crystalline, irregularly variegated red and gray, highly fossiliferous; contains *Brachyprion, Camarotoechia, Dalmanella, Rhynchotrema, Clidophorus, Ctenodonta, Modiolopsis, Pterinea, Bucanella trilobata* (Conrad), *Cycloceras inceptum* (Foerste), and *Phacops pulchellus* Foerste	5±
9. Shale, green	15
8. Sandstone	2
7. Shale, green	15
6. Sandstone, gritty, quartz pebbles as much as ⅛ inch in diameter, highly fossiliferous; contains *Helopora fragilis* Hall, *Phaenopora explanata* Hall, *Lingula cuneata* Conrad, and *Phacops pulchellus* Foerste	5±
5. Shale, green	10
4. Sandstone, red	1
3. Sandstone, thin, green; fossils, small pelecypods	10
2. Not exposed	137
1. Sandstone and grit, rusty, pebbles ⅛ inch in diameter; highly fossiliferous (see p. 236)	20

[a] Exact boundary with the Clinton not determined.

Sequatchie formation (geologic section 56)

The succession, thickness, and relations of the Clinton, Clinch-Brassfield, Sequatchie, and Maysville formations within a mile southeast of Cumberland Gap are shown in the profile section, Plate 60B. There can be no reasonable doubt that the sandstone and grit between the Sequatchie and Clinton in that section represent the Clinch sandstone, since they occupy the stratigraphic position of the Clinch which has its normal character in Wallen Ridge only 13 miles southeast of Cumberland Gap. The main difference in the two sections is that the formation is grading into its marine fossiliferous (Brassfield) facies at Cumberland Gap just as the Juniata passes into the marine Sequatchie (Richmond) facies, as already described.

The Clinch-Tuscarora is the most conspicuous formation in the Valley in Virginia. It stands up above all other formations as the "backbone" of all the great ridges like Massanutten, Clinch, Walker, and East River-Peters mountains. Its relation to the ridges is shown in Plate 39A. Other prominent ridges which owe to the Clinch-Tuscarora sandstone their erosional origin and preservation from leveling by late erosion are Little North Mountain, Great North Mountain, Purgatory Mountain, Catawba Mountain, Potts Mountain, Wolf Creek Mountain, Beartown Mountain (Pl. 8B), Paint Lick Mountain, Morris Knob, House and Barn Mountain, Powell Mountain in Lee County, and Wallen Ridge. In most of these ridges, the resistant Clinch-Tuscarora is inclined at a high angle, as shown in Plate 39B, and crops out along the mountain crests. The ridges result from the wearing away of the weaker rocks on each side, which leaves them standing in high relief. In a few synclinal mountains, such as Morris Knob, Tazewell County, House mountains, Rockbridge County, and Short Mountain, Shenandoah County (Pl. 8A), the flat-lying sandstone protects the underlying weaker rocks from erosion, whereas the rocks on either side have been worn to deep valleys leaving the better protected areas standing above them as ridges or knobs. Short Mountain of the Massanutten group lying northeast of Mt. Jackson, Shenandoah County, is an excellent example of a synclinal mountain capped with almost horizontal Clinch-Clinton (Massanutten) sandstone, which is visible from Virginia Route 266 at the north end of the mountain, and also at the south end of the mountain from the Lee Highway south of Mt. Jackson.

Distribution.—The present distribution of the remnants of the Clinch-Tuscarora indicates that the formation probably extended originally over the entire width of the Valley. It has been entirely removed by erosion southeast of Massanutten Mountain. Its original southeastern limit must remain unknown. The sand of which the formation is composed certainly came from the region southeast of the present Blue Ridge and it is reasonably certain that the formation originally extended southeastward on to the present Piedmont area. The only place in the Valley where the Clinch is certainly absent is the extreme south end of Walker Mountain at and southwest of Seven Springs, Washington County. At Lyons Gap, 4½ miles northeast of Seven Springs, the sandstone is about 50 feet thick and at McCall Gap, 2 miles northeast of Seven Springs, it is 17 feet thick (Pl. 39B). At Seven Springs the Clinch is absent and the Onondaga limestone rests upon the Juniata formation which, as already described, in turn disappears 2 miles southwest of Seven Springs.

Some of the best exhibits of the Clinch-Tuscarora are along Virginia Route 266 on the southeast slope of Kennedy Knob of Massanutten Mountain, 5 miles northwest of Luray; in the gorges of Paddy Run and Duck Run through Paddy Mountain in the southwest corner of Frederick County; in the gorge of North River (Goshen Pass), Rockbridge County; in the Iron Gate gorge on Jackson River 2 miles east of Clifton Forge (Pl. 55A); in the Narrows of New River at the west end of Peters Mountain (Pl. 39A); along U. S. Route 19 on Clinch Mountain southeast of Little Moccasin Gap, Washington County; and on the crest of Powell Mountain, 2 miles east of Stickleyville, Lee County (Pl. 41C).

Thickness.—The thickness of the Clinch-Tuscarora differs greatly within short distances. In the northeastern part of the Valley, along Little North Mountain in Frederick and Shenandoah counties, the thickness of the Tuscarora varies from about 200 feet on the conspicuous ridges to only a few feet in some of the intervening water gap. At a few places, such as west of Chambersville, Frederick County, it is absent. It is apparently as much as 100 feet thick in Paddy Mountain in the southwest part of Frederick County. In Massanutten Mountain the Tuscarora-Clinton (Massanutten) is 500 feet thick, but how much is Tuscarora is not known. The Clinch-Tuscarora is 50 feet in Brocks Gap, Rockingham County; 200 feet in Goshen Pass, Rockbridge County; 60 feet in the Iron Gate gorge, 2 miles east of Clifton Forge, Alleghany County; only 10 feet at Fagg Station, 5 miles northwest of

Christiansburg, Montgomery County; 200 feet in the gorge of New River through Walker Mountain, 3 miles south of Eggleston, and 100 feet in the Narrows of New River, both in Giles County. It is about 125 feet on U. S. Route 19, 1 mile northwest of Holston River, Washington County; 50 feet on Powell Mountain, 2 miles east of Stickleyville, Lee County; and 10 feet on Wallen Ridge, 2 miles southeast of Big Stone Gap, Wise County. Elsewhere, in numerous sections throughout the Valley, the thickness of the Clinch-Tuscarora ranges from 10 to 200 feet. The Brassfield facies at Cumberland Gap, Tennessee, is 20 to 200 feet thick, depending on how much of that section represents the Clinch. (See Pl. 60B.)

Fossils and correlation.—Except in the extreme southwestern part of Lee County the only fossils found in the Tuscarora-Clinch are supposed worm burrows of two kinds: *Scolithus verticalis* Hall, an upright tube or filled cavity slightly thicker than a lead pencil, which penetrates some of the sandstone layers, and *Arthrophycus alleghaniensis* (Harlan), which generally occurs as a mat of small curving annulated branches several inches long on the bedding surfaces of rocks. In Virginia these have been found most abundantly on the crest of East River Mountain near U. S. Route 21, about 2 miles southeast of Bluefield, West Virginia. Another peculiar form occurring in New York and Pennsylvania is *Daedalus archimedes* (Ringueberg), which has not been noted in Virginia. It is a large annulated form regarded as a worm burrow and also referred to *Arthrophycus* by Hall.[138] The Clinch passes into a marine fossiliferous facies in southwestern Lee County and adjoining parts of Tennessee and Kentucky. The best exposure of the fossiliferous limestone facies is at the northwest portal of the tunnel of the Louisville and Nashville Railroad, half a mile southeast of the village of Cumberland Gap, Tennessee. The character, thickness, and relations of this facies are illustrated in the profile section, Plate 60B. Large collections of fossils have been obtained from the basal sandstone (White Oak Mountain), bed 1 of geologic section 59, which is exposed in the road above the tunnel 1000 feet southeast of the northwest portal. A list of these fossils as provisionally identified, or modified after Ulrich,[139] is as follows:

[138] Both forms are illustrated in Paleontology of New York, vol. 2, pls. 1 and 2, 1851.

[139] Ulrich, E. O., Relative values of criteria used in drawing the Ordovician-Silurian boundary: Geol. Soc. America Bull., vol. 37, pp. 344-345, 1926.

TABLE 9.—*Fossils from the base of the Clinch-Brassfield (White Oak Mountain) sandstone southeast of Cumberland Gap, Tennessee*

	1	2	3
Bryozoa:			
Diamesopora sp.?	x		
Helopora fragilis Hall	x	x	x
Phaenopora cf. P. constellata Hall	x		
Phaenopora cf. P. explanata Hall	x		
Brachiopods:			
Lingula cuneata Conrad	x		
"Rhynchotrema", 4 sp			
Pelecypods:			
Clidophorus sp	x		x
Ctenodonta, 2 sp	x		
Cyrtodonta? primigenia? (Conrad)			
Endodesma orthonotum? (Meek and Worthen)	x		
Endodesma sp	x		
Ischyrodonta aff. I. elongata Ulrich	x		
Lyrodesma, 2 sp			
Modiolopsis aff. M. valida	x		
Psiloconcha sp			
Pterinea, 2 sp	x		x
Rhytimya sp	x		
Gastropods:			
*Bucanella trilobata (Conrad)	x	x	
*Hormotoma subulata (Conrad)	x	x	
Liospira cf. L. affinis (Foerste)			
Lophospira litorea (Hall)	x		
Cephalopods:			
*Cycloceras inceptum (Foerste)		x	
*Orthoceras? (Coleolus) clintonensis Foerste		x	
Trilobites:			
*Calymene vogdesi Foerste		x	
Calymene sp			
Liocalymene? sp			
*Phacops pulchellus Foerste		x	

*These fossils from limestone, bed 10 of geologic section 59.
1. These species occur in the Albion (Upper Medina) sandstone at Lockport, or at the mouth of Niagara gorge, New York.
2. These fossils occur in the Brassfield limestone of Ohio.
3. These species occur in the "Rockwood" formation, 70 miles southeast of Cumberland Gap, at Chamberlin, Tenn.
The fossils are referred to as list 1 on profile section B of Plate 60.

The limestone, bed 10 of geologic section 62, is also highly fossiliferous, but the fossils have not been fully determined. (See Part II.) The pelecypods, *Clidophorus, Ctenodonta, Modiolopsis,* and *Pterinea;* the brachiopods, *Camarotoechia,* or *Rhynchotrema, Dalmanella, Brachyprion,* and *Rhipidomella;* the gastropods, *Bucanella trilobata* (Conrad), and *Hormotoma subulata* Conrad; the cephalopods, *Orthoceras (Coleolus?) clintonensis* Foerste, *Cycloceras inceptum* (Foerste);

and the trilobites, *Phacops pulchellus* Foerste and *Calymene vogdesi* Foerste, show that this bed also is to be included in the Clinch-Brassfield. In stratigraphic relations the Clinch corresponds fully with the Brassfield formation of Sequatchie Valley, Tennessee, 100 miles southwest of Cumberland Gap, which carries such distinctive Brassfield fossils as *Lindstromia gainsei* (Davis), *Orthis flabellites* Foerste, *Stricklandinia triplesiana* Foerste, and *Triplecia ortoni* (Meek).

The faunal list from the basal bed of the Clinch near Cumberland Gap includes 18 species judged to be identical with species occurring in the Albion sandstone of New York. This affords ample evidence for the correlation of the Clinch and the Albion. The Albion has been traced across Ontario, Canada, into satisfactory correlation, in part at least, with the Brassfield of Ohio; therefore an approximate correlation of the Tuscarora-Clinch with the Brassfield is firmly established. Likewise, through the fossils, the Cumberland Gap facies of the Clinch is closely related to the White Oak Mountain sandstone of southern Tennessee and northern Georgia.

CLINTON FORMATION

Name.—The Clinton formation was named[140] from Clinton, Oneida County, New York. It is of special interest as the source of the iron ore of Lee County, Virginia, and the Birmingham district, Alabama, as well as of the type locality in New York.

Limits.—The Clinton formation succeeds the Clinch-Tuscarora without apparent break in deposition and extends upwards to the Lockport dolomite of western New York which, so far as known, is the oldest formation overlying the Clinton. In Virginia the Lockport is believed to be absent and the oldest formation overlying the Clinton is the McKenzie limestone (Cayugan)[141] of Frederick and Highland counties. In Massanutten Mountain, the Massanutten sandstone, possibly of Clinton age at the top, is locally, and perhaps generally, overlain by the Bloomsburg formation. In Giles, Bland, and Washington counties the Clinton is locally overlain by the Wills Creek shale or sandstone; in Burkes Garden on the southeast slope of Walker Mountain in Washington County, the Clinton is succeeded by the Oriskany sandstone or the Onondaga chert or limestone (both Devonian). In Catawba Mountain the Clinton seems to be overlain by Helderberg; in Smith Ridge north of Roanoke, Roanoke County, sand-

[140] Conrad, T. A., Observations on the Silurian and Devonian systems of the United States with description of new organic remains: Phila. Acad. Nat. Sci. Jour., vol. 8, pt. 2, pp. 229-230, 1842.
[141] See Table 1.

stone, thought probably to be the top of the Clinton (Keefer), is directly overlain by Onondaga chert. On the southeast slope of Clinch Mountain three-fourths of a mile northwest of Hilton, Scott County, black shale with *Schizobolus,* younger than the Onondaga, is nearly or actually in contact with the top of the Clinton.

Character.—The Clinton formation in Virginia is composed almost entirely of shale and sandstone. The only exceptions observed are two or three thin beds of iron ore in Lee and Wise counties, which, as is the rule with the Clinton "ore," are probably calcareous in the unweathered condition.

The Clinton formation varies geographically in the character and proportions of its constituents. At the northeast and southwest ends of the Valley in Virginia, it comprises a rather homogeneous body of shale and thin layers of sandstone (Cumberland facies). (See Pl. 41A.) About midway of the Valley, where crossed by James and New rivers, the lower half of the formation, which is composed of shale and sandstone, including highly ferruginous sandstone beds of distinctive character, has been termed the Cacapon division. (See Pl. 41B.) In this region, the upper half is composed mainly of white sandstone resembling closely the Clinch, interbedded with shale, both constituting the Keefer member. (Iron Gate facies, see Pl. 55A.) It is here proposed to designate these two lithologic expressions of the Clinton as the Cumberland facies and the Iron Gate facies, respectively. These two facies can be easily recognized in the areas of their typical development. The character of the formation at the north end of the Valley (Cumberland facies) is best displayed by the following section near Cumberland, Maryland:[142]

Geologic Section 60.—North end of Rose Hill, Cumberland, Maryland

	Thickness Feet
Rochester formation (46 feet)	
3. Shale, with several thin beds or layers of limestone, highly fossiliferous	35
2. Keefer sandstone member	
Massive sandstone, fossiliferous	11
Rose Hill formation (552 feet)	
1. Shale, mostly olive or drab, clayey, some light reddish or purplish layers with thin layers of sand-	

[142] Prouty, W. F., and Swartz, C. K., Sections of the Rose Hill and McKenzie formations: Maryland Geol. Survey, Silurian, pp. 70-74, 1923.

	Thickness Feet
stone throughout and two layers of red ironstone, one called Cresaptown iron sandstone, 10 feet thick, 178 feet above the bottom, and one about 8 feet thick, 4 feet above the bottom; fossiliferous throughout	552

Prouty and Swartz treated the Rochester and Rose Hill as distinct formations and included the Keefer sandstone in the Rochester as a member. The writer follows Ulrich[143] by referring the entire section to the Clinton formation with the Rochester and Keefer as members.

This section is nearly duplicated by the section of the Clinton in central Pennsylvania where, in a measured section at Marklesburg southwest of Huntington, Huntington County, the Rochester member is about 50 feet thick, the Keefer member 10 feet thick, and the part below the Keefer (Rose Hill) to the top of the Tuscarora quartzite is 703 feet thick. The lithology throughout is almost identical with that of the Cumberland section, the main difference being the absence in the Marklesburg section of an iron sandstone corresponding to the Cresaptown ore bed. A persistent iron sandstone a few feet thick lies at the base, in the position of the lower iron sandstone at Cumberland. These iron sandstone beds are identical lithologically with the iron sandstone beds of the Cacapon division of the formation.

The Iron Gate facies of the Clinton is illustrated by the following section exposed in the Narrows of New River, Giles County:

Geologic Section 61.—Clinton formation at the south end of the Narrows of New River, Giles County, Virginia

	Thickness Feet
Keefer sandstone member, top not exposed (156 feet)	
12. Sandstone, coarse grained, thick bedded, gray; makes the uppermost riffles in New River in the Narrows	30
11. Not exposed	44
10. Sandstone, like bed 12	72
9. Shale	10

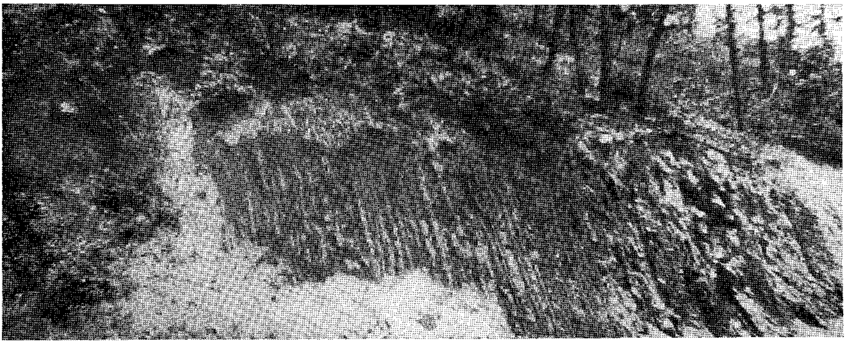
143 Ulrich, E. O., and Bassler, R. S., American Silurian formations: Maryland Geol. Survey, Silurian, charts opposite pp. 245 and 266, 1923.

PLATE 41

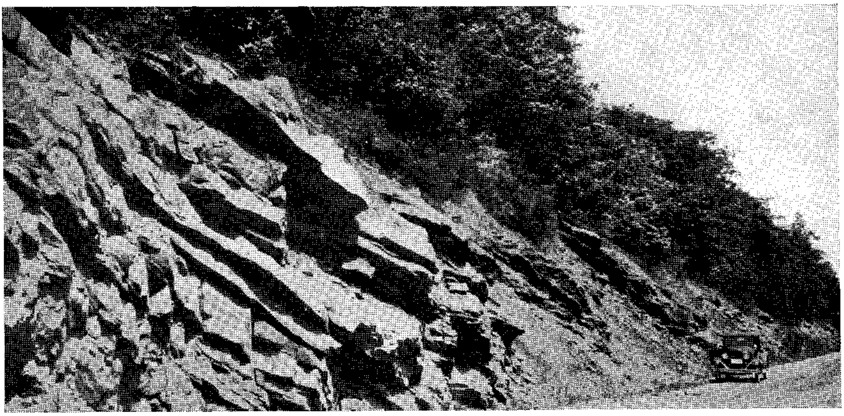
A. Clinton formation in Scott County. This part, about 200 feet below the top, consists of shale with thin layers of sandstone. The Clinton here has no sandstone corresponding to the Keefer, as shown in Pl. 55A. Along U. S. Route 58, 1 mile north of Pattonsville. Looking northeast.

B. Lower beds of the Clinton formation near Goshen, Rockbridge County. Thick beds of ferruginous sandstone jut out of the bank. This is the Cacapon division of the Clinton in the middle part of the Valley in Virginia. The underlying Clinch sandstone is shown in the lower left corner. In Panther Gap, 2 miles northwest of Goshen. Looking southeast.

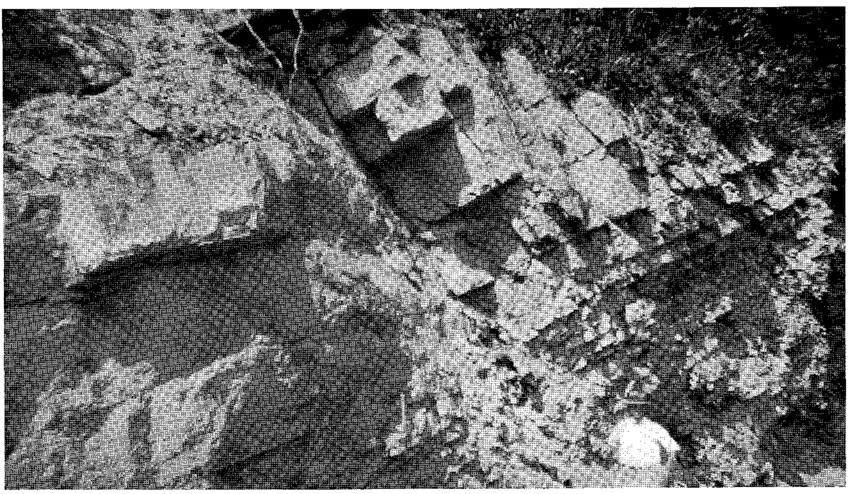
C. Clinch sandstone on Juniata shale in Scott County. The Clinch is thick-bedded, dense, sandstone or quartzite. The contact is at the upper end of the hammer handle. On the summit of Powell Mountain on U. S. Route 58, 1½ miles northwest of Pattonsville. Looking southeast.



A

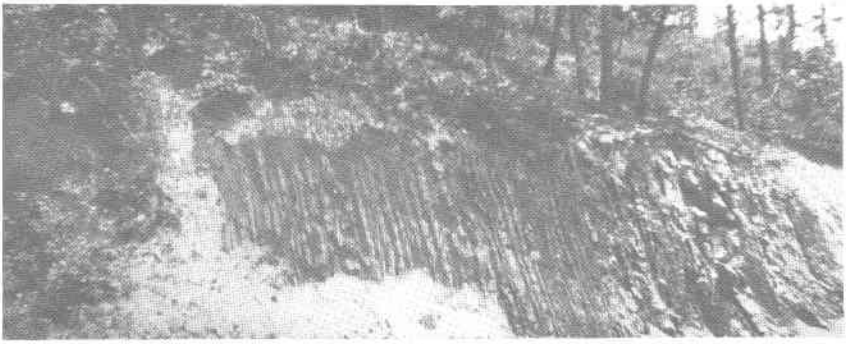


B

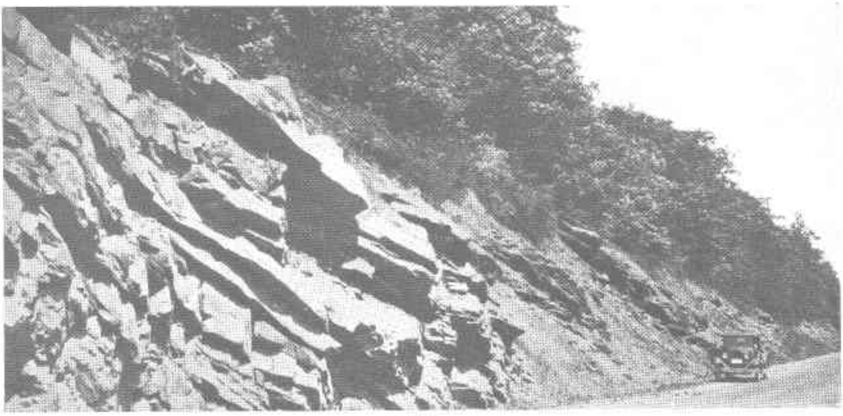


C

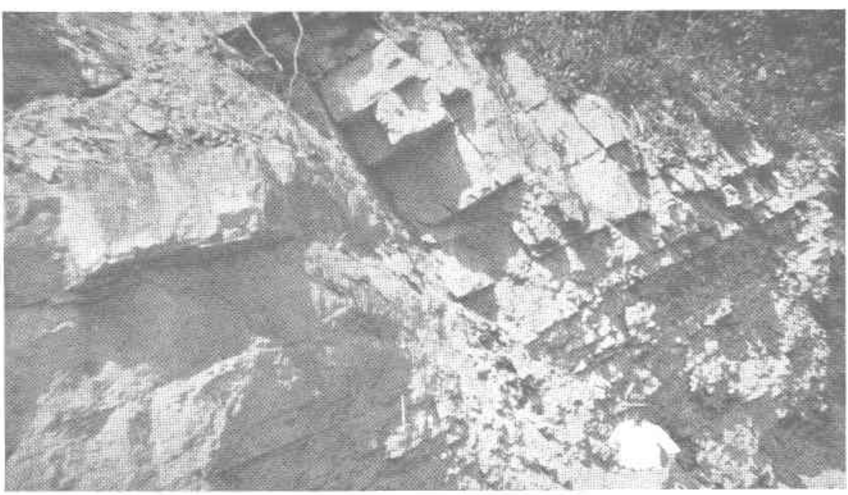
SILURIAN FORMATIONS



A

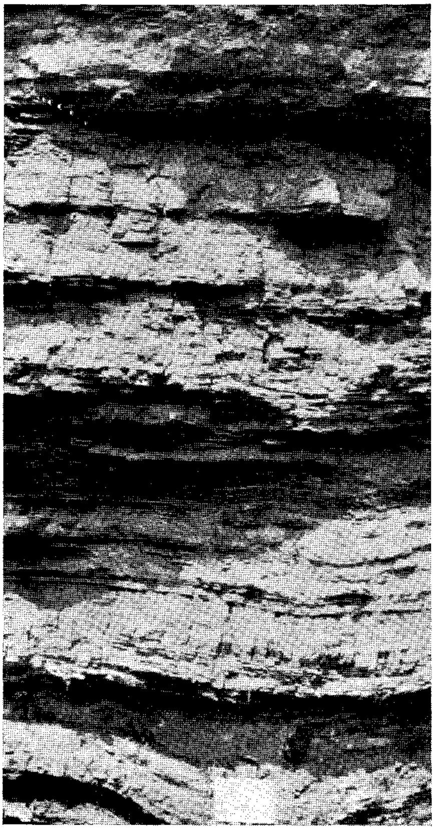


B

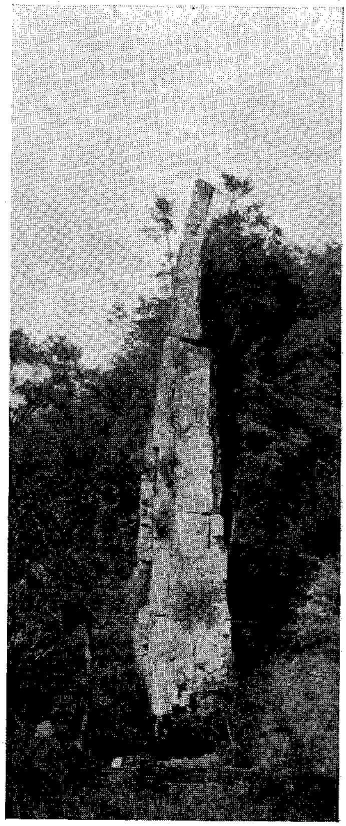


C

SILURIAN FORMATIONS



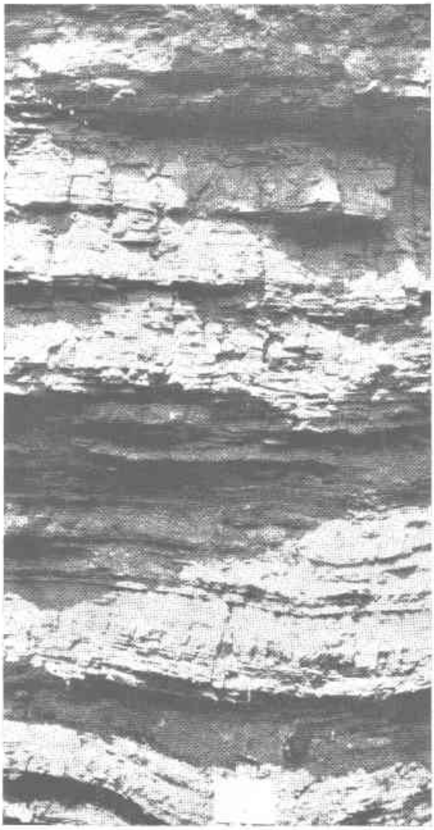
A



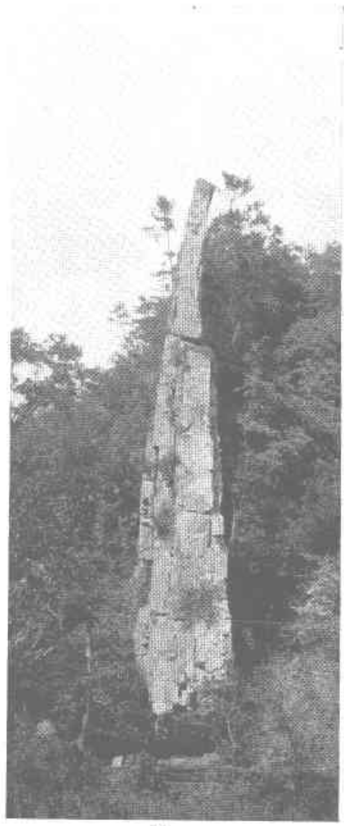
B

C

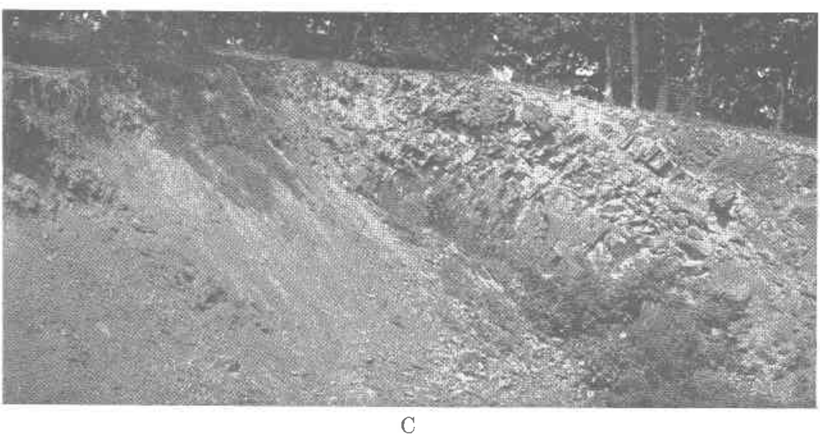
SILURIAN AND DEVONIAN FORMATIONS



A



B



C

Silurian and Devonian Formations

PLATE 42

A. Tonoloway limestone overlain by Keyser limestone, in Alleghany County. The contact is at the bottom of the overhanging ledge near the top. This section shows perfectly the laminated bedding typical of the Tonoloway. Exposed on the axis of a minor anticline in the gorge of Jackson River through Morris Hill-Coles Mountain 11 miles north of Covington. Looking northeast.

B. A resistant bed of vertical Oriskany sandstone in Brocks Gap, Rockingham County. This bed remains after the less resistant adjacent beds have been eroded away. The thickness at the base is about 25 feet. The height is estimated at 75 feet. Looking northeast along the strike.

C. Bloomsburg sandstone overlying McKenzie shale and exposing contact. *Eukloedenella sinuata* and *Dizygopleura swartzi* were collected from the shale. Along U. S. Route 50 at the north end of Great North Mountain, Frederick County. Looking west.

	Thickness Feet
Cacapon division (157 feet)	
8. Sandstone, rather coarse-grained, iron-stained quartz sandstone; very hard and resistant, a typical iron sandstone	30
7. Shale, green and gray with thin sandstone layers identical with rock making the main mass of the formation in Maryland and Pennsylvania	82
6. Sandstone, red iron sandstone like bed 8	5
5. Shale, gray and green	10
4. Sandstone, like beds 6 and 8	5
3. Shale, gray and green	15
2. Sandstone, like beds 4 and 8	5
1. Shale	5

Clinch sandstone (Pl. 39A)

The distinctive characters of this facies of the Clinton as shown in this section are (1) a mass of gray sandstone (beds 9-12) possibly continuous and 156 feet thick with the top not exposed, and (2) the shale and thin gray sandstone below with several beds of iron sandstone, a type of rock characteristic of the lower (Cacapon) part of the Clinton throughout the New River and James River regions. These two divisions of the Clinton are well displayed above the arch of the Clinch sandstone in the Iron Gate gorge, southeast of Clifton Forge. (See Pl. 55A.)

The lower division with red sandstone was named and mapped by Darton[144] as the Cacapon formation, and in colloquial use the term Cacapon for the part of the Clinton carrying red or iron sandstone is permissible. It is to be kept in mind, however, that both the Cacapon and the Keefer sandstone, as developed in the New River and James River regions are subdivisions of the larger Clinton formation and both are of local extent as compared with the extent of the Clinton as a whole. The stratigraphic equivalence of the Iron Gate and Cumberland facies of the Clinton is amply demonstrated by faunal evidence and by areal tracing from one facies into the other. The characteristic Clinton ostracodes, such as occur through the Cumberland facies, occur also in the shale in which the iron sandstone beds are intercalated and occasionally in the iron sandstone itself. The two facies merge laterally into

[144] Darton, N. H., and Taff, J. A., U. S. Geol. Survey Geol. Atlas, Piedmont folio (No. 28), p. 2, 1896.

each other to the northeast and to the southwest so gradually that no exact areal boundary between them can be drawn. The only usage of general applicability throughout the Appalachian Valley is to retain the two divisions, Cacapon and Keefer of the Iron Gate facies, in the Clinton formation.

If the Clinton is represented in the 500 feet of sandstone in Massanutten Mountain, the beds so designated constitute a third sandstone facies of the Clinton.

To summarize the lithologic characters of the Clinton: The Cumberland facies is composed of olive-green, pale greenish-gray shale or, to a very small extent, of red or purplish shale, crowded with thin layers of fine-grained, greenish, rusty weathering, quartz sandstone and an occasional thin layer of impure limestone. All of these combined make up, it is estimated, 90 per cent of its full thickness, and all are so uniform in character and distribution that no consistent and persistent lithological and mappable subdivisions exist, except where the Keefer sandstone is present. The Iron Gate facies is composed in its lower (Cacapon) division of shale and gray sandstone of the type predominant in the Cumberland facies, with several beds of its distinctive iron sandstone, 2 to 30 feet thick in one place or another, distributed through its full thickness. (See geologic section 61.) This iron sandstone is composed almost entirely of quartz grains a millimeter or less in diameter coated with iron oxide which also fills all interstices between the quartz grains. It is dull brownish red; not so brightly colored as the red shale that occurs locally in the Clinton, as described beyond. The rock generally contains clay balls, mostly gray, from the size of a pin head to more than an inch in diameter but prevailingly of intermediate sizes. It is rarely fossiliferous, but *Camarotoechia, Calymene* and ostracodes have been observed. The iron content makes the rock notably heavier than typical sandstone. It is estimated that iron oxide may constitute 10 to 15 per cent of the rock, equivalent to about 10 per cent metallic iron as an average. None of this sandstone, therefore, can be regarded as iron ore. At Cresaptown, Maryland, a similar bed yields samples that contain 24 per cent iron. This type of sandstone is distinctive of this local Cacapon division. Being very hard and resistant to disintegration, it is widely distributed on all surfaces on which the Cacapon division crops out and on the slopes of the ridges below, as well as along the streams crossing its outcrop. Its float serves to indicate without ascent the presence of the basal Clinton on high knobs and ridges, as, for example, House mountains west of Lexington. This type of sandstone is generally absent from the Cumberland facies, but a bed of it lies at the very base at and northeast of Cumberland, Maryland. Possibly the Cresaptown "ore" in the Cumberland section is of that type. In central Pennsylvania only a comparatively thin bed of it is found at the very bottom of the Clinton. Southwest of New River no such sandstone has been observed in the Clinton. The Cumberland facies prevails throughout the southwestern counties of the State.

Red shale.—The Clinton is commonly considered a red formation, but actually it contains very little red rock. A persistent bed of red shale 20 feet thick occurs on the southeast slope of Walker Mountain north of Marion, Smyth County, and a bed of purplish shale on the southeast slope of Powell Mountain is exposed on U. S. Route 58, about a mile north of Pattonsville, Scott County. A bed of red shale, locally partly maroon, about 40 feet thick, is exposed south of Ewing, Lee County[145] and along U. S. Route 58, 1 mile northeast of Cumberland Gap, Tennessee.

Iron ore beds.—The only other rock in the Clinton of distinctive character is fossiliferous iron ore which is composed largely of fragments of fossils impregnated with and cemented by iron oxide. Similar iron ore occurs in the equivalent of the Clinch-Tuscarora (Brassfield) from Chamberlain, Tennessee, to Birmingham, Alabama; otherwise all the fossiliferous iron ore of the Appalachian Valley is in the Clinton.

In the vicinity of Iron Gate, Alleghany County, and on the southeast slope of Horse Mountain, 6 to 8 miles to the southwest, a bed of fossil-bearing iron ore 2 feet thick was mined as late as 1908. A production of 90,000 tons was reported for 1907.[146] The weathered and leached ore contains 46 to 57 per cent metallic iron. In Wise and Lee counties beds of this ore have been extensively mined in the vicinity of Big Stone Gap, Hagans, Rose Hill, and Cumberland Gap. This ore also crops out in Lee County in the fensters and continues under the overthrust block of Cambrian and Lower Ordovician limestone and dolomite.[147] It was mined during the World War in the Fourmile fenster about 2½ miles south of Ewing. Three beds of ore in this district range in thickness from 6 inches to 2½ feet. It is said that the ore is not of as high grade as that in Alleghany County.

The following section of the Clinton in the Big Stone Gap area, condensed from Stose,[148] shows the number and relations of the ore beds.

[145] This outcrop is in a fenster. (See geologic map.)

[146] Hayes, C. W., Iron ores of the United States: U. S. Geol. Survey Bull. 394, p. 88, 1909.

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

[148] Stose, G. W., *in* Eby, J. B., The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, p. 33, 1923.

Geologic Section 62.—Clinton formation in the Big Stone Gap area, Wise County, Virginia

	Thickness Feet
Cayuga group	
11. Conglomerate and sandstone (Wills Creek?)	
Clinton formation (400± feet)	
10. Quartzite with *Scolithus*	15
9. Sandstone, thick bedded, dark red	20
8. Shale, gray, chocolate-colored, pink and buff; many thin layers of gray sandstone with ostracodes	180
7. Shale, soft, olive green to drab, with thin layers of sandstone; contains *Anoplotheca* and *Zygobolba;* lower Clinton	20
6. Iron ore, thin sandstone, thin limestone, fossiliferous	2
5. Shale, gray to brown, with thin layers of sandstone	90
4. Iron ore, oolitic	2-4
3. Sandstone thick bedded, red and gray, and shale	23
2. Iron ore	1-4
1. Shale, thin layers of sandstone; conglomerate at bottom with quartz pebbles as much as ½ inch in diameter	45

Keefer sandstone member.—The Keefer sandstone was named[149] from Keefer Mountain in the southwest corner of Franklin County, Pennsylvania. Almost all of the Keefer is nearly everywhere a gray quartzitic sandstone, rather thick bedded. It closely resembles the Clinch-Tuscarora. (See Pl. 55A.) It evidently changes westward to a sandy limestone 5-10 feet thick, hardly recognizable as a distinct bed, as at a locality on State Route 284, 1½ miles southeast of Crabbottom, Highland County, Virginia, and in the vicinity of Hollidaysburg and Altoona, Pennsylvania. On Cacapon Mountain in the northwest corner of Frederick County, it is a massive sandstone 60 feet thick. On the southeast slope of Catawba Mountain, as shown along Virginia Route 311, just above the Catawba Sanatorium railroad station, Roanoke County, it retains its thick-bedded character and seems to be about 300-400 feet thick. It has the same character in the Iron Gate gorge,

[149] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (No. 179), 1912.

where it is estimated to be about 200 feet thick. No fossils have been observed in the sandstone beds in Virginia, but *Scolithus* tubes occur locally in them in Maryland. Ostracodes and, very rarely, fragments of eurypterids occur in the interbedded shale.

One of the best exhibits of the Keefer is that already mentioned in the Iron Gate gorge. It is extensively exposed on the southeast slope of Catawba Mountain for several miles southwest of State Route 311, and is visible from the road along Mason Creek as far south as Beckner Gap. Another notable exposure is in the gorge of James River just northwest of Eagle Rock as shown in Plate 61. The Keefer is exposed in many places around the north end and sides of Great North Mountain in Frederick County.

The question has been raised whether the sandstone of Tinker Mountain just west of Cloverdale, Botetourt County, and in Smith Ridge to the southwest is Keefer or Clinch. This sandstone has the appearance of Clinch and has heretofore been so regarded; however, convincing reasons require its identification as Keefer. The reasons will appear from the comparison of the section on Catawba Mountain on State Route 311 with the section on Car-

Comparison of sections on Catawba Mountain and Carvins Creek, Roanoke County, Virginia

Geologic Section 63.—Catawba Mountain, State Route 311, above Sanatorium Railroad station, Roanoke County, Virginia	Thickness Feet	*Geologic Section 64.—At dam site of reservoir of Roanoke Water Works, Carvins Creek, Roanoke County, Virginia*	Thickness Feet
Onondaga		Onondaga (30 feet)	
Chert	10±	Shale yellow; *Bollia, Phacops, Styliolina*, etc	20
		Chert	10
Helderberg? (33 feet)		Absent	
Sandstone, ferruginous, fossiliferous; estimated	30		
Not exposed	3		
Clinton (400± feet)		Clinton (155 feet)	
Keefer sandstone, sandstone on southeast slope of mountain	300±	Keefer sandstone, quartzitic, thick bedded	130
		Shale, fragments of a eurypterid	25
Cacapon division?		Absent	
Not exposed on summit; debris of red, highly ferruginous sandstone	100±		
Clinch sandstone		Clinch sandstone, sandstone with small quartz pebbles	15
Sandstone, conglomeratic	25		
Martinsburg shale		Not exposed, probably Martinsburg shale	
Shale and sandstone *Lingula nicklesi, Orthorhynchula* zone			

vins Creek at the dam of the reservoir of the Roanoke Water Works, 1½ miles north of Hollins College. The distance between the two sections is about 7½ miles.

At the dam of the Roanoke Water Works reservoir in the gorge of Carvins Creek, a gray quartzite, 130 feet thick, is immediately overlain by the Onondaga chert which, as shown in the Catawba Mountain section, is but a few feet above the Keefer. If the sandstone of Smiths Ridge is Clinch, two changes must have taken place in the distance of 7½ miles between the top of Catawba Mountain, State Route 311, and the dam site on Carvins Creek. The entire Clinton, including the several hundred feet of the Keefer sandstone, would have pinched out, and the Clinch increased in thickness from 25 feet to 130 feet or more and have been brought into contact with the Onondaga chert. Such a change seems improbable. The thinning of the Clinch and the persistence of the Keefer seem decidedly more probable. A confirmatory fact is the occurrence of fragments of a eurypterid in dark-colored shale at the base of the supposed Keefer sandstone at the dam site. Fragments of eurypterids have been found in the Keefer sandstone of Maryland but none in the Clinch. Hence, the writer considers the sandstone of Tinker Mountain and Smiths Ridge to be Keefer.

Rochester shale and limestone member.—The Rochester member of the Clinton is well developed at Rochester, N. Y., the type locality,[150] and extends westward to the Niagara Gorge where it is excellently displayed and forms the real basis for the name Niagara group in common use. In Virginia the Rochester has been observed in only one place—on the road, State Route 284, about 1½ miles southeast of Crabbottom, Highland County. It is represented here by 25 feet of mostly bluish shale but with thin limestone and sandy layers containing *Reticularia bicostata* (Vanuxem), *Dalmanites* cf. *D. limulurus* (Green), and *Drepanellina clarki* Ulrich and Bassler, three characteristic Rochester fossils. The Rochester extends at least some distance southwestward on this outcrop toward Monterey, but its geographic extent in the State is unknown. It also is continuous northward through West Virginia with the outcrop at Cumberland, Maryland. (See geologic section 60.)

Distribution.—The Clinton occupies the greater part of all of the belts, Clinch and Clinton, northwest of Little North Mountain, and of its line of extension southward.

The Clinton is present in Little North Mountain, north of Green Spring, Frederick County, and also at Pontzer Gap north-

[150] Conrad, T. A., Second annual report on the paleontological department of the survey: New York Geol. Survey 3rd. Ann. Rept., pp. 62-63, 1839.

west of Strasburg, Shenandoah County, but is absent in every exposed section between Green Spring and Wheatfield, Shenandoah County. It occurs in the Short Hills northwest of Natural Bridge, chiefly as Keefer sandstone; in the northern part of Catawba Mountain and on Tinker Mountain, west and north of Roanoke. Red sandstone of Cacapon type occurs in Read-Coyner Mountain northeast of Roanoke, and it is possible that the associated gray quartzite hitherto regarded as Clinch is actually Keefer. No Clinton is present at the south end of Catawba (Paris) Mountain, unless the 10 feet of gray sandstone immediately overlying the Martinsburg shale is Keefer instead of Clinch as it has been regarded. The Clinton is present on Draper Mountain 2 miles south of Pulaski, but its presence in Cove Mountain north of Wytheville is doubtful. It is necessary only to add here that the Clinton, like the Juniata and Clinch, thins out toward the southern end of Walker Mountain between Shannon Gap, 6 miles northwest of Marion, and Lyons Gap, 11 miles west of Marion. Near Shannon Gap the Clinton seems to be no more than 50 feet thick and includes a bed of red shale 20 feet thick, as it does on Virginia Route 88, north of Marion. At Lyons Gap 40 to 50 feet of sandstone regarded as Clinch lies between the Juniata and Onondaga.

The Clinton is best exposed on the road midway between Straight Creek and Crabbottom, Highland County; on U. S. Route 250, a short distance southeast of McDowell; along Virginia Route 501 at Panther Gap, 2 miles northwest of Goshen, Rockbridge County; at the top of Warm Springs Mountain, Bath County; in Iron Gate gorge, 2 miles east of Clifton Forge, Alleghany County; in the Narrows of New River, Giles County; on U. S. Route 21 in Wolf Creek gorge, 1 mile south of Rocky Gap village, Bland County; 4 miles west of Saltville, on Tumbling Run, Washington County; along U. S. Route 19, 1¼ miles north of Holston River, Washington County; along U. S. Route 58 on the southeast slope of Powell Mountain, 1 mile north of Pattonsville, Scott County; and along the Louisville and Nashville Railroad half a mile southeast of Cumberland Gap village, Tennessee.

Thickness.—The thickness of the Clinton ranges from 300 to nearly 600 feet except toward the southwest end of Walker Mountain, where the formation is about 50 feet thick north of Marion and wedges out entirely north of Lyons Gap, 11 miles to the southwest.

Fossils and correlation.—The Clinton in Virginia is not a highly fossiliferous formation. The most abundant fossils are brachiopods and ostracodes. Pelecypods are very scarce. The following list includes most of the brachiopods that have been collected and identified and a considerable number of ostracodes, although several times as many species as are listed have been collected:

Fossils from the Clinton formation in Virginia

Graptolites
- Monograptus sp., rare

Brachiopods
- Anoplotheca hemispherica (Sowerby)
- [a]Camarotoechia neglecta (Hall)
- Chonetes novascoticus Hall
- [a]Homeospira evax (Hall)
- [a]Meristina aff. M. maria (Hall)
- [a]Parmorthis sp., commonly identified as Dalmanella elegantula (Dalman)
- [a]Reticularia bicostata (Vanuxem)
- Rhipidomella hybrida (Sowerby)
- Brachyprion corrugata (Conrad)
- Uncinulus sp.

Pelecypods
- Pterinea, 2 or more species

Pteropods
- Tentaculites sp.?

Trilobites
- Calymene macrocephala? (Prouty)
- [a]Dalmanites limulurus (Green)
- Liocalymene clintoni (Vanuxem)

Ostracodes
- Bonnemaia fissa Ulrich and Bassler
- Bonnemaia obliqua Ulrich and Bassler
- Bonnemaia rudis Ulrich and Bassler
- Bonnemaia transita Ulrich and Bassler
- [a]Drepanellina clarki Ulrich and Bassler
- Mastigobolbina bifida Ulrich and Bassler
- Mastigobolbina lata (Hall)
- Mastigobolbina modesta Ulrich and Bassler
- Mastigobolbina typus Ulrich and Bassler
- Mastigobolbina typus praenuntia Ulrich and Bassler
- Mastigobolbina vanuxemi Ulrich and Bassler

[a] Occur in the Rochester member.

Mastigobolbina virginia Ulrich and Bassler
Zygobolba anticostiensis Ulrich and Bassler
Zygobolba bimuralis Ulrich and Bassler
Zygobolba curta Ulrich and Bassler
Zygobolba decora (Billings)
Zygobolba excavata Ulrich and Bassler
Zygobolba inflata Ulrich and Bassler
Zygobolba prolixa Ulrich and Bassler
Zygobolbina conradi Ulrich and Bassler
Zygosella macra Ulrich and Bassler
Zygosella mimica Ulrich and Bassler
Zygosella vallata Ulrich and Bassler

The most important for correlation of these fossils are *Anoplotheca hemispherica* (Sowerby) which occurs in the Silurian of England and the Clinton of New York, Pennsylvania, and south to Alabama; *Liocalymene clintoni* which ranges from Clinton, New York, south along the Appalachian Valley into Tennessee; *Chonetes novascoticus,* of about the same geographic range; *Mastigobolbina lata, M. typus,* and *Zygobolbina conradi,* all of which range from Clinton, New York, to Tennessee, and the last-named species into northern Georgia. *Zygobolba decora* occurs in the Island of Anticosti and in Big Moccasin Gap near Gate City, Virginia. Nearly all of the above-named fossils are fairly common in the Clinton throughout Virginia, and are easily recognizable. (See Fossil Plates, Part II.) The most serviceable for identification of the formation are *Anoplotheca hemispherica* and *Liocalymene clintoni* which are common, diagnostic, and easily identifiable. One of the most common and characteristic Clinton fossils of New York, Alabama, and Georgia, *Pentamerus oblongatus,* does not occur in the Appalachian Valley of Virginia, whereas the great array of ostracodes in the Clinton of the Valley do not appear in the Clinton of Alabama, and only a very few in the Clinton of Georgia; yet a considerable number occur in the typical Clinton of New York. The substantial equivalence of the Clinton of Virginia with that of New York is fully established by the paleontologic evidence.

HIATUS (?)

According to some geologists no representative of the Lockport dolomite, which overlies the Rochester shale at Niagara Falls, is present in Virginia, Maryland, or central Pennsylvania. Other geologists consider it possible or even probable that the McKenzie limestone, next overlying the Rochester member of the Clinton in Virginia, represents the Lockport. The evidence of the fossils, especially the ostracodes, points to the Cayuga age of the McKenzie, whereas the Lockport belongs in the older Niagara group of the general geologic sequence. The Lockport is here regarded, therefore, as absent in Virginia, causing a hiatus between the Clinton (Rochester member) and the McKenzie.

CAYUGA GROUP

The Cayuga group was named[151] from Cayuga County, New York, where it is composed in ascending order of the Pittsford shale (thin and local), Vernon red shale, the Camillus shale, and the Bertie waterlime. All are best developed and known between Rochester and Buffalo, New York. In Virginia, the group includes in ascending order the McKenzie limestone or shale, the Bloomsburg formation, the Wills Creek formation, and the Tonoloway limestone. The McKenzie and Wills Creek are possibly in part represented in Great North Mountain and Massanutten Mountain by beds included in the Bloomsburg red shale and sandstone.

McKENZIE LIMESTONE

Name.—The formation was named[152] from McKenzie station on the Baltimore and Ohio Railroad, 9 miles southwest of Cumberland, Maryland.

Limits.—The base of the McKenzie limestone is here placed at the top of a bed of sandy laminated limestone, or calcareous sandstone containing *Reticularia bicostata* (Vanuxem), which marks the top of the Rochester shale and which crops out on State Route 284, 2½ miles east of Crabbottom and Straight Creek, Highland County. Its top is placed in the same section at a limestone full of small ostracodes, 170 feet above the *Reticularia bicostata* bed at the base and next below 30 feet of shale.

Character.—As partly exposed southeast of Crabbottom and beginning at the bottom, the McKenzie is composed of 60 feet of soft bluish fissile shale with layers of limestone 1 foot thick; 90 feet of beds unexposed but showing abundant slabs of limestone on the outcrop; and a 15-foot bed of highly fossiliferous, blue, granular limestone, crowded with small ostracodes. On the flanks of Great North Mountain, Frederick County, it has persistently weathered to a yellow shale. No red shale is present in Virginia, but in Washington County, Maryland, and Huntingdon County, Pennsylvania, thin beds of red shale and red sandstone appear in the

[151] Clarke, J. M., and Schuchert, Charles, The nomenclature of the New York series of geological formations: Science, new ser., vol. 10, pp. 874-878, 1899.

[152] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 522, 545, 591, pl. 28, 1911; described by Stose, G. W., and Swartz, C. K., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (No. 179), pp. 5-6, 1912.

middle of the formation. The significance of these occurrences will be discussed in the description of the Bloomburg formation. Other places in Virginia where the McKenzie has been definitely recognized are at the north end of and on the southwest slope of Great North Mountain and in the valley of Bear Garden Run at the southeast base of Cacapon Mountain, all in Frederick County. Just below the Bloomsburg red rock, a few feet of pale yellowish fissile shale contains abundant ostracodes, including at least three McKenzie species. At one place on the southeast slope of Great North Mountain, as much as 100 feet of shale is exposed immediately above the Keefer sandstone.

Distribution.—The known distribution and outcrops of the McKenzie are stated above. It seems reasonably certain that the Crabbottom outcrop continues south a considerable distance in Highland County, although its presence was not observed west of Monterey where the outcrop of the Crabbottom belt should lie. The McKenzie is present as a yellow shale in its weathered state on both slopes of Great North Mountain in Frederick and Shenandoah counties.

Thickness.—In the Crabbottom section the thickness of the McKenzie as there delimited is 165 feet. Some sections in Great North Mountain indicate a thickness of 100 feet. Elsewhere in Virginia its thickness is unknown. At Pinto, Maryland, about 90 miles northeast of Crabbottom on the same line of outcrop, the McKenzie is limestone and is 240 feet thick.

Fossils and correlation.—The McKenzie is notable for the great number of species of minute ostracodes of the genera *Dizygopleura, Eukloedenella, Kloedenella, Kloedenia,* and *Zygobeyrichia.* Only a few species have been identified from the formation in Virginia. A few species of brachiopods are found. The identified species occurring in Virginia are as follows:

McKenzie fossils identified from Virginia

Brachiopods
- Camarotoechia? sp.
- Homeospira evax (Hall)
- Leptaena aff. L. rhomboidalis (Wilckens)
- Lingula? sp.

Ostracodes
- Dizygopleura swartzi Ulrich and Bassler
- Eukloedenella sinuata Ulrich and Bassler

Eukloedenella simplex Ulrich and Bassler
Kloedenia normalis Ulrich and Bassler

The ostracodes listed are only a very few of those occurring in the McKenzie. They were collected partly in the Crabbottom section and partly at the north end of Great North Mountain, 1¼ miles east of Gore, Frederick County, just beneath the Bloomsburg. Similar forms also occur commonly in the Wills Creek formation, but they seem to be more abundant in the McKenzie, and the McKenzie age of the beds containing them may be accepted as a general rule.

BLOOMSBURG FORMATION

Name.—The Bloomsburg formation was so named[153] because it is so well developed and displayed at Bloomsburg, Columbia County, Pennsylvania.

Limits.—The upper and lower limits of the Bloomsburg can not now be definitely determined.

Character.—The Bloomsburg is composed of sandstone and shale and is strikingly distinguished from the strata above and below by its predominant strong red color. Most of the Bloomsburg is presumably nonmarine; however, a few specimens of *Lingula* and of fish scales are reported from the Bloomsburg of Maryland. The red sandstone is especially prominent in Great North Mountain, Frederick County, as shown in exposures on U. S. Route 50 at the north end of the mountain. Layers of green and gray sandstone and shale also occur, as shown in a section exposed along State Route 261 on the southeast slope of Powell Mountain within the Massanutten Mountain group. Here about the lower 170 feet of the formation is exposed and rests upon the Massanutten sandstone (Tuscarora-Clinton?). The strata dip southeast into a narrow syncline. On the southeast limb of the syncline and on the same road, about half a mile farther southeast, higher beds of the Bloomsburg are exposed, as shown in the following section:

[153] White, I. C., The geology of the Susquehanna River region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland: Pennsylvania, Second Geol. Survey, G-7, p. 252, 1883.

Geologic Section 65.—Northwest entrance to Woodstock Gap in Massanutten Mountain, Shenandoah County, Virginia

	Thickness Feet
Onondaga formation	
8. Shale, yellowish gray, lumpy	
Oriskany sandstone (?)	
7. Conglomerate and sandstone, ferruginous	10
Helderberg and Cayuga (?)	
6. Not exposed	300?
Wills Creek formation? (170 feet)	
5. Shale, weathering yellowish, streaks of red, with *Leperditia elongata willsensis* Ulrich and Bassler?	30
4. Not exposed	140
Bloomsburg formation (260 feet)	
3. Sandstone, thick bedded, mainly red, partings of red shale	140
2. Not exposed; lowest beds of Bloomsburg shown in an adjacent section (?)	120
Tuscarora-Clinton (Massanutten) formation	
1. Quartzite, gray, thick bedded; several hundred feet thick.	

In this section, if bed 2 is occupied by Bloomsburg, the known thickness of the Cayuga is 430 feet, to which may be added a large part of bed 6, so that the total thickness of the Cayuga in this locality may be estimated at 600 feet. The lower 260 feet is distinctly of the Bloomsburg type, whereas the upper 300 feet may be of the Wills Creek type. The facts are not determinable because of the lack of a complete exposure.

In Harshberger Gap near the south end of Massanutten Mountain, 2½ miles north of McGaheysville, Rockingham County, the section is not well exposed, but the succession as partly shown in the stream at the bottom of the gap and clearly indicated in the adjacent ridges is as follows:

Geologic Section 66.—In Harshberger Gap, Massanutten Mountain, Rockingham County, Virginia

	Thickness Feet
Onondaga formation (150± feet)	
12. Shale, dark-colored with *Styliolina* abundant	50±
11. Not exposed	100±
Wills Creek? (101 feet)	
10. Limestone, argillaceous; contains *Leperditia elongata willsensis* Ulrich and Bassler, abundant, and *Kloedenia longula* Ulrich and Bassler 50 feet above bottom	60
9. Shale, calcareous	15
8. Sandstone, brown	6
7. Sandstone, hard, white	20
Bloomsburg and Massanutten sandstones(?)	
6. Not exposed; scattered masses of red sandstone in upper 300 feet±	600
Massanutten sandstone (240+ feet)	
5. Quartzite	30
4. Not exposed	200
3. Quartzite	10
Martinsburg shale (in part) 1040 feet	
2. Not exposed	1000
1. Limestone, hard, thick bedded, bluish, weathers brownish and shaly	40

It is known from exposures in Ruckles Gap, 4 miles northeast of Harshberger Gap and on the crests of the adjacent ridges, that the Massanutten sandstone is 500 feet thick and that it is directly overlain by red sandstone and shale of the Bloomsburg. As shown in the preceding section, the latter must be about 340 feet thick, because the direct distance across the vertical beds between the lowest quartzite, bed 3, which is evidently Massanutten, and the sandstone, bed 7, referred to the Wills Creek, is about 840 feet. Deducting 500 feet, the thickness of the Massanutten sandstone, leaves 340 feet for the Bloomsburg. One of the most significant facts in the above section is the occurrence of the Wills Creek formation not more than 100 feet below Middle Devonian shale referred to the Onondaga.

Distribution.—The Bloomsburg in Virginia is present in Great North Mountain as far south at least as Orkney Springs, Shenandoah County, and probably extends to the south end of the mountain. The Bloomsburg occurs along Little North Mountain from Chambersville, Frederick County, to a point south of Van Buren Furnace, Shenandoah County, where it joins, through an *en echelon* fold, the Great North Mountain belt. It evidently underlies the syncline between Great North and Little North mountains. In Brocks Gap, Rockingham County, red sandstone debris above the Clinch-Tuscarora sandstone is probably Bloomsburg but may belong in the Cacapon division of the Clinton. The distribution of the Bloomsburg in the Massanutten Mountain complex has been described. The formation apparently does not occur in other areas in Virginia.

The Bloomsburg is best exposed at the north end of Great North Mountain, on U. S. Route 50, 1¼ miles east of Gore, where a mass of red shale and sandstone is fully exposed in an anticline. It is fully exposed in Baldwins Gap through Little North Mountain, 1 mile north of Marlboro, Frederick County, and on the southeast slope of Great North Mountain, 1 mile north of Orkney Springs. The excellent exposures in Massanutten Mountain have been indicated above.

Thickness.—The thickness of the Bloomsburg at the north end of Great North Mountain can not be readily measured because of minor folding, but it is estimated to be 100-200 feet. In a nearly completely exposed section 1 mile north of Marlboro, Frederick County, it is 100 feet thick. In Massanutten Mountain it apparently ranges from 300 to 400 feet.

Fossils and correlation.—Most of the Bloomsburg is nonmarine and almost unfossiliferous. Its stratigraphic horizon, correlation, and equivalence must, therefore, be determined from its relations to strata of known age. In Great North Mountain it is underlain by a yellow fissile shale, some thin layers of which contain an abundance of small ostracodes referred to the McKenzie. In Massanutten Mountain it is overlain by yellowish calcareous shale with layers having many *Leperditia elongata willsensis* Ulrich and Bassler, referred to the Wills Creek formation. (See Fossil Plates, Part II.) In the Cumberland, Maryland, area and in the Altoona area of central Pennsylvania, a thin bed of red shale lies at the base of the Wills Creek formation, in which it has been included as the Bloomsburg member. Farther southeast, as southeast of Tussey Mountain and southwest of Huntington, Pennsylvania, this bed is much thicker and includes thick layers of red sandstone. In the same general locality a bed of red shale, which is still lower in the stratigraphic sequence, occurs in the McKenzie limestone. According to Swartz,[154] the amount of red-colored rocks increases eastward so that in eastern Pennsylvania almost the entire Cayuga group has a red nonmarine facies. This facies in western New York is named the Vernon shale, near the base of the Cayuga group. It is a parallel example with the Catskill and Mauch Chunk which are nonmarine red formations in eastern New York and Pennsylvania, gradually changing westward into marine fossiliferous formations.

WILLS CREEK FORMATION

Name.—The Wills Creek formation was named[155] from Wills Creek, a large stream near Cumberland, Maryland, along which the formation crops out and was formerly well exposed.

Limits.—The Wills Creek is defined to include all of the strata between the McKenzie limestone below and the well-defined thin bedded black Tonoloway limestone above. These limits hold only in the western areas as exemplified in the Crabbottom section. Even there the top and bottom are not well enough exposed to permit their exact determination. At Cumberland, Maryland, in central Pennsylvania, and in Great North and Massanutten mountains, Virginia, the bottom is marked by the conspicuous Bloomsburg red shale and sandstone.

Character.—Near Crabbottom, Virginia, the Wills Creek is composed of shale and sandstone as shown in the following section along the road to the southeast.

Geologic Section 67.—Along road 2 miles southeast of Crabbottom, Highland County, Virginia

	Thickness Feet
Tonoloway limestone	
Wills Creek formation (120 feet)	
3. Shale	50±
2. Sandstone, rather thick bedded, medium grained, rusty specks throughout; *Pterinea,* one or more	

[154] Swartz, C. K., and F. M., Early Silurian formations of southeastern Pennsylvania: Geol. Soc. America Bull., vol. 42, pp. 621-662, 1931.

[155] Uhler, P. R., The Niagara period and its associates near Cumberland, Md.: Maryland Acad. Sci. Trans., new ser., vol. 2, pp. 19-26, 1905.

Stose, G. W., and Swartz, C. K., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (No. 179), p. 7, 1912.

	Thickness Feet
species, common and *Leperditia elongata willsensis* Ulrich and Bassler abundant	20
1. Shale	50

McKenzie limestone

The red beds (Bloomsburg) occur at or below the horizon of bed 1 of this section at Cumberland, Maryland, in central Pennsylvania near Hollidaysburg, Bellefonte, and Williamsport, and in Huntingdon County. An occasional thin red bed occurs in the Wills Creek formation along the northwest side of the Valley in Virginia. The Wills Creek extends southwestward to Tennessee, except possibly in the vicinity of Big Stone Gap, and is represented by coarse-grained friable sandstone containing the fossils of bed 2. Along the southeast slope of Clinch Mountain from Tannersville, Tazewell County, to Hayter Gap, Washington County, this sandstone is very coarse grained. It is stained and mottled with iron and manganese oxides, and contains the fossils listed above, making it easily recognizable. In the Big Stone Gap area the Cayugan rocks, in part Wills Creek and in part Tonoloway, are composed of limestone, sandy limestone, and sandstone as shown in the following section just south of East Stone Gap, measured by Ulrich[156] and slightly modified by the writer.

Geologic Section 68.—Cayugan rocks just south of East Stone Gap, Wise County, Virginia

	Thickness Feet
Helderberg formation	
Sandstone, porous residual material from limestone	
Cayuga limestone (227 feet)	
10. Limestone, pure, thick bedded, with ostracodes	50
9. Limestone, laminated, fine grained, bluish gray, magnesian	125
8. Not exposed	15
7. Limestone, thin bedded, sandy; contains *Leperditia* and *Pterinea*	6
6. Limestone	3

156 Virginia Geol. Survey Bull. 24, p. 37, 1923.

	Thickness Feet
5. Limestone, siliceous, weathering to soft sandstone, fossiliferous; *Spirifer vanuxemi* Hall and other brachiopods numerous	10
4. Shale, sandy, chocolate-colored, thin layers of sandstone containing *Leperditia*	5
3. Sandstone with small quartz pebbles at top	4
2. Limestone, shaly, with thin sandy plates; contains *Spirifer vanuxemi, Beyrichia, Kloedenia* and *Leperditia*	6
1. Sandstone with small quartz pebbles	3

Clinton formation

Sandstone and shale

In Great North and Massanutten mountains, the Wills Creek is a yellowish shale on weathered exposures but unweathered material is argillaceous limestone. In Harshberger Gap 2½ miles north of McGaheysville the yellowish, shaly limestone with *Leperditia elongata willsensis* directly overlies 340 feet of Bloomsburg red beds and is not far below middle Devonian shale with *Styliolina fissurella.* (See geologic section 66.) Similar shale with *Leperditia* also occurs in exactly the same relations in the northern basin of Massanutten Mountain. (See geologic section 65.) In Great North Mountain an occasional thin bed of red shale occurs in the Wills Creek.

Distribution.—Only the sandstone, beds 1 and 3 of the preceding section, which is typical of the Wills Creek of Virginia, originally persisted southwestward in narrow troughs to Tennessee and is now preserved in several detached areas. It was observed about 1 mile east of Monterey, in the narrow synclinal areas in the vicinity of Doe Hill and Palo Alto, 5 to 10 miles southeast of Crabbottom, and in Jackson Valley northwest of Warm Springs, Bath County. It was not observed in the James Valley and is absent in the Iron Gate gorge, 2 miles east of Clifton Forge, where the Tonoloway limestone lies on the Keefer sandstone. One of the best outcrops of the sandstone is on Granny Run in Seven Mile Mountain, just south of Craig Healing Springs, Craig County. There it is a coarse-grained thick-bedded sandstone[157] of moderate but undetermined, thickness containing especially *Leperditia elongata willsensis* in abundance. (See Fossil Plates, Part II.) It contains fewer specimens of the *Pterineas* common in the fauna everywhere. No trace of

[157] This sandstone was designated as Carboniferous on former editions of geologic maps.

the Wills Creek has been noted on New River in Giles County, but it occurs in typical form with its fossils in the southwestern part of Giles County. The Wills Creek is present on the southeast slope of Clinch Mountain from the vicinity of Asberrys, Tazewell County, southwest to Hayter Gap, and is apparently persistent as a coarse-grained manganese-stained sandstone with characteristic fossils. The formation, 5 to 10 feet thick, is exposed between Clinton and Onondaga beds on Virginia Route 81, 1 mile west of Tannersville. It is exposed at several places along Virginia Route 80, on the lower part of the southeast slope of Clinch Mountain about 1 mile northwest of Hayter Gap village. Sandstone of Wills Creek type containing *Spirifer vanuxemi* Hall and *Pterinea* is exposed on the southeast slope of Powell Mountain on U. S. Route 58, 1¼ miles northwest of Pattonsville, and on Virginia Route 64, sandy limestone with ostracodes occurs on the southeast slope of Powell Mountain, 1 mile north of Blackwater, Lee County. Near Big Stone Gap, Wise County, the Cayugan rocks are 227 feet thick, which is much greater than elsewhere in southwest Virginia. It is believed that the sandy beds, 1 to 7 of geologic section 68, with *Leperditia,* represent the Wills Creek and that the overlying magnesian limestone beds, 9 and 10, 140 feet thick, represent the Tonoloway limestone. Cayugan ostracodes have long been known in the vicinity of Sneedville, Hawkins County, Tennessee, in the Powell Mountain belt, and it is probable that the Wills Creek is represented there.

Thickness.—Southeast of Crabbottom, Highland County, the Wills Creek is about 120 feet thick; at Craig Healing Springs, Craig County, it may be 50 feet thick; and at Big Stone Gap beds provisionally referred to the Wills Creek are 37 feet thick. On the southeast slope of Clinch Mountain, from Asberrys to Hayter Gap, 5 to 10 feet of sandstone is present. Between Pattonsville and Blackwater on the southeast slope of Powell Mountain the thickness was estimated at 20 to 50 feet.

Fossils and correlation.—The identified fauna of the Wills Creek in Virginia is composed of only a few species. They are *Spirifer vanuxemi* Hall; *Pterinea,* one or more species, not abundant but universally distributed; *Hormotoma* cf. *H. rowei* Swartz, rare; *Leperditia elongata willsensis* Ulrich and Bassler, abundant and apparently persistent throughout and characteristic; and *Kloedenia longula* Ulrich and Bassler, rare. Undoubtedly this list could be greatly increased.

The correlation of the Wills Creek of Virginia with the typical Wills Creek of the Cumberland, Maryland, area, rests both upon the fossils and upon actual continuity of outcrop. The Wills

Creek of Maryland is almost identical in lithological character and stratigraphic relations with that in Blair, Huntingdon, and Center counties of central Pennsylvania. It seems to be generally agreed by stratigraphers that the Wills Creek is to be correlated with the Camillus shale of western New York, the middle formation of the typical Cayuga group. There the Camillus shale contains the thick beds of rock salt so extensively worked in western New York and southeastern Michigan. Salt crystals were found between Doe Hill and Palo Alto, Highland County, Virginia, in a piece of limestone apparently from the Wills Creek.

Rock salt.—The occurrence of rock salt in the correlative Camillus of New York and the occurrence of the Wills Creek on the slope of Clinch Mountain northwest of Saltville, Smyth County, suggest that the rock salt in unknown stratigraphic relations at that place may be in the Wills Creek, there deposited in a narrow trough in greater thickness than elsewhere.[158]

TONOLOWAY LIMESTONE

Name.—The Tonoloway limestone was named[159] from Tonoloway Ridge west of Hancock, Washington County, Maryland, where the limestone is exposed. The best exposure of the formation, however, is in a cut on the Baltimore and Ohio Railroad in the vicinity of Pinto, Maryland, 7½ miles southwest of Cumberland.

Limits.—The Tonoloway includes all the rocks in Virginia, Maryland, and central Pennsylvania known to lie between the Wills Creek formation and the Helderberg limestone, or basal part of the Devonian system. It is, therefore, the uppermost formation of the Silurian system in Virginia, and, so far as known, considering its correlated equivalents in New York and eastern Pennsylvania, the uppermost unit of the Silurian system in North America. (See discussion, p. 273.)

Character.—In Virginia, as in Maryland and central Pennsylvania, the Tonoloway is in general a persistently thin-bedded or laminated finely crystalline dark-gray to black limestone. The laminated structure is perfectly shown in an exposure of the upper 30 feet of the formation just above river level in the gorge of Jackson River through Morris Hill-Coles Mountain 11 miles north of Covington, Alleghany County. (See Pl. 42A.) The lower beds of the overlying Keyser are fully exposed here. The laminae, one-fourth to half an inch thick, are them-

[158] See discussion under "Geologic history."

[159] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, Pl. 28, 1911.

Stose, G. W., and Swartz, C. K., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (No. 179), p. 7, 1912.

selves commonly straticulate, as shown on weathered edges. Thicker layers occur at different horizons in the mass, but these, too, are also commonly laminated. The more fossiliferous layers are coarsely crystalline. Very little limestone of compact or glassy texture like that of the Mosheim or the dark-colored limestone of the Athens has been noted. In Maryland thin beds of sandstone and shale are present, but such beds were not noted in fully exposed and widely separated sections in Virginia. Some of the limestone is said to be slightly magnesian.

An unusual type of thin-bedded limestone occurs in Great North Mountain and adjacent areas in Frederick County. The limestone is finely straticulate. The laminae become gray on weathering and give the limestone on oblique surfaces a characteristic appearance like the marbled edges of a book. This feature resembles the banding of varved clays.

Distribution.—The Tonoloway has been observed in the Cayugan belts in Highland, Bath, Alleghany, Craig, Giles, and Bland counties, and possibly in the southern part of Augusta County. The best exposures are on the road, between Crabbottom and Straight Creek, just northwest of Straight Creek Post Office, Highland County; in Brocks Gap, Rockingham County; on U. S. Route 220, on the southwest side of the Iron Gate gorge, Alleghany County; and in the gorge of Jackson River, described above. Laminated limestone identified as Tonoloway composes the narrow strip of Cayugan extending southwest from Eagle Rock. Limestone provisionally referred to the Tonoloway also occurs about 1 mile southeast of Bells Valley, Rockbridge County, and in western Craig County and eastern Bland County.[160] This identification is based on a dark-colored coarse-grained limestone in which a *Camarotoechia,* provisionally identified as *C. tonolowayensis* Swartz, is fairly abundant, and which directly underlies the Devonian Becraft sandstone. Limestone, possibly Tonoloway, has been observed in Baldwins Gap through Little North Mountain, Frederick County. The Tonoloway is not known to occur on New River, Giles County. Limestone, probably Tonoloway, occurs just below the Onondaga chert on Tumbling Run 4 miles west of Saltville, Smyth County. The only other known occurrence of limestone southwest of Bland County that may reasonably be referred to the Tonoloway is that at East Stone Gap, Wise County, as shown in geologic section 68.[161]

The best displays of the straticulate limestone of the Tonoloway are on the west slope of the ridge east of U. S. Route 50, 1½ miles northwest of Hayfield, and on the slopes of Bean Hill, 2 miles northwest of Mt. Williams, both in Frederick County.

[160] Included in Lower Devonian on the geologic map of the Valley.

[161] F. M. Swartz has identified a considerable thickness of limestone at Seven Springs in Massanutten Mountain as Tonoloway: Virginia Geol. Survey Guide Leaflet No. 1, p. 26, 1938.

Thickness.—The Tonoloway southeast of Crabbottom is computed to be 450 feet thick. On the same outcrop belt at Pinto, Maryland, northeast of Crabbottom, the thickness is 600 feet.

Fossils and correlation.—The Tonoloway is apparently not very fossiliferous in Virginia, perhaps because it has not been thoroughly searched for fossils. In Maryland it has yielded a rather large number of species consisting mainly of brachiopods, pelecypods, and ostracodes.

Tonoloway fossils from Virginia

Hydrozoa
  Stromatopora constellata and a tubular species

Brachiopods
  Camarotoechia litchfieldensis (Schuchert)
  Camarotoechia tonolowayensis Swartz
  Hindella (Greenfieldia) congregata Swartz
  Spirifer vanuxemi Hall

Ostracodes
  Dizygopleura sp.
  Isochilina cf. I. subnodosa Ulrich, rare
  Leperditia alta (Conrad)
  Leperditia elongata Weller
  Leperditia scalaris praecedens Ulrich and Bassler

A number of undetermined minute species occur in Maryland, all apparently rare and probably belonging to the genera *Dizygopleura, Kloedenella,* and *Zygobeyrichia. Camarotoechia litchfieldensis, Hindella,* and *Leperditia alta* are the most common forms of the Tonoloway in Maryland. *L. alta* is universally present in the Tonoloway or its equivalent throughout Maryland, Pennsylvania, and New York. It also is reported from the Wills Creek and McKenzie formations of Maryland.

DEVONIAN SYSTEM

General Statement

The stratigraphic units of the Devonian system are listed in Table 1. The distribution of the system and its members are plainly shown on the geologic map of the Valley.[161a] It occupies wide areas along the northwest side of the Valley, which decrease in width southwestward to narrow bands in the vicinity of New River. Southwest of New River a large area is present in Bland County, but southwest of it only narrow belts occur.

[161a] Virginia Geol. Survey Bull. 42, 1933.

Where the Keyser member of the Helderberg limestone is present no break or hiatus is known between the Silurian and Devonian systems. Indeed, the fossils of the Keyser contain a considerable Silurian element and some geologists have assigned the formation, or its equivalent elsewhere, to the Silurian. In the southwest part of the Valley, where the Helderberg limestone and generally the Oriskany sandstone, as well as the Silurian Cayuga group, are absent, a considerable hiatus intervenes between the Silurian and Devonian. A hiatus between the Devonian and Mississippian is caused by the absence of the Kinderhook group (Mississippian) of the Mississippi Valley.

HELDERBERG LIMESTONE

Name.—The Helderberg limestone was named[162] from the Helderberg Mountains in the Albany district of New York, where the post-Keyser members are best developed and exposed.

Limits.—The normal limits of the Helderberg as placed by the Maryland Geological Survey are the Keyser-Tonoloway boundary below and the Becraft-Oriskany (Shriver) contact above. That usage is followed here.

Character.—In general, the Helderberg of the Valley in Virginia is a limestone, but in some parts of the Valley considerable thicknesses of sandstone are found, as is shown by several sections. A good section is along U. S. Route 250, midway between McDowell and Headwaters, Highland County.

Geologic Section 69.—Helderberg limestone on the east slope of Bull Pasture Mountain, Highland County, Virginia

	Thickness Feet
Millboro shale	
23. Shale, black, fissile, more or less plicated	1000±
Onondaga shale (150 feet)	
22. Shale, weathers gray, fissile	60
21. Shale, olive green, rather hackly, with ostracodes	30
20. Shale, gray	10
19. Shale, black, fissile, with *Anoplotheca acutiplicata* (Conrad)	50

[162] Name introduced by Conrad, T. A., in 1839 and variously used by the early geologists of New York State up to 1899 when it was restricted to approximately present usage for the formations between the Oriskany sandstone and the Manlius (Tonoloway?) limestone. Conrad, T. A., *in* New York Geol. Survey 3d. Ann. Rept., 1839; Clarke, J. M., and Schuchert, Charles, The nomenclature of the New York series of geological formations: Science, new ser., vol. 10, pp. 874-878, 1899.

	Thickness Feet
Oriskany sandstone (200? feet)	
18. Sandstone, coarse grained, friable, thick bedded, highly fossiliferous throughout; contains *Spirifer arenosus* (Conrad) and *S. murchisoni* Castelnau....	150
17. Not exposed	50
Helderberg limestone (775 feet)	
Hiatus; Becraft member absent	
New Scotland member	
16. Limestone, argillaceous, some pure, crystalline; chert nodules, layers, and stringers; highly fossiliferous, especially in lower 20 feet; contains *Spirifer macropleurus* (Conrad), *Delthyris perlamellosus* Hall	100±
Coeymans limestone member	
15. Limestone, coarse grained, thick bedded, pinkish, resembles marble; highly crinoidal, large stems; a few brachiopods in section, probably *Gypidula coeymanensis* Schuchert	80±
Keyser limestone member (595± feet)	
14. Shale	20
13. Limestone, thick bedded	70
12. Limestone, argillaceous, thin bedded to laminated, weathers shaly	80
11. Limestone, like bed 12 but contains layers of compact blue limestone, all distinctly laminated	65
10. Limestone, sandy	10
9. Limestone, crystalline	15
8. Limestone, fossiliferous, crinoidal; contains bryozoa, brachiopods, *Atrypa reticularis* (Linné), *Spirifer*, orthoids	20
7. Shale	10
6. Limestone, thick bedded, coarsely crystalline, crinoid stems to ¾ inch in diameter	60
5. Limestone, layers 2-12 inches, shale partings, surface of layers weathers gray or pink, contains ostracodes	60
4. Shale	10

	Thickness Feet
3. Limestone, dark blue, thin bedded to distinctly laminated, weathers pink on surface or pinkish throughout	130
2. Shale, dark-colored	15±
1. Limestone, dark-colored, thin bedded to laminated; resembles Tonoloway to arch of anticline	30

This section is repeated in reverse order to the northwest.

The section is nearly continuously exposed and the dip ranges from 30° SE. for most of the distance to 90° for a short space at the top. The distance across the section was measured by pacing and the computed thicknesses are approximate. The thickness of the Keyser obtained here is greater than would be expected, and it is probable that some of the laminated limestone, bed 3, at the base is Tonoloway. The absence of sandstone in the Keyser is significant in comparison with its presence farther southwest, in Bath and Alleghany counties. A section on Jackson River in the gorge between Coles Mountain and Morris Hill, 1 mile west of Kincaid and 11 miles north of Covington, exhibits this sandstone and other features of the Helderberg sequence.

Geologic Section 70.—Helderberg limestone along Jackson River 1 mile west of Kincaid, Alleghany County, Virginia

	Thickness Feet
Oriskany sandstone	
Helderberg limestone (486 feet)	
Becraft limestone member	
11. Limestone, very thick bedded, coarse grained, fragmental, *Spirifer concinnus* abundant	50
New Scotland limestone member (205 feet)	
10. Limestone, argillaceous, knotty, cherty; *Dalmanites pleuroptyx* (Greene) common; *Eatonia medialis* (Vanuxem)	150
9. Sandstone, thick bedded, white, quartzitic, limy in lower part; *Healing Springs sandstone*	55
Coeymans limestone member (55 feet)	
8. Limestone, sandy, full of crinoid stem plates	20
7. Limestone, thick bedded, coarsely crystalline, fragmental, some pinkish, resembles marble	35

	Thickness Feet
Keyser limestone member (176 feet)	
6. Limestone, bluish, fine grained, a few thin sandy layers, coral horizon (geologic section 71, beds 4-8)	22
5. Sandstone, cross bedded, limy groundmass, more calcareous layers in middle, *Clifton Forge sandstone*....	95
4. Limestone, very nodular; contains *Chonetes jerseyensis* Weller, and *Camarotoechia litchfieldensis* (Schuchert)	5
3. Limestone, thick bedded, partly sandy, partly finely crystalline, pink and gray above, basal 5 feet coarsely crystalline, crinoidal	53
Shale	1
Tonoloway limestone (37 feet exposed)	
2. Limestone, black, thicker bedded than bed 1	18
1. Limestone, black, laminated, with *Leperditia alta* (Conrad) to river level	19

A notable feature of this section is the presence of the two rather thick sandstones, Healing Springs in the basal New Scotland and Clifton Forge in the upper part of the Keyser, of which there is scarcely a trace in the section between McDowell and Headwaters.

Another instructive section is exposed at Island Ford on Jackson River, along U. S. Route 60, 4 miles southeast of Covington.

Geologic Section 71.—Helderberg limestone at Island Ford, 4 miles southeast of Covington, Alleghany County, Virginia

	Thickness Ft.	In.
Oriskany sandstone		
14. Sandstone, coarse grained, friable; contains *Spirifer arenosus* (Conrad), and *Rensselaeria ovoides* (Eaton)?	20	
Helderberg limestone (308 feet)		
Becraft limestone member		
13. Limestone, massive, coarsely crystalline, bluish gray, fossiliferous	75±	
New Scotland member (77 feet)		
12. Limestone, argillaceous, knotty, fossiliferous	50	

		Thickness Ft.	In.
11.	Sandstone, calcareous, weathers to sandstone; *Healing Springs sandstone*	22	
10.	Limestone, unevenly bedded, full of limestone nodules	5	
Coeymans limestone member			
9.	Limestone, massively bedded; contains *Favosites,* crinoid stems, and *Gypidula coeymanensis* Schuchert? in top 4 feet	12	
Keyser limestone member (144+ feet)			
8.	Limestone, sandy; *Favosites* common in lower part	2	6
7.	Limestone, sandy	4	10
6.	Limestone, sandy massive bed, crinoid stems and a few corals	28	
5.	Limestone, with *Stromatopora*	1	
4.	Limestone, massive; contains *Cladopora rectilineata* Simpson, *Favosites* and *Stromatopora*	8	
3.	Sandstone } *Clifton Forge sandstone*	60±	
2.	Limestone } *Clifton Forge sandstone*	16	
1.	Sandstone } *Clifton Forge sandstone*	24±	

The presence here of *Cladopora rectilineata* (see Fossil Plates), one of the main guide fossils of the Keyser limestone, together with the presence of *Chonetes jerseyensis* Weller, another guide fossil of the Keyser, in bed 4 just above the Clifton Forge sandstone in the section on Jackson River (geologic section 70), north of Covington, proves the Keyser age of the sandstone.

The preceding sections show adequately the general nature of the Helderberg formations. The individual units are described below. For more detailed descriptions the reader is referred to another paper.[163]

KEYSER LIMESTONE MEMBER

Name.—The Keyser limestone was named[163a] from Keyser, West Virginia, where it is fully exposed in a limestone quarry.

Limits.—The Keyser limestone includes all the rocks above the Tonoloway limestone and below the Coeymans limestone.

[163] Swartz, F. M., The Helderberg group of parts of West Virginia and Virginia: U. S. Geol. Survey Prof. Paper 158C, pp. 27-75, 1929

[163a] Swartz, C. K., Lower Devonian: Maryland Geol. Survey, pp. 85, 98-102, 1913; also mentioned by Ulrich, E. O., Geol. Soc. America Bull., vol. 22, pp. 563, 590, 591, pl. 28, 1911.

Character.—The Keyser limestone is composed of limestone in both the northwestern and southwestern ends of its areas in Virginia and of limestone and sandstone, more or less interbedded, in the intermediate area between Covington and vicinity in Alleghany County and Warm Springs in Bath County, and thus has two distinct facies. The sandstone facies extends from some undetermined point north of Warm Springs to some point southwest of James River. The sandstone has diminished to a thin basal bed on the southeast slope of Peters Hill, 3 miles northwest of Newcastle, Craig County, whereas the main body of the Keyser is a medium bedded, scantily fossiliferous limestone, as exposed on Johns Creek at the east entrance to its gorge through Peters Hill about 2½ miles west of Newcastle. A little sandstone in thin beds occurs also in the section immediately southeast of Bells Valley, Rockbridge County. In the broad area of Helderberg crossed by Back Creek northwest of Hot Springs, minor folding, probable faulting, and poor exposures of the heterogeneous mixture of limestone, sandstone, and sandy limestone make it impossible to arrange a definite sequence.

Clifton Forge sandstone.—The Clifton Forge sandstone, named by F. M. Swartz,[163b] is a rather coarse-grained, thick-bedded sandstone, which is somewhat calcareous. In places, it includes a thin layer of limestone. Where thickest, it seems to make up about the middle half of the Keyser. So far as known it is present only in Alleghany and Bath counties, and especially in the Back Creek Mountain area of Bath County. Its full thickness, of about 100 feet, is exposed on the north bluff of Jackson River, 1 mile west of Kincaid, and in the bed of Jackson River at Island Ford, 4 miles southeast of Covington, both in Alleghany County.

Distribution.—The Keyser originally extended northwestward from Little North Mountain to the northwest boundary of the State, and from West Virginia southwest beyond Johns Creek, Craig County. It disappears north of New River, along which and southwest of which it has not been definitely recognized. There is evidence of its presence in the Massanutten Mountain area.

The best exposures of the Keyser are along the road across the folded belt between Doe Hill and Palo Alto and on U. S. Route 250, between Headwaters and McDowell, Highland County (geologic section 69); in the gorge of Jackson River through Morris Hill-Coles Mountain; and in the Johns Creek gorge through Peters Hill-Nutters Mountain. The thin sandstone at the base of the formation is exposed near the summit of Peters Hill just south

[163b] Op. cit., p. 29.

of Johns Creek and 2½ miles west of Newcastle, Craig County. Especially good displays of highly fossiliferous limestone occur on the summit of Sand Ridge 2½ miles southwest of Gore, and on the southwest end of the narrow ridge, 1 mile northwest of Hayfield, both in Frederick County.

Thickness.—The Keyser is apparently about 600 feet thick in Highland County. (See geologic section 69.) It is 176 feet thick in the gorge of Jackson River already described, and apparently 200 feet thick at the Johns Creek locality. Swartz[164] has measured the Keyser at several places in Virginia; among them, one about one-fourth of a mile east of McDowell, where he found it 155 feet thick. On Jackson River in the vicinity of Iron Gate gorge and Clifton Forge, Swartz gives the thickness as 104 feet, which agrees with the writer's figure of 100 feet, at the southeast entrance to the Iron Gate gorge. In Baldwins Gap through Little North Mountain, three-fourths of a mile northwest of Marlboro, and on a prominent ridge 1 mile northwest of Hayfield, both in Frederick County, the thickness is about 100 feet.

Fossils and correlation.—The Keyser is highly fossiliferous in some places, especially in its northwestern areas. Along Little North Mountain, fossils are scarce. Brachiopods are the most abundant class in species and individuals. Bryozoa are fairly common in certain localities. A few species of corals are fairly abundant in the upper part of the formation and are generally widely distributed. Some layers contain many minute ostracodes. A list of the fossils, including a number of species, especially brachiopods, identified by F. M. Swartz,[165] follows:

Fossils from the Keyser limestone

Stromatopora constellata Hall

Corals
- Aulopora schohariae Hall
- Aulopora schucherti C. K. Swartz
- Ceratopora? marylandica C. K. Swartz
- Ceratopora sp.
- Cladopora multiseriata Weller
- Cladopora rectilineata Simpson
- Cyathophyllum clarki C. K. Swartz
- Cyathophyllum radiculum Rominger

[164] Swartz, F. M., op. cit., pp. 64, 67.
[165] Op. cit.

Cyathophyllum schucherti C. K. Swartz
Favosites helderbergiae Hall
Favosites schriveri (Herzer)
Striatopora sp?

Cystids
Jaekelocystis papillatus Schuchert
Lepocrinites manlius Schuchert
Pseudocrinites abnormalis Schuchert
Pseudocrinites gordoni Schuchert

Bryozoa
Batostomella interporosa Ulrich and Bassler?
Cyphotrypa corrugata (Weller)
Diplostenopora siluriana (Weller)
Eridotrypa parvulipora Ulrich and Bassler
Fenestrellina altidorsata (Ulrich and Bassler)
Fenestrellina cumberlandica (Ulrich and Bassler)
Fistuliporella marylandica Ulrich and Bassler
Orthopora rhombifera (Hall)
Polypora dictyota Ulrich and Bassler
Stromatotrypa globularis Ulrich and Bassler

Brachiopods
Atrypa reticularis (Linne)
Camarotoechia cf. C. altiplicata (Hall)
Camarotoechia gigantea Maynard
Camarotoechia litchfieldensis (Schuchert)
Chonetes jerseyensis Weller
Cyrtina dalmani (Hall)
Dalmanella clarki Maynard
Dalmanella concinna (Hall)
Delthyris perlamellosus praenuntius F. M. Swartz
Gypidula coeymanensis prognostica Maynard
Leptaena rhomboidalis (Wilckens)
Merista typa (Hall)
Meristella nasutaformis F. M. Swartz
Meristella praenuntia Schuchert
Nucleospira swartzi Maynard
Nucleospira elegans Hall
Pholidops ovata Hall
Rensselaeria mutabilis (Hall)
Rhipidomella emarginata (Hall)
Rhynchospira formosa Hall

Rhynchospira globosa (Hall)
Schuchertella deckerensis (Weller)
Schuchertella deformis (Hall)
Schuchertella sinuata (Hall and Clarke)
Schuchertella sp.
Spirifer modestus Hall
Spirifer octocostatus Hall
Spirifer vanuxemi Hall
Stropheodonta bipartita (Hall)
Strophonella keyserensis C. K. Swartz
Trematospira cf. T. camura Hall
Trematospira sp.
Uncinulus convexorus Maynard
Uncinulus gordoni Maynard
Uncinulus nucleolatus (Hall)
Uncinulus nucleolatus angulatus Maynard
Uncinulus sp.
Whitfieldella? minuta Maynard
Whitfieldella? nucleolata Hall

Pelecypods
Actinopteria cf. A. reticulata Weller
Amphicoelia sp.?
Cypricardinia cf. C. lamellosa Hall
Mytilarca marylandica Ohern

Gastropods
Loxonema fitchi Hall
Straparollus welleri F. M. Swartz

Pteropods
Tentaculites gyracanthus (Eaton)

Cephalopods
Orthoceras cf. O. rigidum Hall

Trilobites
Calymene camerata Conrad
Dalmanites aspinosus Weller
Proetus protuberans Hall

Ostracodes
Dizygopleura subovalis Ulrich and Bassler?
Kloedenia smocki (Weller)
Leperditia elongata Weller
Zygobeyrichia sp.?
Many other species not identified.

Probably the most important species for correlation are *Chonetes jerseyensis* and *Camarotoechia litchfieldensis,* which characterize about the lower one-third of the member, and *Favosites helderbergiae praecedens* and *Cladopora rectilineata,* which seem to occur mainly in the upper two thirds. On the basis of these fossils the Keyser is divided into two fossil zones known as the *Chonetes jerseyensis* zone and the *Favosites helderbergiae praecedens* zone. On the basis of the distribution of several other species of brachiopods, the general zones are subdivided into a number of subzones. For details concerning these subzones the reader is referred to the paper by Swartz cited above.

North of Virginia the Keyser is traceable through central Pennsylvania into the Decker Ferry limestone of New Jersey, which contains many or most of the same fossils as the Keyser of Maryland and Virginia, including *Cladopora rectilineata, Favosites helderbergiae, Chonetes jerseyensis, Camarotoechia litchfieldensis,* and *Stropheodonta bipartita.* The Keyser is accordingly accepted by all geologists as the equivalent of the Decker Ferry limestone. The same assemblage, excluding *Cladopora rectilineata,* occurs in the Cobleskill limestone of eastern New York. *Halysites catenulatus* Linné, *Cyathophyllum inequale* (Hall), and *Camarotoechia? lamellata* Hall, occur in the Keyser of Maryland and Pennsylvania, but only one specimen of the first named has been found in Virginia. They also occur in the Cobleskill and further support the correlation of the Keyser, or at least the *Chonetes jerseyensis* zone, with the Cobleskill.

If this correlation is true, it bears on the age of the Keyser, whether Silurian or Devonian. The Cobleskill limestone is generally accepted as Silurian. It follows that the Keyser, or part of it, is Silurian, or, conversely, if the Keyser is Devonian, the Cobleskill is Devonian. The occurrence of *Camarotoechia litchfieldensis* and *Spirifer vanuxemi,* as in Maryland, in the Keyser tends to support its Silurian age. These forms and others are also present in the Tonoloway, some even in the Wills Creek. If the Cobleskill is correctly assigned to the Silurian and the Keyser to the Devonian, the species cited above, whose fossils occur in both the Cobleskill and the Keyser, lived in the New York area in late Silurian time and migrated into the Maryland-Pennsylvania area where they survived into early Devonian time.

The systemic relations of the Keyser are similar to those of other formations near systemic boundaries in different parts of the world. One group of geologists would give most weight to the surviving remnants of the earlier fauna, another would emphasize the importance of the advent of the new forms as indicating changed conditions, biologic or physiographic, that may be fairly regarded as marking revolutions that demarcate definite periods of earth history just as political revolutions separate definite periods of human history. The questions at issue are primarily of scientific interest and have little, if any, practical importance.

COEYMANS LIMESTONE MEMBER

Name.—The Coeymans limestone was named[166] for the village of Coeymans, Albany County, New York. It took the place of the name Pentamerus limestone originally applied to this division of the Helderberg limestone of the Helderberg Mountains, New York.

Limits.—The Coeymans succeeds the Keyser limestone and is limited at the top by the New Scotland limestone or the Healing Springs sandstone where present at the base of the New Scotland.

Character.—In Virginia as in New York, Pennsylvania, and Maryland, the Coeymans is a massively bedded, coarsely crystalline, blue-gray limestone. In some localities in Virginia parts of it are mottled pale red or pink which, with its coarsely crystalline texture, closely resembles marble. Its crystalline character is partly due to the presence of many crinoidal fragments embedded in the mass. Other fossils are scarce or so closely incorporated in the mass of the rock as to be only recognized with difficulty.

Distribution.—The Coeymans in Virginia seems to be most persistent in the belt extending south from West Virginia through Highland, Bath, and Alleghany counties to James River, south of which it has not been definitely recognized, although it is probably represented by a thin bed for some distance south of the river. It has been generally recognized in detailed work in the broad areas of Helderberg in Bath County, northwest of Hot Springs. It also occurs on the northwest side of Little North Mountain at Bells Valley in Rockbridge County. The name Marble Valley applied to an area southwest of Deerfield, Augusta County, indicates the presence of the Coeymans "marble."

One of the best exhibits of the Coeymans seen by the writer is in a new road cut on U. S. Route 250 on the southeast slope of Bull Pasture Mountain, just west of the abrupt bend in the road from southeast to northeast 1¾ miles west of Headwaters, Highland County. Here the Coeymans is fully exposed and is about 50 feet thick. It is massive, highly crinoidal and partly mottled pink. It is overlain by cherty limestone full of New Scotland fossils and underlain by shale 20 feet thick, regarded as the top of the Keyser. At this place silicified

[166] Clarke, J. M., and Schuchert, Charles, op. cit., 1899.

specimens of a *Meristella* occur near the contact with the New Scotland, in close association with *Spirifer macropleurus* (Conrad). This probably is the species identified by Swartz[167] as *Meristella arcuata* (Hall) and regarded by him as occurring in the top of the Coeymans. Due to the lithologic identity of these silicified fossils and the rock in which they occur with the silicified rock and fossils just above them, the writer would include them in the New Scotland. This fossil at least marks a zone very close to the boundary between the Coeymans and New Scotland. Another good exposure of the Coeymans is in the gorge of Jackson River through Morris Hill-Coles Mountain (geologic section 70), where it has the same thickness, color, texture, and abundant crinoid remains as on Bull Pasture Mountain. It is also displayed as a thick-bedded rock 17 feet thick, with *Gypidula coeymanensis*, at Island Ford on Jackson River, 4 miles southeast of Covington, Alleghany County, where as in the gorge of Jackson River it is overlain by the Healing Springs sandstone. It is also present throughout the structurally complex area of Back Creek Mountain in Alleghany, Bath, and Highland counties.

Thickness.—The Coeymans limestone as already indicated ranges in thickness from 17 to 50 feet, so far as determined.

Fossils and correlation.—In Virginia, the Coeymans has disclosed in abundance only crinoid columnals and rarely *Gypidula coeymanensis*. The *Gypidula* appears only in sections on the face of the rock. Probably other fossils fairly abundant in New York, New Jersey, and Maryland also occur here, but they are completely hidden in the matrix.

Swartz,[168] in different sections, refers the following fossils to the Coeymans. The species marked * occur in the upper 5 feet of his Coeymans section: *Camarotoechia campbellana* (Hall)*, *Leptaena rhomboidalis* Wilckens*, *Meristella arcuata* (Hall)* *Nucleospira ventricosa* (Hall), *Rhipidomella oblata* (Hall)*, *Schellwienella woolworthana* (Hall)*, *Spirifer cyclopterus* Hall, *Stropheodonta arata* (Hall)*, *Uncinulus abruptus* (Hall)*, *Whitfieldella prosseri* Grabau, *Platyceras multiplicatum* F. M. Swartz, and *P. trilobatum* Hall.

The writer classifies the 2 to 5 feet of beds containing the fossils marked * as New Scotland. They seem more nearly related to it in lithologic character and in fossil content, especially where the Healing Springs sandstone is absent as in the section northwest of Headwaters. (See geologic section 69.)

Gypidula coeymanensis is probably the same as *Pentamerus galeatus* identified by Hall from limestone of the same age in the Helderberg

[167] Swartz, F. M., op. cit., p. 57.
[168] Swartz, F. M., op. cit., pp. 59-69.

Mountains and as *Gypidula galeata* identified by Weller from the Coeymans of New Jersey. It is the main guide fossil of the Coeymans from New York through New Jersey and Maryland to Virginia. No doubt exists as to the identification as Coeymans of the bed which, with remarkable persistency in lithologic and paleontologic characters, holds its place in the stratigraphic succession from Virginia to New York.

NEW SCOTLAND LIMESTONE MEMBER

Name.—The New Scotland limestone was named[169] from the village of New Scotland, Albany County, New York, near the Helderberg Mountains. It takes the place of the old lithologic designation "Delthyris Shaly Limestone."

Limits.—In areas where the Helderberg is best developed in Virginia, the New Scotland limestone succeeds the Coeymans limestone and is limited above, either by the Becraft limestone or by the Oriskany sandstone.

Character.—The New Scotland in Virginia is an argillaceous and siliceous, mostly nodular limestone, much of which becomes thin-bedded chert. The chert nodules are scattered through a large part of the formation, embedded in argillaceous and siliceous layers, or packed closely together and separated by thin partings of clay. In places, and perhaps generally, a basal stratum of thick-bedded, cherty, and highly fossiliferous limestone 15 to 20 feet thick, contains an abundance of most of the characteristic fossils of the formation. This stratum is fully exposed in the road cut on U. S. Route 250 on the southeast slope of Bull Pasture Mountain at the angle in the road about 1¾ miles west of Headwaters and 3 miles east of McDowell, Highland County. (See geologic section 69.) The character of the New Scotland described above holds throughout Virginia, except in the vicinity of Big Stone Gap, Wise County. Both chert and fossils are abundantly scattered over its outcrop in road cuts and on the surface generally.

Distribution.—The New Scotland occurs persistently throughout the region northwest of Little North Mountain and from Highland County as far south as Paint Bank and Seven Mile Mountain southwest of Craig Healing Springs, Craig County. Limestone of Helderberg age occurs in the valley of Passage Creek in Massanutten Mountain and its southwestern branches nearly south to New Market Gap.

---

169 Clarke, J. M., and Schuchert, Charles, op. cit., 1899.

The best exposures of the New Scotland are on the southeast slope of Bull Pasture Mountain at the locality already described; at a chert pit on U. S. Route 250, 1½ miles west of McDowell, Highland County; on the north bluff of Jackson River in the gorge through Morris Hill-Coles Mountain; and at Island Ford east of Covington. (See geologic sections 69-71.)

Thickness.—At the Bull Pasture Mountain locality the New Scotland seems to be about 100 feet thick and probably it approaches this thickness generally in Highland County. In the gorge of Jackson River, the thickness is 150 feet or slightly more. At Island Ford the thickness is estimated at 72 feet, including the Healing Springs sandstone in the bottom.

Healing Springs sandstone.—In Bath and Alleghany counties the New Scotland member includes a basal sandstone which was named by Swartz[170] the Healing Springs sandstone from an exposure in the gorge through Little Mountain, 3 miles northwest of Healing Springs, Bath County. This bed is probably a sandy limestone and some layers are evidently calcareous in weathered exposures, but on the whole it is a sandstone as weathered. Its assignment to the New Scotland seems fully justified because a full thickness of Coeymans limestone lies beneath this sandstone wherever it occurs. Its clastic character is more like that of the New Scotland than that of Coeymans, and it is said by Swartz to carry fragments of *Spirifer macropleurus* at its type locality west of Healing Springs. The Healing Springs member is 50 feet thick in the Jackson River gorge and 22 feet thick at Island Ford. According to Swartz it is 20 feet thick west of Healing Springs and 16 feet thick in the vicinity of Clifton Forge.

Fossils and correlation.—The following list comprises the more common fossils in the New Scotland:

Fossils of the New Scotland limestone

Corals
- Favosites conicus Hall
- Favosites helderbergiae Hall
- Pleurodictyum lenticulare (Hall)
- Streptelasma strictum Hall

Crinoids
- Edriocrinus pocilliformis Hall

[170] Swartz, F. M., op. cit., p. 41.

Bryozoa
- Monotrypa sphaerica (Hall)

Brachiopods
- Anoplotheca concava (Hall)
- Atrypina imbricata (Hall)
- Cyrtina varia Clarke
- Dalmanella eminens (Hall)
- Dalmanella perelegans (Hall)
- Delthyris perlamellosus (Hall)
- Eatonia medialis (Vanuxem)
- Eatonia peculiaris (Conrad)
- Eatonia singularis (Vanuxem)
- Leptaena rhomboidalis (Wilckens)
- Leptostrophia becki (Hall)
- Meristella arcuata (Hall)
- Meristella lata (Hall)
- Meristella symmetrica Schuchert
- Nucleospira elegans Hall?
- Platyorthis planoconvexa (Hall)
- Rensselaeria subglobosa Weller
- Rhipidomella assimilis (Hall)
- Rhipidomella oblata (Hall)
- Schellwienella woolworthana (Hall)
- Spirifer concinnus Hall
- Spirifer cf. S. concinnus Hall
- Spirifer cyclopterus Hall
- Spirifer macropleurus (Conrad)
- Stropheodonta arata (Hall)
- Strophonella leavenworthana (Hall)
- Strophonella punctulifera (Conrad)
- Strophonella undaplicata C. K. Swartz
- Trematospira equistriata Hall and Clarke
- Trematospira multistriata (Hall)
- Uncinulus abruptus (Hall)
- Uncinulus vellicatus Hall?

Gastropods
- Platyceras gebhardi Conrad
- Platyceras spirale Hall
- Platyceras trilobatum Hall

Trilobites
- Calymene camerata Conrad
- Dalmanites pleuroptyx (Green)
- Homalonotus vanuxemi Hall

This fauna persists from Virginia to New York and serves to mark the presence of the New Scotland at many intermediate localities and prove its continuance as a well-defined stratigraphic unit. *Spirifer macropleurus* and *Delthyris perlamellosus* are the best guide fossils. The first is unknown apparently at any other horizon but is found at nearly every exposure of the New Scotland. The second, or a variety of it, distinguished by Swartz as *praenuntius,* has been found very rarely in the Keyser limestone, but can be regarded generally as a distinctive New Scotland form.

BECRAFT LIMESTONE MEMBER

Name.—The Becraft limestone was named[171] from Becraft Mountain, Columbia County, New York. The name replaced the earlier names Scutella limestone or upper Pentamerus limestone. The limestone was called Scutella because in New York the bed is crowded with myriads of saucer-shaped fossils known as *Aspidocrinus scutelliformis* Hall.

Limits.—In Virginia the Becraft is generally bounded below by the New Scotland limestone but, in places perhaps, by the Tonoloway limestone where the rest of the Helderberg is absent. It is bounded above by either the Oriskany sandstone or the Onondaga formation, as the sequence varies from place to place.

Character.—The Becraft has two distinct facies—pure limestone in its northern area and predominantly pure sandstone in its southwestern area. Transitional beds are found in areas between the areas containing these facies. The Becraft in the gorge of Jackson River—the most northern point at which it has been clearly recognized—is a thick to massively bedded, coarse-grained, blue-gray limestone, apparently without arenaceous material. It is highly crinoidal and resembles the Coeymans limestone. It preserves this character and sequence as far south as Jackson River between Covington and Clifton Forge, where it is apparently a pure limestone as shown by the fact that it was utilized for flux in the iron furnace at Lowmoor. The old limestone mine at this place is shown in Plate 43B. Farther southwest, in a section on State Route 311, 1 mile south of Newcastle, Craig County, the lower 10 feet of the exposed part is so sandy that where its calcareous cement is leached out by weathering, it becomes a thick-bedded, coarse-grained, friable sandstone, as shown in the following section:

---

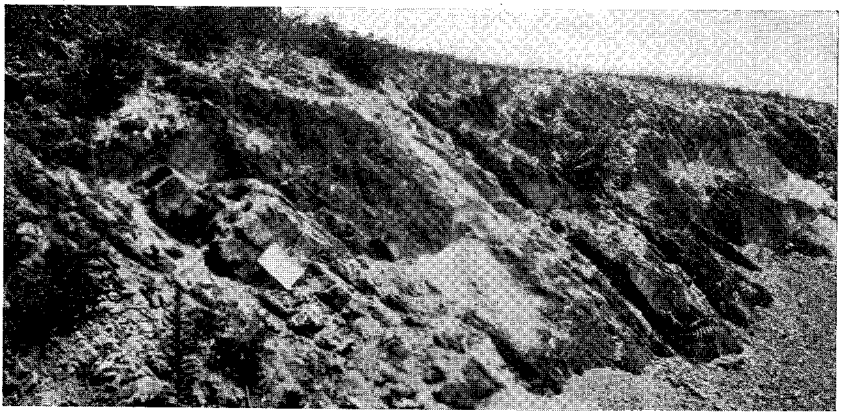
171 Darton, N. H., Preliminary report on the geology of Albany County: New York State Geol. Survey 13th Ann. Rept., pp. 245-246, 1894.

PLATE 43

A. Oriskany sandstone and Onondaga shale (above) near Goshen, Rockbridge County. The notebook is on the contact. The sandstone just below the book is crowded with *Spirifer arenosus* and *S. murchisoni*. Just above the book is a layer of chert about 4 inches thick. The Onondaga is about 120 feet thick here. It is nonfissile and has a dark olive-green color. Along State Route 501, at the southeast entrance of Panther Gap through Mill Mountain 2 miles northwest of Goshen. Looking east.

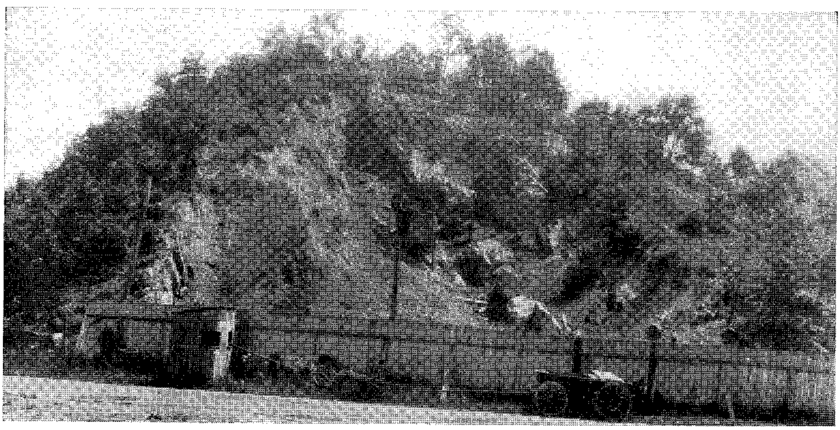
B. Old mine in the Becraft limestone near Lowmoor, Alleghany County. The limestone was used for flux in the smelting furnace. The Oriskany sandstone forms the roof. About half a mile southwest of the railroad junction at Lowmoor. Looking northwest.

C. Sand pit in the Becraft sandstone near Bluefield, W. Va. The beds are overturned and dip about 70° SE. Massively bedded sandstone on the right; shaly sandstone, shale, and chert with fossils in the middle; and Onondaga chert on the left. For list of Becraft fossils here, see geologic section 73, bed 3. Cropping out in the V-shaped cut on the left but concealed by debris, is about 5 feet of typical Oriskany sandstone with a few *Spirifer arenosus*. Along the edge of the cut on the right and just above the sandstone is limestone with *Delthyris perlamellosus*, showing that the limestone is New Scotland. At the entrance to the fair grounds and airport 2 miles southwest of Bluefield. Looking northeast.



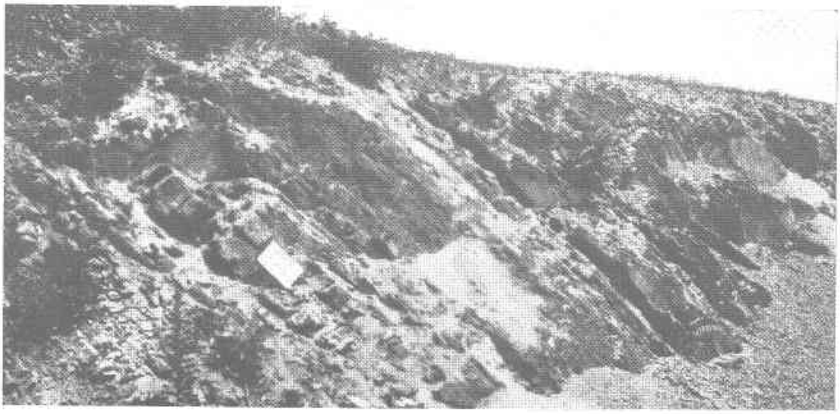
A

B

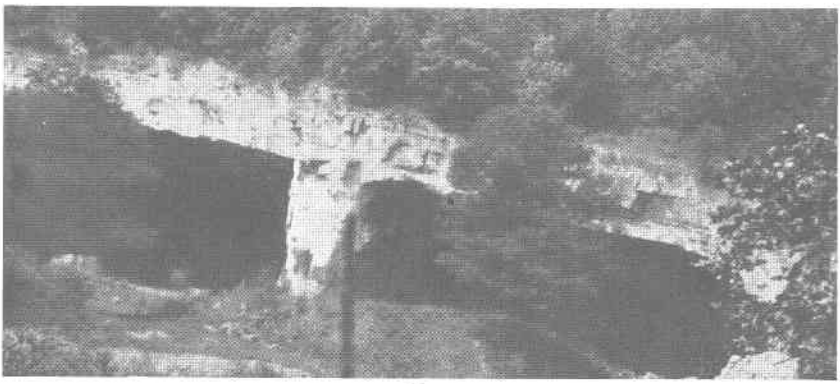


C

Devonian Formations



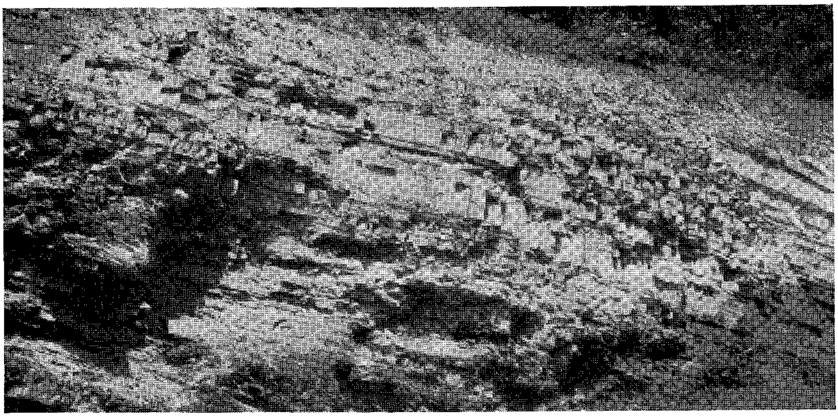
A



B

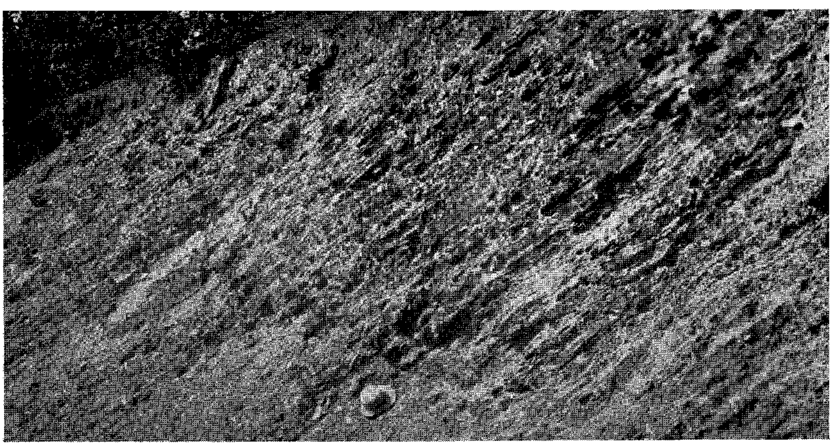
C

Devonian Formations



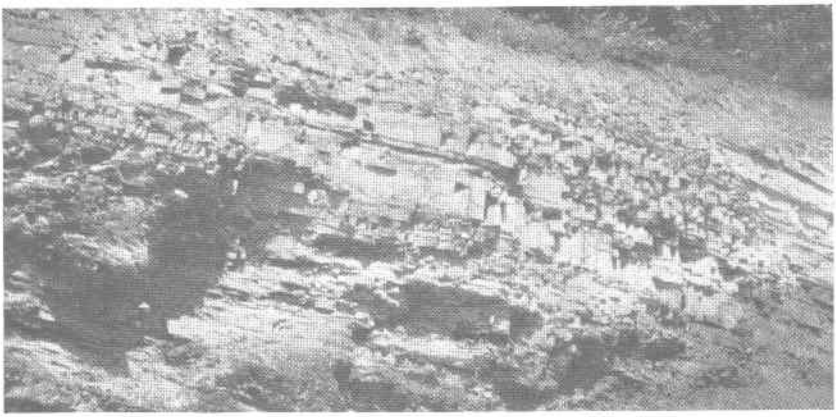
A

B

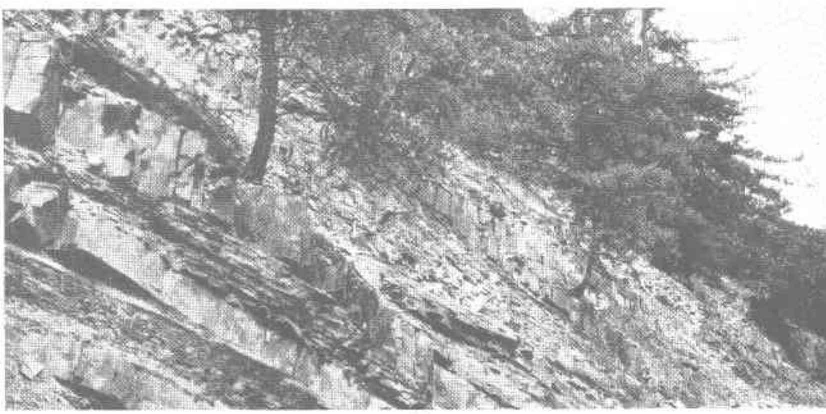


C

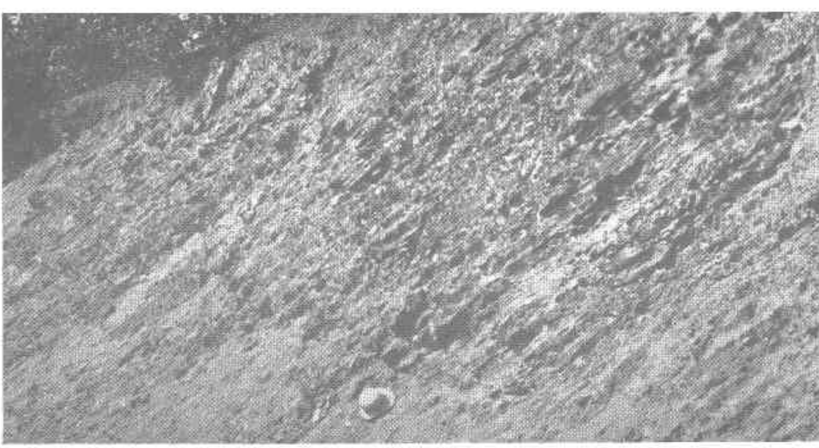
Devonian Shale



A



B



C

DEVONIAN SHALE

PLATE 44

A. Brallier shale in Bland County. The section consists of stiff, siliceous shale above and evenly thin-bedded, blocky jointed, fine-grained sandstone below. This is the typical Kimberling shale of Campbell. Along U. S. Route 21, on the northwest slope of Brushy Mountain, midway between the head of Kimberling Creek and Bastian. Looking northeast.

B. Brallier shale in Augusta County. This section shows more widely separated beds of the characteristic sandstone. Along the old Staunton-Parkersburg pike 3½ miles northwest of Buffalo Gap. Looking northeast.

C. Brallier shale with thinner layers of sandstone in Tazewell County. Along road about 1 mile southwest of Bandys Chapel (Baptist Valley). Looking south.

Geologic Section 72.—Becraft limestone, 1 mile south of Newcastle, Craig County, Virginia

	Thickness Feet
Onondaga limestone	
3. Limestone, argillaceous, and shale exposed	10
Becraft formation (50+ feet)	
2. Limestone, thick bedded, coarsely crystalline, blue-gray, highly fossiliferous; contains *Schellwienella woolworthana* (Hall)?, *Stropheodonta planulata* (Hall), *Uncinulus abruptus* (Hall), *Eatonia peculiaris* (Conrad), and *Spirifer concinnus* Hall	40
1. Sandstone, coarse grained, friable, to bottom of exposure	10+

Still farther southwest, in the vicinity of the Narrows of New River, the formation has become a coarse-grained crinoidal sandstone, as inferred from many scattered exposures on the southeast slopes of East River and Peters mountains. This sandstone facies persists southwest of New River to the vicinity of Burkes Garden in Tazewell County. At the manganese mine on top of Flat Top Mountain near Holly Brook, in western Giles County, about 50 feet of sandstone is exposed. The sandstone is medium thick bedded, coarse grained, friable, and impregnated with manganese oxides in sufficient quantity to be mined. On Buckhorn Mountain northwest of Rocky Gap, the Becraft carries a considerable amount of manganese ore and efforts have been made to mine it.

Geologic Section 73.—Becraft sandstone at the entrance to the fair grounds and airport, Bluefield, West Virginia

	Thickness Feet
Onondaga formation	
6. Chert, siliceous; shale with fossils, 1 to 2 feet at bottom exposed	40
Oriskany sandstone	
5. Sandstone, coarse grained, yellow, with *Spirifer arenosus* (Conrad)	6
Becraft formation (82 feet)	
4. Not well exposed, probably same as bed 3	12

	Thickness Feet
3. Sandstone, thin bedded with thin layers of chert and shale; contains *Favosites helderbergiae* Hall, *Fenestrellina* (*Unitrypa*) sp., *Atrypa reticularis* (Linné), *Leptaena rhomboidalis* (Wilckens), *Meristella arcuata* (Hall), *Nucleospira elegans* Hall, *Spirifer concinnus* Hall, *S. cyclopterus* Hall, *Stenochisma formosa* (Hall), and *Stropheodonta planulata?* (Hall)	20
2. Sandstone, thick bedded, calcareous, friable, weathers to sand	50
New Scotland limestone (?)	
1. Limestone, highly fossiliferous; contains *Delthyris perlamellosus* (Hall) and *Meristella;* exposed	133

This section with its Helderberg fossils near the top shows conclusively that the main mass of sandstone, corresponding to the manganese-bearing sandstone on Flat Top Mountain in character and thickness, is below Oriskany with its main guide fossil, *Spirifer arenosus,* and above limestone containing *Delthyris perlamellosus,* that is reasonably referred to the New Scotland.

In the gorge of Laurel Creek through Buckhorn Mountain, northwest of Rocky Gap village, in a road cut on U. S. Route 21, the Becraft sandstone is fairly well exposed as shown in the section that follows:

Geologic Section 74.—Becraft formation on U. S. Route 21, about three-fourths of a mile northwest of Rocky Gap village, Bland County, Virginia

	Thickness Ft.	In.
Millboro shale		
Black shale, several hundred feet thick		
Onondaga formation		
7. Chert	50	
Becraft formation (110+ feet)		
6. Glauconitic layer		6
5. Clayey rock, thin bedded to laminated with thin layers of chert	20	
4. Not exposed	10	

	Thickness Feet
3. Sandstone, thick and thin bedded, partly conglomeratic, with cross-bedded layers	50
2. Not exposed	30
Clinton sandstone (?)	
1. Sandstone with *Tentaculites* sp.?	10

This section, as well as the section at Newcastle, shows clearly the absence of the Oriskany sandstone and the unconformable relations of the Becraft to the Onondaga limestone. The same condition prevails on Flat Top Mountain.

Distribution.—The Becraft is not present in the sections at Cumberland, Maryland, or Keyser, West Virginia, or in the northeastern part of Highland County, Virginia. It comes into the sequence somewhere between Highland County and the gorge of Jackson River in Bath County. It persists southwestward from this locality, changing to its sandstone facies, toward Flat Top Mountain, western Giles County, and then continues to Round Top, a few miles northeast of Burkes Garden where the Suiter manganese mine was operated during the World War. The presence of the manganese ore at this place indicates that the containing bed is probably the same as that at the Flat Top mine. The Helderberg is definitely absent at the northwest entrance to Burkes Garden where the Clinton is directly overlain by the Onondaga. The Becraft has not been recognized either southeast or southwest of Burkes Garden along the strike of that belt to the southern boundary of the State. The Becraft sandstone facies occurs in the vicinity of Bluefield, West Virginia. (See Pl. 43C.) It is thick bedded to massive in the lower part, more or less thin bedded to shaly in the upper part, and rather fossiliferous. (See geologic section 73.) The Becraft is a coarse-grained, light-gray limestone in Stone Mountain, 5 miles southwest of Richlands. Helderberg, probably Becraft, yielding silicified fossils, is present at the head of Weaver Creek on the southwest slope of Big A Mountain, 4 miles northwest of Honaker, Russell County. In Hunter Valley near Valaho, 30 miles southwest of Big A Mountain, the Helderberg is probably represented by a moderate thickness of rock, in part at least sandstone, presumably Becraft. Outside the belt just described, the Becraft is present as a very massive coarse-grained sandstone around the rim of the Short Hills, 5 miles northwest of Natural Bridge, Rockbridge County, and in the complex knobs and ridges along the southeast slope of East River and Peters mountains from Waiteville, West Virginia, west of Newcastle, to Wolf Creek, Bland County, and probably along Wolf Creek Mountain nearly as far southwest as Burkes Garden.

The best exposures of the Becraft known to the writer are in the Jackson River gorge, 1 mile west of Kincaid, Alleghany County; along Jackson River between Island Ford and Lowmoor; at the manganese mine on Flat Top Mountain in western Giles County; three-fourths of a mile northwest of Rocky Gap village (geologic section 74); a conspicuous exposure of the decayed sandstone as a large sand bank on U. S. Route 21, on the southeast slope of East River Mountain; and a complete exposure at the fair grounds and airport, 2 miles southwest of Bluefield, West Virginia. (See Pl. 43C.) Excellent exposures of the coarse-grained, gnarly sandstone characteristic of Becraft mark the rim of the Short Hills, 5 miles west of Natural Bridge, Rockbridge County, and the northwest slope of Johns Creek Mountain, 2 miles northwest of Simmonsville, Craig County.

Thickness.—At the Jackson River gorge, where the full thickness of the limestone facies of the Becraft is exposed, it is about 50 feet thick and at Island Ford 75 feet. Near Newcastle and at the manganese mine on Flat Top Mountain its exposed thickness is about 50 feet, but the formation is probably somewhat thicker. The only known exposure of the full thickness of the sandstone facies is at the entrance to the fair grounds at Bluefield, West Virginia, where its thickness is 82 feet.

Fossils and correlation.—The limestone facies of the Becraft is rather highly fossiliferous as shown at the exposure 1 mile south of Newcastle. (See list in geologic section 72.) Fossils are less plentiful in the sandstone facies, but a few species occur at one horizon at least at the manganese mine on Flat Top Mountain, Giles County, where *Stropheodonta planulata,* fairly abundant, *Rhipidomella oblata,* represented by a few specimens, and a *Spirifer,* probably *S. concinnus,* and a *Meristella,* probably *M. arcuata,* both represented by a few fragments in the collection, occur. It is a distinctly Helderbergian assemblage. So also is the assemblage occurring in the upper part of the sandstone at the entrance to the fair grounds at Bluefield, West Virginia. (See geologic section 73.) A notable occurrence of bryozoa largely fenestrellinids, in a yellow iron-stained sandstone of the Becraft, may be seen in a road cut on the northwest slope of Peters Hill, 3 miles west of Newcastle. The rock is crowded with these bryozoan remains. The most diagnostic fossil, however, bearing on the age of the Becraft is a species of *Aspidocrinus,* named by Swartz[172] *Aspidocrinus caroli. Aspidocrinus*

[172] Swartz, F. M., op. cit., p. 52.

scutelliformis is the most abundant and characteristic fossil of the Becraft limestone of New York. (See Fossil Plates, Pt. II.) As this fossil has nowhere been found in beds known on other evidence to be older or younger than Becraft, it is reasonably assumed that it lived in Becraft time in Virginia and hence that the strata in which its fossil remains occur are of the same age as the Becraft limestone of New York. An *Aspidocrinus,* which is probably *A. scutelliformis,* is abundant in a limestone at Stone Mountain in the northwestern corner of Russell County, 5 miles southwest of Richlands. *Aspidocrinus caroli* is fairly abundant in the top of the manganese-bearing sandstone along the surface of Flat Top Mountain in western Giles County and also in sandstone of the same type at the southeast base of Wolf Creek Mountain at the entrance of the gap made by Wolf Creek 1½ miles south of Rocky Gap village. A single specimen of *A. scutelliformis* has been found at Big Stone Gap in the higher beds of the Helderberg. A list of Becraft fossils follows:

Fossils from the Becraft formation

Crinoids
- Aspidocrinus caroli F. M. Swartz
- Aspidocrinus scutelliformis Hall

Bryozoa
- Unidentified fenestrellinids

Brachiopods
- Atrypa reticularis (Linné)
- Eatonia peculiaris (Conrad)
- Meristella arcuata (Hall)
- Nucleospira elegans Hall
- Rensselaeria subglobosa Weller
- Rhipidomella oblata (Hall)
- Schellwienella woolworthana (Hall)
- Spirifer concinnus Hall
- Stenochisma formosa Hall
- Stropheodonta planulata (Hall)
- Uncinulus abruptus (Hall)

This list, though small, is sufficient to prove the Helderberg age of the beds. This is of some interest from a stratigraphic standpoint for the reason that the manganese-bearing sandstone of the New River area has generally been identified as Oriskany.

HELDERBERG UNDIVIDED

In the Big Stone Gap area in Wise and Lee counties, Helderberg rocks are distributed in discontinuous patches over a considerable area. Both New Scotland and Becraft are present, but, as no satisfactory separation has been made, these rocks are here treated together. The Helderberg in this area is the upper part of the Hancock limestone.[173]

Character.—The Helderberg of the Big Stone Gap area consists of interbedded limestone and sandstone and is highly fossiliferous at some horizons. Its character is perhaps best shown in several sections published by Stose[174] and Kindle.[175]

Geologic Section 75.—At the cave entrance, 1½ miles northwest of Big Stone Gap, Virginia (After Kindle, op. cit., p. 51)

	Thickness Feet
Genesee (Millboro?) shale (?)	
4. Fissile black shale	35
Onondaga limestone	
3. Gray crystalline limestone with chert; abundant corals	5
Helderberg limestone (110 feet)	
2. Gray subcrystalline limestone with much sandy and argillaceous matter in the upper part; many of the higher beds weather to a buff fine-grained sandstone; fossils abundant	60
1. Hard, dark-colored, coarse-grained limestone with very few fossils	50

Geologic Section 76.—At the old woolen mill on the southeast side of Big Stone Gap, Virginia (After Kindle, op. cit., p. 51)

	Thickness Feet
Genesee (Millboro?) shale (?)	
3. Fissile, black shale	20
Onondaga limestone	
2. Gray coralline limestone and interbedded black chert	8

---

173 Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Morristown folio (No. 27), p. 3, 1896.

174 Stose, G. W., *in* Eby, J. B., The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, pp. 40-43, 1923.

175 Kindle, E. M., The Onondaga fauna of the Allegheny region: U. S. Geol. Survey Bull. 508, p. 51, 1912.

	Thickness Feet
Helderberg limestone	
1. Buff or brownish, somewhat calcareous sandstone	20+

Geologic Section 77.—On the Turkey Cove road near the Wise-Lee county line, Virginia (After Stose, op. cit., p. 41)

	Thickness Feet
Genesee (Millboro?) shale (?)	
9. Shale, black, with *Schizobolus*	
Helderberg formation (38 feet)	
8. Sandstone, crumbly, full of corals	3
7. Sandstone cross bedded, calcareous, fossiliferous	1
6. Limestone, impure	4
5. Limestone, chert banded	3
4. Sandstone, soft, shaly, calcareous, contains chert	4
3. Sandstone with round glistening quartz grains	5
2. Limestone, fossiliferous, sandy	13
1. Sandstone, laminated	5

Geologic Section 78.—Lower part of Helderberg formation at roadside quarry, 1 mile northeast of East Stone Gap, Virginia (After Stose, op. cit., p. 41)

	Thickness Feet
Helderberg formation (78 feet)	
9. Sandstone, porous, fossiliferous, banded	10
8. Chert, white and black, bedded	12
7. Sandstone, coarse grained, porous, fossiliferous	10
6. Chert, white fossiliferous	5
5. Sandstone, coarse grained	3
4. Limestone, siliceous with black and white chert nodules and some sandstone	10
3. Sandstone, granular with rounded glistening quartz grains	3
2. Sandstone, porous, laminated with some thin blue limestone	15
1. Sandstone, buff, calcareous, porous, containing numerous molds of shells	10

Geologic Section 79.—Along the old railroad line to the railroad station of Big Stone Gap, Virginia (By Ulrich; cited by Stose, op. cit., p. 40)

	Thickness Feet
Genesee (Millboro?) shale (?)	
Shale, black	
Onondaga formation (?)	
10. Sandstone, rather coarse grained, calcareous, and having a considerable brachiopod fauna with a few pelecypods and gastropods and no corals..	5
Helderberg formation (128 feet)	
9. Limestone, readily decomposed, fine grained, sandy, bluish or greenish. Upper 7 feet contains sandy chert full of corals and some brachiopods and gastropods. Lower half more sandy	45
8. Chert, containing abundant corals	1
7. Sandstone, brownish, coarse grained, in thin and thick beds, some containing numerous brachiopods and corals	12
6. Limestone, laminated, sandy, weathering to shaly particles; some free silicified fossils	35
5. Sandstone, coarse grained, or fine conglomerate..	3
4. Sandstone, soft, calcareous; argillaceous sandstone, and sandy limestone; some free silicified fossils	13
3. Sandstone, hard, calcareous, with molds of bryozoa	2
2. Limestone, shaly, full of fossils of New Scotland age	10
1. Limestone, massive, crystalline, blue with thin irregular, hard sandstone at base filling shallow depressions in underlying Cayuga limestone	7

A certain discrepancy will be noted between the sections measured by Kindle and by Ulrich. According to Kindle the Genesee (?) shale is underlain by cherty limestone full of corals, whereas in the section given by Ulrich the Genesee (?) is underlain by coarse-grained sandstone without corals. The discrepancy is partly explained by Ulrich who says that the uppermost 5 feet of sandstone, bed 10 of this section, is not present at the place where Kindle obtained his section, where the black shale immediately overlies the coral bed. Probably the coral bed of Kindle's section is the same as the 7-foot coral bed at the top of bed 9 of Ulrich's section.

In the writer's opinion the sandstone, bed 10, and the coral bed are not Helderberg but Onondaga so that the thickness of Helderberg is 121 feet. In general these observers all agree that the Helderberg of the Big Stone Gap area is composed of alternating beds of sandstone and limestone which have a maximum thickness of not more than 133 feet. Several of the beds contain many species of corals and brachiopods and a few pelecypods and gastropods.

Distribution.—The undivided Helderberg is a coarse-grained, friable, fossiliferous sandstone near Pattonsville, Scott County. From this place its outcrop extends northward as a narrow band around the north end of Powell Mountain to the Wallen Valley fault by which it is cut off. This sandstone is exposed on the low ridge just southeast of Pattonsville and at the sharp angle in U. S. Route 58, 1½ miles north of Pattonsville. At this place it is full of large brachiopod shells. Southwest from Big Stone Gap the Helderberg thins and apparently disappears a few miles north of Olinger, Lee County, or has become so thin as not to be detected. Southeast of Wallen Ridge and Powell Mountain, however, it extends southwest into Tennessee, perhaps from the Pattonsville area, for *Aspidocrinus*, probably *A. scutelliformis*, and *Nucleospira elegans* have been found 5 miles northwest of Maynardville.

Thickness.—The thickness of the Helderberg in the vicinity of Big Stone Gap ranges from 38 feet near the Lee County line to perhaps 121 feet at Big Stone Gap. Southwest of the county line, it is supposed to thin out in a few miles.

Fossils and correlation.—The writer obtained a small collection of fossils from Ulrich's beds 6 and 7, and probably from the lower part of bed 9 in the railroad section. These fossils are listed below:

Fossils from the Helderberg limestone as exposed along the old railroad just northeast of Big Stone Gap, Virginia

Corals
- Favosites helderbergiae Hall
- Zaphrentis roemeri Edwards and Haime

Crinoids
  Aspidocrinus scutelliformis Hall[a]

Brachiopods
  Anoplotheca cf. A. fimbriata (Hall)
  Delthyris perlamellosus? (Hall)
  Eatonia medialis (Vanuxem)
  Leptaena rhomboidalis (Wilckens)
  Meristella arcuata? (Hall)
  Nucleospira elegans Hall
  Rensselaeria subglobosa avus Schuchert
  Rhipidomella assimilis (Hall)
  Schellwienella woolworthana (Hall)
  Spirifer concinnus Hall
  Spirifer cyclopterus Hall
  Uncinulus abruptus (Hall)
  Uncinulus cf. U. globulus Schuchert.

This assemblage of fossils is distinctly Helderberg, and, as shown conclusively by *Aspidocrinus scutelliformis,* of Becraft age. All of the brachiopods are recorded from the Becraft elsewhere though not all are exclusively confined to the Becraft. The fossils therefore testify to the Becraft age of the greater part of the Helderberg of this region.

According to Ulrich, bed 2 of his section contains fossils of New Scotland age; thus if bed 1 is also Helderberg, at least 17 feet of New Scotland is present in the Big Stone Gap section. Ulrich gives no list of the New Scotland fossils, and so far as known to the writer, no collections have been made from these lower beds.

HIATUS?

In the most complete sequence in Virginia of this portion of the stratigraphic column the Becraft is succeeded by the Oriskany sandstone, which corresponds exactly with the Ridgely sandstone of the Maryland Geological Survey.[176] In Virginia the Shriver chert, the lower member of the Oriskany in Maryland and Pennsylvania, is absent. Swartz[177] has suggested that the Becraft and Shriver are at least partly equivalent, in which case the extent of this hiatus is curtailed. At present the writer is disposed to regard the Becraft and Shriver as distinct.

---

[a] Pronounced by Edwin Kirk to be identical with *A. scutelliformis* of the Becraft limestone of New York.

[176] Rowe, R. B., Schuchert, Charles, and Swartz, C. K., *in* Maryland Geological Survey, Lower Devonian, pp. 91-94, 1913.

[177] Swartz, F. M., op. cit., pp. 47-48.

ORISKANY SANDSTONE

Name.—The Oriskany sandstone was named[178] from Oriskany Falls, Oneida County, New York. It is one of the best known Devonian formations of the eastern United States.

Limits.—In Virginia the Oriskany rests upon strata ranging in age from Keefer sandstone (Clinton) to the Becraft limestone at the top of the Helderberg. It is everywhere succeeded by beds of Onondaga age.

Character.—The Oriskany is generally a coarse-grained, friable, pure quartz sandstone, but locally it is a moderately coarse grit composed of loosely cemented, well-rounded to subangular quartz grains, 0.5 to 5 millimeters in diameter. The larger grains are scarce. The pure sandstone in some localities is free enough from iron oxide and other impurities to be a high-grade glass sand and it is quarried for such sand near Gore, Frederick County, Virginia, and at points in Maryland and Pennsylvania. On the road on the northwest slope of Morris Hill, 8 miles due north of Covington, Alleghany County, Virginia, the sandstone is divided into two nearly equal parts by a black shale containing *Anoplotheca flabellites* Conrad, a characteristic Oriskany fossil. No similar section has been seen elsewhere in Virginia. The section follows:

Geologic Section 80.—Oriskany sandstone 8 miles north of Covington, Virginia

	Thickness Feet
Onondaga formation	
5. Shale, black	
Oriskany sandstone (38 feet)	
4. Sandstone	15
3. Shale, black, with *Anoplotheca flabellites* (Conrad) and *Orbiculoidea* common	3
2. Sandstone, coarse grained, with *Spirifer arenosus* (Conrad)	20
Becraft limestone	
1. Limestone, coarse grained, crinoidal, blue	30

[178] Hall, James, Third annual report of the fourth geological district of the State of New York: New York Geol. Survey 3rd Ann. Rept., pp. 308-309, 1839.
Vanuxem, Lardner, Third annual report of the geological survey of the third district: New York Geol. Survey 3rd Ann. Rept., p. 273, 1839.

A few species of marine fossils are present in considerable abundance in the Oriskany throughout its extent.

Distribution.—The Oriskany is probably represented in Massanutten Mountain by a sandstone about 10 feet thick which is rarely exposed. It is best developed in the belts northwest of Little North Mountain, and to some unknown distance southwest of James and Jackson rivers. It is not present at Newcastle, Craig County, where the Onondaga is in contact with the Becraft. The only occurrence southwest of New River in this general region seen by the writer is at the fair grounds at Bluefield, West Virginia, where it is 6 feet thick and in contact with the Becraft sandstone, as shown in geologic section 73. The only observed occurrences farther southwest are along the crest and southeast flank of Walker Mountain where it is exposed on the road north from Bland to Wytheville by way of Crocketts Cove; on the summit of the mountain at the crossing of U. S. Route 21, northwest of Wytheville; on the road at the head of Bear Creek, 5 miles northeast of Marion; on Virginia Route 88, 5 miles north of Marion; and on the abandoned road through Shannon Gap, 5 miles northwest of Marion. In McCall Gap through Walker Mountain on the road from Glade Springs to Saltville, the Oriskany is probably represented by coarse-grained brown sandstone 6 inches thick, containing a large *Spirifer* that is probably *Spirifer arenosus*. It is not known southwest of McCall Gap. It is supposed to be nearly continuous between the extreme points described above. Along this entire outcrop it is commonly a coarse-grained iron-stained grit with *Spirifer arenosus*. Apparently it is not more than 5 feet thick. At the extreme southwest it rests directly on the Keefer sandstone or, as north and northwest of Marion, on the thin and undifferentiated Clinton, or as in McCall Gap, on the Clinch sandstone. (See Pl. 39B.)

The Oriskany is most conveniently seen along U. S. Route 250 on the southeast slope of Bull Pasture Mountain, and on U. S. Route 220 between Monterey and Straight Creek, both in Highland County; on U. S. Route 220, between Monterey and Warm Springs; on U. S. Route 50, about half a mile west of Hayfield, Frederick County; and along the road between Gore and Rock Enon Springs, where the sandstone is conspicuously exposed in a vertical ledge. Striking exhibits of the sandstone may be seen just north of Virginia Route 261, about 2 miles northwest of Columbia Furnace, Shenandoah County; on the northwest face of Three Mile Mountain, where it makes a conspicuous ledge, visible from the road to Liberty Furnace; and in Brocks Gap, 1 mile west of Cootes Store, where a hard bed stands as a great vertical wall 75 to 100 feet high. (See Pl. 42B.) Still another exposure easily seen is at the old limestone mine at Lowmoor, Alleghany County. (See Pl. 43B.)

Thickness.—The Oriskany is apparently only 5 to 10 feet thick along its outcrop on the southeast slope of Walker Mountain in Wythe and Smyth counties. It seems to be about 20 feet at Lowmoor and along Jackson and James rivers. It is at least 100 feet thick generally in Highland County and on the slopes of Great North Mountain. It is probably more than 50 feet thick along Little North Mountain, as at Brocks Gap, Rockingham County. It does not appear to be more than 10 to 15 feet thick in the vicinity of Craigsville and Bells Valley, Augusta County.

Fossils and correlation.—The Oriskany in Virginia is rather highly fossiliferous, but the number of species that have been identified is small. They consist of *Edriocrinus sacculus* Hall, *Anoplotheca flabellites* (Conrad), *Meristella lata* (Hall), *Spirifer arenosus* (Conrad), *S. murchisoni* Castelnau, *Rensselaeria ovoides* or *R. marylandica* Hall, and *Rhipidomella musculosa* (Hall), which are the principal guide fossils. Only *Hipparionyx proximus* Vanuxem is wanting to complete the list of guide fossils and it is even possible that one specimen identified as *Rhipidomella musculosa* is really *Hipparionyx proximus*. Many more fossils doubtless occur and could be found by adequate search. Those listed are sufficient to correlate the formation in Virginia with that in Maryland, Pennsylvania, and the type area of New York. The fossils also show the approximate equivalence of the eastern Oriskany with the Little Saline limestone of Missouri and with the Frog Mountain sandstone and Jemison chert of Alabama.

HIATUS

In northeastern New York the Esopus shale, 80 to 100 feet thick, overlies the Oriskany sandstone, and a few feet of Schoharie grit overlies the Esopus and underlies the Onondaga limestone. Neither the Esopus nor the Schoharie occurs in Virginia, and the Onondaga immediately succeeds the Oriskany so that in the most complete sequence a slight hiatus occurs between the Oriskany and Onondaga. The hiatus reaches great magnitude at different places in the State.

ONONDAGA FORMATION

Name.—The Onondaga limestone was named[179] for Onondaga County, New York. This name takes the place of the name Cor-

[179] Hall, James, op. cit., pp. 293-309.

niferous limestone of the early New York geologists, which, until 1900, was widely applied throughout the eastern United States.

Limits.—At different localities in Virginia, the Onondaga is underlain by one or another of the following formations, namely, the Oriskany sandstone, the Becraft limestone, Cayuga beds of Wills Creek age, the Keefer sandstone, the undivided Clinton, the Clinch sandstone, the Juniata formation, and, as along a low ridge between Walker Mountain and Marion, Smyth County, by the *Orthorhynchula* zone of the Martinsburg shale. (See geologic section 83.) The sea thus spread widely over a large area of lowland in this part of the Valley which subsided in Onondaga time.

Character.—Like several other stratigraphic units already described the Onondaga has distinct lithologic facies: shale in the northeastern end of the Valley; limestone and chert south of latitude 37° 30′, especially well developed on the southeastern slopes of Clinch, Wolf Creek, and Walker mountains, southwest of New River; and sandstone in the Big Stone Gap area in Wise County.

In the northeastern area, that is, in Massanutten Mountain and in the belts northwest of Little North Mountain and southwest to Jackson and James rivers, the Onondaga is included in the base of the Romney shale as mapped.[180] The Onondaga in all of these belts is a shale and may be called the Onondaga shale or the Onondaga shale member of the Romney shale. It is almost everywhere dark green, but not black, and is easily distinguishable from the overlying black, fissile shale of Marcellus age. It was observed to be partly black in only three places: On U. S. Route 250 on the southeast slope of Bull Pasture Mountain, Highland County; on the northwest slope of Morris Hill, 10 miles north of Covington, Alleghany County; and on U. S. Route 50 at the southeast end of the gorge of Mill Creek through Mill Creek Mountain, 2½ miles southwest of Romney, W. Va. Much of the greenish shale weathers to a non-fissile, chalky, yellowish rock. It everywhere contains such characteristic Onondaga fossils as *Anoplotheca acutiplicata* (Conrad), *Bollia ungula* Jones, *Amphissites? favulosa* (Jones) and *Octonaria stigmata* Ulrich. In places this yellow rock occurs in association with the chert facies, as at the dam of the Roanoke Water Works on Carvins Creek, 1 mile north of Hollins College. A good section of the shale facies is exposed on Virginia Route 501, at the southeast entrance to Panther Gap, 2 miles northwest of Goshen, Rockbridge County. (See Pl. 43A.)

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

Geologic Section 81.—Onondaga formation northwest of Goshen, Virginia

	Thickness Ft.	In.
Marcellus shale		
7. Shale, black fissile		
Onondaga formation (122 feet)		
6. Shale, olive-green, non-fissile, but silvery and weathering yellowish; contains *Anoplia nucleata* (Hall), *Anoplotheca acutiplicata* (Conrad), *Styliolina fissurella* (Hall), *Phacops rana* (Green)?, *Bollia ungula* Jones, *Amphissites? favulosa* (Jones), *Octonaria stigmata* Ulrich, and *Primitia* sp.?	120	
5. Flint, black		2
4. Shale, sandy		10
3. Chert		1
2. Sandstone, with chert nodules		10
Oriskany sandstone		
1. Sandstone, coarse grained, thick bedded; contains *Spirifer arenosus* (Conrad), *S. murchisoni* Castelnau, and *Plethorhynchus* sp.	25	

The occurrence of chert at the base of the Onondaga in this section is noteworthy. It seems to mark the northeastern limit of the chert facies.

Southwestward from the meridian of Panther Gap to the meridian of 80° 30′, the formation is like the section at Panther Gap, but the thickness of the basal chert progressively increases. At the dam of the Roanoke Water Works on Carvins Creek and on State Route 311, on the southeast slope of Catawba Mountain, one-fourth of a mile northwest of Catawba Sanatorium railroad station, the chert is about 10 feet thick. A small thickness of chert appears in the vicinity of Lowmoor, Alleghany County. At and west of the meridian of 80° 30′ nearly the full thickness of the Onondaga, about 50-100 feet, has become chert and has been mapped as a separate formation. (See geologic section 82.) Although the Onondaga is nearly all chert on the immediate outcrop in this region, occasional exposures of the more deeply buried parts of the formation show it to be composed of limestone. Much of the chert is exceedingly massive, gnarly, and dense. This type prevails at the top and is exposed beneath black shale at many places on the roads crossing Walker and Clinch mountains. The Onondaga in this facies is fully exposed in McCall Gap, through Walker Mountain, along State Route 81, midway between Glade Springs and Saltville. (See Pl. 39B.) A section at this place follows:

Geologic Section 82.—Onondaga formation in McCall Gap, Washington County, Virginia

	Thickness Ft.	In.
Black shale		
Onondaga formation (54+ feet)		
5. Chert, massive, gnarly	10+	
4. Chert, thin bedded	40	
3. Limestone, argillaceous, sandy, thin bedded; leached to a coarse-grained, dark-gray rock, or thin layers of coarse-grained sandstone and chert; fossiliferous; containing *Amphigenia elongata* (Vanuxem), *Chonostrophia reversa* (Whitfield), *Chonetes acutiradiatus* Hall?, *Meristella nasuta* (Conrad), *Pholidops areolata* Hall, *Reticularia fimbriata* (Hall), *Schuchertella pandora* (Billings), *Spirifer duodenarius* (Hall), *S. raricostus* Hall?, *Platyostoma lineatum* Conrad, and *Bollia ungula* Jones	4	
Oriskany (?) sandstone		
2. Sandstone, coarse grained, brown, with a large *Spirifer*, possibly *S. arenosus* (Conrad); if so, this bed is the Oriskany nearly thinned out		4
Hiatus; Clinton absent		
Clinch sandstone		
1. Sandstone, thin bedded, shale partings	17	

At Seven Springs, 1½ miles west of McCall Gap and on the same outcrop, the Onondaga is also composed of coarse-grained, gray rock, evidently a leached argillaceous limestone, of undetermined thickness. It rests here on the Juniata formation, the Clinch sandstone having thinned out in the intervening distance. In addition to most of the fossils listed from McCall Gap, the following occur here: *Anoplotheca acutiplicata* (Conrad), *Centronella glansfagea* Hall?, *Leptaena rhomboidalis*

(Wilckens), *Spirifer macrus* Hall, *S. divaricatus* Hall, *Stropheodonta perplana* (Conrad), *Amphissites? favulosa* Jones, *Bollia ungula* Jones and *Octonaria stigmata* Ulrich. Nearly all of these fossils occur together on the same slab of rock.

In the narrow belt, 2 to 3 miles north and northwest of Marion, the Onondaga is in contact throughout a distance of 8 to 10 miles with the *Orthorhynchula* zone of the Martinsburg—the Juniata, Clinch, and Clinton having pinched out between this belt and Walker Mountain, 1 to 3 miles to the northwest. An exposed section along the bed of Walker Creek, 5 miles slightly northwest of Marion, follows:

Geologic Section 83.—Onondaga formation about 5 miles northwest of Marion, Smyth County, Virginia

	Thickness Ft.	In.
Not exposed, probably black shale of Marcellus age, generally in this belt	50±	
Onondaga formation (59 feet)		
9. Chert	33	
8. Rock, sandy green, glauconitic, phosphatic?	2	6
7. Limestone, argillaceous, siliceous, cherty, sandy; decalcified to a purplish, coarse-grained, porous rock; fossiliferous, containing *Ambocoelia umbonata* Conrad, *Anoplotheca acutiplicata* (Conrad), *Centronella* sp.?, *Meristella nasuta* (Conrad), *Nucleospira concinna* Hall, *Reticularia fimbriata* (Hall), *Schuchertella pandora* (Billings), *Spirifer divaricatus* Hall, *Stropheodonta perplana* (Conrad), and *Platyostoma lineatum Conrad*	4	
6. Not exposed; debris of thin sandstone	8	6
5. Sandstone, shaly, fine grained, greenish gray	11	
Hiatus; Clinch, Clinton, and Lower Devonian absent		
Martinsburg shale (upper part, 93 feet)		
4. Shale, red		2
3. Shale, green		6
2. Shale, red		2
1. Alternating beds of sandstone and thin beds of shale, some red layers with *Orthorhynchula linneyi* (James) at 72 feet above base	92±	

It might be thought that the scattered layers of red shale indicate Juniata, but as red beds at 35 feet below bed 5 are crowded with marine fossils, and as the typical Juniata is everywhere without marine fossils, it is improbable that it occurs in this locality. Likewise the sandstone, bed 5, could be regarded as Clinch, but as the Clinch is definitely absent in other sections on this belt, such an identification would be at least very doubtful.

On the southeast slope of Clinch Mountain, southwest of Burkes Garden, the Onondaga has the same character as it has on Walker Mountain. A good section is exposed on Tumbling Run, 4 miles west of Saltville.

Geologic Section 84.—Onondaga formation 4 miles west of Saltville, Smyth County, Virginia

	Thickness Feet
Millboro shale; Marcellus horizon	
4. Shale, black, fissile, with conodonts	
Onondaga formation (100± feet)	
3. Limestone, medium thick bedded, cherty; contains *Heliophyllum halli* Edwards and Haime, *Anoplotheca acutiplicata* (Conrad), *Anoplia nucleata* (Hall), and *Spirifer duodenarius* (Hall)	100±
Oriskany sandstone (?)	
2. Float of sandstone, green, glauconitic with *Spirifer arenosus* (Conrad)?	(?)
Cayuga group (?)	
1. Limestone, thin bedded, with ostracodes	100±

This section is of especial interest as it shows the Onondaga in its essential nature as a limestone. The swift flowing stream has kept it swept clean and retarded silicification to chert.

Still farther southwest, just northwest of the Poor Valley road, State Route 42, and about half a mile northeast of its intersection with U. S. Route 19, 1 mile north of Holston, Washington County, the greater part of the Onondaga is composed of limestone. The section follows:

Geologic Section 85.—Onondaga formation one mile north of Holston, Washington County, Virginia

	Thickness Feet
Marcellus shale	
7. Shale, black; contains *Schizobolus concentricus* (Vanuxem) and *Leiorhynchus limitare* (Vanuxem)	75
Onondaga formation (60-75? feet)	
6. Sandstone, probably a decalcified sandy limestone; contains *Cystodictya ovatipora* (Hall), *Fenestrellina variopora* (Hall), *Amphigenia curta* (Meek and Worthen), *Anoplotheca acutiplicata* (Conrad), *Anoplia nucleata* (Hall), *Eodevonaria* (*Chonetes*) *arcuata* (Hall), *C. mucronatus* Hall, *Meristella nasuta* (Conrad), *Pentagonia unisulcata* (Conrad), *Reticularia fimbriata* (Hall), *Schuchertella pandora* (Billings), *Spirifer duodenarius* (Hall), *Stropheodonta patersoni* (Hall), *S. perplana* (Conrad), *Cypricardinia indenta* (Conrad), *Bollia ungula* Jones, *Amphissites? favulosa* Jones, *Ctenobolbina* sp.?, *Hollina cavimarginata* (Ulrich), and *Thlipsura* sp.?	5
5. Chert, solid bed	10
4. Not exposed	25±
3. Limestone, cherty; contains *Favosites*, ramose form cf. *F. limitaris* Rominger, *F. proximus* Davis, *Anoplotheca acutiplicata* (Conrad), *Eodevonaria* (*Chonetes*) *arcuata* (Hall), *C. mucronatus* Hall, *Leptaena rhomboidalis* (Wilckens), *Spirifer duodenarius* (Hall), *S. divaricatus* Hall, *Stropheodonta perplana* (Conrad), *Platyostoma lineatum* Conrad, *Bollia ungula* Jones, and *Amphissites? favulosa* Jones	20
2. Not exposed	15
Clinton (Keefer) sandstone	
1. Sandstone; exposed	5±

In the section of the Helderberg at Big Stone Gap (geologic section 79), bed 10 at the top is a pure quartz sandstone, 5 feet thick, with grains ranging from 0.1 to 1 millimeter in diameter cemented with a white substance that looks like a clay derived from feldspar. This bed is said to underlie black shale with *Schizobolus concentricus* which has been regarded as of Genesee age, but which may with greater reason be regarded as of Marcellus age, representing the lower division of the Millboro black shale. (See geologic section 79.) Bed 10, here provisionally identified as Onondaga, contains a mixed assemblage of fossils, most of which are provisionally identified by Ulrich, as follows: *Amphigenia curta* (Meek and Worthen), compared by Ulrich with *A. elongata* (Vanuxem); *Atrypa reticularis* (Linné); *Camarotoechia* cf. *C. transversa* (Hall) or *C. altiplicata* (Hall); *Eatonia medialis* (Vanuxem)?; *Leptaena rhomboidalis* (Wilckens); *Meristella* cf. *M. nasuta* (Conrad) and *M. arcuata* (Hall); *M.* cf. *M. laevis* (Vanuxem) and *M. lata* (Hall); *M.* ? cf. *M. vascularia* Clarke; *Nucleospira* aff. *N. concinna* Hall; *Pentagonia* cf. *P. unisulcata* (Conrad); *Pentamerella?* aff. *P. arata* (Conrad); *Rhipidomella oblata* (Hall)?; *Schellwienella woolworthana* (Hall) or *S. pandora* (Billings); *Spirifer concinnus* Hall; *S. cyclopterus* Hall; *S.* cf. *S. divaricatus* Hall; *S. macropleurus* Hall?; *Delthyris raricosta* Hall; *Strophonella cavumbona* (Hall); *Uncinulus mutabilis* Hall?; *Wilsonia* aff. *W. ventricosa* Hall; *Megambonia* sp.?; *Platyceras tenuiliratum* Hall; *Igoceras pyramidatum* (Hall); *Dalmanites pleuroptyx* (Green); and *Bollia irregularis* Ulrich and Bassler.

Of these forms the *Eatonia, Uncinulus, Wilsonia, Spirifer concinnus, S. cyclopterus* and *S. macropleurus* are distinctly Helderbergian fossils; the *Amphigenia, Spirifer divaricatus, Delthyris raricosta, Pentagonia unisulcata, Nucleospira concinna* are distinctly Onondaga species. On the general principle that the youngest element in a fauna is of the greater weight as evidence of the age of the bed, bed 10 of this section is Onondaga. The Helderberg element can be explained as a survival. Another interpretation is possible. The species may have been derived through erosion from low bars, or from land slightly above sea level and underlain by sediments of Helderberg age, and redeposited with the shells of the Onondaga species living at the time in the surrounding lagoons. Such an occurrence may be seen at the present time along the shores of Chesapeake Bay where Miocene shells are being washed out of the bluffs and mingled with the shells of the living animals.

In the section at the woolen mill at Big Stone Gap (geologic section 76), the Onondaga sandstone bed just described is absent. Beneath the black shale is a bed of highly coralline and cherty limestone 8 feet thick. Kindle[181] reports the following corals from this bed: *Zaphrentis cornicula* (Lesueur), *Z.* cf. *Z. prolifica* Billings, *Cystiphyllum americanum* Edwards and Haime, *C. sulcatum* Billings, *Blothrophyllum decorticatum* Billings, *B. americanum, Heliophyllum*

[181] Kindle, E. M., op. cit., p. 52.

halli Edwards and Haime, *H.* cf. *H. annulatum* Hall, *Diphyphyllum* cf. *D. gigas* Rominger, *Cladopora* cf. *C. expiata* Rominger, *C.* cf. *C. bifurca* Grabau, *C.* cf. *C. crassa* Davis, *Syringopora hisingeri* Billings, *Favosites emmonsi* Rominger, *F. hemisphericus* (Troost), *F. epidermatus* Rominger, *F. canadensis* Billings, *Dendropora* cf. *D. neglecta* Rominger, *Vermipora* cf. *V. fasciculata* Rominger, and *Aulopora* sp.

This is a distinctly Onondaga coral assemblage that could as well be collected from the Falls of the Ohio at Louisville, Kentucky. There seems no ground for reasonable doubt that the bed containing it is of Onondaga age. It probably corresponds to the sandy chert full of corals, the upper 7 feet of bed 9, geologic section 79.

As reported by Kindle[182] the Onondaga extends southwest along the southeast base of Clinch Mountain as far as Mendota at least, where it is represented "by about a foot of limestone weathering to a soft, fine-textured, shaly rock of light blue color." It is highly fossiliferous. Kindle lists 23 species, including such diagnostic Onondaga fossils as *Anoplia nucleata* (Hall), *Eodevonaria* (*Chonetes*) *arcuata* (Hall), *C. mucronatus* Hall, *Meristella nasuta* (Conrad), *Pholidops* cf. *P. areolata* Hall, *Schuchertella pandora* (Billings), *Spirifer varicosus* Hall, *Stropheodonta patersoni* Hall, *Cypricardinia indenta* (Conrad), *Acidaspis callicera* Hall and Clarke, *Phacops crista pipa* Hall, *Amphissites? favulosa* (Jones), and *Bollia obesa* Ulrich.

This limestone is underlain by gray or brownish sandstone and overlain by fissile black shale with *Schizobolus concentricus* (Vanuxem).

In the Massanutten syncline, in the northeastern part of the Valley, the Onondaga is a dark-colored shale or a chalky mudrock weathering to a light red or pink. On the southwest slope of the southeastern ridge of Massanutten Mountain, this reddish rock has yielded such Onondaga fossils as *Bollia ungula, Amphissites? favulosa,* and *Styliolina fissurella,* and also *Phacops rana* which is not confined to the Onondaga. In Harshberger Gap, about 3 miles north of McGaheysville, Rockingham County, the dark-colored shale, not far above the Bloomsburg formation (geologic section 66), carries *Anoplotheca acutiplicata, Anoplia nucleata, Chonetes mucronatus*?, abundant *Styliolina fissurella, Bollia ungula, Amphissites favulosa,* and *Odontocephalus aegeria* (Hall).

Distribution.—The Onondaga is persistent throughout the Valley. It is included in the basal part of the Romney shale as mapped in the northeastern half of the Valley and northwest of Little North Mountain. Southeast of Little North Mountain, except in Massanutten Mountain as noted above, the horizon of the Onondaga has been removed by erosion.

---

182 Kindle, E. M., op. cit., p. 49.

The Onondaga persists to Mendota, Washington County, but 10 miles farther southwest, half a mile northwest of Hilton, on the southeast slope of Clinch Mountain it is absent in a fully exposed section. Here black and gray shale containing *Schizobolus concentricus* at the base lies upon brown sandstone that probably is Clinton. The Onondaga is present at Big Stone Gap, Wise County, but it has not been detected in Lee County to the southwest of Big Stone Gap and its southwestern limit along that belt is unknown.

Among the best places to see the Onondaga are the localities of geologic sections 81-83; also on the road from Saumsville to Van Buren Furnace, Shenandoah County, at the northwest base of Little North Mountain, and about 2 miles northeast of Van Buren Furnace where the shale facies of the Onondaga is exposed directly above thick Oriskany sandstone. The cherty facies is to be seen on every road crossing Clinch and Walker mountains or their equivalents southwest of New River.

Thickness.—The thickness of the Onondaga generally ranges from 50 to 100 feet. At the northwest entrance to Burkes Garden, on Virginia Route 87, it seems to be about 10 feet thick. At the south end of Catawba-Paris Mountain near Fagg railroad station, 7 miles northeast of Christiansburg, it is 2-3 feet thick, and near Mendota, Washington County, as reported by Kindle, it is 1 foot thick, which is the least thickness observed.

Fossils and correlation.—As shown by the lists in the geologic sections the Onondaga contains many species of fossils, principally brachiopods, but also a few characteristic species of ostracodes. A combined list, including all of the most satisfactorily identified species, follows:

Fossils from the Onondaga formation

[a]Corals
- Dendropora cf. D. neglecta Rominger
- Favosites cf. F. limitaris Rominger
- Favosites cf. F. proximus Davis
- Heliophyllum halli Edwards and Haime

Bryozoa
- Cystodictya ovatipora (Hall)
- Fenestrellina variopora (Hall)

[a] For a list of the corals at Big Stone Gap, see p. 301.

Brachiopods
- Ambocoelia umbonata Conrad
- Ambocoelia, small gregarious sp.
- Amphigenia curta (Meek and Worthen)
- Anoplia nucleata (Hall)
- Anoplotheca acutiplicata (Conrad)
- Beachia suessana (Hall)?
- Centronella glansfagea Hall
- Chonetes acutiradiatus Hall?
- Chonetes buttsi Kindle
- Chonetes mucronatus Hall
- Chonostrophia reversa (Whitfield)
- Eatonia peculiaris (Conrad)
- Eodevonaria (Chonetes) arcuata (Hall)
- Leptaenisca australis Kindle
- Meristella nasuta (Conrad)
- Nucleospira concinna Hall
- Pentagonia unisulcata (Conrad)
- Pholidops areolata Hall
- Pholidostrophia pennsylvanica Kindle
- Reticularia fimbriata (Hall)
- Schuchertella pandora (Billings)
- Spirifer divaricatus Hall
- Spirifer duodenarius (Hall)
- Spirifer macrus Hall
- Spirifer raricostus Hall
- Spirifer varicosus Hall
- Stropheodonta patersoni (Hall)
- Stropheodonta perplana (Conrad)

Pelecypods
- Actinopteria sp.?
- Aviculopecten cf. A. pecteniformis (Conrad)
- Cypricardinia indenta (Conrad)
- Lyriopecten cf. L. parallelodontus Hall
- Panenka cf. P. dichotoma Hall

Gastropods
- Platyceras cf. P. dumosum Conrad
- Platyceras cf. P. fornicatum Hall
- Platyceras tortuosum Hall?
- Platyostoma lineatum Conrad
- Strophostylus

Pteropods
- Styliolina fissurella (Hall)

Cephalopods
Tornoceras buttsi A. K. Miller

Trilobites
Acidaspis callicera Hall and Clarke
Dalmanites aspectans Conrad?
Dalmanites eriana Hall
Odontocephalus aegeria Hall
Phacops rana (Green)

Ostracodes
Amphissites? (Bythocypris) favulosa (Jones)
Bollia obesa Ulrich
Bollia ungula Jones
Ctenobolbina sp.?
Hollina cavimarginata (Ulrich)
Octonaria stigmata Ulrich

The most common and best guide fossils of this list are *Anoplia nucleata, Anoplotheca acutiplicata, Amphissites? (Bythocypris) favulosa* and *Octonaria stigmata.*

These fossils are universally distributed throughout the Valley in Virginia, and one or more of them will be found in every exposure of the Onondaga. Less common, but not less diagnostic, are *Cystodictya ovatipora, Fenestrellina variopora, Amphigenia curta, Centronella glansfagea, Chonostrophia reversa, Eodevonaria (Chonetes) arcuata, Pentagonia unisulcata, Spirifer divaricatus, S. duodenarius, S. macrus, Acidaspis callicera, Odontocephalus aegeria,* and *Hollina cavimarginata.*

Nearly all of the above-named species occur in the Onondaga of New York, in the Jeffersonville limestone at the Falls of the Ohio River at Louisville, Kentucky, and in the Columbus limestone in central Ohio. Several of these species, as *Amphigenia curta, Anoplia nucleata, Centronella glansfagea, Eodevonaria (Chonetes) arcuata, Eatonia peculiaris, Spirifer duodenarius,* and others also occur in the Camden chert of middle Tennessee. Thus the Onondaga of Virginia is unmistakably a deposit in a widely expanded sea and contemporaneous with the Onondaga limestone of New York and the Camden chert of middle Tennessee, representing widely separated areas in the eastern United States.

ROMNEY SHALE (RESTRICTED)

Name.—The Romney shale was named by Darton[183] from the outcrops at Romney, West Virginia.

---

[183] Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, p. 17, 1892.

Limits.—According to the original definition or usage the Romney shale included all the strata, mainly dark-colored to black shale, between the Oriskany (Monterey) sandstone below and the greenish shale of the Jennings formation of Darton. The lower half of the Jennings has been recognized as a distinct formation by Butts and named the Brallier shale. There can be no doubt that Darton included in the Romney all the black shale within these limits. A relatively thin black shale at the top has since been removed from the Romney by Swartz and Stose[184] and included by them in the Jennings shale as the "Genesee" shale member. The typical Romney included in ascending order the Onondaga shale, the Marcellus shale, the Hamilton formation, and an upper black shale, the "Genesee" of Stose and Swartz. As the Onondaga has been removed from the Romney by the writer, and as the upper black shale has been removed by Stose and Swartz, the Romney was restricted to include only Marcellus and Hamilton formations as they occur in Frederick and Shenandoah counties, Virginia. (See Table 1.) In a recent detailed survey of Frederick County and vicinity, the Hamilton and Marcellus are treated as separate units and the name Romney will be abandoned.

Owing to the difficulty of separating the various constituents of the original Romney and of representing them as narrow strips on the geologic map of the Valley, with a scale of 4 miles to one inch, they were combined and mapped as the Romney. Outside of Frederick and Shenandoah counties, this treatment is misleading, for the Hamilton thins out and, except for exposures in the valley of Passage Creek in the Massanutten Mountain syncline, has not been definitely recognized southwest of Orkney Springs, Shenandoah County, although it may extend to the south end of Great North Mountain, north of Fulks Run, Rockingham County, and may occur locally in Washington County. (See geologic section 86.) The Romney has been shown on the map to include the areas of the partly equivalent shale of the Monterey and Staunton quadrangles; only, however, because the name was so applied by Darton in those quadrangles. In fact, the name has been used on the map to the parallel 37° 30′ but, because the Hamilton, which makes the larger part of the typical Romney, is absent south of the south end of Great North Mountain that usage is hardly warranted. Still farther southwest, as in the New River region and beyond nearly to Tennessee, the Onondaga has been mapped as a distinct unit, so that all that remains of the

[184] Stose, G. W., and Swartz, C. K., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (No. 179), p. 11, 1912.

original Romney in that part of the Valley is black shale of Marcellus and Portage ages.[185]

Character.—In view of the facts just stated, it is necessary to describe separately the rocks concerned, according to the areas where they occur. In Frederick and Shenandoah counties, the Romney, restricted, includes at the base much black and gray fissile shale, which rests normally upon the Onondaga shale. This shale is overlain by a commonly fossiliferous mass of rock, Hamilton, composed largely of compact, very fine-grained, olive-green, argillaceous sandstone with a characteristic hackly fracture. interbedded with layers of dark-colored, crumbly, non-fissile, clayey rock or shale. The upper 50 feet of the Hamilton in Frederick County is a persistent massively bedded greenish sandstone. The upper part of the Romney restricted is the dark-colored to black, sandy, fossiliferous Naples shale with *Paracardium* and *Probeloceras,* extending up to the light greenish shale of the succeeding Brallier. The Naples is absent in Frederick County and is known only southwest of Orkney Springs in Shenandoah County and farther southwest.

Divisions.—The lower shale corresponds to the Marcellus, the next unit to the Hamilton, and the upper shale ("Genesee" of Swartz and Stose) to some part of the basal Portage, or Naples beds, of the standard Devonian sequence of New York. The Tully limestone, and probably the typical Genesee shale, which lie between the Hamilton and Portage in New York, are absent in Virginia.

Distribution.—With the exception noted above, this sequence of the Romney, restricted, prevails in Frederick and Shenandoah counties and probably in the northern part of Rockingham County to the south end of the Great North Mountain anticline south of Fulks Run. The Hamilton is known to extend south to the vicinity of Orkney Springs, Shenandoah County, and, with the same lithologic characters and equally fossiliferous, it also underlies the broad valley of Passage Creek in the Massanutten Mountain syncline. (See Pl. 4A.)

The best exposures of the Marcellus shale are at Gainesboro, on the road half a mile northwest of Fawcetts Gap, where it overlies the Clinch-Tuscarora sandstone, and on State Route 55, where it is continuously exposed for a mile, beginning half a mile northwest of Cedar Creek. All these localities are in Frederick County. Excellent exposures occur 2 to 3 miles northeast of Van Buren Furnace; on State Route 261, about half a mile northwest of its

[185] This shale has also been called Romney in the Pocahontas and Tazewell folios, U. S. Geol. Survey folios nos. 26 (1896) and 44 (1897).

intersection with State Route 265, 1½ miles northeast of Liberty Furnace; at Alum Springs, 3 miles northeast of Orkney Springs on the road to Methias, West Virginia; and at Orkney Springs; all in Shenandoah County, Virginia.

The best exposures of the Hamilton are just west of Green Springs; on U. S. Route 50, immediately west of Chambersville; and along State Route 55, 1 mile northwest of Cedar Creek, all in Frederick County. In Shenandoah County, the Hamilton may be seen at the junction of State routes 261 and 265 about 1½ miles northeast of Liberty Furnace; along the road half a mile northwest; and half a mile southeast of Dietrich (Fort Cross Roads) in Massanutten Mountain. Beginning about one-fourth of a mile west of Chambersville, Frederick County, the vertical Hamilton is nearly all exposed for 1100 feet along U. S. Route 50.

The basal Portage, Naples beds ("Genesee"), has not been observed in Frederick County and is surely absent. However, dark-colored sandy shale of the Naples ("Genesee"), with an abundance of *Paracardium* and numbers of *Probeloceras* and other fossils, is exposed in Shenandoah County in an open field half a mile southwest of Orkney Springs and on Bennett Run, 2 miles above its mouth and 2½ miles northeast of Bergton.

Thickness.—Conditions of exposure and structure cause unavoidable uncertainty in the determinations of thickness of the Marcellus shale. It appears to be about 500 feet thick on U. S. Route 50 just west of Chambersville, 250 feet thick west of Fawcetts Gap, and possibly 500 feet on the road to Rockland, West Virginia, 1½ miles northeast of Liberty Furnace.

The Hamilton is about 1100 feet thick just west of Chambersville, perhaps as thick 1 mile northwest of Star Tannery, and 750 feet thick 1½ miles northeast of Liberty Furnace. The thickness of the Naples beds is still more uncertain, but is probably 100 to 200 feet. The uncertainty is partly due to the apparent transition of the dark-colored to black shale upward into the Brallier type of shale, as in the vicinity of Orkney Springs and near Bergton. At these places the full thickness of beds that at all resemble the Naples comprises only about 50 feet of dark-colored, stiff, sandy shale with *Paracardium doris* Hall abundant.

MILLBORO SHALE

Name.—The Millboro shale is here named from excellent exposures at Millboro Springs, Bath County, Virginia.

Definition.—The Millboro shale, as above-named and as here used by the writer, includes only the Marcellus and Naples (basal Portage) shales of the original Romney. The name is used for a mappable unit because the Marcellus and Naples constituents cannot be readily separated and mapped. The term is applicable only in areas where the Hamilton is absent, as southwest of Shenandoah County, Virginia.

Character.—The Millboro is almost wholly a black fissile shale in its unweathered condition, but it bleaches, on weathering, to a light-gray color. Locally, as on Draper Mountain, Pulaski County, and in Burkes Garden, Tazewell County, it is a pinkish, soft clay shale, or becomes such on weathering. The typical black shale is so fissile that it splits into very thin flakes. Some gray layers occur, but they comprise only a small proportion of the whole thickness of the formation. In a few places, as in the vicinity of Bath Alum Springs, or McClung, Bath County, large, symmetrical, lenticular concretions occur in the Millboro. Such concretions are rather characteristic of black shale. The characters described above are constant and invariable throughout the Valley in Virginia. A partly compiled section at Millboro Springs, Bath County, the type locality of the Millboro shale, follows: Beginning at Millboro Springs immediately below the Brallier shale and going west, black, fissile shale, dipping 40° E., is continuously exposed for 1000 feet to the end of the exposure. Going north from Millboro Springs, black shale with *Paleschara* (see Fossil Plates, Pt. II) crops out in the road just southeast of Pig Run. The exposure of black shale, crumpled, and having an average dip estimated at 20° SE., extends to the point where the road turns northeast parallel to Pig Run. The ridge to the northwest of the road contains Oriskany sandstone. As the Onondaga lies on top of the sandstone, the contact of the Millboro shale and the Onondaga must be near the road on the southeast side of the ridge. This would make the total distance across the outcrop about 2000 feet. In the 1000 feet continuously exposed west of Millboro Springs, the thickness of shale is about 700 feet. The west end of this exposure is about in strike with the exposure just southeast of Pig Run where *Paleschara* occurs, so that the two sections combine to form practically a continuous section. The thickness of the Millboro below the *Paleschara* zone, with an average dip of 20° SE., would be about 300 feet, thus making about 1000 feet of black shale exposed.

The occurrence of *Paleschara* in the exposure just southeast of Pig Run and of *Leiorhynchus limitare* (Vanuxem), *Ambocoelia* sp. and *Orthoceras* sp.? (see Fossil Plates in Part II) near the bottom of the black shale northwest of Pig Run, is sufficient evidence of the Marcellus age of that lower part of the Millboro. In the upper 100 feet of the Millboro shale in this section such Naples fossils as *Paracardium doris*, and *Buchiola retrostriata* (von Buch) are abundant and *Probeloceras lutheri* Clarke is common. This assemblage proves the Naples age of the upper part of the Millboro. *Paracardium* was noted lower in the section and specimens have been collected 500 feet below the top. If these specimens were not accidently introduced into the collections, about which the writer has doubts, the *Paracardium* zone, and therefore the Naples equivalent, is at least 500 feet thick. In the remaining 200 feet of shale down to the horizon of *Paleschara* no paleontological evidence as to age has been obtained. No evidence of Hamilton was noted in the section and therefore no exact boundary between the Marcellus and Portage (Naples) constituents here was determined.

Just northeast of the summit of Draper Mountain south of Pulaski, and on the north slope of Ramsay Mountain just southeast of Max Meadows, thin black shale occurs at the bottom of the Millboro, but the main mass is a soft, rather non-fissile, pinkish clay rock containing the Naples fauna; also there are small exposures of this type of rock with the Naples fauna on both the north and south sides of Burkes Garden, Tazewell County.

The Millboro assumes a somewhat different facies in the southwestern part of the Valley, as shown by the following section in Washington County:

Geologic Section 86.—On the road and in a ravine one-quarter to half a mile northeast of the village of Hayter Gap, Washington County, Virginia

	Thickness Feet
Brallier shale	
Millboro shale (359 feet)	
Naples horizon	
10. Shale, mainly black, fissile, no fossils found	100
9. Not exposed	88
8. Shale, soft, green, with layers of black shale	110
7. Shale, soft, green; contains *Styliolina fissurella* (Hall), *Pterochaenia fragilis* (Hall), *Buchiola retrostriata* (von Buch), and *Probeloceras lutheri* Clarke	30
6. Shale, black fissile, with *Schizobolus concentricus* (Vanuxem)	30

	Thickness Feet
5. Limestone, drab, argillaceous; contains *Craspedophyllum?* sp., *Heliophyllum halli* E. and H., *Eunella* sp., *Leiorhynchus* sp., *Palaeoneilo plana* Hall, *Phacops rana* (Green), and *Dalmanites* sp., specimens small and scarce; Hamilton (?)	1
Marcellus horizon (46 feet)	
4. Shale, black, fissile; contains *Paleschara* (rare), *Ambocoelia umbonata* (Conrad)?, *Chonetes mucronatus* Hall, *Leiorhynchus* cf. *L. mesacostale* Hall, *Buchiola halli* Clarke, *Actinopteria muricata* Hall (rare), *Paracyclas lirata* Conrad (fragment), *Pterinea* small sp., *Styliolina fissurella* (Hall), *Bactrites aciculatus* (Hall), and *Tornoceras?* sp.	5
3. Limestone with large nodules; contains *Ambocoelia umbonata* (Conrad)?, *Chonetes mucronatus* Hall, *Leiorhynchus mysia* Hall, *Buchiola halli* Clarke, and *Tornoceras uniangulare* (Conrad)?; all pyritized	1
2. Shale, black, fissile; *Schizobolus concentricus* (Vanuxem) abundant in top	40±
Onondaga formation	
1. Chert	50±

If bed 5 of this section is Hamilton, as surmised on scant evidence, it is possible to determine here the exact boundary of the Marcellus and Naples constituents of the Millboro. Elsewhere south of Shenandoah County no similar evidence has been obtained.

Distribution.—The Millboro shale is constant in its occurrence between the Onondaga and Brallier from Highland and Augusta counties southwest to Tennessee, and its distribution in the different synclinal troughs is fully shown on the geologic map of the Valley.[186]

Among the best exhibits of the Millboro shale are those at the type locality near Millboro Springs; along U. S. Route 250, beginning about half a mile west of McDowell, Highland County, and extending west about one mile across a shallow syncline; on State Route 501, across the valley of Jackson River, 3 miles northwest of Warm Springs, Bath County; along U. S. Route 11, between Christiansburg and Radford, where it is almost continuously

[186] Butts, Charles, Virginia Geol. Survey Bull. 42, 1933. In the northern counties where the Onondaga is present the Millboro is designated on the map by the symbol Dr: in the southwestern counties where the Onondaga is shown separately it is designated by the symbol Dbs.

exposed for 2½ miles and thence southwest along the old road nearly to Ingles Ferry, Pulaski County; and on U. S. Route 21, between Hicksville and Bastian, Bland County. The typical black Millboro shale is exposed along Cove Creek 3 miles north of Wytheville; along State Route 88, 5 miles north of Marion; on State Route 81 midway between Broadford and Tannersville, Tazewell County, and at Hayter Gap village, Washington County. Black shale, at least partly Millboro, is exposed on the southeast slope of Clinch Mountain southwest of Hilton and is well shown in a large area at the south end of Powell Mountain in the vicinity of Duffield, Scott County; in the vicinity of Big Stone Gap, Wise County; and near Blackwater, Lee County. The black shale in the southwestern counties probably does not correspond exactly to the Millboro, although it includes a partial equivalent of it.

Thickness.—Unless the width of outcrop where the beds dip steeply is in some places due to duplication by close folding, the thickness of the Millboro varies greatly. At Millboro Springs, west of McDowell, and in the long belt between Christiansburg and Ingles Ferry, the thickness is estimated to be at least 1000 feet. On the north side of Burkes Garden just below the sharp angle in the road, State Route 87, not more than 100 to 200 feet of pink clay rock of Naples age, which represents the Millboro, rests on the Onondaga and is succeeded by Brallier shale. At Hayter Gap the thickness may be at least 400 feet and the part referred to the Naples may be about 350 feet thick, but similar black shale occurs in the Brallier in the southwestern counties of the Valley. The green shale included in the Naples in the section at Hayter Gap may indicate only that the upper black shale, bed 10 of geologic section 86, is in the Brallier. To sum up, the thickness of the Millboro varies from 200 to 1000 feet.

Fossils and correlation.—The fossils and correlation of the Romney shale (restricted) and the Millboro shale are discussed together because of their close relations and for the sake of brevity.

Fossils are generally scarce and very few have been collected from the Marcellus and Naples horizons. They comprise only a few species, mostly small to minute. They are larger and more abundant in the Hamilton, in which some layers are locally crowded with *Tropidoleptus* and *Spirifer*. The lower 100 feet of the Millboro shale has yielded most of the Marcellus forms, and the upper 100 feet most of those of Naples age.

Fossils of the Marcellus member

Corals
- Craspedophyllum sp.?

Bryozoa
- Paleschara sp.?

Brachiopods
- Ambocoelia umbonata (Conrad)
- Ambocoelia sp., abundant
- Anoplotheca cf. A. acutiplicata (Conrad), rare
- Chonetes cf. C. lepidus Hall
- Chonetes mucronatus Hall
- Leiorhynchus limitare (Vanuxem)
- Leiorhynchus mysia Hall
- Orbiculoidea minuta (Hall)
- Orthothetes arctostriata Hall
- Schizobolus concentricus (Vanuxem)
- Strophalosia trunçata (Hall)

Pelecypods
- Actinopteria muricata Hall
- Buchiola halli Clarke
- Buchiola cf. B. retrostriata (von Buch)
- Cypricardinia sp.?
- Leiopteria laevis Hall
- Nuculites triqueter Conrad?
- Paracyclas lirata Conrad
- Praecardium vetustum Hall?

Gastropods
- Pleurotomaria cf. P. ciliata Clarke

Pteropods
- Bactrites aciculatus (Hall)
- Styliolina fissurella (Hall)
- Tentaculites bellulus Hall

Cephalopods
- Orthoceras sp.
- Tornoceras uniangulare (Conrad)?

Conodonts
- Bryantodus sp.
- Hindeodella sp.
- Lonchodina sp.

All these fossils were collected in about a dozen places from Augusta County south to Hayter Gap, Washington County, and within 50 feet above the Onondaga beds. Of these fossils, *Leiorhynchus limitare, L. mysia,* and *Actinopteria muricata* occur in the Marcellus shale of New York, and, so far as known to the writer, in no other formation. The *Paleschara,* if properly identified, is very rare in any one collection but occurs constantly throughout the length of the Valley and also in the Marcellus in association with *Leiorhynchus limitare* at Milesburg near Bellefonte, Center County, Pennsylvania. *Tornoceras uniangulare* occurs in New York from the Marcellus to the basal Portage, the Marcellus specimens being rather larger than the later ones and possibly more like the specimens occurring at Hayter Gap. These fossils, together with the fact that the lower part of the black shale mass underlies the Hamilton in the northern counties, are sufficient evidence of the Marcellus age of the beds discussed.

Fossils of the Hamilton member

The fossils of this list were collected at the following localities: Conicville (Cabin Hill), Shenandoah County; Cedar Grove and Green Spring, Frederick County; Dietrich (Fort Valley), Massanutten Mountain; and 2 miles northeast of Liberty Furnace, Shenandoah County.

Corals
- Cladopora sp.?
- Craspedophyllum sp.?
- Hadrophyllum bifidum Bassler
- Heliophyllum halli Edwards and Haime
- Microcyclus intermedius Bassler
- Pleurodictyum stylopora Eaton?

Blastoids
- Nucleocrinus strichteri Rowley?

Bryozoa
- Fenestrellina, several sp.
- Trematopora cf. T. subquadrata Hall

Brachiopods
- Ambocoelia umbonata (Conrad)
- Athyris spiriferoides (Eaton)
- Atrypa reticularis (Linnaeus)
- Chonetes coronatus (Conrad)
- Chonetes mucronatus Hall

Chonetes scitulus? Hall
Chonetes setigera? (Hall)
Chonetes vicinus (Castelnau)
Cranaena sp.?
Cyrtina hamiltonensis Hall
Douvillina sp.?
Orthothetes arctostriata Hall
Pholidostrophia iowaensis (Owen)
Productella spinulicosta Hall
Reticularia fimbriata (Conrad)
Rhipidomella vanuxemi (Hall)
Spirifer audaculus (Conrad)
Spirifer consobrinus D'Orbigny
Spirifer granulosus (Conrad)
Spirifer mucronatus (Conrad)
Stropheodonta concava Hall
Stropheodonta perplana (Conrad)
Tropidoleptus carinatus (Conrad)

Pelecypods
Actinopteria decussata Hall
Glyptodesma erectum Conrad
Lyriopecten interradiatus Hall
Modiomorpha concentrica Conrad
Nuculites oblongatus Conrad
Paracyclas lirata Conrad
Pterinea flabellum (Conrad)

Gastropods
Loxonema delphicola Hall
Pleurotomaria capillaria Conrad
Pleurotomaria trilix Hall

Trilobites
Phacops rana (Green)

Of these fossils, *Athyris spiriferoides,* the four species of *Spirifer, Chonetes coronatus, Strophoedonta concava, Glyptodesma erectum,* and *Modiomorpha concentrica* are among the most diagnostic fossils of the Hamilton formation of New York and Pennsylvania, and their presence in Virginia leaves no doubt of the Hamilton age of the beds in which they occur.

Fossils of the Naples beds

Worm tracks
- Pteridichnites biseriatus C. K. Swartz

Brachiopods
- Ambocoelia umbonata (Conrad)
- Chonetes lepidus Hall
- Leiorhynchus aff. L. limitare (Vanuxem)
- Schizobolus concentricus (Vanuxem) rare

Pelecypods
- Buchiola retrostriata (von Buch)
- Honeoyea sp.?
- Lunulicardium sp.?
- Nuculites triqueter Conrad
- Ontaria clarkei Beushausen
- Ontaria halli Clarke
- Ontaria suborbicularis (Hall)
- Paracardium doris Hall
- Pterochaenia fragilis (Hall)
- Puella sp.?

Gastropods
- Palaeotrochus praecursor Clarke

Pteropods
- Styliolina fissurella (Hall)

Cephalopods
- Bactrites aciculatus (Hall)
- Bactrites gracilior Clarke
- Manticoceras patersoni (Hall)
- Probeloceras lutheri Clarke

Crustacea
- Spathiocaris emersoni Clarke?

Buchiola retrostriata, Honeoyea, the three species of *Ontaria, Paracardium doris, Manticoceras patersoni,* and *Probeloceras lutheri* are among the most characteristic fossils of the Naples beds of basal Portage age in Ontario County, New York, and their occurrence in the upper 100 to 500 feet of the "Romney" and Millboro is sufficient justification of the tentative application of the name, Naples beds to that part of the section.

As stated above, this upper black shale in Maryland and West Virginia has been called Genesee by Stose and Swartz, and also by the West Virginia Geological Survey. The reason for not using Genesee in this report rests on the fact that the typical Genesee of New York, as restricted by Clarke, carries *Schizobolus* and lacks *Paracardium doris* and some of the other fossils listed above, which occur in the Naples beds overlying the Genesee. The occurence of *Schizobolus* in bed 6 of the Hayter Gap section may indicate the local presence of the Genesee. It is also possible that the black shale with *Schizobolus* at Big Stone Gap, Wise County, and at Duffield, Scott County, is Genesee, although the occurrence of *Schizobolus* in the Marcellus at Hayter Gap makes it equally probable that the black shale with *Schizobolus* at those places is Marcellus.

BRALLIER SHALE[187]

Name.—The Brallier shale was named[188] from Brallier station on the Huntingdon and Broad Top Mountain Railroad, 5 miles northeast of Everett, Bedford County, Pennsylvania.

Limits.—All known facts indicate that the Brallier formation succeeds beds of Naples age because of continuous sedimentation in the Appalachian Valley from Pennsylvania to southern Virginia. The same can be said for the succession of the Hatch-Gardeau shales in western New York which there succeeds the typical Naples beds. Throughout the Valley from Lock Haven, central Pennsylvania, to southern Virginia, the upper limit of the Brallier is placed at the lowest beds with large fossils of Chemung type. The beds containing these fossils do not differ so markedly in lithology from the underlying Brallier as to make a sharp and easily recognizable contact, but within 100 to 200 feet above the lowest fossiliferous beds the rock has undergone a gradual change to lumpy green mudrock with thicker beds of coarse-grained and more unevenly bedded sandstone quite different from the evenly thin-bedded, fine-grained layers of sandstone in the Brallier. Such a paleontologic and lithologic succession holds constantly the full length of the Valley from central Pennsylvania to southern Virginia.

Character.—The Brallier is a rather monotonous mass of subfissile, stiff, more or less sandy and micaceous green shale, commonly with uneven or dimpled surfaces in which are interbedded layers of very fine-grained, evenly thin-bedded, and blocky-jointed greenish sandstone. (See Pl. 44A and B.) In the southwestern counties,

[187] Lower one half to two thirds of the Jennings shale of Darton and of the Kimberling shale of Campbell.

[188] Butts, Charles, Geologic section of Blair and Huntingdon counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, pp. 523-537, 1918.

the mass becomes much thinner bedded with less sandstone, as shown in Plate 44C. In this part of the Valley the appearance of beds of black shale in the lower half of the formation makes its separation from the Naples beds uncertain. The introduction of black shale beds, especially in the lower half of the Brallier, becomes noticeable in Hunter Valley, 3 miles north of Fort Blackmore, Scott County, and at Hilton, Scott County. Such occurrences tend to confirm the idea that the uppermost black shale, bed 10 of the Hayter Gap section, is really in the Brallier.

Distribution.—The Brallier shale persists the full length of the Valley in Virginia. In the belts northwest of Little North Mountain and throughout the northwestern half of the Valley, it occupies extensive elongate areas from the West Virginia line southwestward to Tennessee. One of its largest areas is in Bland County, drained mainly by Kimberling Creek from which the name Kimberling shale of Campbell[189] was taken. The belt just southeast of Clinch Mountain continues southwest 40 miles into Tennessee, to the southwest end of Clinch Mountain. The most southeastern belt of outcrop southeast of Walker Mountain is cut off at its southwestern end by an overthrust fault one mile west of Seven Springs, Washington County. From Cumberland Gap the black shale, whether all Mississippian or all, or part, Brallier (see p. 321), extends continuously near the boundary of the Coal Measures to Chattanooga, Tennessee, whence originated the name Chattanooga shale,[190] which was applied by Campbell[191] to the Brallier of southwest Virginia, as southeast of Clinch Mountain.

Among the best exposures of the Brallier are the following: Along State Route 7, between Gainesboro and Cross Junction, Frederick County; and on U. S. Route 50 beginning a few hundred feet west of Gore and extending three-quarters of a mile west of Gore. The best exposure is in Bland County between Bastian and the top of Brushy Mountain, 1 mile to the southeast, where the full maximum known thickness of about 3000 feet is continuously exposed along U. S. Route 21. Another good exposure of the formation, where it is judged to be equally thick, is on U. S. Route 250 in Highland County, just west of Shenandoah Mountain, where the formation is almost continuously exposed for 3 miles across the strike. It is well exposed in the streets and hills of the southern part of Blue-

[189] Campbell, M. R., Paleozoic overlaps in Montgomery and Pulaski Counties, Virginia: Geol. Soc. America Bull., vol. 5, pp. 171-177, 1894.
[190] Hayes, C. W., The overthrust faults of the southern Appalachians: Geol. Soc. America Bull., vol. 2, p. 143, 1891.
[191] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), p. 2, 1894.

field, West Virginia, and also south of Bluefield, Virginia. In the southwestern part of the State it is excellently exposed on Weaver Creek southwest of Big A Mountain, Russell County, at South Clinchfield (Dump Creek), Russell County, and on U. S. Route 19 half a mile north of the Holston River in Washington County. Here the intercalations of black shale in the lower half of the Brallier can be seen in a ravine a few hundred feet west of the road. The southwesternmost exposure is in the cut to the tunnel of the Clinchfield Railroad at Cassard, Scott County, 6 miles along the strike northwest of the State line.

Thickness.—In Frederick County, just northwest of Gore, the Brallier is about 1500 feet thick; in Bland County, in the large area on Kimberling Creek, it is 3000 feet thick. At the locality just half a mile north of Holston River, the thickness is computed at 1800 feet and it seems to be about the same at Hilton and at Cassard on the same belt. At South Clinchfield, Russell County, the thickness is about 1000 feet, and at Big Stone Gap, it is about 700 to 1000 feet, according to whether the 350 feet of black shale at the top is Brallier. At Cumberland Gap the thickness of the black shale seems to be about 400 feet, but it may or may not be Brallier.

Fossils and correlation.—In the Brallier of Virginia, as in the Brallier of central Pennsylvania, fossils are very minute, very scarce, and hard to find. A few small collections have been made at widely separated points and at different horizons throughout the mass. The few species identified are listed below.

Fossils from the Brallier shale

Worms
- Pteridichnites biseriatus C. K. Swartz, common

Brachiopods
- Ambocoelia umbonata (Conrad)
- Leiorhynchus globuliforme Vanuxem
- Lingulipora williamsana Girty
- Schizophoria striatula (Schlotheim)
- Spirifer mesistrialis Hall
- Spirifer mucronatus posterus Hall and Clarke
- Strophalosia muricata (Hall)

Pelecypods
- Buchiola retrostriata (von Buch)
- Buchiola sp.?

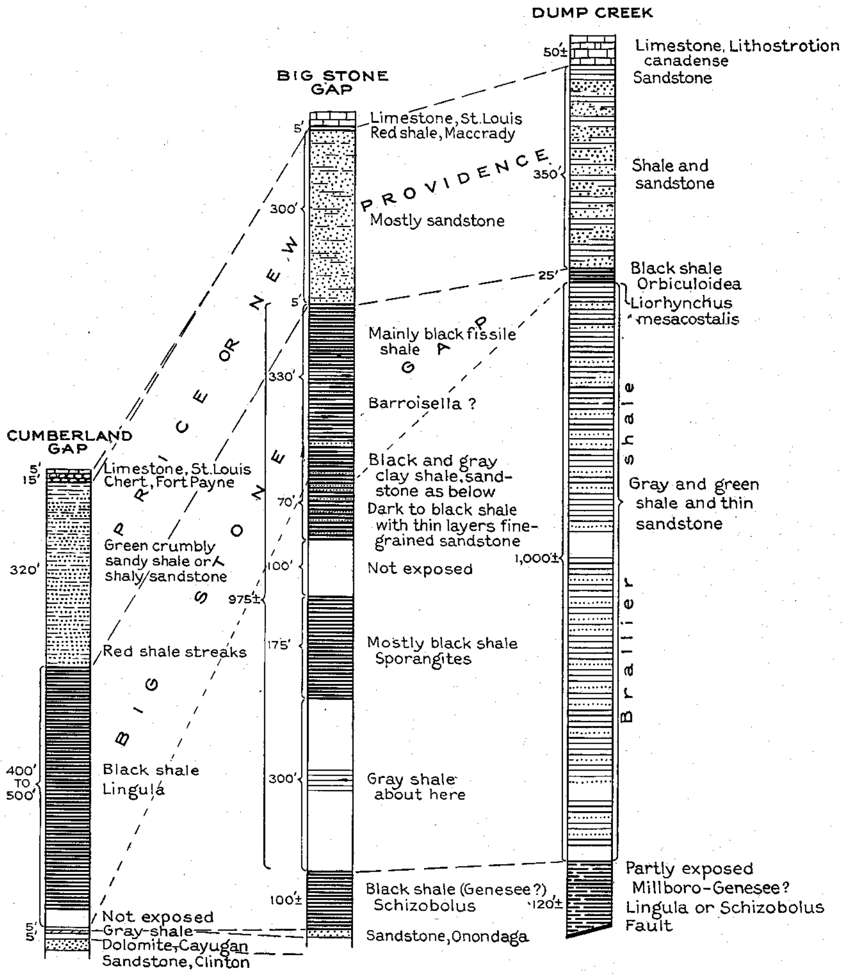
Nuculites triqueter Conrad
Ontaria suborbicularis (Hall)
Palaeoneilo cf. P. constricta (Conrad)
Paracardium doris Hall
Pterochaenia fragilis (Hall)

Cephalopods
Probeloceras lutheri Clarke

A single member of this fauna, *Pteridichnites biseriatus* C. K. Swartz (see Fossil Plates), is fairly common throughout the Brallier and, since 1908, has been used by the writer as a guide fossil. More recently, Bradford Willard of the Pennsylvania Geological Survey has independently discovered and used this form in the same way. It is fairly plentiful on some exposed bedding planes of the fissile, green, siliceous shale. *Leiorhynchus globuliforme* and *Spirifer mucronatus* var. *posterus*, so far found only in Frederick County and rarely there, are rather characteristic fossils of the Ithaca facies of the Portage fauna near Ithaca, New York, and indicate the migration of these members of that fauna into northern Virginia. Elements of that fauna have been reported by Swartz and Stose[192] as far south as Pawpaw, West Virginia, on Potomac River.

The notable thing about this fauna, except the Ithaca element, is that it is a survival of the Naples fauna characteristic of the beds just below the Brallier, whether in Virginia, central Pennsylvania or New York. The same fauna, sparse indeed in the Genesee River area in western New York, also continues up through the Hatch and Gardeau shales, which are identical in lithological character with the Brallier shale and, like it, overlie the Naples beds or their equivalent. This persistent sequence of lithologic character and fauna from central New York through central Pennsylvania into southwestern Virginia leaves no doubt as to the identity of the Brallier with the Hatch and Gardeau and the continuity of the same mass of rocks beneath the synclines occupied by younger formations between New York and Tennessee. The same rocks have been penetrated in test borings for oil in northwestern Pennsylvania, as shown by drill cuttings examined by the writer. Indeed, the name Gardeau would have been applied to this formation were it not for the fact that the Brallier also includes the equivalent of the Hatch shale.

192 Stose, G. W., and Swartz, C. K., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (No. 179), p. 12, 1912.



Sections showing the relations of the Price formation, "Big Stone Gap" shale, and Bralier shale. The Brallier is supposed to extend up to the Price formation at Big Stone Gap, Wise County, and Cumberland Gap, Tennessee. The lower correlation line indicates approximately the base of the beds included in the Big Stone Gap shale by Stose.

NOTE: Lithostrotion canadense should be Lithostrotionella "canadensis" and Liorhynchus mesacostalis should be Leiorhynchus mesacostale.

RELATIONS OF THE BRALLIER TO THE PORTAGE AND BIG STONE GAP SHALES

In Plate 45 the writer has tentatively expressed his interpretation of the relations of the Brallier to the Portage and Big Stone Gap shales of Stose.[193] In the section at South Clinchfield, Russell County, the Brallier is typically developed, is 1000 feet thick, and contains no black shale. It is well exposed along the valley of Weaver Creek north to Big A Mountain. At Big Stone Gap the section is not fully exposed, but the upper 350 feet, called the Big Stone Gap shale, is much like the Brallier but is dark-colored to black. In Hunter Valley the equivalent of the Brallier contains beds of black shale, and it seems probable that the Portage part of the section at Big Stone Gap, which is not exposed, may also contain beds of black shale. It is thought that this transition of the Brallier to black shale continues southwest directly along the strike to Cumberland Gap, where almost all of the interval between the Price sandstone (Mississippian) and the Clinton (lower Silurian) is occupied by black shale. The Helderberg and Cayuga groups, though present at Big Stone Gap, have thinned out northeast of Cumberland Gap. It is surmised that the black shale at Cumberland Gap is in the main a facies of the Brallier or some part of it. It is also thought that the full thickness of black and green shale between the black shale at the base with *Schizobolus* (Naples or Marcellus), and the Price at Big Stone Gap is a facies of the Brallier and includes the Big Stone Gap shale of Stose. In certain parts of the southwestern counties of the Valley a black shale undoubtedly overlies the Brallier at the base of the Price sandstone. This is exposed on Virginia Route 82, 1½ miles northwest of Cleveland, Russell County; on Weaver Creek for three-fourths of a mile southwest of Coombs School; and in a cut of the Clinchfield, Railroad, 2 miles east of Cassard, Scott County. In the black shale half a mile northwest of South Clinchfield, the 350 feet of dark-colored shale next below the Price sandstone at Big Stone Gap, and all of the black shale at Cumberland Gap is named Big Stone Gap shale by Stose[194] and is regarded by Ulrich as Mississippian.[195]

Ulrich regards this black shale as Mississippian because the upper black shale in the Big Stone Gap section contains *Barroisella* cf. *B. subspatulata* (Meek and Worthen) which occurs in the Sweetland Creek

[193] Stose, G. W., *in* Eby, J. B., The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, pp. 46-53, 1923.

[194] Stose, G. W., op. cit., pp. 46-52.

[195] At South Clinchfield, Big Stone Gap, Cumberland Gap, and elsewhere both this black shale and the undoubted Brallier (Portage) are included in a single map unit.

shale of Iowa, considered by some as Mississippian, and conodonts which are either the same as those of the Sunbury shale or are closely related to them. The Sunbury is in the lower part of the Cuyahoga shale (Mississippian) in Ohio and Kentucky. The prevailing black shale of the Big Stone Gap section is apparently laterally continuous with the typical Brallier shale of the South Clinchfield section and also with the black shale of the Cumberland Gap section. These facts seem to indicate that the shale at all of these places is part of one laterally continuous mass and is thus all Brallier. The few fossils noted above, which do not occur in the unquestioned Brallier or in the known Upper Devonian anywhere, tend to offset that evidence. The Mississippian age of the stratigraphic horizon of the *Barroisella* does not seem to be fully established. If the uppermost black shale in the Big Stone Gap section contains conodonts identical with those in the Sunbury shale, that fact would be convincing evidence for the Mississippian age of that shale. Ulrich, however, does not appear to have cited any such species. The Lingulas and Orbiculoideas of the black shale at the different places, as is usual with linguloids, do not afford any convincing evidence for the age of the beds.

CHEMUNG FORMATION

Name.—The Chemung formation was named[196] from Chemung Narrows on Chemung River, 11 miles southeast of Elmira, New York.

Limits.—The lower boundary of the Chemung in Virginia and central Pennsylvania is placed at the zone or horizon at which large fossils, such as *Leiorhynchus, Productella, Spirifer,* and *Leptodesma* appear in the section directly above the thick mass of Brallier shale which, except in Frederick County where a few Ithaca fossils come in, as noted on p. 320, contains only the diminutive fossils of the typical Portage formations of the Genesee River sections in Livingston County, New York. In the writer's experience this horizon is fairly constant and determinable within reasonable limits throughout the Valley in Virginia, as well as in central Pennsylvania, and apparently consistent results are obtained by its use. The appearance of the Chemung fossils is not accompanied by any marked change in lithology. That change is gradual and it is only at some indefinite, though not great, distance above the boundary, as determined by fossils, that a difference in lithology from the Brallier type becomes noticeable. On the northwestern side of the

[196] Hall, James, Third annual report of the fourth geological district of the State of New York: New York Geol. Survey 3rd Ann. Rept., pp. 322-326, 1839.

Valley, as in Highland County, Virginia, and in West Virginia, the top of the Chemung is roughly marked by the appearance of red shale and sandstone which, with only a few thin beds of gray, scantily fossiliferous shale or sandstone, are characteristic of the Hampshire (Catskill) formation in this area. The red beds of the Hampshire are more conspicuously developed in the adjoining parts of West Virginia. In southern Augusta County, as on Elliott Knob, and along the State line, as near High Top Mountain, 4 miles southwest of Mountain Grove, Bath County, the red rock decreases to a few thin beds and the boundary at the top of the Chemung is not as definitely marked lithologically as elsewhere. In such areas the top of the Chemung is placed at the highest marine fossiliferous beds below the lowest red beds. It must be noted, however, that in the southeastern belts of the Chemung an occasional bed of red to chocolate-colored shale or sandstone occurs intercalated in the upper part of the fossiliferous Chemung as, for example, along U. S. Route 50 west of Chambersville, Frederick County. This is in accordance with the general rule that red beds occur at successively lower horizons toward the southeastern side of the Valley and descend as low as the Hamilton in the Catskill Mountains of eastern New York.

Character.—The Chemung is a thick body of sandstone and shale. The sandstone is rather thick bedded; notably so as compared with the sandstone in the Brallier. It is generally arkosic, medium grained, mainly gray to greenish, but to a minor degree reddish and blackish. Characteristic beds, 50-100 feet thick, of thick-layered, fine-grained, and very hard red sandstone occur on Mason Creek north of Salem, Roanoke County, and at the west end of Brushy Mountain on Carlock Creek, 9 miles west of Marion, Smyth County. Such rock also occurs in many other places.

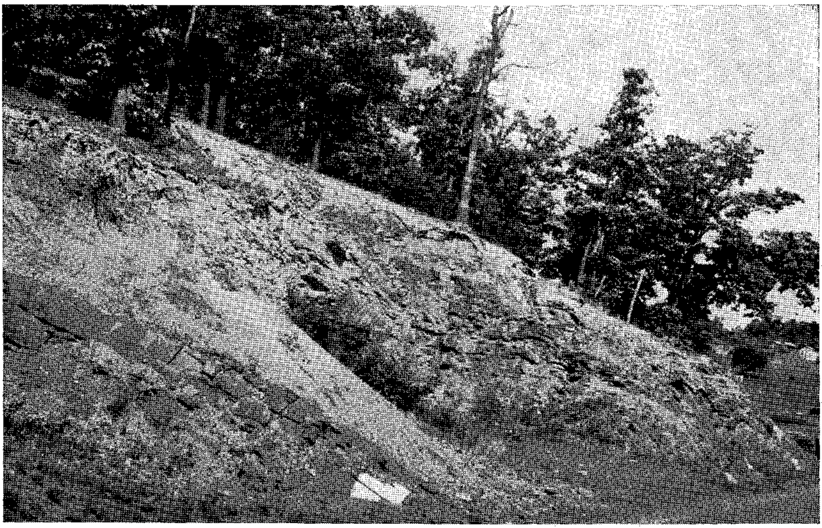
A very thick mass of it, dipping at a high angle, crops out along the crest of Pine Mountain from Tumbling Run, 4 miles west of Saltville, Smyth County, to and northeast of Broadford Gap. As this bed is just below fossiliferous beds of the Price sandstone and seems to afford a good lithologic basal bed in that area, it is provisionally referred to the Price, although its lithology through its similarity to sandstone in the Chemung, suggests that it may belong in that formation. Most of the shale in the Chemung is green, soft and poorly fissile as compared with shale in the Brallier, and is clayey instead of sandy and micaceous like the shale in the Brallier. In general, with some experience, the Brallier and Chemung are readily distinguishable. Thin layers of conglomerate, commonly not more than 1 foot thick, containing quartz

PLATE 46

A. Contact of the upper sandstone of the Hamilton formation with the Brallier shale (marked by the hammer). A hiatus at this contact in Frederick County is due to the absence of the Naples beds which are of considerable thickness farther west, in West Virginia west of Romney. Along U. S. Route 50 about one-third of a mile northwest of Gore, Frederick County. Looking northwest.

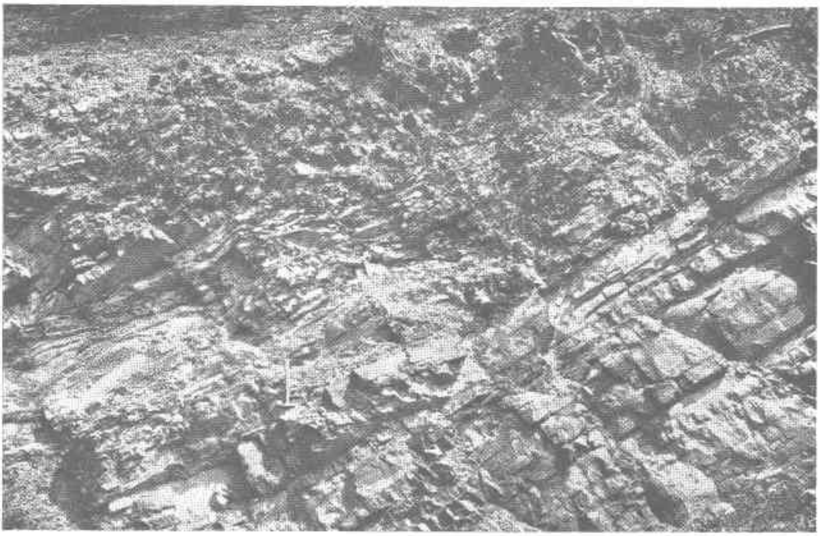
B. Basal sandstones of the Chemung formation. Along U. S. Route 50 about half a mile west of the Virginia-West Virginia line. Looking southeast.

A



B

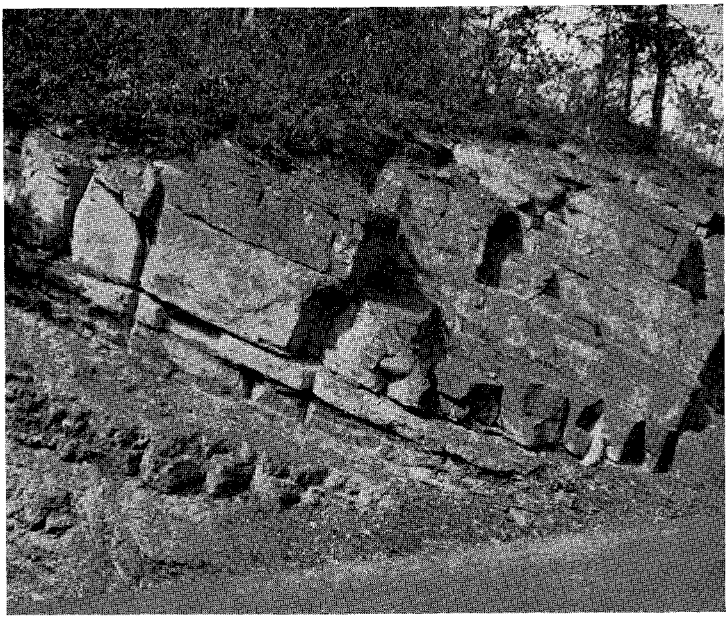
DEVONIAN FORMATIONS



A

B

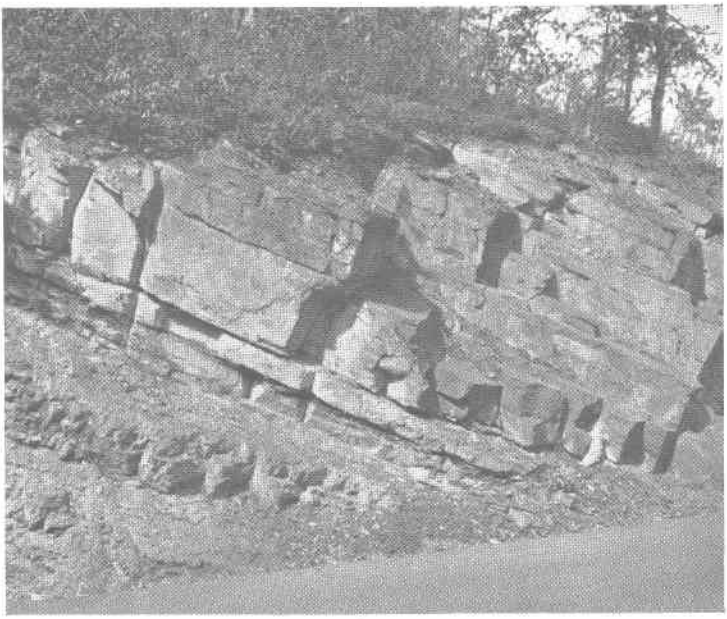
DEVONIAN FORMATIONS



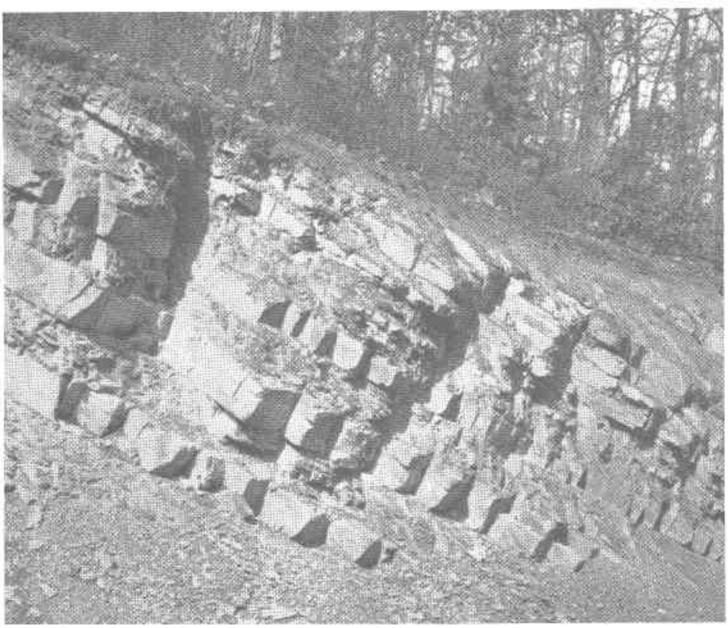
A

B

DEVONIAN FORMATIONS



A



B

Devonian Formations

PLATE 47

Upper Chemung beds in western Augusta County. Medium to thick-bedded argillaceous sandstone is interbedded with arenaceous shale. Some of the shale has a reddish tint which is characteristic of the upper Chemung in northern Virginia. Along U. S. Route 250 on the southeast slope of Shenandoah Mountain about 3 miles northwest of West Augusta. The beds dip 30-40° SE. Beds shown in A are higher in the section than beds shown in B. Photographs by Arthur Bevan.

pebbles, most of which are not more than a quarter of an inch but with some pebbles as large as half an inch to an inch in diameter, are scattered through the mass. Such thin layers of conglomerate occur in the Chemung throughout its entire extent from New York to Virginia. The general lithology and thickness of the Chemung which are typical of most of its occurrences in Virginia are given in the following section on U. S. Route 250, about midway between Staunton and Monterey:

Geologic Section 87.—Chemung formation on the southeast slope of Shenandoah Mountain, Augusta County, Virginia

	Thickness Feet
Hampshire formation (lower part, 143 feet)	
36. Sandstone, thick bedded, red	15
35. Shale and sandstone, yellow and red	35
34. Shale and sandstone, red	33
33. Shale, red	60
Chemung formation (1935 feet)	
32. Shale, soft, green, layers of sandstone; contains *Camarotoechia eximia* (Hall), *Chonetes scitulus* Hall, *Orthothetes chemungensis* (Conrad), and *Spirifer disjunctus* Sowerby	60
31. Sandstone	5
30. Shale	15
29. Sandstone	2
28. Shale, soft, green	45
27. Conglomerate	2
26. Sandstone	20
25. Shale, soft, and arkosic sandstone, with *Camarotoechia congregata* (Conrad)	60
24. Conglomerate	1
23. Sandstone, arkosic, thick bedded	15
22. Shale, soft, green, thin layers of sandstone; contains *Chonetes scitulus* Hall and *Leptodesma* cf. *L. disparile* Hall	60
21. Sandstone, thick bedded, arkosic	15
20. Shale	5
19. Sandstone, arkosic	20

	Thickness Feet
18. Shale, soft, green; thin layers of sandstone in middle; contains *Chonetes setigera* (Hall), *Cypricardella gregaria* (Hall), *Grammysia communis* Hall, and *Tentaculites descissus* Clarke and Swartz	150
17. Sandstone, thick bedded, reddish	20
16. Shale	50
15. Sandstone, thick bedded, mainly greenish	50
14. Shale, green	10
13. Shale, chocolate-colored	10
12. Sandstone, greenish, thick bedded, arkosic	10
11. Not exposed, probably shale; sandstone debris contains *Camarotoechia eximia* (Hall), *Chonetes scitulus* Hall, and *Cypricardella gregaria* (Hall)	80
10. Shale and sandstone, red to chocolate-colored	110
9. Not exposed	40
8. Shale and thin sandstone, with *Leptodesma medon* Hall, 230 feet below top; *Atrypa spinosa* Hall, *Ambocoelia umbonata* (Conrad), *Chonetes scitulus* Hall, *Douvillina cayuta* (Hall), and *Spirifer mesicostalis* Hall, 80 feet below top	670
7. Not exposed; much coarse-grained sandstone debris with *Spirifer mesistrialis* (Hall)	115
6. Not exposed	100
5. Shale	110
4. Sandstone, conglomeratic, with *Spirifer mesistrialis* (Hall)	20
3. Not exposed	40
2. Shale	15
1. Sandstone (top of Shenandoah Mountain)	10
Brallier shale	
Shale and thin sandstone exposed for width of 3 miles, estimated	3000

Several more thin conglomeratic layers, with small quartz pebbles, are present but not noted in the section. It is not improbable that the Chemung-Brallier boundary is even lower than indicated in this section. The beds below bed 1 were not examined.

The Chemung is scantily fossiliferous at this locality and generally throughout this southeastern belt. Along the old Staunton-Parkersburg pike west of Buffalo Gap and on Elliot Knob, both of which are on the same belt of outcrop in Augusta County, only the unweathered edges of the beds are exposed and such fossils as are present are difficult to detect and extract.

Distribution.—The Chemung, except where removed by erosion on the anticlines, persists throughout the full width of the Valley northwest of Little North Mountain in Virginia and West Virginia, and in the continuation of that belt southwest to the vicinity of New River. In West Virginia the Chemung thins out entirely near the Narrows of New River, though a thin bed may be present in the Narrows. It is perhaps 100 feet thick and highly fossiliferous three-fourths of a mile southeast of Lindside, West Virginia, 11 miles northeast of the Narrows. At Bluefield, West Virginia, 24 miles to the southwest, however, the Chemung is absent, and the Price formation, with *Syringothyris* in the basal conglomeratic sandstone, lies upon the Brallier shale, as can be seen in an exposed contact on U. S. Route 19, 2 miles west of Bluefield, Virginia, and half a mile north of St. Clair railroad station. (See Pl. 48D.) This sequence persists southwest along the northwest side of the Valley to Cumberland Gap. Outlying areas of Chemung on the crests of Beards, Rough, and Short mountains between Clifton Forge and Millboro Springs, Bath County, on Patterson Mountain, Botetourt County, and on North and Broad Run mountains, Craig County, show that the Chemung extended all over the intermediate belts of the Valley. The Chemung appears 2 or 3 miles west of Mechanicsburg, Bland County, and continues southwest but thins gradually to the vicinity of Mendota, Washington County, where it disappears. Southeast of Walker Mountain its southwesternmost area is on the top of Brushy Mountain, west of Marion. Southeast of this belt is a large synclinal area around Fort Lewis Mountain northwest of Salem, and another essentially synclinal area in Draper Mountain southwest of Pulaski. These mountains are in strike with each other and in them the present existing Chemung reaches its southeasternmost extent in respect to the width of the Valley in Virginia. It is reasonably inferred that the formation originally extended much farther southeast, even as far as or beyond the Blue Ridge.

Among the best exhibits of the Chemung are the following: Along U. S. Route 250, on the southeast slope of Shenandoah Mountain (geologic section 87); on U. S. Route 21, from 1 to 2½ miles north of Bland; in three belts in Frederick County crossed by U. S. Route 50, between Chambersville and West Virginia; and along Mason Creek north of Salem.

Thickness.—The thickness of the Chemung has been best determined at the locality of geologic section 87 as 1935 feet. It is about 2000 feet thick north of Bland. On U. S. Route 50, 1½ miles southeast of Hayfield, Frederick County, the width of outcrop is 2500 feet, the dip 50 degrees SE., and the thickness approximately 2000 feet. Two thousand feet may then be taken as the approximate thickness of the Chemung in its full development in the Valley. In the gap through Pine Mountain south of Zenobia and 6 miles northeast of Mendota, Washington County, the thickness between uncertain limits can scarcely exceed 150 feet and it is probably nearer 100 feet. The occurrence of *Leiorhynchus mesacostale* Hall, just beneath the black shale of possible Mississippian age half a mile southeast of South Clinchfield, Russell County, may indicate a few feet of basal Chemung at that locality. If that is a fact, it is the only known indication of the Chemung in Virginia west of the meridian of 82 degrees, except in the narrow belt along the northwest limb of the Greendale syncline terminating in the vicinity of Mendota, Washington County.

Fossils and correlation.—In the Chemung of Virginia fossils seem to occur mainly in a few layers scattered through the formation. In some of these, they may be rather plentiful, though the formation as a whole would not be considered as highly fossiliferous as it is in New York. In the course of field work for this report, a considerable number of species has been collected in a more or less casual way, mostly from float, at widely separated localities and generally only a few species at a place. As a result of such collecting, it is not possible to assign the fossils to particular zones though the horizons of a few collections are known. Brachiopods and pelecypods predominate. A general list follows:

Fossils of the Chemung formation in Virginia

Sponges
    Hydnoceras tuberosum Conrad

Worms
    [a]Arenicolites sp.?

[a] Williams, H. S., On the fossil faunas of the upper Devonian; the Genesee section, New York: U. S. Geol. Survey Bull. 41, Pl. 4, figs. 9a, 9b, 1887.

Bryozoa
- Fenestrellina, rare
- Intrapora sp.?
- Rhombopora, one or more species common

Brachiopods
- Ambocoelia umbonata (Conrad)
- Athyris angelica Hall?
- Atrypa reticularis (Linné)
- Atrypa spinosa Hall
- Camarotoechia congregata (Conrad)
- Camarotoechia contracta (Hall)
- Camarotoechia eximia (Hall)
- Camarotoechia horsfordi (Hall)
- Carniferella carinata (Hall)
- Carniferella tioga (Hall)?
- Carniferella virginiana beta (Williams)
- Chonetes scitulus Hall
- Chonetes setigera Hall
- Cryptonella eudora Hall
- Cyrtina hamiltonensis Hall
- Douvillina cayuta (Hall)
- Douvillina extensa Butts, n. sp.
- Douvillina mucronata (Conrad)?
- Elytha (Reticularia) fimbriata (Conrad)
- Leiorhynchus mesacostale Hall
- Orthothetes (Schellwienella) chemungensis (Conrad)
- Productella hirsuta Hall
- Productella lachrymosa (Conrad)
- Productella speciosa Hall?
- Productella sp.
- Schizophoria striatula (Schlotheim)?
- Spirifer disjunctus Sowerby
- Spirifer (Delthyris) mesicostalis (Hall)
- Spirifer mesistrialis Hall
- Stropheodonta perplana nervosa Hall
- Tropidoleptus carinatus (Conrad)

Pelecypods
- Aviculopecten cancellatus Hall
- Aviculopecten duplicatus Hall
- Aviculopecten tenuis Hall
- Cypricardella bellistriata (Conrad)
- Cypricardella gregaria (Hall)

Cypricardella tenuistriata (Hall)
Edmondia subovata Hall
Goniophora glauca Hall
Goniophora hamiltonensis Hall?
Grammysia communis Hall
Grammysia elliptica Hall
Leiopteria cf. L. greeni Hall
Leptodesma lichas Hall
Leptodesma cf. L. longispinum Hall
Leptodesma medon Hall
Leptodesma mortoni Hall
Leptodesma potens Hall
Leptodesma cf. L. rogersi Hall
Leptodesma sociale Hall
Modiola praecedens Hall
Mytilarca chemungensis (Conrad)
Pterinea chemungensis (Conrad)?
Schizodus chemungensis (Conrad)?
Sphenotus clavulus Hall
Sphenotus contractus Hall?

Gastropods
Bellerophon maera (Conrad)
Cyclonemina crenulistriata Clarke and Swartz
Cyclonemina multistriata Clarke and Swartz
Ectomaria ecclesiae? Clarke and Swartz
Ectomaria marylandica Clarke and Swartz
Loxonema terebrum Hall
Platyceras compressum Clarke and Swartz

Pteropods
Tentaculites descissus Clarke and Swartz

Trilobites
Phacops rana (Green)

Supplementing the above fossils are the following species collected from the lower part, probably the lower 200 feet, of the Chemung on Little Back Creek, within half a mile north of State Route 501 and 2½ miles northwest of Mountain Grove, Bath County:

Ambocoelia umbonata Conrad
Atrypa reticularis (Linné)
Atrypa spinosa Hall

Carniferella (Dalmanella) carinata (Hall)
Carniferella tioga (Hall)?
Cryptonella eudora Hall
Douvillina mucronata or D. cayuta (Hall)
Elytha (Reticularia) fimbriata (Conrad)
Leiorhynchus mesacostale Hall
Mytilarca chemungensis (Conrad)
Phacops rana (Green)
Productella lachrymosa Hall
Rhipidomella vanuxemi (Hall)?
Schizophoria striatula Schlotheim?
Spirifer (Delthyris) mesicostalis (Hall)
Spirifer sp.
Tropidoleptus carinatus (Conrad)

The fossils of the first list would appear in any complete Chemung list from New York or Pennsylvania, and there can be no doubt of the Chemung age of the beds containing them. The supplementary list includes several species that are especially characteristic of the typical Chemung at Chemung Narrows, New York, for example *Carniferella carinata* and *C. tioga, Douvillina mucronata, Productella lachrymosa, Tropidoleptus carinatus, Mytilarca chemungensis,* and *Phacops rana?*. *Tropidoleptus carinatus* is not of course to be regarded as a strictly Chemung fossil, but it actually does occur in the lower part of the Chemung, in the general region of the type section at Chemung Narrows if not actually in that section.[197]

The absence of *Spirifer disjunctus* from the supplementary list is notable. It, however, is known to occur slightly higher in the Little Back Creek section, and, on adequate search, probably would be found in the lower beds in which the collections were made. Its occurrence just above the Brallier shale in association with most of the species collected on Back Creek is shown by the following species collected half a mile west of Queen in the southeast corner of the Ebensburg quadrangle, Bedford County, Pennsylvania, just above 1500 feet of Brallier shale and at the base of 2500 feet of Chemung: *Ambocoelia umbonata, Atrypa spinosa, Carniferella carinata, Delthyris mesicostalis, Leiorhynchus mesacostale, Productella lachrymosa, Schizophoria striatula, Spirifer disjunctus, Stropheodonta perplana nervosa, Aviculopecten duplicatus, Leiopteria?, Pterinea chemungensis,* and *P. rigida?*. Nearly every species of these last two lists was observed by the writer in the course of a short search in the lower 20 feet of the rocks exposed above the highway in Chemung Narrows.

It is significant that a fauna, typical of the Chemung formation at

[197] Williams, H. S., and others: U. S. Geol. Survey Geol. Atlas, Watkins Glen-Catatonk folio (No. 169), p. 10, 1909.

Chemung Narrows, N. Y., which also occurs in Pennsylvania and Virginia, is underlain by beds faunally and lithologically identical with the Hatch and Gardeau shales of the typical Portage of Genesee Valley, Livingston County, New York.

HAMPSHIRE (CATSKILL) FORMATION

Name.—The Hampshire formation was named by Darton[198] from Hampshire County, West Virginia, where the formation crops out extensively and is well displayed. It has been supposed that the red rocks of this formation are the westward extension of the red Catskill formation of the Catskill Mountains in eastern New York; hence, the name Catskill formation has been applied to them in western New York, central Pennsylvania, and Maryland. They were even called Catskill by the writer on the geologic map of the Valley. It has recently been demonstrated[199] that the Catskill formation of the type locality in the Catskill Mountains of eastern New York corresponds mainly to the Hamilton and Portage formations, and that the Chemung and Hampshire formations are younger than the true Catskill. Thus if they were ever present in eastern New York, they would have overlain the Catskill and extended above the top of the present Catskill Mountains. Hence, the name Catskill can not properly be applied to the red rocks here described under the restored name Hampshire formation. The relations are graphically expressed by Figure 2.

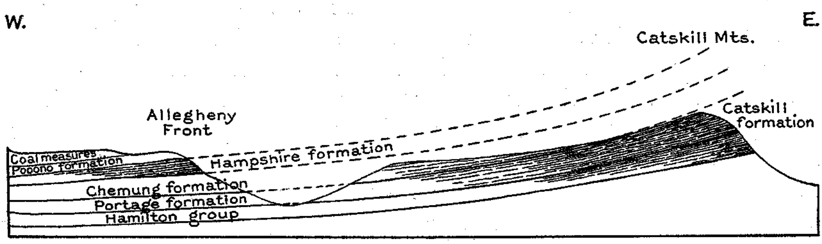


FIGURE 2.—Sketch section from the Catskill Mountains of New York to the Allegheny Front in Pennsylvania, showing the relations of the Hampshire and Catskill formations. The black lines indicate red shale and red sandstone, which diminish westward and rise into higher formations.

Limits.—The Hampshire formation is bounded below everywhere by the fossiliferous green and gray, or, as in central Pennsylvania,

[198] Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, pp. 13, 17, 18, 1892.

[199] Chadwick, G. H., Hamilton red beds in eastern New York: Science, new ser., vol. 77, pp. 86-87, 1933; History and value of the name "Catskill" in geology: New York State Mus. Bull. 307, 116 pp., 1936.

chocolate-colored shale and sandstone of the Chemung. It is everywhere succeeded above by the nonmarine, coal-bearing Pocono sandstone.

Character.—The most distinctive characteristic of the Hampshire is its red color, which matches most closely the particular shade of red named vinaceous drab in Ridgway's chart of colors.[200]

The Hampshire is composed of moderately thick-bedded arkosic and micaceous sandstone and of lumpy or non-fissile mudrock. The sandstone probably predominates. A few gray beds occur, and some localities north of Virginia contain a sparse marine fauna. It is estimated that in the areas of the Hampshire in Frederick, Shenandoah, and Rockingham counties, as well as in the adjoining areas in West Virginia, 75 per cent of the Hampshire mass is red. Farther southwest, as on Elliot Knob, Augusta County, and in Highland County, as well as in southern Pendleton County, West Virginia, much greenish, micaceous, thin flagstone occurs. Still farther southwest, as on or near the State line west of Bath County, the amount of red rock has decreased to occasional beds, none of which are judged to be more than 50 feet thick. The exposures in that locality do not afford full knowledge of the character of the formation.

Distribution.—The main areas of the Hampshire in Virginia are in Frederick, Shenandoah, and Rockingham counties within a few miles southeast of the State line. The largest area is in western Rockingham County and there is a large triangular area in northeast Frederick County at the southwest end of Sleepy Creek Mountain, West Virginia, which ends on the southwest at the State line. In the median part of the Valley no Hampshire occurs southwest of Elliot Knob. The only other occurrences are on or near the State line west of Highland and Bath counties, as shown on the geologic map. A synclinal area of undetermined limits, not shown on the map, lies on and just southeast of the State line in Bath County. The axis of this syncline lies near Flag Knob, 1 mile northwest of Mountain Grove and near High Top Mountain on the State line 4 miles southwest of Mountain Grove.

The Hampshire formation is very largely exposed in two synclinal belts on U. S. Route 50, Frederick County. The best exposure is on U. S. Route 33, between Rawley Springs and Shenandoah Mountain and a mile beyond in West Virginia. Here nearly the full thickness is exposed dipping southeast somewhat more

[200] The Rome, Moccasin, Juniata, Bloomsburg, and Mauch Chunk formations also have this color.

steeply than the gradient of the road. It is probably the best exposure of the Hampshire in the State and, being on a paved highway, is very accessible.

Thickness.—As measured on U. S. Route 33 from the summit of Shenandoah Mountain down to the Chemung in West Virginia, the thickness of the Hampshire is about 2000 feet. The thickness in Maryland given by the Maryland Geological Survey is also about 2000 feet. The thickness at High Top on the State line in Bath County is at least 1000 feet and may be considerably more.

Fossils and correlation.—No fossils have been found in the Hampshire in Virginia. In Pennsylvania a few brachiopods and pelecypods of Chemung types occur at wide intervals in the gray bands and an occasional fish scale, *Holoptychius,* occurs in the red sandstone. It is known also that a number of fossils, survivors of Chemung types, as well as others not known in the Chemung elsewhere, occur in the attenuated equivalent of the Hampshire in northwestern Pennsylvania and western New York. The facts do not seem to indicate that the Hampshire should be considered as later or younger than uppermost Devonian. It seems to be the extension into eastern North America of the uppermost part of the continental and fresh water Old Red sandstone facies of the Upper Devonian which reaches its maximum development in central Scotland, where it is faunally distinguished by fossil fishes, including *Holoptychius.*

HIATUS

The Hampshire (Catskill) is succeeded in Virginia by the Price-Pocono formation which is of Burlington age. No formations of Kinderhook age, which normally underlie the Burlington, are known, unless the upper part of the black shale at Big Stone Gap is of that age, as thought by Ulrich. Hence, a hiatus occurs between the Hampshire and the Price-Pocono through the absence of the Kinderhook group, perhaps 200 feet thick in the Mississippi Valley. The Knapp sandstone of northwestern Pennsylvania and western New York, which contains such Kinderhook fossils as *Paraphorhynchus, Shumardella,* and *Eumetria altirostris* White, which is the same as *Rhynchospirina scansa* (Hall and Clarke), directly overlies beds of Hampshire (Catskill) age, known in that region as the Conewango formation.

CARBONIFEROUS ROCKS

The Devonian system is succeeded by a thick mass of rocks, some of which are terrestrial and include coal beds, and some of which are marine and contain the same general types of invertebrate fossils throughout, such as *Productus* and *Syringothyris*. As the terrestrial and marine beds are interbedded, the entire assemblage of strata is more or less bound together by common types of plants and animals. Hence, these rocks were formerly combined into a system called the Carboniferous system from the abundance of terrestrial vegetation, much of which is now represented by the carbonaceous matter of the coal beds. These great accumulations of vegetal (carbonaceous) matter also indicate a similarity of climate and physiographic conditions during the accumulation of these rocks. This has been regarded as another link binding them all together. The lower parts of the Carboniferous rocks contains much less coal and is much more largely of marine origin. The upper parts contain much more coal and are more largely of terrestrial origin. Many geologists prefer to subdivide these rocks into three systems, the Permian, not present in Virginia, the Pennsylvanian, and the Mississippian, in descending order. This is the writer's preference and is followed here. The United States Geological Survey still calls these rocks the Carboniferous system and subdivides them into three series, Permian, Pennsylvanian and Mississippian. It is the practice of many European geologists to include only the Mississippian and Pennsylvanian rocks in the Carboniferous, with the overlying Permian being considered as a distinct system.

MISSISSIPPIAN SYSTEM

The subdivisions of the Mississippian system in Virginia are given in Table 1.

PRICE-POCONO FORMATION

Names.—The Price formation was named from Price Mountain, Montgomery County, Virginia. The Pocono formation was named from Pocono Mountain in eastern Pennsylvania. The two names are practically synonymous. Pocono was introduced by Lesley[201] in 1877, and Price by Campbell[202] in 1894. Pocono being the older name and having been used in northern Virginia by Darton in 1892 should, on account of priority and for simplification of nomenclature, be applied throughout Virginia.

---

201 Lesley, J. P., The Boyd's Hill gas well at Pittsburgh, Pennsylvania: Second Pennsylvania Geol. Survey, Report L, pp. 221-227, 1876.

202 Campbell, M. R., Paleozoic overlaps in Montgomery and Pulaski counties, Virginia: Geol. Soc. America Bull., vol. 5, p. 177, 1894.

Limits.—The Price-Pocono extends upward from the Hampshire (Catskill), or, where that formation is absent, from the Chemung formation, as along Little Walker, or Brushy, Mountain in Bland, Montgomery and adjoining counties; or from the Brallier shale, as at Bluefield, to the Fort Payne chert, as at Cumberland Gap; or to the St. Louis limestone, as at Little Stone Gap; or to the Warsaw formation, as in the Greendale syncline and near Richlands; or to the Maccrady formation, as at Saltville and at Pulaski.

The name Pocono is here applied in northern Virginia as far south as western Alleghany County, where the formation occurs on the high knobs along the State line. The name Price is applied throughout the region from southern Alleghany and western Botetourt counties to Tennessee.

Character.—The Price-Pocono is generally a clastic formation composed of shale and sandstone but in some places has two or more beds of coal which are most prominent in Pulaski and Montgomery counties. It contains no limestone. The Price facies of the formation southwest of New River has at the bottom locally a quartz conglomerate, the Cloyd (see p. 343), containing quartz pebbles as much as 1½ inches in diameter. Elsewhere, as along the northwest base of Pine Mountain in Smyth County west of Saltville, the basal part is composed of thick- to moderately thick-bedded, fine-grained, purplish sandstone. Near the top the Price is commonly marked by one or more beds of sandstone. At Little Stone Gap, Wise County, the greater part of the Price consists of medium thick-bedded sandstone. (See geologic section 89, and Plate 49C.) Besides the sandstone strata mentioned above, the main constituents of the Price are thin-bedded sandstone, greenish clay, and sandy shale containing relatively thin layers of greenish, micaceous sandstone. A little red shale occurs in the bottom of the Price at Cumberland Gap, as it does in the bottom of the New Providence formation at Irvine and north of Staunton in central Kentucky.

The general character of the Price is shown in the following sections:

Geologic Section 88.—Price formation at Cumberland Gap, Tennessee

	Thickness Feet
Fort Payne chert	
3. Chert, thin bedded	15

	Thickness Feet
Price formation	
2. Shale, arenaceous, with thin layers of shelly sandstone; a few thin layers of faintly reddish shale and a few fossils in the lower 50 feet or so	320
Brallier shale (?)	
1. Shale, black (only about upper 100 feet exposed near railroad station)	

Geologic Section 89.—Price formation in Little Stone Gap, Wise County, Virginia

	Thickness Feet
St. Louis limestone	
Hiatus; Warsaw limestone and Fort Payne chert absent	
Price formation (225 feet)	
3. Sandstone, some faintly reddish, shale partings partly red (Maccrady)	25
2. Sandstone, medium thick bedded, fine grained, greenish	150
1. Shale, greenish, thin layers of sandstone to bottom of exposure	50

The bottom of the Price in the above section was not certainly determined. The formation probably extends lower, and it may be as much as 300 feet thick.

Geologic Section 90.—Price formation on the Clinchfield Railroad on Cowan Branch of Opossum Creek, 6 miles west-southwest of Gate City, Scott County, Virginia

	Thickness Feet
Price formation[a] (971± feet)	
13. Sandstone, thick bedded, siliceous	50
12. Conglomerate	1

[a] Top not certainly determined.

		Thickness Feet
11.	Sandstone, fine grained, laminated, brownish, shale partings; contains *Fenestrellina herrickana* (Ulrich), *F. regalis* (Ulrich), *F. subflexuosa* (Ulrich), *F. tenax* (Ulrich), *Chonetes shumardanus* De Koninck, *Reticularia pseudolineata* (Hall), *Spirifer striatiformis* Meek, *Spiriferina* sp.?, and *Syringothyris* sp., in upper part	200
10.	Not exposed, bridge over Cowan Branch	160
9.	Shale, dark-colored, sandy	45
8.	Sandstone, thick bedded, fine grained; contains *Cystodictya lineata* Ulrich, *Hemitrypa* sp.?, *Fenestrellina herrickana* (Ulrich), *F. tenax* (Ulrich), *Chonetes* aff. *C. shumardanus* De Koninck, *Delthyris novamexicana*? (Miller), *Productus* sp.?, and *Proetus* sp.?	75
7.	Shale, with layers of sandstone (Pl. 7B)	120
6.	Sandstone, rotten, argillaceous; contains *Taonurus* sp.?, *Batocrinus* sp. (Burlington), *Fenestrellina herrickana* (Ulrich), *F. regalis* (Ulrich), *F. tenax* (Ulrich), *Polypora impressa* (Ulrich), *Chonetes illinoisensis* Worthen, *Delthyris novamexicana* (Miller), *Productella concentrica* (Hall)?, *Productus* (*Dictyoclostus*) *burlingtonensis* (Hall), *Productus*, one or more small species,[b] *Spirifer striatiformis* Meek, *Cypricardinia scitula* Herrick, *Schizodus triangularis* Herrick?, *Bucanopsis* sp.?, and *Pleurotomaria* sp.?	20
5.	Shale, olive-colored, crumbly	120
4.	Sandstone, crumbly	60
3.	Shale, soft, olive-colored	120±
2.	Not exposed; thickness slight?	
1.	Shale, black, with *Orbiculoidea* sp. Exposed on railroad at points 1¼ and 2 miles east of Cassard; cf. section east of Dump Creek. (See Pl. 45.)	

Some parts of this section are uncertain, especially the lower part (beds 1-6) which was partly compiled from observations at detached but closely contiguous points on the curve of the rail-

[b] Cf. Herrick, C. L., Denison Univ. Bull., Jour. Sci. Lab., vol. 3, Pl. 3, figs. 18, 20, 22, 25; vol. 4, Pl. 3, figs. 10 and 15.

road. The upper 600 feet (beds 7-12) is not in doubt, but a possible gap may exist between beds 6 and 7. Regardless of possible errors, the section is essentially correct and presents a satisfactory expression of the marine facies of the Price in southwest Virginia.

Geologic Section 91.—In Broadford Gap, 6 miles northeast of Saltville, Smyth County, Virginia

	Thickness Ft.	In.
Warsaw limestone (85± feet?)		
23. Limestone	10	
22. Not exposed; partly Maccrady?	75	
Maccrady formation (70+ feet)		
21. Sandstone, red	5	
20. Not exposed	20	
19. Sandstone, red	45	
Price formation (609 feet)		
18. Sandstone, green, and shale	50	
17. Coal, impure, worthless	2	
16. Shale	10	
15. Coal, impure, worthless		6
14. Sandstone	15	
13. Coal, impure, worthless	1	6
12. Shale	40	
11. Sandstone, 18 inches of conglomerate; with *Syringothyris* sp.	60	
10. Shale	25	
9. Sandstone, thin glauconitic layer at top	5	
8. Sandstone, thin bedded, shale partings, red layers in 2 feet near top; contains *Camarotoechia* sp.?, *Chonetes* sp.?, *Syringothyris* sp.?, *Allorisma* sp.?, *Aviculopecten fragilis* (Herrick)?	200	
7. Sandstone, medium to thick bedded, fine grained, hard, purplish. Conspicuously exposed and strong ridgemaker for miles along Pine Mountain of this region; Broadford sandstone of Reger?[203]	200	

[203] Reger, D. B., Pocono stratigraphy in the Broadtop Basin of Pennsylvania: Geol. Soc. America Bull., vol. 38, pp. 397-410, 1927.

	Thickness Ft.	In.
Chemung formation (?) (250 feet partly exposed)		
6. Not exposed	75	
5. Shale, black	10	
4. Sandstone, thin bedded, shale partings	100	
3. Not exposed	50	
2. Sandstone, thin bedded, with *Camarotoechia* sp. and poorly preserved pelecypods	15	
1. Not exposed to Smyth-Tazewell county line. *Spirifer disjunctus* Sowerby from float derived less than 100 feet below bed 2.		

This section is of especial interest because it shows the overlying Maccrady formation near its type locality, which is 4 miles southwest of Broadford, and also because of the three coal beds in the upper part of the Price. The limits of the Chemung and Price have not been satisfactorily determined by the writer. The reddish sandstone, bed 7, is identical in character with red sandstone elsewhere in the Chemung. Reger,[204] however, reports that it carries *Syringothyris,* and so it should be regarded as Price. The *Camarotoechia* of bed 2 is valueless as an index of age. The Chemung is present not far below bed 2, as shown by the occurrence of *Spirifer disjunctus* Sowerby. *Spirifer disjunctus* occurs immediately below the purplish sandstone of bed 7 in the gorge of Tumbling Run, 4 miles southwest of Saltville, so, in that section, the Chemung certainly extends up to the base of bed 7 and probably the base of that bed can be safely taken as the boundary between the Price and the Chemung.

Geologic Section 92.—Warsaw and Price formations on U. S. Route 19, 2 miles west of Bluefield, Virginia

	Thickness Feet
St. Louis limestone	
Warsaw formation	
10. Mudrock, soft, brownish; contains *Fenestrellina* and *Fenestralia*	55
Maccrady formation	
9. Not exposed	40

[204] Reger, D. B., op. cit., p. 405.

	Thickness Feet
Price formation (360 feet)	
8. Not exposed	100
7. Shale, stiff, sandy, sandstone layers	30
6. Shale, includes a layer of ferruginous rotten rock or leached argillaceous limestone in middle (Pl. 48C); contains *Chonetes* sp., *Productus* two sp., *Syringothyris textus* (Hall)?, *Cypricardinia scitula* Herrick, *Myalina* sp.?, *Streblopteria* cf. *S. squama* Herrick, *Euphemites galericulatus* (Winchell), *Pleurotomaria* sp.?, and *Oxydiscus cyrtolites* (Hall)	55
5. Not exposed	20
4. Shale, dark-colored	5
3. Shale, thin sandstone layers, with *Taonurus* in bottom	130
2. Rotten rock, with *Rhipidomella oweni* Hall and Clarke	5
1. Sandstone, with beds of conglomerate as much as 1 foot thick (Pl. 48D); contains *Camarotoechia sappho* (Hall), *C.* cf. *C. contracta* (Hall), *Schuchertella crenistria* (Phillips)?, *Rhipidomella* sp.?, *Punctospirifer solidirostris* (White), *Syringothyris textus* (Hall), *Aviculopecten cooperi* Herrick, and *Paracythere granopunctata* Ulrich and Bassler	15
Hiatus; Chemung absent	
Brallier shale	

The fossils listed in the preceding sections show that the Price facies of the Price-Pocono formation in southwestern Virginia is of marine origin, except possibly its upper beds with coal in the Broadford section in Pine Mountain. A thin coal or carbonaceous layer with fossil plants occurs as far southwest as Big Moccasin Gap, 2 miles southeast of Gate City, Scott County. The Price with marine fossils extends along the northwest side of the Valley to New River. The section 2 miles west of Bluefield, Virginia, as well as another section just to the south, shows marine fossils throughout with no trace of coal. Marine fossils occur in the Price in Caseknife Ridge just south of Pulaski, and also on Poverty Creek, 7 miles west of Blacksburg, Montgomery County, where a rusty sandstone 10 feet thick, overlying a conglomerate 1 foot thick, contains an abundance of *Chonetes* cf. *C. illinoisensis*

Worthen, also *Spiriferina depressa* Herrick, and an ostracode, a species of *Barychilina.* The position of this bed is about midway between the Cloyd conglomerate at the base of the Price and the Merrimac coal bed, the main bed of the Price of the region. This is the northeasternmost occurrence of marine fossils in the Price known to the writer, but doubtless the marine beds extend farther in that direction.

The occurrence of coal in the Price is of great interest, both on account of its economic importance and also on account of the fact that it is, with the exception of coal of Devonian age in the island of Spitzenberg, probably the oldest commercial coal in the world. The coal of southern Scotland seems to be nearly of the same age. These Price-Pocono coals have been fully described by Campbell and Holden. According to Campbell,[205] "Coal beds occur at many horizons in the Price formation, but the most important beds are found near its middle. Several measurements in this region [Montgomery County] show that the most important coal beds are about 1000 feet above the base of the formation marked by the contact of the conglomerate member ["Ingles" conglomerate] and the underlying Devonian sandstone, and about 700 feet below the base of the red shale overlying the Price formation [Maccrady shale]." The coal is usually classed as semianthracite. The thickest beds are in Montgomery, Pulaski, Wythe, and Bland counties. Most of the mining has been done in the Merrimac bed in Montgomery and Pulaski counties, where that bed reaches its maximum thickness of about 15 feet, including its partings of shale. The coal is generally rather high in ash, but the best of it compares favorably with the anthracite coal of Pennsylvania.

Cloyd conglomerate member.—The conglomerate member of the Price, lying at its base, is a coarse-grained, white quartz sandstone having lenses and layers of conglomerate with quartz pebbles as much as 1½ inches in diameter. The name Ingles conglomerate has been applied to this sandstone, because a similar sandstone occurs in Ingles Mountain a few miles southeast of Radford, Montgomery County. The sandstone in Ingles Mountain, however, is the Clinch sandstone, of Silurian age. Just beneath it lie beds containing *Orthorhynchula linneyi* (James) and *Lingula nicklesi* Bassler, the two main guide fossils of the *Orthorhynchula* zone at the top of the Martinsburg shale. The name Cloyd conglomerate is here substituted for Ingles from the strong development and conspicuous exposure of the sandstone in Cloyd Mountain, the

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

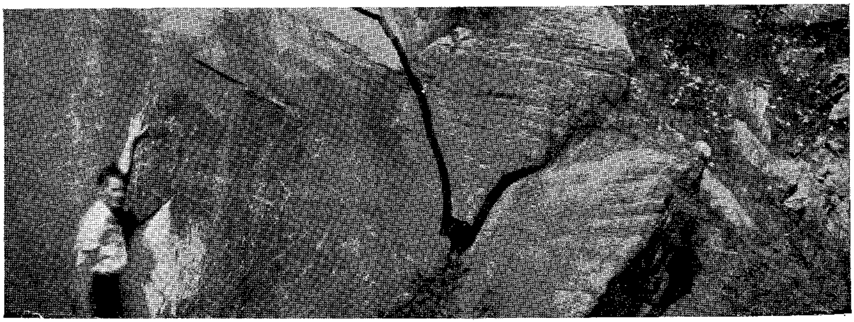
PLATE 48

A. Loyalhanna facies of the Ste. Genevieve limestone. This is a cross-bedded siliceous limestone. Along West Virginia Route 56, one-fourth of a mile north of Fill Run school, 3 miles northwest of Durbin. This point is near the beginning of the transition of the typical Ste. Genevieve to the Loyalhanna facies which persists northward and becomes most perfectly developed in the vicinity of Johnstown, Pa.

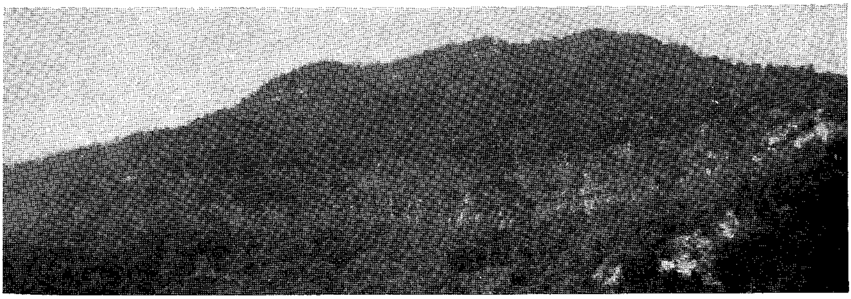
B. Ledge of Ste. Genevieve and Gasper limestones on the southeast escarpment of the Pinnacle at Cumberland Gap. Above this ledge in the trees is the Glen Dean limestone from which the fossils of the list, p. 383, were collected. The summit is occupied by the basal part of the Lee sandstone of Pottsville age. The Gap is at the low sag in the crest on the left. The escarpment is 1000 feet high. Looking northwest.

C. Shale and thin-bedded sandstone of the Price formation. Along U. S. Route 19, about 2 miles southwest of Bluefield, Va. Looking southwest.

D. Basal beds of the Price formation, near Bluefield, Va. Same locality as C. The strata are overturned. The bottom bed is rather thick-bedded sandstone with *Syringothyris*. It is not far below the beds shown in C. This bed rests upon Brallier shale, as the Chemung, Hampshire, and Kinderhook formations are absent here. Looking southeast.

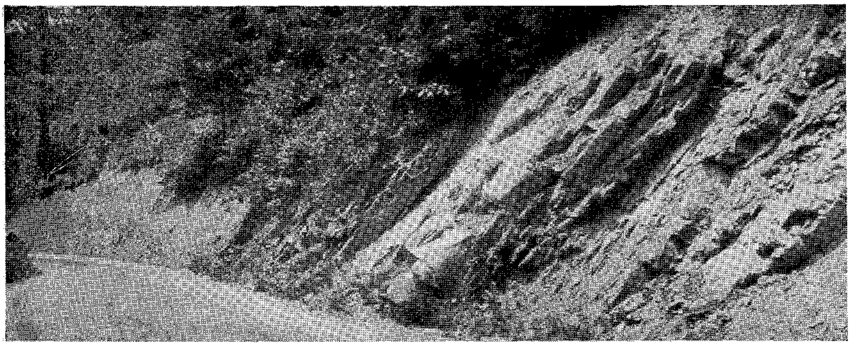


A



B

C

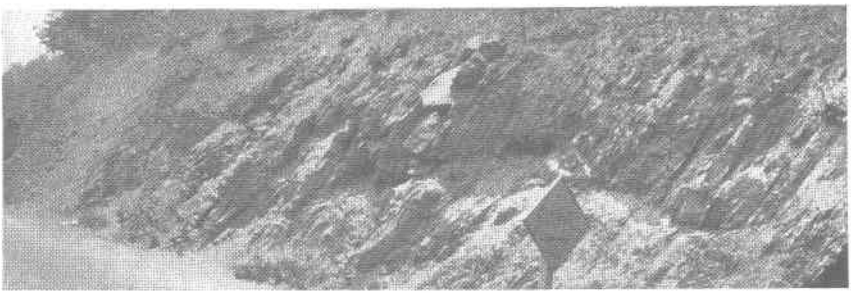


D

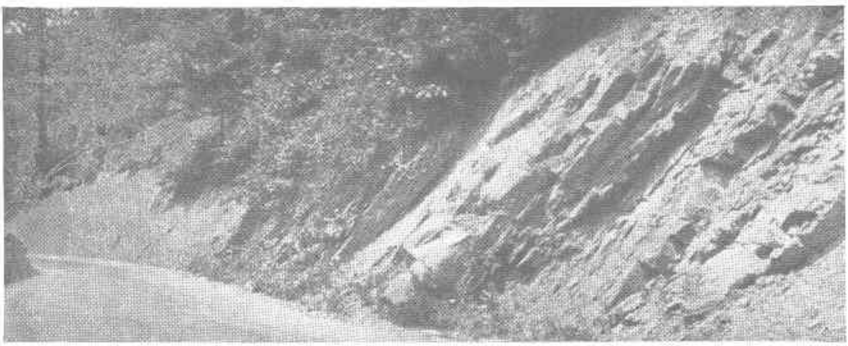
MISSISSIPPIAN FORMATIONS

A

B

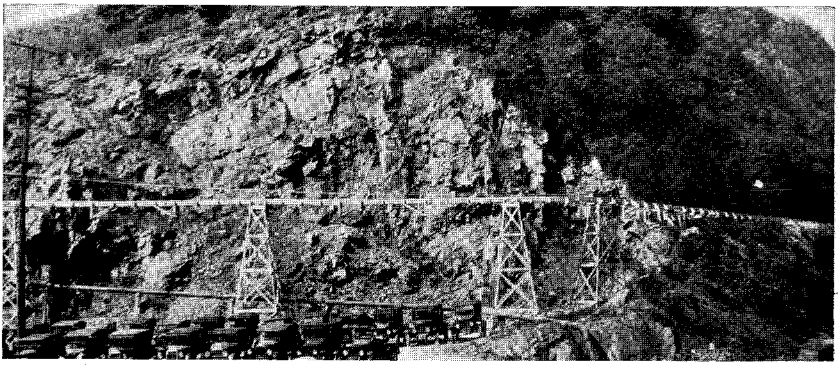


C

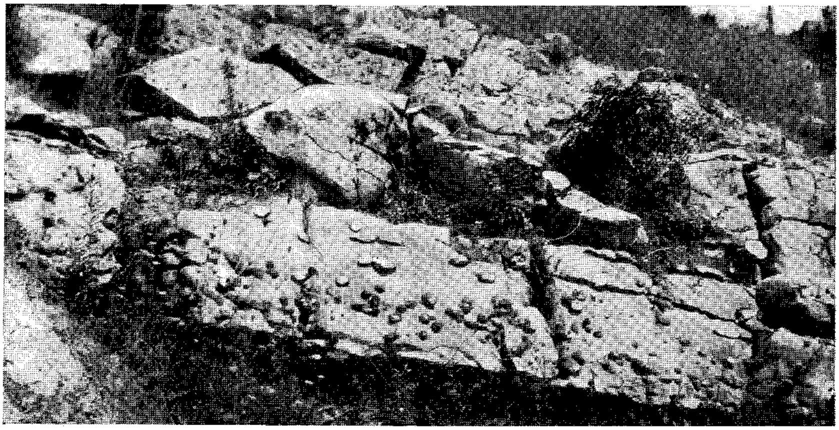


D

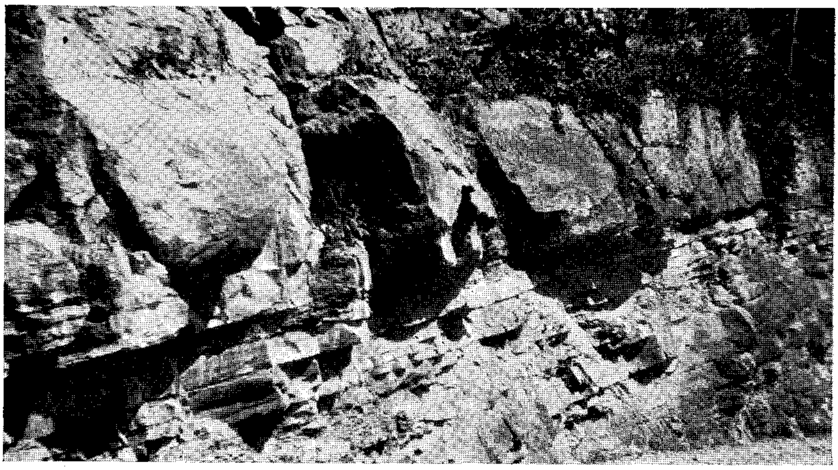
MISSISSIPPIAN FORMATIONS



A

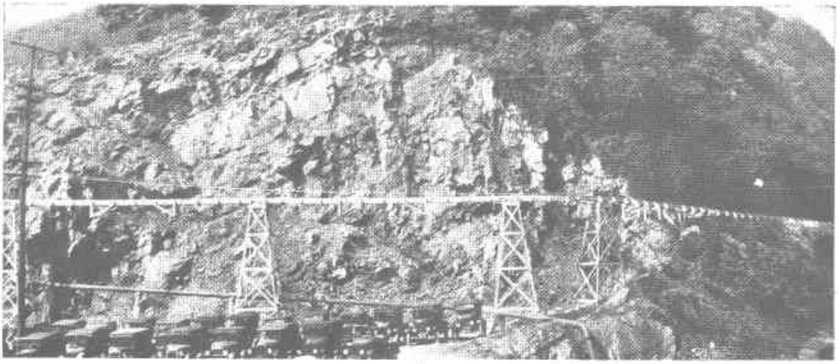


B

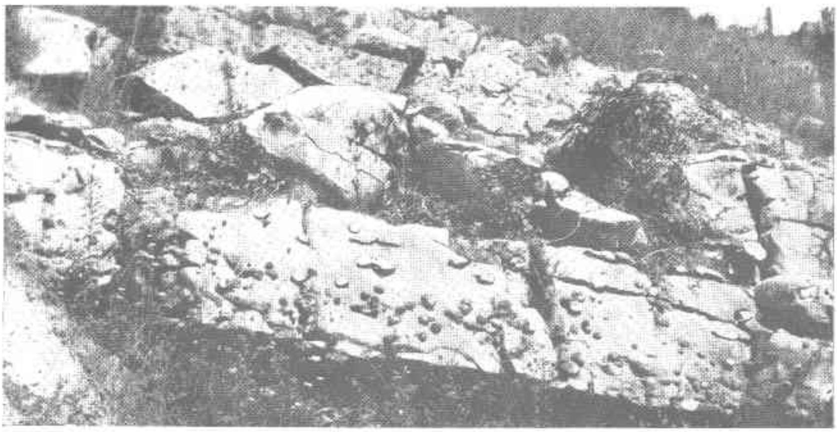


C

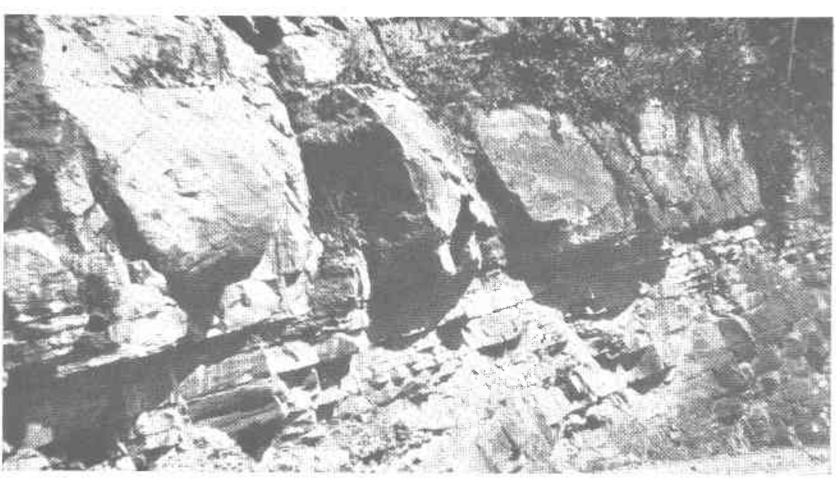
MISSISSIPPIAN FORMATIONS



A



B



C

MISSISSIPPIAN FORMATIONS

PLATE 49

A. St. Louis limestone near Saltville, Smyth County. Just southwest of the Mathieson Alkali Works. Looking southwest.

B. St. Louis limestone, with nodules of black chert, in Tazewell County. Along road beside Lowe Branch, and 600 feet southeast of the Norfolk & Western Railroad, about 1 mile northwest of Bandys Chapel (Baptist Valley). Looking northeast.

C. Evenly bedded uppermost sandstone of the Price formation overlain by the massive basal bed of St. Louis limestone. In Little Stone Gap, 6 miles northeast of the town of Big Stone Gap, Wise County. Looking northeast.

part of Little Walker Mountain southwest of New River in Pulaski County.[206]

The Pocono facies of the Price-Pocono formation is almost entirely a coarse-grained, gray, thick-bedded sandstone with only a little shale, so far as known, and no commercial coal beds. Thin coals occur in some localities as near North River Gap (Stokesdale) in Augusta County, where a small quantity has been mined for local use.

Distribution.—The main bodies of the Price formation occur in Pine Mountain in Scott, Washington, and Smyth counties along the northwest limb of the Greendale syncline and northeastward beyond the syncline to a point northwest of Ceres, Bland County; in a long area extending from Max Meadows northeast along the southeast slope of Little Walker, or Brushy, Mountain, to Millers Cove west of McAfee Gap, Roanoke County; and the Price Mountain area south of Blacksburg, Montgomery County. The last two areas include the outcrops of most of the workable coal beds. A belt strictly marine and without coal, extends from Cumberland Gap along the Cumberland escarpment to the head of the Big Stone Gap cove and thence southward around the south end of Powell Mountain to the great St. Paul fault near Duffield. Another belt extends through Bluefield, Virginia, into West Virginia at the Narrows of New River. The main area of the Pocono facies is the synclinal area extending from North River Gap, Augusta County, to a point north of Rawley Springs, Rockingham County. Elsewhere it is confined to a few high summits in Augusta and Rockingham counties, as Elliott Knob in Augusta County; and a few very small areas on high knobs along the Virginia-West Virginia line as far south as western Alleghany County. Some of the State-line areas are shown on the geologic map, but most of them have been omitted through oversight or lack of knowledge. Such areas are on High Knob, 1 mile southwest of U. S. Route 33, northwest of Rawley Springs; on Reddish Knob, 2 miles southwest of the crossing of the Briery Branch road; and on Hightop, 4½ miles southwest of Mountain Grove, Bath County.[207].

The best expression of the Price formation is in Pine or Little Mountain and Little Walker-Brushy-Cloyd Mountain. Pine Mountain lies about 1 mile southeast of Clinch Mountain. The Price formation is well exposed at the localities of geologic sections 88-91, and can be easily examined at those places. Fossils

[206] See U. S. Geol. Survey topographic map of the Dublin quadrangle.

[207] These areas are shown on the county geologic maps of West Virginia, by the West Virginia Geological Survey.

can be collected at Cowan Branch; Bluefield, Virginia; and at Broadford Gap. Good partial exposures may be seen at the clay pit just southwest of Richlands and on the road from Richlands to Cedar Bluff about 1 mile southeast of Richlands. Good collections of fossils have been made at those places. A fine exposure of almost the full thickness of the Price is along the road southeast of Bluefield, Virginia. Much of the Price can be seen on New River in the vicinity of the Parrott mine, on Poverty Creek, 5 miles northeast of New River, and along U. S. Route 23, from Toms Creek to the top of Brushy Mountain.

An excellent display of the Pocono facies may be seen on Stone Coal Creek in the northeast corner of the Salem quadrangle, and on the southeast slope of Caldwell Mountain in the southwest corner of the Eagle Rock quadrangle. The Cloyd ("Ingles") conglomerate is exposed on the top of Brushy Mountain on U. S. Route 23 and is especially well developed and exposed on the southeast slope of Cloyd Mountain, where it makes broad white sloping surfaces on the mountain side conspicuously visible from the plain and roads north of Dublin, Pulaski County.

The best exposures of the Pocono sandstone are at Rawley Springs, Rockingham County, and at North River Gap or Stokesdale, Augusta County. Good exposures are at the top of Elliott Knob, Augusta County, and on Hightop on the State line 4½ miles southwest of Mountain Grove, Bath County.

Thickness.—The Price is about 300 feet thick at Cumberland Gap and at Little Stone Gap, Wise County. In Pine Mountain it has a thickness of about 1000 feet. It is 609 feet thick in Broadford Gap if the base of Broadford sandstone is taken as the bottom. At and near Bluefield, Virginia, the thickness is 360 feet. Campbell[208] reports a thickness of 1700 feet in Brushy and Price mountains in Montgomery County, and about 600 feet in Bland and eastern Smyth counties. The Price evidently reaches its maximum thickness, as well as the maximum thickness of its coal beds, in Montgomery and Pulaski counties.

Fossils and correlation.—The Price part of the Price-Pocono formation in the southwestern part of the State is, as shown by fossils, predominantly of marine origin. Some beds are highly fossiliferous and collections, including a considerable number of species, were hastily made in the course of the survey for this report. Information as to the regional and stratigraphic distribution of the fauna is afforded by the lists in the geologic sections of the Price. It is probable that with additional search the number of

[208] Campbell, M. R., op. cit., p. 24.

species could be doubled and better specimens could be obtained. Not all of the identifications are certain, but they are reasonably reliable for nearly all the species given in the following list.

Fossils from the Price formation in Virginia

Plants
- Lepidodendron scobiniforme Meek
- Triphyllopteris lescuriana (Meek)

Worm trails?
- Taonurus cf. T. crassus (Hall)

Crinoids
- Batocrinus sp.
- Platycrinus sp.

Bryozoa
- Cystodictya americana Ulrich
- Cystodictya lineata Ulrich
- Fenestrellina herrickana (Ulrich)
- Fenestrellina meekana (Ulrich)
- Fenestrellina regalis (Ulrich)?
- Fenestrellina subflexuosa (Ulrich)
- Fenestrellina tenax (Ulrich)
- Polypora impressa (Ulrich)?
- Rhombopora, several sp.

Brachiopods
- Athyris aff. A. crassicardinalis White
- Athyris lamellosa (Leveille)
- Camarotoechia cf. C. contracta (Hall)
- Camarotoechia sappho (Hall)
- Chonetes illinoisensis Worthen
- Chonetes shumardanus De Koninck
- Chonetes, several other species
- Cliothyridina glenparkensis Weller
- Cryptonella (Terebratula) inconstans (Herrick)
- Delthyris novamexicana (Miller)
- Dielasma burlingtonensis White
- Eumetria cf. E. osagensis (Swallow)
- Productella concentrica (Hall)?
- Productus (Dictyoclostus) burlingtonensis Hall
- Productus duplicostatus A. Winchell
- Productus (Dictyoclostus) fernglenensis? Weller

Productus, several small species
Productus (Worthenella) wortheni Hall
Pseudosyrinx cf. P. gigas Weller
Punctospirifer solidirostris (White)
Reticularia cooperensis (Swallow) ?
Reticularia pseudolineata (Hall)
Rhipidomella oweni Hall and Clarke
Schuchertella crenistria (Phillips) ?
Spirifer imbrex? Hall
Spirifer cf. S. marionensis Shumard
Spirifer striatiformis Meek
Spirifer winchelli Herrick
Spiriferella? schucherti (Rowley)
Spiriferina depressa Herrick
Spiriferina cf. S. octoplicata (Sowerby)
Syringothyris texta (Hall)

Pelecypods
Allorisma consanguinatus Herrick
Aviculopecten cooperi Herrick
Aviculopecten cf. A. newarkensis Winchell
Conocardium pulchellum White and Whitfield
Crenipecten crenistriatus Meek?
Cypricardella aff. C. bellistriata (Conrad)
Cypricardinia scitula Herrick
Dexiobia? sp.
Goniodon ohioensis Herrick
Leda sp. ?
Myalina sp.?
Palaeoneilo cf. P. marshallensis Winchell
Schizodus cf. S. chemungensis Hall
Schizodus triangularis Herrick
Sphenotus cf. S. senilis (Herrick)
Streblopteria media Herrick
Streblopteria squama Herrick?

Gastropods
Bucanopsis sp.
Euphemites galericulatus (Winchell)
Loxonema cf. L. yandellanum Hall
Oxydiscus cyrtolites (Hall)
Pleurotomaria stella Winchell
Pleurotomaria sp.?

Cephalopods
    Orthoceras indianense Hall

Trilobites
    Phillipsia meramecensis Shumard
    Proetus sp.?

Nearly all the fossils of the list occur in the Cuyahoga formation of Ohio. Especially significant for correlation with the Cuyahoga are *Euphemites galericulatus, Oxydiscus cyrtolites,* and the species of *Streblopteria.* Such species as *Athyris lamellosa, Chonetes shumardanus, Rhipidomella oweni,* and *Syringothyris texta* correlate the Price with the New Providence formation of Kentucky and southern Indiana which can be traced into the Cuyahoga of Ohio on the one hand, and on the other correlated through its crinoids found in Button Mould Knob south of Louisville, Kentucky, and in Tennessee, with the Burlington limestone of the Mississippi Valley. Certain plant fossils, such as species of the fern *Triphyllopteris, Lepidodendron corrugatum* and *L. scobiniforme* (see Fossil Plates) occurring in association with the coal beds of the Price at different places as far south as Big Moccasin Gap, 2 miles west of Gate City, Scott County, show the equivalence of the Price with the Pocono of Pennsylvania. Plants are reported from the coal in the Pocono in North River Gap, Augusta County. They occur rather abundantly at an old mine on Stony Fork of Reed Creek just 6 miles northwest of Wytheville, Wythe County, and in the dump from the Lewis tunnel on the Chesapeake and Ohio Railroad half a mile east of Alleghany Station, Alleghany County. David White collected these plants also in a gap of Pine Mountain, 2 miles east of Gate City, Scott County.

MACCRADY SHALE (RESTRICTED)

Name.—The Maccrady shale was named by Stose[209] from the village of Maccrady, 2 miles northeast of Saltville. This shale was also named Pulaski shale by Campbell[210] from Pulaski, Pulaski County, where it is thick and well exposed. The name Pulaski was, however, preoccupied and was necessarily abandoned. The main body of rocks included in the Maccrady of Stose is of Warsaw age and can not, according to prevailing geologic usage, be included in the same formation with the red shale (Maccrady restricted) at its base which is of Osage age and closely related to

[209] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, p. 234, 1913; Virginia Geol. Survey Bull. 8, pp. 51-73, 1913.

[210] Campbell, M. R., Paleozoic overlaps in Montgomery and Pulaski counties, Virginia: Geol. Soc. America Bull., vol. 5, pp. 171, 178, 1894.

the Price formation, of which it might properly be regarded as a member. Hence, the Maccrady is restricted to the red beds at the base of the Maccrady as defined by Stose. In the section published by Stose,[211] the lower bed, 90 feet thick, seems to be based on an exposure at Broadford and includes all the red rock of the Maccrady (restricted) and perhaps some of the upper Price as indicated by the three thin layers of impure coal that occur in the Broadford section a short distance below the red shale. (See geologic section 91.)

Limits.—The Maccrady directly overlies the Price. In the Greendale syncline, including the type locality, and in the Big Stone area, the overlying formation is of Warsaw age.

Character.—The Maccrady throughout its main areas is composed mainly of coarse-grained lumpy red shale or sandy mudrock. The following section at the curve on the railroad track just west of town shows all of the formation exposed at Macrrady:

Geologic Section 93.—Maccrady formation (restricted) near Maccrady, Smyth County, Virginia

	Thickness Feet
Warsaw limestone (lower 35 feet)	
5. Limestone, argillaceous, fossiliferous	30
4. Shale, gray	5
Maccrady formation (60 feet)	
3. Not exposed	30
2. Shale, red	30
Price formation	
1. Sandstone, gray and green, fine grained	10

In this section there can be no more than 60 feet of Maccrady (restricted) even if the covered interval is fully occupied by red shale.

Another, and completely exposed, section of the Maccrady in the same belt is on the Holston River road 2 miles southeast of Hayter Gap village, and north of the river opposite the mouth of Finley Creek:

[211] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, p. 233, 1913.

Geologic Section 94.—Maccrady formation (restricted) southeast of Hayter Gap village, Washington County, Virginia

	Thickness Ft.	In.
Warsaw formation (lower 22 feet)		
11. Shale, green	15	
10. Limestone	2	
9. Shale, green	5	
Maccrady formation (39+ feet)		
8. Shale, red	10	
7. Limestone, argillaceous	10	
6. Shale, green	3	
5. Shale, red	6	
4. Limestone, yellow	0	6
3. Shale, red	6	
2. Shale, blue	4	
Price formation		
1. Sandstone, thick bedded	20±	

This is the only section seen by the writer in which the Maccrady contains any rock other than red shale or mudock, or beds that may even be classed as coarse-grained, loosely cemented sandstone. However, the reddish sandstone with partings of red shale in the top of the Price at Little Stone Gap, Wise County, has been referred to the Maccrady by Stose.[212]

Red shale with fossils occurs a few hundred feet west of Horton Summit, or Sunbright Station, 2 miles northeast of Duffield, Scott County. The section here is as follows:

Geologic Section 95.—Maccrady and overlying formations near Duffield, Scott County, Virginia

	Thickness Feet
Ste. Genevieve limestone	
4. Limestone, thick bedded, oolitic, with *Platycrinus penicillus* Meek and Worthen	75±
St. Louis limestone	
3. Limestone, medium thick bedded, blue gray, finely crystalline, with *Lithostrotionella prolifera* (Hall)	13

[212] Stose, G. W., *in* The Geology and Mineral Resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, pp. 52-53, 1926.

	Thickness Feet
Maccrady formation (40 feet)	
2. Shale, red	10
1. Shale, red with compact non-fissile layers; contains Cuyahoga fauna composed of *Athyris lamellosa* (Leveille), *Chonetes* aff. *C. illinoisensis* Worthen, *C. shumardanus* De Koninck, *Cliothyridina* sp.?, *Productus rushvillensis* Herrick?, *Reticularia cooperensis* (Swallow)?, *Rhipidomella* cf. *R. dimunitiva* Rowley, *Rhipidomella* sp., *Spirifer* cf. *S. marionensis* Shumard, *Spiriferella? schucherti* (Rowley), *Spiriferina depressa* Herrick, *Punctospirifer subellipticus* (McChesney), *Conocardium pulchellum* White and Whitfield, *Streblopteria media* Herrick, and *Phillipsia meramecensis* Shumard	30

The characteristic feature of the Maccrady (restricted) is its red color. The correlation of the Maccrady with the red shale at Pulaski and elsewhere, as made by Stose and by Campbell, was based on this feature as well as on the stratigraphic position of the red shale which everywhere overlies the Price.

Distribution.—The Maccrady red shale has been observed as far southwest of Saltville along Holston River as the meridian of 82 degrees, about opposite the mouth of Toole Creek. Here it is 20 feet thick. If it extends farther southwest, as to U. S. Route 19, it should crop out in the river beneath the bridge, 2 miles northwest of Greendale and not be visible.

Northeast of Saltville, on the southeast slope of Brushy Mountain the Maccrady occupies a wide area, and it extends thence northeast along the strike as far as State Route 8, near the head of Toms Creek, 3 miles north of Blacksburg. Along this strike it crops out in several elongate detached belts, as shown on the geologic map. In intervening belts it has been faulted out or covered by overthrust masses of older rocks. The Maccrady is present as a thin bed from Bluefield, Virginia, to the Narrows of New River at a point half a mile southeast of Rich Creek. This outcrop continues northeast and the red shale is finely exposed and of considerable thickness a quarter of a mile northwest of Red Mill and 1½ miles northwest of Gap Mills, West Virginia. It extends along this outcrop belt farther northeast to U. S. Route 60, about half a mile southeast of Alleghany Station, Alleghany County, where a small area occupies the bottom of a small syncline. This is the northeasternmost area of the Maccrady known.

The best exposures of the Maccrady are on New River at Churchwood and south of Parrott; on State Route 8, just south of Toms Creek, 3 miles north of Blacksburg; on State Route 100, about 8 miles north of Dublin; and west and north of Pulaski. There is a partial exposure at the southeast entrance to Broadford Gap.

Thickness.—As shown by the preceding sections, the Maccrady probably is not more than 50 or 60 feet thick on the northwest side of the Greendale syncline. It seems to be much thicker on the southeast slope of Brushy Mountain north of Chatham Hill, Smyth County. At Churchwood on New River, Campbell[213] estimated the thickness as 800 feet. On State Route 8, about 3 miles north of Blacksburg, a thickness of apparently 200 feet is exposed along an overthrust fault.

Fossils and correlation.—No fossils either of plants or animals have been found in the Maccrady, except at Sunbright, Scott County, as listed in geologic section 95. That fauna is clearly Cuyahogan. If the red rock containing it is truly Maccrady and not a red bed belonging in the Price, the Maccrady is proved by this fauna to be of Cuyahoga age and therefore should be grouped with the Price as Osagian.

HIATUS

The Maccrady is succeeded by rocks of Warsaw age in the Greendale syncline and by St. Louis limestone in other places. A hiatus thus exists above the Maccrady because beds of Keokuk age are generally absent, or beds of both Keokuk and Warsaw ages are missing, as at Sunbright and Little Stone Gap. (See geologic sections 89 and 95.)

FORT PAYNE CHERT

Name.—The Fort Payne chert was named[214] from Fort Payne, De Kalb County, Alabama.

Limits.—Cumberland Gap is the only place where the Fort Payne is present in Virginia. Here it succeeds the Price formation and is overlain by the St. Louis limestone as the Warsaw formation is absent.

[213] Campbell, M. R., op. cit.

[214] Smith, E. A., *in* Squire, Joseph, Report on the Cahaba coal field: Alabama Geol. Survey, pp. 155-156, 1890.

Character.—In Virginia the Fort Payne is a bedded chert with partings of shale. The layers of chert are about 2 to 6 inches thick.

Distribution.—The Fort Payne has been observed only at Cumberland Gap on the highway, 350 feet southeast of the summit at the Gap, where it is fully exposed. It may extend some distance northeastward along the face of the Cumberland escarpment. The formation occupies a very extensive area to the southwest of Cumberland Gap in Tennessee and Alabama.

Thickness.—The Fort Payne at Cumberland Gap is 20 feet thick.

Fossils and correlation.—No fossils have been obtained from the chert in Virginia. It is identified as Fort Payne on account of its lithological character and stratigraphic position. The main body of the Fort Payne chert is of Keokuk age, as determined by fossils collected in Alabama and Tennessee.

WARSAW FORMATION

Name.—The Warsaw formation was named by James Hall[215] from Warsaw, Illinois.

Limits.—The Warsaw as used by the writer includes all the beds which lie between the Keokuk limestone, or Fort Payne chert, and the St. Louis limestone. In Virginia the Warsaw rests either upon the Maccrady or the Price formation with an intervening hiatus, except at Cumberland Gap where the Keokuk, or Fort Payne, is present beneath it.

Character.—The Warsaw in Virginia is prevailingly a shale or argillaceous limestone that weathers to shale or coarse-grained mudrock, in which are intercalated layers of limestone and of sandstone. A typical section is exposed on U. S. Route 19, just south of the bridge across the North Fork of Holston River, 2 miles north of Greendale, Washington County. The section at this place follows:

---

[215] Hall, James, Observations upon the Carboniferous limestones of the Mississippi Valley: Am. Assoc. Adv. Sci. Proc., vol. 10, p. 56, 1857.

Geologic Section 96.—Warsaw formation north of Greendale, Washington County, Virginia

	Thickness Feet
St. Louis limestone	
Limestone, thick bedded, black	
Warsaw formation (515+ feet)	
22. Limestone, argillaceous, shaly	30
21. Shale, dark colored	23
20. Shale, black	1
19. Limestone, argillaceous	80
18. Not exposed; soft rock?	30
17. Shale, black, fissile; contains *Tetracamera*? sp., and *Syringothyris* sp.	10
16. Limestone, argillaceous, compact, probably weathers shaly	35
15. Limestone, shaly; fragmentary *Fenestrellina* and *Cystodictya*, abundant	30
14. Limestone, compact, argillaceous, thick bedded	30
13. Limestone, laminated	5
12. Limestone, compact, thick bedded	30
11. Limestone, shaly, fossiliferous, fragmentary, fenestrellinids abundant	65
10. Limestone, coarsely crystalline, bluish, fossiliferous	30
9. Sandstone, medium grained, bluish gray, rather soft	10
8. Limestone, argillaceous, and shale	5
7. Sandstone, coarse grained, cross-bedded	20
6. Not exposed	65
5. Limestone	5
4. Not exposed; river and bridge for distance of about 500 feet. (Warsaw, Maccrady, and Price?)	250±
Price formation	
3. Sandstone reported at bottom of north pier of bridge	(?)

	Thickness Feet
2. Not exposed	30±
1. Sandstone, in road at angle near north end of bridge	5±

It will be noted that this section is 515 feet thick to the bottom of the exposed Warsaw, whereas the corresponding published section[216] is only 465 feet thick. The difference is mainly accounted for in beds 14, 15, and 22 of the above section. As possibly 100 feet or more of the Warsaw is not exposed beneath the river here, it seems safe to estimate the total thickness at 600 feet. Judging from the predominance of shaly argillaceous limestone in this section, it seems probable that the large amount of coarse-grained dark-gray, friable, fossiliferous mudrock commonly displayed on the weathered outcrop of the Warsaw was derived from such limestone through leaching.

The sandstone beds 7 and 9 are of interest, because it seems that the gas in the deep wells at old Early Grove post office, Scott County, 9 miles northwest of Bristol, occurs at or near the horizon of those beds.

Distribution.—The Warsaw is best developed, most persistent, and thickest in the Greendale syncline in which it extends along the northwest limb from Tennessee to Broadford, Smyth County. A narrow belt also extends along the southeast limb of the syncline, next to the Saltville fault, from Cedar Branch to Blackwell, where a few Warsaw fossils were found in characteristic mudrock. The outcrop on the northwest limb of the Greendale syncline follows closely the south base of Pine Mountain. Outside of the Greendale syncline the presence of the Warsaw can not be certainly affirmed although shaly rock or argillaceous limestone and thin layers of purer limestone between the Maccrady or Price, and the St. Louis limestone, may represent the Warsaw, as in the vicinity of Bluefield; 2 miles southwest of Bandy, Tazewell County; and 1 mile southeast of Richlands, Tazewell County.

One of the best exposures of the Warsaw is on the north-south part of the road between Cedar Branch and Maccrady, Smyth County. The exposure on U. S. Route 19, just south of Holston River, described in geologic section 96, is equally good. Another very good display is on the west loop of the road north of Holston River opposite the mouth of Finley Creek, 2 miles southwest of Hayter Gap Village, Washington County.

[216] Butts, Charles, Oil and gas possibilities at Early Grove, Scott County, Virginia: Virginia Geol. Survey Bull. 27, 1927.

Thickness.—The best determinations show a thickness of 500 to 600 feet for the Warsaw in the Greendale syncline.

Fossils and correlation.—The Warsaw is highly fossiliferous. The fossils consist mainly of fenestrellinid bryozoa, but brachiopods of the genera *Spirifer* and *Productus* are common, though of few species. *Spiriferina, Composita,* and *Cliothyridina* are less common. Pelecypods of the genus *Aviculopecten* are common and some of the genus *Posidonomya* (*Caneyella*?) have been found. A list follows:

Fossils from the Warsaw formation in Virginia

Corals
- Amplexus sp.?
- Zaphrentis sp.?

Bryozoa
- Anisotrypa, or Stenopora, sp.
- Cystodictya? sp.
- Dichotrypa flabellum (Rominger)
- Fenestralia sancti-ludovici Prout
- Fenestrellina serratula (Ulrich)
- Fenestrellina tenax (Ulrich)
- Fenestrellina, several closely related species
- Hemitrypa proutana Ulrich
- Polypora biseriata Ulrich
- Polypora varsoviensis Prout
- Rhombopora simulatrix Ulrich
- Septopora sp.
- Tabulipora tuberculata (Prout)

Brachiopods
- Camarotoechia sp.?
- Composita trinuclea (Hall)
- Dielasma? sp.
- Echinoconchus alternatus (Norwood and Pratten)
- Productus (Dictyoclostus) inflatus McChesney?
- Productus (Linoproductus) ovatus Hall
- Productus sp.?
- Spirifer bifurcatus Hall
- Spirifer keokuk Hall
- Spirifer leidyi Norwood and Pratten
- [a]Spiriferina sp.?

[a] Cf. Weller, Stuart, The Mississippian Brachiopoda of the Mississippi Valley basin: Illinois Geol. Survey Mon. 1, pl. 35, figs. 39-40, 1911.

Pelecypods
- Aviculopecten monroensis Worthen?
- Aviculopecten sp.
- Aviculopecten or Crenipecten, 2 sp.
- Goniophora?
- Posidonomya? cf. Caneyella vaughani Girty
- Sanguinolites multistriatus Worthen?

Trilobites
- Griffithides cf. G. portlocki Meek and Worthen

The most diagnostic of these fossils for correlation are *Fenestralia sancti-ludovici, Polypora biseriata, P. varsoviensis,* and *Hemitrypa proutana,* which seem to occur in the Warsaw formation of the Mississippi Valley more generally than in the St. Louis limestone, if, indeed, they occur in the actual St. Louis. The species of *Spirifer* are less diagnostic. *Spirifer keokuk* was referred by Weller to the upper beds of the Keokuk, but since that reference was made it has been agreed by Weller, Girty, and Ulrich that these uppermost beds should be assigned to the Warsaw. As *Spirifer keokuk* is very common in the basal Warsaw in central Kentucky in association with such strictly Warsaw fossils as *Talarocrinus simplex* (Shumard), *Athyris densa* Hall, *Productus magnus* Meek and Worthen, *Spirifer lateralis* Hall, and *Spirifer washingtonensis* Weller, *Spirifer keokuk* Hall can be confidently accepted as a Warsaw fossil. The species *Aviculopecten* with which the Virginia forms are provisionally identified are also Warsaw species of the Mississippi Valley. The Warsaw age of the formation here described is also attested by its position, which is here, as in the Mississippi Valley, immediately beneath the St. Louis limestone which is surely denoted in Virginia by the presence of its two diagnostic fossils *Lithostrotionella "canadensis"* (Castelnau) and *L. prolifera* (Hall).

ST. LOUIS LIMESTONE

Name.—The St. Louis limestone was named by Englemann[217] from St. Louis, Missouri, which is located upon a wide outcrop of the limestone.

Limits.—In Virginia the St. Louis rests upon the Fort Payne chert or upon the Price formation, as in the Cumberland Gap-Big Stone Gap area, and southeast of South Clinchfield, Russell County; upon the Maccrady or possibly upon Warsaw, as at Bluefield, in the Narrows of New River, 1 mile southeast of Richlands, and 2 miles southeast of Bandy, Tazewell County. It is succeeded by

[217] Englemann, Henry, Remarks on the St. Louis limestone: Am. Jour. Sci., 2d ser., vol. 3, pp. 119-120, 1847.

the Ste. Genevieve limestone everywhere from Ste. Genevieve, Missouri, to the Appalachian Valley.

Character.—The St. Louis in Virginia is almost everywhere a thick-bedded, fine-grained, black limestone. (See Pl. 49A.) Some of its beds are marked by abundant nodules, plates, and stringers of black chert (Pl. 49B), but the writer has seen no oolitic beds in it. At Little Stone Gap the formation is composed of two parts as shown in geologic section 99. Some from the Big Stone Gap of Powell River is of lithographic texture, but very little such rock occurs in the St. Louis of Virginia or throughout eastern Kentucky, although such rock is common at St. Louis and locally in central Kentucky. A shale lying next beneath the thick-bedded Ste. Genevieve limestone, at least locally, as on U. S. Route 19 just south of Holston River, and in the Narrows of New River is here included in the St. Louis.

The character and stratigraphic relations of the St. Louis are indicated by the following sections:

Geologic Section 97.—Mississippian formations at Cumberland Gap, Tennessee

	Thickness Feet
Ste. Genevieve limestone	
4. Limestone, oolitic (lowest beds of formation)	27
St. Louis limestone	
3. Limestone, compact, weathers yellowish	2
Fort Payne formation	
2. Chert, thin-bedded, shale partings	15±
Price formation	
1. Shale and argillaceous sandstone	320

Geologic Section 98.—Mississippian formations in the gap of Powell River, 1 mile northwest of Big Stone Gap, Wise County, Virginia

	Thickness Feet
Ste. Genevieve limestone	
4. Limestone, oolitic, with *Platycrinus penicillus* Meek and Worthen in bottom.	
St. Louis limestone	
3. Limestone, impure, cherty, with *Productus* (*Dictyoclostus*) cf. *P. inflatus* McChesney	20

	Thickness Feet
Maccrady shale	
2. Shale, red and green	10
Price formation	
1. Shale and thin sandstone	

Geologic Section 99.—Mississippian formations at Little Stone Gap, Wise County, Virginia

	Thickness Feet
Ste. Genevieve limestone	
4. Limestone, oolitic	
St. Louis limestone (50 feet)	
3. Limestone, cobbly, cherty, with *Productus* cf. *P. inflatus* McChesney[a]	28
2. Limestone, thick bedded, cherty (Pl. 49B)	22
Price or Maccrady formation	
1. Sandstone, partly reddish, red shale partings (Pl. 49C)	25

Geologic Section 100.—Mississippian formations 1 mile south of South Clinchfield, Russell County, Virginia

	Thickness Feet
Ste. Genevieve limestone	
4. Limestone, oolitic, with *Platycrinus penicillus* Meek and Worthen	
St. Louis limestone	
3. Limestone, medium thick bedded, dark-colored, crystalline; contains abundant *Lithostrotionella "canadensis"* (Castelnau), and *Syringopora virginica,* n. sp.	40–50
Price and Maccrady?	
2. Not exposed	100±
Price formation	
1. Shale and sandstone	200±

[a] See Virginia Geol. Survey Bull. 24, Pl. 10B.

Geologic Section 101.—Mississippian formations 2½ miles southwest of Bandy, Tazewell County, Virginia

	Thickness Feet
Ste. Genevieve limestone (?)	
11. Limestone, thin bedded below with no fossils; thicker bedded above with *Platycrinus penicillus* Meek and Worthen 200 feet above bottom. May be St. Louis in lower part	390±
St. Louis limestone (?) (85 feet)	
10. Limestone, thick bedded, dark-colored, crystalline, nodules of black chert abundant (Pl. 49B); contains *Bellerophon sublaevis* Hall and *Strophostylus* cf. *S. carleyanus* (Hall)	25
9. Shale	10
8. Limestone, thick bedded, coarsely crystalline; with *Lithostrotionella "canadensis"* (Castelnau) and *L. prolifera* (Hall), rather abundant	50
St. Louis or Warsaw limestone	
7. Limestone, argillaceous, thin bedded to shaly	50
Maccrady formation (?) (35+ feet)	
6. Mudrock, yellow-green with layers of red rock 1 to 3 feet thick	18
5. Shale or mudrock, red	8
4. Shale	1½
3. Limestone, thick bedded, yellow, argillaceous	8
Price formation, upper part (42 feet)	
2. Shale	2
1. Sandstone, thin bedded, bluish, micaceous to bottom of exposure	40

The only beds in this section whose age is certain are bed 8 with *Lithostrotionella* and the upper 100 feet of bed 11 which contains *Platycrinus penicillus*.. Bed 10 is provisionally referred to the St. Louis because of its lithologic character. The nodules of black chert are practically of general occurrence in the St. Louis of Virginia. *Bellerophon sublaevis* Hall is reported from the St. Louis limestone at St. Louis, and the same, or another large species similar to *B. sublaevis,* occurs in the St. Louis at Ste. Genevieve, Missouri. It is also reported from beds of Chester age, and is either a long-ranging species or has not been closely discriminated in all identifications.

Geologic Section 102.—Mississippian formations in the Narrows of New River on the Norfolk and Western Railroad, half a mile south of Rich Creek, Giles County, Virginia[a]

	Thickness Feet
Ste. Genevieve limestone, basal part	
5. Limestone, coarse grained, crystalline, gray, with *Platycrinus penicillus* Meek and Worthen	8
St. Louis formation (250 feet)	
4. Shale, calcareous	30
3. Limestone, thick bedded, black, crystalline, with nodules of black chert	140
2. Not exposed	80
Maccrady shale	
1. Shale, red, not well exposed	20±

The shale of bed 4 appears to be the same as bed 3 of the following section on U. S. Route 19.

Geologic Section 103.—Mississippian formations in the Greendale syncline on U. S. Route 19, one eighth of a mile south of bridge over Holston River, Washington County, Virginia

	Thickness Feet
Ste. Genevieve limestone, lower part (80 feet)	
5. Limestone, full of nodular chert	15
4. Limestone, thick bedded, gray, coarsely crystalline, cherty; *Platycrinus penicillus* Meek and Worthen abundant	65
St. Louis formation (314 feet)	
3. Shale	50
2. Limestone, thick bedded, black, crystalline; contains *Syringopora virginica*, n. sp., *Orthothetes kaskaskiensis* (McChesney), *Arachaeocidaris* spines and *Melonechinus* plates	264
Warsaw limestone	
1. Limestone (bed 22 of geologic section 96)	30

[a] See Pl. 59B.

The shale, bed 3, of undetermined age, is for convenience included in the St. Louis.

Distribution.—The St. Louis limestone is present in the Greendale syncline from the Tennessee line north to Cedar Branch, about 1 mile northeast of Saltville. It crops out in a narrow strip along the northwest limb of the syncline. Just to the west of Cedar Branch the outcrop swings around the axis of the syncline, which pitches to the southwest, and extends thence southwest along the southeast limb of the syncline to the vicinity of Blackwell where the outcrop is terminated by the Saltville fault. The St. Louis also is present, as a thin layer generally, at the base of the Ste. Genevieve limestone at all places where observations were made along the northwest side of the Valley from Cumberland Gap to the Narrows of New River. Along this strike the St. Louis extends into West Virginia at least as far north as Marlinton, Pocahontas County.

The best places to see the St. Louis are at a point 1½ miles west of Yuma railroad station, 2 miles southwest of Gate City, Scott County; just north of Holston River about one-fourth of a mile east of the bridge on U. S. Route 23, 2 miles south of Gate City, where two species of *Lithostrotionella* are fairly abundant; on U. S. Route 19, one-fourth of a mile south of Holston River and about 2 miles north of Greendale, Washington County; opposite the plant of the Mathieson Alkali Works at Saltville (Pl. 49A); along the railroad on the north side of the gap at Saltville; and about one-third of a mile west of Cedar Branch. On the northwest outcrop the best exposures are about one mile southeast of South Clinchfield, or 1½ miles northwest of Cleveland, Russell County; on the road midway between Bandy and Bandys Chapel (Baptist Valley); and 1 mile south of Richlands, Tazewell County. At these last three places *Lithostrotionella* is abundant. It is also well exposed on the Norfolk and Western railroad in the Narrows of New River, three-fourths of a mile south of Rich Creek, West Virginia.

Thickness.—The thickness of the St. Louis on U. S. Route 19, one-fourth of a mile south of Holston River, including about 50 feet of shale at the top, is 314 feet. On the Cumberland escarpment from Cumberland Gap to Big Stone Gap the thickness is 5 to 20 feet; at Little Stone Gap it is 50 feet; 1 mile southeast of South Clinchfield it is 50 feet; and 1 mile southeast of Richlands it is 115 feet thick and possibly more. On the northwesternmost outcrop 2½ miles southwest of Bandy its thickness is 50 feet or more. In the Narrows of New River, the exposed thickness is 110 feet, and possibly about 100 feet more is unexposed down to the red Maccrady shale.

Fossils and correlation.—The St. Louis is sparingly fossiliferous in Virginia, but the following fossils have been identified:

Fossils from the St. Louis formation in Virginia

Algae
- Genera and species undetermined

Corals
- Lithostrotionella "canadensis" (Castelnau)
- Lithostrotionella prolifera (Hall)
- Syringopora virginica Butts, n. sp., common

Crinoids
- Platycrinus cf. P. penicillus Meek and Worthen (very rare)

Bryozoa
- Dichotrypa flabellum Rominger?
- Fenestralia sancti-ludovici Prout
- Fenestrellina serratula (Ulrich)
- Hemitrypa sp.?
- Polypora biseriata Ulrich
- Polypora cf. P. varsoviensis Prout

Brachiopods
- Cliothyridina hirsuta (Hall)
- Girtyella indianensis (Girty)?
- Orthothetes kaskaskiensis (McChesney)
- Productus (Linoproductus) altonensis Norwood and Pratten
- Productus (Dictyoclostus) inflatus McChesney
- Spirifer bifurcatus Hall
- Spirifer leidyi Norwood and Pratten

Gastropods
- Bellerophon sublaevis Hall
- Strophostylus cf. S. carleyanus (Hall)

The two species of *Lithostrotionella* characterize the St. Louis throughout its extent from Missouri to the Appalachian Valley and are conclusive evidence of the St. Louis age of the limestone here described. *Syringopora virginica*[218] occurs with the *Lithostrotionella*

[218] Specimens of this form from the St. Louis at Glasgow Junction, Kentucky, and probably the same from the St. Louis in Washington County, southern Indiana, are in the U. S. National Museum.

at all points in Virginia and also at almost every exposure of the St. Louis even where *Lithostrotionella* is absent and is therefore a sure guide to the identification of the St. Louis. Neither *Lithostrotionella* nor *Syringopora* has been found along the escarpment from Cumberland Gap to Little Stone Gap. It is of interest that *Lithostrotionella* occurs northeast in West Virginia at least to a point 4 miles southwest of Marlinton, which is almost exactly due east of Morehead, Kentucky, a few miles south of which is the most northern occurrence of *Lithostrotionella* noted by the writer in Kentucky.

STE. GENEVIEVE LIMESTONE

Name.—The Ste. Genevieve limestone was named by Shumard[219] from Ste. Genevieve, Missouri, where the formation was first recognized.

Limits.—The stratigraphic limits of the Ste. Genevieve from the Mississippi Valley to the Appalachian Valley in Virginia south of New River, are, in eastern Kentucky and Virginia, the St. Louis limestone below and the Gasper limestone above, but in western Kentucky and westward, the Bethel, or Aux Vases sandstone, lies above it. This is according to Ulrich's classification for the Mississippi Valley and western Kentucky, about which there are some differences of opinion.

East of Christian County, Kentucky, where the Bethel sandstone thins out, the Ste. Genevieve and Gasper are in contact and are lithologically inseparable notwithstanding the hiatus between them. Ulrich has proposed the name Monte Sano limestone, from Monte Sano near Huntsville, Alabama, to include both formations. However, it has been the general practice to separate the two units by means of the fossils. The Ste. Genevieve contains the diagnostic fossil *Platycrinus penicillus* Meek and Worthen which does not occur in the Gasper, and the Gasper contains several species of the crinoid *Talarocrinus,* none of which occur in the Ste. Genevieve as delimited in Virginia. These fossils occur so near together that the boundary can be located approximately within a small margin of error.

Character.—The Ste. Genevieve limestone occurs in Virginia in two different facies; pure oolitic limestone along the Cumberland escarpment and the northwestern margin of the Valley next to the coal fields, and predominant shale with subordinate limestone beds along the middle belt of the Greendale syncline from Saltville, Smyth County, to Tennessee. A section measured on the escarpment of the Pinnacle at Cumberland Gap follows:

---

219 Shumard, B. F., Observations on the geology of the County of Ste. Genevieve, Missouri: St. Louis Acad. Sci. Trans., vol. 1, p. 406, 1860.

Geologic Section 104.—Ste. Genevieve limestone at Cumberland Gap, Tennessee

	Thickness Feet
Gasper limestone	
9. Limestone, gray, oolitic	
Ste. Genevieve limestone (85 feet)	
8. Limestone, gray, oolitic, with *Platycrinus penicillus* Meek and Worthen at top	25
7. Limestone, compact, buff	5
6. Limestone, light gray, crystalline; contains *Productus (Linoproductus) ovatus* Hall, and *Composita trinuclea* (Hall)	10
5. Limestone, compact, bluish	10
4. Limestone, oolitic, fossiliferous	5
3. Limestone, compact, thin bedded, variegated purplish and grayish	5
2. Limestone, oolitic, thick bedded, gray; contains *Platycrinus penicillus* Meek and Worthen and *Michelinia* sp.	25
St. Louis limestone	
1. Limestone, yellowish, compact, a single bed	2

The cliff beneath the Pinnacle at Cumberland Gap, the lower half made by the Ste. Genevieve, and the upper half by the Gasper, is shown in Plate 48B. The Ste. Genevieve is substantially the same in character northeastward along the Cumberland escarpment through Big Stone Gap, Little Stone Gap, and Sunbright near Duffield, to the syncline between South Clinchfield and Cleveland. Farther northeast, as in the belt between Bandy and Bandys Chapel (Baptist Valley), Tazewell County, the Ste. Genevieve appears to be a more generally compact non-oolitic limestone, as shown in the following section:

Geologic Section 105.—Ste. Genevieve limestone between Bandy and Bandys Chapel (Baptist Valley), Tazewell County, Virginia

	Thickness Feet
Gasper limestone (lower part)	
10. Limestone, medium thick bedded, compact, blue with *Pentremites* abundant	50±

	Thickness Feet
Ste. Genevieve limestone (390 feet)	
9. Limestone, compact, blue, with *Platycrinus penicillus* Meek and Worthen	25
8. Limestone, crinoidal, thick and thin bedded, bluish gray, crystalline; some argillaceous layers; nodules of black chert, generally small; contains small *Pentremites, Platycrinus penicillus* Meek and Worthen, and *Cliothyridina* sp.	55
7. Limestone, mainly thick bedded, compact, blue	140
6. Limestone, compact, blue, evenly thin bedded	35
5. Limestone, argillaceous and pure, crinoidal; contains *Platycrinus* bases and elliptical stem plates but without spines so far as observed	25
4. Limestone, more or less argillaceous, thick bedded	35
3. Limestone, argillaceous, shaly	35
2. Limestone, thin bedded	40
St. Louis limestone	
1. Limestone, cherty (Bed 10 of geologic section 101).	

The boundary between the Ste. Genevieve and the St. Louis is uncertain in this section. The St. Louis may extend up to bed 5.

One of the best exposures of the Ste. Genevieve in the State, seemingly all compact limestone, is found 3 miles northeast of Bluefield, West Virginia. The section begins at the top on the Norfolk and Western Railroad at a point about south of Rocky Gap and extends southeast across the narrow valley.

Geologic Section 106.—Ste. Genevieve limestone, 3 miles northeast of Bluefield, West Virginia

	Thickness Feet
Gasper limestone	
5. Limestone, compact, blue; contains *Talarocrinus* sp. and *Dizygocrinus* sp. 50 feet above base	
Ste. Genevieve limestone	
4. Limestone, compact, bluish gray, rather thick bedded; *Platycrinus penicillus* Meek and Worthen at very bottom and at the top in the railroad cut	400

	Thickness Feet
St. Louis limestone (180 feet)	
3. Limestone, dark-colored, cherty, scattered exposures..	30
2. Not exposed; mostly float of black cherty and blue slabby limestone	150
Maccrady formation	
1. Soil, red, and fragments of red shale	20±

In the Narrows of New River the character is similar, but 100 feet of shaly limestone occurs at the top. The character of the Ste. Genevieve in the Greendale syncline is illustrated by the following section, nearly all exposed on U. S. Route 19, between Greendale and Holston River, beginning at the bottom about half a mile south of the river.

Geologic Section 107.—Ste. Genevieve formation between Greendale and Holston River, Washington County, Virginia

	Thickness Feet
Fido sandstone	
27. Sandstone, thick bedded, friable, red; *Pentremites maccalliei* Schuchert? persistent	50±
Gasper limestone	
26. Limestone, *Talarocrinus* sp. at top; base undetermined	1025±
Ste. Genevieve formation (1502 feet)	
25. Red rock, gnarly, calcareous, argillaceous, sandy and ferruginous; crowded with curled fenestrellinid bryozoa, persistent in the Greendale syncline	60
24. Limestone, argillaceous, shaly	15
23. Sandstone, brown, soft, stained red on joint faces	30
22. Limestone, argillaceous, shaly	15
21. Limestone, sandy, coarse grained, crinoidal layers	30
20. Limestone, thick bedded, argillaceous, weathers shaly	160
19. Sandstone, bluish, fine grained, calcareous	2
18. Limestone, like bed 20	240
17. Shale; weathered argillaceous limestone?	50
16. Limestone, thick bedded, argillaceous	60
15. Limestone, coarse grained, crinoidal, with *Platycrinus penicillus* Meek and Worthen	30

	Thickness Feet
14. Limestone, thick bedded, argillaceous	100
13. Limestone, shaly	60
12. Shale	60
11. Limestone, thick bedded; breaks down into shaly debris	50
10. Limestone, medium thick bedded, coarse grained, blue gray, sandy; *Platycrinus penicillus* Meek and Worthen, bases in bottom	60
9. Limestone, coarsely crinoidal; *Hydreionocrinus* spines	30
8. Limestone, argillaceous, shaly	5
7. Sandstone, evenly bedded, soft, red layers 6 inches to 2 feet thick	45
6. Limestone, sandy, with *Platycrinus penicillus* Meek and Worthen	5
5. Limestone, rather pure, thick bedded, medium grained, crinoidal, bluish gray, with *Platycrinus penicillus* Meek and Worthen	140
4. Limestone, argillaceous, weathers mostly to shale; some thin layers of coarse crinoidal limestone with *Platycrinus penicillus* Meek and Worthen	175
3. Limestone, full of chert nodules	15
2. Limestone, thick bedded, coarsely crystalline, gray, nodules of black chert, abundantly fossiliferous (Pl. 50C); contains *Platycrinus penicillus* Meek and Worthen and *Productus parvus* Meek and Worthen	65
St. Louis formation	
1. Shale (bed 3 of geologic section 103)	50

The top of the Ste. Genevieve is placed at the top of bed 25, because this bed is persistent and recognizable at least from a point 3 miles southwest of Gate City to the Saltville fault about 1 mile southwest of Blackwell, Washington County, and because *Platycrinus penicillus* occurs in the immediately underlying beds. That fossil occurs just beneath the top about 1 mile west of Blackwell and not more than 100 feet below 1 mile northwest of Lindell, on Virginia Route 80, and at a less distance below it about 1 mile north of Whites Mill, Washington County. That the red bed should be included in the Ste. Genevieve is also indicated by the rare occurrence of *Pentremites princetonensis* Ulrich, and possibly of *P. pulchellus* Ulrich, two Ste.

Genevieve fossils, in limestone a short distance above it on Toole Creek, 1 mile north of Whites Mill.

The thickness of the various members listed, as well as the total thickness, is the minimum that seems deducible from the field data, which consist of the measured distance of 3000 feet across the outcrop normal to the strike, on U. S. routes 19 and 250 northwest of Greendale and of Lindell, respectively, where the dip averages about 30° SE.

Toward the southwest part of the Greendale syncline in Virginia, the Ste. Genevieve undergoes a change of facies, and its upper part is largely composed of brown sandstone, as shown in the following section on a small tributary of Opossum Creek 3 miles southwest of Gate City:

Geologic Section 108.—Ste. Genevieve formation southwest of Gate City, Scott County, Virginia

	Thickness Feet
Fido sandstone	
18. Sandstone, thick bedded, red	50±
Gasper limestone	
17. Limestone	800
Ste. Genevieve formation (960 feet)	
16. Limestone, red (cf. bed 25 of geologic section 107)	50±
15. Not exposed	110
14. Sandstone, soft, brown	200
13. Limestone, argillaceous, shaly	60
12. Sandstone, brown	10
11. Shale	20
10. Limestone, pure, coarse grained, fragmental, with *Platycrinus penicillus* Meek and Worthen	20
9. Not exposed	20
8. Limestone, pure	5
7. Not exposed	50
6. Limestone, cherty	10
5. Not exposed	120
4. Limestone, blue, fine grained, cherty	40
3. Not exposed	200
2. Limestone, cherty, with *Platycrinus penicillus* Meek and Worthen	45
St. Louis limestone	
1. Limestone, dark-colored to black	150

The brown sandstone, bed 14, is included in the Ste. Genevieve because it is below the red limestone, bed 16, which is the same as bed 25 at the top of the Ste. Genevieve in the Greendale section.

Distribution.—The Ste. Genevieve crops out in two belts; a narrow almost continuous belt along the Cumberland escarpment near the coal fields from Cumberland Gap to New River northeast of Bluefield, West Virginia, and a wide belt extending along the middle of the Greendale syncline from Tennessee to Saltville.

The best exposures of the Ste. Genevieve in the northwest belt are at Cumberland Gap; in a quarry at the southeast end of the Big Stone Gap of Powell River 1 mile northwest of the town of Big Stone Gap; 3 miles northeast of Bluefield, West Virginia (geologic section 106); and on the Norfolk and Western Railroad in the Narrows of New River. The best exposures in the Greendale syncline are on Virginia Route 80 about 1 mile northwest of Lindell; on U. S. Route 19, slightly more than a mile north of Greendale; on the bluff of Holston River along the north side of the narrow spur enclosed by the long meander about 1 mile south of Hilton, Scott County; and on the small tributary of Opossum Creek 3 miles southwest of Gate City (geologic section 108).

Thickness.—The thickness of the Ste. Genevieve is 85 feet at Cumberland Gap, 180 feet at Big Stone Gap, 400 feet at Bluefield, West Virginia, and in the Narrows of New River. In the Greendale syncline the thickness is about 1000 feet southwest of Gate City, possibly 1300 feet at the meander southeast of Hilton, and approximately 1500 feet at the localities on routes 19 and 80.

Fossils and correlation.—The Ste. Genevieve limestone is moderately fossiliferous, and some beds consist largely of fossil fragments, such as crinoidal plates. Fenestrellinid bryozoa, which have not been collected or studied, are abundant in the argillaceous limestone in the Greendale syncline. Other fossils, such as brachiopods and gastropods, are numerous but are generally so firmly embedded in the matrix that they can not be obtained. In the course of field work for several years, only a few small collections were made and most of these were obtained at widely separated points. They were especially sought because the diagnostic *Platycrinus penicillus* is everywhere present.

Fossils in the Ste. Genevieve formation in Virginia

Corals

- Cystelasma quinqueseptatum Ulrich
- Triplophyllum spinulosum (Edwards and Haime)

Blastoids

- Pentremites princetonensis Ulrich
- Pentremites pulchellus Ulrich

Crinoids
    Platycrinus penicillus Meek and Worthen

Brachiopods
    Cliothyridina hirsuta (Hall)
    Composita trinuclea (Hall)
    Productus (Dictyoclostus) inflatus McChesney
    Productus (Dictyoclostus) parvus Meek and Worthen
    Productus (Dictyoclostus) scitulus Meek and Worthen
    Pustula genevievensis (Weller)
    Spiriferina sp.

Pelecypods
    Astartella sp.

Gastropods
    Pleurotomaria? piasaensis Hall
    Pleurotomaria?, one or more species related to Spergen limestone species described by Hall
    Strophostylus cf. S. carleyanus (Hall)

Of these, *Cystelasma quinqueseptatum,* the two species of *Pentremites, Platycrinus penicillus, Productus (Dictyoclostus) parvus,* and *Pustula genevievensis* may be considered as diagnostic of the Ste. Genevieve limestone. *Platycrinus penicillus* is an index fossil because, so far as known, this form occurs only in the Ste. Genevieve and may be found in every exposure of this limestone in the entire area of its occurrence. The writer has verified this fact by personal examination throughout that area.

The Ste. Genevieve occurs everywhere in the same sequence; St. Louis limestone below containing the two species of *Lithostrotionella;* Ste. Genevieve in the middle with *Platycrinus penicillus;* and Gasper above with *Talarocrinus.* The writer, however, thinks that the Ste. Genevieve of Virginia represents only the Fredonia member of the formation as it occurs in the Mississippi Valley.

Traced northward, the Ste. Genevieve passes into the Loyalhanna limestone of Pennsylvania. This change of facies in the Appalachian Valley begins in the vicinity of Durbin, West Virginia, as seen in a highway cut half a mile north of Fill Run School 3 miles northwest of Durbin. (See Pl. 48A.) Five and a half miles southwest of Fill Run school along the same belt, the place of the cross-bedded limestone shown in Plate 48A is taken by oolitic gray limestone of normal Ste. Genevieve aspect, but here, in close association with the limestone, are intercalated thin layers of slightly pinkish, cross-laminated rock that apparently contains scattered fine grains of quartz sand. This change of facies takes place in West Virginia about 1 degree of latitude farther north than in central Kentucky, where it begins about on the latitude of Irvine and is complete at Carter, 60 miles north of Irvine.

HIATUS

In southern Illinois and western Kentucky the section through the Ste. Genevieve into the Gasper limestone is as follows:

	Feet
Gasper limestone	
Bethel sandstone	50-100
Ste. Genevieve limestone (275 feet)	
Limestone, Ohara member	95
Sandstone, Rosiclare	20
Limestone and oolite, Fredonia member	160

In this section *Platycrinus penicillus* Meek and Worthen ranges from the Fredonia limestone into the lower part of the Ohara member but is rare or absent in the upper part of that bed. *Talarocrinus* occurs in the upper part of the Ohara member and in the Gasper but has never been found in the Fredonia limestone nor, with a rare exception reported by Ulrich, anywhere associated with *Platycrinus penicillus*. In southwest Virginia, especially in the northwest belt of the Valley, the limestone with *Platycrinus penicillus* extends up to the Gasper with *Talarocrinus*. No beds corresponding to the Ohara limestone and Bethel sandstone have been found. Hence it appears that a hiatus exists between the Ste. Genevieve and Gasper in the State. The occurrence of *Platycrinus penicillus* in the Ste. Genevieve and of any species of *Talarocrinus* in the Gasper seems to be a valid criterion for the separation of the two formations.

GASPER LIMESTONE

Name.—The Gasper limestone was named[220] from Gasper River in Warren County, Kentucky, on the bluffs of which the formation crops out extensively to a height of 80 feet or more above the river.

Limits.—In Virginia the Gasper limestone lies between the Ste. Genevieve limestone below and the Glen Dean limestone or Bluefield shale above, as along the northwest belt of the Valley; or between the Ste. Genevieve limestone and the Fido sandstone, as in the Greendale syncline.

[220] Butts, Charles, Descriptions and correlation of the Mississippian formations of western Kentucky: Kentucky Geol. Survey, Mississippian formations of western Kentucky, p. 64, Frankfort, 1917.

Character.—The Gasper limestone occurs in two facies; pure limestone along the northwest belt of the Valley near the coal fields and predominantly argillaceous limestone and shale in the Greendale syncline. At Cumberland Gap it consists of thick-bedded, gray, largely oolitic limestone 175 feet thick with *Talarocrinus* in the upper part. (See Pl. 48B.) It is overlain by the Glen Dean limestone and is underlain by oolitic, crinoidal Ste. Genevieve limestone with *Platycrinus penicillus* Meek and Worthen (bed 8 of geologic section 104). Its character is adequately expressed in detail in the following sections:

Geologic Section 109.—Gasper limestone 3 miles northeast of Bluefield, West Virginia[221]

	Thickness Feet
Bluefield shale	
Gasper limestone (515 feet)	
11. Limestone, argillaceous, shaly	30
10. Limestone, thick bedded	10
9. Limestone, argillaceous, shaly	30
8. Limestone, coarse grained, fragmental	5
7. Limestone, argillaceous	45
6. Limestone, highly crinoidal, with *Pterotocrinus serratus* Weller abundant	25
5. Limestone, thick bedded, argillaceous	60
4. Limestone, coarse grained, crinoidal, cherty; contains *Pentremites patei* Ulrich, *P. welleri* Ulrich, *Pterotocrinus serratus* Weller, *Talarocrinus* sp.?, *Glyptopora punctipora* Ulrich, *Septopora cestriensis* Prout, *Eumetria verneuilana* (Hall), *Productus* (*Dictyoclostus*) *inflatus* McChesney, and *Spiriferina* sp.	30
3. Limestone, argillaceous, thick bedded	30
2. Limestone, compact, blue; contains *Fenestrellina serratula* (Ulrich), *F. tenax* (Ulrich), several other species of *Fenestrellina*, *Meekopora?* sp., *Polypora cestriensis* Ulrich, *Rhombopora* sp.?, and *Productus* (*Linoproductus*) *ovatus* (Hall) in the middle; *Pentremites planus* Ulrich, *Dizygocrinus* sp.?, *Talarocrinus* two sp., and *Bellerophon* sp., 50 feet above bottom	250
Ste. Genevieve limestone	
1. Limestone, with *Platycrinus penicillus* Meek and Worthen in top; top of bed 4 of geologic section 106	

[221] This section is continuous upward with the Ste. Genevieve limestone of geologic section 106.

A section similar to the preceding, measured accurately by rule, except the upper part, at a quarry at Nemours, West Virginia, 1 mile northeast of the State line and 5 miles northwest of Bluefield follows:

Geologic Section 110.—Gasper limestone in a quarry at Nemours, West Virginia[a]

	Thickness Ft.	In.
Bluefield shale?		
Gasper limestone (431± feet)		
25. Limestone, blue, estimated	40±	
24. Not exposed; estimated	50±	
23. Limestone, blue; contains *Archimedes proutanus* (Ulrich), *Brachythyris chesterensis* Butts, *Composita trinuclea* (Hall), and *Productus* (*Dictyoclostus*) *inflatus* McChesney; estimated	25±	
22. Not exposed; railroad; estimated	50±	
21. Limestone, coarse grained, thick bedded, crinoidal; contains *Triplophyllum spinulosum* (Edwards and Haime) *Pentremites "godoni"* Ulrich, *P. patei* Ulrich, *P. planus* Ulrich, *P. planus*? var. with convex ambulacra cf. *P. conoideus* Hall or *princetonensis* Ulrich, *P.* cf. *P. springeri* Ulrich, *Talarocrinus cornigerus* (Shumard), *Chonetes chesterensis* Weller, *Cliothyridina sublamellosa* (Hall), *Composita trinuclea* (Hall), and *Girtyella indianensis* (Girty)	12	
20. Limestone, thick bedded, argillaceous	20	
19. Limestone, argillaceous	2	6
18. Limestone, coarse grained, crinoidal, shale partings 6 inches thick	12	6
17. Limestone, argillaceous	16	
16. Limestone, blue, compact	5	
15. Limestone, coarse grained, crinoidal, with *Pentremites* and *Talarocrinus*	9	
14. Limestone, mostly argillaceous, some crinoidal	20	6
13. Limestone, oolitic, light gray, crinoidal	5	6
12. Limestone, massive, argillaceous	9	6
11. Limestone, massive, drab, oolitic	14	
10. Limestone, thick bedded, compact, bluish, argillaceous bands, weathers yellowish	9	6

[a] See Plate 51C.

	Thickness Ft.	In.
9. Limestone, thick bedded, compact, cross bedded	10±	
8. Limestone, coarse, crinoidal	4	
7. Limestone, thick bedded, compact, argillaceous	29	
6. Limestone, earthy	5	6
5. Limestone, compact, blue, probably somewhat argillaceous	20	
4. Limestone, thick bedded, compact, bluish, weathers gray	37	
3. Limestone, compact, blue	6	
2. Limestone, compact, argillaceous, weathers to shale or shaly limestone	16	
1. Limestone, compact, blue; at railroad level	3	

In the field it was thought that the lower part of this section is Ste. Genevieve, but in view of the thickness of more than 500 feet of the Gasper at Bluefield, as shown in the preceding section, and of the fact that *Platycrinus penicillus* was not found after careful search, it seems most probable that the entire section is Gasper.

The following section is in the Greendale syncline, along U. S. Route 19:

Geologic Section 111.—Gasper limestone 1 to 1½ miles northwest of Greendale, Washington County, Virginia

	Thickness Feet
Fido sandstone	
6. Sandstone, thick bedded, coarse grained, friable	50
Gasper limestone (1025 feet)	
5. Limestone, thick bedded, somewhat argillaceous; contains *Pentremites planus* Ulrich, *P. welleri* Ulrich, *Globocrinus unionensis?* (Worthen) and *Talarocrinus inflatus* Ulrich	180
4. Limestone, thick bedded, crinoidal, partly reddish, more or less argillaceous, with *Pentremites planus* Ulrich	145
3. Limestone, argillaceous, shaly, weathers to shale; fenestrellinid bryozoa abundant	200
2. Limestone, more or less argillaceous, shaly, weathers to shale; fenestrellinid bryozoa abundant in some layers	500

Ste. Genevieve formation

1. Red rock, argillaceous, calcareous (bed 25 of geologic section 107).

Another section in the Greendale syncline is exposed on Langford Branch, a small northern tributary of Opossum Creek 3½ miles southwest of Gate City, Scott County.

Geologic Section 112.—Gasper limestone and Fido sandstone southwest of Gate City, Scott County, Virginia

	Thickness Feet
Fido sandstone	
2. Sandstone, coarse grained, red	50±
Gasper limestone	
1. Limestone, argillaceous, shaly, cut by strong joints about perpendicular to the bedding (Pl. 50B); highly fossiliferous layers with *Pentremites* and *Globocrinus;* fossils fragmentary	800
Ste. Genevieve limestone (See geologic section 108.)	

The proportion of gray oolitic rock in the Gasper decreases northeastward from Cumberland Gap along the northwestern belt next to the coal fields and such rock is absent in the Greendale syncline. At Cumberland Gap the Gasper and the Ste. Genevieve are pure, gray, oolitic limestones as they are throughout Kentucky. In the Greendale syncline the argillaceous facies indicates a nearby southeastern land mass, from which much silt was derived during Ste. Genevieve time. This was mixed with calcareous sediment in the course of deposition.

Distribution.—The Gasper limestone persists, except where faulted out, along the northwest side of the Valley, at least as far northeast as Marlinton, West Virginia. It is also brought up in the midst of Bluefield shale by the sharp anticline in Abbs Valley about midway between Falls Mills and Pocahontas. The Greendale synclinal belt extends from Tennessee northeast to a point about 1 mile southwest of Saltville.

Among the best exposures of the Gasper are those of the preceding sections; at the quarry 1 mile northwest of the town of Big Stone Gap; along the road between Bandys Chapel and Bandy about 1 mile northwest of Bandys Chapel; along the road crossing the narrow syncline between Cleveland and South Clinchfield; and along the road crossing the north end of that syncline 2 miles northwest of Coulwood (Finney). The upper half of the Gasper is well exposed in the Narrows of New River along the Norfolk and Western Railroad half a mile south of Rich Creek. In the Greendale syncline, besides the exposures at the locations of the sections, others about equally good occur on State Route 80, about 1 mile north of Lindell and on U. S. Route 58, 2 miles southeast of Hilton, Scott County. The Gasper is well exposed in nearly every ravine and along all roads crossing the Greendale syncline southwest of Lindell.

Thickness.—The Gasper is 175 feet thick at Cumberland Gap. Its thickness 1 mile northwest of Big Stone Gap has been published as 136 feet,[222] but, as the boundaries have not been certainly determined at that place, the thickness may be somewhat greater. The thickness increases northward to more than 400 feet at Nemours, 500 feet at Bluefield, West Virginia, and about 450 feet in the Narrows of New River. In the Greendale syncline the thickness varies from 800 to 1025 feet.

Fossils and correlation.—The Gasper does not appear to be highly fossiliferous in Virginia, yet in the course of several years' field work a considerable number of species have been collected from the limestone facies of the northwest belt and the shale facies of the Greendale syncline. Most of these fossils are listed below:

Fossils from the Gasper limestone in Virginia

Corals
- Amplexus sp.?*
- Campophyllum gasperense Butts †
- Michelinia?
- Syringopora, sp.
- Triplophyllum spinulosum (Edwards and Haime) *

Blastoids
- Pentremites cf. P. conoideus Hall or princetonensis Ulrich
- Pentremites cf. P. gemmiformis Hambach
- Pentremites "godoni" Ulrich †
- Pentremites patei Ulrich †
- Pentremites planus Ulrich (P. godoni Defrance?)
- Pentremites pyriformis Say * †
- Pentremites welleri Ulrich * †

Crinoids
- Agassizocrinus cf. A. ovalis Miller and Gurley †

[222] Stose, G. W., *in* Eby, J. B., The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia: Virginia Geol. Survey Bull. 24, p. 57, 1923.

* From the shale facies in the Greendale syncline.
† Diagnostic species.

Eupachycrinus cf. E. maniformis (Yandell and Shumard) *
Globocrinus unionensis (Worthen) *
Pterotocrinus serratus Weller †
Talarocrinus cornigerus (Shumard) †
Talarocrinus inflatus Ulrich * †
Talarocrinus ovatus Worthen * †
Talarocrinus sexlobatus (Shumard) †
Talarocrinus several other sp.?

Bryozoa
Archimedes proutanus Ulrich
Cystodictya labiosa Weller
Fenestrellina serratula (Ulrich) *
Fenestrellina tenax (Ulrich) *
Fenestrellina, several other sp.
Fistulipora sp. *
Glyptopora punctipora Ulrich * †
Lyropora cf. L. ranosculum Ulrich
Meekopora? sp.

Brachiopods
Brachythyris chesterensis Butts †
Chonetes chesterensis Weller
Cliothyridina sublamellosa (Hall) *
Composita trinuclea (Hall) *
Eumetria verneuilana (Hall)
Girtyella indianensis (Girty)
Productus (Dictyoclostus) inflatus McChesney *
Productus (Linoproductus) ovatus (Hall)
Reticularia setigera (Hall) *
Spirifer pellaensis Weller?
Spiriferina spinosa (Norwood and Pratten) *
Spiriferina transversa (McChesney) *

*From the shale facies in the Greendale syncline.
†Diagnostic species.

Pentremites with depressed or concave ambulacral areas, like *P. "godoni"* Ulrich, does not occur below the Gasper anywhere, and any such form may be safely regarded as post-Ste. Genevieve. So far as the writer knows, no species of *Talarocrinus* has ever been found in the Fredonia limestone or the lower Ohara member of the Ste. Genevieve, or in any formation later than the Gasper. These fossils, even if represented only by half of a basal plate or by a radial plate (see Fossil Plates), are to be regarded as diagnostic of the Gasper east of central Kentucky and of northern Alabama. *Pterotocrinus serratus* is also a good index fossil which is abundant at several localities in the northwestern belt. *Cystodictya labiosa* and *Campophyllum gasperense* are equally good index fossils, but they are rare in Virginia.

HIATUS

In the standard section of the Chester group of the Mississippi and Ohio valleys in Illinois and Kentucky, the Gasper limestone is succeeded by the following formations:

4. Glen Dean limestone
3. Hardingsburg sandstone
2. Golconda limestone
1. Cypress sandstone

It is believed probable that the Cypress sandstone and the Golconda limestone are absent in Virginia in the Greendale syncline, and that both, together with the Hardinsburg sandstone, are absent in the northwestern belt, which leaves a hiatus in Virginia between the Gasper and the Glen Dean limestones or between the Gasper and the Fido sandstone which immediately overlies the Gasper in the Greendale syncline.

FIDO SANDSTONE

Though thin this sandstone is so important as a horizon marker that its recognition and description as an independent unit are justified.

Name.—The Fido sandstone was named by the writer[223] from Fido, an old post office on U. S. Route 58, in Scott County 6 miles southwest of Mendota.

Limits.—The Fido sandstone lies between the Gasper limestone, with *Talarocrinus* at the very top, and the Cove Creek limestone containing *Pterotocrinus depressus* Lyon and Casseday? at the base.

Character.—The Fido sandstone is a thick-bedded, argillaceous, sandy rock, some parts of which are highly calcareous. On weathering and leaching it becomes a coarse-grained, friable sandstone. Its distinctive feature is its red color which makes it easily recognizable.

Distribution.—This sandstone occurs only in the Greendale syncline within which it is known to extend in a narrow belt from a point about 1 mile southwest of Yuma and 3 miles southwest of Gate City, Scott County, to the Saltville fault midway between Lindell and Blackwell, Washington County. It probably extends southwest along

[223] Butts, Charles, Oil and gas possibilities at Early Grove, Scott County, Virginia: Virginia Geol. Survey Bull. 27, 1927.

this belt to Tennessee.[224] It crops out also along the axis of a minor anticline, which passes near the old post office of Early Grove, in the Bristol quadrangle.

Good exposures of the Fido sandstone occur 1 mile southwest of Yuma, Scott County, in or near U. S. Route 58, from the vicinity of Fido southwest to the sharp bend of the road where it turns northwest to Hilton; on U. S. Route 19, about 1 mile north of Greendale; and on Virginia Route 80, about half a mile northwest of Lindell.

Thickness.—The Fido sandstone, 50 to 75 feet thick, does not vary greatly in thickness.

Fossils and correlation.—The Fido sandstone is somewhat fossiliferous, but the fossils are poorly preserved. Fenestrellinid bryozoa are most plentiful. Fragments of a large *Pentremites* seem to be *Pentremites maccalliei* Schuchert. *Pentremites* of this type have been found on U. S. Route 19, 1 mile northwest of Greendale, and at Early Grove. The similarity of this large *Pentremites* to *P. obesus* Lyon of the Golconda in Illinois suggests that the stratigraphic horizon of the Fido sandstone is near that of the Golconda limestone. Its position just above the Gasper suggests its possible correlation with the Cypress sandstone which commonly occupies that horizon in southern Illinois and western Kentucky. On the other hand, the Fido is overlain by a bed in the Cove Creek limestone that is crowded with the wing plates of a *Pterotocrinus* that appears to be *P. depressus* Lyon and Casseday, a species cited by Ulrich[225] only from the Glen Dean limestone, in which, according to published lists, it occurs at every locality from southern Illinois to Grayson County, Kentucky. Hence, the Fido from its stratigraphic position could equally well be correlated with the Hardinsburg sandstone which in the Mississippi and Ohio valleys lies between the Golconda and Glen Dean limestones. As the Hartselle sandstone of Alabama also occupies the position of the Hardinsburg and is nearer the locality of the Fido, it is believed most probable that the Fido sandstone is to be correlated with the Hardinsburg.

GLEN DEAN LIMESTONE—BLUEFIELD SHALE—COVE CREEK LIMESTONE

These three names designate three different facies of what is believed to be the same stratigraphic unit in different areas. In order to avoid the impression of three different formations the unit is described under a single hyphenated heading.

[224] Its outcrop is marked on the geologic map of the Valley (Virginia Geol. Survey Bull. 42) by the boundary line between the Gasper-Ste. Genevieve belt and the Cove Creek limestone belt.

[225] Ulrich, E. O., The formations of the Chester series in western Kentucky and their correlates elsewhere: Kentucky Geol. Survey, Mississippian formations of western Kentucky, p. 227, 1917.

Names.—The Glen Dean limestone was named by the writer[226] from Glen Dean, Breckinridge County, Kentucky; the Bluefield shale by Campbell[227] from Bluefield, West Virginia; and the Cove Creek limestone by the writer[228] from Cove Creek in the Greendale syncline, Scott County, 5 miles southwest of Mendota, along which the white-weathering limestone in the formation is locally conspicuously displayed.

Limits.—This unit is bounded below by the Gasper limestone along its northwestern belt next to the coal fields and by the Fido sandstone in the Greendale syncline, and is bounded above on the northwest by the Stony Gap sandstone, the basal member of the Pennington formation. In the Greendale syncline it is bounded above by shale and shaly sandstone of the Pennington formation.

Character.—The Glen Dean limestone consists of interbedded limestone and shale as shown in the following sections. The first is on the southeast slope of the Pinnacle directly above Cumberland Gap village.

Geologic Section 113.—Glen Dean formation at Cumberland Gap, Tennessee

	Thickness Feet
Pennington formation	
6. Sandstone, Stony Gap sandstone ?	75-100
Glen Dean formation (380 feet)	
5. Not exposed on long slope; probably mostly shale	145
4. Limestone, thick bedded, fine grained, gray	50
3. Shale and argillaceous shaly limestone in thin layers, interbedded, fossiliferous; contains *Triplophyllum spinulosum* Edwards and Haime, *Pentremites brevis* Ulrich, *P. canalis* Ulrich, *P. pyramidatus* Ulrich, *P. tulipaeformis* Hambach, *Agassizocrinus conicus* Owen and Shumard, *Pterotocrinus spatulatus* Wetherby, *Archimedes communis* Ulrich, *Fenestrellina* 2 sp., *Lyropora* sp.?, *Prismopora serrulata* Ulrich, *Tabulipora ramosa* (Ulrich), *T. tuberculata* (Prout), *Camarophoria explanata* (McChesney), *Cliothyridina sublamellosa* (Hall), *Composita trinuclea* (Hall), *Eumetria verneuilana* (Hall), *Or-*	

[226] Butts, Charles, Descriptions and correlation of the Mississippian formations of western Kentucky: Kentucky Geol. Survey, Mississippian formations of western Kentucky, p. 97, 1917.

[227] Campbell, M. R., U. S. Geol. Survey Geol. Atlas (No. 26), Pocahontas folio, p. 3, 1896.

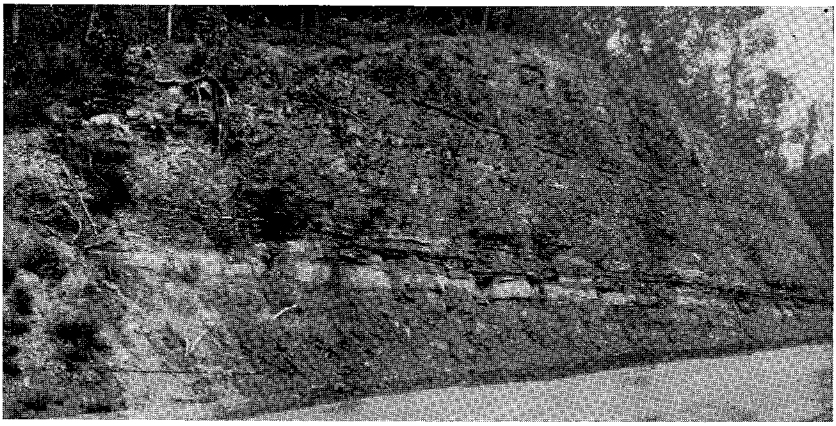
[228] Butts, Charles, Oil and gas possibilities at Early Grove, Scott County, Virginia: Virginia Geol. Survey Bull. 27, p. 16, 1927.

PLATE 50

A. Pennington formation in Giles County. This section consists of thin-bedded sandstone and dark-colored calcareous shale. Along State Route 8, just across New River, northwest of Lurich. Looking north.

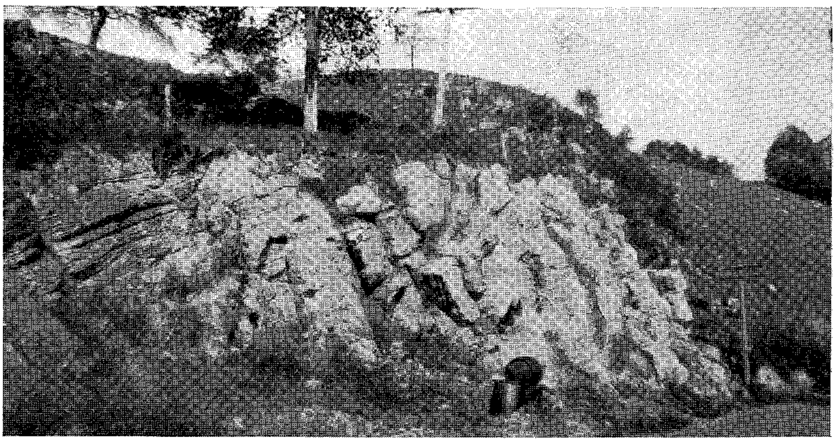
B. Gasper limestone near Gate City, Scott County. Strong parallel joints simulate original bedding planes. The true thin beds dip to the right and cut across the joints. This feature resembles slaty cleavage. Along the road a short distance north of Opossum Creek, 1 mile southwest of Yuma, and 3½ miles southwest of Gate City. Looking east.

C. Basal bed of the Ste. Genevieve limestone in Washington County. It is full of *Platycrinus penicillus*. When first examined in 1926 this limestone had a good many specimens of *Platycrinus penicillus,* both spiny stem plates and bases of the calyx, on the partly weathered surfaces of the beds. The exposure has been partly destroyed by more recent road work. Shale, marking the top of the St. Louis formation (geologic section 107, bed 1), underlies this bed. Along U. S. Route 19, about half a mile south of Holston River. Looking southwest.



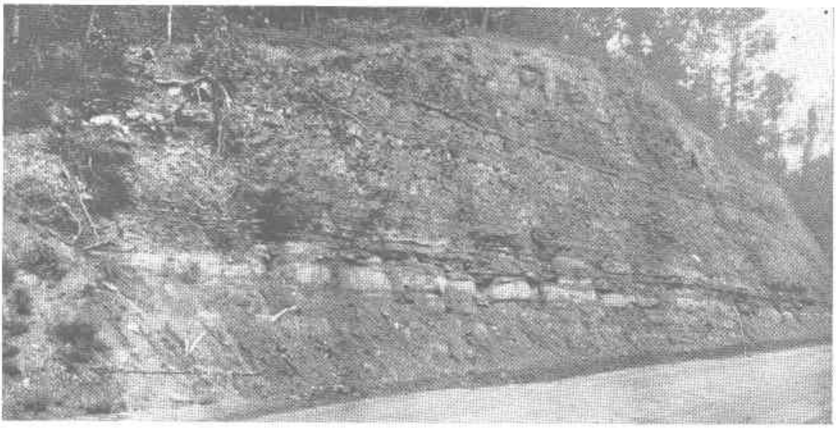
A

B



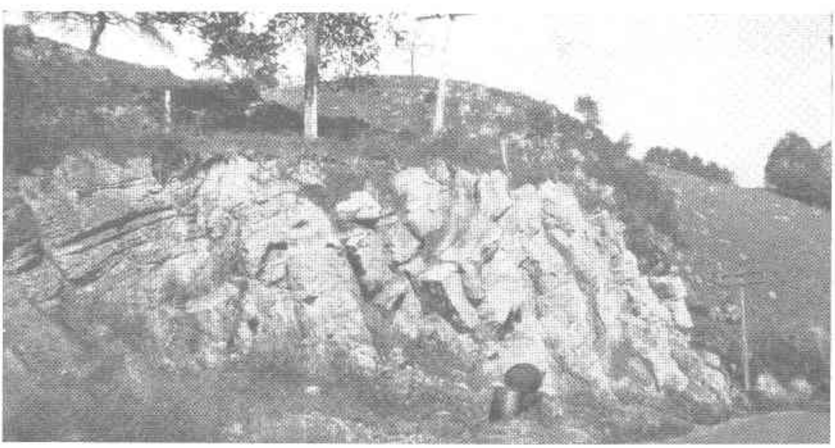
C

MISSISSIPPIAN FORMATIONS



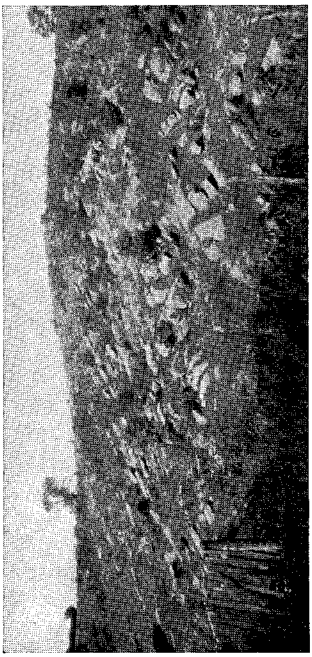
A

B

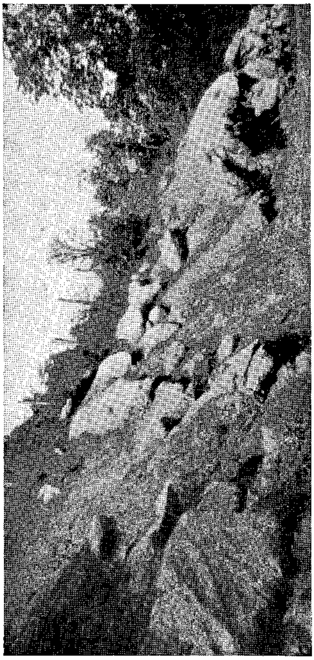


C

MISSISSIPPIAN FORMATIONS



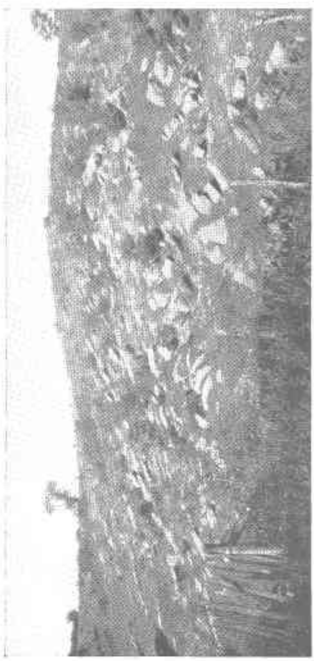
A



B

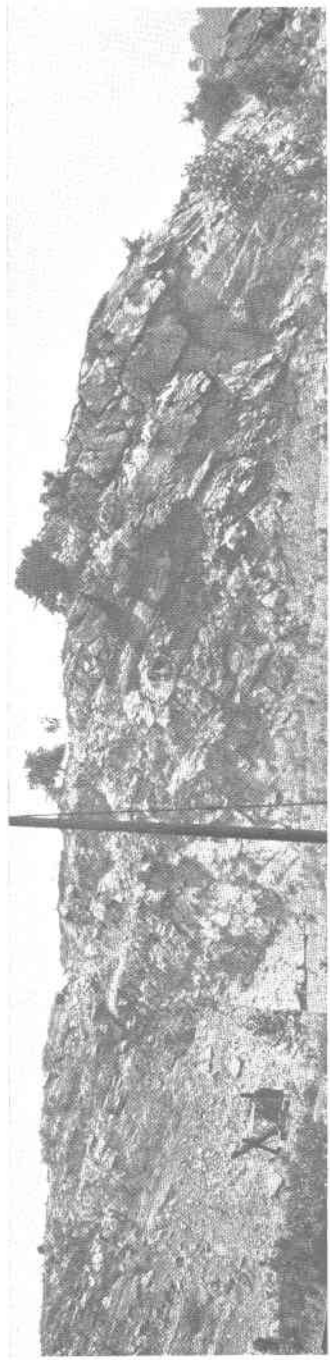
C

MISSISSIPPIAN LIMESTONES



A

B



C

MISSISSIPPIAN LIMESTONES

PLATE 51

A. Cove Creek limestone in the Greendale syncline, Washington County. Just east of U. S. Route 19, four-fifths of a mile northwest of Greendale. Looking southwest.

B. Gasper limestone in the Greendale syncline. It contains *Pentremites "godoni"* Ulrich, *Talarocrinus inflatus* Ulrich and *Globocrinus unionensis* (Worthen). Along U. S. Route 19, 1 mile northwest of Greendale. The Fido sandstone immediately overlies this limestone (at left). Looking northwest.

C. Quarry in Ste. Genevieve (?) and Gasper limestones. *Talarocrinus* occurs in the beds at the top opposite the pipe and, therefore, the beds above (right) are Gasper. This is a good exhibit of the Gasper, and possibly of the Ste. Genevieve in the lower part (left). North end of the Abbs Valley anticline at Nemours, W. Va., three-fourths of a mile northeast of the State line. The dip is to the northeast on the northeastward pitching axis of the anticline.

	Thickness Feet
thothetes kaskaskiensis (McChesney) ?, *Reticularia setigera* (Hall), *Spiriferina spinosa* (Norwood and Pratten), and *S. transversa* (McChesney)	65
2. Limestone, compact, gray, in layers 4 inches to 1 foot thick	30
1. Limestone, shaly and nodular, interbedded with shale; with *Archimedes distans* Ulrich and *Prismopora serrulata* Ulrich, in bottom	90
Gasper limestone	

Attention is directed to the occurrence of *Prismopora serrulata* in the bottom of bed 1, and to the occurrence of the same form, together with *Pentremites, Pterotocrinus,* and *Agassizocrinus* in bed 3. These are all characteristic Glen Dean fossils, being so far unknown in any other formation, except possibly a rare occurrence of *Prismopora serrulata* in the Gasper in the Mississippi Valley. That species is common, however, in the Glen Dean and is so generally distributed in that formation that its occurrence can be safely taken as satisfactory proof of the Glen Dean age of the containing rocks. Thus the Glen Dean on the Cumberland escarpment rests upon the Gasper; the Hardinsburg sandstone, Golconda formation, and Cypress sandstone which intervene in the Mississippi and Ohio valleys are absent here.

Another section of the Glen Dean is exposed along the Interstate Railroad in the Big Stone Gap of Powell River, 1 mile northwest of the town of Big Stone Gap.

Geologic Section 114.—Glen Dean formation northwest of Big Stone Gap, Wise County, Virginia

	Thickness Feet
Pennington formation (part)	
8. Sandstone, Stony Gap	100±
Glen Dean formation (425 feet)	
7. Shale, thin, argillaceous limestone and some thin layers of sandstone	65
6. Shale	35
5. Limestone, argillaceous	5
4. Shale	35

	Thickness Feet
3. Limestone; contains *Fenestrellina cestriensis* (Ulrich), *F. tenax* (Ulrich), *Meekopora clausa* Ulrich, and *Septopora subquadrans* Ulrich	20
2. Shale	65
1. Limestone, argillaceous, shaly, and shale	200

Gasper limestone

About 75 feet below the top of bed 1, these fossils were collected: *Archimedes distans* Ulrich, *A. meekanus* (Hall), *Fenestrellina cestriensis* (Ulrich), *Polypora approximata* Ulrich, *Rhombopora minor* Ulrich, *Chonetes chesterensis* Weller, *Cliothyridina sublamellosa* (Hall), *Composita subquadrata* (Hall), *Dielasma* sp.?, *Eumetria verneuilana* (Hall), *Orthothetes kaskaskiensis* (McChesney), *Productus* (*Dictyoclostus*) aff. *P. inflatus* McChesney, *Spirifer increbescens* Hall, *Spiriferina spinosa* (Norwood and Pratten), and *S. transversa* (McChesney).

No diagnostic Glen Dean fossils, except *Meekopora clausa,* occur in this collection; nevertheless those named also occur in the Glen Dean elsewhere. A single specimen has been identified as *Meekopora clausa,* but the identification may be wrong. *Septopora subquadrans* seems to be generally distributed in the Glen Dean elsewhere and is rarely cited from higher formations. It may be regarded as most probable that the beds containing it here are Glen Dean. The absence of diagnostic forms may be due to inadequate collecting, as the species listed were hastily collected at only a few horizons in the entire thickness of the rocks here referred to the Glen Dean. On stratigraphic and lithologic grounds, the rocks of this section correspond exactly to those of the Glen Dean at Cumberland Gap, and the belt is undoubtedly continuous along the escarpment between Cumberland Gap and Big Stone Gap.

The Gasper in this section also appears to be thinner than might be expected from its thickness at Cumberland Gap and at Bluefield, West Virginia. However, the boundary as placed separates two distinctly different lithologic units corresponding exactly to the Glen Dean and Gasper throughout Lee and Wise counties, and is probably correctly located.

The Bluefield shale is composed mainly of shale, as shown in the following sections, but includes thin beds of limestone and sandstone.[229]

[229] Many of the limestones and sandstones with their separating beds of shale have been recognized and named as members by the West Virginia Geological Survey (Reger, D. B., Mercer, Monroe, and Summers counties: West Virginia Geol. Survey, 1926). Such members are more or less local and inconstant, and not of sufficient importance to be recognized in a general discussion such as this.

Geologic Section 115.—Bluefield shale on U. S. Route 19, 3 miles northeast of Bluefield, West Virginia

	Thickness Feet
Pennington formation (part)	
20. Sandstone, Stony Gap	100
Bluefield shale (1015 feet)	
19. Shale, alternating yellowish and red	75
18. Shale, yellowish, thin layers of sandstone	60
17. Shale, red	30
16. Sandstone	15
15. Shale, red	10
14. Shale, yellow	30
13. Not exposed; probably shale	30
12. Shale, yellow	15
11. Shale, red	30
10. Sandstone	15
9. Shale, yellow, layer of sandstone in bottom	70
8. Shale, red	15
7. Shale, yellow	165
6. Sandstone, wave-marked	5
5. Shale, bluish	50
4. Not exposed; probably shale	115
3. Shale, yellow-green, fragile	80
2. Shale, calcareous, or limestone, argillaceous, with fenestrellinid bryozoa abundant	5
1. Shale, yellowish and greenish	200

On the northwest side of the syncline northwest of Bluefield, the Bluefield shale has substantially the same character and thickness. A section directly across the strike, along a road about 1 mile southwest of Pocahontas, Tazewell County, Virginia, follows:

Geologic Section 116.—Bluefield shale southwest of Pocahontas, Tazewell County, Virginia

	Thickness Feet
Stony Gap sandstone	
4. Sandstone	100±
Bluefield shale (950 feet)	
3. Shale, red	200
2. Shale, calcareous, gray, leached; argillaceous limestone	750
Gasper limestone	
1. Limestone, thick bedded	

So far as observed the Bluefield shale has everywhere the character shown by these two sections.

The Cove Creek limestone in the Greendale syncline is intermediate in character between the Glen Dean limestone and the Bluefield shale. It is predominantly rather thick bedded and argillaceous, is commonly laminated, and as a whole weathers readily to shale. In its basal part it contains much fine-grained limestone in rather thick layers, most of which weathers distinctly white and makes a striking appearance on Cove Creek, 5 miles southwest of Mendota, and along U. S. Route 19, 1 mile northwest of Greendale. Its general character is best displayed by a section along U. S. Route 19, from a point about half a mile northwest of Greendale to a point about a mile northwest of Greendale.

Geologic Section 117.—Cove Creek limestone northwest of Greendale, Washington County, Virginia

	Thickness Feet
Pennington formation (part)	
7. Not exposed; sandy debris like rocks in first exposure above. (See geologic section 120.)	230±
Cove Creek limestone (1013 feet)	
6. Limestone, argillaceous, shaly	115
5. Limestone, crinoidal, cross-bedded, partly reddish, with *Pterotocrinus* sp.? and *Archimedes communis* Ulrich	30
4. Sandstone, red	10

	Thickness Feet
3. Limestone, fragmental, reddish; contains *Triplophyllum* sp., *Pentremites, Pterotocrinus,* and bryozoa	8
2. Limestone, argillaceous, compact, thick bedded	350
1. Limestone, compact, blue, thick bedded, argillaceous; shelly at bottom with abundant *Pterotocrinus depressus* Lyon and Casseday; weathers white	500

Fido sandstone

The upper boundary of the Cove Creek may not be at the lower edge of the covered interval as taken here, but the lack of exposure is probably due to shale which, being wholly clastic as in the Pennington, seems more probably referable to that formation than to the Cove Creek limestone.

Distribution.—The Glen Dean is present along the Cumberland escarpment, roughly midway up the slope, from Cumberland Gap to Little Stone Gap, Wise County, thence south around the south end of Powell Mountain to the St. Paul fault just north of Horton Summit. Northeast of Horton Summit along the southeast margin of the coal fields, it is intermittently absent, through faulting, or present in narrow strips as far northeast as Big A Mountain, Russell County. The northeast extension of the typical Glen Dean along this belt beyond Horton Summit is unknown.

The Bluefield shale occurs in Virginia only in the Hurricane Ridge syncline marked by Falls Mills, Tazewell County, and in the northward projection of Virginia along New River at the Narrows. In the Hurricane Ridge syncline, its outcrop extends southwest and swings around the axis of the syncline 1½ miles southeast of Bandy. On the southeast limb of the syncline it crosses the State line into West Virginia less than half a mile north of Bluefield, Virginia, extends thence to the Narrows of New River, just south of Rich Creek, West Virginia, and thence northeast in West Virginia to the boundary between Randolph and Tucker counties, where, together with the Pennington (Hinton) and Bluestone formations, it merges into the Mauch Chunk shale of the West Virginia Geological Survey.

The Cove Creek limestone occurs only in a single belt in the Greendale syncline, extending from the State line in Scott County, 12 miles southwest of Gate City, northeast to the Saltville fault just north of Lindell, Washington County.

Thickness.—The Glen Dean so far as known is 300 to 400 feet thick in Lee and Wise counties; the Bluefield shale about 1000 feet thick in Tazewell County; and the Cove Creek limestone about 1000 feet thick according to determinations that seem the best possible at present.

Fossils and correlation.—The Glen Dean in Virginia is moderately fossiliferous; some layers are highly so. *Pentremites,* fenestrellinid bryozoa, and brachiopods are most common. Small collections have been made at Cumberland Gap and Big Stone Gap, but they probably do not fully represent the Glen Dean fauna of the State. Only a few species of the bryozoa have been identified.

Fossils from the Glen Dean formation in Virginia

Corals
- Triplophyllum spinulosum Edwards and Haime

Blastoids
- Pentremites brevis Ulrich
- Pentremites canalis Ulrich
- Pentremites pyramidatus Ulrich
- Pentremites tulipaeformis Hambach
- Pentremites, two other species?

Crinoids
- Agassizocrinus conicus Owen and Shumard
- Pterotocrinus spatulatus Wetherby

Bryozoa
- Archimedes communis Ulrich
- Archimedes distans Ulrich
- Archimedes meekanus Hall
- Fenestrellina cestriensis (Ulrich)
- Fenestrellina tenax (Ulrich)
- Fenestrellina, several other species
- Fistulipora sp.?
- Lyropora sp.?
- Meekopora clausa Ulrich
- Polypora approximata Ulrich
- Prismopora serrulata Ulrich
- Rhombopora minor Ulrich
- Septopora subquadrans Ulrich
- Tabulipora ramosa (Ulrich)
- Tabulipora tuberculata (Prout)

Brachiopods
- Camarophoria explanata (McChesney)
- Chonetes chesterensis Weller
- Cliothyridina sublamellosa (Hall)
- Composita subquadrata (Hall)
- Composita trinuclea (Hall)
- Dielasma sp.?
- Eumetria verneuilana (Hall)
- Orthothetes kaskaskiensis (McChesney)
- Productus (Dictyoclostus) aff. P. inflatus[a] (McChesney)
- Reticularia setigera (Hall)
- Spirifer increbescens Hall
- Spiriferina spinosa (Norwood and Pratten)
- Spiriferina transversa (McChesney)

Pelecypods
- Aviculopecten, 2 sp.
- Sphenotus?

Ostracodes
- Primitia?
- Other species unidentified

[a] This form seems to have slightly finer ribs than typical D. inflatus (McChesney).

Many of these fossils occur, in Kentucky and farther west, only in the Glen Dean limestone. *Prismopora serrulata* occurs at the very base at Cumberland Gap and *Meekopora clausa* 285 feet above the bottom in the Big Stone Gap section. They indicate thus the Glen Dean age of the entire thickness of beds between the Gasper and the Stony Gap sandstone.

About all the brachiopods of the Glen Dean listed above and some of the bryozoa, including *Fenestrellina tenax* and *Septopora subquadrans,* occur in the Bluefield shale in the area west of Bluefield, West Virginia.[230] The *Pentremites, Pterotocrinus, Agassizocrinus, Meekopora clausa,* and *Prismopora serrulata* have, however, not been reported from that region. In addition these brachiopods have been found: *"Diaphragmus" elegans* (Norwood and Pratten), *Girtyella indianensis* (Girty)?, *Productus* (*Linoproductus*) *ovatus* (Hall), and *Spirifer pellaensis* Weller. The Bluefield has yielded numerous species of pelecypods and gastropods, only a few of which have been noted in the Glen Dean.

The Bluefield occupies exactly the same stratigraphic position as the Glen Dean, and its correlation with the Glen Dean is warranted on that ground. Its fossils are not incompatible with that correlation.

[230] Reger, D. B., Mercer, Monroe and Summers counties: West Virginia Geological Survey, County Repts., pp. 851 to 855, 1925.

The Cove Creek limestone is also correlated with the Glen Dean, mainly on stratigraphic grounds, and that correlation, too, is supported by such meager fossil evidence as has been obtained. *Archimedes communis* Ulrich is a common Glen Dean fossil.

PENNINGTON FORMATION

Name.—The Pennington formation was named by Campbell from Pennington Gap, Lee County.[231] The name Hinton has also been applied to this formation by Campbell[232] and by the West Virginia Geological Survey, but as the Hinton seems plainly the same as the Pennington, and as the name Pennington has priority, it is used throughout in this text.

Limits.—Along the northwest side of the Valley, the Pennington begins at the base with the Stony Gap sandstone which directly overlies the Glen Dean limestone in Lee and Wise counties and the Bluefield shale in Tazewell County. It extends up to the coal measures in Lee and Wise counties, marked at the base by sandstone or conglomerate in the Lee formation. In Tazewell County, Virginia, and in adjacent parts of West Virginia, the Pennington is limited at the top by the Princeton conglomerate which is separated from the coal measures by the thick Bluestone formation (Mississippian). Both the Princeton and Bluestone appear to be absent in Lee and Wise counties, so a hiatus is present in that region between the Pennington and the coal measures. In the Greendale syncline, the bottom of the Pennington is the horizon at which clastic rocks become predominant in passing upward through the Cove Creek limestone. The boundary is not marked by any distinctive or persistent bed.

Character.—The Pennington formation is almost wholly composed of shale and sandstone and contains but a few thin beds of impure limestone. (See Pl. 50A). The sandstone is mainly in thin layers, fine grained, greenish, and red. A few beds are conglomeratic. Some of the conglomeratic beds are hard enough to make hogbacks on the slopes, as on the southeast slope of Little Stone Mountain, 1 mile north of the town of Big Stone Gap. The shale is largely coarse-grained, crumbly, or lumpy mudrock, commonly red, but some beds are yellowish or greenish, or nearly black and calcareous. The red color is the most distinctive characteristic of the formation in its northeastern areas. It shows extensively in the soil and is notably conspicuous in the large areas northwest of Bluefield, Virginia, and West Virginia, where some red beds are as much as 150 feet thick. In the Greendale syncline the

[231] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, pp. 28, 37, 1893.

[232] Campbell, M. R., and Mendenhall, W. C., Geologic section along the New and Kanawha rivers in West Virginia: U. S. Geol. Survey Ann. Rept. 17, pt. 2, p. 487, 1896.

major part of the Pennington is shale and sandstone. A little fossiliferous, calcareous sandstone that looks like limestone in fresh condition is present, but it is easily reduced to sandstone by leaching. Minor amounts of red shale and sandstone are also present.

The general character of the Pennington is fully shown by the following sections:

Geologic Section 118.—Pennington formation in Big Stone Gap, Wise County, Virginia[233]

	Thickness Ft.	In.
Lookout (Lee) conglomerate, very coarse at the base		
Pennington shale (1025 feet)		
32. Green calcareous shale	5	7
31. Green and red sandstone	1	11
30. Blue shale	6	2
29. Coal	1	4
28. Bluish shale	10	4
27. Green sandstone	2	10
26. Olive-green shale	7	4
25. Soft, nonfissile, variegated shale	10	6
24. Sandstone	3	7
23. Soft red shale	8	0
22. Sandy shale	4	0
21. Bluish sandstone	19	0
20. Concealed, probably shale	506	10
19. White sandstone, cross bedded	49	0
18. Conglomerate, white quartz pebbles; makes hogback	7	8
17. Bluish-yellow calcareous shale	27	0
16. Blue sandy shale	10	5
15. Limestone, very impure and fossiliferous	4	1
14. Calcareous and argillaceous sandstone	7	10
13. Calcareous shale, very fossiliferous	6	0
12. Blue sandstone, cross bedded	12	0
11. Purple and green shale	9	5
10. Shale, slightly sandy	4	3
9. Green and purple shale	4	7

[233] Measured by Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, pp. 28, 37, 1893.

	Thickness Ft.	In.
8. Argillaceous sandstone	8	4
7. Fine-grained sandstone	13	5
6. Sandstone, regularly bedded	80	0
5. Sandstone, much cross bedded (Stony Gap sandstone)	107	0
4. Dark-blue calcareous shale	9	0
3. Sandy shale	7	7
2. Argillaceous shale	3	0
1. Heavy sandstone (Stony Gap sandstone) Southern Railroad tunnel	67	0

Newman (Glen Dean) limestone, shaly at top

The small amount of red shale in this section is evident, but more may occur in the concealed interval. About the same part of the section is unexposed in the type locality, Pennington Gap, 16 miles to the southwest, so it is impossible to determine from these sections the character of the rocks in the middle part of the Pennington in Lee and Wise counties.

The best section of the Pennington examined by the writer is on Virginia Route 85, within 1 mile northwest of Bluefield, Virginia. It shows the heterogeneous character of the formation.

Geologic Section 119.—Pennington formation northwest of Bluefield, Virginia

	Thickness Feet
Princeton conglomerate	
39. Sandstone, conglomeratic	65
Pennington formation (1872 feet)	
38. Shale, lumpy, green	10
37. Sandstone	10
36. Shale, olive green, crumbling	50
35. Sandstone, flaggy, shale partings, thick bedded in lower 15 feet	40
34. Mudrock, red	30
33. Not exposed	30
32. Shale, crumbling, and sandstone	20
31. Shale, green, thin layers of sandstone, 3 layers of reddish shale; sandstone predominating at bottom makes cliff 50 feet high	120

		Thickness Feet
30.	Not exposed; probably mainly shale	100
29.	Mudrock, red, with layers of red sandstone 1 to 4 feet thick	200
28.	Sandstone, red	10
27.	Shale or mudrock, red	10
26.	Sandstone, gray, decomposed	10
25.	Shale, yellow, decomposed argillaceous limestone	40
24.	Shale, red	25
23.	Sandstone	10
22.	Shale, green and red	35
21.	Sandstone, green	10
20.	Shale, yellow	25
19.	Sandstone	10
18.	Shale, red	150
17.	Sandstone, red	10
16.	Shale, red, layers of sandstone	100
15.	Sandstone	10
14.	Shale, red, layers of sandstone	75
13.	Shale, yellow-green	75
12.	Shale, mainly red mudrock	125
11.	Sandstone	10
10.	Shale, green	20
9.	Shale	10
8.	Mudrock, red	100
7.	Sandstone, massive	7
6.	Shale, green	40
5.	Shale, red and green	40
4.	Sandstone, thick bedded	30
3.	Shale, red, with thick layers of sandstone	50
2.	Shale, red, yellow and green, with sandstone	150
1.	Sandstone, gray, flaggy, Stony Gap sandstone	75

A thickness of 1250 to 1350 feet for the Pennington (Hinton) in the Bluefield area is given by Campbell[234] and Reger[235] and their map-

[234] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Pocahontas folio (No. 26), p. 3, 1896.

[235] Reger, D. B., Mercer, Monroe and Summers counties: West Virginia Geol. Survey, County Repts., pp. 295-298, 1926.

ping of the outcrop in the immediately adjacent area would not permit a greater thickness even if the rocks are vertical. Hence, it seems probable that the thicknesses of the different members in the preceding section are in error, and that some error also is involved in the computation from dip and width of outcrop, due to unobserved structural irregularities.

About half of the total thickness is red rock, mainly shale or nonfissile, lumpy, mudrock, which is the prevailing textural characteristic of the red rock in all the red formations of the Appalachian Valley from Cambrian to Mississippian, inclusive.

The character of the Pennington in the Greendale syncline is shown by the following section exposed on U. S. Route 19 about half a mile northwest of Greendale.

Geologic Section 120.—Pennington formation northwest of Greendale, Washington County, Virginia

	Thickness Feet
Pennington formation (1205 feet)	
16. Top not exposed; no post-Pennington beds present in the Greendale syncline	
15. Not exposed to top of hills; estimated	200±
14. Shale and sandstone, thin, interbedded, partly red	130
13. Sandstone, calcareous ?	50
12. Sandstone, fine grained, bluish, argillaceous and calcareous, weathers to shale	115
11. Shale	80
10. Sandstone, thick bedded, reddish	15
9. Shale and sandstone, interbedded	40
8. Sandstone and shale, red	20
7. Limestone, crinoidal, reddish, with *"Diaphragmus" elegans* Norwood and Pratten	5
6. Sandstone, shale partings; partly calcareous; reduced to fine-grained sandstone by weathering; fossiliferous; contains crinoid stem plates three-fourths of an inch in diameter, *Fenestrellina cestriensis* (Ulrich) ?, *Polypora* sp.?, *Chonetes chesterensis* Weller, *Cliothyridina sublamellosa* (Hall), *Composita?*, *"Diaphragmus" elegans* (Norwood and Pratten), *Dielasma arkansanum* Weller, *Dielasma* sp.? (short, broad form), *Eumetria verneuilana* (Hall), *Orthothetes kaskaskiensis* (McChesney), *Pustula*	

	Thickness Feet
sp. ?, *Pugnoides* cf. *P. boonensis* (Shumard), *Spirifer increbescens* Hall, *Aviculopecten?* sp., pelecypod cf. *Solenopsis* sp., *Sphenotus* sp. ?, *Sulcatopinna missouriensis* (Swallow)	80
5. Shale	15
4. Sandstone, spheroidal in middle	115
3. Sandstone, evenly bedded, red and blue, with *Productus* abundant	30
2. Sandstone, shaly, reddish	60
1. Not exposed; abundant small pieces of shale and sandstone	250±

Cove Creek limestone (See geologic section 117)

It is impossible to be certain about the limits and thickness of the Pennington in this section for lack of exposure at the bottom, and because in the Greendale syncline generally its top is nowhere limited by an overlying formation. The thickness given is probably a minimum for the Greendale syncline.

The Stony Gap sandstone member[236] is a thick- to thin-bedded, fine-grained, siliceous, gray sandstone. In Big Stone Gap some layers are perfectly ripple-marked. Its thickness in Virginia is about 100 feet.

Many shale and sandstone members and a few limestone members have been recognized and named by Reger,[237] who has described also six beds or streaks of coal, or carbonaceous shale, too thin to be of commercial value. Only a single thin bed was noted at the top of the formation in Virginia in both Pennington Gap and Big Stone Gap.

Distribution.—In the northwest belt next to the coal fields, the Pennington extends as a narrow band along the Cumberland escarpment from Cumberland Gap to Big Stone Gap and around the head of the Big Stone Gap cove. It continues south around the south end of Powell Mountain and thence northeast to a point about 2 miles southwest of Saint Paul, where its outcrop is cut off by the Saint Paul overthrust. It is covered by the overthrust mass to a point about 1 mile northeast of Clinchfield, Russell County, where it emerges and continues northeast to Big A Mountain, where it is also covered by an overthrust. To the northeast of Big A Mountain the outcrop of the Pennington is offset to a point about 1½ miles north of Honaker, and thence in an area reaching a mile in width it extends to Stone Mountain,

[236] Reger, D. B., op. cit., pp. 298, 371.
[237] Reger, D. B., op. cit., pp. 330-378.

6 miles southwest of Richlands, where it is cut off by the Richlands fault. From Richlands a belt extends continuously to the West Virginia line near Pocahontas, Virginia. Southwest of the West Virginia line, the formation crops out on both limbs of the syncline making a narrow V-shaped area including a long narrow strip of the Bluestone formation in the arms of the V. This outcrop continues thence into West Virginia, passing just northwest of Bluefield and reenters Virginia in the projection of the State north of the Narrows of New River. Thence its outcrop continues northeast in West Virginia to the Randolph-Tucker county line, where, with the Bluefield shale and overlying Bluestone formation, it merges into the Mauch Chunk shale of the West Virginia Geological Survey. The small patches of Mississippian along the crest of Pine Mountain on the State line northwest of Dickenson County are Pennington.

The Stony Gap sandstone is persistent as the basal member of the Pennington from Bluefield, West Virginia, to Cumberland Gap. It is also fairly thick along the crest of Pine Mountain on the northwest boundary of the State, at least from Pound Gap to Osborn Gap, a distance of 6 miles.

In the Greendale syncline the outcrop of the Pennington occupies a broad belt along the southeast side and extends from the Tennessee line northeast to a point about 5 miles northeast of Greendale, where the axis of the syncline is crossed by the Saltville fault. South of Gate City the outcrop is entirely covered by the overthrust mass for a distance of 8 miles.

The best exposure of the Pennington seen by the writer is on Virginia Route 85, 1 mile northwest of Bluefield, Virginia, where geologic section 119 is located. The red soil derived from the red shale of the formation can be well seen on the roads crossing the Hurricane Ridge syncline, as on State Route 81, from Tazewell to Shrader. It is fairly well exposed in Osborn Gap on Pine Mountain northwest of Clintwood, Dickenson County. Partial exposures may be seen in Big Stone and Pennington gaps.

The Stony Gap sandstone is best displayed at Stony Gap northwest of Bluefield, West Virginia; a quarter of a mile southwest of the Pinnacle in Mercer County, West Virginia, five miles north of Bluefield; on Virginia Route 81, not far north of Adria, Tazewell County; and at Callagan tunnel on the Southern Railway one mile northwest of the town of Big Stone Gap. The Stony Gap sandstone is also well shown in Osborn Gap; and at Raven Rock in Letcher County, Kentucky, just northwest of Pound Gap, which is at the place where U. S. Route 23 crosses Pine Mountain northwest of Pound, Wise County.

Thickness.—The Pennington is about 1300 feet thick in Tazewell County and 1000 feet thick in Pennington Gap, but is only about 150 feet thick at Cumberland Gap, where it is represented mainly by a sandstone in the lower half that may reasonably be identified as the Stony Gap sandstone. The diminished thickness at Cumberland Gap is in agreement with the thickness of 50-200 feet farther west in eastern Kentucky and southwest into the Birmingham district, Alabama. The formation is about 800 feet thick on the crest of Pine Mountain north of Dickenson County and presumably for some distance to the northeast.

Fossils and correlation.—The Pennington is moderately fossiliferous in Virginia, both in its northwestern belt and in the Greendale syncline. Small collections were made in Virginia, in the Greendale syncline only and mainly along U. S. Route 19 northwest of Greendale. These forms are listed below:

Fossils in the Pennington formation

Bryozoa
- Archimedes communis? Ulrich
- Fenestrellina cestriensis (Ulrich)
- Fenestrellina serratula (Ulrich)?
- Fenestrellina tenax (Ulrich)
- Polypora sp.?

Brachiopods
- Chonetes chesterensis Weller
- Cliothyridina sublamellosa (Hall)
- Composita subquadrata? (Hall)
- "Diaphragmus" elegans (Norwood and Pratten)
- Dielasma cf. D. arkansanum Weller
- Eumetria verneuilana (Hall)
- Orthothetes kaskaskiensis (McChesney)
- Pugnoides cf. P. boonensis (Shumard)
- Pustula sp.?
- Spirifer increbescens Hall?

Pelecypods
- Aviculopecten, 2 sp.
- Leptodesma sp.?
- Sulcatopinna missouriensis (Swallow)

Ostracodes
- Hollinella cestriensis Ulrich?

Below is a list given by Reger[238] of some fossils collected on Virginia Route 85, 1⅓ miles northwest of Bluefield, Virginia. The

[238] Reger, D. B., op. cit., p. 847.

fossils were obtained from a limestone 1 foot thick, 10 feet below the Princeton conglomerate.

Fossils from the Pennington formation northwest of Bluefield, Virginia

(Collected by D. B. Reger and identified by G. H. Girty.)

Archimedes aff. A. negligens Ulrich
Aviculopecten monroensis Worthen
Cliothyridina sublamellosa (Hall)
Composita subquadrata (Hall)
Conocardium sp.
"Diaphragmus" elegans (Norwood and Pratten)
Edmondia? sp.
Eumetria vera (Hall)
Fenestrellina sp.?
Griffithides mucronatus Girty ?
Myalina sp.
Orthothetes kaskaskiensis (McChesney)
Schizodus sp.
Spiriferina spinosa (Norwood and Pratten)

The most significant fossil of the preceding lists for correlation is *Sulcatopinna missouriensis* (Swallow). This is a diagnostic fossil of the Menard and Clore limestones of latest Mississippian age in southern Illinois and thus indicates the late Mississippian age of the Pennington. *Sulcatopinna* was collected at a point on the Clinchfield Railroad about a quarter of a mile north of the State line and 5 miles southwest of Gate City; on the Southern Railway about a quarter of a mile northeast of Benham Station; and on U. S. Route 19, about half a mile northwest of Greendale.

PRINCETON CONGLOMERATE

Name.—The Princeton conglomerate was named by Campbell[239] from Princeton, Mercer County, West Virginia.

Limits.—The Princeton conglomerate lies between the Pennington (Hinton) formation below and the Bluestone formation above and forms the only recognizable horizon between them.

Character.—The Princeton conglomerate is a conglomeratic sandstone, containing pebbles, mainly of quartz, scattered through it, either singly or in nests. Pebbles that have been identified as limestone occur in the bottom, but they may prove to be pellets of indurated clay. It is

[239] Campbell, M. R., and Mendenhall, W. C., op. cit., pp. 487, 489.

generally thick bedded and coarse grained. Locally, it contains thin layers of shale.

Distribution.—In Virginia the Princeton conglomerate occurs only in the Hurricane Ridge syncline between Bluefield, Virginia, and Falls Mills, and in another strip adjacent to the coal fields, extending from the State line southwestward near Pocahontas and Boissevain to the fault 2 miles southwest of Boissevain. In the Hurricane Ridge syncline the Princeton crops out on both sides of the axis from the State line southwest to a point south of Shrader, where the two belts converge at the axis of the syncline.

The best exposure of the Princeton conglomerate seen by the writer in Virginia, is at the bend of Virginia Route 85, 1 1/3 miles northwest of Bluefield, Virginia. It is also exposed in the road at Falls Mills but not so conspicuously. The best exposures are on the roads both west and east of Princeton, West Virginia.

Thickness.—The thickness of the Princeton conglomerate is generally 40 to 50 feet.

Fossils and correlation.—Only a few fragments of fossil plants have been found in the Princeton, and they indicate no more than its late Mississippian (Chester) and pre-Pottsville age.

BLUESTONE FORMATION

Name.—The Bluestone formation was named by Campbell[240] from Bluestone River which flows through its main area of outcrop north of Princeton, West Virginia.

Limits.—The Bluestone formation extends upward from the Princeton conglomerate to the base of the Pennsylvanian, or coal-measure, rocks. It is the uppermost Mississippian formation of Virginia and is probably as young as the youngest Mississippian of the Mississippi Valley, if not younger.

Character.—The Bluestone formation is essentially a continuation upward of the Pennington type of lithology—gray and green, fine-grained sandstone, and red, and greenish or bluish shale. A thin layer of impure fossiliferous limestone, which is very rare, and thin layers of coal occur at several horizons. Were it not for the Princeton conglomerate, no basis would exist for separating the Bluestone from the Pennington. No well exposed sections of the Bluestone were observed by the writer in Virginia. As the entire thickness of the forma-

[240] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Pocahontas folio (No. 26), p. 3, 1896.

tion does not occur in Virginia, except possibly in the extreme northwest belt near Pocahontas and Boissevain, and as no coal-measure rocks are present elsewhere in Virginia to mark its top, a section was examined in Mercer County, West Virginia. This section extends from Bluestone River to the top of the spur between Middleton Fork and Lashmeet Branch 4 miles northwest of Princeton.[240a]

Geologic Section 121.—Bluestone formation northwest of Princeton, West Virginia

	Thickness Feet
Pottsville sandstone at top, with coal bed	30
Bluestone formation (609 feet)	
25. Clay	1±
24. Shale, yellow-green	30
23. Shale, dark, slabby, slightly sandy	30
22. Shale, yellow-green	15
21. Sandstone	3
20. Shale, yellow-green	7
19. Shale, red, flaky or pulverulent	35
18. Sandstone	15
17. Not exposed	75
16. Shale, red	7
15. Not exposed	15
14. Shale, red	7
13. Not exposed	30
12. Shale, red	7
11. Not exposed	15
10. Shale, red, and sandstone, yellow	7
9. Not exposed	40
8. Shale, yellow-green, flaky, a little red	35
7. Sandstone	15
6. Shale, red	15
5. Shale, yellow-green	80
4. Sandstone, flaggy	10
3. Shale	80

[240a] See Bluefield, West Virginia, topographic map.

	Thickness Feet
2. Sandstone, cross bedded	15
1. Shale	20
Princeton conglomerate	35
Not exposed to river	70

A similar and more continuous section, but not complete because it is not delimited at the top by Pottsville rocks, has been made south of Princeton.[241] Reger[242] has recognized a number of shale or sandstone members in the Bluestone.

Distribution.—The Bluestone formation in Virginia is present only in the Hurricane Ridge syncline between Bluefield and Falls Mills, and in a narrow belt next to the coal fields, passing just southeast of Pocahontas and Boissevain. Its terminal outcrop is 2 miles slightly southeast of Shrader. The largest areas of the formation, and the best exposures, are along and northwest of Bluestone River northwest of Princeton and in the Hurricane Ridge syncline between Bluefield and Princeton. Many good exposures, including large thicknesses of red shale, as well as large areas of red soil, may be seen along U. S. Route 19, between Bluefield and Princeton. Only partial exposures showing dark-colored or gray shale and sandstone were seen by the writer in Virginia along Virginia Route 85, and on the Norfolk and Western Railroad half a mile southeast of Falls Mills.

Thickness.—The thickness of the Bluestone formation exceeds 600 feet, but it has not been determined exactly because nowhere are the top and bottom present and determinable at places in close proximity. Geologic section 121 was made at as favorable a place as could be found, but its top and bottom are at least half a mile apart horizontally, and the amount of dip is uncertain. In the section south of Princeton measured by Reger,[243] the thickness obtained is 620 feet, but here the top is not present. Both Campbell and Reger estimated the maximum thickness at 800 feet.

[241] Reger, D. B., Mercer, Monroe, and Summers counties: West Virginia Geol. Survey, County Repts., p. 196, 1925.
[242] Op. cit., pp. 330-378.
[243] Reger, D. B., op. cit., p. 196.

Fossils and correlation.—The writer made only one collection from the Bluestone formation; along State Route 85, half a mile southeast of Falls Mills. It contains an abundance of a small pelecypod suggesting *Naiadites* and of an ostracode which, according to Bassler,[244] has not been determined even generically. Reger[245] lists the following fossils from the Bluestone, identified by Girty: *Allorisma andrewsi* Whitfield?, *Caneyella richardsoni* Girty, *Cypricardella* aff. *C. oblonga* Hall, *Edmondia equilateralis* Girty, *Nucula* sp., *Parallelodon* aff. *P. micronema* (Meek and Worthen), and *Spathella*? sp. These fossils afford no evidence for correlation, but if the Pennington of the Greendale syncline is correctly correlated with the Pennington of the northwest side of the Valley, and, if the horizon of *Sulcatopinna missouriensis* of the Greendale syncline occurs in the upper part of the Pennington of the northwest belt not far below the Princeton conglomerate, then the upper part of the Pennington of the northwest belt would be correlated with the Menard and Clore formations of the Mississippi Valley, and the Bluestone could reasonably be correlated with the Degonia sandstone and Kincaid limestone which overlie the Clore limestone in southern Illinois. *Sulcatopinna missouriensis* is reported by Weller[246] from the Kincaid limestone in some localities.

RELATIONS AND EQUIVALENCES OF THE GREENBRIER AND NEWMAN LIMESTONES

In a number of publications the strata between the Price and Pennington formations have been included together as single formation and have received two names, the Greenbrier limestone in the Bluefield region and West Virginia generally, and the Newman limestone in Lee, Wise, Scott, and Washington counties, Virginia. The Greenbrier and the Newman are not exactly equivalent, as the Newman includes the Glen Dean limestone, regarded as equivalent to the Bluefield shale, which is not included in the Greenbrier. Neither is the Newman of Lee and Wise counties quite equivalent to the Newman of the Greendale syncline, which includes the Warsaw limestone. The Warsaw is not present in Lee and Wise counties. The correlations of these formational units are expressed in Table 10 below:

[244] Personal communication.
[245] Reger, D. B., op. cit., p. 847.
[246] Weller, Stuart, The geology of Hardin County and the adjoining part of Pope County: Illinois State Geol. Survey Bull. 41, p. 222, 1920.

TABLE 10.—*Relations and equivalences of the Greenbrier and Newman limestones to the units used in this report.*[a]

	Bluefield area	Cumberland Gap and Big Stone Gap areas		Greendale Syncline	
	Pottsville group		Pottsville group		(No higher formation present)
	Bluestone formation		Hiatus		
	Pennington formation		Pennington formation		Pennington formation
Greenbrier limestone	Bluefield shale	Newman limestone	Glen Dean limestone	Newman limestone	Cove Creek limestone Fido sandstone
	Gasper limestone Ste. Genevieve limestone St. Louis limestone		Gasper limestone Ste. Genevieve limestone St. Louis limestone		Gasper limestone Ste. Genevieve limestone St. Louis limestone
	Hiatus	Hiatus			Warsaw limestone
Price formation	Price formation	Price formation	Price formation	Price formation	Price formation

[a] The Greenbrier and Newman are equivalent to the formations named in the columns to their right, respectively.

HIATUS

The Bluestone does not appear to be represented in Lee and Wise counties and it has not been definitely recognized southwest of Tazewell County. In those southwestern counties, therefore, a slight hiatus occurs between the Pennington formation and the overlying Lee formation. This hiatus increases westward, and at South Portsmouth, Kentucky, and along the western margin of the Appalachian Plateaus, generally, the uppermost part of the Pottsville group rests upon Mississippian of the age of the Price formation. That fact means that all of the lower part of the Pottsville group and all of the Mississippian above the Price are absent

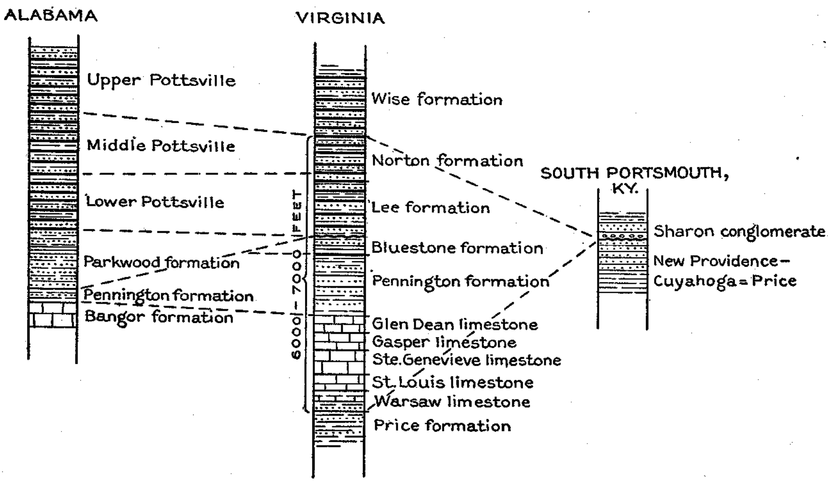


FIGURE 3.—Ideal sections to show the hiatus between the Mississippian and Pennsylvanian systems west of the Appalachian Plateaus. A thickness of 6000 to 7000 feet of strata present in southwest Virginia is absent at South Portsmouth, Kentucky, and in that general area of Kentucky and Ohio.

at South Portsmouth. This hiatus is even greater southward, for in Alabama, between the base of the Pottsville and the Floyd shale, the top of which may represent part of the Pennington, lies the Parkwood formation, 2200 feet thick, which is also absent at South Portsmouth. So far as known, this formation is not represented in Virginia. Geologists generally regard the Parkwood as Pennsylvanian, but older than Pottsville. Thus, if the Parkwood is not represented in Virginia, there is also a great hiatus between the Bluestone and the Pottsville, although they seem to form an unbroken sequence. These conditions and their interpretation are graphically illustrated by the sections of Figure 3.

PENNSYLVANIAN SYSTEM

GENERAL STATEMENT

The Pennsylvanian system includes the main body of coal-bearing rocks of the United States east of the Rocky Mountains. The full sequence of these rocks is shown in Table 1. The older coal-bearing rocks of the Price formation, as well as younger rocks with thin and unimportant coal beds of the Permian system overlying the Pennsylvanian in the southwestern corner of Pennsylvania and along Ohio river in West Virginia and southeastern Ohio are excluded from the Pennsylvanian. The name, Pennsylvanian, was taken from the State of Pennsylvania which was long the chief coal mining region of the eastern United States. The Pennsylvanian system in the eastern United States comprises the following formations named in descending order: Monongahela formation, Conemaugh formation, Allegheny formation, and Pottsville group.

Only the Pottsville group has certainly been recognized in Virginia, but it is possible that the Harlan sandstone, occupying the highest knobs in Wise County, is of Allegheny age.

POTTSVILLE GROUP

The Bluestone formation, like all of the preceding Paleozoic formations, is predominantly of marine origin. In places and at times small areas were above sea level and occupied by fresh water swamps, or because of some other condition sea water was excluded. In such areas terrestrial plants grew and formed thin coal beds. With the close of Bluestone deposition and the beginning of the Pottsville epoch a great change came over the areas of the present eastern North America. The sea bottom was built up or underwent general emergence above sea level. Subsequently the land underwent gentle, intermittent and differential subsidence and upon its subsiding surface, gravel, sand, and mud were deposited on land and in fresh-water swamps or lakes instead of dominantly in the sea as in earlier Paleozoic periods. In the swamps grew luxuriant vegetation which accumulated in bogs to form the great coal deposits of the Appalachian coal fields. The earliest deposits of this new epoch, with their coal beds, constitute the lower coal measures, or Pottsville group of formations.

The name Pottsville is from Pottsville, Pennsylvania, and was originally applied to the lowest 1200 feet or so of the coal-bearing rocks of the anthracite coal fields of east-central Pennsylvania.

Its application has been extended to equivalent formations elsewhere. The group of the anthracite fields is subdivided into lower, middle, and upper Pottsville. The equivalents of these three divisions occur in the coal fields of southwestern Virginia. These rocks in Virginia have been mapped in great detail and exhaustively described in a series of bulletins.[247]

The Pottsville group of Virginia is composed almost entirely of a homogeneous and monotonous succession of beds of sandstone and shale in which are intercalated numerous beds of coal. Only two thin beds of limestone a few inches to a few feet thick have been reported in Virginia. The general character of the Pottsville is shown by the sections of Plate 52, and by detailed sections given under the description of the individual formations. The feature of chief interest and importance is the coal, in beds distributed through the group from bottom to top. For convenience of description and reference, these Pottsville strata have been subdivided into formations, but these have no strongly distinctive lithologic features by which they can be easily distinguished one from another. These subdivisions follow in order of superposition:

- Pottsville group
  - Harlan sandstone (possibly of Allegheny age)
  - Wise formation
  - Gladeville sandstone
  - Norton formation
  - Lee formation

LEE FORMATION

Name.—The Lee formation was named as Lee conglomerate by Campbell[248] from Lee County, Virginia.

Limits.—The Lee formation includes the coal-measure strata lying above the Bluestone formation, as in Tazewell County, or the Pennington formation as in Lee and Wise counties, and is marked at the top by a persistent sandstone known in the Big Stone Gap area as the "Bee Rock." A similar, and perhaps the same, sandstone forms the top of the Lee in Tazewell County. This sandstone is apparently the same as the Harvey conglomerate of McDowell County, West Virginia. The basal member of the Lee in Wise and Lee counties is a thick-bedded sandstone with conglom-

[247] Virginia Geol. Survey Bulls. 12, 18, 19, 21, 22, 24, and 26.

[248] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, p. 36, 1893.

erate layers at the base. Similar rock occurs along the Virginia-Kentucky line north of Wise, Dickenson, and Buchanan counties. A thicker bed of sandstone and conglomerate a few hundred feet above the bottom is known as the Bald Rock conglomerate. A distinctive feature of the sandstone beds of the Lee is that they are composed almost entirely of pure quartz sand with a considerable sprinkling of quartz pebbles, generally less than half an inch in diameter. In some layers the pebbles are so abundant as to make a conglomerate. A detailed section of the Lee formation as exposed in Little Stone Gap between Big Stone Gap and Norton, Wise County, follows:

Geologic Section 122.—Lee formation through Little Stone Gap, Wise County, Virginia[249]

	Thickness Ft.	In.
Lee formation (1837± feet)		
62. Sandstone, massive, slightly conglomeratic (Bee Rock)	80	
61. Shale	20	
60. Coal, bloom		
59. Clay		4
58. Shale, dark gray	25	
57. Coal		6
56. Shale	10	
55. Coal, bloom		
54. Shale, carbonaceous	3	
53. Shale	30	
52. Sandstone, arkosic	20	
51. Coal		3
50. Clay		2
49. Coal	1	11
48. Clay	10	
47. Sandstone, arkosic	50	
46. Shale, thin bedded	50	
45. Shale, clayey	35	
44. Coal		3
43. Clay		2

[249] 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. 99, 1923.

		Thickness Ft.	In.
42.	Coal	1	6
41.	Sandstone, light gray	20	
40.	Unexposed; probably shale	260	
39.	Conglomerate, massive	80	
38.	Shale, dark gray	40	
37.	Coal	2	6
36.	Clay		2
35.	Shale, sandy	70	
34.	Conglomerate	75	
33.	Unexposed	40	
32.	Shale	15	
31.	Shale	6	
30.	Coal	3	
29.	Shale, gray, clayey	1	
28.	Shale, sandy	60	
27.	Sandstone	10	
26.	Sandstone (?) not clearly exposed	60	
25.	Conglomerate (Bald Rock member)	160	
24.	Shale	10	
23.	Sandstone, gray	20	
22.	Shale	70	
21.	Coal		6
20.	Sandstone	5	
19.	Shale	90	
18.	Sandstone	10	
17.	Shale	100	
16.	Coal	1	
15.	Shale	60	
14.	Sandstone	30	
13.	Shale, sandy	5	4
12.	Coal	2	
11.	Shale, sandy	9	
10.	Sandstone	10	
9.	Shale, clayey, squeezed	3	
8.	Sandstone, soft, lumpy	7	

	Thickness Ft.	In.
7. Shale, dark, fossil plants (*Neuropteris pocahontas*)	5	
6. Shale, sandy	7	6
5. Sandstone	10	
4. Shale, sandy, coal streak 12 feet from top	33	
3. Conglomerate, massive, greenish	21	
2. Shale	50	
1. Conglomerate	37	

The lower third, approximately, of this section probably corresponds to the lower third of the Lee in northeastern Tazewell County, in which are the celebrated Pocahontas coal beds shown in Plate 52 in the section for Tazewell County. The occurrence of *Neuropteris pocahontas* 158 feet above the base is significant.

Distribution.—The Lee conglomerate crops out in a belt of irregular width along the southeast edge of the coal fields from Tazewell County to Cumberland Gap, Lee County. A broad belt also extends along the southeast slope of Pine Mountain in northern Dickenson and Wise counties. The Lee is, of course, continuous under the higher coal measures between the two belts.

The basal sandstone of the Lee is exposed on the summit of the Pinnacle, and also in the gap, at Cumberland Gap. Much of the entire Lee is exposed in both Pennington and Big Stone gaps. In both gaps the three prominent sandstone and conglomerate members described above are well exposed. The Bald Rock conglomerate is conspicuously exposed near Millers Yards of the Southern Railway about 2 miles northwest of Dungannon.

Thickness.—On its southeast outcrop from Tazewell to Wise counties, the Lee ranges from 1530 to 1800 feet in thickness. It thins to the northwest and is only about 800 feet thick on the crest and southeast slope of Pine Mountain in Wise and Dickenson counties. The "Bee Rock" sandstone is 95 to 120 feet thick, the Bald Rock conglomerate about 200 feet, and the basal sandstone and conglomerate beds with local shale beds may reach a thickness of about 250 feet.

Fossils and correlations.—No marine fossils have been reported from the Lee formation in Virginia, but they are known at several horizons in the adjacent counties of West Virginia and doubtless occur in Virginia. The Lee was deposited mainly in fresh water lakes and swamps and on low-lying plains near sea level, and marine animals could not live in such habitats. On the other hand, plants of various primitive types, such as ferns and giant club mosses (*Lepidodendron*), flourished in the swamps and their remains accumulated as extensive peat bogs which subsequently were converted into the coal beds of the formation. A few of the plants are listed below and some are shown on the Plates in Part II. The plants were collected in the adjacent counties of West Virginia and should occur also in Virginia. The identifications were made by David White.[250] The species prefixed by an asterisk (*) occur also in the Pottsville of the anthracite coal fields of Pennsylvania but almost entirely in the lower half; those prefixed by a dagger (†) are confined mainly to the middle part of the Pottsville of the anthracite coal field.

Lower Pottsville fossil plants, mainly from the horizon of the Pocahontas No. 3 coal

Ferns and fern-like plants
- Aneimites adiantoides (Lindley and Hutton) Bailey
- Aneimites fertilis D. White
- Eremopteris macilenta (Lindley and Hutton) D. White
- Sphenopteris hoeninghausii Brongniart
- *Alethopteris cf. A. grandifolia Newberry
- Alethopteris sp. D. White
- *Neuropteris pocahontas D. White
- *Neuropteris smithii Lesquereux

Calamites
- *Asterocalamites scrobiculatus (Schlotheim) Zeiller

Lycopods
- Lepidodendron selaginoides Sternberg

Fossil plants from the Quinnimont-Fire Creek coal[a]

Ferns and fern-like plants
- Aneimites tenuifolius (Goeppert) D. White
- *Mariopteris pottsvillea D. White
- Mariopteris dimorpha (Lesquereux) D. White

[250] White, C. D., The fossil flora of West Virginia: West Virginia Geol. Survey, vol. 5(A), pp. 390-453, 1913.

[a] This coal is about the horizon of the lower Horsepen coal of Tazewell County.

Sphenopteris divaricata Geinitz and Gutbier
Sphenopteris hoeninghausii Brongniart
*†Sphenopteris microcarpa Lesquereux
†Sphenopteris, 3 other sp.
Alethopteris sp. D. White
Megalopteris sewellensis Fontaine?
*Neuropteris smithii Lesquereux
*Neuropteris lindleyana Sternberg (probably N. pocahontas, according to White)

Calamites
*Asterocalamites scrobiculatus (Schlotheim) Zeiller

Lycopods
*Lepidodendron veltheimianum Sternberg
†Lepidophyllum campbellianum Lesquereux

Fossil plants from the Sewell coal[a]

Ferns and fern-like plants
†Eremopteris cheathami Lesquereux
Mariopteris pottsvillea n. var. D. White
†Sphenopteris microcarpa Lesquereux
(var. dissecta in middle Pottsville)
*Pecopteris? serrulata (Dawson) D. White[b]
Megalopteris sewellensis Fontaine
†Alethopteris lonchitica (Schlotheim) Sternberg
†Alethopteris serlii (Brongniart) Goeppert
†Alethopteris evansi Lesquereux
†Callipteridium, 3 sp.
Neuropteris schlehani Stur
Neuropteris biformis Lesquereux
†Neuropteris elrodi Lesquereux

Calamites
Calamites approximatus Schlotheim

Lycopods
Lepidodendron sternbergii Brongniart
Sigillaria cf. S. reticulata Lesquereux
†Whittleseya elegans Newberry

[a] This coal probably falls within the seaboard coal group of Tazewell County, Virginia.
[b] First appearance of Pecopteris.

NORTON FORMATION

Name.—The Norton formation was named by Campbell[251] from the town of Norton, Virginia.

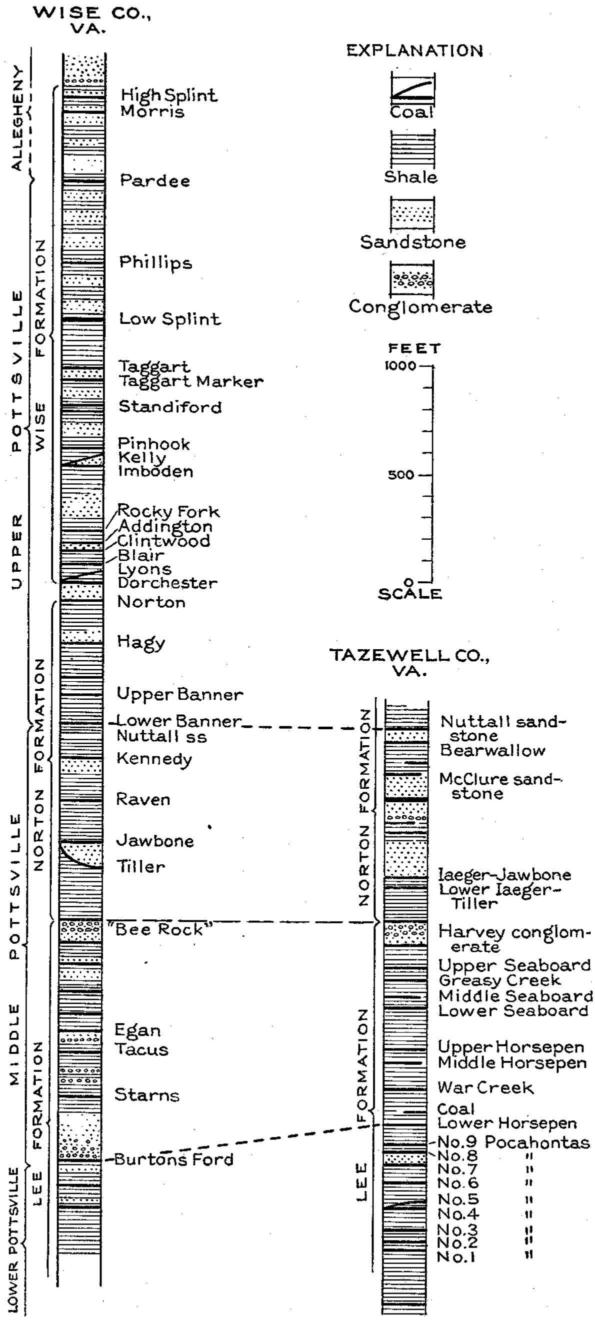
Limits.—The Norton formation includes all the strata, with several coal beds, lying between the "Bee Rock" sandstone at the top of the Lee formation and the overlying Gladeville sandstone.

Character.—The Norton is composed of a succession of strata of shale and sandstone with nine minable coal beds distributed through it. (See Pl. 52, section for Wise County.) It has no intrinsic characters by which it could be distinguished lithologically from the other formations, but it can be defined generally by its fairly distinctive and persistent bounding formations, "Bee Rock" sandstone below and Gladeville sandstone above, which can be recognized from their lithologic character in combination with their stratigraphic position. The Norton includes one conglomeratic sandstone member 150 feet thick, which, on the southeast slope of Pine Mountain in Dickenson and Wise counties, makes a notable hogback or line of knobs. This underlies the Kennedy coal bed and has been named the McClure sandstone. The Nuttall sandstone, a very prominent cliff-maker along New River in Raleigh and Kanawha counties, West Virginia, has been traced into Virginia and may underlie the Lower Banner coal, but it is not as conspicuous a member in Virginia as in West Virginia.

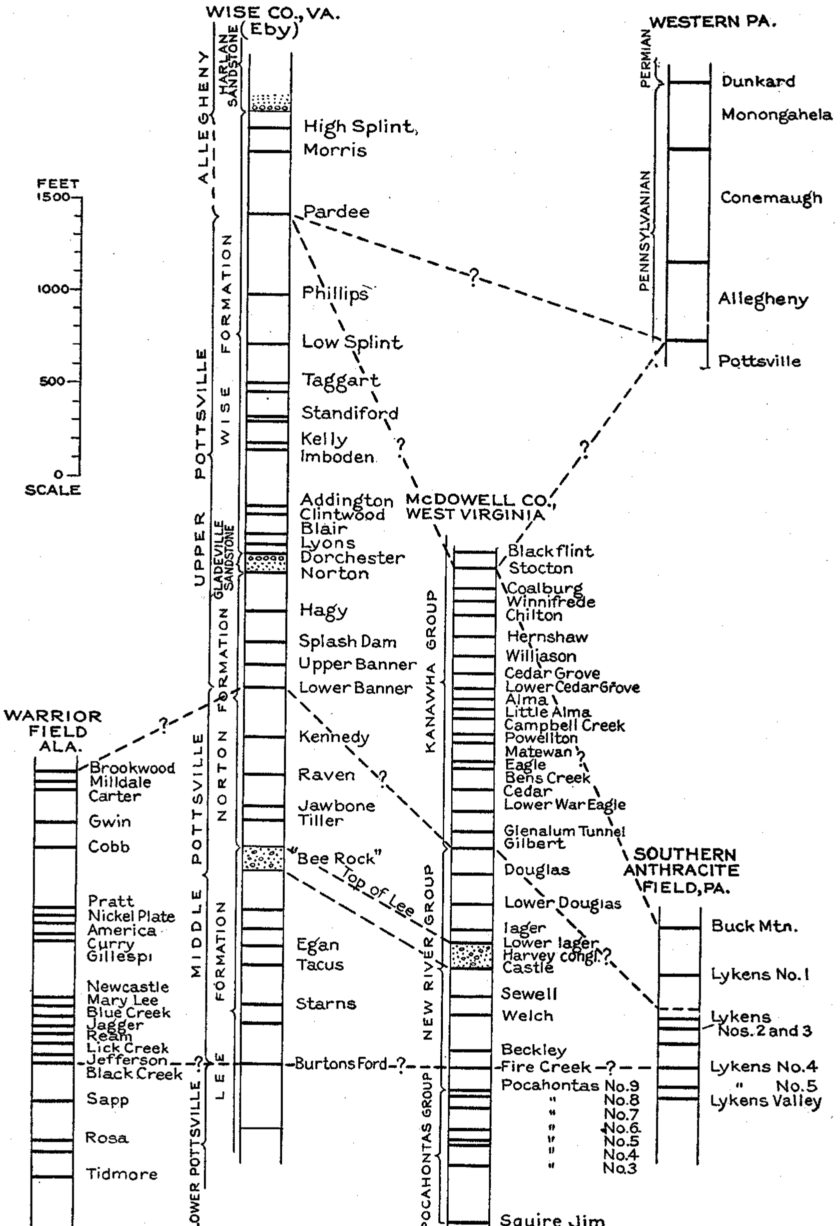
Distribution.—The Norton formation occupies the larger part of Buchanan and Dickenson counties and most of the coal field of Russell County and eastern Wise County. It forms narrow strips on both the north and the south sides of Wise County and outlying patches on Powell Mountain in Wise and Scott counties. The Norton is partially exposed along many roads, streams, and railroads, but no known exposure is complete. The best two partial sections recorded are near Coeburn and Tacoma, Wise County. One of these is 1½ miles east of Tacoma and extends up the face of the bluff from the Norfolk and Western Railroad to the Wise-Coeburn pike. Although 960 feet is exposed, neither the top nor the bottom is included. The other is on the Wise-Coeburn road due west of Coeburn and extends to the summit of the ridge. Here 708 feet is exposed from the Gladeville sandstone down to the Kennedy coal. The section east of Tacoma, Wise County, is given below.[252] It is 1½ miles east of Tacoma, meas-

[251] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, p. 34, 1893.
[252] Eby, J. B., op. cit., p. 105.

VIRGINIA GEOLOGICAL SURVEY BULLETIN 52 PLATE 52



Measured sections of the Pennsylvanian coal-bearing rocks of Virginia; from Virginia Geol. Survey Bull. 19 (1919) on Tazewell County (T. K. Harnsberger) and Bull. 24 (1923) on Wise County (J. B. Eby).



Sections to show provisional correlation and equivalence of the Pennsylvanian formations from Pennsylvania to Alabama. The boundaries of the Lower, Middle, and Upper Pottsville divisions are indicated by continuous dashed lines.

ured northward from the bench mark at 2000 feet above sea level on the Norfolk and Western Railroad, up the face of the bluff to the Wise-Coeburn pike.

Geologic Section 123.—Norton formation east of Tacoma, Wise County, Virginia

	Thickness Ft.	In.
Norton formation (968± feet)		
17. Shale, sandy; elevation at top, 2790 feet	40	
16. Sandstone, massive	75	
15. Shale, sandy	50	
14. Sandstone, massive, arkosic	160	
13. Shale	55	
12. Coal, Upper Banner, elevation 2440 feet	4	6½
11. Shale	150	
10. Coal, Lower Banner, elevation 2325 feet	3	9
9. Shale	20	
8. Sandstone	20	
7. Shale	40	
6. Sandstone	15	
5. Shale	105	
4. Coal, Kennedy, caved pit, elevation 2180 feet		
3. Shale, with thin sandstone beds	170	
2. Coal, Raven, caved pit		
1. Shale	60	

As in a section 1½ miles west of Coeburn and about half a mile east of the preceding section, the thickness between the Upper Banner and the Gladeville sandstone is 362 feet, the top of this section evidently begins close below the Gladeville sandstone. Below the Raven coal to the top of the Lee formation is about 500 feet of shale and sandstone with the Jawbone and Tiller coals about in the middle. No continuous exposure of this part of the Norton formation has been published, from which it is inferred that none is known.

Thickness.—The Norton formation is 825 feet thick along the southeast slope of Pine Mountain in Buchanan, Dickenson, and Wise counties, and 1300 to 1500 feet thick along the southeast border of the coal fields. Like the Lee, the Norton thins markedly northwestward.

Fossils and correlation.—Apparently no fossil plants have been identified and listed from the Norton formation in Virginia, but a list of fossils from the Nuttall sandstone as identified by David White has been published.[253] As the Nuttall sandstone has been traced into Virginia and if, as has been thought, it underlies the Lower Banner coal, it belongs in the Norton formation and its fossils represent to some degree the plant life of that time in Virginia.

Fossil plants from the Nuttall sandstone

*Annularia cuspidata Lesquereux
Archeopteris stricta Andrews
Asterophyllites minutus Andrews
*Calamites approximatus Sternberg
Lepidodendron rushvillense Andrews
*Mariopteris acuta (Brongniart) Zeiller
Mariopteris muricata (Schlotheim) Zeiller
*Mariopteris pygmaea D. White
Pecopteris plumosa Sternberg

GLADEVILLE SANDSTONE

Name.—The Gladeville[254] sandstone was named from Gladeville, the former name of the town of Wise, Wise County.

Limits.—The Gladeville lies between the Norton formation below and the Wise formation above. It is not mapped separately but is included with the Norton formation in a single map unit on the geologic map of the Valley. It lies in the top of this unit throughout, just below the lower boundary of the Wise formation.

Character.—The Gladeville is a medium coarse-grained, gray, quartzose, and locally conglomeratic sandstone. At Wise it is a hard, resistant stratum forming a bench on which the town is built. In northern Wise, Dickenson, and Buchanan counties, it is less quartzose and more arkosic and less persistent, so it does not show in outcrop so well as farther south. In western Wise County, the lower part is a conglomerate.

---

[253] White, C. D., The fossil flora of West Virginia: West Virginia Geol. Survey, vol. 5(A), p. 435, 1913.
[254] Campbell, M. R., op. cit., p. 33.
*Middle Pottsville.

Distribution.—The Gladeville sandstone is persistent throughout the coal fields of southwestern Virginia but less conspicuous in outcrop in Buchanan County than in other parts. It is well exposed in the vicinity of Wise and along the road between Wise and Glamorgan. It is especially prominent in southern Dickenson County, where it forms a number of ridges and low plateaus like Big, Porter, and Sandy ridges, Flat Spur 4 miles northeast of Dante, and the large flat area 3 miles northeast of Toms Creek. It is well displayed for miles along Pound River.

Thickness.—The thickness of the Gladeville ranges from 50 to 150 feet, being greatest in southern Dickenson and Wise counties.

Fossils.—The Gladeville sandstone seems to be destitute of fossils.

WISE FORMATION

Name.—The Wise formation was named by Campbell[255] from Wise County.

Limits.—The Wise formation is bounded below by the Gladeville sandstone and above by the Harlan sandstone which caps the highest knobs in Wise County, as Black Mountain.

Character.—The Wise formation comprises shale, sandstone, and 18 coal beds. It is estimated that about one-third of it is sandstone. Most of this is arkosic and contains a large proportion of feldspar grains which by decomposition give it a white, speckled appearance. In this respect the Wise formation differs noticeably from the Lee in which the sandstones are almost exclusively composed of grains and pebbles of quartz. A notable exception is the Addington sandstone member of the Wise which is hard and quartzose. A limestone 8 inches thick occurs in Black Mountain, 215 feet above the Phillips coal, and a limestone containing marine fossils occurs on the west side of Black Mountain in Kentucky, 50 to 100 feet above the Pardee coal. This limestone horizon has been reported in Virginia at the head of Pot Camp Fork and just below the State line at the summit, where it is a calcareous sandstone. Other thin limestones are reported in the upper part of the Wise. Two other fossiliferous horizons in sandstone have been noted, one about 60 feet below the Imboden coal on the South Fork of Pound River just west of the place where the river is crossed by the Norton road, and the other on the same road just north of and 50 feet below Fox Gap.

[255] Campbell, M. R., op. cit., p. 34.

Distribution.—The Wise formation occupies most of the northern half of Wise County and a wide strip in the northeastern part of Lee County, extending to the Kentucky line. The Wise formation extends as a wedge into northern Dickenson County. Only a few hilltop outliers of the formation occur in the eastern half of Dickenson County. A large irregular area of the Wise occupies the northern half of Buchanan County, where it is interspersed with bands of the Norton formation along the streams and is fringed with small hilltop outliers. The Wise is not present in Tazewell or Russell counties, but a narrow strip of it marks the county line along Sandy Ridge northeast of Dante. This distribution of the Wise is controlled by the northwest dip of the strata, whereby higher beds to the northwest have escaped erosion. The Wise once extended over the entire area of the coal fields in the southwestern part of the State.

The Wise is best exposed along State Route 68, from Exeter to the Wise-Lee county line and thence northwest along that line to the summit of Black Mountain. This section, given below, comprises 1898 feet. It is exposed from Laurel on Looney Creek to the summit of Black Mountain at The Double. Still another exposure is on Preacher Creek from Andover to the summit of Black Mountain.[256] A section measured from the westernmost exposure of the Imboden coal bed at Exeter, northwestward along the Keokee-Exeter pike to the Wise-Lee county line, thence north along the county line to the top of Black Mountain, and thence northeastward one-eighth of a mile to the top of knob on the mountain crest follows:[257]

Geologic Section 124.—Harlan sandstone and Wise formation along the Lee-Wise county line, Virginia

	Thickness Ft.	In.
Harlan sandstone (100 feet)		
53. Shale, elevation at top, 3820 feet	20	
52. Conglomerate, massive	80	
Wise formation (1898 feet)		
51. Shale	132	
50. Sandstone	25	
49. Shale	38	

[256] 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; geologic sections, pp. 88-91, 1923.
[257] Eby, J. B., op. cit., pp. 87-88.

	Thickness Ft.	In.
48. Sandstone, steep cliff at top	125	
47. Shale[a]	102	
46. Sandstone, thin bedded	91	
45. Shale	38	
44. Sandstone	22	
43. Shale	50	
42. Sandstone, thin bedded at top	10	
41. Shale	10	
40. Sandstone, very hard, ledge making	10	
39. Shale	44	
38. Sandstone, soft, medium grained	10	
37. Shale	130	
36. Sandstone	20	
35. Shale	40	
34. Sandstone	5	
33. Shale, sandy	55	
32. Sandstone, massive, ledge making	10	
31. Shale	75	
30. Sandstone, massive	15	
29. Shale	75	
28. Sandstone	8	
27. Shale	155	
26. Sandstone, soft, with hard cap-rock	40	
25. Shale	23	
24. Sandstone	5	
23. Shale	10	
22. Sandstone	8	
21. Shale	2	
20. Sandstone	10	
19. Shale	60	
18. Coal, Taggart, caved pit, elevation 2385 feet		
17. Shale	44	
16. Sandstone, soft	5	
15. Shale	55	
14. Sandstone, soft, coarse grained	18	

[a] About the horizon of the Pardee coal?

	Thickness Ft.	In.
13. Shale	82	
12. Sandstone, coarse grained	5	
(Keokee-Exeter road, B. M. 2194 feet)		
11. Sandstone	20	
10. Shale	10	
9. Coal, bloom		
8. Shale	10	
7. Sandstone	95	
6. Shale	75	
5. Sandstone, coarse grained, hard, gray	20	
4. Coal		6
3. Clay		6
2. Shale	5	
1. Coal, Imboden, caved pit, elevation 1958 feet		

The upper 1453 feet of this section contains several minable coal beds, including the Pardee bed, 400-550 feet below, and the High Splint bed, 50-80 feet below the Harlan sandstone, which were not exposed along the line of the section.

None of these sections extends below the Imboden coal. They are supplemented by a section on the North Fork of Pound River beginning on the road at the bench mark of 1772 feet, half a mile north of and going south to Flat Gap, and thence east half a mile along the road to the summit of the dividing ridge. This section extends from 83 feet above the Imboden coal to 100 feet below the Clintwood coal, and to within 50 feet or so of the top of the Gladeville sandstone at the base of the Wise formation. This is exposed, or at least present, at river level at the starting point. The section follows:[259]

Geologic Section 125.—Wise formation, half a mile north of Flat Gap, Wise County, Virginia

	Thickness Ft.	In.
Wise formation (597± feet)		
25. Shale, elevation at top, 2070 feet	20	
24. Coal	1	

[259] Eby, J. B., op. cit., pp. 103-104.

		Thickness Ft.	In.
23.	Shale	20	
22.	Coal, Kelly	2	1
21.	Shale	30	
20.	Sandstone	10	
19.	Coal, Imboden (?)		6+
18.	Shale	40	
17.	Coal		4
16.	Shale		4
15.	Coal		2
14.	Shale	10	
13.	Sandstone	10	
12.	Shale	20	
11.	Coal		2
10.	Shale	20	
9.	Sandstone	10	
8.	Shale, brown and gray	240	
7.	Sandstone	8	
6.	Shale	20	
5.	Sandstone	10	
4.	Shale, sandy	21	
3.	Coal, Clintwood, elevation 1825 feet	2	
2.	Sandstone	21	
1.	Shale, sandy (B. M. 1772 feet)	80	

The 150 feet below the Clintwood coal includes the horizon of the Blair, Eagle, and Dorchester (Glamorgan) coals.

Another good section of the lower 1200 feet of the Wise, and showing the position of the Eagle, Blair, and Dorchester (Glamorgan) coals, can be seen in Buchanan County. It lies along and northwest of Rockhill Creek from a point midway between Grass Springs and Old Field branches to Dicks Branch; thence it ascends Dicks Branch to its head, and turns east along the ridge to a high knob. The section follows:[260]

[260] Hinds, Henry, The geology and coal resources of Buchanan County, Virginia: Virginia Geol. Survey Bull. 18, p. 47, 1918.

Geologic Section 126.—Wise formation in Buchanan County, Virginia

	Thickness Feet
Wise formation (1070 feet), top not present	
45. Sandstone, coarse grained, moderately coherent	80
44. Shale	65
43. Sandstone, coarse grained, weathers granular	30
42. Sandstone, shaly, and shale	15
41. Sandstone, reddish brown, medium grained, poorly exposed at base	100
40. Shale	20
39. Sandstone, white and coarse grained at top, brown and medium grained at base	50
38. Shale	30
37. Cedar Grove coal horizon (?)	
36. Sandstone, fine grained	10
35. Shale	10
34. Sandstone, coarse grained, weathers white to yellow and granular	50
33. Shale, yellow	20
32. Sandstone, fine grained, shaly	10
31. Shale	10
30. Sandstone, light brown, medium grained, compact	30
29. Alma coal horizon	
28. Sandstone	25
27. Shale	50
26. Sandstone, coarse grained	25
25. Shale or shaly sandstone	15
24. Sandstone, fine grained	15
23. Shale	10
22. Campbell Creek coal horizon	
21. Sandstone, moderately coarse grained	35
20. Concealed, chiefly shale	146
19. Sandstone, fine grained	10
18. Shale	5
17. Coal, Clintwood	4

		Thickness Feet
16.	Sandstone, coarse grained, massive	75
15.	Eagle coal horizon	
14.	Shale, blue	30
13.	Blair coal, approximate position	
12.	Concealed	85
11.	Coal bloom, Dorchester (Glamorgan)	
10.	Shale	10
Gladeville sandstone		
9.	Sandstone, medium grained	60
Norton formation (145 feet)		
8.	Concealed, probably shale	45
7.	Hagy coal horizon	
6.	Sandstone	25
5.	Shale, blue, compact	15
4.	Concealed, probably shale	15
3.	Sandstone	20
2.	Shale and shaly sandstone	25
1.	Splash Dam coal horizon	

Thickness.—The Wise formation ranges in thickness from 2100 feet at the head of Pound River to about 2300 feet in the western part of Wise County. Its full thickness is present only in the Black Mountain area, where it is overlain by the Harlan sandstone on the summit of the mountain. The thickness that has escaped erosion decreases through Dickenson County, so that nearly all the Wise has been removed from a wide strip west of the Dickenson-Buchanan county line. In northern Buchanan County, the maximum thickness of the Wise is about 1200 feet, as it is near the State line north of Rockhill Creek.

Fossils and correlation.—The Wise formation is nearly equivalent to the Kanawha formation of West Virginia, and the fossil plants of that formation occur also in the equivalent coal beds in Virginia. Most of the Kanawha plants are of species different from those of the Lee and Norton formations. Several species from the Eagle coal of West Virginia, the horizon of which is believed to be near the base of the Wise formation in Virginia, as identified by David White,[261] are listed below.

[261] White, C. D., The fossil flora of West Virginia: West Virginia Geol. Survey, vol. 5(A), pp. 436-442, 1913.

Fossil plants from the Eagle coal of West Virginia

Ferns and fern-like plants
- *Eremopteris cf. E. lincolniana D. White
- *Mariopteris inflata (Newberry) White
- *Mariopteris muricata (Schlotheim) Zeiller
- Mariopteris acuta (Brongniart) Zeiller
- Mariopteris nervosa (Brongniart) Zeiller
- *Sphenopteris spinosa Goeppert
- *Sphenopteris furcata Brongniart
- Sphenopteris, 3 other species
- Pecopteris cf. P. integra (Andrae) Schimper
- Alethopteris decurrens (Artis) Sternberg
- Alethopteris serlii (Brongniart) Goeppert
- Neuropteris flexuosa Sternberg
- *Neuropteris cf. N. zeilleri Potonie

Calamites
- Calamites ramosus Artis
- *Asterophyllites minutus Andrews
- Asterophyllites rigidus (Sternberg) Brongniart
- *Annularia acicularis (Dawson) Renault
- *Sphenophyllum cuneifolium (Sternberg) Zeiller
- *Sphenophyllum furcatum (Lindley and Hutton) Geinitz

Lycopods
- Lepidodendron cf. L. dichotomum Sternberg
- Lepidodendron obovatum Sternberg

*Modified survivors of the older Pottsville species.

The species of fossil plants listed below are from the Cedar Grove coal, which is 500 feet above the Eagle coal and which is about the same as the Low Splint coal of Wise County.[262]

Fossil plants from the Cedar Grove coal of West Virginia

Ferns and fern-like plants
- Eremopteris cf. E. sauveuri (Crepin) D. White
- Cheilanthites obtusilobus dilatus (Lesquereux) D. White
- Mariopteris cf. M. jacquoti (Zeiller) D. White
- Mariopteris andraeana (v. Roehl.) D. White
- *Mariopteris nervosa (Brongniart) Zeiller
- Mariopteris sphenopteroides (Lesquereux) Zeiller
- Sphenopteris spinosa Goeppert
- *Sphenopteris cf. S. dubuissonis Brongniart

[262] White, C. D., op. cit., pp. 436-442.

Sphenopteris geniculata Germar and Kaulfuss
Sphenopteris hildrethi Lesquereux
Alethopteris lonchitica (Schlotheim) Sternberg
*Alethopteris serlii (Brongniart) Goeppert
Neuropteris flexuosa Sternberg
Neuropteris cf. N. gigantea Sternberg
Neuropteris cistii Brongniart

Calamites
*Calamites suckowi Brongniart
*Calamites cistii Brongniart
*Calamites ramosus Artis
Asterophyllites lycopodioides Zeiller
*Annularia radiata Brongniart
*Annularia ramosa (Artis) Weiss
Sphenophyllum cuneifolium (Sternberg) Zeiller

Lycopods
*Lepidodendron clypeatum Lesquereux
*Lepidodendron veltheimianum Sternberg

*Species also occurring in post-Pottsville formations.

Fossil plants from the Stockton coal, which is about 700 feet above the Cedar Grove coal in West Virginia and which appears to be equivalent to the Pardee, or to the High Splint, coal, of Virginia are listed below.[263]

Fossil plants from the Stockton coal of West Virginia

Ferns and fern-like plants
†Cheilanthites cf. C. nummularius (Gutbier) D. White
†Sphenopteris cf. S. broadheadi D. White
†Sphenopteris hymenophylloides Brongniart
Sphenopteris karwinensis Stur
†Sphenopteris mixta Schimper
†Sphenopteris ophioglossoides (Lesquereux) D. White
†Sphenopteris tenella Brongniart
†Pecopteris villosa Brongniart
†Neuropteris rarinervis Bunbury
†Neuropteris ovata Hoffman
†Neuropteris scheuchzeri Hoffman

Calamites
Asterophyllites equisetiformis (Schlotheim) Brongniart
†Annularia stellata (Schlotheim) Wood

[263] White, C. D., op. cit., pp. 436-442.

†Annularia sphenophylloides (Zenker) Gutbier
Sphenophyllum cuneifolium (Sternberg) Zeiller
Sphenophyllum lescurianum D. White
†Sphenophyllum emarginatum (Brongniart) Koenig

Lycopods
†Lepidodendron lanceolatum Lesquereux
†Lepidodendron cf. L. brittsi Lesquereux
†Lepidodendron modulatum Lesquereux
†Lepidophyllum lanceolatum Lindley and Hutton?
Sigillaria fissa Lesquereux

†Species occurring in the Allegheny formation.

In discussing the correlations suggested by the preceding lists of fossil plants, it is necessary to have clearly in mind the typical Pottsville sequence as especially developed in the Southern Anthracite coal field of Pennsylvania. This sequence, so far as the plant-bearing horizons are concerned, is as follows:

Upper Pottsville
Lykens coal No. 1

Middle Pottsville
Lykens coals Nos. 2 and 3

Lower Pottsville
Lykens coals Nos. 4, 5, and 6

It is shown graphically in Plate 53.

In the fossil lists from the Lee formation, including the Pocahontas No. 3 coal bed, the species preceded by an asterisk (*) occur exclusively in the Lykens Nos, 4, 5, and 6 coals of the lower Pottsville and do not occur in the middle Pottsville, Lykens Nos. 2 and 3 coals. Likewise the same species do not, so far as the lists show, occur above the Quinnimont, or Fire Creek, coal in Virginia; hence about the lower half of the Lee, or the part up to and including the horizon of the Quinnimont coal, is of lower Pottsville age, based upon the sequence in the anthracite coal basins. According to Pennsylvania usage, these rocks are the oldest of the Pennsylvanian rocks and coals in North America. The lower 800 feet of the coal measures of the Warrior coal field of Alabama and the lower 3000 feet or more of the coal measures of the Cahaba coal field of Alabama are lower Pottsville. The fossil plants of the Sewell coal and mainly of the Nuttall sandstone include a large proportion of species that occur in the middle Pottsville, Lykens Nos. 2 and 3 coals, of the Southern Anthracite field. As the horizon of the Sewell coals falls in the Lee near the top, about the upper half of the Lee is of middle Pottsville age. The Nuttall sandstone is the uppermost member of the middle Pottsville group of West Virginia, and if, as thought, the Nuttall occurs in the Norton formation of Virginia just below the Lower Banner coal, it follows that the lower half of the Norton is of middle Pottsville age.

The lower part of the Wise formation is characterized by plants that show distinct evidence of their inheritance of characters from the plants of the middle Pottsville, but are specifically distinct as shown by the species of the Eagle coal, about 110 feet above the Gladeville sandstone at the base of the Wise formation. Plants collected at a horizon in the Wise supposed to be 75 feet or so below the Eagle coal contain other descendants closely related to the preceding species, whereas at the horizon of the Cedar Grove coal, nearly all the species are distinctly different from the preceding middle and lower Pottsville forms, and a few species that survive into the post-Pottsville (Allegheny formation) appear. Hence, it appears that no distinct dividing horizon or set of beds separates all the middle Pottsville forms from the upper Pottsville forms. Sedimentation and life were continuous so that some of the earlier species continued to live after the later forms had developed. The two living groups overlapped each other, and their remains were buried together. By the time the Cedar Grove and closely associated coal beds accumulated, the older species of plants had apparently become extinct and species that continued to live on into Allegheny time had begun to appear. Although most of the plants of the Wise do not occur in the upper Pottsville of the anthracite coal fields, marked by Lykens No. 1 coal, they do occur in Virginia distinctly above and in superposition to beds containing the lower and middle Pottsville flora of the typical Pottsville in Pennsylvania, so that the larger part of the Wise formation is clearly of post-middle Pottsville, and therefore of upper Pottsville, age. The fossil plants of the upper Pottsville, marked by the Lykens No. 1 coal of the Southern Anthracite basin, are all specifically distinct from the plants of the middle and lower divisions of the typical Pottsville, although none of those plants appear to be of the same species as any of the plants of the Wise.

The Stockton coal, the highest coal of the Kanawha formation, shows a preponderance of species that are not recorded from lower coal beds, but which are the most abundant species of the Allegheny formation. These species are generally distributed at that horizon from western Pennsylvania to Oklahoma, where they characterize the Hartshorne formation. Though the Stockton coal has been classified[264] as upper Pottsville, the fossil plants clearly indicate its correlation with the Allegheny. The horizon of the Stockton coal in the coal measures of Virginia has not been determined. The Stockton coal is several hundred feet above the Cedar Grove coal of West Virginia, whose horizon is near that of the Taggart, or the Low Splint, coal in the Wise formation. The Stockton is also thick and might reasonably be correlated with the Pardee coal of the Wise formation. The Pardee is 600 to 700 feet above the Low Splint coal. This correlation may be corroborated in the future by the discovery of evidence pointing to the correlation of the Kanawha black flint, just above the Stockton coal, with the fossiliferous limestone just above the Pardee coal. Should these suggested correlations be verified, and the Allegheny age of the Stockton coal be established, the part of the Wise formation above the Pardee coal would be of Allegheny, instead of upper Pottsville, age.

The correlation of the Pennsylvanian formations of Virginia with those of Pennsylvania, West Virginia, and Alabama is indicated in the sections of Plate 53.

The Pottsville group in Virginia is 4500 to 5000 feet thick, whereas in Pennsylvania its thickness is about 1200 feet. The group thickens southwestward and in the Cahaba basin of Alabama the Pottsville becomes 9000 to 10,000 feet thick.

Invertebrate fossils.—The writer found a few invertebrate fossils in the Pottsville around the head of Pound River. A fossiliferous limestone occurs just above the Pardee coal high on Black Mountain. H. R. Wanless[265] collected fossils from this limestone and associated beds on State Route 67 west of Appalachia. He has provisionally identified them specifically as follows:[266] *Chonetes* aff. *C. granulifer* Owen, *Marginifera* aff. *M. muricatina* Dunbar and Condra, *M. haydenensis* Girty?, and *Productus semireticulatus* Martin. In addition he has identified the following genera: *Derbya, Linoproductus, Spirifer, Pinna, Pleurophorus, Yoldia, Bellerophon,* and *Schizostoma.* From a horizon several hundred feet lower and west of Appalachia, Wise County, Virginia, he recognized the following genera: *Chonetes, Marginifera, Aviculopecten, Phanerotrema,* and *Schizostoma.* About 150 feet lower he recognized a few specimens of *Derbya.* Marine fossils are reported at several horizons in the equivalent Pennsylvanian strata of

[264] Hennen, R. V., Wyoming and McDowell counties: West Virginia Geol. Survey, County Reports, p. 51, 1915.
[265] Personal communication.
[266] Unpublished manuscript.

McDowell and Wyoming counties, West Virginia.[267] Undoubtedly some of these fossiliferous beds extend into Virginia, and their ultimate discovery only awaits further search.

The fossils cited occur in the Pennsylvanian of Ohio, West Virginia, Alabama, and the Mississippi Valley. Any of them might be found in Virginia.

HARLAN SANDSTONE

Name.—The Harlan sandstone was named by Campbell[268] from Harlan County, Kentucky.

Limits.—The Harlan sandstone next overlies the Wise formation and extends to the tops of the highest knobs of Black Mountain on and near the Kentucky-Virginia line in Wise County. The Harlan has, therefore, no upper limit in Virginia fixed by an overlying formation. It is the youngest Paleozoic formation in the State. Its base is 30 to 50 feet above the High Splint coal, the highest minable coal of the Wise formation.

If the still younger Paleozoic rocks of the Allegheny, Conemaugh, Monongahela, and Dunkard formation of West Virginia were present, they would extend the Paleozoic rocks and the surface of the region at least 2000 feet above the highest knobs on Black Mountain.

Character.—The Harlan sandstone is composed mainly of sandstone and conglomerate through which are intercalated beds of shale which in most sections comprise about half of the rocks. The lowest stratum of sandstone and conglomerate, 40 feet thick, makes a cliff extending long distances at the base of the formation. The Harlan includes also two or more thin beds of coal which are poorly exposed and little known. None appears to be more than 2 or 3 feet thick. The general character of the formation is shown by the following sections. The first was measured west from Laurel on Looney Creek to the summit of Black Mountain at The Double.[269]

---

[267] Hennen, R. V., op. cit., pp. 51-59.
[268] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, p. 31, 1893.
[269] Eby, J. B., op. cit., p. 89.

Geologic Section 127.—Harlan sandstone and Wise formation on Black Mountain, Wise County, Virginia

	Thickness Feet
Harlan sandstone (580 feet)	
17. Shale (elevation at top, 4150 feet)	10
16. Sandstone	20
15. Unexposed	45
14. Sandstone	30
13. Unexposed	20
12. Sandstone	32
11. Unexposed	45
10. Sandstone	63
9. Unexposed	52
8. Sandstone, massive, buff	158
7. Unexposed, probably sandstone	105
Wise formation (upper 553 feet)	
6. Unexposed (High Splint coal bed in here)	150
5. Sandstone	10
4. Unexposed, probably shale	255
3. Sandstone	105
2. Shale	25
1. Pardee coal, hard	8

Another section was measured from Roda up Mudlick Creek to the crest of Black Mountain.[270]

Geologic Section 128.—Harlan sandstone and Wise formation on Black Mountain, Wise County, Virginia

	Thickness Ft.	In.
Harlan sandstone (387 feet)		
13. Shale (elevation at top, 3520 feet)	10	
12. Shale and sandstone	325	
11. Sandstone	10	
10. Coal, bloom	2	1+
9. Sandstone	40	

[270] Eby, J. B., op. cit., p. 91.

	Thickness Ft.	In.
Wise formation (upper 414 feet)		
8. Unexposed (High Splint coal in here)	115	
7. Sandstone, fine grained, arkosic	40	
6. Shale	65	
5. Shale, sandy	15	
4. Shale	15	
3. Sandstone	55	
2. Shale	105	
1. Pardee coal (elevation 2760 feet)	4	2

A section measured on Halls Branch of Mudlick Creek to the crest of Bluff Spur follows:[271]

Geologic Section 129.—Harlan sandstone and Wise formation, Wise County, Virginia

	Thickness Feet
Harlan sandstone (495 feet)	
7. Shale (elevation at top, 3750 feet)	50
6. Shale, with sandstone beds	365
5. Conglomerate, massive	65
4. Sandstone, massive	15
Wise formation (upper 127 feet)	
3. Unexposed	40
2. Sandstone, thin bedded	12
1. Shale	75

Distribution.—The Harlan sandstone in Virginia occurs only on the summit of Black Mountain and its spurs in northwestern Wise County near the State line.

Thickness.—It is reported that the Harlan may be as much as 750 feet thick. In general, the thickness is determined by the height of the various knobs on Black Mountain, and consequently the actual thickness present in Virginia varies from place to place as indicated by the sections given above. The thickness could be as much as 550 feet in only a few places, and throughout most of its area, it is less than 400 feet.

[271] Eby, J. B., op. cit., p. 92.

Fossils and correlation.—Abundant plant remains are reported from some beds in the Harlan, but no collections containing identifiable material are known to the writer. He also knows of no identification of species from the Harlan. If the Stockton coal is of Allegheny age, and is correlatable with the Pardee coal underlying the Harlan sandstone by 400 to 550 feet, the Harlan must also be Allegheny. David White[272] suggests this in his discussion of the Anderson sandstone of Tennessee, the upper part of which, at least, he provisionally correlates with the Harlan sandstone.

IGNEOUS ROCKS[272a]

Besides the amygdaloidal lava in the Unicoi sandstone briefly described (p. 27), igneous rocks occur at other places in the Valley north of the latitude of Greenville, Augusta County. Most of these are in the vicinity of Monterey, Highland County, but a few others are widely scattered, as shown on the geologic map of the Valley.[273] The most notable occurrences are Mole Hill west of Harrisonburg; Sounding Knob, 3 miles due south of Monterey; and Pyramid Hill, three-fourths of a mile southwest of Monterey. Probably the largest outcropping body is a dike along the road for 1½ miles south of Greenmont Church, 5 miles slightly west of north of Harrisonburg, Rockingham County.

These igneous rocks form either dikes or volcanic plugs. They are generally dark-colored, very heavy, and weather with a rusty gray color. In a molten condition, they were intruded into the Paleozoic rocks from the deeper parts of the earth, probably since Late Pennsylvanian, for similar rocks have been intruded into the coal measures of southern Illinois. It is presumed that these injections took place in Triassic time, for such rock is common in the Triassic formations of Virginia, which occur in basins in the Piedmont province east of the Blue Ridge.

---

[272] White, C. D., Deposition of the Appalachian Pottsville: Geol. Soc. America Bull., vol. 15, p. 282, 1904.

[272a] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Monterey folio (No. 61), p. 5, 1899; U. S. Geol. Survey Geol. Atlas, Staunton folio (No. 14), p. 3, 1894.

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

GEOLOGIC STRUCTURE

DEFINITIONS

HORIZONTAL STRATA

As the stratified rocks of the earth's crust were formed by sediment deposited in bodies of water, such as oceans, seas, and lakes, they must have been originally laid down as horizontal or nearly horizontal layers or strata. From what is known of the present distribution of strata, it is evident that some groups must originally have occupied areas thousands of square miles in extent. For example, the Martinsburg shale and Clinch-Tuscarora sandstone and their equivalents under other names originally extended from Lake Ontario nearly to the latitude of Knoxville, Tennessee, and occupied, as flat sheets, an area approximating 100,000 square miles.

FOLDS AND FAULTS

In the Valley of Virginia the rocks, except for horizontal strata in small and widely separated areas, are now almost everywhere inclined at low or high angles and are commonly bent upward into arches (anticlines) and downward into troughs (synclines). In many places they are broken by great fractures (faults) that displace the strata. Some folds are relatively upright and symmetrical. Others are inclined or even overturned. (See Pls. 56A and B, 59A, and 61.)

OVERTHRUSTS

The folding and breaking of the strata bear witness to the former activity of horizontal compressive forces within the earth's crust sufficient to crumple and break sequences of strata, in some instances thousands of feet thick. The places where the strata still remain horizontal or are only gently folded indicate zones or regions of relatively less intense lateral compression, whereas inclined or overturned folds indicate zones of relatively greater compression. When lateral compression became sufficiently intense, masses of folded strata broke along certain lines and moved bodily forward over rocks that then lay in front of them. Such breaks or overthrusts have permitted overriding blocks, in some instances, to travel distances of several or even many miles over the underlying, or overridden, rocks. (See Pls. 62 and 59C.) Plate 58B illustrates on a small scale the nature and origin of overthrust faults.

FENSTERS AND KLIPPEN

Erosion acting on the deformed rock masses has selectively etched out the weaker rocks into valleys and other depressions and left the resistant rocks standing as ridges and knobs. Where erosion has cut through an overthrust mass to expose the rocks beneath it, the opening thus made through the overriding mass is called a window, or fenster. Parts of the overriding block that have become detached by erosion from the parent mass are called klippen, because in the Alps, where these phenomena were first recognized, such masses of older overriding rock were generally harder than the underlying rocks and were bordered by cliffs.

SHINGLE BLOCKS

Overlapping blocks between overthrust faults are generally called shingle blocks because they lap over each other like shingles on a roof. (See Pl. 63, sections G, H, and I.)

OUTLIERS AND INLIERS

Masses of younger rock in normal succession which have become detached from their parent masses by erosion and are now surrounded by older rocks are called outliers; conversely, masses of older rocks in normal sequence exposed by erosion in the midst of younger rocks are called inliers. Outliers and inliers differ from klippen and fensters in that they are composed of rocks in normal succession whereas klippen and fensters owe their positions to displacement by overthrust faults. Whether the rock formations shown on a geologic map are in normal succession or not can be ascertained by reference to the "Explanation" of the map, which shows the formations in their normal vertical sequence.

HIATUSES

Hiatuses occur through the absence, in some areas, of formations from their proper place in the sequence. For example, in Lee County the members of the Blount group are absent and the Lowville limestone which, in a full sequence, overlies the Blount group, is in direct contact through deposition with the Lenoir limestone which normally underlies the Blount group. In such cases the abnormal contact does not indicate a fault. This condition is illustrated by Figure 4. Such a gap in the sequence of strata is called a hiatus. One type of gap is called a disconformity, in distinction from an angular unconformity, as shown in Figure 5. In a disconformity the adjacent strata are parallel and in an angular unconformity they are discordant.

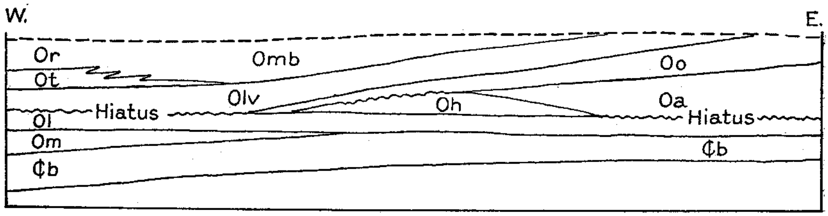


FIGURE 4.—Diagram illustrating hiatuses, or contacts due to the absence of formations. For example, on the left the Lowville limestone (Olv) is in contact with the Lenoir limestone (Ol). The Holston limestone (Oh), the Athens shale (Oa), and the Ottosee limestone (Oo), that in a complete sequence intervene between the Lowville and Lenoir, are absent on the northwest side of the Valley, as in Lee County and in Hightown Valley, Highland County. Omb, Martinsburg shale; Or, Reedsville shale; Ot, Trenton limestone; Ꞓb, Beekmantown dolomite. The symbols are those used on the geologic map (Virginia Geol. Survey Bull. 42, 1933).

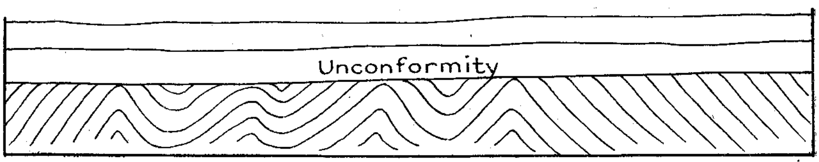


FIGURE 5.—Diagrammatic sketch illustrating an unconformity.

UNCONFORMITY

Where strata have been tilted and folded, planed by erosion, and then resubmerged, the boundary between the edges of the inclined strata and the subsequent deposits constitute an angular unconformity. (See Fig. 5.) No such condition within the Paleozoic sequence has been seen by the author in the entire Valley from central Pennsylvania to Alabama. It is, therefore, practically certain that no extensive compressive folding occurred at any time within the period of the deposition of the Paleozoic strata in the southern Appalachian region, although such folding, with resulting unconformities, occurred in the region now occupied by eastern Pennsylvania. The movements in the Paleozoic were vertical elevation and depression, or gentle warpings of the ocean bottoms. Extensive areas were raised slightly above sea level for a long time, after which resubmergence took place and sedimentation was resumed.

MINOR STRUCTURES

Commonly as a result of compressive forces, the soft shales and thin bedded limestones or sandstones are plicated as shown in Plate 57A and C, or a structure known as slaty cleavage is produced where closely spaced cleavage planes commonly cut across the bedding planes as shown in Plate 57B. Many layers of rock are cut by intersecting joints developed after consolidation of the rock, as shown in Plate 54D, or by strong parallel joints as shown in Plate 50B.

Characteristic minor structures, formed during the course of the deposition of the sediment of which the hard rocks are composed, are wave or ripple marks produced by waves or ripples in shallow water acting upon the soft bottom sediment as shown in Plates 20A and 54A. Such beds are surely indicative of relatively shallow water. In places the shallow water through evaporation disappeared and left muddy bottoms exposed to the sun. The drying mud shrank and produced cracks as sun cracks or mud cracks, such as are common at the present day. Such sun cracks are shown in Plate 54C and are as with ripple marks equally convincing evidence of shallow water. Another original structure is cross bedding, as shown in Plate 54B. This is a very common feature of rocks laid down in water having considerable current as at the mouths of large rivers or in ocean currents like the Gulf Stream.

STRUCTURAL FEATURES OF THE VALLEY AND ADJACENT PLATEAUS

In the Appalachian Valley in Virginia all the structural features described above are represented and in the discussion which follows many examples are given. The structural features of the region are described systematically so far as practicable, beginning with the Blue Ridge faults on the southeast and proceeding westward across the Valley. Fault planes can seldom be actually observed in the Valley because of poor exposures; however, the fault relations may be clearly recognized because of the abnormal relations of the associated strata, such as older rocks lying upon younger rocks. Such recognition depends on a knowledge of the stratigraphy of the area and the ability of the geologist to recognize the different formations by means of their fossils or by their lithologic character and their position in the general stratigraphic sequence. (See Fig. 6.)

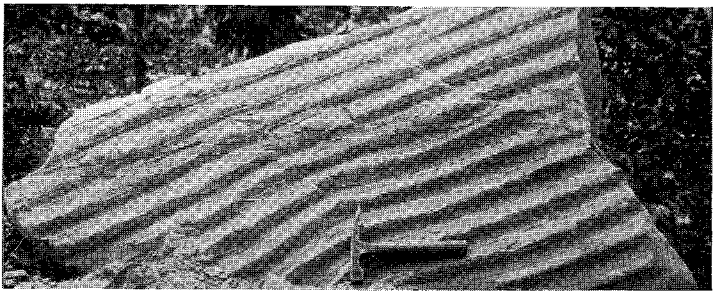
PLATE 54

A. Wave-marks in Pocono sandstone. A loose block from a steep slope above U. S. Route 33, in the gorge of Dry River about 1 mile north of Rawley Springs, Rockingham County.

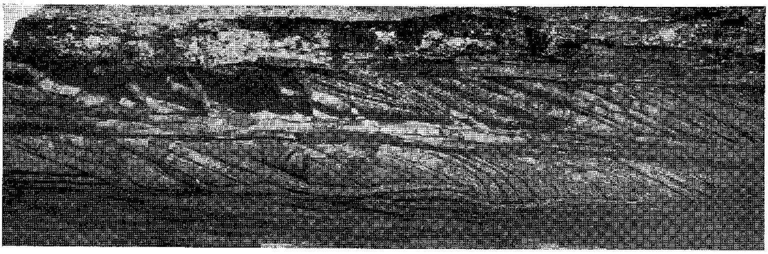
B. Cross-bedding in Pottsville sandstone. Two cross-bedded layers, each between 1 and 2 feet thick, occur between horizontally deposited beds. At Pilot Falls on Caney Fork near Clifty, Cumberland County, Tenn. Such cross-bedded sandstones are not uncommon in the Pottsville formation in Virginia.

C. Mud-cracks in Moccasin limestone. Along U. S. Route 19, on Little Indian Creek 2½ miles southwest of Wardell, Tazewell County.

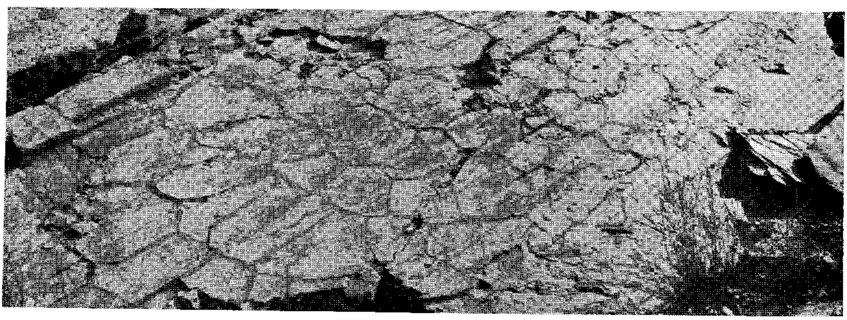
D. Joints in Moccasin limestone. Same locality as C. Looking southeast.



A



B



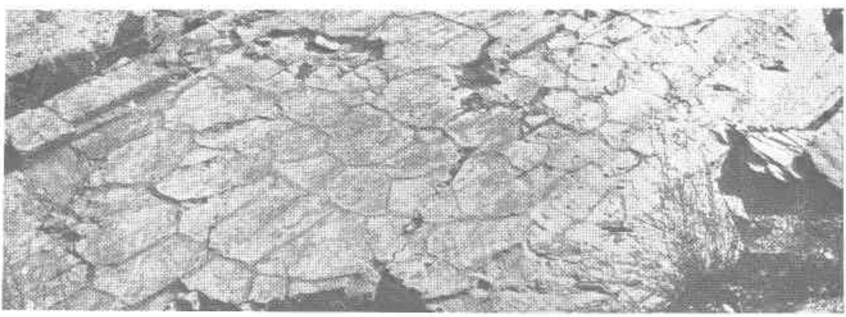
C

D

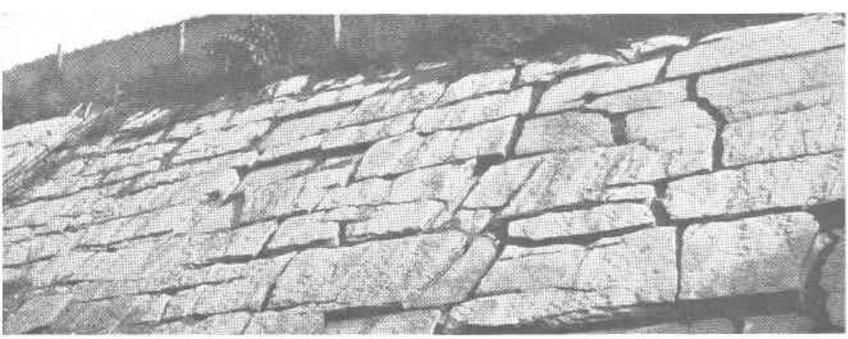
Structural Features

A

B

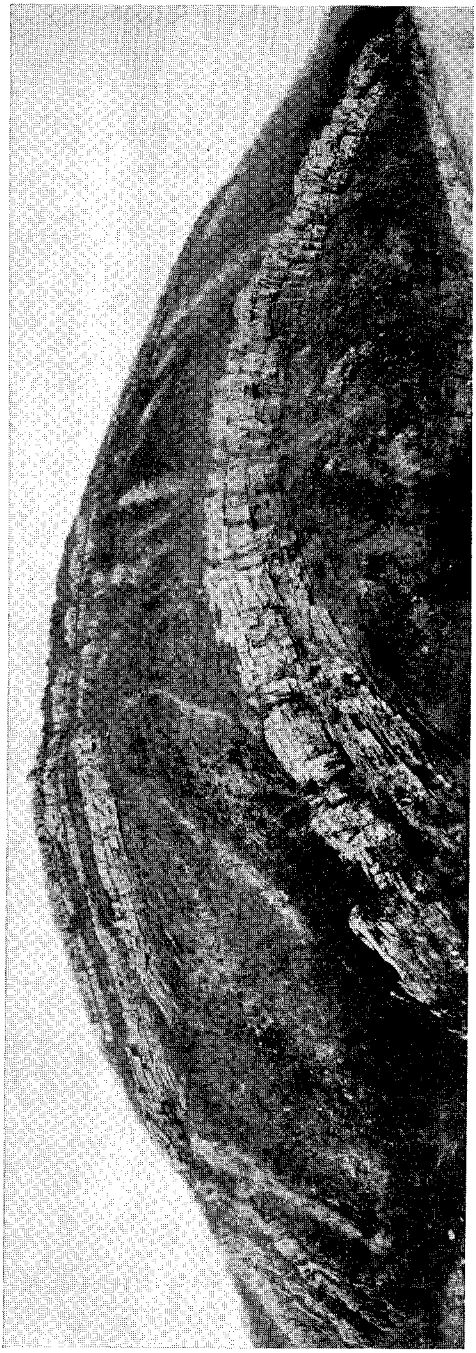


C



D

STRUCTURAL FEATURES

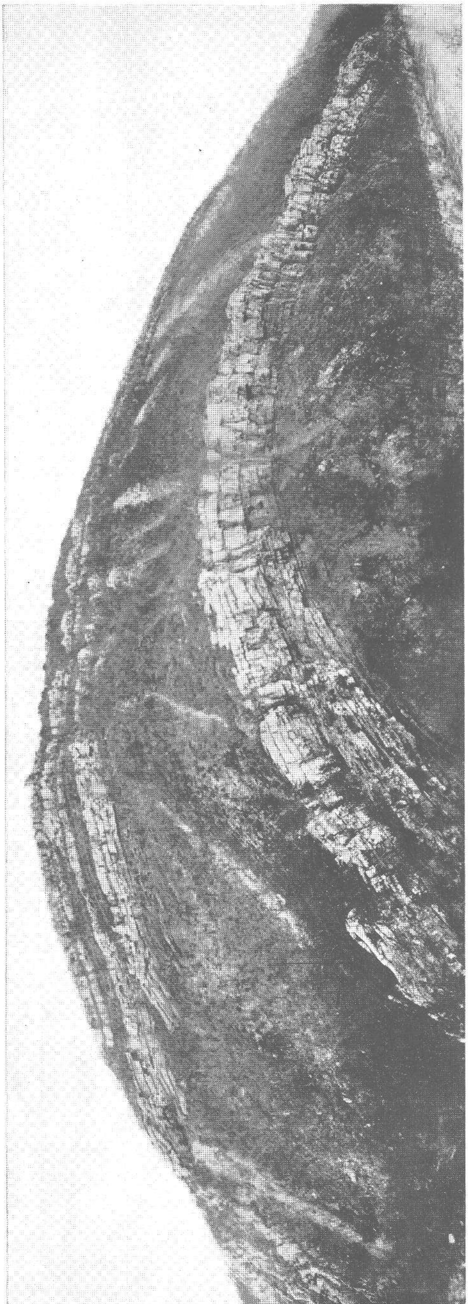


A

B

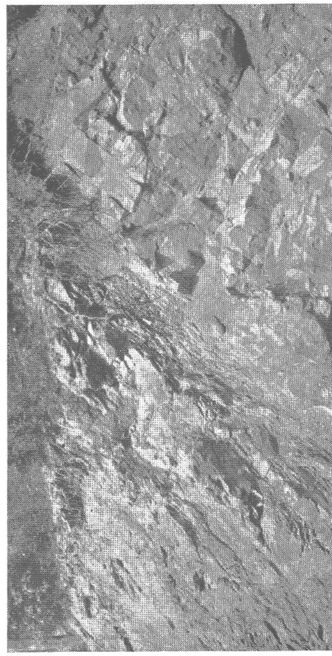
C

ANTICLINES



A

B



C

ANTICLINES

PLATE 55

A. Iron Gate arch in the gorge of James River through Rich Patch Mountain, about 1½ miles southeast of Clifton Forge, Alleghany County. The lowest arched ledge is Clinch sandstone. Below the Clinch to the river level is the Juniata formation. Above the Clinch to the upper ledges is the Cacapon division of the Clinton formation, characterized by several beds of dark-red, highly ferruginous sandstone (iron sandstone). At the top is the Keefer sandstone member of the Clinton, in several ledges. This is the type section of the Iron Gate facies of the Clinton. The arch of Clinch sandstone is about 1000 feet across. This is the most perfect example of an anticline exposed in the Appalachian Valley of Virginia. It is overturned at its northwest end, as shown in Plate 56A. Looking northeast.

B. Horizontal flexure in the Athens limestone. Near head of Toad Run, 4½ miles west of Lexington, Rockbridge County. Besides the unusual structure, the picture shows well the character of the Athens limestone with its dark shaly partings which persists widely in this part of the Valley. Looking northeast.

C. Overturned northwest limb of an anticline showing the Clinch sandstone dipping southeast (left), beneath the Juniata shale. In normal position the Clinch overlies the Juniata. At road intersection about 1 mile southeast of Bluefield, Virginia. Looking southwest.

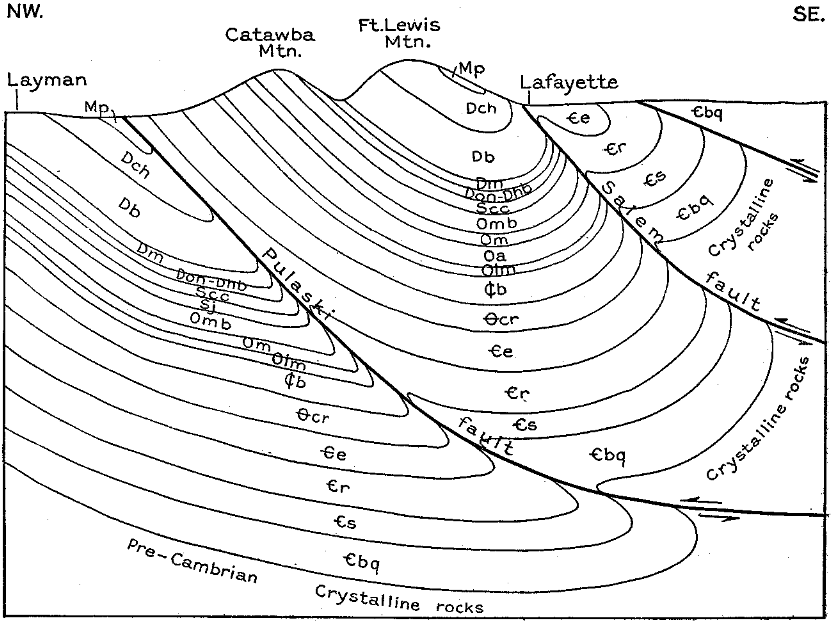


FIGURE 6.—Ideal structure section through Lafayette and Layman west of Salem, Roanoke County. The vertical scale is about 3 times the horizontal. This sketch shows how faults are detected at the surface by abnormal contacts of formations and by the pinching out, or abruptly cutting out, of formations, such as is shown on the geologic map (Virginia Geol. Survey Bull. 42) for 10 miles southwest of Lafayette. The formations are denoted by the following symbols: Mp, Price formation; Dch, Chemung formation; Db, Brallier shale; Dm, Millboro shale; Don-Dhb, Onondaga formation and Helderberg limestone; Scc, Clinton formation and Clinch sandstone; Sj, Juniata formation; Omb, Martinsburg shale; Om, Moccasin limestone; Oa, Athens shale; Olm, Lenoir limestone and Mosheim limestone; Ȼb, Beekmantown dolomite; Ɵcr, Copper Ridge dolomite; Ꞓe, Elbrook limestone; Ꞓr, Rome formation; Ꞓs, Shady dolomite; Ꞓbq, Chilhowee group.

BLUE RIDGE FAULTS

One of the main structures of the Valley is a great fault extending far along the Blue Ridge, north of Roanoke, probably its full length, and along the northwest front of the Blue Ridge plateau southwest of Roanoke. In several areas the existence of this fault is evident. One area in Warren County extends from a point east of Front Royal to a locality east of Bentonville. For about 10 miles along the Blue Ridge here, pre-Cambrian crystalline rocks are thrust westward over Paleozoic formations so that for 4 miles just southwest of Front Royal the pre-Cambrian is in contact with and overlies the Beekmantown limestone. Another place where this overthrust fault may be still better recognized is in the large cove north of Montvale, Bedford County. Here a large area occupied by the Rome formation is bounded by a fault along which on the east, north, and northwest pre-Cambrian crystalline rocks are thrust into contact with the Rome and formerly, before erosion had penetrated to its present depth, extended over and above the Rome. Some Chilhowee rocks belonging also to the overthrust block still persist in the ridge between the cove and the main part of the Valley. Fulhardt Knob, so conspicuous from the Lee highway (U. S. Route 11) north of Cloverdale, marks the southern extremity of the ridge of overthrust Chilhowee rocks. These Chilhowee rocks were thrust over the Rome area from some original position southeast of the cove now occupied by the Rome. The fault plane appears to be nearly horizontal. The movement upon the fault plane must have been at least 6 miles northwestward. The Rome area may be called a semi-fenster, because it is not entirely surrounded by the overthrust block, which has been completely worn away in Bedford Gap between the villages of Blue Ridge and Villamont, which now affords a passage to the Norfolk and Western Railroad and to U. S. Route 460. Exposures of what is probably this same flat thrust crop out along the northwest base, or escarpment, of the Blue Ridge just south of Virginia. At and west of Mountain City, Tennessee, there is a probable northwest displacement of 14 miles on a relatively flat thrust plane.[274] The northwestern outcrop of this fault passes through Damascus, Washington County, Virginia. On the northwest slope of Delaney Mountain, Tennessee, 4 miles south of the State line and 12 miles southeast of Bristol, the Unicoi sandstone is thrust into contact with the Athens shale. Northeast of Damascus for many miles this fault seems to lie mainly within the Chilhowee group, for northward nearly to Hiwassee, Pulaski County, the Shady dolomite crops out apparently in normal relations to the Erwin quartzite at the top of the Chilhowee group. From Hiawassee northeast to a point south of Roanoke the Chilhowee is thrust over the Shady into contact with the Rome. At the northwest base of Fulhardt Knob, 9 miles north of Roanoke, the Shady reappears apparently in normal contact with the Chilhowee but possibly is separated by the great fault that surrounds the Montvale cove. This outcrop of Shady persists as far north as Buena Vista and possibly farther north. There seems to be space available for the Shady to be present

[274] Butts, Charles, and others, Southern Appalachian region: XVI Internat. Geol. Cong. Guidebook 3, Excursion A-3, Pl. 26, 1933.

on the old State Route 13, 2 miles northeast of Buena Vista, although it was not seen. For a long distance along this highway southeast toward White Gap the Erwin quartzite is continuously exposed and seems to dip normally beneath the formations lying to the northwest of it. Beginning a few miles southwest of Glasgow, Rockbridge County, and extending northward to a point within 8 miles of Waynesboro, the main fault along the Blue Ridge has been located provisionally southeast of the Blue Ridge, partly in the pre-Cambrian crystalline rocks, but southwest of Waynesboro it is mapped as crossing the Chilhowee group to the northwest base of the Blue Ridge. From Buena Vista northeast to Riverton the lack of exposures, largely due to the deep accumulation of gravel washed from the Blue Ridge which has spread over a wide area of flat land at its northwestern base, makes the determination of the presence or absence of a fault by actual observation impossible or dependent upon the rare chance of finding a favorable exposure. It is supposed that the manganese deposit 1½ miles east of Crimora, 6 miles northeast of Waynesboro, is upon the Tomstown (Shady) dolomite. The surroundings at the mine indicate that the Tomstown is beneath the quartzite that has been thrust upon it, thus affording some evidence of the persistence of a fault at the northwest base of the Blue Ridge. Arnold Valley, a few miles southeast of Natural Bridge, is a flat valley in which scattered exposures show that it is occupied by dolomite. The Valley is surrounded on all sides but the north by Chilhowee and pre-Cambrian rocks. The facts point to a flat overthrust extending from the south end of the Valley due west to James River, a distance of 3 miles over the Shady.

Beginning 2 miles northeast of Front Royal, the Tomstown (Shady) crops out northwest of the fault, which probably runs to the east, possibly into the pre-Cambrian. The Tomstown (Shady) continues in a wide, well-exposed belt, apparently in normal sequence above the Erwin (Antietam) quartzite, to the north boundary of the State.

Evidence is accumulating that the Chilhowee strata are cut somewhat diagonally by a number of overthrust faults, which extend northwestward from the Blue Ridge front into the limestones of the Valley. From this fact a hypothesis can be drawn that instead of a single clean-cut fault plane, on which the Chilhowee and some of the underlying pre-Cambrian are thrust northwest, there is in reality a thrust zone at depth, into which the faults that crop out, or are thought to do so, merge. The Chilhowee and older rocks have apparently been thrust on such a zone in some places, as in Montvale Cove, far to the northwest over the limestones of the Valley. Though no such fault zone has been detected for long distances along the Blue Ridge, it is still possible that it exists and that the Valley rocks may extend southeastward beneath parts of the Blue Ridge and the Piedmont. It is improbable that such great overthrusts as that of the Montvale cove or that northwest of Mountain City, Tennessee, are of just local extent.

MASSANUTTEN SYNCLINE

One of the major structural units of the Valley in Virginia is the Massanutten syncline, which extends from Berkeley County, West Virginia, passing just east of Winchester, southwest nearly to Greenville, Augusta County. The main area of the syncline is occupied by the Martinsburg shale. The syncline is not a single symmetrical trough but is affected by several subordinate anticlines and synclines. (See sections P-P′ and Q-Q′ on the geologic map, Virginia Geological Survey Bull. 42, 1933.) These minor structures are plainly revealed by the ridges of Massanutten sandstone within the main ridges bounding the mountain. On the Lee highway (U. S. 211) on the southeast slope southeast of New Market Gap, a pronounced anticline is distinctly expressed by opposing dips in the Martinsburg shale. At various points within the syncline, both north and south of Massanutten Mountain, other minor folds are indicated by variations in the dip, but no example of a complete anticline or syncline, even a minor one such as shown in Plate 57C, where the beds cross the axis from one limb to the other, has been observed. Short Mountain southeast of the Lee highway between Edinburg and Mount Jackson is an example of a synclinal outlier of the main Massanutten complex. On three traverses across the Massanutten syncline, two north of Massanutten Mountain on State Route 7 and U. S. Route 50 and one south of the mountain on U. S. Route 250 between Staunton and Fishersville, probably at least 90 per cent of the determinations show a dip of 30-75° SE, across the syncline. In a few places the dip varies from vertical to as low as 4° NW. These facts indicate that the southeast limb of the syncline is overturned. The southeast dips on the northwest limb are normal. It has not been possible in any of the traverses across the syncline outside of Massanutten Mountain to locate the axis of the overturned syncline or the axial plane of division between the northwest and southeast limbs. The total distance across the syncline on the roads named is about 4 miles, and the dip averages about 45° SE. If the rocks all dip regularly, this dip would indicate a thickness of more than 6000 feet, which is 2000 feet more than the maximum as determined in the vicinity of Endless Caverns. The apparent extra thickness may therefore be due to repetition of the beds by minor folds which do not appear in any sections open to inspection. It is reasonably certain that such folds would appear in a fully exposed section across the syncline to the depth of 100 feet.

New Market Gap is located on the axis of a cross anticline on which the protecting cap of the Massanutten sandstone was raised so high that it has been worn through by erosion down to the Martinsburg shale in the gap. The folds pitch in both directions northeast and southwest from the gap. Though the Massanutten syncline appears to end on the south near Greenville, essentially the same structure extends southwest to the vicinity of Buchanan. The lower Devonian rocks mark the axis of the syncline in Short Hills, 5 miles northwest of Natural Bridge. These beds are believed to have been once continuous with the Devonian beds in Massanutten Mountain. The syncline southwest of Greenville has been obscured and partly obliterated by faulting, by offsetting of axes and by convergence of the Little North Mountain fault with the syncline southwest of Rawley Springs, Rockingham County. As a result, the formational outcrops to the west and northwest of Buchanan have complex structure and disordered distribution.

BELT NEXT NORTHWEST OF THE BLUE RIDGE

Between the Blue Ridge and the Massanutten syncline, marked on the northwest by the southeast margin of the Martinsburg shale, the dip is generally toward the southeast. This might be interpreted as indicating that the formations as a body are overturned northwestward. Hence, the younger and stratigraphically higher formations would dip southeast toward and beneath the older and lower rocks of the Blue Ridge. If that interpretation is correct, younger formations underlie older in a wide belt next northwest of the Blue Ridge front. Such a relation could only be brought about by overturning or inverting a very thick mass of rocks, that is, turning them upside down. To avoid such an extreme conclusion it is believed that the rocks are crumpled with the formation of minor folds or wrinkles, and that in most instances these minor folds are overturned toward the northwest. Thus in most of the scattered outcrops, only the beds or layers with a southeast dip are exposed. This would give the impression that the whole body of the respective formations is overturned. Section R-R′ of the geologic map shows the interpretation of bodily overturning on the right and of minor fold overturning for several miles east of Opequon Creek. Section M-M′ west of Waynesboro and Section P-P′ through Luray show the conception of overturned minor folds which give the false impression that whole formations are completely overturned and lie bottom side up in a nearly horizontal position. A good example of one of the overturned wrinkles suggesting a good-sized anticline is to be seen in Luray Caverns and vicinity. In the caverns the Beekmantown dolomite dips about 10° SE., as can be plainly seen in the roof. In the village of Luray, 1 mile southeast of the cave and 250 feet lower in altitude, the Conococheague dolomite crops out and dips 25° SE. If these dips persist between the cave and the town, the Beekmantown would dip under the Conococheague. To the west of the cave at and west of Hamburg, the dip of the Beekmantown is 40-80° SE., and at the river side northwest of Hamburg the dip in the Chambersburg limestone is 15° SE., so that the rocks at that point are overturned, the Chambersburg, Athens, and Lenoir plainly passing beneath the Beekmantown. The same condition is shown on both sides of the Lee highway a mile southwest of Hamburg where the Chambersburg, Athens, and Lenoir dip 30° SE., and pass for some distance underneath the Beekmantown. Thus overturning on a large scale occurs at and west of Luray. Interpretation of the structure is shown in Figure 7. Southeast dips prevail along this belt from

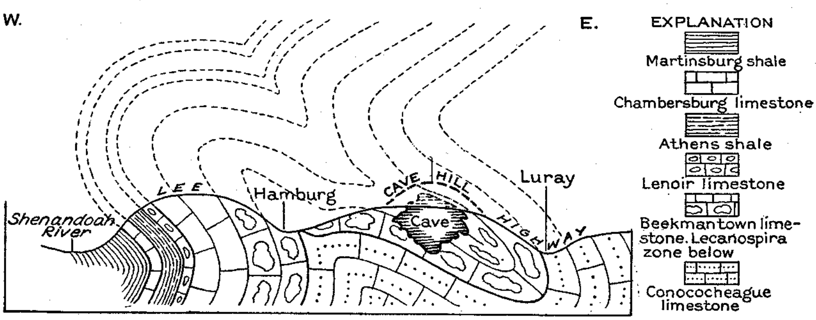


FIGURE 7.—Sketch structure section, through Luray Caverns, showing the overturned structure. The Lee Highway is projected into the plane of the section. Vertical scale exaggerated. *Lecanospira* occurs on Cave Hill.

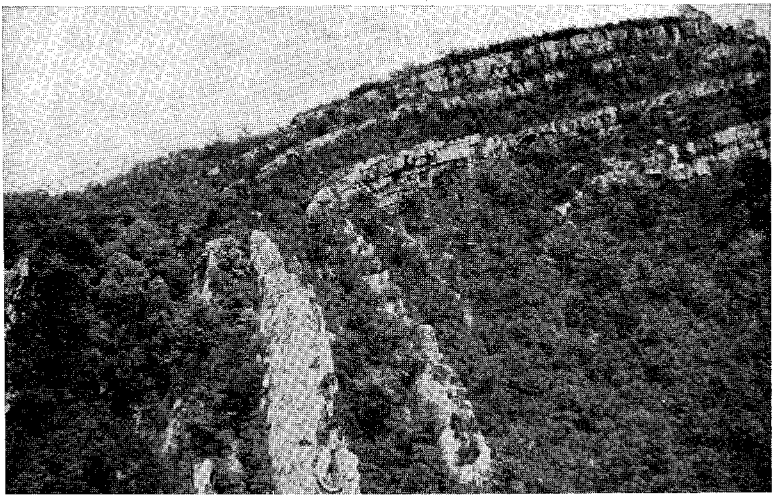
Roanoke southwest to Tennessee, indicating many overturned minor folds. The occurrence of narrow synclines and consequently intervening narrow anticlines is notably displayed by the number

PLATE 56

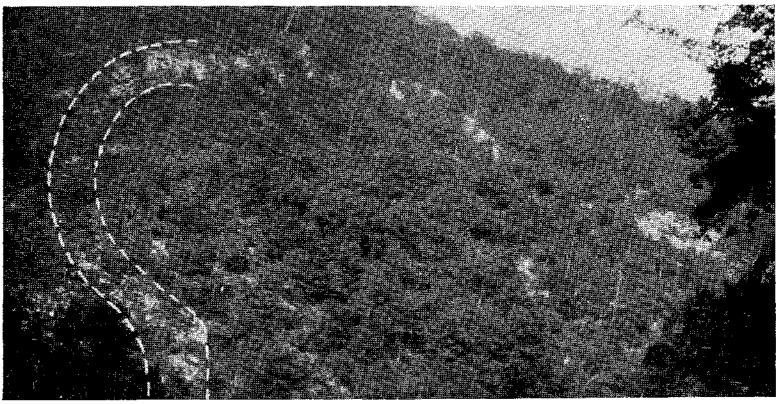
A. Northwest end of the Iron Gate arch, slightly overturned, showing the Keefer sandstone member of the Clinton formation. Note the fault at the top (right), with upthrow on the northwest. Looking east from a point on the Chesapeake and Ohio Railroad about half a mile east of Clifton Forge, Alleghany County. This is an excellent example of the steeply inclined, or overturned, northwest limb of an anticline, which is a common structural condition in the Appalachian Valley.

B. Overturned arch of Clinch sandstone at the south end of Carpenter Mountain. On Hayes Creek, 4 miles south of Covington, Alleghany County. This is the same general structure as in the Iron Gate gorge, shown in A, 12 miles to the northeast. Looking northeast.

C. Anticline in Brallier shale. Southwest bank of Craig Creek, 5 miles northwest of Eagle Rock. An example of a small symmetrical arch.



A

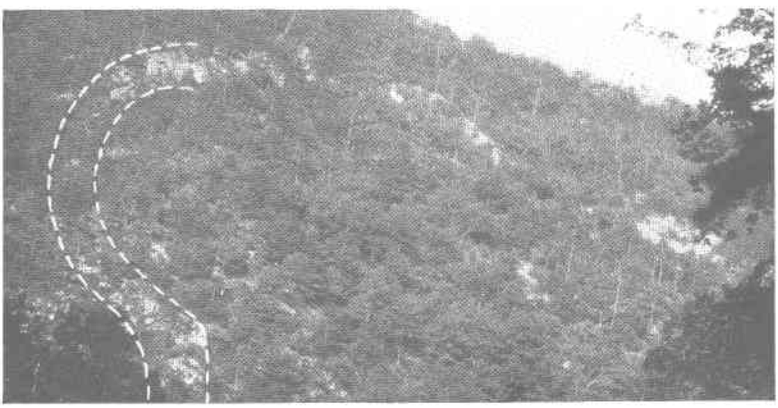


B

C

ANTICLINES

A



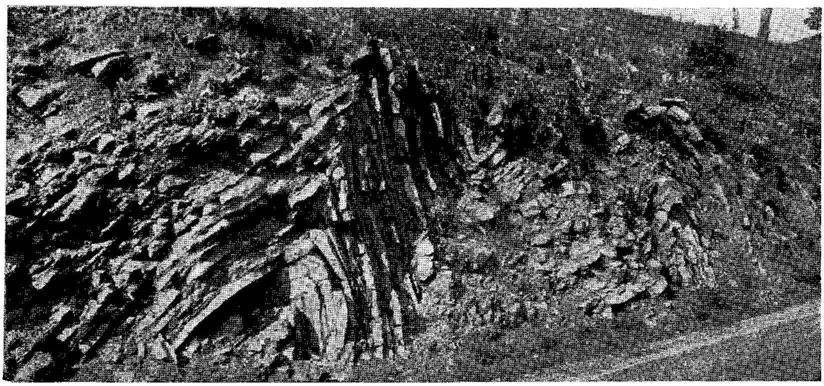
B

C

ANTICLINES

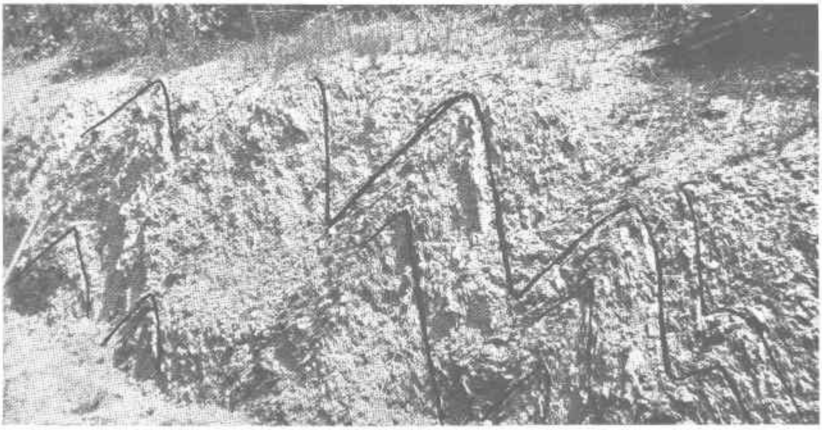
A

B

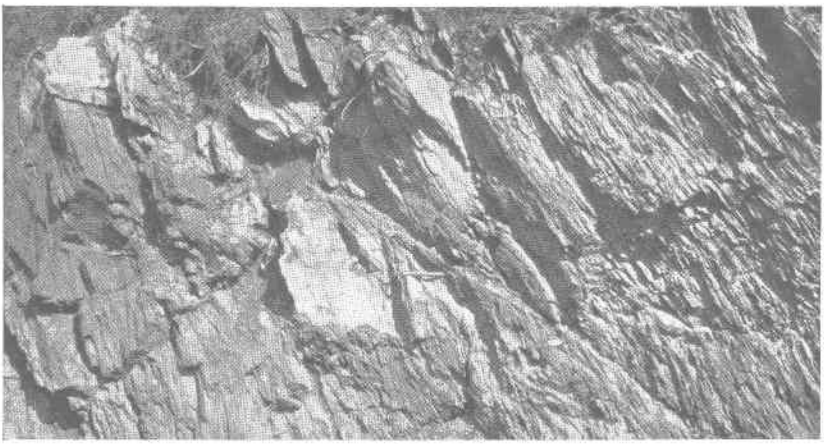


C

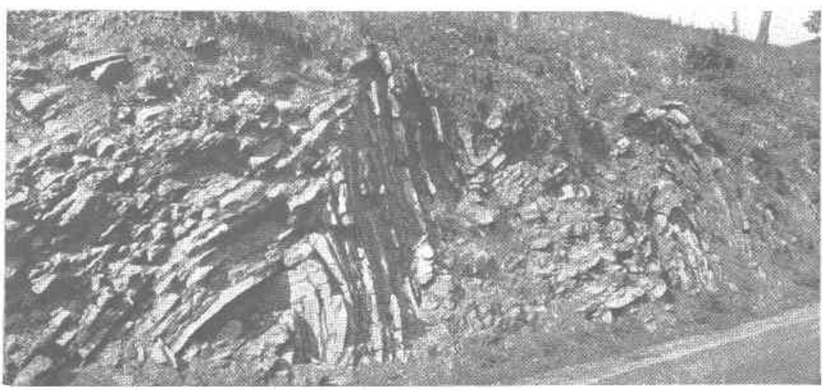
FOLDS AND CLEAVAGE



A



B



C

FOLDS AND CLEAVAGE

PLATE 57

A. Soft shale, probably Rogersville, intricately crumpled by lateral pressure. Along road, 2½ miles southwest of Blackwater, Lee County.

B. Slaty cleavage in the Moccasin limestone in Giles County. The conspicuous break in the middle, just above the hammer, and the parallel but less conspicuous one 2 feet lower, are bedding planes dipping about 45° SE. Along State Route 8, about 1 mile northwest of Newport. Looking northeast.

C. Contorted thin-bedded limestone in the basal (Trenton) part of the Martinsburg formation. Along State Route 80, about 1 mile northwest of old Rosedale, Russell County. Looking northeast. These minor folds are common in the Martinsburg of Tazewell and Russell counties. An extraordinary example is clearly exposed in a new cut along U. S. Route 19, about 1 mile north of Tazewell.

of narrow elongate areas of Athens shale southeast of Abingdon. Each area of Athens lies in a narrow and relatively deep syncline with the opposing dips on each side of the axis very steep and the limbs of the syncline so closely pressed together that the axes are very obscure and may be located only by careful examination, if at all.

In southern Wythe and Smyth counties is a belt of very complicated structure in which faults, folds, and detached masses of overthrust sheets (klippen) are involved. This area has been recently described by Currier[275] and the structure illustrated by a number of sections. No further explanation will be made here. The most important structural problem is whether the Erwin quartzite masses of Pond, Glade, and Lick mountains are anticlines connected with their roots or are completely detached masses of overthrust sheets (klippen). Currier clearly shows that both Pond Mountain and Glade Mountain are klippen, but indicates that Lick Mountain is faulted on the north side. The problems are difficult of solution because of lack of exposures at critical places that would afford direct and conclusive evidence as to the relations of the quartzite to the surrounding rocks. The quartzite areas are high hills or mountains that yield an immense amount of rock waste which is washed down to their bases and completely conceals the contacts. Currier's exposition of the structure should be accepted until a better one is advanced.

SALEM FAULT

The Salem fault extends from the vicinity of Cloverdale, Botetourt County, southwest to a point 3 miles west of Christiansburg where it appears to merge with the Pulaski fault. About one mile south of the Salem fault is a smaller fault extending from Christiansburg southwest to a minor fault by which the formations are cut off by the Rome formation. Contrary to the general rule this fault is downthrown on the southeast, bringing the Lenoir limestone, exposed in the quarry about 4 miles south of Radford down, into contact with the Elbrook limestone northwest of the fault. Apparently the fault plane is vertical.

PULASKI FAULT

With the exception of the Blue Ridge fault, the Pulaski fault is the most prominent one in the Valley. It is a low angle or flat overthrust, and the overthrust block includes, according to lo-

[275] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, Pl. I, 1935.

cality, strata from the Rome and intervening formations probably up to the Price, as in Fort Lewis Mountain. This fault extends from Greenville, Augusta County, southwest to the vicinity of Marion, where it enters a complex of minor faults in which it can scarcely be recognized, but it may continue southwest through the Marion area as the Seven Springs fault which persists to Tennessee and crosses the State line about a mile east of the line between Scott and Washington counties. This is a continuous line of faulting, but it can not be affirmed with certainty that this line represents a single continuous fault. It is more likely that several independent but closely spaced and slightly offset faults constitute a fault zone. The broad flat overthrust nature of the Pulaski fault is revealed by two great reentrants, one between Buchanan and Eagle Rock, Botetourt County, and the other north and southwest of Pulaski, including Draper Mountain on the south. In both localities younger beds up to the Maccrady shale can be seen passing under the Rome and Elbrook formations. Further evidence is afforded by the fensters of Devonian shale south and north of Radford and of the Price formation in Price Mountain south of Blacksburg. Furthermore, coal mines in the Price formation in Price Mountain have been extended beneath the Elbrook limestone and coal beds have also been penetrated at a depth of 2000 feet near New River north of Radford by bore holes starting on the surface in the Elbrook limestone. The Elbrook is normally many thousand feet below the Price, and if the bore holes had been carried to a depth of 10,000 feet or so the Elbrook would have been penetrated a second time in the same holes. No such relation of the Elbrook and Price could exist except through overthrusting of the older and lower Elbrook upon the much younger and stratigraphically higher Price.

Some features of great geological interest are connected with the Pulaski fault. The fault sheet itself has been folded, and a syncline extends along its middle. Fort Lewis Mountain is a pronounced synclinal basin half cut out on the southeast by the Salem fault. This basin is delimited at the northeast by the transverse strike of Tinker Mountain and on the southwest by the transverse strike of the formations between Lafayette, Montgomery County, and Price Mountain. This syncline is represented in the Dublin plain by the syncline of Conococheague limestone and farther southwest by the narrow syncline of Pine Ridge southwest of Wytheville containing the Athens shale along its axis. On the northeast the synclinal area of Athens shale north of Fincastle, Botetourt County, seems to be in this same overthrust syncline. If this interpretation is correct the rocks of all these synclinal areas have been thrust several miles northwestward from their original positions and thus brought into line with the Massanutten syncline, but really their rocks belong to a belt that originally lay southeast of the Massanutten syncline.

Going deeper in the section into the overridden rocks, a synclinal axis in the broad area of the Price southeast of Pulaski, in the Draper Mountain-Pulaski region, continues northeast beneath the Pulaski thrust block and shows in places in fensters. North and south of Radford Devonian shale shows through the overthrust sheet; in Price Mountain the Price formation appears in a large fenster southwest of Blacksburg. This overridden syncline in the younger rocks beneath the thrust plane appears to continue northeastward to crop out along the margin of the overthrust block southeast of Eagle Rock. The higher Devonian shales and the Price formation are probably truncated by the fault southwest of Eagle Rock; hence, they do not crop out next to the trace of the fault plane southeast of Eagle Rock. It will be noted from the geologic map, however, that the Silurian and lower Devonian rocks as well as the middle Devonian black shale crop out, and it is probable that the younger Devonian and Price formations underlie the fault block at no great distance southwest of the trace of the fault plane.

The Marion dome seems to be in the overridden strata and possibly acted as a buttress upon which the Pulaski fault was frayed into several branches, most of which are of local extent. The main branch appears to be continued southwest as the Seven Springs fault. At Seven Springs the Copper Ridge dolomite is in contact with the Millboro shale along a vertical or highly inclined fault plane. This fault southwest of Seven Springs cuts across the course of Walker Mountain and completely eliminates the syncline of which Walker Mountain is the northwest limb. Farther southwest in Tennessee along Bays Mountain, which is in strike with Walker Mountain, the amount of the fault diminishes, and both limbs of what may be called the Bays Mountain syncline are present in Bays Mountain, Hawkins County, Tennessee.

Assuming that the Pulaski fault, or fault zone, extends from Greenville, Augusta County, to Tennessee, as identified and mapped, its length in Virginia is 210 miles, and it extends perhaps 100 miles into Tennessee. The total known distance across the thrust block through Pulaski is 10 miles. That is not the actual measure of the total horizontal displacement, for the block must have extended much farther northwest before its front was eroded back to its present position, and on the south the distance along the fault plane to the actual break across the strata will always remain unknown. It would be a conservative estimate that the horizontal displacement is as much as 20 miles. The nature of the Pulaski overthrust fault and of the rocks above and below it is graphically shown by section I-I′ on the geologic map of the Valley. (See Virginia Geological Survey Bull. 42, 1933.)

Credit for the tracing of the Pulaski fault and its interpretation must be accorded M. R. Campbell and R. J. Holden.[276]

STAUNTON FAULT

The trace of the Staunton fault plane extends from the vicinity of Brownsburg, Rockbridge County, to that of Endless Caverns, Rockingham County. Attention is called to two features of special interest in connection with this fault. A mile west of Burketown, Rockingham County, is a detached area of the overthrust block several square miles in extent, shown on the geologic map, consisting mainly of Conococheague and Beekmantown dolomites resting upon the Athens and Martinsburg formations. This is a true klippe. (See Fig. 8.) Another interesting feature

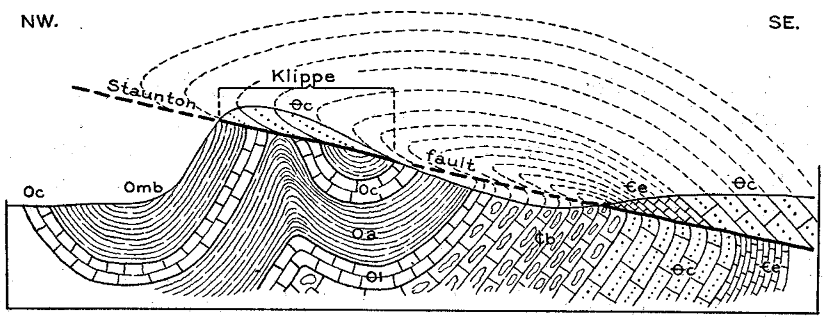


FIGURE 8.—Diagrammatic section through the north end of a knob 1 mile southwest of Mt. Crawford, Rockingham County, showing the klippe of Conococheague limestone and its origin. Not to scale. Omb, Martinsburg shale; Oc, Chambersburg limestone; Oa, Athens shale; Ol, Lenoir and Mosheim limestones; Ꞓb, Beekmantown limestone; Ꞓc, Conococheague limestone; Ꞓe, Elbrook limestone. The symbols used are those on the geologic map (Virginia Geol. Survey Bull. 42, 1933).

and a clear demonstration of the overthrust, is the passage of the Lenoir limestone beneath the thrust, 2 miles northeast of Galena and its reappearance 1 mile southwest of Burketown, both in Augusta County. The Lenoir rises to the fault plane between the two

[276] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 43-44. 1925.

points about 2 miles southeast of the trace of the fault. (See Fig. 9.) At its southwest end a mile or two northwest of Brownsburg, the Staunton fault merges with the Little North Mountain fault in a complex tangle that has not been satisfactorily explained, and the mapping in that area is probably incorrect.

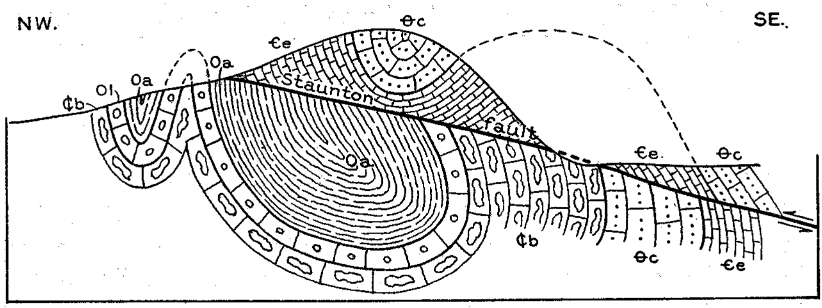


FIGURE 9.—Ideal structure section about 1 mile northeast of Verona, Augusta County. This is an interpretation based upon observations 2 miles northeast of Galena and 1 mile southwest of Burketown. (See geologic map, Virginia Geol. Survey Bull. 42, 1933.) Not to scale. Oa, Athens shale; Ol, Lenoir limestone; Ꞓb, Beekmantown dolomite; Ꞓc, Conococheague limestone; Ꞓe, Elbrook dolomite. The symbols are those used on the geologic map.

NORTH MOUNTAIN FAULT

The North Mountain fault is another of the major faults of the Valley. With its frayed out branches in the south, it extends a distance of about 150 miles in Virginia. Northward it continues an unknown distance into West Virginia. The eastward trend of the trace of the fault plane west of Swoope, 7 miles west of Staunton, southwest of which the fault block has been eroded away, shows an original overthrust of at least 3 miles, and presumably it was greater. On the north in Frederick County a large fault follows the northwest base of Apple Pie Ridge, passing half a mile northwest of White Hall. About 1 mile southeast of Nain it diverges to a southerly course which it follows to a point about 1½ miles southwest of Winchester and apparently dies out in a synclinal axis some distance farther south. About 2000 feet northwest of this fault at the Virginia-West Virginia line another fault crops out and continues in a sinuous course southwest, approaching the southeast base of Little North Mountain which it reaches half a mile south of Green Spring. Thence southward its throw increases so that in the vicinity of Chambersville it becomes the main fault which, so far as known, continues to the vicinity of Saumsville, Shenandoah County, where it divides into a number of diverging branches which extend no great distance to the southwest. The structure at the southwest end of the faulted zone is not fully understood. The general course of the fault is apparently prolonged southward by a number of offset branches of relatively small displacements and the fault, or fault zone, terminates to the northwest of Buchanan in the complex of minor faults and folds in that area.

Along the line of Little North Mountain from West Virginia to Wheatfield, Shenandoah County, there is great irregularity in the distribution and thickness of formations which to a minor degree are due to small faults but which in the main are due to variations in deposition. This irregularity may have produced a line of weakness which determined the locus of the fault and the uplifting and overturning of the formations which all along dip to the southeast toward the North Mountain fault. From the preceding description it will be seen that the geologic map is erroneous in detail for the Little North Mountain belt through Frederick County.

Between the Massanutten syncline and the Little North Mountain fault is a minor syncline composed of the offset elliptical areas of Martinsburg shale marked by Broadway and Edom, Rockingham County, on the north, and by Long Glade, Augusta County, on the south. Between this synclinal belt and the Massanutten syncline is a minor anticline bringing up a long narrow strip of Conococheague limestone. Shenandoah Caverns are located in the middle and near the axis of the anticline between Quicksburg and Mount Jackson, Shenandoah County.

GREAT NORTH MOUNTAIN ANTICLINE

The principal structure west of the Little North Mountain fault is the Great North Mountain anticline which begins on the north at the State line near Shockeyville and persists with increasing prominence to the vicinity of Gainesboro, Frederick County, where it becomes pronounced. The axis pitches strongly to the north. On U. S. Route 50, about 2 miles southwest of Gore where the main axis crosses the road, the symmetrical fold is well displayed in the red Bloomsburg shale on the east side of the road. The anticline with increasing uplift extends southwest to Fulks Run, Rockingham County. In the southwest corner of Frederick County, its axis passes into West Virginia and reenters Virginia about 5 miles east of Bergton, Rockingham County. With the increasing height of the anticline, its protecting top of Tuscarora-Clinch sandstone has been eroded off and a deep intermon-

PLATE 58

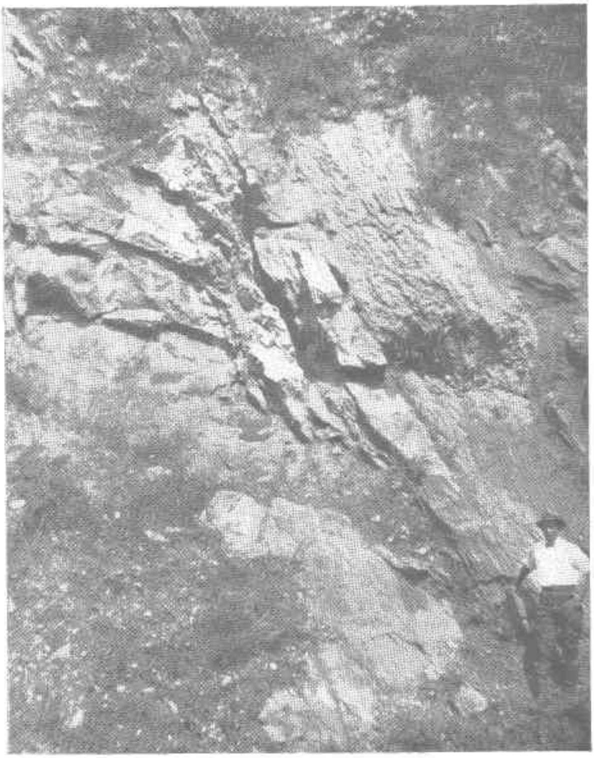
A. Copper Creek fault on which the Rome formation (Cambrian) has been thrust up against beds of Beekmantown age (left). The fault is nearly vertical here. Cut on the Clinchfield Railroad just north of Copper Creek and about 1 mile south of Clinchport, Scott County. Looking east.

B. A minor overthrust fault. The movement was upward from left to right. The stratigraphical displacement is indicated by the offset thin layer of sandstone (*a-a′*). Cut on the Pennsylvania Railroad in Packsaddle Gap of Conemaugh River through Chestnut Ridge, about 1 mile east of Blairsville intersection, Pennsylvania. Looking southeast. Similar faults, but commonly less well exposed, are found in the Valley in Virginia.

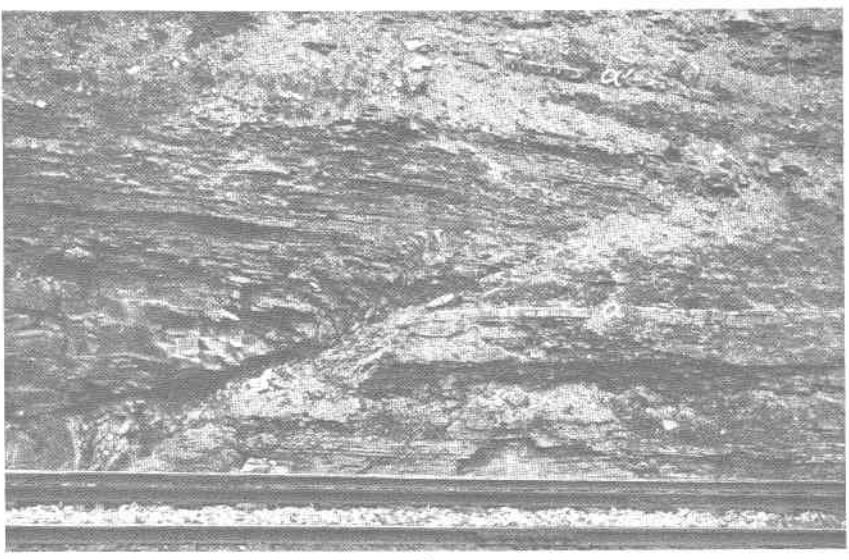
A

B

THRUST FAULTS

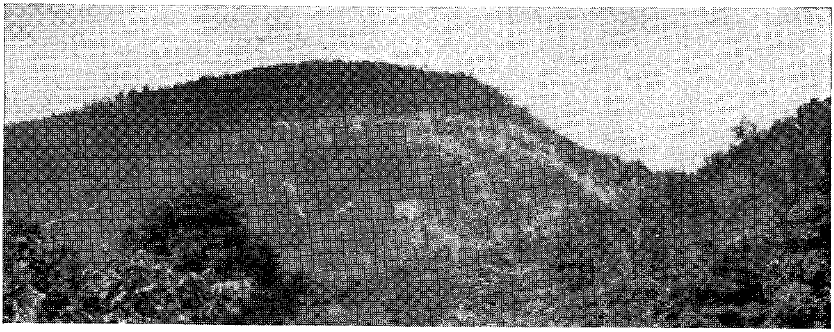


A



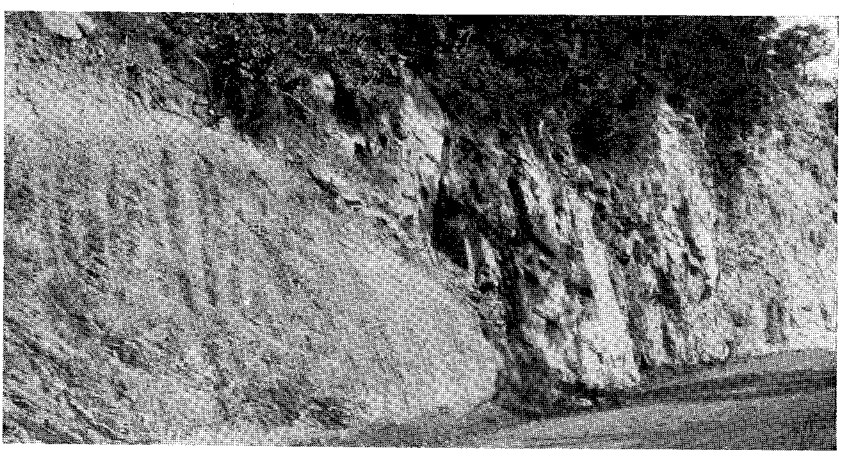
B

THRUST FAULTS



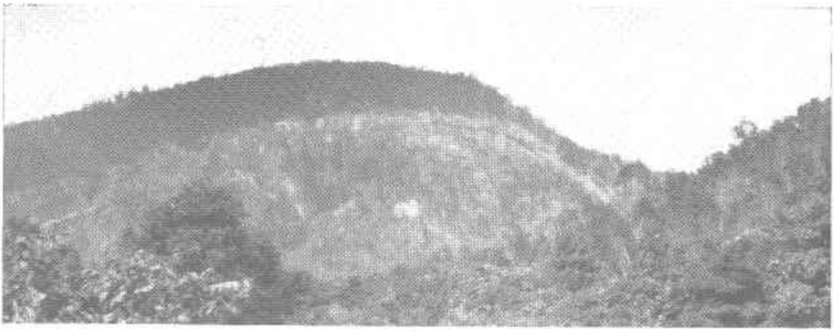
A

B



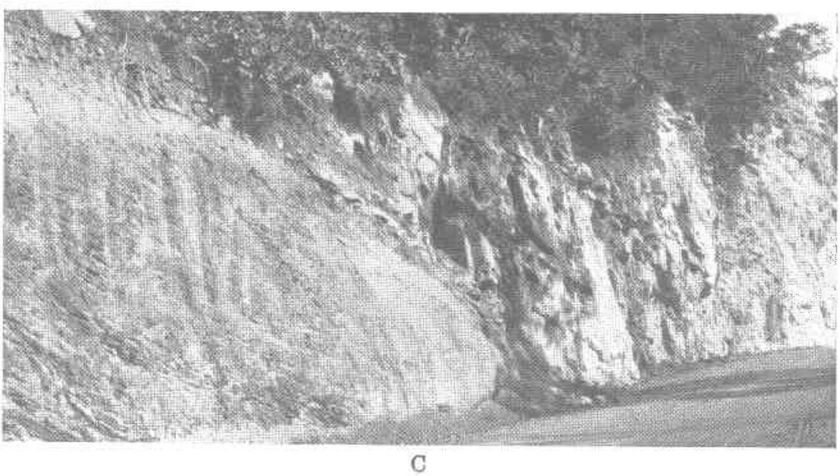
C

FOLDS AND FAULT



A

B



C

FOLDS AND FAULT

PLATE 59

A. Overturned arch of Clinch sandstone. The overturned limb (left) is obscured by the forest. South end of Mays Mountain, 4 miles northwest of Buchanan, Botetourt County. Looking northeast from a point about 1 mile distant.

B. Parallel beds of limestone on the west bluff of New River, half a mile south of Rich Creek, W. Va. The bands from left to right are beds of limestone in the St. Louis, Ste. Genevieve, and Gasper formations, which are overturned so that they dip 60° SE. They are on the northwest limb of an overturned anticline, faulted on the southeast by the St. Clair fault (shown in C). Before erosion, these beds continued upward, curved over the site of East River Mountain, and extended southeastward an unknown distance across the Valley. Looking west across New River.

C. St. Clair fault in the Narrows of New River, Giles County. Beekmantown dolomite (right) has been thrust over Devonian shale. The stratigraphic displacement is 5000 to 6000 feet. The fault dips about 30° SE., and is perfectly exposed for a short distance, which is a rare occurrence in the Appalachian Valley. Along State Route 8, 1 mile south of Rich Creek, W. Va. Looking southeast.

tane valley, occupied by the head streams of Paddy Run, has been eroded in the relatively soft Martinsburg shale. On both sides of this narrow valley are high mountainous ridges made by the Tuscarora-Clinch sandstone on the opposite limbs of the anticline separated by the valley. The ridge on the southeast limb is known as Paddy Mountain. These ridges present some of the most rugged and picturesque topography in the State which must be seen to be appreciated. An impression of it can be had from Plates 2A and B.

The Great North Mountain anticline is a composite structure. A number of minor anticlines extend near its crest and there is probably a fault along and just northwest of the crest. There are a number of minor folds in the low ground at its southeast base.

On the southeast of Great North Mountain is a well-defined syncline marked by Mt. Williams, Frederick County. This is a southern extension of the great syncline in West Virginia occupied by the Sleepy Creek synclinal mountain, capped by the Pocono sandstone. The southern tip of this mountain comes approximately to the State line in the middle of the triangular area of the Hampshire (Catskill) formation northwest of DeHaven. This syncline continues southwest and broadens out into a wide area to the east of Orkney Springs, then dies out or, south of Great North Mountain near Fulks Run, merges with the syncline northwest of the mountain.

ELLIOTT KNOB SYNCLINE

Northwest of the Great North Mountain anticline is a syncline occupied by the Hampshire formation, the axis of which lies near Whitacre, Frederick County. This syncline passes into West Virginia about 5 miles southwest of Gore and reenters Virginia 2 miles northeast of Bergton, Rockingham County. Thence it continues southwest through the long strip of the Pocono formation west of Rawley Springs and Stokesville, and through Elliott Knob to end south of Rockbridge Alum Springs. It is conceivable that this structure may continue southwest as far as a locality west of Marion, though, if so, it is interrupted by cross anticlines and slight axial offsets. As Elliott Knob is about the middle of this syncline, it may be conveniently named the Elliott Knob syncline.

DEERFIELD ANTICLINE

West of the Elliott Knob syncline is an anticline, inconspicuous at the northeast where it is occupied by Brallier shale west of Bergton and by younger formations west of Rawley Springs. It becomes prominent in Walkers Mountain southwest of Deerfield, Augusta County. (See Pl. 40B.) It may be called the Deerfield anticline. This anticline splits into two branches southwest of Deerfield, one on the east running through Panther Gap and ending in Big Ridge a mile north of Gala, Botetourt County, and one to the west passing near Millboro Springs and ending 1 mile northeast of Coronation,[277] Bath County, 7 miles northeast of Clifton Forge. The axis of the eastern branch continues southwest in the Brallier shale and lies along Patterson Creek between Patterson and Price mountains in western Botetourt County, 10 to 15 miles northeast of Newcastle, Craig County.

McCLUNG SYNCLINE

Northwest of the Deerfield anticline is a broad syncline occupied by the Hampshire, Chemung, and Brallier formations. The main trough of this syncline passes southwest near McClung, Bath County, and the name McClung syncline is suggested for it. Its axis is marked by several high ridges occupied at the top by the Chemung formation one of which, Beards Mountain, lies to the west of Coronation and ends on the southwest, 3 miles northeast of Clifton Forge. The Millboro Springs branch of the Deerfield anticline and the Rich Patch anticline, marked by Iron Gate, split the main McClung syncline into two minor synclines, the northwestern one ending near Lowmoor, Alleghany County, and the southeastern passing southeast of the Rich Patch anticline and merging with the Elliott Knob syncline west of Gala. The sprawling area, occupied by the Clinch-Clinton and younger formations in the midst of the general synclinal areas just described, is marked by complexly folded minor anticlines and synclines. The anticlinal axes bring up the older formations which are marked by long, narrow, closed strips, or by long, narrow reentrants of the Clinch-Clinton formations. The axis of the Rich Patch anticline, which is bordered by Pads Creek and the Chesapeake and Ohio Railroad, extends northeast through Griffith and Crane and separates the two minor synclinal axes described above. They are marked by the two narrow strips of Chemung on opposite sides of the railroad in the vicinity of Crane. These occupy the summits of Rough Mountain on the northwest and of Short Mountain on the southeast.

These minor folds affect the entire width of the area of the Brallier shale all through this broad synclinal belt. Some of them are exposed in the bluffs along Cow Pasture River a mile

[277] This place is mislocated, 3 miles northeast of its true position, on the geologic map of the Appalachian Valley.

southwest of Griffith, on the road along Wilson Creek, 2-3 miles northeast of Clifton Forge, and along the road from Clifton Forge to Warm Springs Valley by way of McGraw Gap. Some also show along U. S. Route 60, and in the bluffs northwest of this road southwest of Clifton Forge as far east as a mile beyond Lowmoor. Two pronounced anticlines in the Brallier shale are exposed along U. S. Route 250, within 1 mile southeast of Headwaters on Shaws Fork of Cow Pasture River, Highland County.

The details described above are inserted to give examples of the general rule that all the major structures in the Valley are affected by superimposed minor folds and even faults. The mapping and description of these structures awaits more detailed topographic surveys when larger scale and more accurate base maps have been made. The details described indicate the extremely complex structure of the western parts of Highland, Bath, and Alleghany counties.

RICH PATCH ANTICLINE AND OTHER FOLDS

Northwest of the Elliott Knob syncline is the Rich Patch anticline through the north end of which is cut the Iron Gate gorge of James River, 1½ miles southeast of Clifton Forge, Alleghany County.

West of the McClung syncline in Highland, Bath, and Alleghany counties is a succession of narrow subparallel anticlines and synclines. The main structures are the Hot Springs anticline extending northward through Bolar and Trimble and pitching out southward southeast of Covington; and the Hightown anticline extending from Crabbottom, Highland County, to a point west of Falling Springs, Alleghany County, where its axis overlaps the axis of another minor anticline south of Falling Springs. Actually this anticline extends southwest and is continued through Sweet Chalybeate Springs into West Virginia by its southeast limb, the northwest limb having been faulted out by the St. Clair fault which extends about 8 miles into Virginia northeast of Sweet Chalybeate Springs. Between the Hot Springs and Hightown anticlines is the Monterey syncline extending south to the State line west of Sweet Springs, West Virginia. West of the Hightown anticline in Alleghany County is a syncline containing the Chemung formation and east and southeast of Alleghany are small patches of the Pocono and Maccrady formations. Lewis tunnel on the Chesapeake and Ohio Railroad is on the northwestern margin of the Pocono in this area.

SALTVILLE-BLAND FAULT

The Saltville-Bland fault extends from the north end of the anticlinal Sinking Creek Valley, Craig County, southwest through Bland and Saltville to Tennessee southwest of Cassard Post Office, and for 50 miles into Tennessee, a total distance of 200 miles. It bounds the Greendale syncline on the southeast. At Greendale. Washington County, the lower part of the Honaker dolomite is brought up against the Pennington formation near the top of the Mississippian, a total stratigraphic displacement of 14,000 feet. Along the State line south of Gate City and northeast to Ketron, in southwestern Washington County, the single fault is replaced by several smaller faults having in places a greater displacement, for locally the Rome formation is faulted against the Pennington. (See section C-C′ on geologic map, Virginia Geological Survey Bull. 42, 1933.) Northward, the Saltville fault crosses the Greendale syncline diagonally and gradually eliminates from outcrop all of the Mississippian formations so that within a few miles northeast of Bland the Honaker dolomite is brought into contact with the Brallier shale. Still farther northeast the displacement decreases and for a long distance only Cambrian to Ordovician formations are involved. The fault may extend through the gap at the apex of the Sinking Creek anticline south of Newcastle; if so, the displacement is so small that its presence could not be detected under the conditions of exposure.

GREENDALE SYNCLINE

The Greendale syncline is a major structure, important because it includes in its axial part the youngest formations occurring in the middle of the Valley between the Blue Ridge and the Appalachian Plateaus. These beds are of Mississippian age and contain fossils which afford criteria for correlation with the typical Mississippian of the Mississippi Valley. The uppermost formation, the Pennington, corresponds to formations high in the typical Mississippian in southern Illinois and western Kentucky. The thickness of the Mississippian in the Greendale syncline at the fault boundary is 6000 to 7000 feet. It is most reasonable to assume that these strata, prior to faulting, extended many miles east of their present location and possibly even to or southeast of the Blue Ridge. Similarly it may be expected to have had also corresponding extension toward the northwest.

The axis of the Greendale syncline pitches to the southwest so that, following the axis southwestward from Saltville, successively younger formations are encountered, including the Pennington formation which points out northward 4 miles northeast of Greendale. As the axis of the syncline is very near the Saltville-Bland fault on the southeast, it follows that only the northwest limb of the syncline, including all the formations down to the Rome, crops out as far northwest as the Copper Creek fault. The continuous sequence of formations, almost completely exposed, and the uniform southeast dip are displayed along State Route 71 and U. S. Route 19, from the Copper Creek fault just south of Brookside Inn to Greendale. This is probably the best section exposed in the State. Northeast of U. S. Route 19, as at Little Moccasin Gap on the county line 6 miles northwest of Greendale, the northwest limb of the syncline is greatly modified by superimposed minor folds. The general flattening of the dip in this region results in a widely expanded area of Clinch sandstone capping Clinch Mountain northward to Burkes Garden. Just northeast of Little Moccasin Gap are some notable inliers of Martinsburg shale where streams have cut down through the Clinch, and in a broad synclinal depression southeast of Belfast Mills are outliers of Millboro shale in the axis of a local syncline.

The length of the Greendale syncline along the axis from Saltville southwest nearly to the State line is about 45 miles. The structure, however, as determined from the extent of the Mississippian formations, extends from northeast of Bland southwest to the south end of Clinch Mountain, 25 miles northeast of Knoxville, Tennessee, a distance of 170 miles. The southeast dip from the Copper Creek fault to the Saltville fault along State Route 71 and U. S. Route 19 averages about 30 degrees.

Two minor features of this syncline are worthy of mention. Toward the middle of the syncline at Early Grove, Scott County, a former post office on U. S. Route 58, 10 miles northwest of Bristol, is a minor anticline (section CC′ on geologic map), which is of interest from the fact that deep wells located on it near Early Grove struck a reservoir of natural gas. This is the only known occurrence in the State of natural gas in commercial amount. The second minor feature is a klippe, or remnant of an overthrust sheet, of the Honaker dolomite which covers an area of a few hundred acres, 6 miles southwest of Early Grove.[278] This is significant as evidence that the Mississippian rocks of the Greendale syncline were once covered by an overthrust sheet of Honaker

[278] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), p. 6, and areal geology and structure section maps, 1899.

dolomite extending north at least a mile beyond the present northern boundary of that formation at the Saltville fault.[279]

COPPER CREEK FAULT

The fault here named the Copper Creek extends from Clinchport, Scott County, to Belfast Mills, Russell County, where it ends in the axis of an anticline. South of Clinchport and in the vicinity of Lebanon, the fault, as mapped, is apparently flexed or offset in a peculiar fashion. Probably the details of the fault at these places have not been accurately determined.

JOHNS CREEK SYNCLINE AND SEVEN MILE MOUNTAIN ANTICLINE

The Johns Creek syncline in which Johns Creek in the southwest part of its course is located lies almost entirely in the northwestern part of Craig County. As bounded by the Brallier shale it is a symmetrical canoe-shaped syncline having rather narrow ends on both the northeast and southwest. Its most notable feature is the narrow median anticline of Cayuga and Helderberg formations,[280] and Millboro shale, constituting Seven Mile Mountain southwest of Craig Healing Springs.

BANE DOME, KIMBERLING BASIN, AND BURKES GARDEN DOME

Three structures located on the same line of strike in Giles, Bland, and Tazewell counties are among the most notable structural features of the Valley in Virginia. From northeast to southwest they are the Bane dome, Kimberling basin, and Burkes Garden dome. The Bane dome occupies an elliptical area in Giles County. The center is occupied by a small area of the Rome formation on the apex at Bane. To the northeast the Bane dome is extended in three anticlinal offshoots, the main one of which, Sinking Creek anticline, extends north along Sinking Creek into Craig County; the others pitch out into the southwest slopes of Butt Mountain east of Pearisburg. The Burkes Garden dome at the southwest end of the belt has an area of Beekmantown dolomite on its axis. Both the Bane and Burkes Garden domes are conspicuous examples of anticlinal valleys. Between the two domes lies the broad Kimberling synclinal basin which is essentially quadrangular. It is a cross syncline with about the same

---

[279] The situation indicates a rather flat thrust and suggests that the Mississippian formations may extend southeast beneath the Honaker dolomite farther than is indicated on section C-C′ of the geologic map.

[280] On the geologic map of Virginia, edition 1928, the Cayuga and Helderberg formations were mapped as Pocono-Price.

width across as the two anticlines. An anticlinal axis evidently extends the full length of the area occupied by these structures, as indicated by the anticlinal extension of the Bane dome in Flat Top Mountain south of No Business Creek on the northeast and the similar extension of the Burkes Garden dome in Round Mountain on the southwest. This axis must extend as a low anticline through the northwest side of the Kimberling basin. As the Brallier shale has an unusual thickness in this area and as the Chemung is also thick and formerly extended over the Kimberling basin, it is reasonable to surmise that the weight of the sediments was so great that the forces adequate to elevate the rocks of the two domes were insufficient to raise the rocks of the basin to the same height. It is also possible that the rocks of the basin were down—warped in respect to the domes.

NARROWS FAULT

The Narrows fault extends from northeastern Giles County, passing half a mile or so northwest of the town of Narrows, to northeastern Tazewell County where it splits into two branches and dies out in a few miles farther southwest.

LICK MOUNTAIN SYNCLINE

Lick Mountain syncline is named from a long narrow synclinal mountain, called Lick Mountain, in the main axis of the syncline beginning on the northeast about 6 miles southwest of Tazewell, Tazewell County. The syncline apparently extends in varying width from West Virginia northeast of Narrows, Virginia, to Lebanon, Russell County. Lick Mountain, House and Barn Mountain, and Elk Garden Ridge, capped with narrow areas of Clinch sandstone, mark the main axis. Deskin Mountain marks a subordinate axis separated from Lick Mountain by a low anticline. The depression of the axis northeastward is indicated by the small area of Brallier shale north of Cove Creek, Tazewell County.

ST. CLAIR, HONAKER, AND CLINCHPORT FAULTS

The St. Clair fault crops out a few miles northwest of the Narrows fault and extends from southern Alleghany County through West Virginia to New River, where it crosses the projection of Giles County about 4 miles northwest of the town of Narrows and reenters West Virginia through which it continues parallel to the Narrows fault southwestward to the vicinity of Honaker, Russell County. It is here intersected by the Russell

Fork fault and is practically continued to the southwest by the Honaker fault. This fault splits east of Castlewood. The north branch continues to a point near Dungannon where it seems to be offset to the northwest for a mile or so by the Clinchport fault. Apparently the St. Clair, Honaker, and Clinchport faults combine to form a single fault zone 170 miles long in Virginia and West Virginia. Where the St. Clair fault crosses the road 2½ miles north of the town of Narrows, the fault plane is exposed showing dolomite low in the Beekmantown, faulted up over Devonian, probably Brallier shale. (See Pl. 59C.) The fault exposed near Indian, Tazewell County (Pl. 62B), is also the St. Clair or a split of that fault. The trace of the Clinchport fault is rather sinuous and perhaps instead of one continuous fault the general movement has been along several overlapping but closely spaced faults constituting a fault zone. The south course across the Rye Cove syncline south of Duncans Mill is apparently due to the erosion of the fault block that formerly extended over Rye Cove, and it is possible that the formations of Rye Cove extend northeast some distance beneath the thrust plane.

HURRICANE RIDGE SYNCLINE

The Hurricane Ridge syncline enters Virginia from West Virginia east of Falls Mills, Tazewell County, and extends southwest through Tazewell County to Bandys Chapel (Baptist Valley). The Bluestone formation occupying this syncline is the youngest pre-Pennsylvanian formation in the Valley.

ABBS VALLEY ANTICLINE

The Abbs Valley anticline extends southwest along Abbs Valley from Nemours, West Virginia, to a locality about 2 miles east of Pocahontas, Virginia. The axis of this anticline is indicated by the narrow strip of Gasper and Ste. Genevieve formations, about 1 mile southeast of Pocahontas and Boissevain, Virginia.

RYE COVE SYNCLINE

The Rye Cove syncline is conspicuously expressed in Rye Cove by the wide area of Lowville and Trenton limestones in the middle part. The syncline pitches northeast from the cross anticline which brings up the Maryville limestone along the axis at the locality of broken Silurian and Devonian rocks, 3 miles southwest of Pattonsville, Scott County. Thence southwest the axis pitches southwest so that the Nolichucky shale and Copper Ridge dolomite are caught in the long ridge a mile southeast of Blackwater, Lee County. The axis of this syncline passes through, or near, the Natural Tunnel, in Scott County.

ST. PAUL AND RICHLANDS FAULTS

The southeast margin of the coal measures is a faulted zone in which the St. Paul fault, southwest of Big A Mountain, Russell County, and the Richlands fault northeast of Stone Mountain to Boissevain, Tazewell County, are the main structures. The St. Paul fault is of large displacement in the vicinity of St. Paul, where the Maryville limestone is thrust against the coal measures (Pottsville). The fault is partly exposed at the west end of the first tunnel on the Norfolk and Western Railroad about 1 mile southwest of St. Paul. A photograph of this exposure has been published in the Bristol folio.[281] The stratigraphic displacement was estimated by Campbell at 15,000 feet. The dip of the fault plane is 12 degrees. If this dip persists, the horizontal displacement would be 13 miles.

This belt is so much dissected by minor faults and by small folds that considerable uncertainty exists about the continuity of the supposed major faults named above. The St. Paul fault seems to be a fairly definite and continuous structure southwest of St. Paul to Tennessee, except for the short distance through the structural and stratigraphic tangle southwest of Pattonsville. This fault has also been called the Hunter Valley fault from Hunter Valley south of Valaho, Scott County.

NEWMAN RIDGE SYNCLINE

On the northeast, between Duffield, Scott County, and St. Paul, Wise County, only the overturned axial part of the Newman Ridge syncline crops out along the southeast base of Powell Mountain. Most of the southeast limb is overridden by the thrust-block above the St. Paul fault. Southwest of Duffield, the syncline continues through Pattonsville, southwest of which the axial part is nearly faulted out. Still farther southwest, a few miles northeast of Blackwater, the syncline deepens and includes Devonian and Mississippian rocks. It continues southwestward into the Butt of Newman, Hancock County, Tennessee, the axis being occupied by the Mississippian rocks of Newman Ridge. The name is taken from Newman Ridge. The knot, 2 to 3 miles southwest of Pattonsville, probably belongs to the buried southeast limb

[281] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), p. 5, 1899.

of the syncline which has been uncovered by local erosion of the overthrust mass of Maryville limestone. The disturbed condition of the strata here probably indicates that they were just beneath the fault plane and were broken up and disorganized by the formation of the fault and by the friction resulting from the subsequent overthrust movement.

WALLEN VALLEY FAULT

A pronounced fault extends along the southeast base of Wallen Ridge from the vicinity of Big Stone Gap into Tennessee. This fault is unnamed on the geologic map of the Valley, but the name Wallen Valley fault[282] has been applied to it elsewhere.

POWELL VALLEY ANTICLINE

The Powell Valley anticline extends from the vicinity of Little Stone Gap, 2 miles southwest of Norton, Wise County, to Tennessee. It broadens to the southwest and pitches to the northeast. Its axis passes through or near the fensters southeast of Ewing and Rose Hill, Lee County. Eastward from the head of the cove south of Little Stone Gap this anticline extends as a low, scarcely definable structure for a long distance through the coal measures of southern Wise County, into western Russell County where it dies out 1½ miles south of Dante.

RUSSELL FORK FAULT

The Russell Fork fault[283] extends northwest across the coal measures from Big A Mountain into Kentucky. Thus it strikes northwest transversely to the faults in the Valley. The fault plane is thought to be highly inclined or vertical and the movement is believed to have been predominantly lateral rather than vertical as it was in the Valley faults. Hence, it is a tear fault or a blatt. The block to the southwest of the fault moved to the northwest about 2 miles relatively to the rocks northeast of the fault. This fault is the northeast boundary of the Cumberland overthrust block which is described on page 464.

MIDDLESBORO SYNCLINE

Northwest of the Cumberland escarpment marked by the State line northwest of Lee County, is a broad synclinal basin, the axis

---

[282] Wentworth, C. K., Russell Fork fault of southwest Virginia: Jour. Geology, vol. 29, no. 4, p. 353, 1921.
Butts, Charles, Fensters in the Cumberland overthrust block in southwestern Virginia: Virginia Geol. Survey Bull. 28, p. 7, 1927.
[283] Wentworth, C. K., op. cit.

of which must pass near Middlesboro, Kentucky. The axis enters Virginia 1½ miles northwest of Pardee; extends thence northeast and passes 2½ miles northwest of Clintwood; crosses Russell Fork, 3 miles southeast of the State line; and continues thence northeast into the midst of the broad area of the Wise formation in northern Buchanan County.

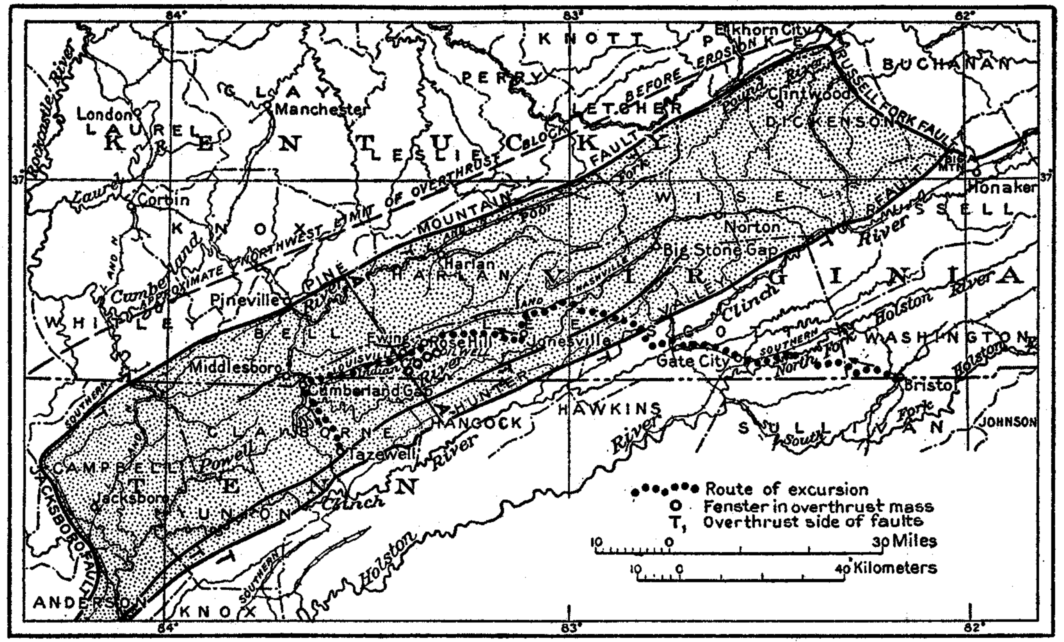
PINE MOUNTAIN FAULT

The Pine Mountain fault crops out chiefly along the northwest base of Pine Mountain in Kentucky. It is exposed in very small areas in Lee County southeast of Ewing and Rose Hill which are windows or fensters in the Cumberland overthrust block near the axis of the Big Stone Gap anticline. On this axis the rocks of the overthrust block were worn thin by erosion and in a few small areas were worn through so as to expose the younger rocks of the overridden block, thus making the fensters. As shown in Plate 59A, the thrust plane is conceived as being nearly flat and extending on the soft Millboro (Chattanooga) shale beneath the Middlesboro basin to crop out at the northwest base of Pine Mountain, Kentucky, where the Millboro shale is brought up into contact with the coal measures immediately northwest of the fault. Although nearly flat as a whole, the fault plane is arched above the fenster and dips northwest and southeast from it. Possibly the region was slightly arched on the Big Stone Gap anticline after the formation of the fault. The distance from the fenster to the outcrop of the Pine Mountain fault is 17 miles. This affords an intimation of the possibility of the extension of these fault planes far back from their outcrops.

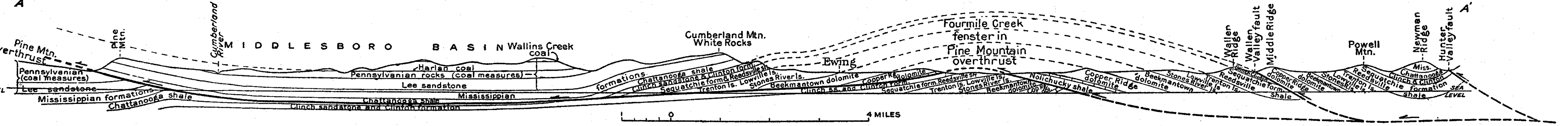
CUMBERLAND OVERTHRUST BLOCK

The Cumberland overthrust block was named by Wentworth.[284] It is shown in Plate 60A. The southern boundary of the block is shown as the St. Paul (Hunter Valley) fault, but strictly this boundary should be placed at the Wallen Valley fault, at least in the southwestern two-thirds of the block, because, according to the structure section given by Wentworth, only the block northwest of the Wallen Valley fault is unbroken to the Pine Mountain fault on the northwest boundary. As shown by the section, the Pine Mountain, Wallen Valley, and St. Paul faults are supposed to merge at depths and combine into a general thrust zone along which all the blocks

[284] Wentworth, C. K., Russell Fork fault of southwest Virginia: Jour. Geology, vol. 29, no. 4, p. 351, 1921.

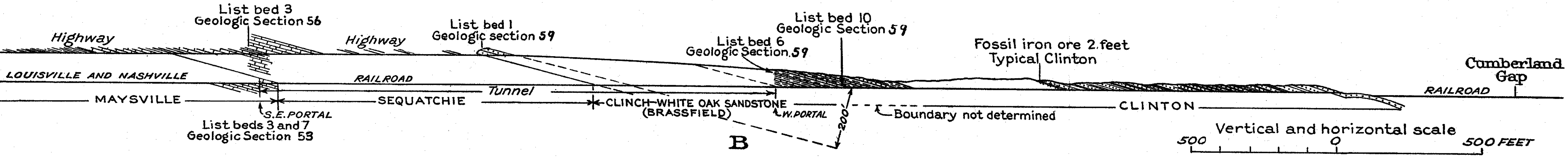


A, Map and section of the Cumberland overthrust block, showing the Fourmile fenster and other features. (From Internat. Geol. Congress Guidebook 3, 1932.) B, Section of the upper Reedsville shale (Maysville), Sequatchie, Clinch-Brassfield, and Clinton formations along the Louisville and Nashville Railroad for 1 mile southeast of the town of Cumberland Gap, Tennessee. "List" refers to list of fossils from the designated bed. C, Section along the Norfolk and Western Railroad through Pepper Ferry to show the structure of the overthrust Elbrook limestone and the Pulaski fault in the Devonian fenster. The fault crops out 800 feet south of Pepper Ferry which is 1 mile northwest of East Radford, Montgomery County. (See Virginia Geol. Survey Bull. 25, Pls. 6 and 9A, 1925.)

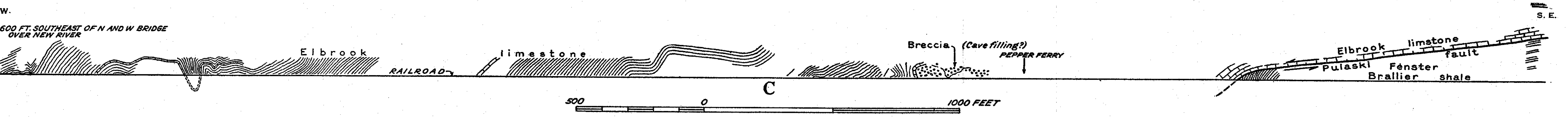


MAP AND SECTION OF CUMBERLAND OVERTHRUST BLOCK

A



B



C

moved. The Pine Mountain thrust fault at the base of the Cumberland overthrust block nowhere crops out to the southeast of the small fensters, and its existence and extent southeast of its outcrop is only revealed by the fensters. The length of the block is 125 miles, its width 25 miles, and its total area about 3000 square miles.

The movement on the Russell Fork fault is about 2 miles, the movement on the Jacksboro fault bounding the block on the southwest, in Tennessee, is about 10 miles, and the movement along the line of the section (Pl. 60A) is about 7 miles. The movement was pivotal, the pivot being at the northeast end near the Russell Fork fault. The interpretation stated above seems to be reasonably deducible from the facts as known at present, but it should not be accepted as final. The situation demands more critical examination by specialists in structural geology.

STRUCTURE OF THE COAL MEASURES

The strata of the coal measures in the large areas in the southwestern part of the State, vary in a broad sense but relatively little from their original horizontal attitude. Throughout most of the coal fields the dip is so slight that it would be hardly noticeable in any exposure of usual extent. A few structures, however, that are of more than the usual amplitude and linear extent are noteworthy. The Powell Valley anticline and the Newman Ridge and Middlesboro synclines have been described.

Another moderately pronounced structure is the Dry Fork anticline, the axis of which lies about 3 miles northwest of the southeast boundary of the coal field and extends eastward from a point north of Big A Mountain, Russell County, through Russell and Tazewell counties into McDowell County, West Virginia, 5½ miles west of Shraders. Two other fairly pronounced structures, the Buck Knob anticline and the Dorchester syncline, extend from the south margin of the coal field north of Little Stone Gap, north to the Middlesboro syncline.

From the Dry Fork anticline the rocks dip south to the southeast edge of the coal field in Tazewell and Russell counties at a rate of about 200 feet to the mile. North of the Dry Fork axis through eastern Buchanan County, the dip is constantly northward to Kentucky, with local variations resulting in structural terraces and local basins and domes. The total net dip is 2750 feet in 28 miles, or an average of about 100 feet to a mile. This is a dip of 1 degree, an amount that is imperceptible in any ordinary exposure. On a section from the axis of the Powell Mountain anticline, 1 mile south of Dante, Russell County, through Clintwood to the axis of the Middlesboro syncline, the total dip is 1400 feet, or 78 feet to a mile. This is much less than 1 degree. From the Middlesboro syncline, the rocks rise northwestward, with a gradually increasing dip to the crest of Pine Mountain. The entire amount of rise is 2850 feet in the distance of 3¼ miles, or 875 feet to a mile. In western Wise County, the structural trends are north and south with westward dip west of the Buck Knob anticline.

The structure of the coal fields is shown in detail by structure contours in the county reports on the coal measures.[285]

The angle of dip of the thrust planes varies from horizontal to vertical as shown by Plates 60A and 58A. The dip of the same plane varies from place to place. As shown in the section of Plate 60A, the dip of the Pine Mountain fault is reversed in the Fourmile fenster and the change in less than half a mile to the north from limestone of the Nolichucky in contact with the Clinton formation to Copper Ridge dolomite in contact with the Clinton, proves that the fault plane has an irregular configuration in that locality. The Copper Creek fault is steep at the point shown in Plate 58A, but probably flattens at some depth and probably flattens also in its position above the surface to the west of the point shown before the overthrust mass was eroded off. Dips as low as 12-15° have been observed, and at a few places dips of 30° have been determined through mining operations. The dip seems to be 25-30° on the St. Clair fault, as shown in Plates 59C and 62B. As clearly shown by the fensters through the Pulaski thrust block between Wytheville and Blacksburg, the Pulaski fault plane must be on the average nearly flat or dip southeast at a very low angle.

Variation in angle of dip of the fault planes is indicated by the variable southeastward slope of the planes as represented in the cross sections on the geologic map of the Valley. The actual attitude of the fault planes, except in a few very limited areas, as described above, is unknown and may ever so remain as they are so deeply buried beneath the surface that they may never be accessible to observation. It is supposed, however, that all these overthrust fault planes descend to a common level, or sole, or to a thicker zone in the earth's crust on which the main movement of the overlying part of the crust took place and from which breaks or offshoots arose which reached upward to crop out as fault traces on the surface. (See Pl. 60A.)

[285] Virginia Geol. Survey Bulls. 12, 18, 19, 21, 22, 24, and 26.

LOCAL AREAS OF INTENSE DEFORMATION

A few small areas of much broken and displaced strata have been noted. One area is just east of Ben Hur, Lee County, and another is between Dryden and Olinger, Lee County. The Big Stone Gap area, Wise County, and the small area 1 to 3 miles southwest of Pattonsville, Scott County, are others. Another area is 1 to 4 miles west of McAfee Gap, Roanoke County, and another is 1 or 2 miles north of Salem, Roanoke County. The Reed-Coyner Mountain fenster (?) northeast of Roanoke and the north end of Crawford Mountain (Pl. 61), half a mile northwest of Eagle Rock are others. These structures may be explained as the result of local torsional stresses in the vicinity of the overlapping ends of anticlines or synclines; also perhaps as adjustments of the rocks to the resistance offered by hidden obstacles which caused deflections in the directions of the deforming forces; to disruption by faults; or to friction just beneath the fault planes.

FENSTERS OR WINDOWS

In Price Mountain south of Blacksburg the small area of Price is completely enclosed by Rome and Elbrook rocks which once completely covered the Price. The cover was worn through by erosion so that Price Mountain is a true fenster. Another example is the fenster between Wytheville and Max Meadows, Wythe County, where the younger rocks are completely surrounded by the much older Rome formation which was thrust over them along the Pulaski fault and subsequently eroded from the small area of the fenster. Another small area of complex structure and of seemingly incongruous geologic relations is that of Reed and Coyner mountains, 4 to 9 miles northeast of Roanoke. This feature has been interpreted as an elevated fenster, but the interpretation is open to serious doubt. (See geologic map of the Appalachian Valley and section J-J'.)

INLIERS

The exposures of Martinsburg shale in small subcircular areas beneath the younger Clinch sandstone on Clinch Mountain northeast of Little Moccasin Gap, 8 miles northwest of Abingdon, Washington County, are perfect examples of inliers. Erosion by streams cutting into the arch of an anticline has produced these inliers. Another striking example is the series of small oval areas of the older Juniata formation exposed beneath the Clinch sandstone, where small streams cross the axis of a minor anticline northwest of Horton, Botetourt County. The area of Beekmantown dolomite in Burkes Garden, and the small area of the Rome formation on the summit of the Bane dome, Giles County, are typical inliers. The formations in inliers are separated from the overlying younger formations by normal contacts in a regular sequence of beds, whereas those in fensters are separated by overthrust faults which cause older rocks to surround the windows of younger rocks.

KLIPPEN

Klippen are not common in the Appalachian Valley of Virginia. The best example of one is west of Burketown. (See Fig. 9.) Another small one, where the Honaker dolomite is thrust upon the Pennington formation, is in the Greendale syncline southwest of Early Grove, Scott County. (See geologic map of the Appalachian Valley.) Klippen are of special significance as evidence of the former extension of an overthrust sheet.

OUTLIERS

Outliers like inliers are composed of rocks in normal sequence. Examples are many, among which are the two small areas of Devonian black shale surrounded by Clinch-Clinton rocks 2 or 3 miles southeast of Belfast Mills, Russell County, and another area of Brallier shale. 2 miles east of Bells Valley, Rockbridge County.

GEOLOGIC HISTORY

PALEOZOIC ERA

The history of the Appalachian Valley began at a remote time when eastern North America was an extensive lowland occupied by igneous and metamorphic rocks such as granite, schist, and gneiss. This lowland was produced by preceding ages of erosion upon rugged uplands which extended from the Atlantic seaboard northwest through Canada to the Arctic region. The Canadian shield and the Piedmont region of Virginia are now parts of that area which was continuous across the Appalachian Valley belt before its subsidence. About 450 million years ago, this old upland began to sink along a belt extending from Newfoundland to Alabama and the long, comparatively narrow trough that was formed was flooded with water from the seas at either end and perhaps through inlets from the Atlantic on the southeast. (See Fig. 10.)[286] In its origin and nature this trough was somewhat similar to Hudson Bay, in which marine waters have flooded a large area on the continent. At first the trough was relatively narrow through Virginia. Its axis probably lay along a zone now marked by the Blue Ridge. Its southeastern margin was at least as far southeast as Charlottesville, Albemarle County, where remnants of the early Cambrian (Chilhowee) sandstone, the earliest deposits in the trough, still exist. The location of the northwest margin is unknown, because the Cambrian rocks are deeply buried by younger formations. As shown by deep wells, early Cambrian rocks are not present beneath central Ohio and central Kentucky; hence the trough did not extend that far northwest. Presumably its northwest margin lay at least as far west as the present northwest boundary of Virginia. In time and with continuous but very slow subsidence the trough expanded westward. By late Cambrian (Nolichucky) time the Mississippi Valley region was at least partly submerged as shown by fossils, regarded as of Nolichucky age, from a deep well near Nicholasville, 10 miles south of Lexington, Kentucky, and by such fossils from central Wisconsin and central Missouri. By Nolichucky time connections had been established with seas transgressing eastward from the Pacific Ocean. Submergence of the Mississippi Basin was repeated many times throughout the remainder of Paleozoic time.

---

[286] See also Schuchert and Dunbar, Outlines of historical geology, Fig. 37A, 1937.

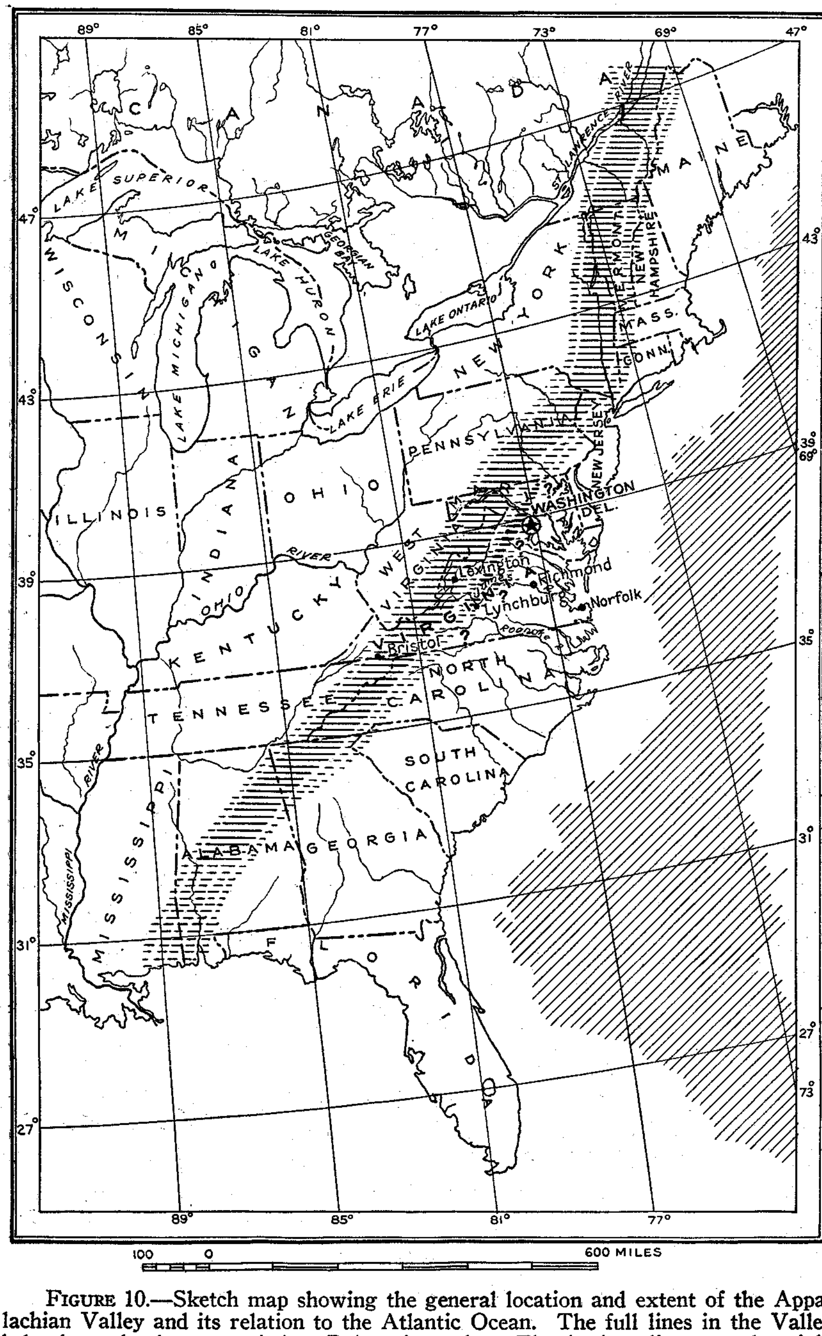


FIGURE 10.—Sketch map showing the general location and extent of the Appalachian Valley and its relation to the Atlantic Ocean. The full lines in the Valley belt show the known existing Paleozoic rocks. The broken lines on the right show outlying areas of these rocks in the Piedmont province; on the left, the hypothetical extent of the Valley rocks beneath the Appalachian Plateaus. The broad hachured area shows the hypothetical Paleozoic Atlantic Ocean; the unshaded area shows the land mass (Appalachia) from which the Valley sediments were derived.

CAMBRIAN PERIOD

Rivers from the bordering lands flowed into the Appalachian trough as soon as it began to form. They carried their load of sediment, just as modern rivers do, and the currents and waves of the sea in the trough distributed this sediment over the bottom just as they now do over the bottoms of existing seas. This marine sedimentation marks the beginning of recorded Cambrian time.

EARLY CAMBRIAN TIME

Chilhowee epoch.—The first sediments deposited in the Appalachian trough consisted of quartz sand and fragments of feldspar that had accumulated as a deep residuum on the old pre-Cambrian lands. These materials formed pure quartz sandstones or beds of arkose composed of grains of quartz and feldspar. Thus originated the Unicoi sandstone in the south and the equivalent Loudoun and Weverton formations in the north.

About the middle of Unicoi time molten rock poured out as a lava flow from some unknown locality and flowed over the sandy sea bottom. This solidified into the amygdaloidal rock now interbedded in the Unicoi sandstone in southern Virginia and northern Tennessee. The approximate age of this lava flow, as determined by an analytical method based on radioactivity, is 450 million years.[287] The validity of this method is generally accepted by chemists, physicists, and geologists.[288] As the amygdaloid is only about 1000 feet above the base of the Cambrian rocks, its known age gives an approximate date for the beginning of the Cambrian period, which is also the beginning of the Paleozoic era.

As the coarser materials were carried away, the old land was probably reduced to still lower levels and gentler slopes. The gradients and velocities of the rivers decreased so that they could transport only silt and finer sand. This accumulated in the sinking trough above the Unicoi sediment to form the material of the present Hampton-Harpers shale. Still later, the lands were uplifted so that the rivers acquired increased transporting power sufficient to carry coarse sand into the trough to form the Erwin quartzite in the south and the Antietam sandstone in the north.

The Erwin and Antietam contain brachiopod shells, *Hyolithes,* and fragments of trilobites, *Olenellus.* Fossils of these genera are, so

---

287 National Research Council, Report of the Committee on the Measurement of Geologic Time; Lane, A. C., Chairman, National Research Council, Annual meeting of the Division of Geology and Geography, p. 39, Apr. 27, 1935.

288 Schuchert, Charles, and Dunbar, C. O., op. cit., pp. 38-40.

far as known, the oldest definitely determined animal remains. They occur in other parts of the earth in rocks of about the same age.

These fossils are rather highly organized and were developed through a long line of ancestors which must have lived somewhere through many preceding ages, although no unquestionable animal remains have so far been found in rocks older than the Erwin sandstone. Brachiopods now live only in sea water, as do the king crabs, probably the nearest living relative to trilobites. It is therefore believed that these early forms were marine animals, that is, they lived only in sea water. The absence of their remains from rocks older than the Erwin, as the Unicoi and Hampton, may be accounted for on the assumption that those sediments were deposited in fresh water lakes which were obviously destitute of marine animals and probably of fresh water animals that possessed hard skeletal parts capable of preservation as fossils. Low forms of plant life, known as calcareous algae, existed in ages preceding the Erwin epoch and, in some regions, as for example western Montana, their remains are abundant in rocks that are considered to be older than the Unicoi and Hampton.

Some geologists now regard the Cambrian period as beginning with the oldest rocks containing fossils, such as the Erwin sandstone, and regard the nonfossiliferous sedimentary rocks older than the Erwin as pre-Cambrian but Paleozoic, because Paleozoic life ancestral to the forms in the Erwin and contemporaneous formations must have existed somewhere during the time of the deposition of those older rocks.

Shady epoch.—At the end of Erwin time one of the most abrupt changes in the entire history of Appalachian sedimentation took place. Instead of clastic sediment, such as sand and silt, a great body of limy sediment was laid down. It contained, in general, very little clastic material such as prevailed in Chilhowee time. This limy sediment consolidated to form the Shady dolomite, probably after the substitution of magnesium carbonate for part of the original calcium carbonate. The abruptness of the change from the Erwin to the Shady type of sedimentation is shown in the quarry on James River about 1 mile northeast of Buchanan, Botetourt County. (See Pl. 14B.) Such a change may be explained as follows: Through the long ages of Chilhowee sedimentation the land had been worn down to a very low level and most of the clastic material had been carried away. The streams became sluggish and had little transporting power. Arid climates may have been a contributing factor but probably not the controlling one. In the long ages of Chilhowee sedimentation great quantities of calcium (lime) carbonate, the substance of limestone, must have been carried into the sea water in solution. The calcium carbonate accumulated perhaps to the point of saturation. The water was also highly charged with magnesium carbonate which before final consolidation of the limy precipitate partly replaced the calcium carbonate and formed magnesian limestone, or dolomite, of which the Shady is mainly composed.

Whatever the true detailed history of Shady deposition, it is certain that the entire mass of the formation was derived from the land and carried into the Appalachian trough in solution by the rivers.

Invertebrate life flourished at times and in some localities in the Shady epoch. The principal types were trilobites, including the early Olenelloids which continued from the Erwin epoch; brachiopods, including new genera not yet known in the Erwin; and the earliest known gastropods, *Pelagiella, Stenotheca,* and *Helcionella.* Another common form was *Archaeocyathus* which seems to be related to the sponges and corals. No plant fossils have been reported.

In Chilhowee time the Appalachian trough extended from Pennsylvania to Alabama, and in Shady time it extended from Newfoundland and Labrador to Alabama. Its extent northwestward across the valley is not known, because the Chilhowee and Shady rocks are exposed only along the southeast margin of the trough, and their northwestern margins are deeply buried by younger rocks and have not been located by borings. Therefore, the width of the Appalachian trough in Shady time can not be determined. It is known, however, that the Shady deposits did not extend as far west as central Ohio and Kentucky because their absence has been proved by deep borings into the pre-Cambrian basement.

Rome epoch.—The Shady epoch came to a close with the resumption of clastic sedimentation, including red muds, a new element in Appalachian geology. The change was about as abrupt and complete as the change from the Erwin to the Shady sediments. Rome sedimentation was highly variable, presumably because of more or less rapid topographic and climatic changes in the land areas from which the sediments were derived. As the land was raised and more rain fell, the activity of the streams increased. They carried to the sea the residual clastic material which had accumulated through the ages in which the calcium carbonate of the Shady had been leached out of the rocks. These disintegrated rocks comprising the residuum, or soil, furnished sand and silt to the streams. The red sediments derived their color from iron oxide which had formed in the residual mantle on the land. The red soil now covering the Piedmont region over much of the Southern States is a modern example of the source of red sediments.

The large lenses of dolomite and the beds of limestone scattered through the Rome suggest local land-locked basins in the Rome sea in which evaporation caused concentration of calcium and magnesian carbonates and the precipitation of dolomite.

The ripple marks and sun cracks on the surfaces of some layers of these rocks show that the beds were laid down in shallow water. The presence of the Rome formation near the Blue Ridge and also along the northwest side of the Valley adjoining the coal measures shows that the Rome sea extended over the present Valley, and from the great thickness of the Rome near the coal measures it is also certain that the formation and the sea in which it accumulated extended a long distance west over the area now occupied by the coal measures of southwest Virginia, eastern Kentucky, and West Virginia, beneath which the Rome formation must be present. Deep wells show that the Rome is absent beneath central Ohio and Kentucky so that the Rome sea did not extend that far west.

Life similar to that of Shady time, with trilobites and brachiopods prominent, continued through the Rome epoch, but was apparently limited to short periods and small areas, as persistent search is necessary to find any fossils in the formation.

MIDDLE CAMBRIAN TIME

Rutledge, Rogersville, and Maryville epochs.—In Middle Cambrian time the sediments deposited were predominantly clastic in the Valley south of the latitude of Knoxville. Northeastward to Russell County, Virginia, they were chiefly limy (Rutledge and Maryville limestones). Still farther northeast they consisted of dolomite (Honaker) and along the southeast side of the Valley in Virginia and Pennsylvania, of argillaceous limestone (Elbrook). Some argillaceous sediment was brought into this northern sea to form the Rogersville shale, the clayey bands in the limestone, and the disseminated clay in the Elbrook. Low land and sluggish streams, with consequent precipitation of carbonates from the sea water, may account for the prevailing limestone and dolomite in this part of the Valley in middle Cambrian time. The predominance of clastic sedimentation (Conasauga formation) in the southern part of the Valley, including southern Tennessee, Georgia, and Alabama, indicates higher land and vigorous erosion in the Piedmont region of those states, the rivers of which emptied into the southern end of the Appalachian Valley trough.

The life of middle Cambrian time, at least as preserved as fossils, consisted still almost solely of trilobites and brachiopods. They are of different genera and species from those of Rome time. The most diagnostic middle Cambrian genus is *Paradoxides,* a trilobite which is common in Europe and along the northeast coast of North America, as in Newfoundland and as far south as the vicinity of Boston, Massachusetts. It also occurs, though very rarely, in northwestern Vermont, but is not known in the Appalachian Valley, from which it is inferred that the Appalachian trough was not connected with the Atlantic sea, unless locally and briefly.

LATE CAMBRIAN TIME

Nolichucky epoch.—The Nolichucky epoch was one of alternating shale and limestone deposition, indicating alternations of physiographic and possibly climatic conditions. Sometimes precipitation would be locally abundant and cause transportation of much fine silt from bordering lands of low relief. At other times conditions were more favorable for the deposition of limestone. Fine clay in suspension was intermittently deposited in layers to form the gray bands on the weathered surfaces of many layers of limestone as illustrated on Plate 19B. In Nolichucky time the Appalachian trough had expanded westward into central Kentucky, as shown by fossils regarded as of Nolichucky age brought up in the drillings from a deep well in the vicinity of Nicholasville about 10 miles south of Lexington.

Life appears to have flourished rather more abundantly in Nolichucky time than in the preceding ages. Trilobites still predominated; but they were of different genera and species from the earlier forms. Linguloids were the most common brachiopods. New types not recorded from the older times were crinoids, cystoids, and branching types of graptolites. But all the new forms, with evolutionary changes, were descended from earlier forms. Probably not a single species or genus of trilobites survived from the Shady into Nolichucky time.

Conococheague-Copper Ridge epoch.[289]—In this epoch the entire Appalachian Valley region was flooded and the waters spread westward into Wisconsin and Missouri. The deposits were limestone which on the northwest side of the Valley was converted into dolomite, the Copper Ridge dolomite. At times, great quantities of quartz sand were delivered to the sea either at the mouths of large rivers or along wide beaches. Some of it may have been carried by winds. Thence it was transported by sea currents and spread out on the sea bottom in broad

[289] For discussion of differences of opinion about classification, see footnote 55.

sheets which were solidified by cementation and pressure into the extensive sandstone lenses in the Conococheague and Copper Ridge. So far as known at present, both the Conococheague and Copper Ridge are nearly devoid of organic remains except those of calcareous algae (*Cryptozoon*). (See Pl. 21C.) Trilobites and linguloid brachiopods have been found in the Conococheague at a few localities. The rare gastropod genus *Scaevogyra,* coiled left instead of right, lived locally in Copper Ridge time. Fossils of it have been found in the vicinity of Norris Dam, Tennessee.

The ripple-marked and mud-cracked sandstone (Pl. 20A) and ripple-marked limestone clearly show that the water of the Appalachian trough during much of this time was relatively shallow. Only in shallow water could bottom sediments be affected by the waves and ripples. Locally, they were even exposed to air and sun so that they dried out and cracked. Similar cracks may be seen at any mud hole now.

ORDOVICIAN PERIOD

The Ordovician period is thought by investigators of the duration of geologic time to have begun about 400 million years ago.

Chepultepec epoch.[290]—Limestone deposition continued through the Chepultepec epoch, possibly into the Stonehenge epoch of Beekmantown time, for there is some evidence that the upper beds here included in the Chepultepec may be of Stonehenge age. As the Chepultepec limestone thins to a few feet in the middle of the Valley in southern Virginia, the western shore line must have been located in that region. The width of the submerged area apparently was narrower there than at either the north or the south ends of the trough. A large land area seems to have been present northwest of southwestern Virginia in Kentucky and West Virginia. The sea spread northwest into the Altoona region of central Pennsylvania, and from the south end of the Valley trough it expanded westward into Missouri. The accession of sand that marked certain stages in Conococheague time ceased entirely in Chepultepec time.

Animal life, especially cephalopods, mainly small curved forms, and gastropods, was moderately abundant and widespread in Chepultepec time. Gastropods were represented by *Sinuopea,* the ubiquitous *Helicotoma uniangulata,* and others. This was the first appearance of cephalopods in the Valley.

[290] For discussion of differences of opinion about classification, see footnote 62.

BEEKMANTOWN TIME[291]

Nittany or Longview epoch.—The deposition of the Nittany followed that of the Chepultepec along the southeast side of the Appalachian trough. In Nittany time the entire Appalachian trough was submerged northward from Alabama as shown by the presence of *Lecanospira* in the Nittany or corresponding formations of the same age. In all of the Valley except in Frederick and Clarke counties, Virginia, and northeastward through Maryland into Franklin County, Pennsylvania, dolomite instead of limestone was deposited in the Nittany epoch. The limestone and dolomite are complementary facies of Nittany deposition. The conditions controlling the character of the differing deposits are not understood.

The life of the Nittany epoch in Virginia, as recorded by observed fossils, consisted principally of gastropods, of which the several species of *Lecanospira* and the large genus *Roubidouxia* were the most abundant and widespread. Their fossil remains distributed over the whole area attest the wide dispersion of the living animals. Other genera of gastropods, as *Hormotoma, Eccyliopterus,* and *Ophileta,* were fairly common. Cephalopods, straight, curved, and coiled—the last type rare, continued from the Chepultepec sea. Brachiopods were represented by *Syntrophina* and the locally abundant *Finkelnburgia.* Trilobites were rare, the most common perhaps being *Hystricurus.*

Unrecorded interval(?).—An unrecorded interval of time may intervene between the Nittany and the Bellefonte in Virginia, because the Axemann limestone which separates the two formations in central Pennsylvania is possibly absent.

Bellefonte epoch.—The submergence of Nittany time continued through Bellefonte time, and deposition of dolomite in southern Virginia and of limestone in northern Virginia continued. The northward change to limestone had been practically completed at the latitude of Staunton, Augusta County, where the limestone facies of the Bellefonte is 1500 feet thick. This is much thicker than the dolomite facies in southern Virginia, and may indicate more rapid sedimentation in the north or the absence in the south of beds corresponding to the younger beds of the limestone facies of the north. Limestone deposition prevailed in Bellefonte time across Maryland into southern Pennsylvania.

So far as indicated by fossil remains gastropods were the prevailing types of life in Bellefonte time. *Ceratopea,* the operculum of a gastropod, is confined to the Bellefonte in Virginia. Other gastropods were *Ophileta, Homotoma, Coelocaulus, Orospira, Fusispira,* and *Pleth-*

[291] For discussion of differences of opinion about the classification of the Beekmantown, see footnote 67.

ospira. The Bellefonte epoch was also notable for the appearance of the large, closely coiled cephalopods, such as *Eurystomites, Tarphyceras,* and *Campbelloceras.* (See Fossil Plates in Part II.) Trilobites were rare. Graptolites in considerable variety occur in New York and Arkansas, but none are known in Virginia. Up to the end of Bellefonte time no pelecypods (clams) had yet appeared. A form, *Nicholsonella,* somewhat doubtfully classed as a bryozoon, occurs very rarely in the uppermost beds of the Bellefonte equivalent. If this is truly a bryozoon it is the earliest known representative of that class.

Unrecorded interval.—The absence of the Buffalo River group of the Mississippi Valley from the Appalachian Valley signifies an interval of dry land which is also suggested by the conglomerate with angular chert pebbles at the base of the Murfreesboro in southwest Virginia. (See Pl. 23B.) This interval lasted in other parts of the Appalachian trough all through the Murfreesboro until the beginning of Mosheim deposition. Buffalo River time is of especial interest, however, because of the introduction of pelecypods and bryozoa, which occur in the Everton limestone member of the Buffalo River series in Arkansas, where the Everton immediately succeeds beds corresponding to the uppermost Beekmantown of the Appalachian Valley. From this it can be concluded at present that any rocks containing pelecypods or bryozoa are of post-Beekmantown age.

STONES RIVER TIME

Murfreesboro epoch.—In the Murfreesboro epoch the western part of the Appalachian trough in Virginia from Lee County to Craig County was resubmerged and the Murfreesboro formation was deposited. The emergence of Buffalo River time, however, continued along the southeast belt of the trough, southeast of the Greendale syncline, and apparently throughout all of the Valley north of the latitude of Craig County. In all of this area either the Mosheim or Lenoir limestone directly succeeds the Beekmantown without the intervention of the Murfreesboro.

The Murfreesboro is the oldest unquestioned Ordovician deposit in the Appalachian trough. Its Blackford and St. Clair facies indicate considerable diversity in physical geography and climate in different regions tributary to the trough during Murfreesboro time. The conglomerate, red shale, and chert in the Blackford facies seem to indicate a deeply weathered land with moderate local relief as the source of the sediment, whereas the pure limestone of the contemporary St. Clair facies indicates a lowland swept clean of clastic material, or a land area on the Beekmantown dolomite which was naturally comparatively free of clastic material, as the source of the limy sediment. Probably the streams were sluggish owing to low gradient and could transport only calcareous or other matter in solution, all of which may have been discharged into more or less landlocked basins.

The life of the Murfreesboro showed some advance over that of the Beekmantown. Pelecypods (clams), bryozoa, ostracodes (*Leperditia, Leperditella,* and *Isochilina*), and corals (*Tetradium*) appeared. Of gastropods, *Lophospira, Raphistomina,* and *Helicotoma* were the predominating forms. A few genera of trilobites, *Pterygometopus* and *Bathyurus,* were present but their remains are not abundant. The genera *Dinorthis* and *Strophomena* among the brachiopods made their first appearance in the Murfreesboro epoch.

Mosheim epoch.—The Mosheim sea seems to have been lagoonal with more or less disconnected basins from which terrigineous material was excluded, and in which only the purest lime carbonate was deposited. These basins were scattered along the full length of the trough from Alabama to Maryland and seem to have been distributed most continuously along the middle part of the trough. Distance from the land, very low lands, or lands directly underlain by limestone would account for the absence of earthy material which would be deposited near the shores not far from the mouths of the streams.

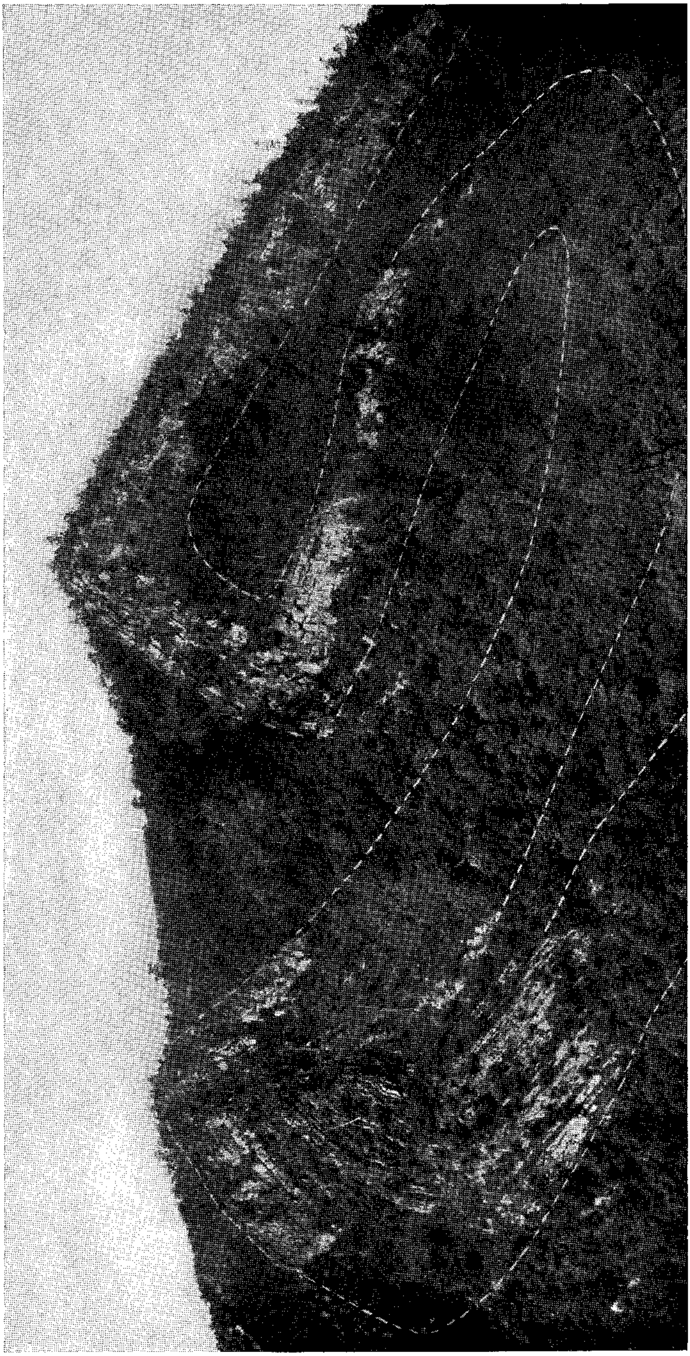
The prevailing life of Mosheim time in the trough was composed of gastropods, some of them very large species of *Lophospira.*

Lenoir epoch.—Lenoir time was marked by a general subsidence and submergence of the Appalachian trough. The Lenoir is present in greater or less thickness at almost every locality throughout the Valley where its horizon is exposed.

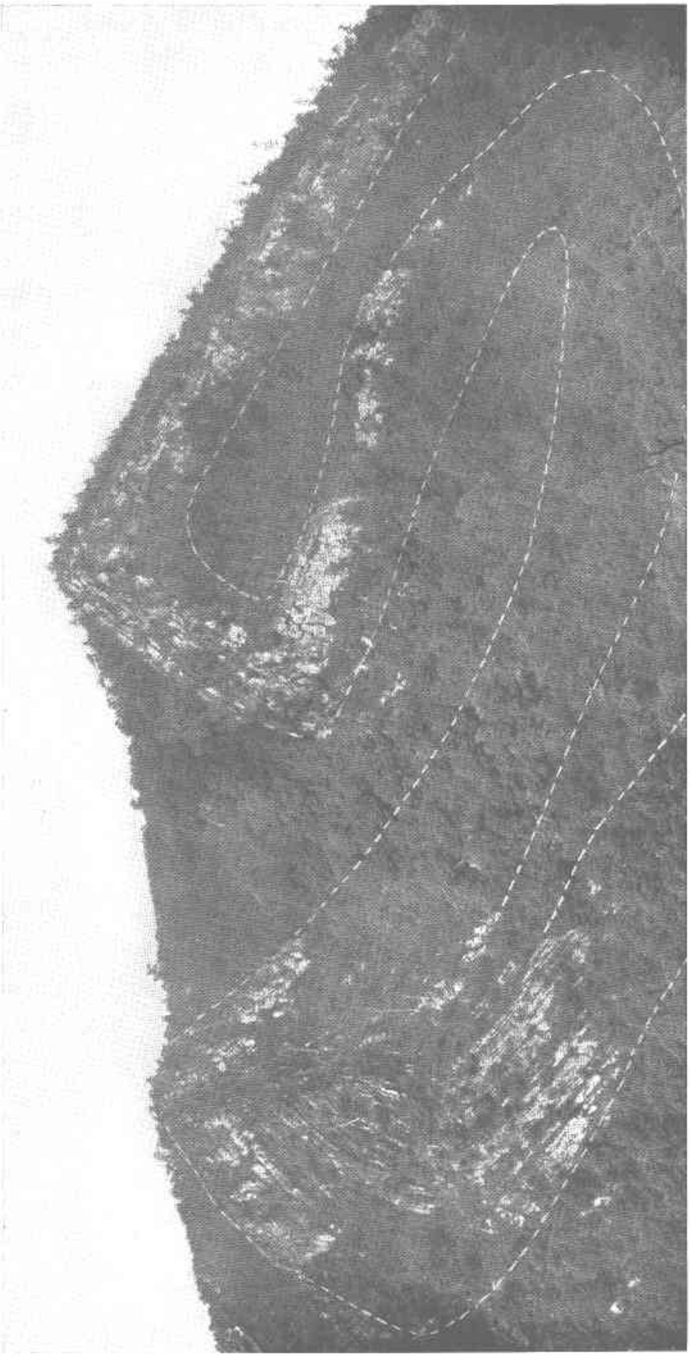
Many layers are composed of fragments of crinoids and shells and stems of branching Bryozoa. Shallow water and a genial climate favorable to marine life can reasonably be inferred during Lenoir time because the formation contains abundant fossilized remains of the sea animals of the time. The sea bottom must have been densely populated with crinoids, bryozoa, and brachiopods in a manner similar to that of shallow tropical seas which teem with many forms of life today. The black color of the limestone is probably caused by disseminated carbonaceous matter derived from the decaying animal tissues. The sea must have carried large amounts of silica in solution, much of which was precipitated to form the nodules of black chert. Gastropods, especially the large *Maclurites magnus* and perhaps other species, also inhabited the Lenoir sea.

PLATE 61

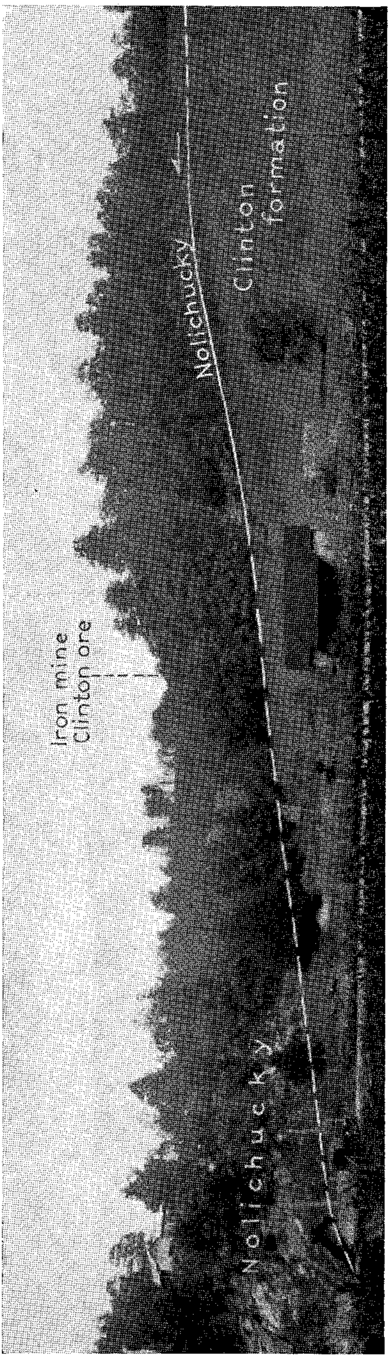
Double overturned folds in sandstone near Eagle Rock, Botetourt County. This sandstone is probably the Keefer member of the Clinton. These folds differ from the general type of overturned folds in the Valley in that they are overturned toward the southeast instead of to the northwest. Northeast end of Crawford Mountain, three-fourths of a mile northwest of Eagle Rock. Looking southwest across James River. Photograph taken in 1913. (See p. 436.)



OVERTURNED FOLDS



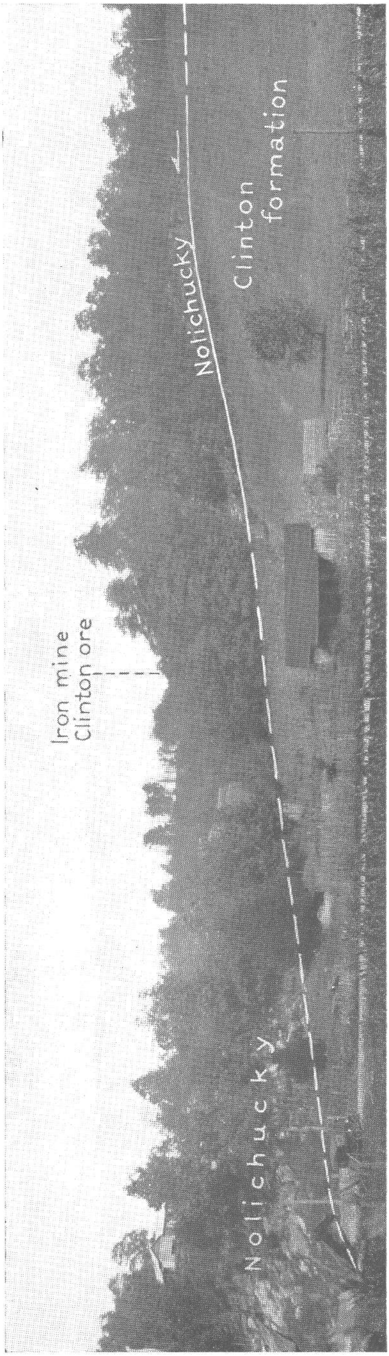
OVERTURNED FOLDS



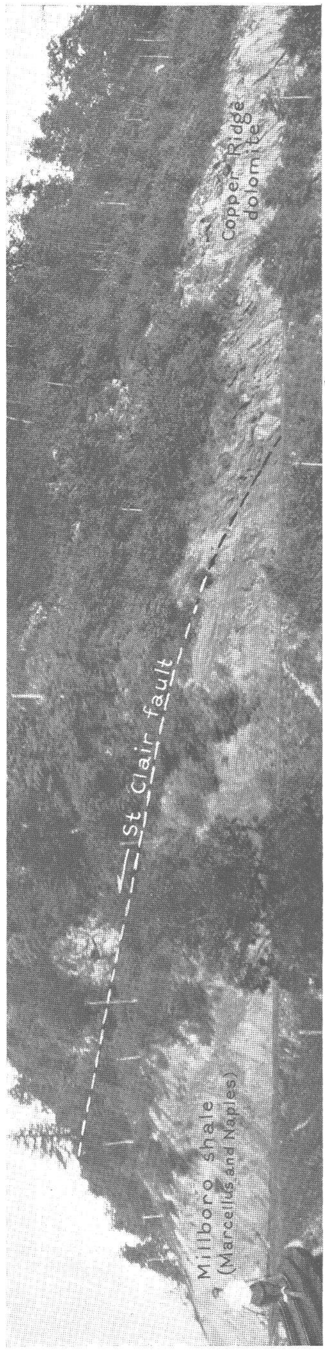
A

B

OVERTHRUST SHEETS



A



B

OVERTHRUST SHEETS

PLATE 62

A. Fourmile fenster in the Cumberland overthrust block in Lee County. Along Fourmile Creek and State Route 62, about 2 miles south of Ewing. The limestone in the edge of the trees is Nolichucky which has been overthrust from the southeast (right) upon the Clinton. The Clinton ore, in two beds, crops out and has been mined in the ravine, about half a mile from the road, where it is overlain by Copper Ridge dolomite. The fault plane is uneven and cuts across the formations. The total northwest movement of the overthrust mass may be as much as 7 miles. The fault beyond the fenster dips to the northwest, and emerges along the northwest base of Pine Mountain in Kentucky, 17 miles northwest of the fenster, where it is known as the Pine Mountain fault. The overthrust mass has been eroded through at this locality, and also at several other places in an area for 5 miles to the northeast, thus exposing the overridden younger rocks beneath it. Such an area is called a fenster (window). The section in Pl. 60A shows the nature of the fault and the relations of the formations affected by it. Looking northeast. (See p. 464.)

B. Copper Ridge dolomite thrust over Millboro shale in Tazewell County. This is one of the rare exposures of an overthrust fault surface in the Appalachian Valley. Cut on the Norfolk and Western Railroad at the bridge over Clinch River midway between Indian and Cedar Bluff. Looking northeast. (See p. 436.)

BLOUNT TIME

Holston epoch.—The Lenoir epoch was brought to a close by an extensive uplift of the sea bottom which confined the sea water to a relatively narrow area lying in general along the middle of the Appalachian trough from south of Knoxville, Tennessee, to Lexington, Virginia. In this sea sedimentation similar to that in the preceding Lenoir time continued, and the limestone that later became the celebrated Holston marble was deposited. This sea lay between the present sites of Walker Mountain on the southeast and Wallen Ridge on the northwest. An arm of the sea extended to Lexington, but its connection with the main body of the sea is unknown. Somewhere the Holston sea joined the Atlantic Ocean, as shown by the presence of fossil brachiopods of the genera *Productorthis* and *Paurorthis* which were migrants from the Baltic region of Europe, where they are common and where they probably originated. The connection with the Atlantic was probably established in Lenoir time, for many of the Lenoir animals are of eastern origin.

The Holston sea, like the Lenoir, was densely populated by bryozoa, brachiopods, pelecypods, crinoids, and trilobites, the fragmental remains of which are packed together and recrystallized to give the Holston its qualities as a marble.

Whitesburg epoch.—At the end of Holston time the entire Appalachian trough was uplifted, and the water drained off except in a long, narrow, and shallow channel extending near its middle from the Coastal Plain in Alabama at least to Lexington, Virginia. This channel reached its maximum depth in the vicinity of Whitesburg, 10 miles northwest of Morristown, Tennessee. The existence of this narrow channel, the uplift of the sea bottom, and the contraction of the sea are inferred from the fact that the characteristic sediment and fossils of the Whitesburg occur only along the narrow belt indicated and have not been identified elsewhere either to the southeast or northwest of that belt.

Brachiopods and trilobites were the most common animals of the Whitesburg sea. The most characteristic forms were species of the trilobite genus *Telephus*.

Athens epoch.—The Whitesburg epoch was closed by an extensive tilting of the land which raised the part of the Appalachian trough northwest of the line of Clinch Mountain into dry land and submerged a great area along the southeast side of the trough extending from Frederick County, Virginia, at least to the present Coastal Plain in southern Alabama. The deepest submergence was east of Bristol and Knoxville, where the greatest thickness of Athens sediment accumulated. An enormous body of sediment was laid down in this depression which indicates a corresponding and complementary elevation of the tributary land which furnished the sediment. Clay and sand were both carried into the embayment, the sand being deposited mainly at the southeast and the fine clay along the depression northward through Virginia to Frederick County and southward through Tennessee into northwest Georgia and northeast Alabama. At one time a large quantity of coarse gravel containing pebbles of quartzite 4 to 6 inches in diameter was transported to the sea by a torrential river and carried far out over the flat bottom of the trough to the vicinity of what is now Fincastle, Botetourt County. (See Pl. 28A.) The source of the quartzite pebbles must have been rocks of the Piedmont area southeast of the Blue Ridge, for no such rocks were elsewhere accessible to streams entering the Appalachian trough. The great thickness of the Athens and the coarse-grained sandstone in it east of Bristol indicate that the source of the sediments was in that direction. The Athens there seems to be like a delta deposit. In some localities in Athens time the sea was clear and relatively free from clastic sediment. One such place was in Crocketts Cove, north of Walker Mountain and northwest of Wytheville; another was north and west of Harrisonburg, where the greatest body of relatively pure limestone is found.

Graptolites were characteristic of the life of Athens time. They were floating forms which drifted into the Appalachian trough with gentle currents from the Atlantic through one or more connecting inlets or straits. Graptolite life was ubiquitous. The fossilized remains of some genera and species occur in North America, Australia, Scandinavia, and England.

Unrecorded interval.—No formation in Virginia corresponds to the Tellico formation southeast of Knoxville, Tennessee. The emergence of the Appalachian area in Virginia in Tellico time appears to have been complete.

Ottosee epoch.—Succeeding the Tellico epoch the Appalachian trough in much of Virginia and Tennessee was submerged and the Ottosee limestone laid down. The sea of Ottosee time extended northwest across the trough from Sevier County east of Knoxville, Tennessee, at least as far as a line marked by the Cumberland escarpment on the border of the coal field in Lee County, Virginia, and to Big A Mountain west of Honaker, Russell County. The Ottosee was thus a widely transgressive sea over the middle of the Appalachian trough. The Ottosee limestone lies unconformably upon different older formations as upon the Lenoir limestone, in Rye Cove, Scott County, and on the northwest slope of Wallen Ridge; and upon the much younger Tellico formation in Tennessee.

In Ottosee time the sea was densely populated with brachiopods and bryozoa which belong to the eastern or Atlantic fauna of that time. They prove the close relation of the Ottosee formation and its forms to the preceding formations of the Blount group and their fauna.

The crustal oscillations and shifting of the seas during the Blount age are typical of the history of the Appalachian trough throughout Paleozoic time.

BLACK RIVER TIME

Lowville epoch.—The Lowville epoch was one of widespread submergence of the area that is now the eastern United States. The southeast shore, as marked by existing rocks, lay near a line passing 20 miles southeast of Knoxville, Tennessee, near Wytheville, Pulaski and Roanoke, Virginia, and north of Roanoke probably along a line near the meridian of 79° 30′. Thence the flooded area extended westward beyond the Mississippi River. East of the meridian mentioned in Virginia the land was dry because of upwarping of the sea bottom. The sediments of the Moccasin facies of the Lowville formation were derived from high land lying to the southeast. This conclusion is based on the increase and preponderance of the red shale and argillaceous limestone in that direction. The Moccasin facies reaches a maximum in northwest Georgia. In the part of the trough now included in the northwest belt of the Valley and hence far removed from the source of the clastic sediment of the Moccasin facies, only pure limestone was deposited. The Moccasin red beds and the pure limestone to the northwest are instructive examples of differing facies of contemporary deposits resulting from different physical and climatic conditions controlling the character of deposits in different areas.

The life of Lowville time consisted largely of gastropods. Brachiopods, bryozoa, ostracodes, and trilobites were common and of different species from those of the preceding epochs.

Chambersburg epoch.—In the Chambersburg epoch the dry land area of Lowville time in the northeastern part of the trough in Virginia sank below sea level, and the Chambersburg limestone was deposited. The submergence appears not to have affected the region west of the meridian of 79° 30′ except in Lee, Giles, and Pulaski counties where either the Chambersburg, as in the Draper Mountain area, or the possibly equivalent Eggleston in Giles and Lee counties, are present. The submergence extended into the type region of the Chambersburg in Franklin County, Pennsylvania. Argillaceous limestone of the Eggleston was deposited in Giles and Lee counties but elsewhere the deposits in the Chambersburg sea were limestone.

Volcanic eruptions occurred in Chambersburg-Eggleston time. This is shown by volcanic ash now altered into the persistent bentonite beds in the Chambersburg and Eggleston formations. The source of the ash is unknown. These eruptions began, however, in Lowville time and continued into Trenton time. The ash or dust was ejected from the volcanic vents with explosive force. It became suspended in air and drifted far from its source with the prevailing winds of the time, and finally settled down as a mantle upon the ground or in the sea. Such altered ash beds, of Lowville to Trenton age, are also known in Alabama, Georgia, central Kentucky, and central Pennsylvania.

MIDDLE AND LATE ORDOVICIAN TIME

Martinsburg epoch and Trenton and Reedsville epochs.—The lower part of the Martinsburg shale was deposited in Mohawkian time, in the Trenton epoch; the upper part in Cincinnatian time, in the Reedsville, or Eden and Maysville epochs. These relations make the chronological classification difficult.

From the beginning of Trenton time to the end of Reedsville time the Appalachian trough was submerged. On the one hand the submergence extended into central New York and Canada, and on the other to southwestern Ohio, southeastern Indiana, central Kentucky, and Tennessee. Knowledge of the wide extent of the sea in these epochs is necessary in order to understand the sources and nature of the materials of the several formations.

The Martinsburg is thickest in the Massanutten syncline. It must have extended southeast to the line of the Blue Ridge and probably much farther before thinning out against the southeastern shoreline of the Appalachian trough. The source of Martinsburg sediments in the Massanutten syncline and probably throughout the Valley, almost wholly clastic, was presumably the land to the southeast. This sediment was transported northwestward into and across the trough. In the Trenton epoch the clastic sediment predominated as far northwest as the middle of the trough where much limestone was deposited in clearer waters as the distance to the source of land sediment to the southeast became greater. In Lee County and northeast to central Pennsylvania the Trenton is wholly limestone. In the Cincinnatian part of the Martinsburg epoch deposition of land-derived clastic sediment predominated northwest to the line of the present Cumberland escarpment, but limestone deposition increased in that direction, indicating clearer water, less earthy sediment, and more abundant precipitation of lime carbonate.

From the preceding brief discussion it may be inferred that the kind and character of the sedimentary strata of any area depend almost entirely upon the physical geography and climate of the time of their deposition. Conversely, the physical geography and climate can largely be inferred from the character and distribution of the rocks.

Throughout Martinsburg (Trenton-Reedsville) time the sea swarmed with invertebrate life, except perhaps on the southeast, where as in the region of the Massanutten syncline, there is less evidence of life. Here sedimentation was probably rapid and conditions unfavorable to life or at least unfavorable to the preservation of many forms as fossils. Farther out in the trough where the water was probably shallow, clear, and warm, life abounded. Brachiopods, pelecypods, and bryozoa were the most numerous forms.

At the close of Cincinnatian time the entire Appalachian region from central Pennsylvania to east Tennessee was submerged, as shown by the relatively thin zone containing *Orthorhynchula linneyi* which occurs in the uppermost bed of the Martinsburg and Reedsville.

Oswego epoch.—The Oswego epoch began with an abrupt and revolutionary change in the Appalachian trough in Virginia and Pennsylvania. The abundant life of the preceding epoch was compelled to withdraw from those regions. The character of the sediment and the distribution of the Oswego indicate a different source and a vigorous agent of transportation. The maximum thickness of the Oswego in central Pennsylvania indicates that the source of sediments lay in that direction. It seems probable that the Canadian shield in the vicinity of the present Great Lakes underwent considerable elevation, and that swift rivers flowed southeast and delivered their load of coarse quartz sand to a coastal plain in central Pennsylvania whence the sand was distributed by sea currents southeastward into Virginia. The sand may have been spread about by distributaries, as in modern deltas, and by winds, waves, and currents. Tidal waves and hurricanes may have aided in the process. Such conditions were unfavorable to life. At about the same time in the Cincinnati region life was comparatively abundant.

Juniata epoch.—Opinions differ as to whether the Juniata epoch should be placed in the Silurian or Ordovician period. Ulrich is the author and chief advocate of the view that it is Silurian and others, including the author, are inclined to the same opinion. The United States Geological Survey and probably the majority of geologists still regard the Juniata and its correlated, Richmond beds, as Ordovician.

In the Oswego and Juniata epochs the southeast belt of the Appalachian trough had apparently been elevated above sea level, as indicated by the absence of the Oswego and Juniata formations in Massanutten Mountain. The southeastern margin of the sea was along or southeast of the present site of Little North Mountain, where both formations are present, and along or southeast of Walker Mountain in

Washington County where the Juniata is present. But within 3 miles southeast of Walker Mountain the Juniata is absent on the north flank of the Marion dome. The Juniata is also present in Draper Mountain, Pulaski County. Northwest from this probable southeast shoreline, the Juniata sea extended to southwestern Ohio where it is represented by the highly fossiliferous marine limestones of the Richmond group.

The Juniata throughout its extent is unfossiliferous, but plainly water-laid. These facts may be explained by assuming that the Appalachian trough in Virginia was occupied by fresh water in Juniata time which merged with the marine water of the interior sea about on the meridian of Cumberland Gap where the horizon of the Juniata is occupied by shale and limestone, some red, carrying representatives of a marine Richmond fauna.

The red sediment could have been derived from the southeastern Appalachian upland which had been deeply weathered during Oswego time and mantled with a red soil like that of the southern Piedmont region of today. If so, it was carried by rivers flowing northwest into the submerged area. Or, it may have been derived from the Canadian land north of Lake Ontario and spread out over a wide coastal plain by streams, such as the distributaries of a delta.

Silurian Period

Clinch epoch.—The Clinch was another epoch of nonmarine sedimentation in the Appalachian trough. It seems that the whole area from central Pennsylvania to Tennessee was a vast sand flat near sea level submerged intermittently by the tide by which at times the sediment was distributed, and at other times swept by storms which blew away the finer sediment. The residue, like ordinary beach sand, remained to form the Clinch-Tuscarora sandstone. Conditions were apparently unfavorable for life in the area of sand deposition; at least no fossils have been preserved. The area of sand accumulation covered the entire trough in Virginia from Massanutten Mountain west at least to the zone of the Allegheny Front and the Cumberland escarpment of today, and to the meridian of Cumberland Gap where marine fossils begin to appear in the Clinch, which merges at that place into the Brassfield limestone of the interior sea.

Clinton epoch.—In Clinton time the subsidence of the Appalachian trough was resumed. The entire area in Virginia northwest of Little North Mountain in Frederick County and Walker Mountain in Washington County was submerged.[292] The Clinton may not be present in

[292] For convenience of reference, present geographic features are named throughout the discussion of geologic history. It should be borne in mind, however, that the zones represented by the existing features were far to the southeast during the times of Paleozoic sedimentation and that the former width of the Appalachian trough has been much decreasd by folding and thrust faulting to the northwest near the close of the Paleozoic era.

Massanutten Mountain, but it is present in Draper Mountain south of Pulaski and probably in the Catawba-Tinker Mountain belt northwest of Roanoke, and in Read-Coyner Mountain northeast of Roanoke. These places probably mark approximately the southeast shore line of the Clinton sea. The sea extended northwest across the trough in Virginia and into West Virginia, and probably extended west into central Kentucky and Ohio.

The deposits in the Clinton sea of the Valley in Virginia were clastic throughout. About midway of the length of the trough the maximum amount of red ferruginous sandstone, in the lower half, and of gray sandstone (Keefer) at the top were deposited. These are the distinctive features of the Iron Gate facies of the Clinton. Both northeast and southwest of this middle area the Cumberland shale facies of the Clinton was deposited. The source of the Clinton sediments seemingly was a southeastern land mass.

The Clinton contains the "fossil" iron ore of the Clinton area of central New York and of the Birmingham district, Alabama. In Virginia the main occurrence of Clinton iron ore is in Alleghany and Lee counties. The iron was probably derived from deeply weathered rocks of the land, carried in solution into shallow lagoons, where animal life on the bottom was abundant. Here iron oxide was precipitated and partly replaced the calcium carbonate of the skeletal parts of various animals living on the bottom, and so accumulated in sufficient quantity to form iron ore. The red sandstone layers of the Iron Gate facies derived their ferruginous content from the same source, but the amount of iron was insufficient to form ore.

The Keefer sandstone member at the top of the Clinton probably indicates uplift of the land and revived drainage in the region southeast of the middle of the trough, where the Keefer reaches its maximum thickness.

After the Keefer sandstone was deposited the sea seems to have withdrawn from most of the trough. Only a narrow embayment remained in the area that is now Highland County, in which a small thickness of shale of Rochester age was deposited.

Ostracodes were the principal inhabitants of the trough in Virginia in Clinton time. Their fossils are very abundant throughout the entire length of the Valley. A few species of trilobites and brachiopods were also present. The absence of *Pentamerus* through Pennsylvania, Virginia, and Tennessee was noteworthy. This genus occurs commonly in New York at the northern end of the trough and in Alabama and Georgia at the southern end. Why it did not enter the other parts of the trough can not easily be explained. *Anoplotheca hemispherica*, which accompanies *Pentamerus* in the northern and southern regions, ranged throughout the entire length of the trough. The first known

Spirifers appeared in late Clinton time, hence any bed of rock containing *Spirifer* is younger than Ordovician. The same is true of any rock containing graptolites that have an axis and cells arranged only on one side, such as *Monograptus*.

Cayuga epoch.—The Cayuga sea spread south over all the trough in northern Virginia to about the latitude of Orkney Springs in Shenandoah County and west into West Virginia. In Bloomsburg and Wills Creek time it extended southeast over the Massanutten Mountain area as far as its southern tip southeast of Harrisonburg, and southwest possibly to the south end of Great North Mountain in Rockingham County. But in Bloomsburg time the sea probably did not cover the north part of Highland County, for the Bloomsburg appears to be absent there. The Cayuga sea probably did not reach the regions of Catawba and Draper mountains because there the Cayuga rocks are also absent. Throughout Wills Creek and Tonoloway time the sea extended along the northwest side of the Valley by way of Big Stone Gap to northern Tennessee in the vicinity of Sneedville, Hancock County. In this latitude the sea extended eastward to the vicinity of Hayter Gap, Washington County, where a thin sandstone, probably of Wills Creek age, occurs on the southeast flank of Clinch Mountain. This is probably near the southeast margin of the Cayuga sea.

The distribution of the Cayuga deposits seems to indicate a shallow lagoonal sea with considerable shifting of areas of deposition through warping or oscillation of the sea bottom.

The Bloomsburg sea received mostly red sediment which clearly was swept southwestward from a land area east of the part of the Appalachian trough now marked by northeastern Pennsylvania. This conclusion is based on the fact that the red rock of the Bloomsburg extends into northeast Pennsylvania, where it reaches probably its maximum thickness of several hundred feet. Like most red rocks, the Bloomsburg contains no fossils. Several explanations may be offered: The water may have been sufficiently charged with red mud to be uncongenial to animal life; the water may have been brackish or too nearly fresh for marine organisms; the sea may have been very shallow and subject to intermittent desiccation or the area of deposition may have been a vast mud flat slightly above sea level most of the time.

The most distinctive feature of the life of the Cayugan sea was the great abundance of minute ostracodes, such as *Kloedenia*. Some layers of limestone contain thousands of their minute shells to the cubic inch.

DEVONIAN PERIOD

EARLY DEVONIAN TIME

Helderberg epoch.—In Keyser time the sea again spread over the trough in the Frederick County area, and extended westward into West Virginia and southwestward beyond the area crossed by James River. In this region submergence was continuous throughout most of Helderberg time, except perhaps in the Frederick County area, where deposits of Coeymans and Becraft age have not been recognized. After New Scotland time this area apparently became dry and the sea shifted southward into a belt extending from Giles to Wise counties. In these areas the Helderberg is represented only by its Becraft member. In Bath and Alleghany counties limestone was deposited in Becraft time, but in Giles County and to the southwest the sediment was mainly coarse sand. This was probably carried from a southeastern land area by a river that emptied into that part of the trough. The occurrence of *Aspidocrinus* near Clinch River 5 miles northeast of Loyston, Tennessee, shows that the Becraft arm of the sea extended that far southwest. The deposits of the Helderberg seas were mainly limestone except the Becraft which contains sand. In New Scotland time, clay and silica were contributed by the streams. This silica is now combined in the argillaceous, knotty limestone and the abundant chert.

Life was abundant throughout the Helderberg time. In New Scotland time brachiopods, especially large *Spirifers* and *Meristellas,* were the dominant forms.

Oriskany epoch.—In Oriskany time the north end of the Appalachian trough in Virginia was submerged as far south as the site of James River today. The submergence probably extended into the northern syncline of Massanutten Mountain where a thin sandstone, apparently at the Oriskany horizon, is present, at least locally. A thin Oriskany sandstone at Bluefield, West Virginia, suggests that a tongue of the Oriskany sea extended southwest to that place. It may also mean that the Bluefield locality was on the margin of an Oriskany sea that extended northwestward into West Virginia. The sea extended farther southwest in Virginia, where the Oriskany is only a thin bed, or possibly a series of detached lenses, on the southeast slope of Walker Mountain as far south as Smyth County.

The maximum thickness of the Oriskany is along a belt extending from Cumberland, Maryland, where the formation is the thickest, into Highland County, Virginia. The formation thins out entirely southeast of this belt along the southeast margin of the trough, and likewise southwest of New River. It also decreases greatly in thickness northeastward into eastern Pennsylvania. It is therefore reasonable to infer that the sand may have been derived from a land mass in or toward Canada and transported into the Appalachian trough by one or more rivers flowing from the northwest; or it may have been carried in from the southeast by rivers entering the trough near Cumberland, Maryland. The brachiopods with large, coarse-ribbed shells, such as *Spirifer, Rensselaeria* and *Plethorhynchus,* and the smooth-shelled *Meristella* were the most characteristic forms of life in the Oriskany sea.

MIDDLE DEVONIAN TIME[292a]

Onondaga epoch.—In Onondaga time, as in the Lenoir and Lowville epochs of the Ordovician period, almost the entire area of the Appalachian trough in Virginia was flooded, except along the line of the Cumberland escarpment in Lee County, southwest of Big Stone Gap, and also south of Mendota. Apparently the Onondaga sea did not extend into Tennessee. As the Onondaga is present on the southeast limb of the Massanutten syncline it is reasonable to suppose that the Onondaga sea extended southeast at least to the line of the Blue Ridge.

In the northeast half of the trough in Virginia clay mixed at times with a little lime was brought into the sea; in the southern half limy sediments predominated, as suggested by the fact that the Onondaga of that region is mostly composed of chert which in many places is derived from limestone through silicification. At Big Stone Gap the Onondaga contains a 10-foot bed of sandstone, which indicated different conditions for a time in that area. As limestone with abundant corals predominates at Big Stone Gap, the deposition of this sandstone should be regarded merely as a local episode. The facts suggest that the north end of the trough, as in northern Virginia and central Pennsylvania, was near land of low relief from which only fine sediment was derived, whereas the south end was farther from land, or the land was so near to sea level that little clastic sediment was discharged into the trough. Consequently the water was clear and the deposition of limy sediments predominated.

The life of Onondaga time in Virginia consisted largely of *Styliolina,* brachiopods, ostracodes and bryozoa. Trilobites were represented mainly by the genus *Phacops. Styliolina* made its first appearance in the Onondaga, and some layers of limestone are composed almost wholly of their small, pointed shells.

Marcellus epoch.—The Marcellus sea occupied much of the width of the trough throughout Virginia. It extended southeast into the Massanutten Mountain area.

[292a] Partly "Romney."

Marcellus time was notable for the deposition of much black silt along the trough from eastern New York to southern Virginia. It was the first deposition of that type of sediment in the Appalachian trough.

The origin of the black sediment is not well understood. The color is due to carbonaceous matter which, so far as known, could only have had an organic origin. Stagnant water charged with very fine silt held long in suspension, together with carbonaceous matter from decaying animals and vegetable matter, may be imagined. The Marcellus shale is not highly fossiliferous, so that life, either plant or animal, was apparently not abundant in the Marcellus sea. However, great quantities of floating vegetation, which decayed so rapidly and completely that none of it was preserved in the shale as fossils, might have been present. Such vegetation might have been composed of plant spores, pollen grains, bacteria, or low forms of algae. Some layers of black shale are crowded with fossil spores and spore cases, known as sporangites.

Other known forms of life in the Marcellus sea were mostly dwarf species of brachiopods and pelecypods. *Styliolina* was also abundant. An excess of carbon dioxide in the water may have caused the depauperate life. Oxygen was insufficient for healthy growth.

Hamilton epoch.—In Hamilton time the northern part of the Appalachian trough in Virginia was submerged as far southeast as the Massanutten syncline where, as in Fort Valley, the Hamilton is thick. The Hamilton sea narrowed southwestward and probably ended near the south end of Great North Mountain in Shenandoah County, as Hamilton rocks have been identified as far southwest as Orkney Springs. Southwest of Shenandoah County the trough was dry land during Hamilton time.

A change in physical geography must have brought Marcellus time to a close, for the Hamilton sea received mostly rather coarse, clastic sediment, which suggests moderate elevation of the tributary lands and increased transporting power of the streams flowing into the Appalachian sea.

Brachiopods were the most abundant forms of Hamilton life. *Tropidoleptus* made its first appearance. Several species of *Spirifer* were abundant and large species of *Stropheodonta* were fairly common as were a few pelecypods, such as *Pterinopecten* and *Pterinea*. Many genera and species of pelecypods lived in eastern New York, the type locality of the Hamilton, but so far as known most of these forms did not migrate into the part of the Appalachian trough in Virginia.

LATE DEVONIAN TIME[292b]

Unrecorded interval.—Middle Devonian time ended with the Hamilton epoch. In New York and Pennsylvania the Tully limestone

[292b] Partly "Romney."

was the first deposit of late Devonian time. The Tully is not present in Virginia.

Naples epoch.—The earliest upper Devonian rocks in Virginia are the dark-colored and black shales representing the Naples beds, or basal Portage, of New York. They occur near Orkney Springs but not in Frederick County north of Orkney Springs or in Massanutten Mountain. They occur in the fenster of Read and Coyner mountains northeast of Roanoke, in Draper Mountain south of Pulaski, and in all the Devonian areas from Shenandoah County to Tennessee. Fossils and rocks of Naples age have not, however, been identified in the belt south of Clinch Mountain in Scott County or in the black shale at Cumberland Gap. The Naples sea probably spread over the entire area of the northwestern side of the Appalachian trough, northwest of the limestone belt exposed along the southeast side of the Valley, and may have extended southeast over the limestone belt from which its deposits have since been eroded. Silts and muds only were supplied to the sea from the adjacent lowlands.

The most characteristic life of the Naples sea was small pelecypods (clams) such as *Buchiola, Paracardium,* and *Pterochaenia,* and coiled cephalopods (goniatites) such as *Probeloceras* and *Manticoceras.*

Brallier epoch.—In the Brallier epoch the conditions of black shale deposition gave way to those of gray muds and fine sand. The source of the Brallier sediment was land probably of moderate elevation along the southeast side of the Appalachian trough from the latitude of Wytheville, Virginia, to eastern New York and New England. It may be inferred that the greatest accession of sediment was along the part of the trough in Virginia between Bland and Shenandoah counties, for that area now contains the thickest deposits. The generally fine texture of the sediments and the absence of coarse sand and gravel comprise the evidence that the tributary lands were of moderate relief. Abundant rainfall may be inferred and large run-off in streams of low gradient with relatively slow currents that could transport only clay and very fine sand. The finer clay floated in suspension and gradually settled to form thin layers of shale, and gentle currents distributed the fine sand over the bottom in even layers, to form the characteristic sandstone layers of the Brallier. The thinly laminated, fine textured shale, the absence of coarser sandstone, and the intercalated layers of black shale in Scott and Lee counties suggest that the source of the sediments was to the southeast as stated. Only the very finest material was transported to these distant regions. The intercalated beds of black shale indicate a temporary recurrence of Naples conditions in Scott and Lee counties. As the Brallier is present and of great thickness in Draper Mountain, Pulaski County, and in Fort Lewis Mountain, Roanoke County, it is inferred that the Brallier sea extended southeast at least as far as the present position of the Blue Ridge. It is reasonable to believe that the entire Appalachian trough was submerged in Brallier time.

The paucity or almost complete absence of life in Virginia in Brallier time probably indicates deep, cold, or muddy water that was inhospitable to the marine invertebrates of the time. Some representatives of the Ithaca fauna occurring near Ithaca, New York, in rocks continuous with the Brallier, migrated southwest through Pennsylvania and Maryland into Frederick County, Virginia.

Chemung epoch.—The Chemung epoch in Virginia and Pennsylvania begins with the appearance of large brachiopods which do not occur in the Brallier or in the upper Portage (Gardeau and Hatch) beds of New York. The appearance of these forms is not accompanied by any noticeable change in sediments, but a change gradually did take place after a little time. Coarser, less evenly bedded rocks, with some thin beds of quartz conglomerate, appear not far above the introductory fossil horizons and show that the tributary land was higher and that the rivers had greater transporting power. The upwarping of the tributary land that had been in progress during Brallier time was accelerated in Chemung time. The south end and northwest margin of the trough were elevated so that Chemung deposits are absent. The Chemung sea extended along the northwest margin of the Valley only as far as New River northeast of Bluefield, West Virginia. It extended down the middle of the trough to the vicinity of Mendota, and as far toward the southeast side of the trough as the area now marked by Draper and Fort Lewis mountains. In Frederick County the sea extended southeast at least to Little North Mountain. In Massanutten Mountain and farther southeast erosion has cut below the Chemung horizon and removed any evidence of its possible former existence there or even farther southeast.

The greatest known thickness of the Chemung is in Huntingdon County, central Pennsylvania. That part of the Appalachian trough was thus probably nearest to the source of the sediments. The mouth of some large river may have discharged a load of sediment into that general region and this was perhaps spread out north and south by currents and mingled with sediment brought in by smaller tributaries along the sides of the trough. The Chemung therefore may be compared to a long series of coalesced deltas.

The appearance of the Chemung fauna was simultaneous along the Appalachian trough from Chemung Narrows, New York, to Bath County, Virginia. It was composed mostly of brachiopods and pelecypods, chiefly of new species and mainly of new genera, that is, of specific forms that are not known in any older formations. A very few like *Tropidoleptus carinatus* and *Spirifer mesistrialis* were survivors from the Hamilton and Tully, but most of the Chemung invertebrates had evidently originated in some other province, perhaps in the permanent oceans, whence they migrated into the Appalachian trough at the beginning of Chemung time through some inlet or strait connecting with the ocean. Originating thus, the ancestors and earlier forms representing evolutionary stages of the Chemung animals are buried in the depths of the oceans. Hence, the Chemung animals appeared in the Appalachian trough as if newly created.

Hampshire epoch.—In the Hampshire epoch the marine Chemung sea was replaced by a low subsiding coastal plain perhaps dotted with fresh-water lakes. Upon the coastal plain or in the lakes an enormous body of iron-stained, red sediment was deposited. Deposition of red sediment began in late Chemung time on the southeast margin of the present Hampshire area, for red beds are there intercalated with gray beds of the upper Chemung containing marine fossils.

In Virginia the greatest body of these red sediments, so far as the portions remaining after extensive erosion show, was distributed in a broad belt extending from Frederick County into Augusta County and northwestward far into West Virginia.

The Hampshire is destitute of marine fossils, and for the most part contains no remains of animal life. A few specimens of a fern, *Archaeopteris,* and scarcer scales of a fresh water fish, *Holoptychius,* have been found in Pennsylvania. The fern is of terrestrial origin, and the fish lived in the rivers of the time. Detached scales were occasionally washed out into the basin of deposition.

The red sediment originated on land southeast of the trough, which extended southwest from New England into southern Virginia. This is amply proven by the fact that the Hampshire thins rapidly and the red rock disappears to the west. The whole formation passes laterally into marine fossiliferous beds in northwestern Pennsylvania, which presumably continues beneath the coal fields of western Pennsylvania and West Virginia.

The Brallier, Chemung, and Hampshire formations together dwindle in northeastern Ohio to a few hundred feet of fine-grained, gray, siliceous rocks, comprising the Chagrin formation. The Chagrin probably extends south beneath the eastern side of the Appalachian Plateaus.

Mississippian Period

Unrecorded interval.—In earliest Mississippian time the Appalachian trough seems to have been above sea level, as no rocks of Kinderhook age, the oldest of the Mississippian period, occur in the Valley of Virginia. Either no record of Kinderhook events was made there or it was not preserved.

Pocono-Price-New Providence epoch.—When the approximately contemporaneous rocks of the Pocono-Price-New Providence epoch were deposited, the south end of the Appalachian trough in Virginia was flooded with marine waters; the middle part was alternately flooded and dry; the northern end was dry land, or in places a flood plain or coastal plain slightly above sea level. On the northern dry land the Pocono sandstone was deposited. Here and there small accumulations of vegetal material were made in swamps and later became beds of impure coal. The Pocono sandstone was deposited as far southwest as Fort Lewis Mountain northwest of Roanoke. The Price beds with marine fossils and coal were laid down in Draper Mountain just south of Pulaski. These areas are only a relatively short distance from the Blue Ridge. Remnants of equivalent rocks lie on the boundary between Virginia, Kentucky and West Virginia. It can therefore reasonably be inferred that the deposits once extended entirely across the trough. In the middle part of the trough, as in Pulaski, Montgomery, and adjacent counties, the coal swamps were larger and more enduring. In these originated the coal beds of that region through the accumulation of vegetal matter, as peat has accumulated in bogs in recent times. Intercalated in the coal-bearing rocks of fresh-water origin are thin beds with marine fossils, such as brachiopods. Thus the central part of the trough was flooded temporarily at different times with marine waters from the New Providence sea to the southwest. Dry land and fresh-water conditions are indicated by the types of plants composing the coal. These could not grow in salt water. At times dry land, either as long, low capes or as islands in the New Providence sea, extended as far south as Big Moccasin Gap east of Gate City, for coal-forming plants have been collected in Pine Mountain just east of the gap.

In the extreme southwestern part of the trough in Virginia, as shown in Lee, Wise, Russell, Scott, and Washington counties, marine conditions prevailed through New Providence time. This is proved by the occurrence of marine fossils through the full thickness of the Price and New Providence rocks. Similar or identical invertebrates inhabited the New Providence and Cuyahoga seas of Kentucky and eastern Ohio. The Maccrady formation was also laid down in the New Providence epoch.

The known life of the New Providence sea consisted mainly of brachiopods, including the earliest *Productus* in Virginia, pelecypods, bryozoa, and gastropods. The plant life of the swamps included large ferns, *Triphyllopteris* and a *Lepidodendron* with small leaf scars, *L. scobiniforme,* by which it can be distinguished from forms of Pennsylvanian age that have large leaf scars. (See Fossil Plates in Part II.)

It is believed that the Pocono-New Providence epoch was contemporaneous with the Burlington epoch of the Mississippi Valley.

Unrecorded interval.—As no rocks of known Keokuk age occur in Virginia, except possibly in a small area at Cumberland Gap, virtually no events of the Keokuk epoch are recorded in the State.

Warsaw epoch.—In the Warsaw epoch the sea occupied a strait coinciding with the Greendale syncline and bordering areas. Warsaw rocks extended the full length of the syncline from Tennessee to a point northeast of Saltville. As the Mississippian rocks of the Greendale syncline are cut off to the southeast by a fault no evidence of their former extension southeast of the present remnant of the syncline remains, although such extension is probable. Beds doubtfully identified as Warsaw occur on the northwest side of the Valley in the vicinity of Richlands and Bandy, Tazewell County, but the formation has not been identified on the northwest side of the Valley southwest of Richlands. In Kentucky the Warsaw disappears eastward in Estill and Rockcastle counties. The community of animal species in the sea of the Appalachian trough and the interior sea of the Mississippi Valley proves that the apparently isolated seas had same connection through which the main invertebrates migrated from one into the other. Ulrich reports the Warsaw in the vicinity of Hinton, West Virginia, and possibly the connection may have been by way of that area and Richlands, Virginia.

The marine invertebrate life of the Warsaw consisted mainly of brachiopods, pelecypods, and bryozoa. *Spirifer bifurcatus, Fenestralia sancti-ludovici,* and *Polypora varsoviensis* are some of the more diagnostic fossils occurring in Virginia.

St. Louis epoch.—In St. Louis time the south end of the Appalachian trough in Virginia was submerged southeast of the axis of the Greendale syncline and as far north as the Appalachian Plateaus near Bluefield, West Virginia. This distribution of the sea is indicated by the facts that in the Greendale syncline the St. Louis limestone extends north to Saltville, and that it is present locally along the northwest side of the Valley from Cumberland Gap to Bluefield and extends thence northward into West Virginia as far as Marlinton, Pocahontas County. The sea also extended westward to Rowan County, Kentucky. The extension of the St. Louis sea southeast of the site of the Greendale syncline was probable but that can not be known because the formation is cut out by a fault and, in the belt between the syncline and the Blue Ridge, its horizon has been eroded away.

Throughout its known extent the St. Louis sea was clear and free from clastic sediment. Some silica was brought in which supplied the material for the chert nodules locally common in the limestone. (See

Pl. 49B.) That part of the St. Louis sea in which the limestone was deposited was either distant from land or was bordered by broad lowlands. The dark color of the limestone almost everywhere suggests the presence of much carbonaceous matter in the sea. At the beginning of St. Louis time a lagoon containing much carbonaceous matter lay along the belt now marked by the Greendale syncline, in which accumulated the muds of the black shale at the bottom of the limestone.

The St. Louis sea was inhabited by brachiopods mainly of the genera *Productus* and *Spirifer,* and a great abundance of fenestrellinid bryozoa. In Virginia the diagnostic corals *Lithostrotionella* and a species of *Syringopora* were always present.

Ste. Genevieve and Gasper epochs.—The Ste. Genevieve and Gasper rocks indicate continuous deposition of similar sediments in a sea which covered the southern end of the Appalachian trough in Virginia as far southeast as the Greendale syncline and as far northwest as the Narrows of New River. The sea spread westward into the Mississippi Valley. The great thickness (2300 feet) of the Gasper and Ste. Genevieve in the Greendale syncline and the predominance of clastic sediment warrant the conclusion that the sea extended far southeast of the syncline.

The clastic facies of the Ste. Genevieve and Gasper in the Greendale syncline indicates proximity to land of moderate relief on the southeast, whereas the pure oolitic limestone along the Cumberland escarpment on the northwest shows a clear, open sea in that part of the trough. Such a sea also extended westward into the Mississippi Valley. Westward to western Kentucky this sea received scarcely any clastic sediment, and the deposition was almost wholly calcium carbonate. Pure limestone on the crest of Newman Ridge at Blackwater, Lee County, indicates that the clear, open sea extended southeast to that locality.

Extension of the formations over a wide belt southeast of the Greendale syncline would agree well with the southeastern extension of the partly contemporaneous Mauch Chunk shale, 3000 feet thick, southeast of the southern anthracite coal field in eastern Pennsylvania.

The Ste. Genevieve and Gasper seas were thickly populated by brachiopods, fenestrellinid bryozoa, and crinoids.

Fido epoch.—The deposition of the Fido sandstone was a minor episode in the geological development of the Greendale synclinal area. It is of interest because of the different character of the sediment deposited during the brief period between the deposition of the limestone at the top of the Gasper and the beginning of deposition of the overlying Cove Creek limestone. No satisfactory explanation of the source of the red sands of the Fido or of the conditions which brought about their deposition is known.

Glen Dean-Cove Creek-Bluefield epoch.—In the Glen Dean-Cove Creek-Bluefield epoch the sea in Virginia had the same extent as in the Ste. Genevieve and Gasper epoch, but the character of the deposits shows that there were changes in physical geography or climate, in different parts of the area. Less clastic sediments were delivered in the south while the Cove Creek limestone was being deposited. This may have been the result of planation of the land to the southeast during Ste. Genevieve-Gasper time, through erosion and removal of the great body of sediment that accumulated in those formations in the Greendale syncline. On the subdued topography erosion was less active, and less clastic sediment in proportion to limy matter in solution was discharged into the sea in Cove Creek time. In the area on the line of the Cumberland escarpment of today still farther from the source of supply, the clastic material received by the Glen Dean sea was still less than it was in the area of the Greendale syncline, and the proportion of limestone in the Glen Dean is greater than in the Cove Creek. The Bluefield shale in the Bluefield region, however, indicates that the tributary land must have been elevated and the drainage revived, so that a great body of mud and silt was delivered to the sea in the same area in which, in the Ste. Genevieve and Gasper epochs, pure limestone was laid down.

Life was abundant in the Glen Dean and Bluefield areas of the sea, but was very scarce in the Cove Creek area, at least so far as fossil remains indicate. The prevailing forms were brachiopods, bryozoa, and crinoids.

Pennington epoch.—Clastic sedimentation prevailed in the Pennington epoch. The sea covered the southern end of the Appalachian trough north to the vicinity of Bluefield in Virginia and extended much farther north into West Virginia. By reasoning similar to that involving the Ste. Genevieve and Gasper epochs, the sea may have extended southeast over the Valley area and connected with the Mauch Chunk sea or coastal plain, whichever was the site of Mauch Chunk deposition. As Pennington sedimentation seems to have been at a maximum in the Bluefield, West Virginia, area and to have diminished in all directions away from that region, it may reasonably be inferred that the principal source of the Pennington sediment lay to the southeast of that region. The sediment was delivered to the trough somewhere to the southeast of that region, perhaps in a part of the Appalachian trough from which all deposits of the later Paleozoic ages have been eroded off, so that the evidence of their former southeastward extent has been entirely removed. A remnant of the coarser sediment that may have been derived from the high land to the southeast still remains in the Rocky Gap sandstone. The delivery of the characteristic red sediment of the Pennington began in late Bluefield time but reached its maximum in the Pennington epoch after the deposition of the Rocky Gap sandstone.

On the basis of the fossil remains, life was comparatively scarce in the Pennington sea in Virginia and was largely composed of brachiopods of the genus *Productus,* which lived chiefly at times of lime deposition, for their fossils occur for the most part in the impure limestone beds of the formation.

Coal-forming conditions, that is, swamps with abundant vegetation, existed locally in Bluefield and Pennington times, as thin beds of coal are known in a few places.

Princeton and Bluestone epochs.—The Princeton sandstone and Bluestone formation are usually regarded as having been deposited in the closing stages of the Mississippian period. The extent of the Bluestone sea can not be determined. The deposits escaping erosion show that it spread over a large area in West Virginia northwest of Bluefield, and over an area in Virginia southwest of Bluefield. All evidence as to its southeastward extent in the Appalachian trough southeast of Bluefield has been removed by erosion. The deposition of the Princeton sandstone was but an episode in the deposition of the uppermost Mississippian formations. The presence of a few fossils shows that the Bluestone was of marine origin.

PENNSYLVANIAN PERIOD

Pottsville epoch.—During Pottsville time the Appalachian trough was slowly but intermittently subsiding. Most of the time the surface was slightly above sea level, being kept in that position by the accession of sand and clay which built up the earth's crust in this region as rapidly as it subsided. During short intervals subsidence was relatively faster; the surface sank below sea level and was occasionally flooded, as shown by thin, intercalated beds containing marine fossils. The surrounding lands were more or less constantly undergoing elevation, and the streams were transporting vast quantities of sand and silt and occasionally much quartz gravel. Each area of successive subsidence in the trough was filled up in a relatively short time and became land again. The land, being low and flat and near sea level most of the time, was occupied by vast swamps densely covered with vegetation which was continually maturing, dying down, and annually shedding its leaves, or being broken by storms. This dead vegetation accumulated constantly in the stagnant water of the swamps by which it was preserved from decay. It thickened greatly in vast peat bogs, which were afterward depressed below sea level and buried by succeeding deposits of sand and clay. In the course of time through great pressure from the overlying sediments, from bacterial decay, and from the loss of volatile gases and water, the peat was changed into beds of bituminous coal. This process continued until the Pottsville coal measures of Virginia, 5000 feet or more thick with many successive coal beds, were accumulated. The first coal beds formed were the Pocahontas coals of Tazewell County, and among the latest formed were the Pardee and High Splint coals of Black Mountain, Wise County.

That much of the area previously occupied by the trough, as well as that in the interior to the west, was above the sea during the time of growth of the coal vegetation is obvious from the fact that the coal-forming vegetation was unlike marine types of plants and must have grown on dry land or in fresh water swamps. Subsidence below sea level was intermittent, as shown by thin beds of rock containing the shells of marine invertebrate animals that are intercalated in the rocks between some coal beds. The animals were brachiopods, pelecypods, and crinoids, types that could live only in salt water. Thus the landscape of Pottsville time was a vast plain near sea level dotted with patches of the vegetation peculiar to the time.

The southeastern extent of the area of deposition of coal-measure clastic sediments and of coal swamps of Pottsville time is unknown. It would require a long distance for 5000 feet or more of Pottsville rocks to thin out against the land from which the sediment was derived. In comparison with the Southern Anthracite basin in eastern Pennsylvania and the Coosa coal field, the most southeastern coal basin of Alabama, the southeastern limits of the Pottsville deposits in the Valley of Virginia might reasonably be considered as the Massanutten syncline in northern Virginia and an area an unknown distance southeast of the present site of the Greendale syncline in southern Virginia (Washington and Smyth counties).

Allegheny, Conemaugh, and Monongahela epochs.—The Allegheny, Conemaugh, and Monongahela epochs are not represented by deposits in Virginia. No record of them is preserved, unless the Harlan sandstone and the underlying rocks down to the Pardee coal are considered to be of Allegheny age. These epochs are well recorded in West Virginia, Pennsylvania, and Ohio by rocks that, together with numerous coal beds, aggregate 1500 feet in thickness. The record of these sedimentary rocks extends greatly the history of the Paleozoic era furnished by the deposits in the Appalachian trough in Virginia.

PERMIAN PERIOD

The Permian was the concluding period of the Paleozoic era of earth history and, like the three preceding epochs, is not now represented by any records of sedimentation in Virginia. It is a reasonable inference that all these epochs were represented by deposits in the Appalachian Valley area, which have been eroded.

AMOUNT AND RATE OF PALEOZOIC SEDIMENTATION

The maximum thicknesses of the different Paleozoic formations, if added together as though all were present and superposed in some part of the Appalachian trough, would total about 55,000 feet, as shown by the generalized columnar section on the geologic map of the Appalachian Valley. Actually, few, if any, of the formations extended over the whole area of the trough. It is therefore estimated that the average thickness of the sediments, if spread over the entire area of the trough in Virginia, would be about 30,000 feet or, roughly, 6 miles. The area of the Valley in Virginia is approximately 10,000 square miles. Hence, the total volume of sediment deposited was about 60,000 cubic miles. If this material were spread over all that part of Virginia southeast of the Blue Ridge, whence much of it must have been derived, it would raise the level of that part of the State to 10,000 feet above the sea. No doubt, however, some of the sediment was derived from a land mass that extended eastward beyond the present Atlantic coast line.

Assuming for the purpose of calculation that sedimentation was continuous and that the entire amount of sediment was spread uniformly over the bottom of the trough each year through the entire 250 million years of the Paleozoic, the average rate of sedimentation would have been 15/10,000 of an inch a year. It is obvious that the rate of sedimentation was variable, for limy sediments precipitated from solution, either chemically or through the agency of marine organisms, must have accumulated at much slower rates than muds and sands. It should be noted also that there were numerous intervals when sedimentation was slight or nil in the trough.

It is not pretended that any of these figures are accurate. They are introduced to express strikingly the facts that the amount of erosion in the old mass of eastern Virginia and of sedimentation in the Appalachian trough were enormous and that the rates of erosion and deposition were almost infinitely slow. The incessant activity of such common geologic processes through long periods of geologic time have, however, produced profound and far-reaching changes in the continent.

POST-PALEOZOIC HISTORY

Post-Paleozoic time is divided by geologists as follows:

Cenozoic era
- Quaternary period
  - Recent epoch
  - Pleistocene (glacial) epoch
- Tertiary period
  - Pliocene epoch

Miocene epoch
Oligocene epoch
Eocene epoch
Mesozoic era
Cretaceous period
Jurassic period
Triassic period

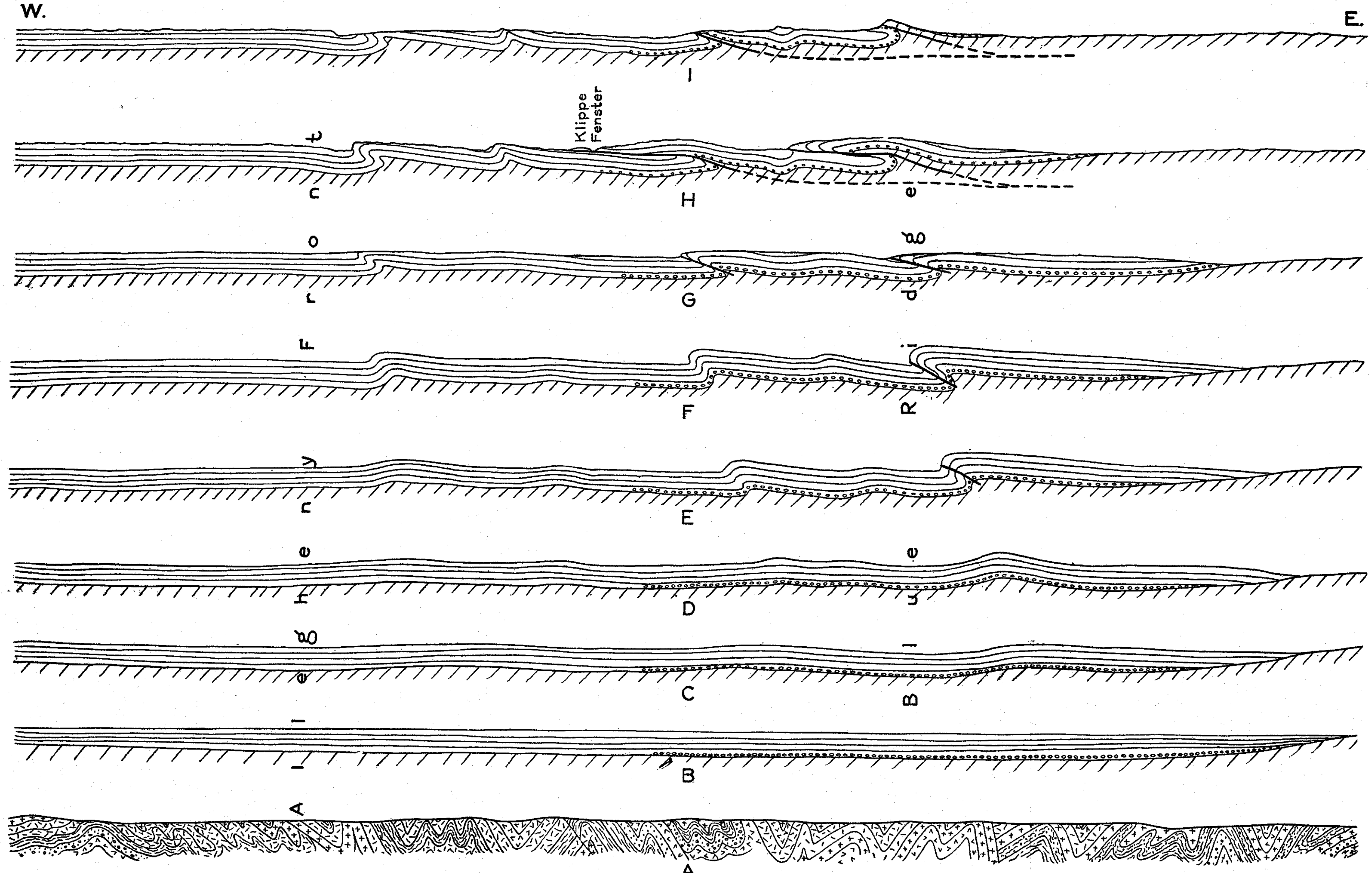
EROSION AND PENEPLANATION

As shown in the preceding chapter the Appalachian Valley region on the whole was subsiding during Paleozoic time, although with temporary interruptions during which some areas of the trough became dry land. An example is the region northwest of Clinch Mountain, which was dry land through all of Athens time, and in Lee County was dry land through all of Blount time. This is an inference drawn from the absence of the Athens next northwest of Clinch Mountain and of the entire Blount group in Lee County. Marine deposits are not made on dry land, and, conversely, the absence of marine deposits in a given sequence indicates the absence of the sea and the existence of dry land during that period or during a subsequent period in which the previous deposits were removed by erosion before the sea of the next epoch spread over the region.

The changes from sea to dry land can be explained, generally speaking, in one of two ways, or by a combination of both: Differential subsidence, by which the sea bottom in some areas sank faster than in others and the sea was drained off into the deeper parts leaving dry land where the bottom was stationary or less depressed; and local or regional upwarping of the sea bottom until it was raised above sea level.

As stated, the predominating movement in the Appalachian trough throughout all of Paleozoic time was subsidence, the net amount of which was about 6 miles. The surface of the erosional plain developed on the pre-Cambrian rocks, which was near sea level at the beginning of the Cambrian period, was 6 miles below sea level before the close of the Permian period. The evidence of shallow water deposits, such as ripple marks and mud cracks, shows that the sinking trough was filled with sediment about as fast as it sank, so that the sea was relatively shallow most of the time. One can picture the Paleozoic sea as studded with low, sandy or muddy banks and scattered islands and fringed generally with low capes and peninsulas, all separated by shallow seas, straits, lagoons, and inlets. The variations in the thickness and the distribution of the formations would be explained by some such geographic conditions. No such condition exists anywhere on the earth at present, partly because of relatively recent uplift of all the continental masses with respect to sea level, but the East Indian archipelago, or Australasia, perhaps comes nearest to it. The hypothetical condition of the Appalachian region at the close of the Permian period is shown on Plate 63, section B. Toward the end of the Paleozoic era subsidence of the Appalachian trough ceased, and a movement of elevation began by which the former sea bottom was raised into dry land which has persisted above sea level to the present. This profound change is known as the Appalachian revolution. The cause of the elevatory movement of this segment of the earth's crust that, after 250 million years of fairly continuous depression, began to lift the enormous weight of 60,000 cubic miles of rock that had accumulated during the period of subsidence, is not known, but the fact of the profound change is beyond question. There are several theoretical explanations. Accompanying this vertical upward movement of the earth's crust, beginning either at the same time or not long after, geologically speaking, was a horizontal movement caused by enormous lateral pressure from the southeast. As a result of this lateral compression the entire thick mass of approximately horizontal Paleozoic strata was folded, faulted, and overthrust to the northwest, as described under Geologic Structure. That no similar folding took place in the Appalachian trough in Virginia at any time in the course of Paleozoic sedimentation is shown by the original approximate horizontality and parallelism (conformity) of the Paleozoic formations. At no place from central Pennsylvania to Alabama has a single example of a strong, angular unconformity been seen; that is, of one set of beds lying upon the edges of tilted, older beds that had been beveled by subaerial erosion. (See Fig. 4.) As such highly tilted beds could only be produced, except in special, local cases, by severe lateral compression, their absence shows that in this part of the trough in the Paleozoic era no lateral compression sufficient to fold the strata took place.

The epoch of folding and faulting of the Appalachian trough lasted a long time. No record of the time of completion of these movements exists. The fact that the Permian strata in West Virginia are themselves folded shows that the folding began after those Permian beds were deposited and lithified. That the Valley area was uplifted to a considerable height soon after the Permian period may be inferred from the great thickness of Triassic sediments in the Piedmont region east of Warrenton, Virginia, and at many other places east of the Blue Ridge. These sediments



Generalized sections to illustrate successive stages in the development of the Appalachian Valley in Virginia. A, Surface of folded and eroded pre-Cambrian rocks at beginning of Paleozoic era; B, General condition in the Appalachian geosyncline at the end of Paleozoic deposition; C-I, Progressive stages of the major deformation and erosion of the Paleozoic strata, much generalized. G, H, and I show shingle blocks, resulting from slicing of the rocks along great overthrust faults. I, Present condition.

may have been partly derived from the Paleozoic rocks of the Appalachian Valley. In Fairview Township, 7 miles south of Harrisburg, Pennsylvania, a sandstone pebble taken from gravel referred to the Triassic contains a fossil rhynchonellid, probably *Plethorhynchus,* indicating that the pebble was derived from the Oriskany sandstone. The nearest outcrop of Oriskany from which the pebble could have been derived is in the Valley north of Harrisburg; also no Oriskany beds occur farther southeast. From this it can reasonably be inferred that some of the great gravel deposit, covering many square miles in that locality, was derived from the Appalachian Valley north of Harrisburg. The inference can be carried further to embrace some of the Triassic deposits in the Piedmont of Pennsylvania and southward, especially the conglomerates, as in Loudoun County, Virginia, that contain abundant limestone pebbles.

The folding and faulting probably went on so very slowly that they would have been imperceptible to any one living during that time. The movement of many miles of the separate overthrust blocks presumably was the aggregate of many small spasmodic movements, first on one fault and then on another, distributed through the entire period of movements. Each sudden movement would have produced an earthquake just as an instantaneous movement of several feet along the San Andreas rift, or fault, produced the San Francisco earthquake in 1906. Violent earthquakes must have occurred during the entire time of folding and faulting.

Erosion was active during all the time of elevation and deformation of the trough. As soon as the land rose above sea level it was attacked by the agents of weathering, and by rains, and winds. Reduced to rock waste, the debris was carried off by the streams to be redeposited in some basin or in some body of water, such as a lake, or in the ocean into which the streams emptied. Thus, it is believed, the Triassic deposits of the Piedmont region and later the Cretaceous and Tertiary deposits of the Atlantic Coastal Plain originated. Erosion unceasingly wears the land down toward sea level, and its counterpart—sedimentation—likewise unceasingly builds the sea bottom up toward sea level. This process is a matter of every day observation. After every rain the streams are muddy. This muddiness is due to suspended fine soil or silt which is being swept down toward the sea, its final resting place. It is obvious that this process is lowering the land surface toward sea level. At this level the land would have no slope and no further drainage to the sea. Consequently no further erosion of the land could take place. The level of the sea is the limit or base level of erosion. This limit is not actually attained, but with the crust of the earth stable for enough time such a result would be inevitable.

The rate of erosion has been measured in a few places. The Ganges River in India carries to the sea 6,368,000,000 cubic feet of sediment annually.[293] At this rate the area of the Ganges drainage basin would be lowered 1 foot in 1751 years. The Mississippi discharges 7,471,411,200 cubic feet of sediment annually, enough to lower the drainage basin of the river about 1 foot in 4600 years.[294] At the rate of 1 foot in 5000 years the whole earth, with an average elevation of 2000 feet, would be reduced to sea level in 10,000,000 years. It should be noted, however, that the rate of lowering the land would materially decrease as the elevation is lowered.

SUMMIT PENEPLAIN

The lateral movements, folding, and faulting of the Paleozoic rocks in time entirely ceased. The vertical uplift likewise stopped. Erosion, however, continued until much, or all, of the Appalachian Valley region was reduced to a lowland near sea level. Such a surface produced by erosion is called a peneplain, which means almost a plain. That such a peneplain was actually produced is indicated by several lines of evidence. One of the most significant is the remnants of surfaces that bevel the folded rocks. Much later, renewed elevation permitted this peneplain to be eroded and dissected by the rejuvenated streams.

The first peneplain has been named the Summit peneplain because remnants of it are thought to be preserved on a few high summits in the area, such as Poor Mountain south of Roanoke, altitude 3980 feet; Elliott Knob, 13 miles west of Staunton, 4400 feet; Beartown Mountain, Russell County, 4600 feet; and Spruce Knob, Randolph County, West Virginia, 4800 feet. However, there is at present a tendency among physiographers to regard these summits as low knobs or monadnocks on the Summit peneplain.

SCHOOLEY PENEPLAIN

The formation of the Summit peneplain by erosion had taken many millions of years. Its vertical uplift, some hundreds or thousands of feet, as shown by the present altitude of remnants, doubtless required more millions. Meanwhile erosion and dissection were in progress which, after another quiescent period, again wore down much of the surface nearly to sea level forming a second and

[293] LeConte, Joseph, Elements of geology, 4th edition, p. 11, 1896.
[294] LeConte, Joseph, op. cit.

younger peneplain, the Schooley, named from Schooley Mountain in northern New Jersey, on which a large remnant of it is preserved.

According to accepted views and to the description of Paleozoic history hitherto given, the drainage during Paleozoic time was westward from the eastern highlands, the source of the sediments, toward the Appalachian trough. Now, however, much of the main drainage is eastward, for example the Juniata and Susquehanna rivers in Pennsylvania, and the Potomac, James, and Roanoke rivers in Maryland and Virginia.

If the Triassic formations of the Piedmont province are composed of material largely derived from the Valley area, as intimated above, the reversal of drainage may have been intiated during the Triassic period, continued through the period of formation of the Summit peneplain, and perhaps completed upon the Schooley peneplain. Through uplift of the Valley area the slopes were reversed, from westward during the Paleozoic era to eastward during the Mesozoic era, and the streams adjusted themselves to the changed slopes. Some large rivers, like the New and Tennessee, did not reverse their directions but continued in their western courses.

The Schooley peneplain prior to uplift was nearly flat and had but few ridges to obstruct the streams, some of which took courses directly across the belts of highly inclined, resistant strata, and when the region was again uplifted, continued in their courses across these hard strata and in the course of time cut the present water gaps in them. These are among the most striking topographic features of the Valley now.

The amount of uplift after the formation of the Schooley peneplain differed in different parts of the region. Like the Summit peneplain, the Schooley was elevated some 2000 to 3000 feet, dissected and largely destroyed by the inexorable attacks of weather and erosion. Supposed remnants of it in Virginia are preserved on the crests of Clinch, Walker, Rich, and Massanutten mountains at altitudes of 2500 to 3500 feet, and on the ridge along the State line west of Monterey at 4000 to 4600 feet. These knobs were probably unreduced areas or monadnocks standing above the Schooley peneplain.[295]

HARRISBURG PENEPLAIN

After another very long period of erosion, an extensive part of the Valley region was again reduced to a flat or gently rolling

[295] Wright, F. J., The physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, pp. 12-13, 1925.

surface near sea level. This surface is called the Harrisburg, or Valley-floor, peneplain.[296] The development of the Harrisburg peneplain was most nearly complete along the southeastern belt next to the Blue Ridge and particularly along Shenandoah River in the vicinity of Winchester (Pl. 1A and B), where it now slopes gradually from 1000 feet at the base of Little North Mountain to 500 feet near Shenandoah River. Disregarding irregularities the peneplain surface rises southward from the Winchester area to an altitude of 1000 feet at Harrisonburg, 2000 feet in the plain around Dublin and Pearisburg, 2200 feet at Wytheville, Wythe County, and 2500 feet in the vicinity of Rural Retreat between Wytheville and Marion, Smyth County. Thence it descends to about 2200 feet at Abingdon (Pl. 2D) and descends still farther through Tennessee to the Coosa plain in Alabama at about 500 feet above the sea. Probably this belt was not everywhere reduced to its lowest level, which was reached in the Winchester and Coosa areas, but was a gradational plain rising southward toward the general divide which is now about 2500 feet above sea level and separates the New River and Tennessee River drainage basins at Rural Retreat. It is believed, however, that to a considerable extent the present differences in elevation are due to differential uplift, the maximum being in the area of highest altitude. New River was flowing on this peneplain at the completion of the uplift, at an altitude of 2100 feet. This is shown by river gravel on a small terrace remnant at that level north of New River just west of Stony Creek, and 3 miles northeast of Pearisburg, Giles County. This gravel must have been derived from the Blue Ridge province about the headwaters of New River, for it contains many large pebbles of vein quartz, which is abundant in the Piedmont rocks but is scarce in, if not absent from, the rocks west of the Blue Ridge. Since the completion of the Harrisburg peneplain New River has intrenched itself to the depth of 500 feet below the terrace level described above, the present altitude of the river bed being about 1575 feet. Such trenching could only occur in an uplifted region. Hence, the erosive power of New River was increased when the region was elevated, and it cut down its bed farther toward sea level.

Evidence that the Harrisburg peneplain was elsewhere traversed by meandering streams is found in the stream gravel scattered over the present surface in the vicinity of Reed Creek between Max Meadows and Wytheville and upon the upland surface along Cedar Creek west of Middletown, Frederick County. Another evidence of uplift is the intrenched meanders of the North Fork of Shenandoah

[296] Wright, F. J., op. cit., p. 5.

River at the northwest base of Massanutten (Powell) Mountain south of Woodstock, which are a very striking topographic feature. Such meanders form only on broad floodplains where streams have very low gradients and thus sluggish currents. With uplift the currents are accelerated and the streams intrench their channels below the level ground on which the meanders were developed. Intrenched meanders are thus evidence of regional uplift.

Deposits of stream gravel are not confined to the peneplain surface. Interruptions occur in the course of down-cutting, when downward erosion seems to have ceased. The streams cut laterally and widened their valleys as well as deepened them. In these widened valleys the streams meandered from one side to the other and left extensive deposits of gravel on the inner curves of their meanders. Among the numerous examples of such gravel deposits are the following: Gravel overlying the edges of the tilted Devonian shale in a road cut on U. S. Route 60, 1 mile west of Lowmoor, Alleghany County, 50 feet above the present level of James River. Another deposit extends 100 feet above Holston River on the low slope a mile or so northwest of the village of Sevenmile Ford, Smyth County. Still another lies about 100 feet above Holston River northeast of the bridge on Route U. S. 421 in Tennessee, 8 miles east of Bristol. A notable deposit, containing many large well-rounded boulders of sandstone or quartzite, lies on the slope about 200 feet above New River, between Pembroke and Ripplemead, Giles County. Another similar deposit lies upon the beveled edges of the Keefer sandstone at the south entrance to the Narrows gorge, about 1 mile west of Narrows village. This is well exposed in a road cut and shows the contact between the terrace gravel and the sandstone at road level 75 feet above the river. About 1 mile farther north in the gap, the same gravel deposit lies upon the beveled edges of vertical Moccasin beds and the contact is also well exposed.

The significance of these features is that they indicate a condition that made the rivers unable to carry away the load delivered to them from their tributary streams. A possible explanation of these features is as follows: The rivers may have cut their beds to so low a gradient that their currents and transporting power were greatly reduced, or precipitation may have been greatly increased and much more debris was delivered to the rivers than they could transport, so that it accumulated upon the river beds. It is tempting to ascribe the accumulation of waste to excessive rainfall in glacial time. With time the conditions changed; either the region was raised and the velocity and transporting power of the streams were renewed or precipitation became less. In either case, the rivers resumed their down-cutting, swept out the accumulated waste except such remnants of gravel as have been described, and have cut down 75 to 100 feet since their rejuvenation. A very perfect example of the recent accumulation of waste is in the beds of Dry River and Skidmore Fork northwest of Rawley Springs, Rockingham County. Another explanation is that the deposits accumulated in the inner curve of meanders and were left stranded as the rivers cut below them in the outer curve.

Transverse streams, such as the New, James, Potomac, and Susquehanna rivers, received the drainage from the areas lying between them. The streams carrying this drainage naturally eroded the soft rocks faster than the hard ones. As the soft and hard rocks of the Valley lie in alternating subparallel belts trending northeast, the streams in time became adjusted to the soft and more easily eroded belts, which are those underlain by shale and limestone, and thus developed the long northeast-southwest valleys and streams, like Back Creek, Walker Creek, Wolf Creek, Sinking Creek, and Shenandoah River. All these valleys have been carved out by their streams since the time of the Summit or the Schooley peneplain, depending upon which peneplain was the important factor in the final adjustment of the drainage to its present courses.

Though the validity of the peneplain theory can hardly be doubted, any effort to reconstruct the details of peneplanation is beset with difficulties and much diversity of opinion has resulted. The former existence of peneplains is demonstrated by the general drainage arrangements, by such topographic features as concordant altitudes of ridge crests and other interstream highlands, and by the existence of water gaps such as the Narrows of the New River and the striking gap through Walker Mountain, traversed by State Route 100 between Dublin and Pearisburg. (See Pl. 3B.) Plainly, a peneplain is the inevitable end product of the erosion process that can be seen in action at the present day, if conditions of erosion remain undisturbed by uplift or tilting of the land.

Detailed descriptions of the peneplains in Virginia have been given by Wright.[297]

AGE OF PENEPLAINS

Attempts have been made to date geologically some peneplains. The most notable attempt was that of W. M. Davis[298] who believed that the inclined surface of the uplifted Schooley peneplain is overlain by Cretaceous deposits in northern New Jersey. Such a relation would prove that Schooley peneplanation was completed in or before Cretace-

[297] Wright, F. J., The physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, 1925; The newer Appalachians of the South, Part 1, Between the Potomac and the New rivers: Denison Univ. Bull., Jour. Sci. Laboratories, vol. 29, pp. 73-101, 1934; The newer Appalachians of the South, Part 2, South of the New river: Denison Univ. Bull., Jour. Sci. Laboratories, vol. 31, pp. 93-142, 1936.

[298] Davis, W. M., and Wood, J. W., Jr., The geographic development of northern New Jersey: Proc. Boston Soc. Nat. Hist., vol. 24, p. 385, 1890.

ous time. Johnson[299] has come to a similar conclusion but thinks the Cretaceous strata overlie the pre-Schooley or Summit peneplain rather than the Schooley. Both conclusions have been questioned by others.

Granting for sake of discussion the truth of Davis' conclusion, the Schooley peneplain may have been completed 70 million years ago. Other physiographers have thought the Schooley peneplain was completed in early Tertiary time, or about 60 million years ago. Assuming the existence of an earlier peneplain, now dimly conceived as the Summit peneplain, such a peneplain may have been completed by the end of Jurassic time, or about 120 million years ago. That would allow 80 million years for the structural deformation of the Paleozoic rocks and the reduction of the Valley region to a peneplain by the end, say, of Jurassic time. The age of the Harrisburg peneplain is commonly regarded as late Tertiary. Accordingly, its age might be approximately 13 to 17 million years.

These figures have no positive or exact value. They only indicate roughly the order of events and possible periods of time involved in their consummation. One thing is certain: The present configuration of the Appalachian Valley in Virginia has been produced in the manner and by the means described and the process has been continuing for the 200 million years since the Valley region began to rise above the level of the sea. The operation of these forces will not cease while the land remains above the sea, and the rains fall, the winds blow, and the waters run down to the sea.

A few of the stages of the geologic history of the Valley are graphically represented in Plate 63.

POST-PALEOZOIC LIFE

It is reasonable to think that the Appalachian Valley was covered with vegetation during all of post-Paleozoic time, while all of the structural deformation and the topographic development, described above, were in progress. Various kinds of strange animals lived in the swamps or roamed through the forests on the hills. Very few plants of the preceding Pennsylvanian age survived. The great trees such as *Lepidodendron* and *Sigillaria* became extinct and so did most, or all, of the great assemblage of ferns characteristic of the coal swamps.

TRIASSIC LIFE

The vegetation of the Triassic included large trees similar to those whose trunks are preserved in the petrified forests of Arizona, plants like the modern horsetails, or *Equisetum,* and a large variety of ferns or

[299] Johnson, Douglass, Stream sculpture on the Atlantic slope: a study in the evolution of Appalachian rivers, New York, Columbia University Press, 1931.

fernlike plants, all generically different from the plants of the preceding coal measures. Among the ferns were representatives of the family *Osmundaceae,* the direct ancestors of the modern regal fern, *Osmunda regalis.* Dinosaurs, gigantic reptiles, lived in the earliest Triassic as shown by their abundant footprints in the Triassic strata of the Connecticut Valley and by footprints in Triassic beds in the vicinity of Leesburg, Virginia. These reptiles probably lived largely in swampy places and fed on the swamp vegetation of the time, but doubtless some types roamed through the upland forests of the Valley. A very few jawbones resembling those of low orders of mammals of the size of rats or squirrels, have been found in association with Triassic coal beds in North Carolina, but these are not now believed to be mammalian. Doubtless such animals inhabited the Valley uplands, and their bodies were occasionally washed into the lakes or lagoons in which coal matter was accumulating. Amphibians (such as frogs), crocodiles, and insects, such as dragon flies, cockroaches, and grasshoppers, which came into existence in late Paleozoic time, doubtless were common inhabitants of the land and air of Triassic time in Virginia, although no remains have been reported. It is of interest that such insects, some noxious, have an ancestry running back in time 200 million years.

JURASSIC LIFE

No Jurassic rocks or Jurassic fossils are known in the eastern United States. Yet as erosion progressed steadily during Jurassic time the eroded material must have been deposited somewhere. The most obvious explanation is that it was transported across the Piedmont region and deposited along the Atlantic border where it is now buried by later deposits of Cretaceous and Tertiary age. In such deposits, if accessible, might be found the fossils of plants and animals such as those that inhabited the Appalachian Valley in Jurassic time, scanty remains of which would have been transported the long distance to the sea by the rivers. Absence of Mesozoic fossils from the Appalachian Valley itself is easily accounted for by the fact that any local deposits within the areas, which may have contained such remains, have been entirely removed by Mesozoic and Tertiary erosion. Remains of terrestrial plants and animals can not be preserved for any length of time on the lands on which they lived because of lack of favorable sites for permanent burial.

Terrestrial plants resembling the common sago palm, a familiar greenhouse plant, the *Ginkgo,* commonly known as the maidenhair tree, the pine, the fir, and the *Sequoia,* the *arbor vitae,* and a great variety of ferns having no close living relatives, lived in Jurassic time elsewhere. It is a reasonable supposition that they also grew upon the hills of the

Appalachian Valley. Giant dinosaurs such as *Iguanodon, Brontosaurus,* and *Diplodocus* probably inhabited the river valleys and low swampy places, and the flying reptiles, pterosaurs, whose fossilized remains are found elsewhere in Jurassic rocks, probably flew overhead. Probably the earliest types of birds like *Archeopteryx* flitted about from tree to tree. But of all of them we have no record in the Appalachian Valley, because there are no Jurassic rocks in which their remains could have been preserved. It is also probable that representatives of low orders of mammals, like marsupials lived in the Valley area in Jurassic time. Such forms inhabited the rocky Mountain region and notably southern England in that period.

CRETACEOUS LIFE

In the older Cretaceous beds of Virginia and Maryland, which crop out through Washington, D. C., remains of living genera of plants such as *Sassafras,* poplar, pine, and *Sequoia* occur. Associated with them are species of genera now extinct but closely related to living genera. The *Sassafras* and poplar are flowering plants belonging to the most modern class of plants known as angiosperms, or plants having their seeds enclosed in a capsule. The early Cretaceous angiosperms are perhaps about the earliest of that group of plants to make their appearance on the earth. The familiar sycamore, though not reported from the eastern United States, lived in Greenland at this time and is about the most ancient kind of hardwood tree known to man.

In later Cretaceous time the flowering plants had increased in number and the forests of the Valley area must have been largely composed of them. The willow, oak, poplar, fig, sycamore, *Magnolia, Sassafras, Eucalyptus,* and dogwood were present, and the forests of the time must have had a very modern aspect, although the time was about 30 to 50 million years ago. The tulip tree, or yellow poplar, is reported from the Cretaceous beds of Greenland and of the Mississippi embayment, but apparently no fossil remains of it have been found in the Atlantic Coastal Plain deposits. Thus it would appear that neither of these ancient trees, sycamore or yellow poplar, lived in the Appalachian Valley area in Cretaceous time.

A few scattered bones and teeth of dinosaurs have been found in the Cretaceous deposits of the Atlantic Coastal Plain in Maryland and elsewhere. These are enough, however, to show that dinosaurs were living in this region in Cretaceous time and probably roamed over parts of the Valley. The flying reptiles, pterosaurs, birds, and insects lived on the lands.

TERTIARY LIFE

From the beginning of Tertiary time, probably about 15 to 20 million years ago, the vegetation of the Appalachian Valley was much like that of today. The forests were composed mostly of the common and familiar genera of hardwood and evergreen trees. The following are a few common trees living at the very beginning of the Tertiary period: Redbud, walnut, fig, holly, dogwood, sweet fern, and bread fruit tree. Many genera of trees now extinct and some now represented by species living in other parts of the world were also present. The common ferns and flowering plants doubtless bedecked the ground.

The Tertiary period was the age of mammals. The early Tertiary mammals were all unlike those of the later part of the Tertiary period. In the middle Tertiary such modern forms as lions, dogs, wolves, foxes, weasels, minks, skunks, raccoons, and rodents, such as rabbits and gophers, and hoofed animals, like deer and horses, are known to have lived in the Rocky Mountain region. It is reasonable to suppose that some at least of these animals may also have inhabited the Valley region.

In the latest Tertiary and in Pleistocene (glacial) time the animals took on a very modern aspect and all the modern types were represented. Elephants, mammoths, and mastodons inhabited the earth and fossil remains of some have been found in the Valley region. In Europe some of these animals lived during the time of early man, for drawings of the mammoth and the reindeer made by primitive man are found on the walls of caves in southern France.

In Pleistocene time the musk ox and reindeer were driven southward by the glacial ice as it moved south into the United States. They doubtless inhabited the Valley. Likewise the northern spruce was driven south and forests of it are still living on Mount Rogers, Virginia, and Mount Mitchell, North Carolina, where the climate approaches that of their northern habitat. These areas of spruce are "island remnants" of the formerly extensive spruce forests of the Appalachian region.

APPENDIX A

Peaks in the Valley and Ridge province in Virginia, with altitudes of 4000 feet or more, include the following:

Peak	*Altitude Feet*	*Location*
Beartown Mountain	4604	Russell County, 3± miles southeast of Rosedale.
Red Oak Ridge	4579	Tazewell County, 3 miles southwest of Burkes Garden.
Whiterock Mountain	4550	Junction of Russell, Tazewell and Smyth counties, 4 miles north of Saltville.
Rams Horn	4530	Virginia-West Virginia boundary, 8½ miles southwest of Monterey.
Morris Knob	4510	Tazewell County, 7 miles southwest of Tazewell.
Hutchinson Rock	4503	Tazewell County, northwest rim of Burkes Garden.
State line, several knobs	4500	Virginia-West Virginia line west of Monterey.
Paddy Knob	4494	Virginia-West Virginia line, 8 miles southwest of Monterey.
Elliott Knob	4473	Augusta County, 14 miles west of Staunton on North Mountain.
Bear Mountain	4467	Highland County, Virginia-West Virginia line, 5 miles northwest of Monterey.
Redrock Mountain	4434	Along Russell-Smyth County line, 3½ miles northwest of Saltville.
Snowy Mountain	4428	Along Virginia-West Virginia boundary, 3½ miles north of Crabbottom.
Bald Knob	4410	Augusta County, 10 miles northwest of Mt. Solon, on Chestnut Ridge.
Peak with lookout tower	4402	Tazewell County, just southwest of Burkes Garden. On Garden Mountain.
Slate Springs	4400+	Rockingham County, 7 miles west of Rawley Springs.
Allegheny Mountain	4400+	Junction of Highland, Bath and Pocahontas counties, 18 miles north of Hot Springs.

Peak	*Altitude Feet*	*Location*
Tamarack Ridge	4400+	Virginia-West Virginia boundary, 8 miles northwest of Monterey.
Sounding Knob	4400+	Highland County, 5 miles south of Monterey.
Jack Mountain	4400+	Highland County, 4 miles east of Monterey.
Riven Rocks	4400+	Highland County, 4½ miles northeast of Monterey.
Reddish Knob	4398	Virginia-West Virginia boundary, 23 miles northwest of Staunton.
Bald Knob	4368	Giles County, just south of Mountain Lake.
Chimney Rock	4361	Tazewell County, 4½ miles northwest of Burkes Garden.
Shenandoah Mountain	4345	Virginia-West Virginia boundary at Shenandoah Tower, 19 miles northwest of Harrisonburg.
Wolf Pen Gap	4345	Tazewell County, 5 miles northwest of Burkes Garden.
Salt Pond Mountain	4327	Giles County, just east of Mountain Lake.
East River Mountain	4310	Tazewell County, 4¾ miles northwest of Burkes Garden.
Wilson	4300+	Tazewell County, 5 miles northwest of Burkes Garden.
Mad Sheep	4256	Bath County, 16½ miles north of Hot Springs.
The Peak	4245	Tazewell County, 1 mile southeast of Tazewell on Rich Mountain.
Peak	4230	Tazewell County, 1½ miles southeast of Tazewell.
Bald Knob	4228	Bath County, 3 miles south of Healing Springs on Warm Springs Mountain.
Clinch Mountain	4223	Washington County, 4 miles east of Hansonville.
Doe Mountain	4200+	Giles County just west of Mountain Lake.
Hayter Knob	4200+	Russell-Washington county line, 3± miles south of Elk Garden.
The Stamp	4200+	Highland County, 7½ miles northwest of Monterey.

Peak	Altitude Feet	Location
High Knob	4200+	Virginia-West Virginia boundary, 8 miles northwest of Rawley Springs.
Jack Mountain	4200+	Augusta County, 23 miles northwest of Churchville.
Bald Knob	4200+	Augusta County, Shenandoah Mountain, 12 miles west of Mt. Solon.
Redoak Knob	4200+	Highland County, 5 miles northwest of Monterey.
Middle Mountain	4200+	Highland County, 5½ miles northwest of Monterey.
Short Ridge	4198	Tazewell County, 5 miles northwest of Burkes Garden.
Butt Mountain	4195	Giles County, 7 miles northeast of Pearisburg.
High Knob	4162	Wise County, 3 miles south of Norton.
The Double	4150	Wise County line, 6 miles northwest of Big Stone Gap.
Chestnut Ridge	4117	Tazewell County, 5 miles north of Burkes Garden.
Big Ridge	4116	Tazewell County, 3½ miles southeast of Bluefield.
High Top	4107	Virginia-West Virginia boundary, 21 miles northwest of Harrisonburg.
Brushy (Glade) Mountain	4100+	Smyth County, about 7 miles northeast of Marion.
Short Mountain	4100+	Tazewell County, 5 miles south of Pounding Mill.
Dundore Mountain	4100+	Rockingham County, 5½ miles northwest of Rawley Springs.
Shenandoah Mountain	4100+	Several knobs in western Augusta County.
Back Creek Mountain	4100+	Highland County, 6 miles southwest of Monterey.
Monterey Mountain	4100+	Highland County, 1½ miles northwest of Monterey.
Flat Top Mountain	4100	Giles County, 9 miles southwest of Pearisburg, at union of Pearis and Sugar mountains.
Brushy Top	4070	Giles County, 4½ miles northwest of Mountain Lake.

Peak	*Altitude Feet*	*Location*
Dial Rock	4062	Tazewell County, 5 miles northwest of Burkes Garden.
Buckhorn Knob	4057	Giles County, 10 miles southwest of Narrows.
Mad Tom	4050+	Virginia-West Virginia boundary, 16 miles north of Hot Springs.
Morris Knob	4050	Peak on Garden Mountain along Bland-Tazewell County line.
Rich Mountain	4041	Tazewell County, 2 miles southeast of Tazewell.
Peters Mountain	4035	Along Virginia-West Virginia line, about 8 miles north of Mountain Lake.
Hog Ridge	4035	Rockingham County, 35 miles north-northwest of Harrisonburg.
Grassy Knob	4002	State line, 9 miles northwest of Monterey.
Clinch Mountain	4000+	Many knobs, unnamed, along Clinch Mountain in Russell and Tazewell counties above 4000 feet.
Camp Rock	4000+	Scott-Wise County line, 5 miles south of Norton.
Fork Mountain	4000+	Giles County, 4 miles northwest of Mountain Lake.
Bald Knob	4000+	Virginia-West Virginia boundary, 14 miles southwest of Monterey.
Warm Springs Mountain	4000+	Alleghany and Bath counties, Covington and Hot Springs area.
Lantz Mountain	4000+	Highland County, 5½ miles northwest of Monterey.
Garden Mountain	4000+	Tazewell County, surrounding Burkes Garden.
Big Bend	4000	Bland-Wythe County line, 7 miles southeast of Burkes Garden.

SUBJECT INDEX

D

INDEX OF FOSSIL NAMES

NOTE: New genera, species, and varieties listed below are illustrated and described in Part II of this Bulletin.

M

LOCALITY INDEX

NOTE: This index contains the names of most of the places near which geologic data are given in the text. The county references are incomplete; the listings of town, rivers, and mountains in the counties should also be consulted.

D

N

S

COMMONWEALTH OF VIRGINIA

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 52

Geology of the Appalachian Valley in Virginia

By

CHARLES BUTTS

Part II—Fossil Plates and Explanations

PREPARED IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

UNIVERSITY, VIRGINIA

1941

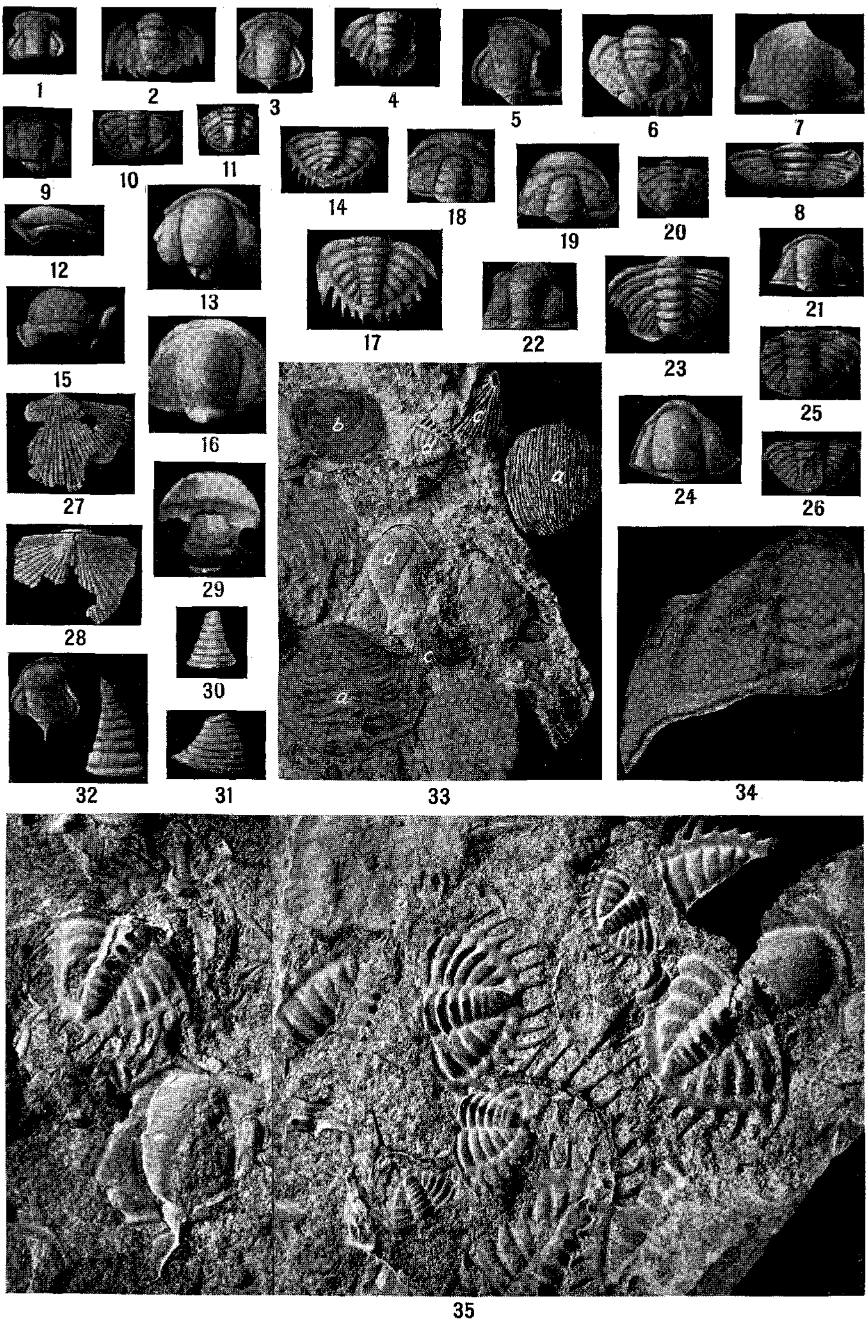
RICHMOND:

Division of Purchase and Printing

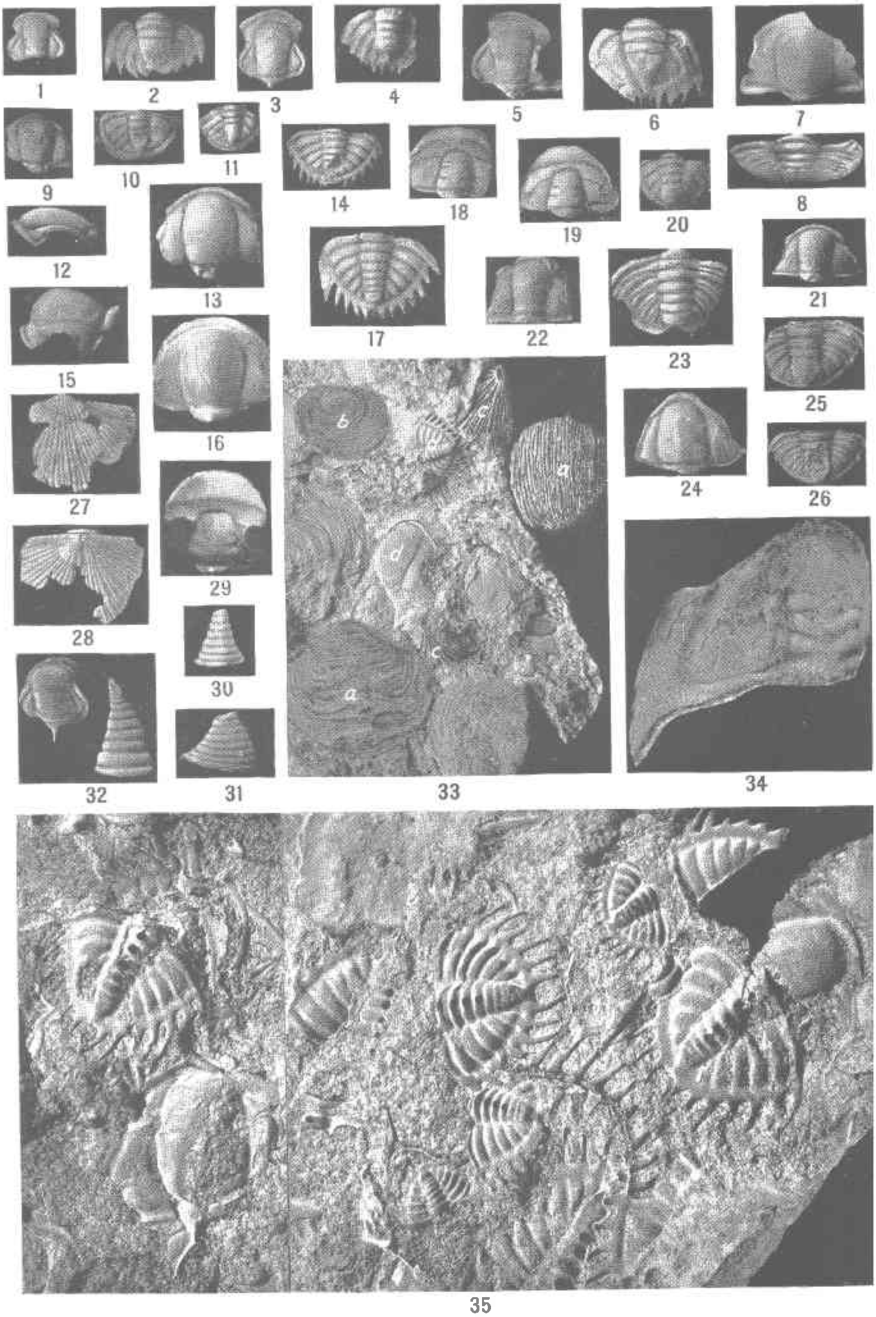
1941

CONTENTS

Fossil Plates and Explanations



SHADY FOSSILS



SHADY FOSSILS

PLATE 64.—SHADY FOSSILS[1]

FIGURE

1, 2. *Prozacanthoides virginicus* Resser.
Head and tail. Shady dolomite; Fossil Point 1 mile northeast of Austinville, Wythe County. Also occurs on old tram grade on Clear Creek about 1000 feet northwest of Fossil Point. U. S. N. M. 94749.

3, 4. *Prozacanthoides excavatus* Resser.
Head and tail. Occurrence as 1. U. S. N. M. 94752.

5, 6. *Prozacanthoides expansus* Resser.
Head and tail. Occurrence as 1. U. S. N. M. 94753.

7, 8. *Bicaspis austinvillensis* Resser.
Head and tail. Tail, × 2. Shady dolomite. Occurrence as 1. U. S. N. M. 94735.

9–11. *Bonnia crassa* Resser.
9, head; 10, 11, tails. Occurrence as 1. U. S. N. M. 94757.

12–14. *Kootenia browni* Resser.
12, head, side view; 13, head, dorsal view; 14, tail. Occurrence as 1. U. S. N. M. 94762.

15–17. *Kootenia virginiana* Resser.
15, head, side view; 16, head, dorsal view; 17, tail. Occurrence as 1. U. S. N. M. 94761.

18. *Proliostracus granulatus* Resser.
Head. Occurrence as 1. U. S. N. M. 94741.

19. *Proliostracus goodwini* Resser.
Head. Occurrence as 1. U. S. N. M. 94740.

20, 21. *Bonniella minor* Resser.
Tail and head. Occurrence as 1. U. S. N. M. 94739.

[1] All the fossil figures are of natural size, except those designated in the plate descriptions by the notations × 2, × 4, etc., which indicate that the figures are two or four or more times the natural size, respectively. Fossil localities not in Virginia are designated by states

Unless otherwise specified, all the specimens are in the United States National Museum and bear the numbers given in the accompanying plate descriptions.

FIGURE

22, 23. *Bonniella virginica* Resser.

Head and tail. Wax impression of head, × 2. Occurrence as 1. U. S. N. M. 94731.

24–26. *Olenoides hybridus* Resser.

24, head; 25, 26, tails. Occurrence as 1. U. S. N. M. 94732.

27, 28. *Nisusia* cf. *N. festinata* (Billings).

Ventral and dorsal valves. Incomplete specimens etched out with acid. Occurrence as 1. A widely distributed Lower Cambrian fossil; known as far north as Labrador. U. S. N. M. 91905.

29. *Austinvillia virginica* Resser.

Head. Occurrence as 1. U. S. N. M. 94742.

30, 31. *Helcionella buttsi* Resser, × 2.

30, edge; 31, side view. A fossil gastropod shell allied to the limpets. The shell tapered to an apex as in the specimen of Fig. 32. Occurrence as 1. U. S. N. M. 94726.

32. *Helcionella callahani* Resser and *Zacanthoides nitidus* Resser, × 2.

Side view of *Helcionella* and dorsal view of head of *Zacanthoides*. Occurrence as 7. U. S. N. M. 94727, 94728.

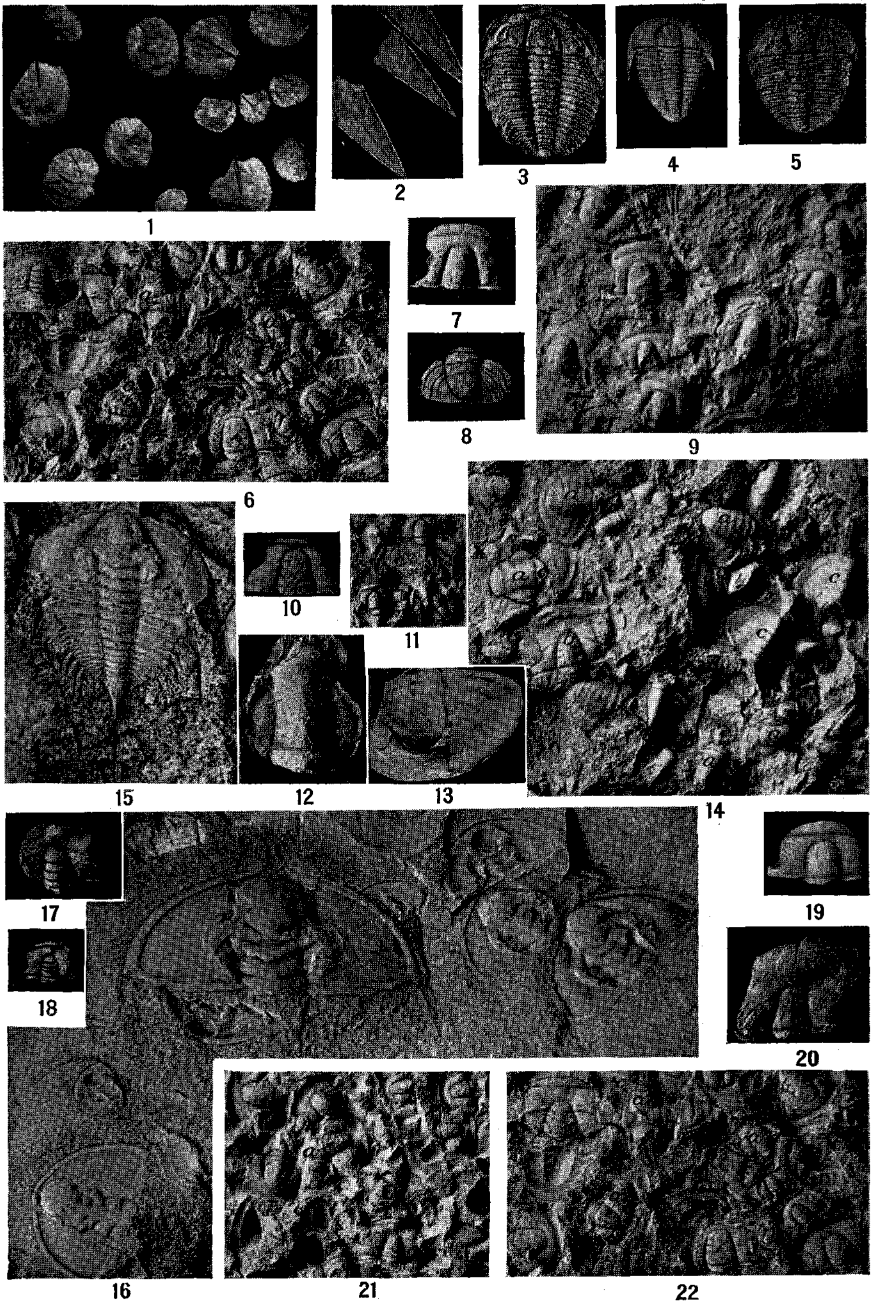
33. Small slab, with three species: a and b, *Kutorgina* cf. *K cingulata* Billings; a, ventral valve; b, dorsal valve; c, *Nisusia* cf. *N. festinata* (Billings); d, *Kootenia browni* Resser. Occurrence as 1. *Nisusia* and *Kutorgina* are among the oldest known brachiopods. U. S. N. M. 94733.

34. *Olenellus austinvillensis* Resser.

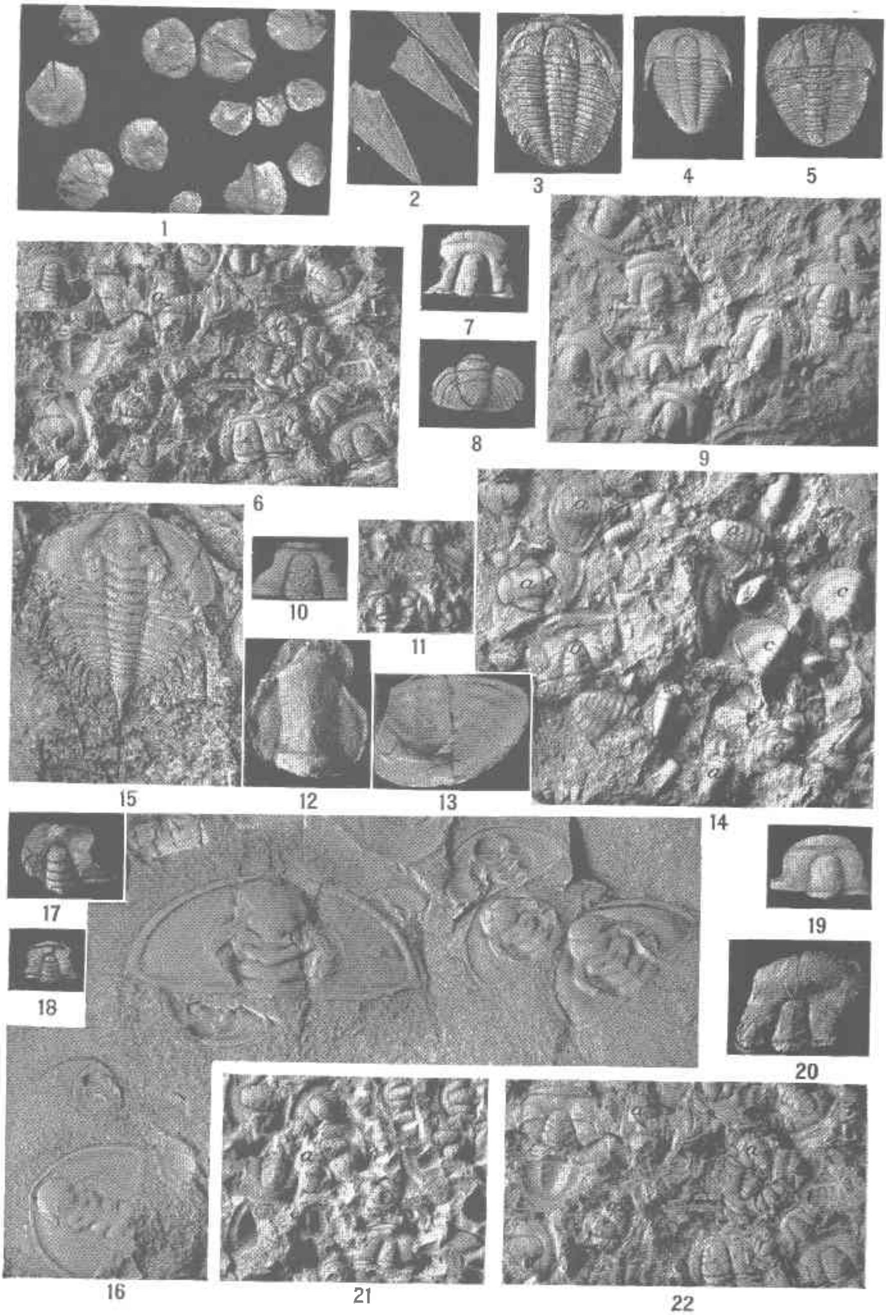
Head. Occurrence as 1. U. S. N. M. 94767.

35. *Kootenia currieri* Resser.

Part of slab with several specimens; mainly tails, with well-preserved tail spines. Two partly preserved heads, one in upper right, and another in the lower left corner. Shady dolomite; along road to Buddle Branch three-fourths of a mile southeast of Austinville, Wythe County. U. S. N. M. 94770.



SHADY AND ROME-WAYNESBORO FOSSILS



SHADY AND ROME-WAYNESBORO FOSSILS

PLATE 65.—SHADY AND ROME-WAYNESBORO FOSSILS

FIGURE

1. *Acrotreta buttsi* Resser, × 4.
   Thickly crowded on the surface of a thin layer which is blacked out in the figure. Rome (Waynesboro) formation; cut on the Chesapeake and Ohio railroad at city station, Waynesboro, Augusta County. Also half a mile southeast of Nance, Botetourt County. Rarely found in Virginia. U. S. N. M. 94778.

2. *Hyolithes wanneri* Resser and Howell, × 2.
   Rome formation; along U. S. Route 460, 1 mile southwest of Webster, Botetourt County. U. S. N. M. 92723.

3. *Ptychoparella michaeli* Resser, × 2.
   Lower Cambrian, Shady dolomite; three-fifths of a mile northwest of Bethany and about 2 miles due east of Austinville, Wythe County. U. S. N. M. 94781.

4. *Ptychoparella buttsi* Resser, × 2.
   Rome formation; Lee Highway at angle in road one-third of a mile northeast of Garst's store and 3½ miles southwest of Buchanan, Botetourt County. This point is on the abandoned road a few hundred feet east of its present location. U. S. N. M. 94771.

5. *Poliella virginica* Resser, × 2.
   Occurrence as 3. U. S. N. M. 94782.

6. *Alokistocarella typicalis* Resser (b) and *Alokistocare virginicum* Resser (a).
   Middle Cambrian, Rome formation, near top and about 100 feet below the base of the Rutledge limestone. Along road about 4 miles southwest of Purchase and 6½ miles southwest of Clinchport, Scott County. U. S. N. M. (a) 94816; (b) 94807, upper left-hand corner.

7–9. *Elrathiella buttsi* Resser.
   Middle Cambrian, Rome formation. 7, 9, top of formation along road 1 mile northeast of Bandys Chapel (Baptist Valley) about 4 miles west of Tazewell, Tazewell County. U. S. N. M. 94790. 8, tail, × 2, about 600 feet below the Rutledge limestone along State Route 71, 900 feet north of old

FIGURE

Cresswell and 2 miles north of Bolton, Russell County. U. S. N. M. 94779. (See Part I, Pl. 15D.)

10, 11. *Solenopleurella minor* Resser.

Middle Cambrian, Rome formation near the top. 10, head, × 4, occurrence as 8; 11, heads, × 2, occurrence as 7. U. S. N. M. 94779a, 94783.

12. *Glossopleura virginica* Resser.

Head. Middle Cambrian, Rome formation; about 200 feet below the Rutledge limestone along State Route 82, 1 mile southeast of Cleveland, Russell County. U. S. N. M. 94787. (See Part I, Pl. 16C.)

13. *Glossopleura buttsi* Resser.

Tail. Top of Rome formation; Aldrich, Shelby County, Alabama. U. S. N. M. 90169.

14, a. *Anoria bantius* (Walcott).

Heads and tails. The heads have long narrow glabellae and the tails have strong furrows. Occurrence as 12. U. S. N. M. 94788.

b. *Alokistocare? clevelandense* Resser.

Head. Occurrence as 12. U. S. N. M. 94789.

c. *Glossopleura virginica* Resser.

Smooth tails. Occurrence as 12. U. S. N. M. 94787.

15. *Olenellus buttsi* Resser.

Rome formation; along road about 1½ miles north of Montevallo, Alabama. Shows an entire trilobite as well as a good specimen of the genus *Olenellus*. U. S. N. M. 94777.

16. *Olenellus romensis* Resser and Howell.

Slab with several heads. Occurrence as 2. U. S. N. M. 92721.

17, 18. *Alokistocare virginicum* Resser.

Specimen of 17 somewhat distorted. Occurrence as 6. (See also Figs. 6a, 21a, and 22a.) U. S. N. M. 94811.

FIGURE

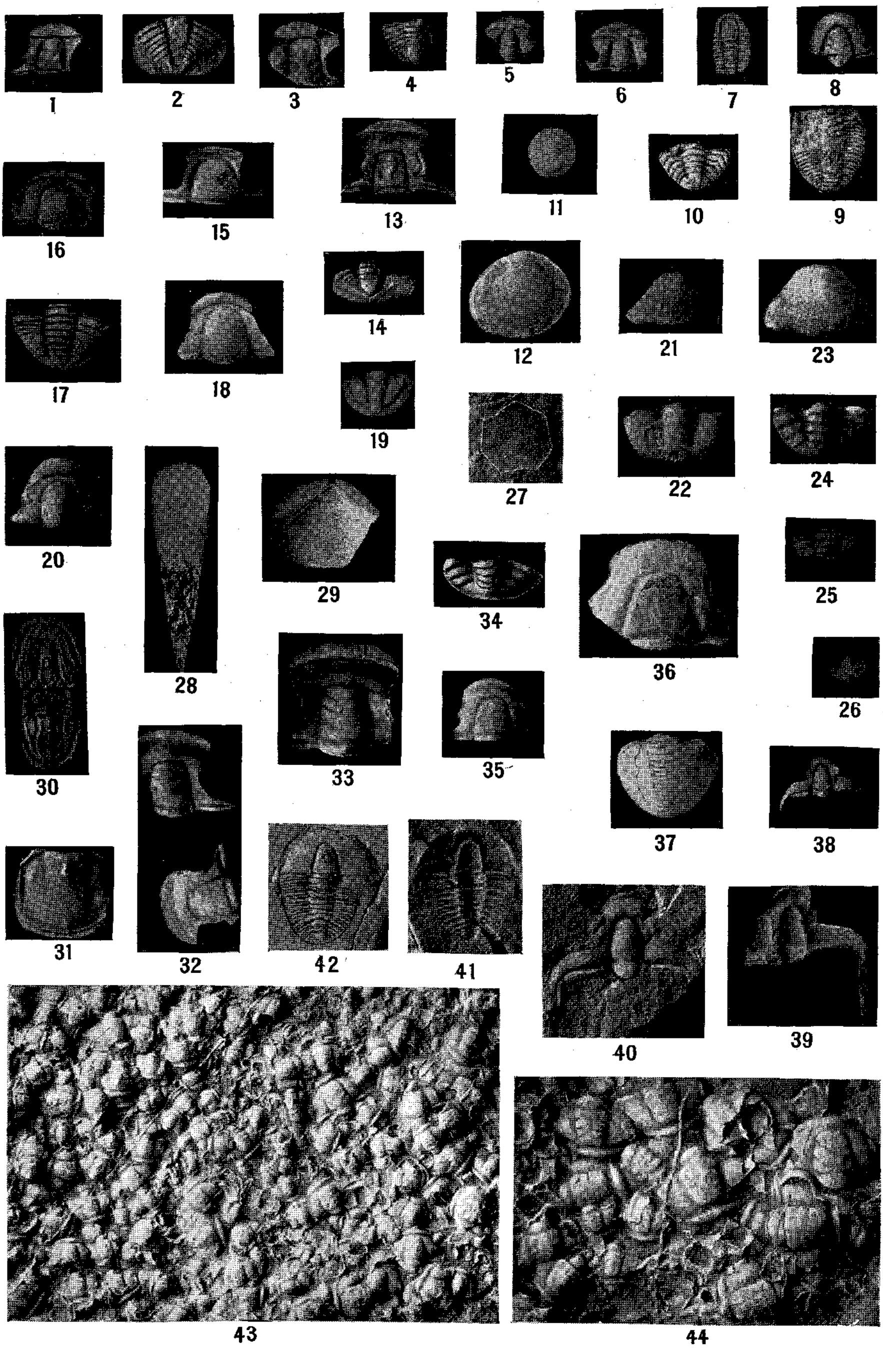
19. *Solenopleurella virginica* Resser.
    Occurrence as 4. U. S. N. M. 94772.

20. *Amecephalina poulseni* Resser.
    Associated with specimens of Figs. 3 and 5. Occurrence as 3. U. S. N. M. 94780.

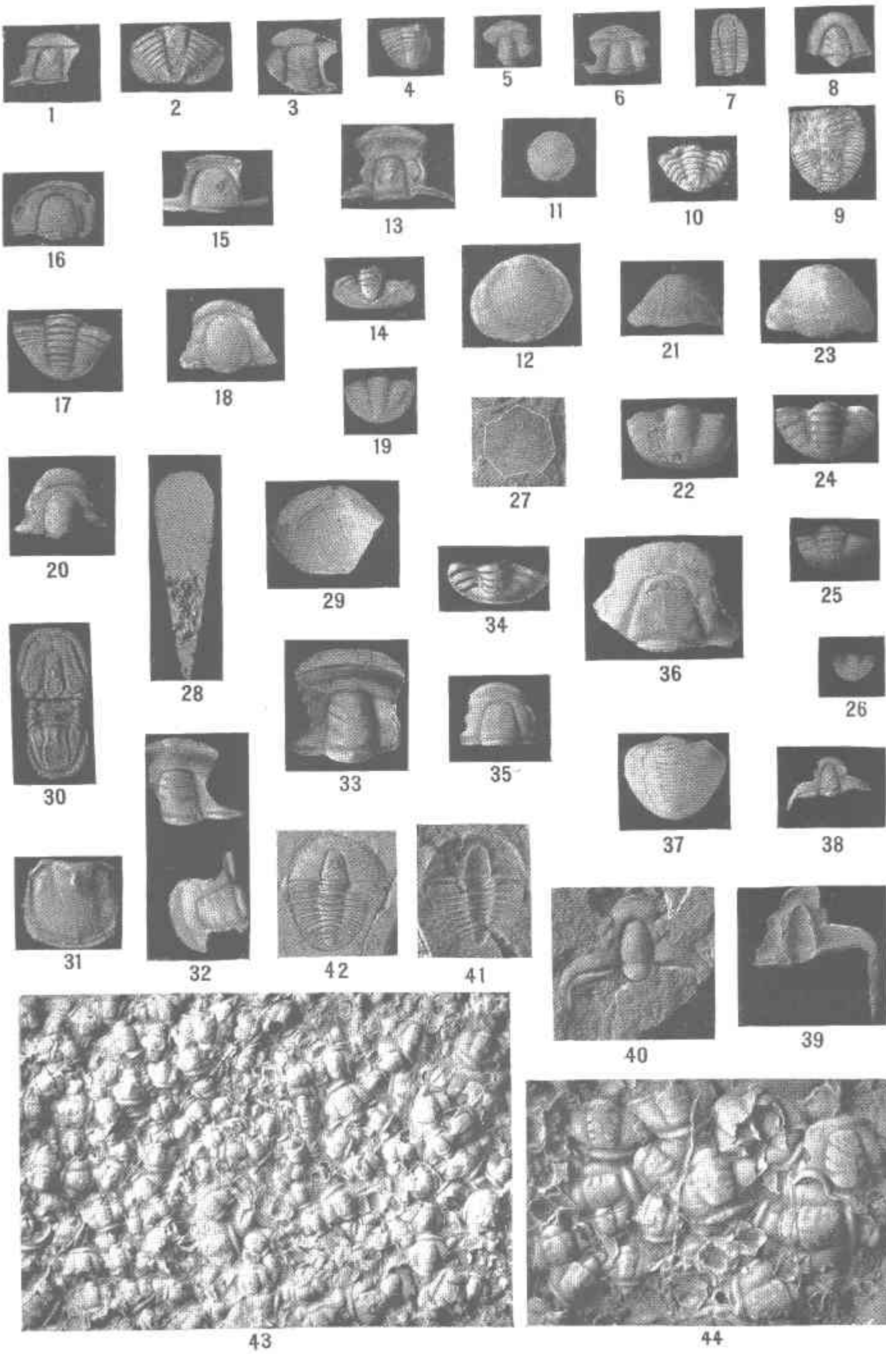
21. *Acrocephalops exigua* Resser.
    Just to right of middle of lower margin. Also *Alokistocare virginicum* (a) and *Alokistocarella typicalis,* heads. Occurrence as 6. U. S. N. M. 94806.

22. *Acrocephalops teres* Resser.
    Upper left corner. Also *Alokistocare* (a) and *Alokistocarella.* Occurrence as 6. U. S. N. M. 94816.

The fossils illustrated by Figs. 6-14, 17, 18, 21, and 22, listed here as occurring in the upper part of the Rome formation, have been assigned by Resser to the overlying Rutledge formation. (See Geol. Soc. America Spec. Paper No. 15, 1938.)



Rutledge and Nolichucky Fossils



RUTLEDGE AND NOLICHUCKY FOSSILS

PLATE 66.—RUTLEDGE AND NOLICHUCKY FOSSILS

FIGURE

1, 2. *Genevievella campbelli* Resser, × 1½.

Head and tail. Nolichucky formation; vicinity of Goodwins Ferry, Giles County. U. S. N. M. 94969, 94969a.

3, 4. *Genevievella wallacensis* Resser.

3, head, × 2; 4, associated tail. Nolichucky formation; one-eighth of a mile southeast of Wallace, Washington County. U. S. N. M. 94981.

5. *Genevievella clinchensis* Resser.

Head. Nolichucky formation; Copper Ridge, 11 miles northwest of Knoxville, Tenn. U. S. N. M. 94979.

6. *Genevievella virginica* Resser.

Head. Nolichucky formation; 3 miles northeast of Abingdon, Washington County. U. S. N. M. 94982.

7. *Terranovella bristolensis* Resser, × 2.

Head and thorax. Nolichucky formation; reservoir on Mumpower Creek, 3¾ miles north of Bristol, Washington County. U. S. N. M. 94986.

8, 9. *Terranovella buttsi* Resser, × 2.

8, head; 9, thorax and tail. Nolichucky formation; half a mile northwest of Holston Mill and 5 miles southeast of Marion, Smyth County. U. S. N. M. 94984.

10. *Terranovella bristolensis* Resser, × 3⅓.

Tail. Occurrence as 7. U. S. N. M. 94986.

11, 12. *Dicellomus appalachia* Walcott, × 2.

Ventral valves of a large and of a small specimen. Nolichucky formation. 11, in railroad cut one-fourth of a mile east of Clinchport, Scott County; 12, occurrence as 1. U. S. N. M. 97282, 97283.

13, 14. *Clevelandella aruno* (Walcott).

Head and tail. Conasauga formation, Nolichucky horizon; 1½ miles southwest of Cleveland, Tenn. U. S. N. M. 61718.

15. *Blountiella buttsi* Resser.

Head. Occurrence as 6. U. S. N. M. 94962.

FIGURE

16, 17. *Blountia rogersvillensis* Resser, × 2.
Head and tail. Nolichucky formation; along Big Creek, 4 miles northeast of Rogersville, Tenn. U. S. N. M. 94959.

18. *Maryvillia bristolensis* Resser.
Head. Nolichucky formation; reservoir 3½ miles north of Bristol, Washington County. U. S. N. M. 94963.

19. *Blountia bristolensis* Resser, × 2.
Tail. Occurrence as 18. U. S. N. M. 94942.

20. *Blountia alexas* Walcott, × 2.
Head. Occurrence as 16. U. S. N. M. 62785.

21, 22. *Kingstonia apion* Walcott, × 2.
Head and tail. Conasauga formation, Nolichucky horizon; 5 miles west of Cleveland, Tenn. U. S. N. M. 70252, 70253.

23, 24. *Kingstonia walcotti* Resser, × 3⅓.
Head and tail. Occurrence as 5. U. S. N. M. 94937.

25. *Kingstonia clevelandensis* Resser, × 2.
Tail. Occurrence as 21. U. S. N. M. 94950.

26. *Kingstonia virginica* Resser, × 2.
Tail. Occurrence as 6. U. S. N. M. 94941.

27. Cystid or crinoid plate.
Nolichucky formation; Prospectdale, 4 miles south of Pearisburg, Giles County. Common in the Nolichucky of Virginia and Tennessee. U. S. N. M. 94988.

28, 29. *Hyolithes curticei* Resser.
Tube and operculum. Occurrence as 5. U. S. N. M. 94989.

30. *Proagnostus bulbus* Butts, × 4.
Conasauga formation, Nolichucky horizon; Cedar Bluff, Cherokee County, Ala. U. S. N. M. 94867.

31. *Oedorhachis greendalensis* Resser, × 4.
Tail. Nolichucky formation; half a mile southeast of Greendale, Washington County. U. S. N. M. 94861.

32. *Aphelaspis walcotti* Resser.
Heads. Nolichucky formation; cut at bridge of Norfolk and Western Railway over Buchanan Branch 2½ miles southwest of Saltville, Smyth County. U. S. N. M. 94923.

FIGURE

33. *Aphelaspis quadrata* Resser.

Head. Occurrence as 5. U. S. N. M. 94924.

34. *Aphelaspis simulans* Resser, × 2.

Tail. Nolichucky formation; 1 mile northwest of Washburn, Tenn. U. S. N. M. 94925.

35. *Maryvillia widnerensis* Resser.

Head. Elbrook dolomite, Nolichucky horizon; Widner Branch, 13 miles east of Abingdon, Washington County. U. S. N. M. 94956.

36, 37. *Maryvillia masadensis* Resser.

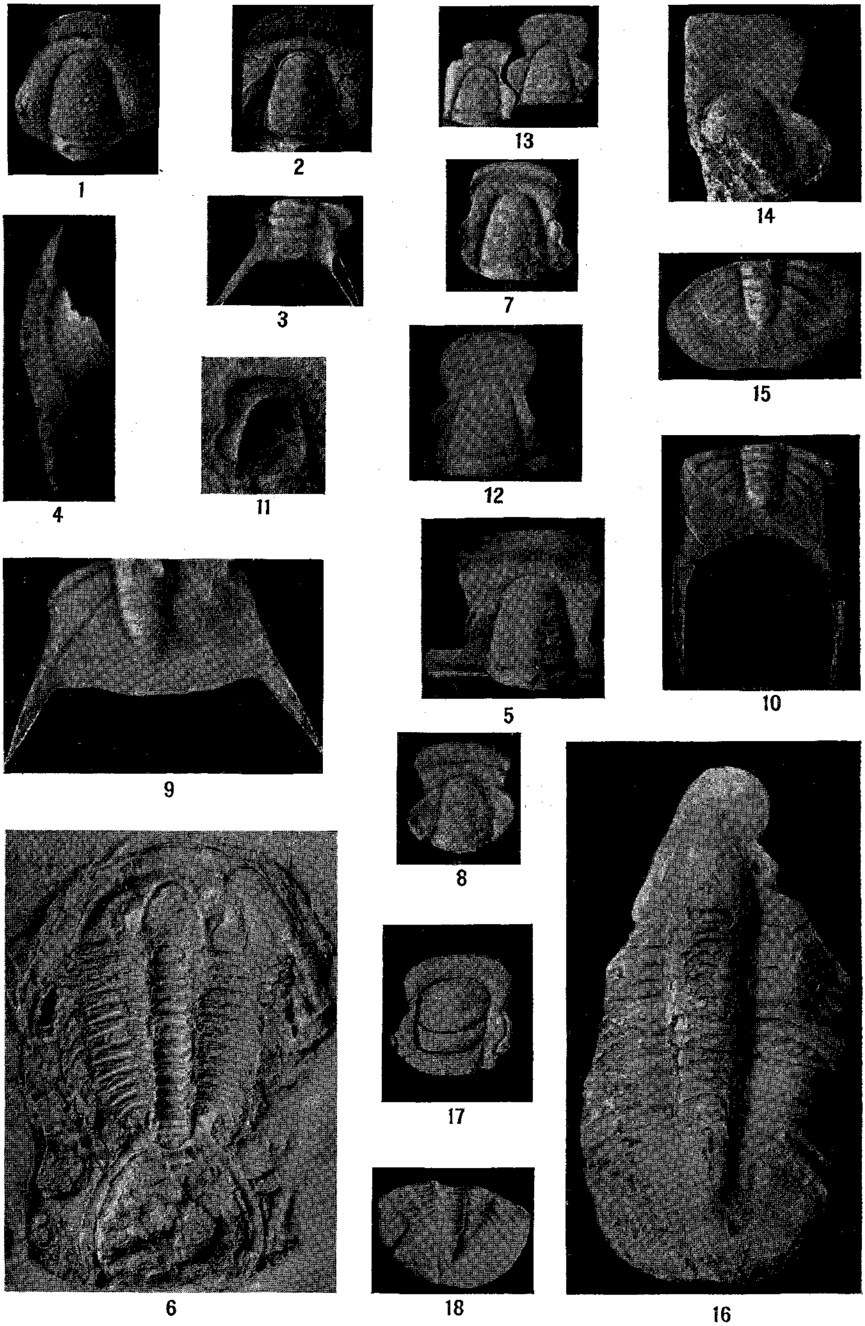
Head and tail. Occurrence as 35. U. S. N. M. 94964.

38–42. *Norwoodella saffordi* (Walcott).

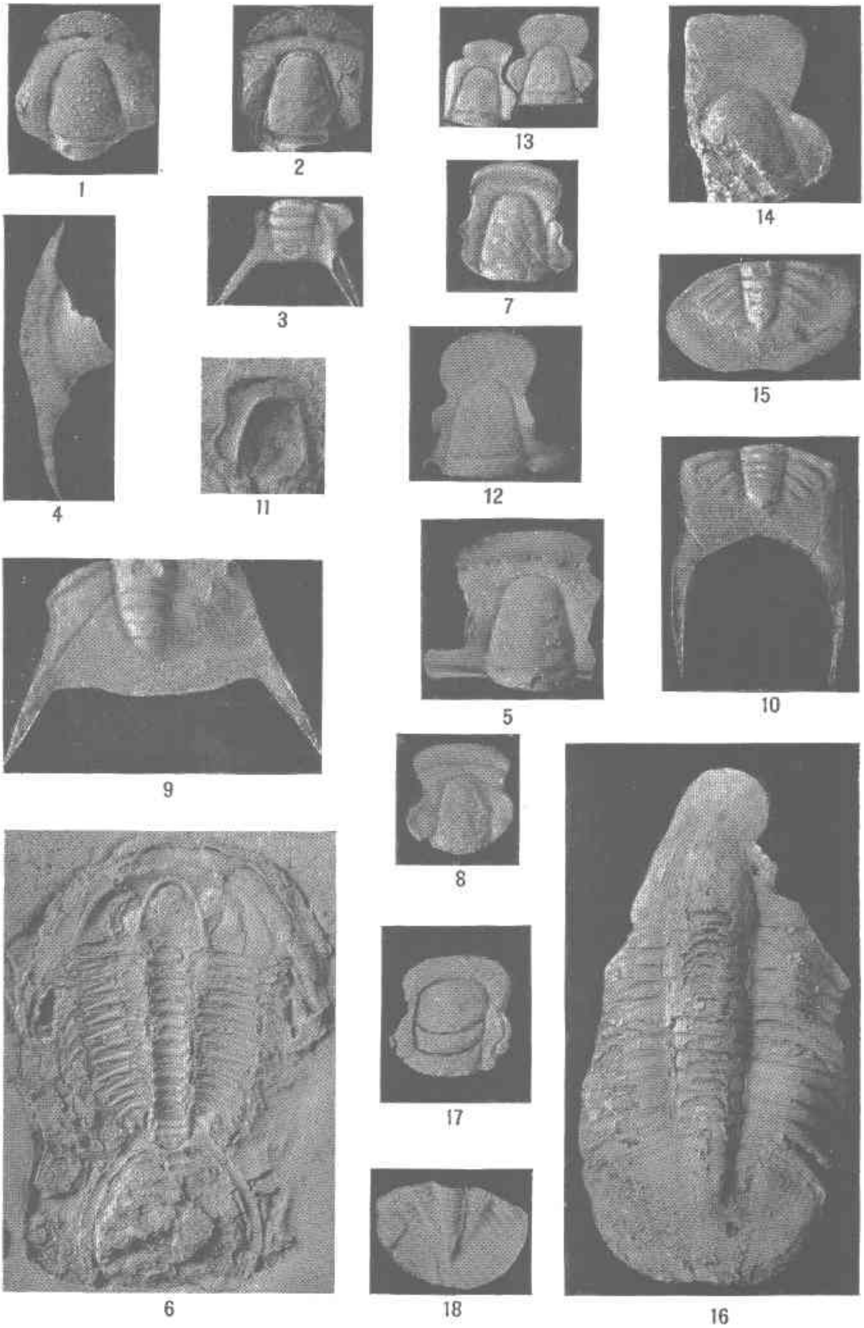
38-40, heads; 41, 42, counterparts of an entire specimen; 41, external mold; 42, internal mold; 38, 40, internal molds; 39, external mold of various heads. Nolichucky formation. 38, 39, along State Route 71 half a mile southeast of Old Cresswell and 1½ miles northwest of Bolton, Russell County; 40-42, Rogersville, Tenn. 38, 39, U. S. N. M. 97281; 40, 94890; 41, 42, 61599.

43, 44. *Solenopleurella buttsi* Resser.

43, slab with many heads; 44, × 2, part of same slab enlarged but not the part shown in 43. Rutledge limestone; 1 mile northwest of Fairview, Scott County. U. S. N. M. 94786.



NOLICHUCKY AND CONOCOCHEAGUE FOSSILS



NOLICHUCKY AND CONOCOCHEAGUE FOSSILS

PLATE 67.—NOLICHUCKY AND CONOCOCHEAGUE FOSSILS

FIGURE

1–4. *Tricrepicephalus* sp.

1, 2, heads. 1, exterior, × 2; 2, partly exterior, partly internal mold; 3, tail; 4, free cheek, internal mold. Nolichucky formation; two-fifths of a mile southeast of Greendale, Washington County. U. S. N. M. 97284.

5. *Tricrepicephalus simplex* Resser.

Internal mold. Conasauga formation, Nolichucky horizon; Murphrees Valley, Ala. U. S. N. M. 94915.

6. *Tricrepicephalus cedarensis* Resser.

External mold. Conasauga formation, Nolichucky zone; Cedar Bluff, Cherokee County, Ala. U. S. N. M. 94955.

7. *Crepicephalus greendalensis* Resser.

Head, internal mold. Nolichucky formation; half a mile southeast of Greendale, Washington County. U. S. N. M. 94912.

8, 9. *Crepicephalus buttsi* Resser.

Head and tail, internal molds. Nolichucky formation; 2 miles east of Cleveland, Russell County. U. S. N. M. 94908.

10. *Crepicephalus rectus* Resser, × 5.

Tail, internal mold. Nolichucky shale; War Gap 8 miles northwest of Rogersville, Tenn. U. S. N. M. 94916.

11. *Coosia calanus* (Walcott).

Head, external mold. Nolichucky formation; Wolf Creek 6 miles northeast of Rocky Gap, Bland County. U. S. N. M. 62789.

12. *Coosia robusta* (Walcott).

Head, internal mold. Nolichucky formation; Copper Ridge 11 miles northwest of Knoxville, Tenn. U. S. N. M. 57590.

13, 14. *Coosia latilimbata* Resser.

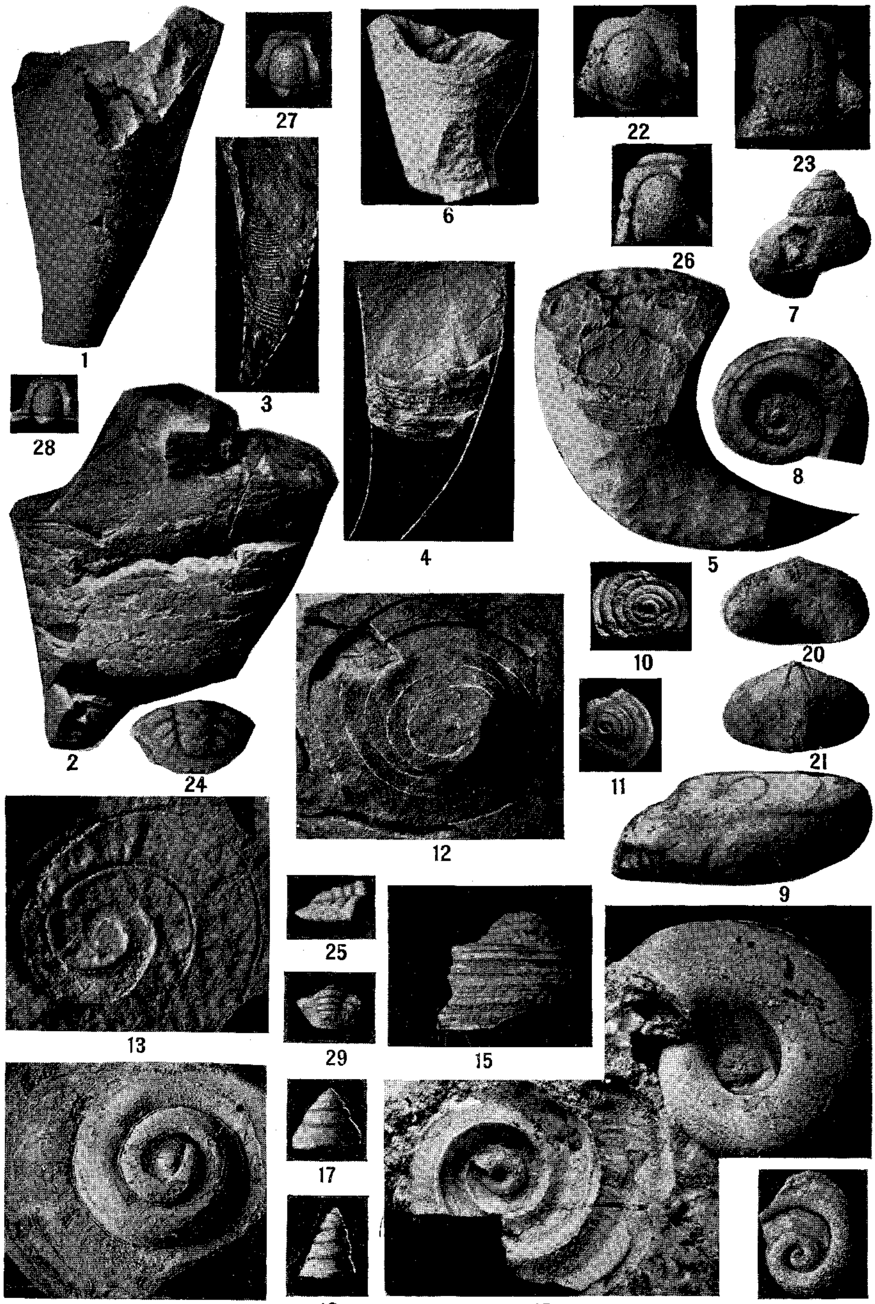
Heads, internal molds. Nolichucky formation. 13, Queens Knob 3 miles north of Wytheville, Wythe County; 14, cut at bridge of Norfolk and Western Railway over Buchanan Branch 2½ miles southwest of Saltville, Smyth County. U. S. N. M. 94918, 94903.

FIGURE

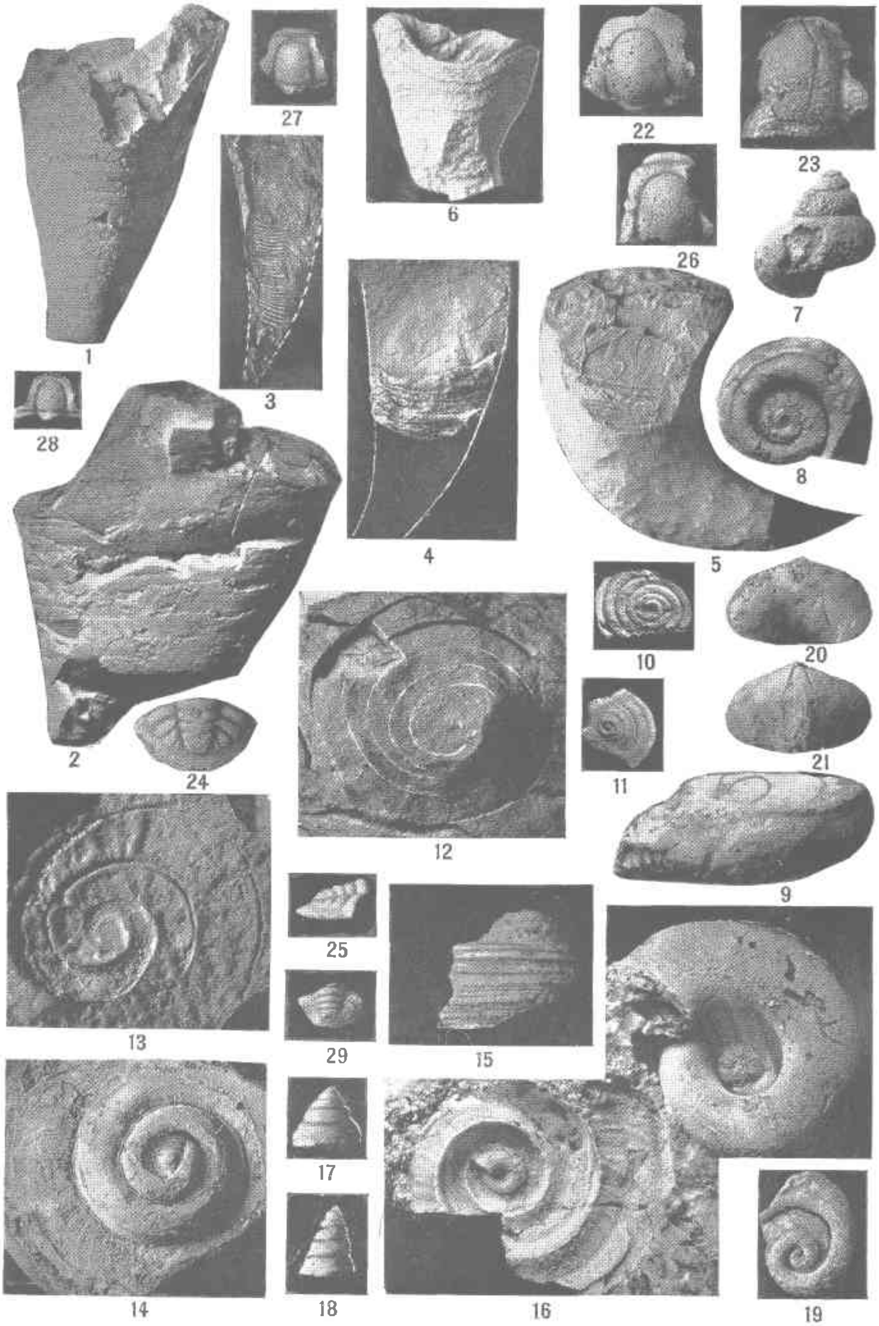
15. *Coosia calanus* (Walcott).
    Tail, internal mold. Occurrence as 11. U. S. N. M. 62790.

16. *Coosia superba* Walcott.
    Internal mold. Occurrence as 6. U. S. N. M. 57589.

17, 18. *Tellerina wardi* (Walcott).
    Head and tail, internal molds. Conococheague limestone; along Lee Highway (old location), 1 mile north of Natural Bridge, Rockbridge County. U. S. N. M. 94998.



Chepultepec and Beekmantown Fossils



CHEPULTEPEC AND BEEKMANTOWN FOSSILS

PLATE 68.—CHEPULTEPEC AND BEEKMANTOWN FOSSILS

FIGURE

1, 2. *Clarkoceras* sp.

Edge and side views of same specimen. Chepultepec residual chalky chert; along U. S. Route 25 and in shallow ravine by house below Gobblers Knob 3½ miles southeast of Cumberland Gap village, Tennessee. (See Middlesboro sheet.) U. S. N. M. 97285.

3. *Dakeoceras?* sp.

Natural longitudinal section in limestone. Such fossils are generally distributed in the Chepultepec but scarce and hard to find. Along State Route 501 at top of hill 3 miles northwest of Lexington, Rockbridge County. U. S. N. M. 97286.

4. *Dakeoceras* sp.

Outline of lower end restored. Chepultepec limestone; slope 50-100 feet above road and three-fourths of a mile northeast of Cambria, Montgomery County. U. S. N. M. 97287.

5. *Levisoceras* sp.

Chepultepec limestone; 500 feet northeast of the road 1 mile northwest of Fishers Hill, Shenandoah County. U. S. N. M. 97288.

6. *Hemithecella expansa* Ulrich and Bridge, n. gen. and sp.

Dorsal view. Chepultepec formation in an old quarry one-fourth mile southeast of the Lee Highway and about 6 miles northeast of Bristol, Washington County. Figured specimen: U. S. N. M. 97289. A thin, transversely arched, triangular plate, broadest and highest anteriorly, tapering posteriorly to a slender spine, the dorsal longitudinal profile concave upward, ventral profile flat. Anterior end with a shallow, central emargination, the extremities evenly rounded to join the lateral margins. A thin septum in the posterior third of the shell, parallel to and almost in the plane of the ventral margin. In internal molds this septum is indicated by two spines along the median line, placed one above the other, the upper one shorter than the lower. Surface of internal molds smooth; outer surface marked by growth lines which parallel the curvature of the anterior margin. The genus resembles *Hyolithes,* but is proportionately much broader, and differs in the sinuate anterior margin, the concave dorsal profile and in the lack of a continuous ventral plate. Genotype:—*Hemithecella expansa*

FIGURE

Ulrich and Bridge, n. sp. Length 25 mm., breadth 20 mm., height at anterior end 7 mm., depth of anterior emargination 4 mm. The unfigured holotype, U. S. N. M. 96211, is from the Gasconade chert of Camden County, Missouri. Sections and fragments of these forms are of occasional occurrence in the Chepultepec limestone throughout Virginia. Numbers of specimens occur in dolomite at the top of the Natural Tunnel, Scott County, at the south portal. They are very obscure on the weathered surfaces of the limestone and hard to find. They are known elsewhere in the Gasconade formation of Missouri with which the Chepultepec is correlated on the basis of a good many fossils in common, and the limestone containing these forms in Virginia is, therefore, correlated with the Chepultepec and Gasconade.

7. *Sinuopea* aff. *S. basiplanata* Ulrich and Bridge.

Chepultepec limestone; along State Route 91 at intersection with northeast road 2 miles south of Saltville, Smyth County. U. S. N. M. 97290.

8, 9. *Helicotoma uniangulata* (Hall).

Internal molds in chalky chert. 8, top; 9, side view of another specimen showing the lateral profile characteristic of *Helicotoma*. Note the ridge toward the outer margin of 8, which suggested the name *uniangulata*. Occurrence as 1. U. S. N. M. 97291a, 97291b.

10. *Ozarkispira subelevata* Ulrich and Bridge, n. sp.

Chepultepec formation; along road three-fourths of a mile northwest of Indian Rock, Botetourt County. Figured specimen: U. S. N. M. 97292. Diameter 14 to 16 mm., height 3 mm.; whorls, about 6, narrow, very slowly enlarging, about 1.5 mm. across the top, flat across the top, smoothly rounded and slightly embracing the preceding whorl on the umbilical side; apical angle 170 to 180 degrees; distinguished from *O. rotuliformis* (Meek)=*O. leo* Walcott, by its larger size and greater apical angle. The unfigured cotypes, U. S. N. M. 96210, of this species are from the Ellenburger limestone of Texas.

11. *Ophileta* sp.?

Chepultepec limestone; along Southern Railway at crossing of Linwood Street in Bristol, Tenn. U. S. N. M. 97293.

FIGURE

12. *Ophileta* cf. *O. complanata* Vanuxem.

Internal mold. Chepultepec or Stonehenge limestone; about 4 miles north-northeast of Middletown, Frederick County. U. S. N. M. 97294.

13. *Eccyliomphalus* sp.?

Internal mold and section. Occurrence as 12. This type is rather common in the Chepultepec. U. S. N. M. 97295.

14–16. *Lophonema?* sp.

14, apical view, impression of the external mold shown in 16 (lower); 15, side view of an impression of the external mold of the body whorl of another specimen and perhaps another species, to show character of ornamentation; 16, internal mold (upper right) of umbilical side of a specimen. Beekmantown, *Ceratopea* zone; along road 1¼ miles northeast of Bolar, Bath County. U. S. N. M. 97296a, 97297, 97296b.

17, 18. *Gasconadia putilla* (Sardeson).

Chepultepec limestone; in old quarry about one-fourth of a mile southeast of the Lee Highway and 6 miles northeast of Bristol, Washington County. *Gasconadia* is a widely distributed Chepultepec or Gasconade genus. U. S. N. M. 97298a, 97298b.

19. *Eccyliopterus* sp.?

Internal mold of the umbilical side. Occurrence as 11. U. S. N. M. 97299.

20, 21. *Syntrophina* aff. *S. campbelli* (Walcott), × 2.

Internal molds. Ventral and dorsal views of same specimen. Beekmantown, Nittany? horizon; from chert at the base of steep slope just southeast of State Route 71 and about half a mile east of Bolton, Russell County. Associated pieces of chert contain specimens of *Lecanospira* and *Hystricurus* which prove their Nittany age. U. S. N. M. 97300.

22. *Jeffersonia* sp.

Internal mold of head in chert, dorsal view. Beekmantown, horizon of Jefferson City limestone of Missouri lying between the *Lecanospira* and *Ceratopea* zones; along road 1½ miles southeast of Whites Mill, Washington County. U. S. N. M. 97301.

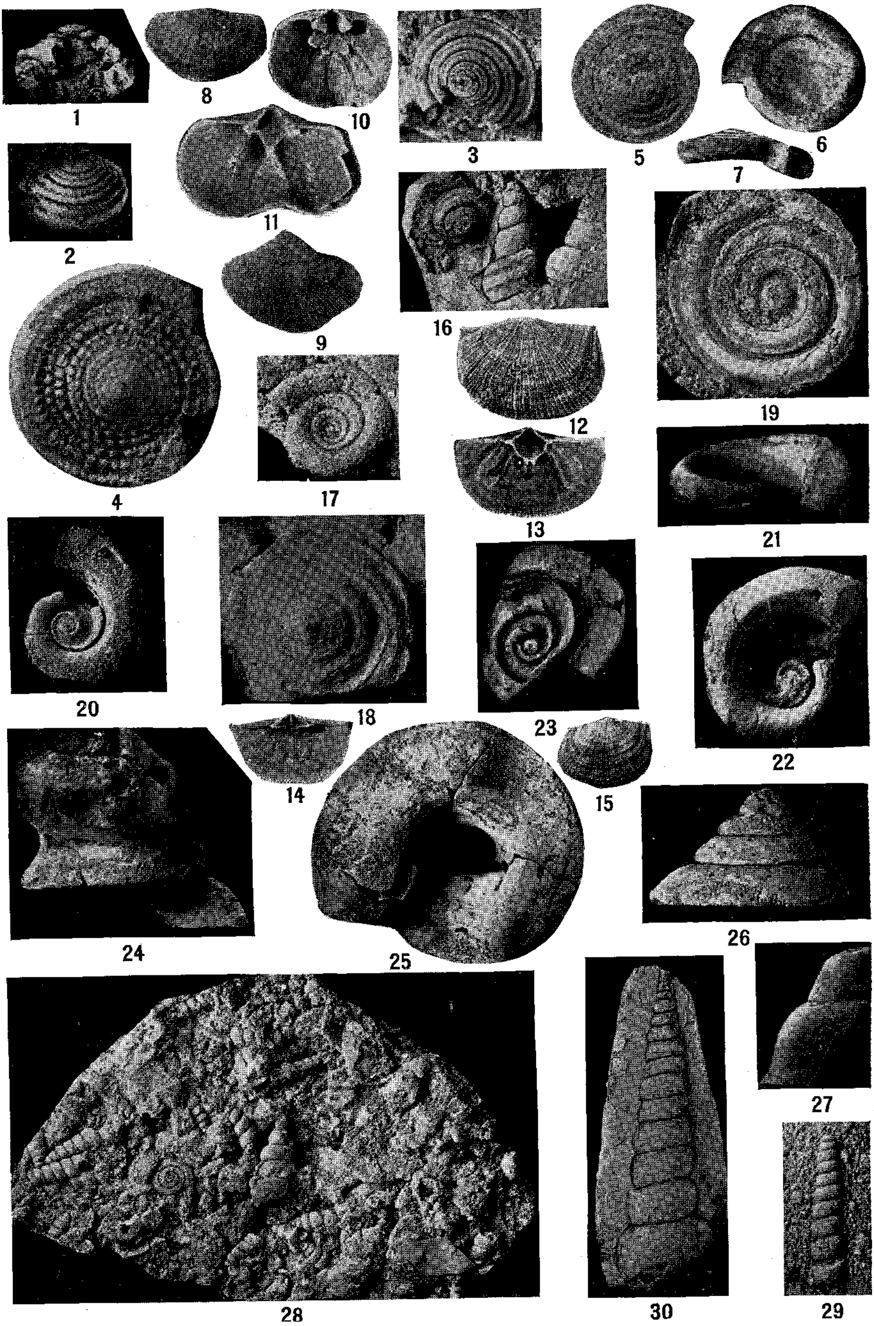
FIGURE

23–25. *Bathyurus?* sp., × 2.

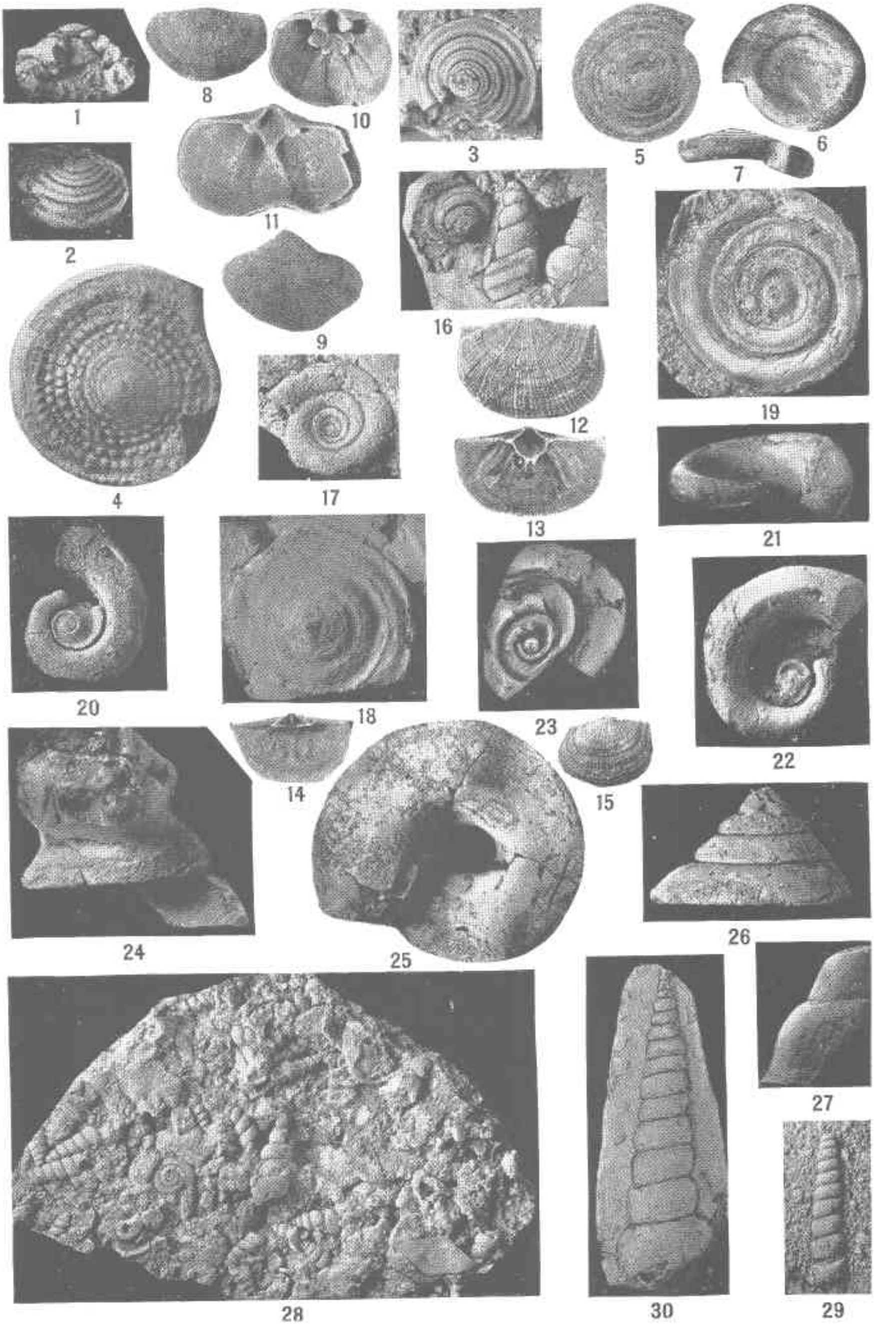
Internal molds in chert. 23, head, dorsal view; 24, dorsal, 25, side view of a tail. Beekmantown, *Ceratopea* horizon; along State Route 91 about 2½ miles south of Saltville, Smyth County. 23, U. S. N. M. 97302a; 24, 25, 97302b.

26–29. *Hystricurus conicus* (Billings).

Internal molds. 27, × 2; 26-28, heads, dorsal views; 29, tail, dorsal view. Beekmantown, *Lecanospira* zone. 26, 29, near summit of Gobblers Knob about 100 feet directly above the locality of the Chepultepec species shown in 1, associated with *Lecanospira;* 27, occurrence as 20; 28, occurrence as 22. U. S. N. M. 97304a, 97305, 97303, 97304b.



CHEPULTEPEC AND BEEKMANTOWN FOSSILS



CHEPULTEPEC AND BEEKMANTOWN FOSSILS

PLATE 69.—CHEPULTEPEC AND BEEKMANTOWN FOSSILS

FIGURE

1–3. *Orospira* sp.

1, 3, internal molds; 1, profile view showing section as exposed in broken part of 3; 3, apical view; 2, wax impression of the external mold of the original shell covering the upper side of 3, showing the character of the external surface of the shell. Beekmantown, *Ceratopea* zone; chert pile at a point 4¼ miles nearly north of Roanoke, which contains a mixture from different zones, such as *Lecanospira salteri* (Pl. 70, fig. 10). 1, 3, U. S. N. M. 97314a; 2, 97314b.

4. *Orospira* sp.

Impression from an external mold of the upper surface showing well the prominent nodes on the whorls characteristic of the genus. Beekmantown, *Ceratopea* zone; along road about 6½ miles west-southwest of Greenville, Augusta County. U. S. N. M. 97315.

5–7. *Orospira?* sp.

Bears some resemblance to *Ophileta*. Internal molds. Apical, umbilical, and side views. Spire of 7 restored in photograph. Beekmantown, *Ceratopea* zone; along U. S. Route 21 about 1¼ miles east of Sharon Springs, Bland County. U. S. N. M. 97316.

8–11. *Tetralobula delicatula* Ulrich and Cooper, × 2.

8, dorsal valve; 9, ventral valve; 10, interior of a dorsal valve; 11, interior of a ventral valve. Chepultepec limestone; along road midway between Quicksburg and Forestville, Shenandoah County. U. S. N. M. 91094g, 91094b, 91094j, 91094f.

12–15. *Finkelnburgia buttsi* Ulrich and Cooper.

12, 13, exterior and interior of a ventral valve, × 1⅓; 14, 15, interior and exterior of a dorsal valve, × 2. Occurrence as 8. U. S. N. M. 91380a, 91380k, 91380d, 91380c.

16. *Hormotoma?* sp. and *Lophonema* sp.

Lophonema in upper left corner. Impression from external molds. Occurrence as 5. U. S. N. M. 97317.

17, 18. *Ophileta* sp.

Probably 2 sp.; 17, internal mold of the umbilical side of a specimen; 18, poorly preserved internal mold of the upper

FIGURE

side of another specimen. Beekmantown, *Lecanospira* zone. 17, 2½ miles east of the railroad station, Bluefield, W. Va.; 18, along U. S. Route 33, 1½ miles southwest of Keezletown, Rockingham County. U. S. N. M. 97318, 97319.

19. *Ophileta* cf. *O. solida* Butts.

Impression of an external mold of the upper side. Beekmantown, probably *Ceratopea* horizon; from stone fence along highway about 2¼ miles northeast of Blacksburg and three-fourths of a mile west of Lusters Gate, Montgomery County.

The specimens of *Ophileta* figured are not good. Specimens representing several species are common in the Beekmantown and the underlying Chepultepec. (See Geology of Alabama, Ala. Geol. Survey, Spec. Rept. No. 14, Pl. 16, Figs. 11, 14, 15-18 for better representations of the genus.) U. S. N. M. 97320.

20–22. *Eccyliopterus* sp.?

Internal molds. 20, umbilical view of a specimen; 21, 22, side and apical views of another specimen. Beekmantown, base of the Nittany; half a mile south of Loves Mill and 16 miles east of Abingdon, Washington County. 20, U. S. N. M. 97321a; 21, 22, 97321b.

23. *Maclurites affinis* (Billings)?

A poorly preserved internal mold of the lower side of a specimen in chert, provisionally referred to this species. Beekmantown, *Ceratopea* zone; along road about 3 miles southeast of Moscow, Augusta County. A rather common fossil of the Axemann limestone between the *Lecanospira* and *Ceratopea* zones in Central Pennsylvania. U. S. N. M. 97322.

24–27. *Roubidouxia,* 2 sp.

24, 25, 27, seem to be *R. umbilicata* Ulrich and Bridge; 26, may be a different species with narrower whorls and slightly different contour of the sides of the shell with the sutures less deeply impressed; 24-26, internal molds in chert; 27, impression of an external mold of two whorls showing the external contour of the shell; 24, side view showing the shape of the whorls (transverse section of the basal whorl); 25, basal view of 24, showing the umbilicus; 26, side view of a nearly complete shell, probably another whorl or two at the apex not preserved. Beekmantown, Nittany zone. 24, 25,

FIGURE

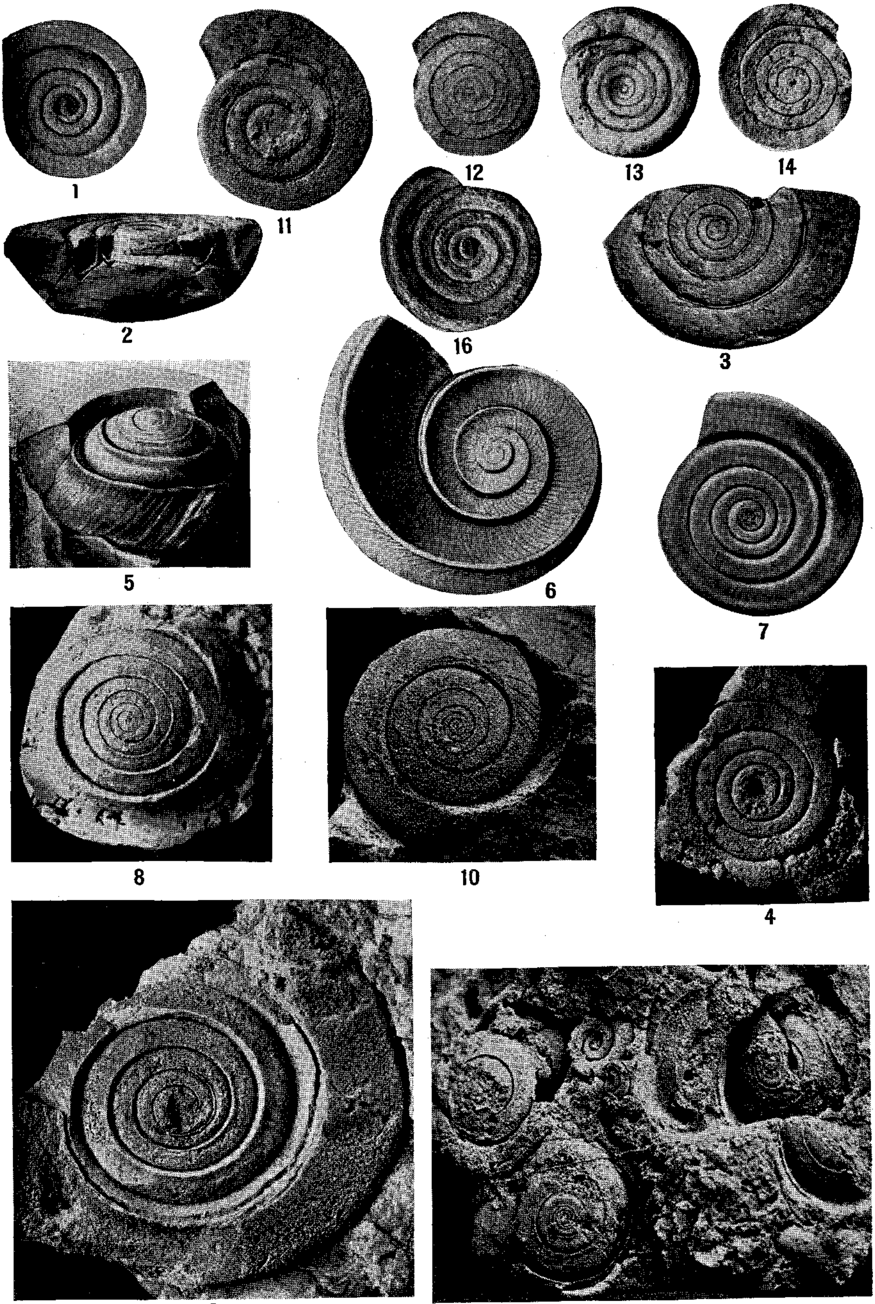
about half a mile northeast of Nickelsville, Scott County; 26, along back road to Max Meadows 1 mile northeast of Wytheville, Wythe County; 27, locality as 17. *Roubidouxia* is a unique and easily identifiable shell, fairly common and widely distributed, everywhere associated with *Lecanospira,* and equally characteristic of the Nittany horizon of the Beekmantown. 24, 25, U. S. N. M. 97323; 26, 97324; 27, 97325.

28, 29. *Coelocaulus delicatulus* Butts, n. sp.

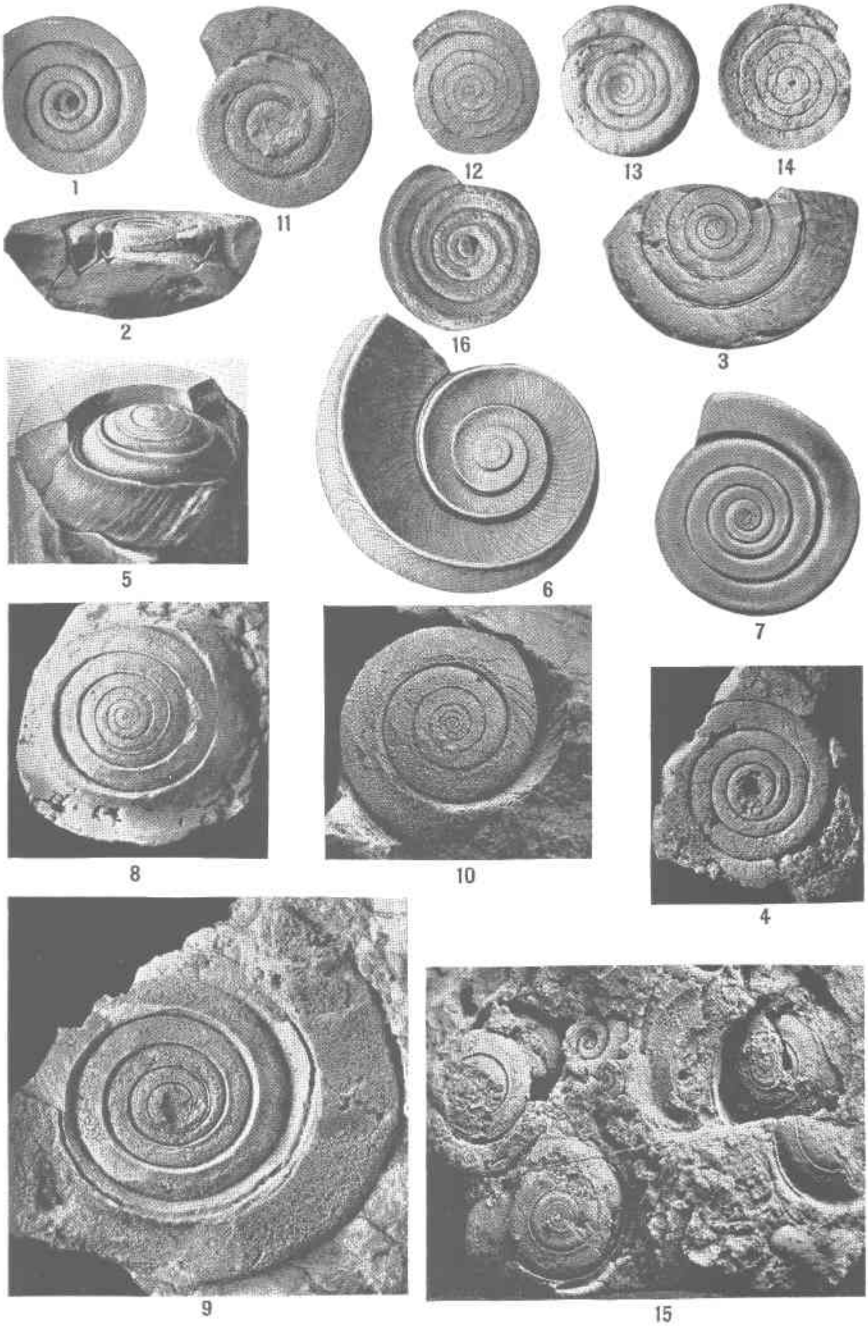
Distinguished from *C. linearis* (Billings) by its smaller size and fewer whorls. 29, × 2. Beekmantown, *Ceratopea* zone; along road at head of Rattle Creek (Bristol quadrangle) 3 miles northwest of Abingdon and one-eighth of a mile south of road intersection. This species is common in the spongy chert of the uppermost beds of the Beekmantown in southwestern Virginia, commonly associated with *Orospira.* Cotypes: U. S. N. M. 97326a, 97326b.

30. *Coelocaulus* sp.?

Impression of an external mold in chert. Beekmantown, *Ceratopea* zone; 1 mile northwest of Old Sweet Springs, W. Va. U. S. N. M. 97327.



BEEKMANTOWN FOSSILS



BEEKMANTOWN FOSSILS

PLATE 70.—BEEKMANTOWN FOSSILS

FIGURE

1-7, 16. *Lecanospira compacta* (Salter).

1, 3, 4, 7, internal molds, umbilical views (7, after Salter); 16, internal mold of depressed spire of 1; 2, natural section of 3, showing shape of whorls; 5, oblique view showing shape of whorls, part of umbilical surface of an outer whorl, and external mold of depressed spire; 6, restoration of exterior of spiral surface. Beekmantown, Nittany horizon. 1-3, 16, Morristown, Tenn., collected by Charles T. Cate; 4, Sinking Creek Valley, Craig County; 5-7, Beauharnois near Montreal, Canada, after Salter, Canadian Organic remains, Decade 1, p. 16, Pl. 3, 1859. 1, 16, U. S. N. M. 97306a; 2, 3, 97306b; 4, 97307.

8, 9. *Lecanospira sigmoidea* Ulrich and Bridge?

External molds of the depressed spire. 9, preserves part of the internal mold of the body whorl, on the right. The external mold of the depressed spire is the most characteristic expression of the fossils of this genus and the most certain criterion for its identification. Beekmantown, Nittany horizon. 8, occurrence as 1; 9, along State Route 80 about half a mile northwest of Blackford, Russell County. U. S. N. M. 97308, 97309.

10. *Lecanospira salteri* Ulrich and Bridge.

Beekmantown, Nittany horizon; pile of chert about 1 mile due south of Hollins College and 4½ miles nearly north of Roanoke, Roanoke County. U. S. N. M. 97310.

11. *Lecanospira* sp.?

Seems to differ from the other species figured by fewer and more rapidly expanding whorls. Beekmantown, Nittany horizon; along road, 800 feet northeast of Draper, Pulaski County. U. S. N. M. 97311.

12–14. *Lecanospira* cf. *L. biconcava* Ulrich and Bridge.

Differs from other species of *Lecanospira* in the more shallow concave spire and the slightly concave umbilical surface. 12. wax impression of the concave spiral surface shown in 14, convex toward the observer; 13, internal mold of the umbilical surface; 14, internal mold of the spiral surface. Basal beds of the Beekmantown; ridge just south of Wassum

FIGURE

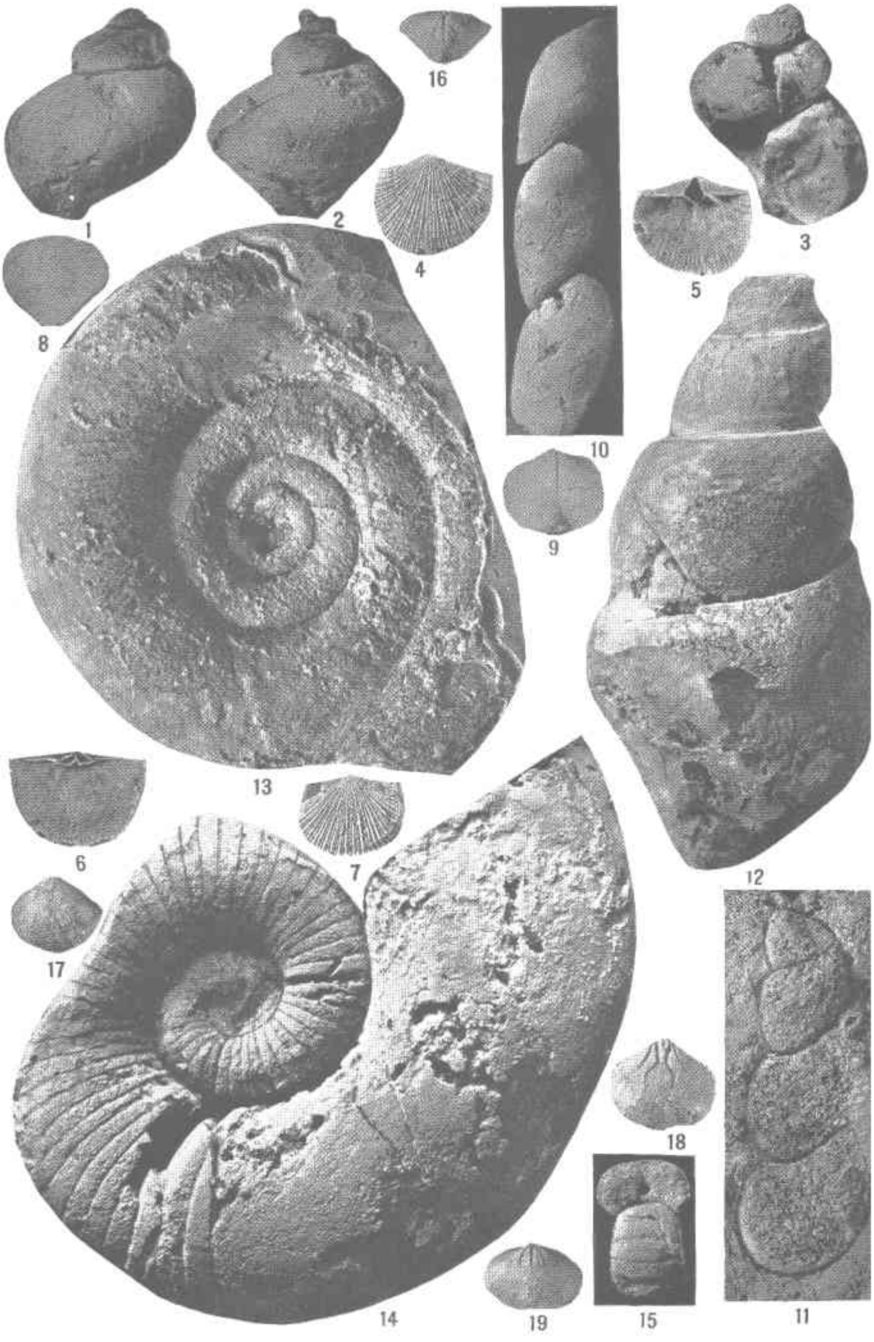
Valley and 4 miles northwest of Marion, Smyth County. This seems to be about the oldest known form of *Lecanospira.* U. S. N. M. 97312.

15. *Lecanospira* sp.

Slab with several specimens. Beekmantown, Nittany horizon; top of Cave Hill directly above the Luray Caverns, Page County. U. S. N. M. 97313.

The entire genus *Lecanospira* is confined to the lower 1000 feet or less of the Beekmantown which is, therefore, known as the *Lecanospira* zone. It occurs in that zone throughout a broad belt extending from the northwest Highlands of Scotland, throughout Newfoundland, Quebec, and the Appalachian Valley to Texas and the Arbuckle Mountains of Oklahoma. It is one of the most persistent and easily identified guide fossils known.

BEEKMANTOWN FOSSILS



Beekmantown Fossils

PLATE 71.—BEEKMANTOWN FOSSILS

FIGURE

1–3. *Plethospira* aff. *P. cassina* (Whitfield).

Internal molds. 3, side showing aperture of 1. Beekmantown, *Ceratopea* zone. 1, 3, northwest slope of Chestnut Ridge about 2 miles east-southeast of Harrisonburg, Rockingham County; 2, north end of spur in north meander of Clinch River, just west of 82d meridian and 4 miles southwest of Blackford, Russell County. 1, 3, U. S. N. M. 97340; 2, 97341.

4–7. *Finkelnburgia virginica* Ulrich and Cooper, × 1⅓.

Silicified specimens etched from limestone. 4, 5, exterior and interior of a ventral valve; 6, interior of dorsal valve; 7, exterior of dorsal valve. Beekmantown limestone, Nittany horizon; in old quarry just northeast of Middletown-Marlboro road about 3 miles northwest of Middletown, Frederick County. 4, 5, U. S. N. M. 91410c; 6, 91410a; 7, 91410d.

8, 9. *Syntrophina campbelli* (Walcott), × 1⅓.

8, dorsal; 9, ventral view. Chepultepec? horizon; about one-fourth of a mile northeast of Tenn. Route 32 and 2 miles northwest of Tazewell, Claiborne County, Tenn. This specimen, like specimen of Pl. 68, figs. 20 and 21, was collected from a pile of chert which also contained *Lecanospira*, making its reference to the Chepultepec doubtful. U. S. N. M. 91615.

10. *Hormotoma longispira* Butts, n. sp.

Distinguished from *Hormotoma gracilens* by the large, elongate, loosely coiled, and relatively slender whorls. Beekmantown, Nittany horizon; 1¼ miles northeast of the railroad station, Cloverdale, Roanoke County. Holotype: U. S. N. M. 97342.

11. *Hormotoma* sp.?

Internal mold in chert. Beekmantown, Nittany zone; Yellow Branch, 4½ miles east-southeast of Rose Hill, Lee County. U. S. N. M. 97343.

12. *Fusispira obesa* (Whitfield).

Internal mold in chert. Beekmantown, *Ceratopea* zone; along road on Snake Run 1½ miles northeast of Iron Hill Springs, Alleghany County. U. S. N. M. 97344.

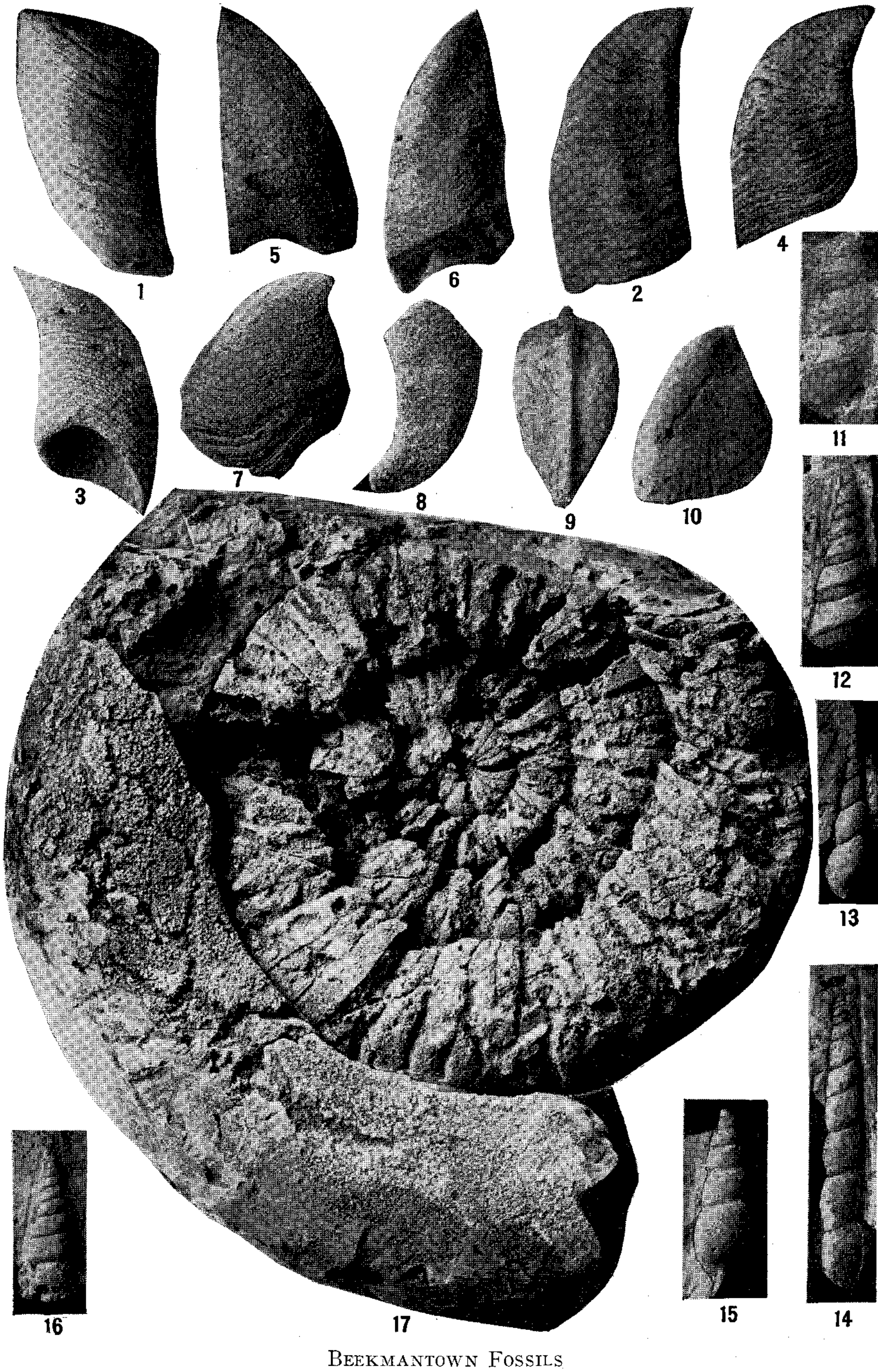
FIGURE

13. Coiled cephalopod, genus and species undescribed.
    Plaster cast of an external mold. Beekmantown, *Ceratopea* zone near top; along road about 1¼ miles northeast of Bolar, Bath County. U. S. N. M. 97345.

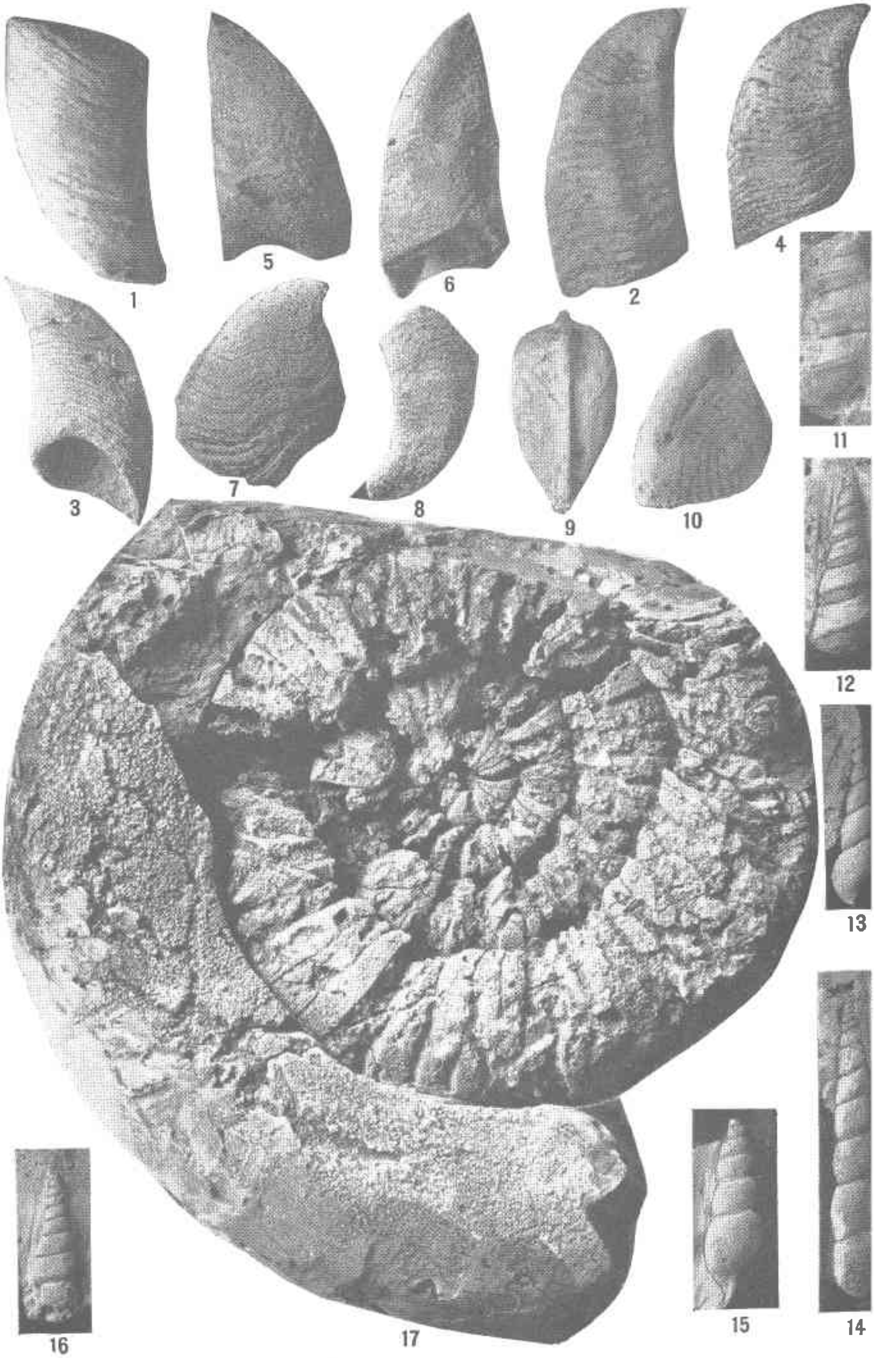
14. *Campbelloceras virginianum* (Hyatt) emend Foerste.
    Internal mold in chert. Beekmantown, *Ceratopea* zone; Brushy Hills 2 miles northwest of Lexington, Rockbridge County. U. S. N. M. 9611.

15. *Tarphyceras?*
    Inner whorls showing shape of whorls and position of siphuncle. Beekmantown, *Ceratopea* zone; exact locality not known.

16–19. *Xenelasma syntrophoides* Ulrich and Cooper.
    16, 19, internal molds of a dorsal valve, different poses of same specimen; 17, exterior of ventral valve; 18, internal mold of ventral valve. 16, 17, 19, × 1⅓; 18, × 2. Beekmantown, *Lecanospira* zone?; chert pile in field 1¼ miles due south of Hollins College, Roanoke County. The doubt about the horizon of this species arises from the fact that pieces with *Lecanospira* (Pl. 70, fig. 10) and other pieces with *Orospira* (Pl. 69, figs. 1-3) are found in the same chert pile, thus indicating that material from both the *Lecanospira* and *Ceratopea* horizons are mixed. 16, 19, U. S. N. M. 91684b; 17, 91684j; 18, 91684l.



BEEKMANTOWN FOSSILS



BEEKMANTOWN FOSSILS

PLATE 72.—BEEKMANTOWN FOSSILS

FIGURE

1–4. *Ceratopea* sp. (Operculum of unknown gastropod.)

1, 2, opposite sides of a specimen; 3, 4, opposite sides of another specimen. Beekmantown, *Ceratopea* zone. 1, 2, Falling Spring Valley, in angle between U. S. Route 220 and Warm Springs Mountain road to Clifton Forge about one-eighth of a mile northeast of Bath County line; 3, 4, Smithville, Ark. 1, 2, U. S. N. M. 97328; 3, 4, 97330.

5, 6. *Ceratopea keithi* Ulrich.

Opposite sides of a silicified specimen etched from limestone with acid. Beekmantown, *Ceratopea* zone; along Denton Branch at road intersection about three-fourths of a mile southeast of Holston River and 7 miles slightly southeast of Abingdon, Washington County. U. S. N. M. 97329.

7. *Ceratopea tennesseensis* Oder.

Beekmantown, *Ceratopea* zone; one-fourth of a mile north of Middle River and half a mile northwest of the Lee Highway, Augusta County. U. S. N. M. 97331.

8. *Ceratopea subconica* Oder.

Occurrence as 7. U. S. N. M. 97332.

Ceratopea is as characteristic of the upper part of the Beekmantown as *Lecanospira* is of the middle part. It occurs in the Jefferson City and higher members of the Beekmantown in Arkansas and Missouri, in the Newala limestone of Alabama, and in the Bellefonte dolomite of Pennsylvania, and has not been found in any other part of the geological column.

9, 10. *Euchasma blumenbachi* (Billings)?

A bivalve crustacean; internal mold; hinge and lateral views; 10, shows faintly the radiating ribs, very similar to, if not identical with, Billings, species. Beekmantown, *Ceratopea* zone; Brushy Hills about 2 miles northwest of Lexington, Rockbridge County. It is associated with *Campbelloceras virginianum*. (See Pl. 71, fig. 14.) U. S. N. M. 97333.

11. *Ectomaria?* sp.

Internal mold in chert. Beekmantown, *Ceratopea* zone; along road 1¼ miles east-northeast of Sharon Springs, Bland County. U. S. N. M. 97334.

FIGURE

12. *Lophospira* sp.?
    Internal mold in chert. Occurrence as 11. U. S. N. M. 97335.

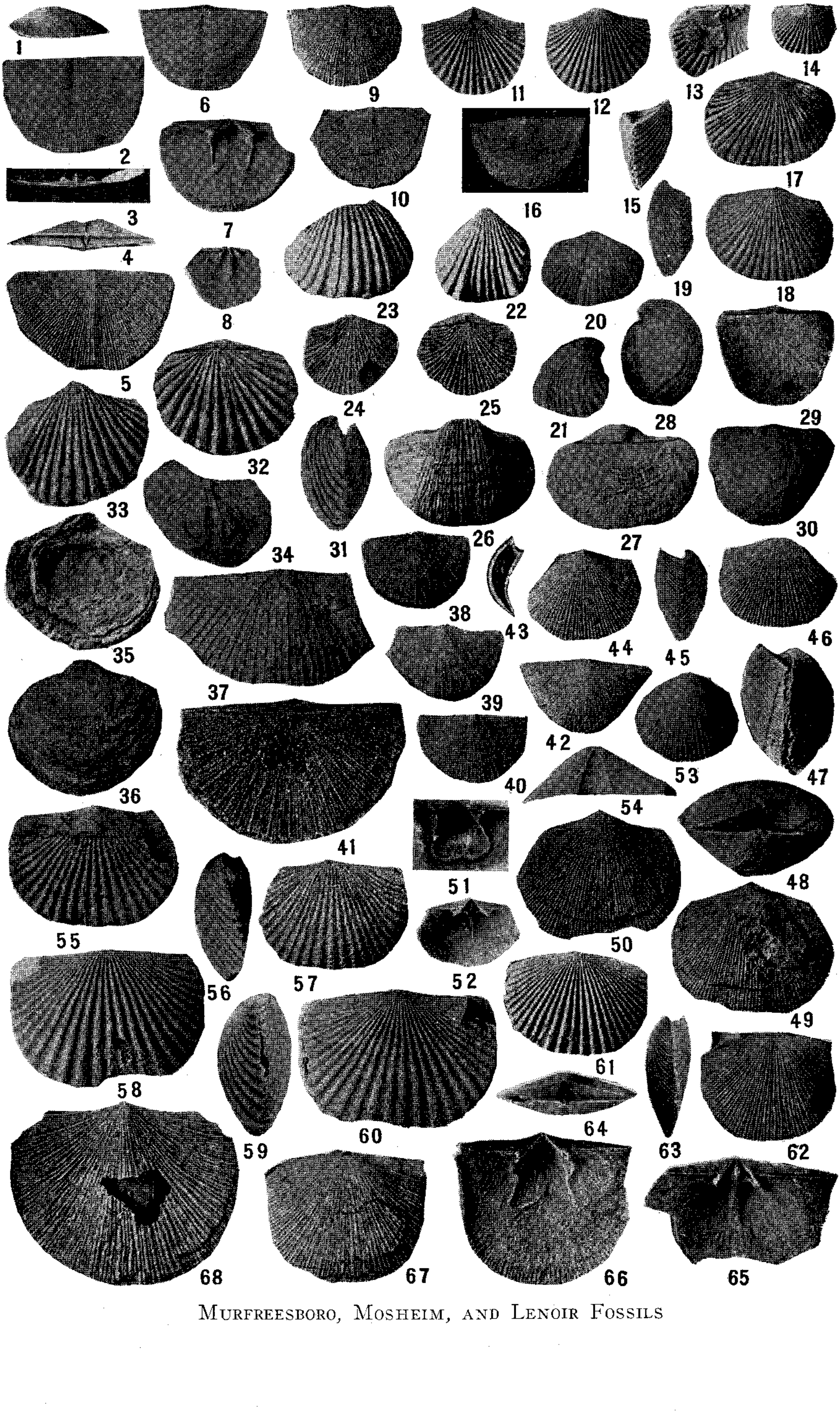
13. *Hormotoma* aff. *H. artemesia* (Billings).
    Internal mold in chert. Beekmantown, *Ceratopea* zone; Sugar Loaf knob 10 miles west of Staunton, Augusta County. U. S. N. M. 97336.

14. *Hormotoma* sp.?
    Internal mold. Occurrence as 11. U. S. N. M. 97337.

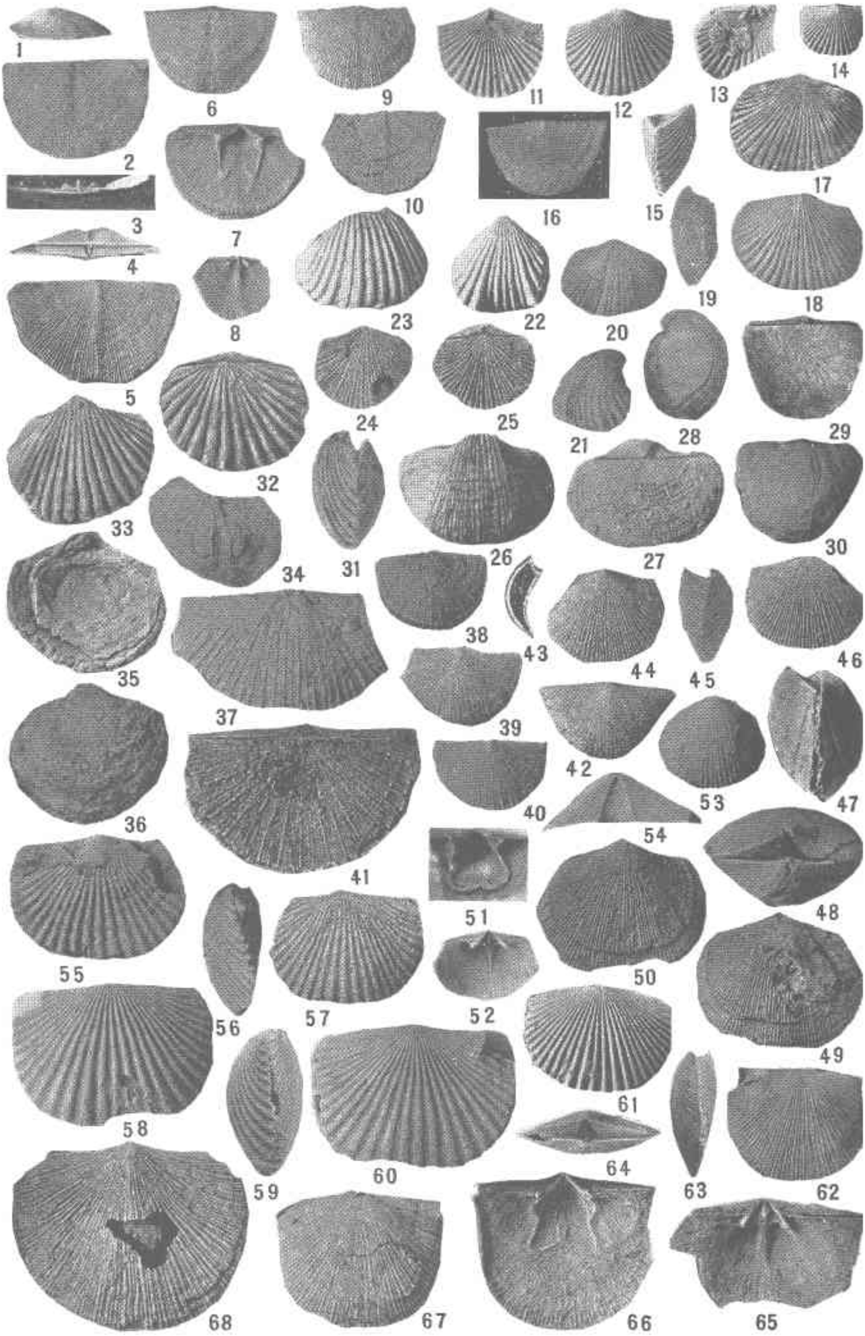
15. *Hormotoma gracilens* (Whitfield).
    Internal mold in chert. Beekmantown, *Lecanospira* zone; along U. S. Route 33 about 1½ miles south-southwest of Keezletown, Rockingham County. U. S. N. M. 97338.

16. *Turritoma acrea* (Billings).
    Internal mold in chert. Occurrence as 1. U. S. N. M. 97339.

17. *Centrotarphyceras macdonaldi* (Hyatt).
    Internal mold in chert. Beekmantown, *Ceratopea* zone; half a mile west of Strasburg Junction, Shenandoah County. U. S. N. M. 97496.



Murfreesboro, Mosheim, and Lenoir Fossils



MURFREESBORO, MOSHEIM, AND LENOIR FOSSILS

PLATE 73.—MURFREESBORO, MOSHEIM, AND LENOIR FOSSILS

FIGURE

1–10. *Valcourea strophomenoides* (Raymond).

1, 6, profile and dorsal views of a specimen; 2, 5, dorsal and ventral views of another individual; 3, posterior view of the dorsal valve of another specimen showing prominent hinge teeth and cardinal process; 4, posterior or hinge view of another individual retaining both valves, the dorsal valve above; 7, interior of ventral valve; 8, interior of dorsal valve; 9, 10, dorsal and ventral views of another specimen. Lenoir limestone. 1, 2, 4-8, along Whistle Creek 2 miles northwest of Lexington, Rockbridge County; 3, southeast foot of Brushy Hills 1½ miles due west of Lexington; 9, 10, quarry of Mathieson Alkali Works at Porterfield, 5 miles east of Saltville, Smyth County. 1, 6, U. S. N. M. 98177a; 2, 5, 98177b; 3, 98178; 4, 98177c; 7, 98177d; 8, 98177e; 9, 10, 98179.

11–15. *Hesperorthis* cf. *H. tricenaria* (Conrad).

11, 12, 15, dorsal, ventral, and profile views of the same individual; 14, dorsal valve of a smaller specimen; 13, interior of the dorsal valve of another specimen. Occurrence as 1. 11, 12, 15, U. S. N. M. 98180a; 13, 98180b; 14, 98180c.

16. *Rafinesquina* sp.

Ventral valve. Lenoir limestone; North Fork of Roanoke River 3 miles southeast of Blacksburg, Montgomery County. U. S. N. M. 98217.

17–19. *Plectorthis exfoliata* (Raymond)?.

Dorsal, ventral, and profile views of the same individual. Lenoir limestone; quarry at Marion, Smyth County. Rare. U. S. N. M. 98181.

20, 21. *Oxoplecia transversa* Butts, n. sp.

Distinguished by its width relative to its length. 20, dorsal; 21, profile view of a specimen. Stones River (Murfreesboro) limestone; Rye Cove, Scott County. Holotype: U. S. N. M. 98182.

22, 23. *Camarotoechia plena* (Hall)?

Dorsal and ventral valves. Lenoir limestone; Marcem quarry 2 miles west of Gate City, Scott County. U. S. N. M. 98220a, 98220b.

FIGURE

24, 25. *Dalmanella?* sp., × 4.

Ventral and dorsal views. Holston limestone; locality as 9. U. S. N. M. 98183.

26–28. *Productorthis* sp.

Ventral, dorsal, and profile views of the same individual. Occurrence as 17. Rare, only this specimen and a fragment of another found. This and a few specimens, possibly another species, in the Holston limestone at the Porterfield quarry, Smyth County, and at McNutt quarry near Sharon Springs, Bland County, (Pl. 80, figs. 4-10) are the only known occurrences of this genus in America. Its main occurrence is in the Baltic regions of Europe whence it invaded America in Lenoir and Holston times. U. S. N. M. 98184.

29, 30. *Rafinesquina* cf. *R. minnesotensis* (Winchell).

Dorsal and ventral views of the same individual. Lenoir limestone; Pearisburg, Giles County. U. S. N. M. 98185.

31–33. *Hebertella?* sp.

31, 32, profile and dorsal views of the same individual; 33, ventral view of another specimen. Occurrence as 17. 31, 32, U. S. N. M. 98221a; 33, 98221b.

34–36. *Christiania?* cf. *C. lamellosa* Bassler.

34, interior of ventral valve; 35, 36, dorsal and ventral views of the same specimen. Occurrence as 17. 34, U. S. N. M. 98214a; 35, 36, 98214b.

37. *Sowerbyites* sp., × 3.

Occurrence as 9. U. S. N. M. 98186.

38–41. *Sowerbyella* sp.

38-40, ventral views of 3 small specimens, × 2; 41, dorsal view of 40, × 4. Occurrence as 9. Abundant in same bed with *Monotrypa*. (See Pl. 74, figs. 31-35.) 38, U. S. N. M. 98213a; 39, 98213b; 40, 41, 98213c.

42, 43. *Sowerbyites* sp.

42, ventral view; 43, sectional view showing curvature of valves. Occurrence as 22. U. S. N. M. 98187a, 98187b.

FIGURE

44–52. *Mimella* sp.

44-46, ventral, profile, and dorsal views of the same specimen; 47-50, profile, posterior, ventral, and dorsal views of another individual; 51, interior of ventral valve; 52, interior of dorsal valve. Compare with interior of *Pionodema,* (Pl. 92, fig. 7). 44-46, occurrence as 22; 47-52, occurrence as 1. Common. 44-46, U. S. N. M. 98191; 47-50, 98188a; 51, 98188b; 52, 98188c.

53, 54. *Mimella* sp.

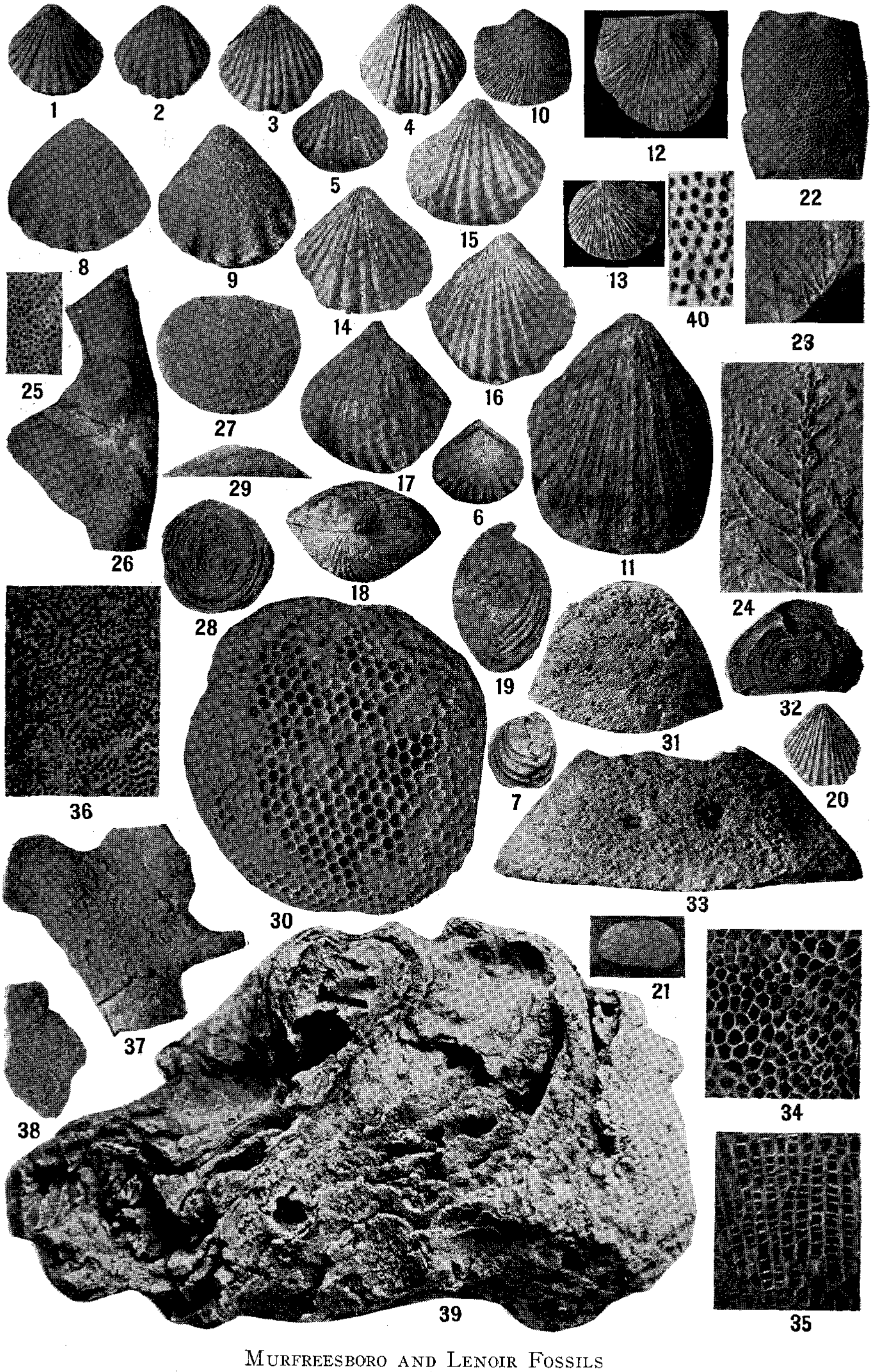
53, ventral valve; 54, posterior view of different specimen. Stones River (Murfreesboro) limestone; Willow Spring, Washington County. U. S. N. M. 98190a, 98190b.

55–61. *Dinorthis atavoides* Willard.

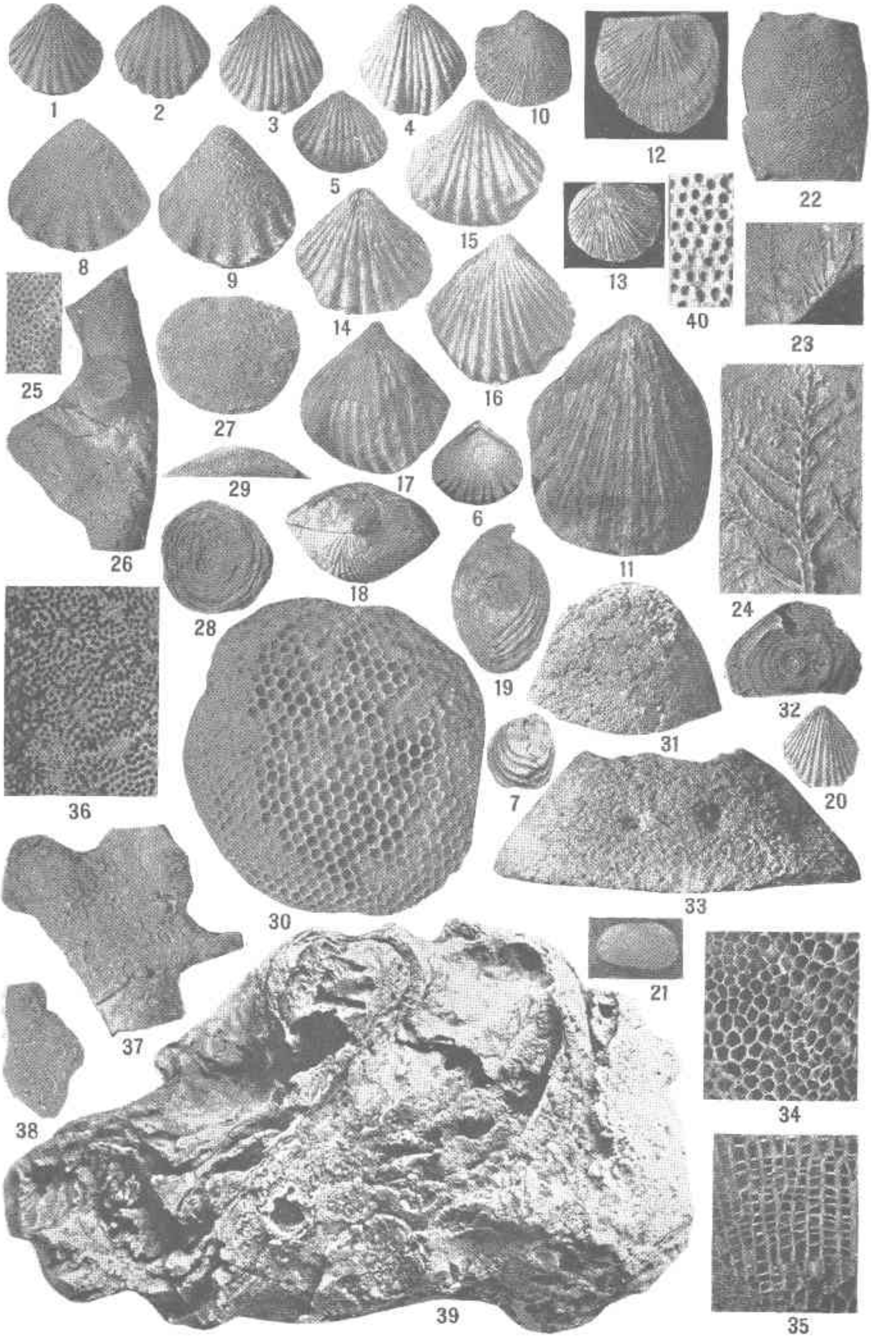
55-57, ventral, profile, and dorsal views of the same individual; 58-60, ventral, profile, and dorsal views of another specimen; 61, ventral view of another specimen. Lenoir limestone. 55-57, Templeton Branch 5 miles northwest of Gate City, Scott County; 58-61, locality as 22. 55-57, U. S. N. M. 98215; 58-60, 98216a; 61, 98216b.

62–68. *Multicostella* cf. *M. platys* (Billings).

62-64, ventral, profile, and posterior views of an individual; 65, interior of a dorsal valve; 66, interior of a ventral valve; 67, dorsal view; 68, ventral views of 2 specimens. Occurrence as 1. 62-64, U. S. N. M. 98189a; 65-68, 98189b, 98189c, 98189d, 98189e.



MURFREESBORO AND LENOIR FOSSILS



MURFREESBORO AND LENOIR FOSSILS

PLATE 74.—MURFREESBORO AND LENOIR FOSSILS

FIGURE

1–7. *Camarella* sp.

1, 2, dorsal and ventral views of an average sized specimen; 3, 4, dorsal and ventral views of a larger specimen; 5-7, ventral, dorsal, and profile views of a small specimen with 4 ribs in the sinus and 5 ribs on the fold. Lenoir limestone; Whistle Creek 2 miles northwest of Lexington, Rockbridge County. 1, 2, U. S. N. M. 98192a; 3, 4, 98192b; 5-7, 98192c.

8. 9. *Camarella varians* Billings? × 4.

Dorsal and ventral views. Lenoir limestone; Yellow Branch 5 miles southeast of Rose Hill, Lee County. Rare, only this one specimen found. U. S. N. M. 98193.

10. *Paurorthis* sp., × 2.

Ventral valve. Stones River limestone; Rye Cove, Scott County. U. S. N. M. 98194.

11–13. *Paurorthis* sp.

11, × 4; 12, 13, × 2. 11, 13, ventral valves; 12, dorsal valve, 3 individuals. Lenoir limestone; quarry at Marion, Smyth County. U. S. N. M. 98195a, 98195b, 98195c.

14–19. *Camarotoechia plena* (Hall)?

14, 15, dorsal and ventral views of an average sized specimen; 16-19, dorsal, ventral, posterior, and profile views of a large specimen. Lenoir limestone; south base of Big A Mountain 3 miles northwest of Honaker, Russell County. 14, 15, U. S. N. M. 98196a; 16-19, 98196b.

20. *Zygospira* (?) cf. *Z. acutirostris* (Hall), × 3.

Stones River (Murfreesboro) limestone; 600 feet south of St. Clair station on Norfolk and Western Railway and 6 miles southwest of Bluefield, W. Va. U. S. N. M. 98197.

21. *Modiolopsis* cf. *M.? consimilis* Ulrich.

Left valve. Residual chert of the Stones River (Murfreesboro) limestone. Associated with abundant small *Leperditia*. Along State Route 8 about 2 miles northeast of Pearisburg, Giles County. U. S. N. M. 98218.

22. *Mesotrypa?* sp.

Occurrence as 11. Rare. U. S. N. M. 98219.

FIGURE

23, 24. *Glauconome* sp.

24, part of 23, × 4. Occurrence as 11. Rare in America, occurs in the Baltic region of Europe. U. S. N. M. 97347.

25, 26. *Dekayella?* sp.

25, part of 26, × 4. Lenoir limestone; Marcem quarry 2 miles west of Gate City, Scott County. Abundant. U. S. N. M. 97348.

27–30. *Monotrypa* sp.

27, view of the celluliferous surface; 29, profile view of the same specimen; 28, epithecal view of a specimen; 30, celluliferous surface of a small specimen, × 4. Occurrence as 11. Abundant. 27, 29, U. S. N. M. 97349a; 28, 97349b; 30, 97349c.

31–35. *Monotrypa* sp.

31, profile view of a zoarium of average size; 32, epithecal view of a smaller specimen; 33, profile view of a large, broken specimen; 34, deep transverse sectional view, × 4; 35, longitudinal section, × 4. Lenoir limestone; quarry of the Mathieson Alkali Works about 5 miles east of Saltville, Smyth County. U. S. N. M. 97350a, 97350b, 97350c, 97350d, 97350e.

36–38. *Constellaria* sp.

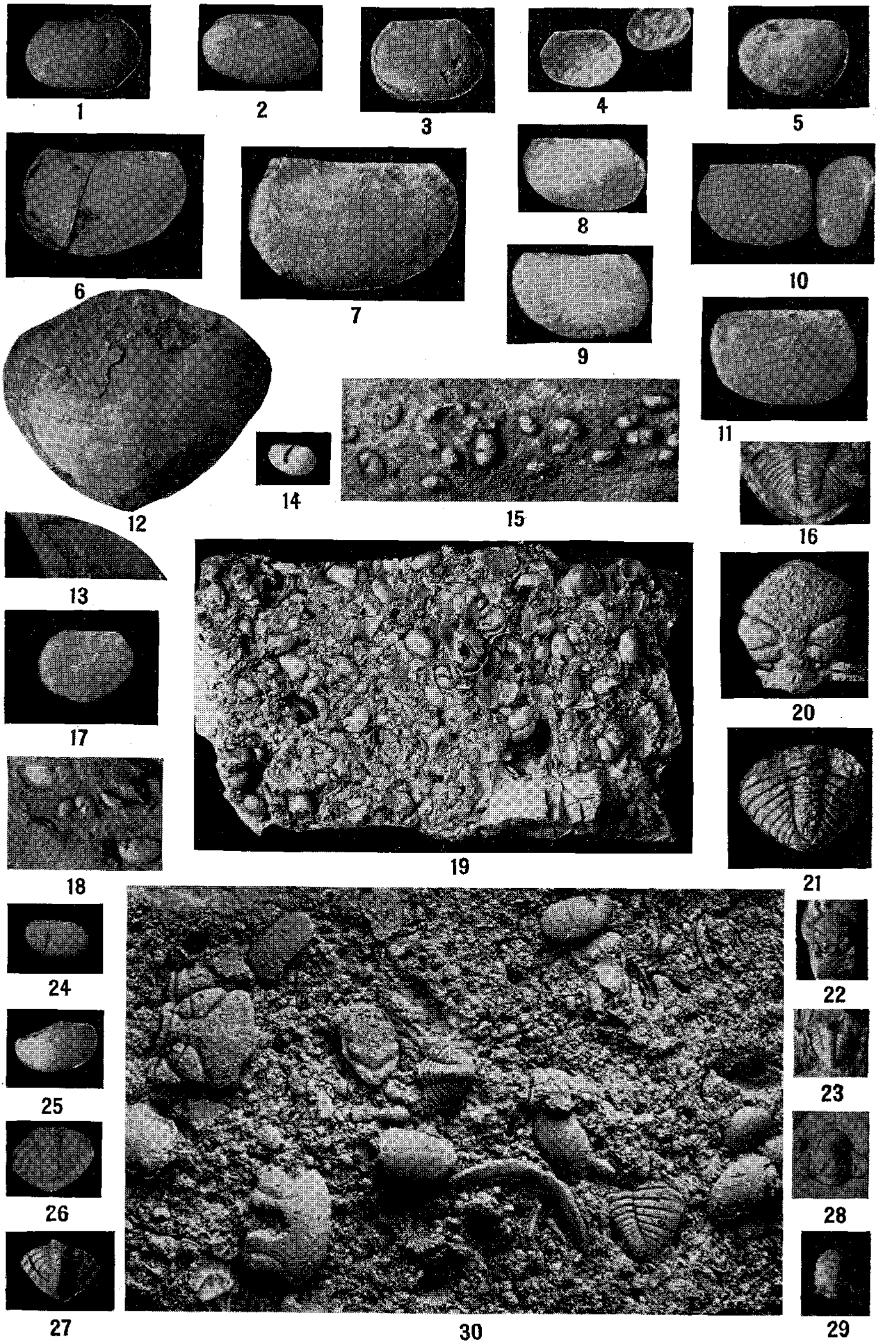
37, 38, two silicified specimens; 36, enlargement of part of 38, × 4. Occurrence as 25. 37, 38, U. S. N. M. 97351b, 97351a.

39. *Monticulipora?* sp.

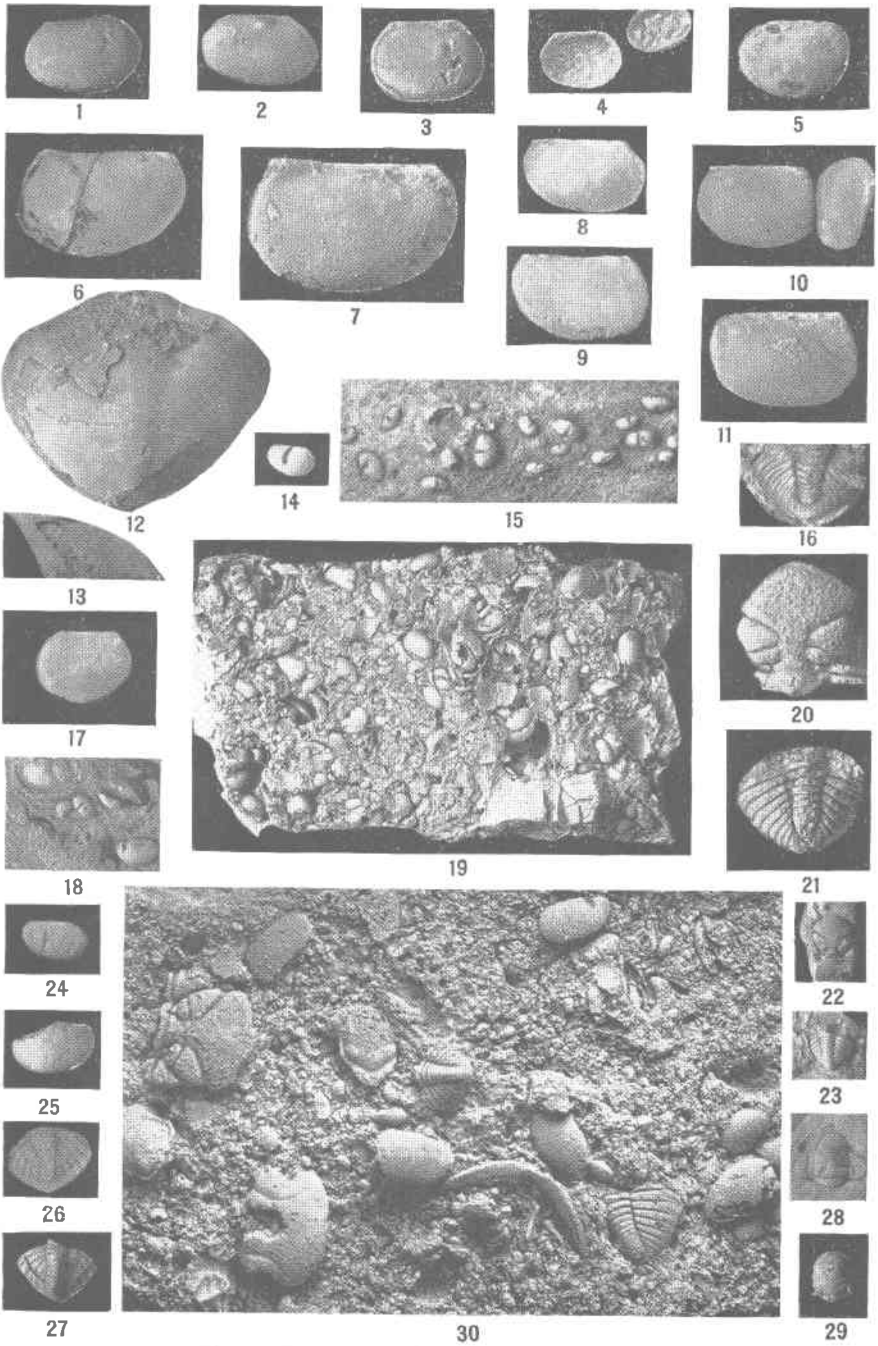
Occurrence as 1 and 25. U. S. N. M. 97352.

40. *Mesotrypa?* sp.

Enlargement from 22, × 4.



MURFREESBORO, LENOIR, AND HOLSTON FOSSILS



MURFREESBORO, LENOIR, AND HOLSTON FOSSILS

PLATE 75.—MURFREESBORO, LENOIR, AND HOLSTON FOSSILS

FIGURE

1, 2. *Isochilina* sp., × 4.

Right and left valves. Lenoir limestone; North Fork Roanoke River about 3 miles southeast of Blacksburg, Montgomery County. U. S. N. M. 97353a, 97353b.

3–5. *Leperditia* sp., × 4.

3, 5, right valves; 4, interior of right valve. Occurrence as 1. U. S. N. M. 97354a, 97354b, 97354c.

6–9. *Isochilina* sp., × 4.

6, 7, right valves; 8, 9, left valves. Stones River (Murfreesboro) limestone; Yellow Branch 5 miles southeast of Rose Hill, Lee County. U. S. N. M. 97355a, 97355b, 97355c, 97355d.

10, 11. *Isochilina* sp., × 4.

Left valves. Stones River (Murfreesboro) limestone; along State Route 58 about 1½ miles west of Jonesboro, Lee County. U. S. N. M. 97356a, 97356b.

12, 13. *Homotelus?* sp.

Dorsal and profile views of a tail. Stones River (Murfreesboro) limestone; Rye Cove, Scott County. U. S. N. M. 97357.

14, 15. *Leperditella?* sp., × 4.

14, left valve; 15, surface of chert nodule with several specimens of both valves. The actual area of 15 is 3 x 10 millimeters. Chert nodules in basal Stones River (Murfreesboro) limestone; 2¾ miles southwest of Rye Cove School, Scott County. These small ostracodes are abundantly sprinkled over the surface of chert nodules in association with *Pterygometopus* and *Bathyurus* shown in 22, 23, 28, 29. U. S. N. M. 97358a, 97358b.

16. [a]*Pterygometopus* cf. *P. annulatus* Raymond, × 2.

Tail. Horizon uncertain, Stones River (Murfreesboro) or Ottosee limestone; Rye Cove, Scott County. U. S. N. M. 97359.

---

[a] The name *Calliops* has recently been substituted for the American trilobites referred to the genus *Pterygometopus*. Delo, David M., Jour. of Paleontology, vol. 9, no. 5, p. 417, 1935. See also Geol. Soc. America Spec. Paper No. 29, 1940.

FIGURE

17. *Aparchites* sp., × 4.
Right valve. Lenoir limestone; quarry at Marion, Smyth County. U. S. N. M. 97360.

18. *Eurychilina?* sp., × 4.
Left valve. Occurrence as 14. U. S. N. M. 97361.

19. *Leperditia?* sp.
Slab crowded with carapaces. Stones River (Murfreesboro) limestone in residual chert in road bank midway between Pearisburg and Ripplemead, Giles County. This form is widely distributed in the Stones River. U. S. N. M. 97362.

20, 21. [a]*Pterygometopus* sp.
20, wax impression of an external mold of a head, × 2; 21, tail. Chert in Lenoir (?) limestone; along road at intersection of State Routes 64 and 71 about 1½ miles southwest of Dickensonville, Russell County. U. S. N. M. 97363a, 97363b.

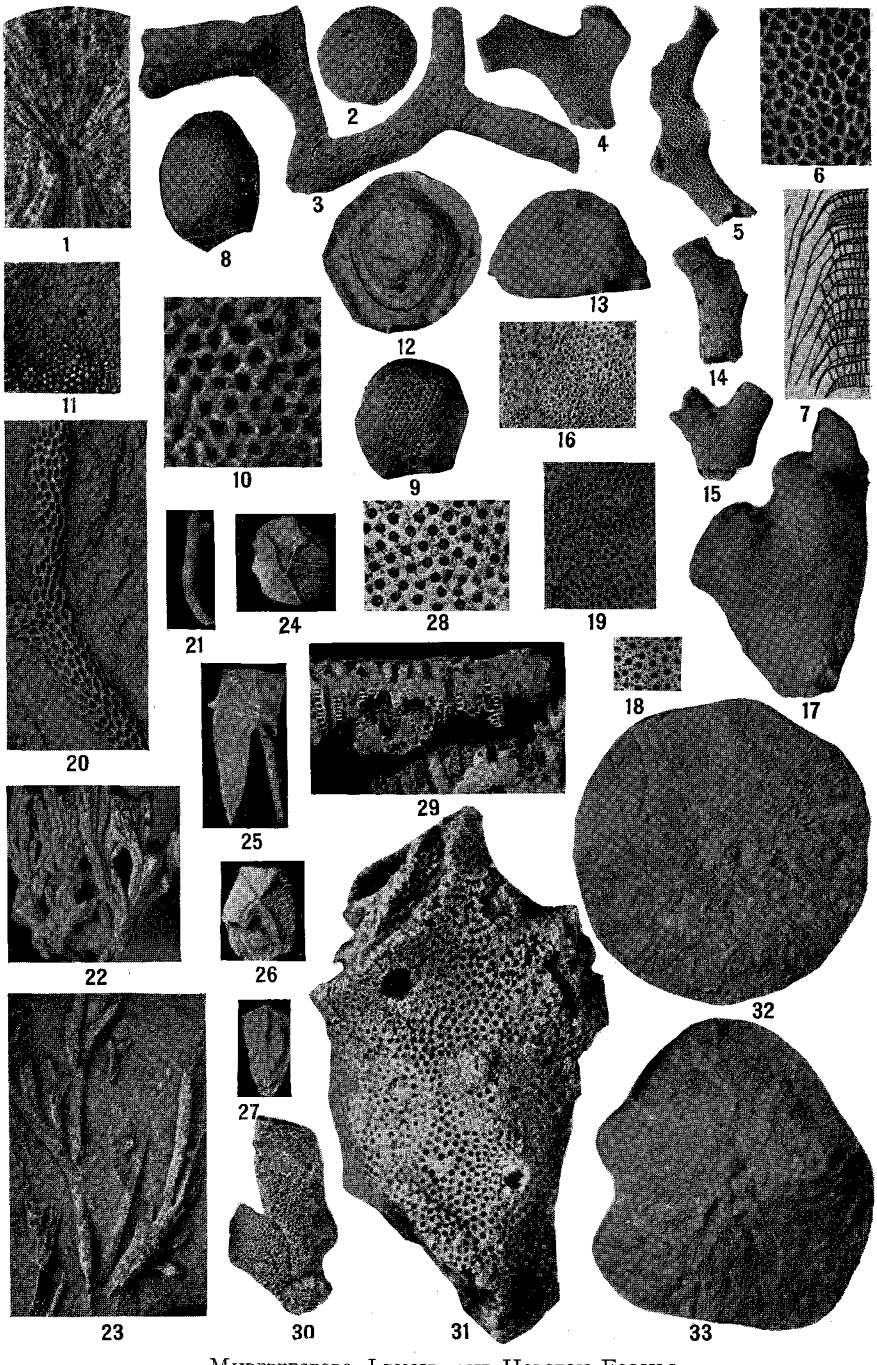
22, 23. *Pterygometopus* sp.
Occurrence as 14. U. S. N. M. 97364a, 97364b.

24, 25. *Leperditia* cf. *L. fabulites pinguis* Butts.
Occurrence as 14. U. S. N. M. 97365a, 97365b.

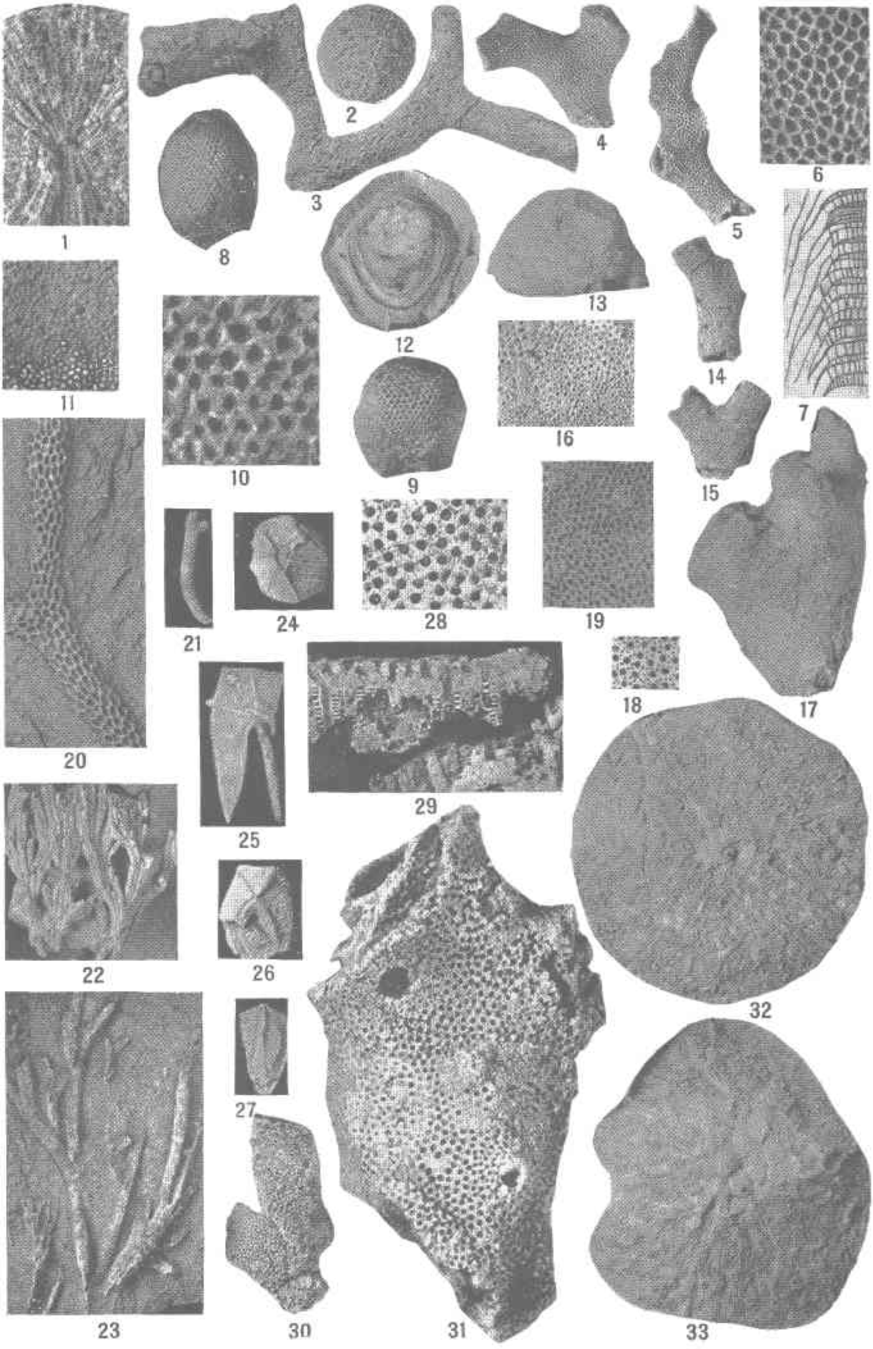
26–29. *Bathyurus* sp., × 2.
26, 27, tails; 28, 29, heads. Chert nodules in base of Stones River (Murfreesboro) limestone. 26, 1½ miles west of Jonesville, Lee County; 27-29, locality as 14. U. S. N. M. 97366, 97367a, 97367b, 97367c.

30. [a]*Pterygometopus, Illaenus?,* and *Leperditia.*
Slab of chert with characteristic assemblage. Occurrence as 20. U. S. N. M. 97368.

[a] The name *Calliops* has recently been substituted for the American trilobites referred to the genus *Pterygometopus*. Delo, David M., Jour. of Paleontology, vol. 9, no. 5, p. 417, 1935. See also Geol. Soc. America Spec. Paper No. 29, 1940.



MURFREESBORO, LENOIR, AND HOLSTON FOSSILS



Murfreesboro, Lenoir, and Holston Fossils

PLATE 76.—MURFREESBORO, LENOIR, AND HOLSTON FOSSILS

FIGURE

1, 2. *Hindia* cf. *H. parva* Ulrich.

2, entire specimen; 1, radial section showing internal structure, × 4. Lenoir limestone; Marcem quarry about 2 miles west of Gate City, Scott County. U. S. N. M. 97369a, 97369b.

3. *Dekayella?* sp.

Lenoir limestone; Yellow Branch 5 miles southeast of Rose Hill, Lee County. A common form attached to weathered surfaces. U. S. N. M. 97370.

4–6. *Batostoma* sp.

4, 5, fragments of branches showing external appearance; 6, showing size and shape of zooecia, × 4. A common form revealed on weathered surfaces of the Lenoir limestone. Locality as 3. U. S. N. M. 97371a, 97371b, 97371c.

7. *Batostoma varium* Ulrich.

Longitudinal section to show general manner of growth of *Batostoma*. (Geol. of Minnesota, vol. 3, pl. 25, fig. 23, 1895.)

8–10. *Nidulites ovoides* Butts, n. sp.

8, 9, exterior view of two specimens. 10, a part of 9, × 4, showing the form and size of the openings of the radial tubes. Differs from *Nidulites pyriformis* in its ovoid shape as contrasted with the pear shaped outline of *N. pyriformis*. Lenoir limestone 3 miles southeast of Blacksburg, Montgomery County. Cotypes: U. S. N. M. 97372a, 97372b.

11–13. *Cyphotrypa* sp.

11, a small part of the surface of 13, × 4, to show shape and size of the zoecia. 12, epithecum; 13, profile view. Occurrence as 1. U. S. N. M. 97373.

14–16. *Nicholsonella* sp.

14, 15, fragments of 2 individuals; 16, small part of 15, × 4, to show size and arrangement of zoecia. Occurrence as 3. U. S. N. M. 97374a, 97374b.

17–19. *Nicholsonella pulchra* Ulrich.

17, nearly entire specimen; 19, part of 17, × 4, showing size and spacing of zoecia. 18, drawing showing interzoecial

FIGURE

papillae, × 6. (Based on Geol. of Minnesota, vol. 3, pl. 21, fig. 9, 1895.) 17, 19, occurrence as 3. 17, 19, U. S. N. M. 97375; 18, 43552.

20, 21. *Eridotrypa?* sp.

Slender ramose species. 20, enlargement of 21, × 4; 21, fragment, natural size. Lenoir limestone; quarry at Marion, Smyth County. Common at that place. U. S. N. M. 97376.

22. *Tetradium* cf. *T. halysitoides* Raymond, × 4.

Silicified coralites, longitudinal view. Stones River limestone; 1½ miles southeast of Dryden, Lee County. U. S. N. M. 97377.

23. *Tetradium syringoporoides* Ulrich, × 4.

Longitudinal view. Stones River (Murfreesboro) limestone; locality as 22. U. S. N. M. 97378.

24–27. *Cheirocrinus?* sp.

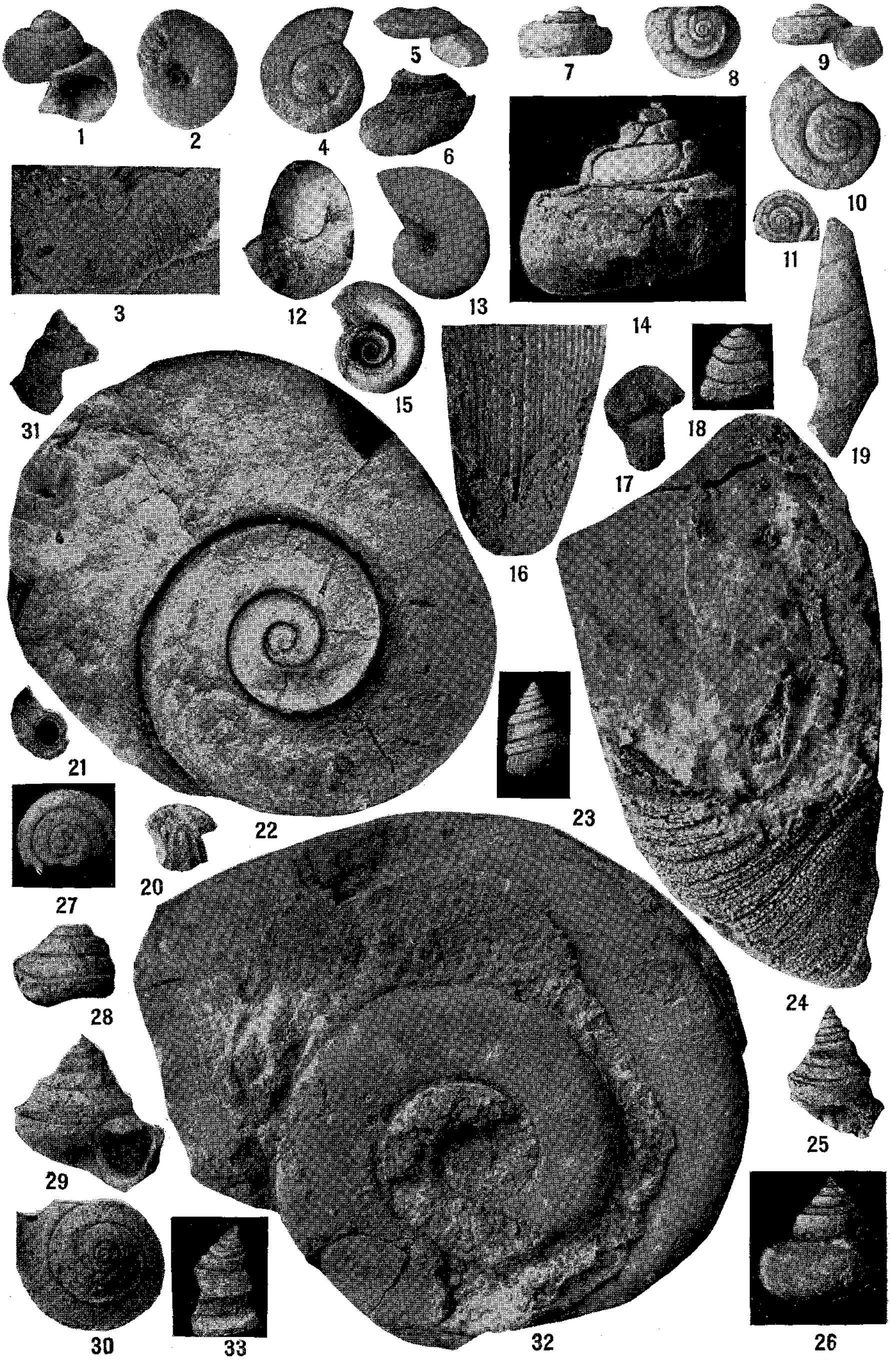
Detached plates. Occurrence as 20. U. S. N. M. 97379a, 97379b, 97379c, 97379d.

28–31. *Mesotrypa* sp.

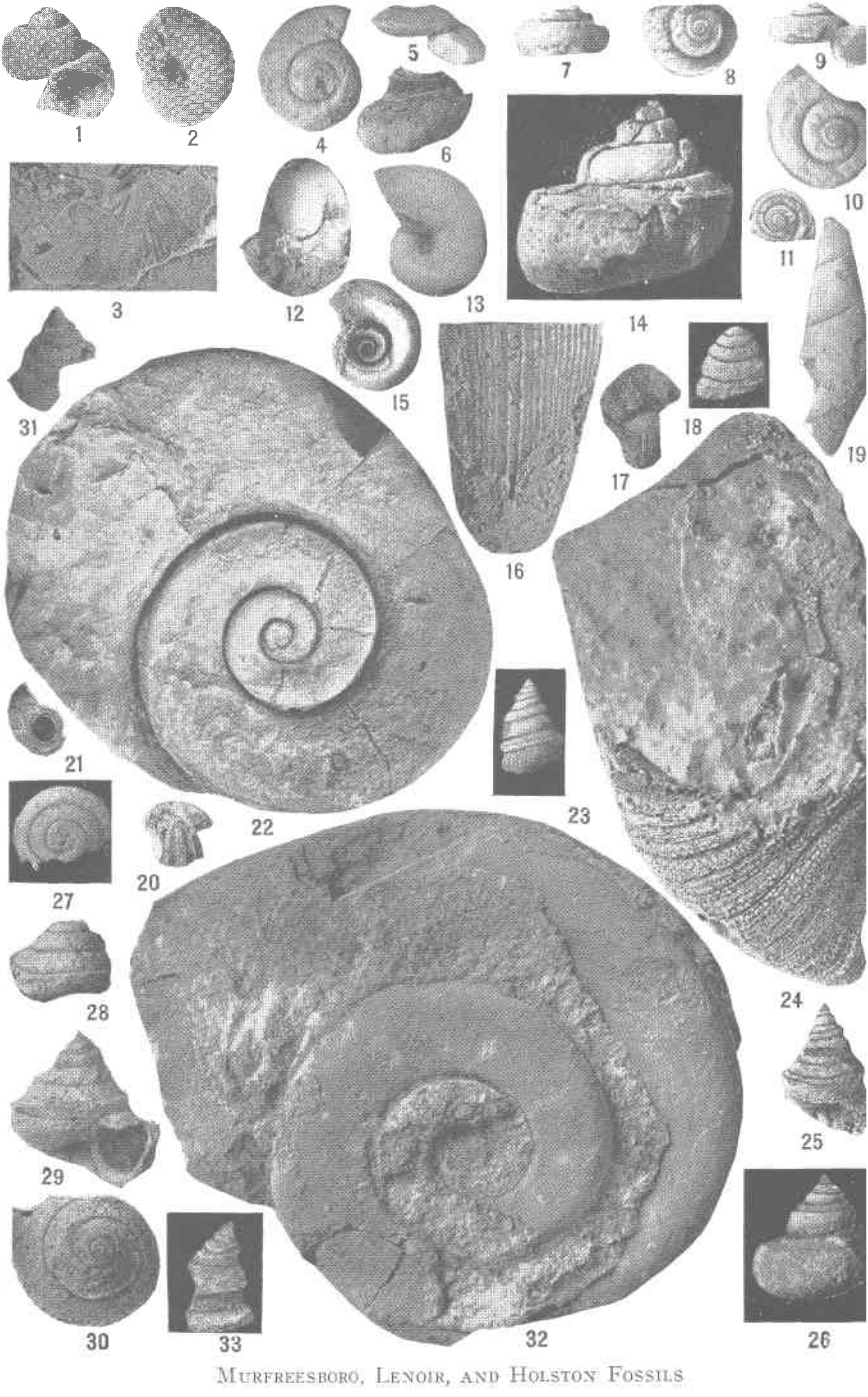
28, small part of surface of 30, × 4, to show shape and spacing of zoecia. 29, longitudinal section of 31, × 4, showing mesopores with many diaphragms. 30, 31, exteriors of two fragments; 31, × 2. Occurrence as 3. U. S. N. M. 97380a, 97380b.

32, 33. Sponge cf. *Anthaspidella* or *Zittelella.*

Common in upper part of Lenoir limestone in the Marion quarry and elsewhere. Many individuals on the surface of some layers of limestone. U. S. N. M. 97381a, 97381b.



MURFREESBORO, LENOIR, AND HOLSTON FOSSILS



MURFREESBORO, LENOIR, AND HOLSTON FOSSILS

PLATE 77.—MURFREESBORO, LENOIR, AND HOLSTON FOSSILS

FIGURE

1–3. *Holopea scrutator* Raymond?

1, 2, apertural and umbilical views of an internal mold. 3, small part of an external mold of the under side of the basal whorl of a fragment showing the revolving lines which are on the exterior of the shell, × 4. Associated with *Eotomaria?* sp. (Pl. 78, figs. 24-28.) Stones River (Murfreesboro) limestone; Willow Spring, Washington County. U. S. N. M. 97382a, 97382b.

4, 5. *Liospira* cf. *L. decipiens* Ulrich.

Apical and profile views of an internal mold. Lenoir limestone; along east slope of Angels Rest Mountain three-fourths of a mile west-southwest of Pearisburg, Giles County. U. S. N. M. 97383.

6–11. *Helicotoma tennesseensis* Ulrich and Scofield.

6, impression of an external mold in chert; 7, 8, profile and apical views of an impression of an external mold; 9, 10, profile and apical views of an exfoliated specimen; 11, apical view of an impression of an external mold of a small specimen. Stones River (Murfreesboro and Lenoir) limestones. 6, Lenoir limestone; along Whistle Creek 2 miles northwest of Lexington, Rockbridge County; 7-11, Stones River; 7, 8, top of spur half a mile northeast of the junction of Stony Creek with New River and 3¼ miles northeast of Pearisburg, Giles County; 9, 10, Yellow Branch 5 miles southeast of Rose Hill, Lee County; 11, Stones River, near base; about 2¾ miles southwest of Rye Cove School, Scott County. Associated with *Leperditella, Bathyurus,* and *Pterygometopus,* as shown on Pl. 75. 6, U. S. N. M. 97385; 7, 8, 97384; 9, 10, 97386; 11, 97387.

12, 13. *Sinuites* sp.

Edge and side views of a specimen. Lenoir limestone; Marcem quarry 2 miles west of Gate City, Scott County. U. S. N. M. 97388.

14. *Trochonemella trochonemoides* (Ulrich)?

Side view of a large specimen. Mosheim limestone; along State Route 58 just south of Hardys Creek and 5 miles northeast of Rose Hill, Lee County. U. S. N. M. 97389a.

FIGURE

15–17. *Kokenospira virginiana* Butts, n. sp.

Larger than *K. costalis* (Ulrich) and has 12 or more revolving lines on each side of central band, instead of 7 as in *K. costalis*. Largest shells three-fourths of an inch in diameter. 15, side, 17, edge view of same specimen; fine striae, as in 16, visible on the specimen. 16, edge view of outer whorl of another specimen showing band and the revolving furrows characteristic of the genus, × 4. This figure posed wrong end up. Rare; apparently only one other species known or described in America, *K. costalis* (Ulrich), of which a single specimen is known. Fourteen specimens of *K. virginiana* collected. Occurrence as 12. Holotype: 15, 17, U. S. N. M. 97390a; paratype: 16, 97390b.

18. *Eotomaria?* sp.

Profile view of a specimen. See 27 for apical view. Occurrence as 14. U. S. N. M. 97391a.

19. *Subulites* sp.

Lenoir limestone; Marcem quarry 2 miles west of Gate City, Scott County. U. S. N. M. 97392.

20, 21. *Tetranota* cf. *T. bidorsata* (Hall).

Edge and side views of a specimen. Occurrence as 12. U. S. N. M. 97393.

22. *Maclurites* sp.

Supposed umbilical view of a specimen giving the appearance of left hand coils. Lenoir limestone; in Pearisburg, Giles County. U. S. N. M. 97394.

23. *Lophospira* aff. *L. elongata* Butts?, × 2.

Occurrence as 14. U. S. N. M. 97397.

24. *Maclurites* sp.

Operculum of a large specimen. Lenoir? limestone; Rye Cove about 3 miles southwest of Rye Cove School, Scott County. U. S. N. M. 97395.

25. *Lophospira centralis* Ulrich.

Silicified specimen preserving parts of the shell. Occurrence as 12. U. S. N. M. 97398.

FIGURE

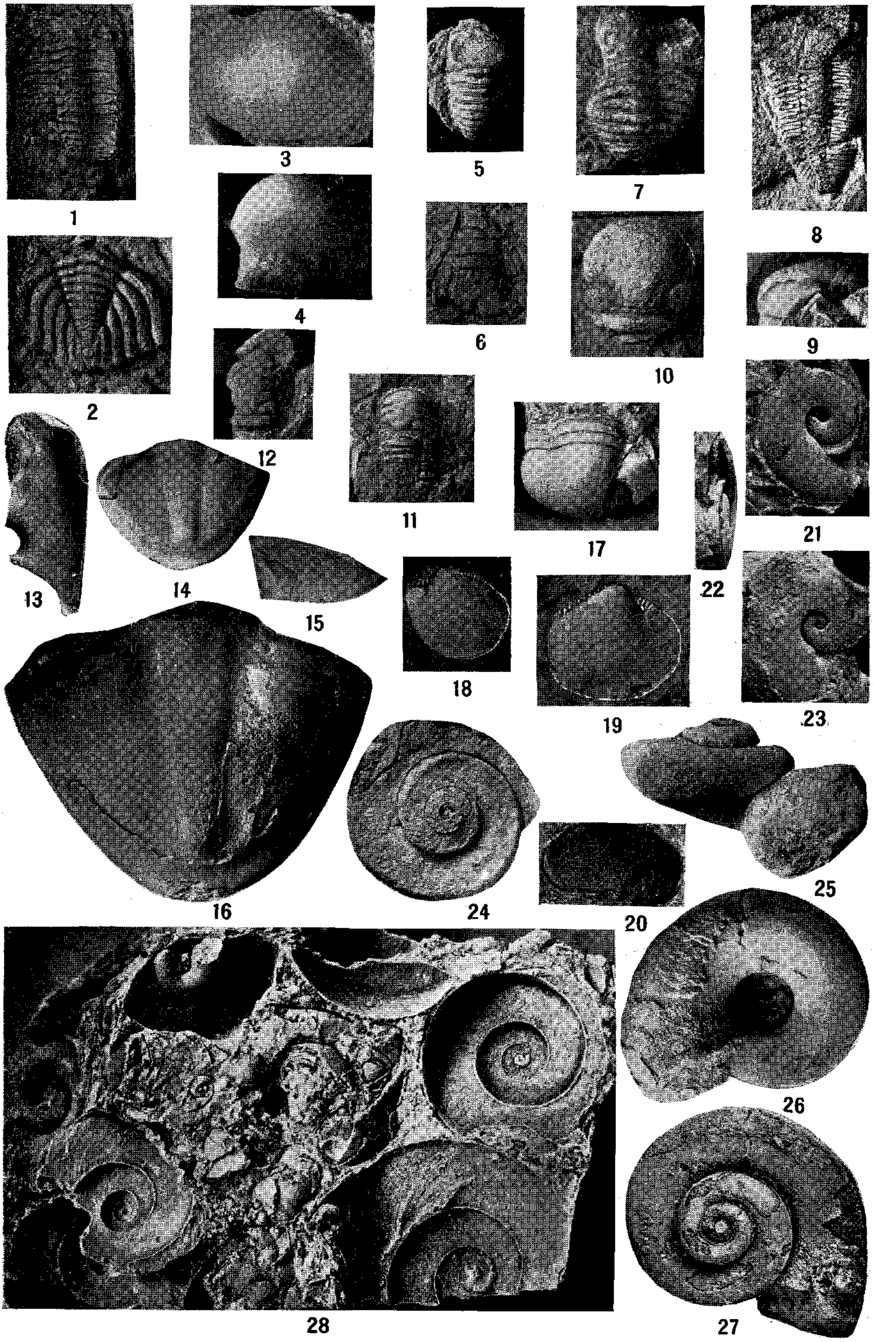
26. *Trochonemella trochonemoides* (Ulrich)?, × 2.
Small specimen. Occurrence as 14. U. S. N. M. 97389b.

27, 28. *Eotomaria?* sp.
27, apical view of 18; 28, profile view of another specimen. Occurrence as 14. U. S. N. M. 97391a, 97391b.

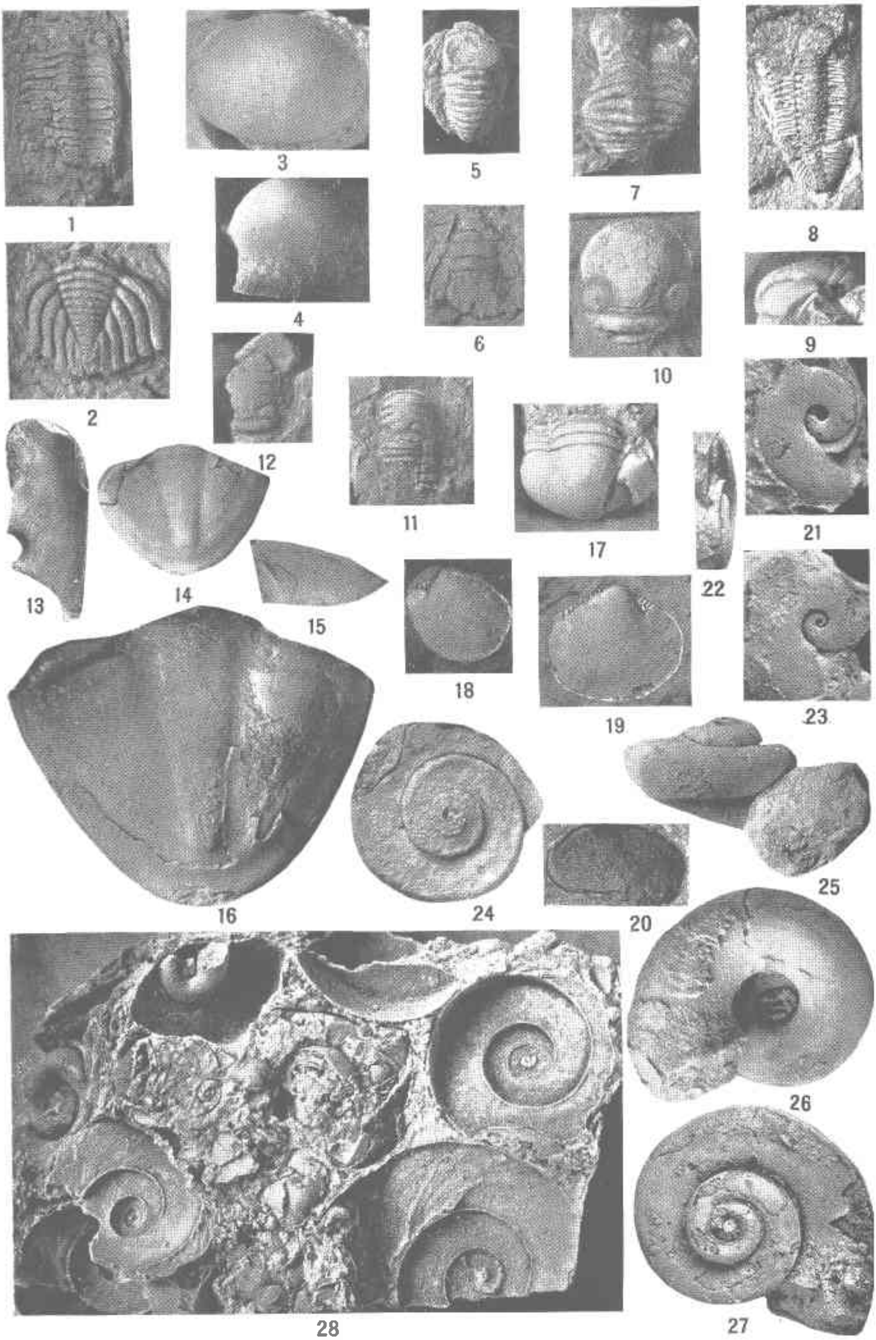
29, 30. *Trochonemella trochonemoides* (Ulrich)?
Apical and profile views of a small specimen that seems to differ in the slopes of the whorls from the forms shown in Fig. 14. Occurrence as 14. U. S. N. M. 97389c.

31, 33. *Lophospira* cf. *L. bicincta* (Hall).
Fragmental. 31, external mold in chert, concave toward the observer; 33, clay impression from 31. Murfreesboro limestone; top of spur half a mile northeast of mouth of Big Stony Creek and 3¼ miles northeast of Pearisburg, Giles County. U. S. N. M. 97399.

32. *Maclurites magnus* Lesueur.
Supposed umbilical view of a specimen giving the appearance of left-hand coil. Lenoir limestone; along Norfolk and Western Railway 2¼ miles southwest of Marion, Smyth County. U. S. N. M. 97396.



MURFREESBORO, LENOIR, AND HOLSTON FOSSILS



MURFREESBORO, LENOIR, AND HOLSTON FOSSILS

PLATE 78.—MURFREESBORO, LENOIR, AND HOLSTON FOSSILS

FIGURE

1, 2. *Pliomerops canadensis* (Billings).

1, thorax; 2, tail, × 2. Lenoir limestone; quarry at Marion, Smyth County. U. S. N. M. 97400a, 97400b.

3, 4. *Bumastus* cf. *B. lioderma* Raymond.

Head, dorsal and profile views. Lenoir limestone; Rye Cove, Scott County. U. S. N. M. 97401.

5, 6. *Remopleurides* sp.

5, thorax with imperfect head; 6, imperfect tail. Occurrence as 1. U. S. N. M. 97402a, 97402b.

7. *Encrinurus* sp.

Poorly preserved specimen. Occurrence as 1. U. S. N. M. 97403.

8. *Pterygometopus* sp.

Thorax and tail. Lenoir limestone; 1 mile northeast of Galena, Augusta County. U. S. N. M. 97404.

9. *Illaenus* cf. *I. consimilis* Billings.

Tail, profile view. Dorsal view shown in fig. 17. Stones River (Murfreesboro) limestone; 1½ miles south of Rye Cove School, Scott County. U. S. N. M. 97405.

10. *Sphaerexochus* sp., × 2.

Head. Restored on lower left. Occurrence as 1. U. S. N. M. 97406.

11, 12. *Ceraurinus?* sp.

11, head and part of thorax; 12, imperfect head. 11, Lenoir limestone; 3 miles southeast of Blacksburg, Montgomery County; 12, locality as 1. U. S. N. M. 97407, 97408.

13–16. *Homotelus* sp.

13, free cheek; 14, 16, dorsal views of two tails; 15, profile view of 14. Lenoir limestone; Dunkard Church 6 miles north of Buchanan, Botetourt County. 13, U. S. N. M. 97409a; 14, 15, 97409b; 16, 97409c.

17. *Illaenus* cf. *I. consimilis* Billings.

Tail, dorsal view of 9. Occurrence as 9. U. S. N. M. 97405.

FIGURE

18, 19. *Ctenodonta* sp.

Left and right valves. Stones River (Murfreesboro) limestone; Willow Spring, Russell County. Associated with *Eotomaria?* Abundant. U. S. N. M. 97410a, 97410b.

20. *Modiolopsis* cf. *M.? consimilis* Ulrich.

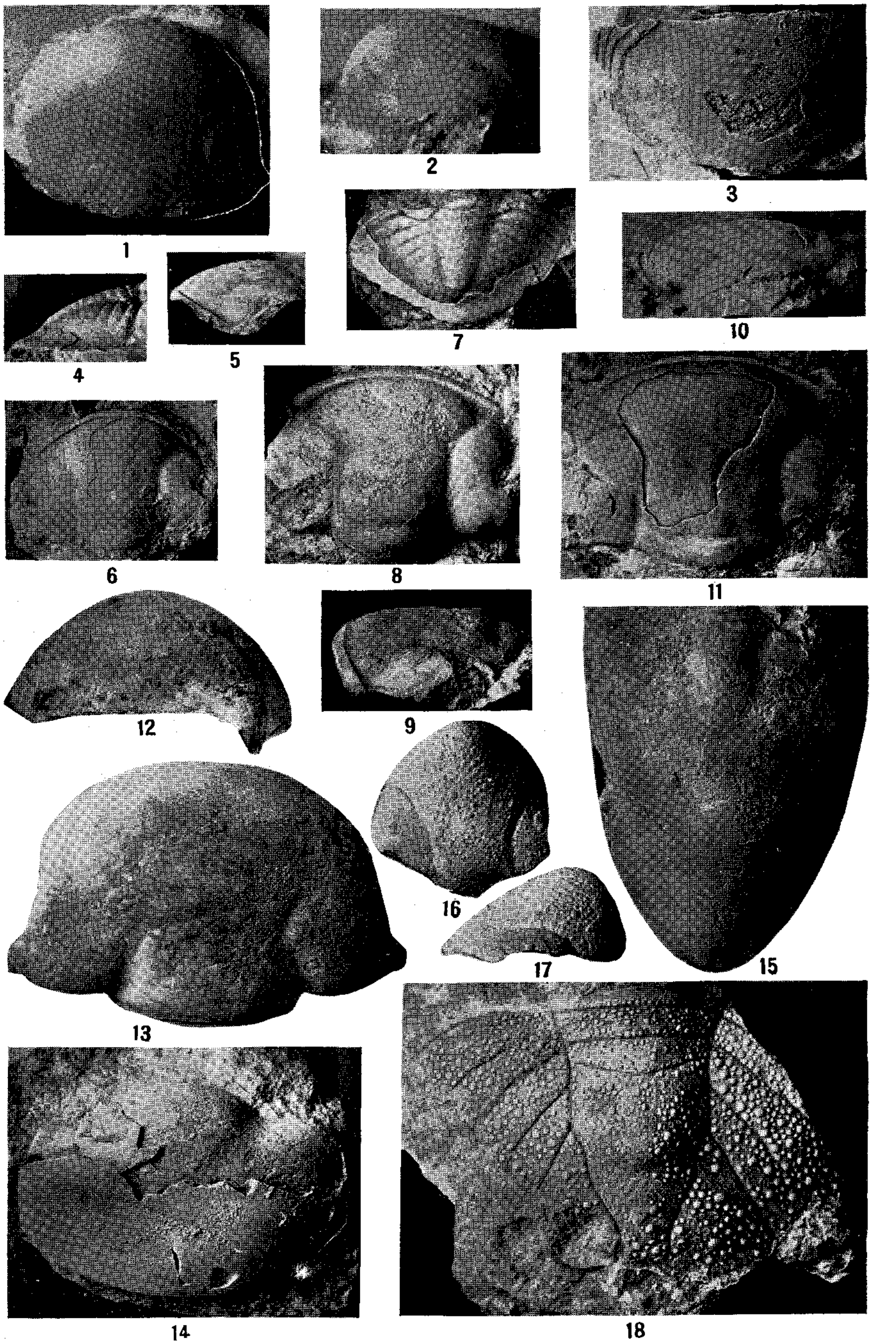
Clay impression of the external mold of an imperfect left valve. Occurrence as 18. U. S. N. M. 97411.

21–23. *Oxydiscus catilloides* (Raymond) ?, × 3.

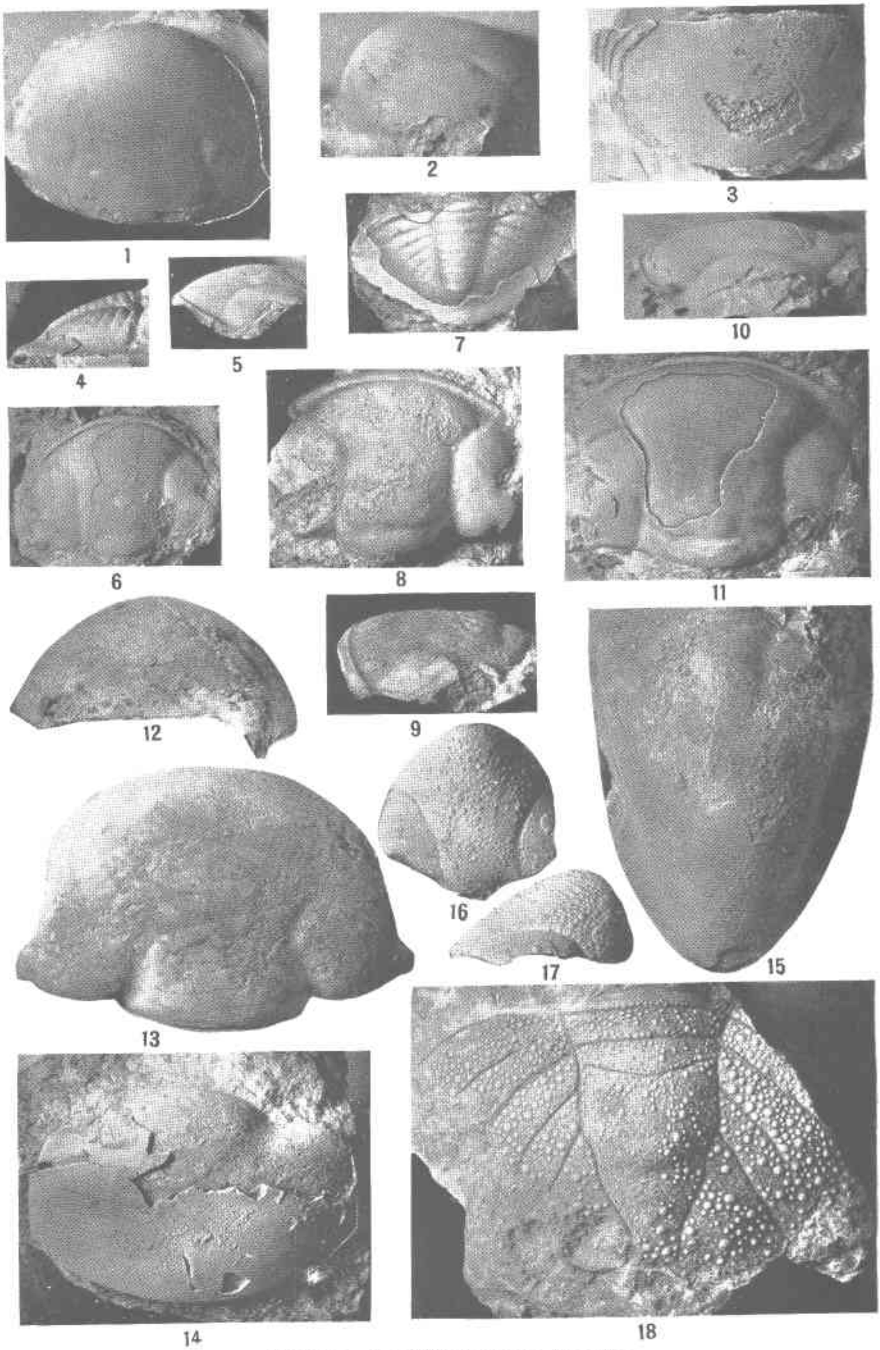
21, 23, side views of two specimens; 22, edge view of 21. Occurrence as 18. 21, 22, U. S. N. M. 97412a; 23, 97412b.

24–28. *Eotomaria?* sp.

24, impression from an external mold on the upper right corner of 28; 25-27, profile, umbilical, and apical views of the internal mold of a specimen; 28, piece of a large mass crowded with shells of this species. The lines of ornamentation are visible on some specimens. Occurrence as 18. 25-27, U. S. N. M. 97413a; 24, 28, 97413b.



HOLSTON AND WHITESBURG FOSSILS



HOLSTON AND WHITESBURG FOSSILS

PLATE 79.—HOLSTON AND WHITESBURG FOSSILS

FIGURE

1–3. *Bumastus lioderma* Raymond?

1, 2, dorsal and profile views of a head; 3, dorsal view of a tail. Holston limestone; quarry of the Mathieson Alkali Works at Porterfield about 5 miles east of Saltville, Smyth County. 1, 2, U. S. N. M. 97414a; 3, 97414b.

4–9. *Basilicus* sp.

5, 6, profile and dorsal views of a head; 8, 9, dorsal and profile views of another head; 4, 7, profile and dorsal views of a tail. Holston limestone. 5, 6, Tilson Mill about 16 miles north of Marion, Smyth County; 8, 9, locality as 1; 4, 7, McNutt quarry 9 miles southwest of Bland, Bland County. 4, 7, U. S. N. M. 97415; 5, 6, 97416; 8, 9, 97417.

10, 11. *Basilicus* sp.

Dorsal and profile views of a head. Limestone, exact age uncertain, a few feet thick between the Lenoir and Chambersburg limestones; along the Southern Railway about 600 feet northeast of Strasburg intersection and about 1 mile west of Strasburg, Shenandoah County. U. S. N. M. 97418.

12–14. *Illaenus fieldi* Raymond?

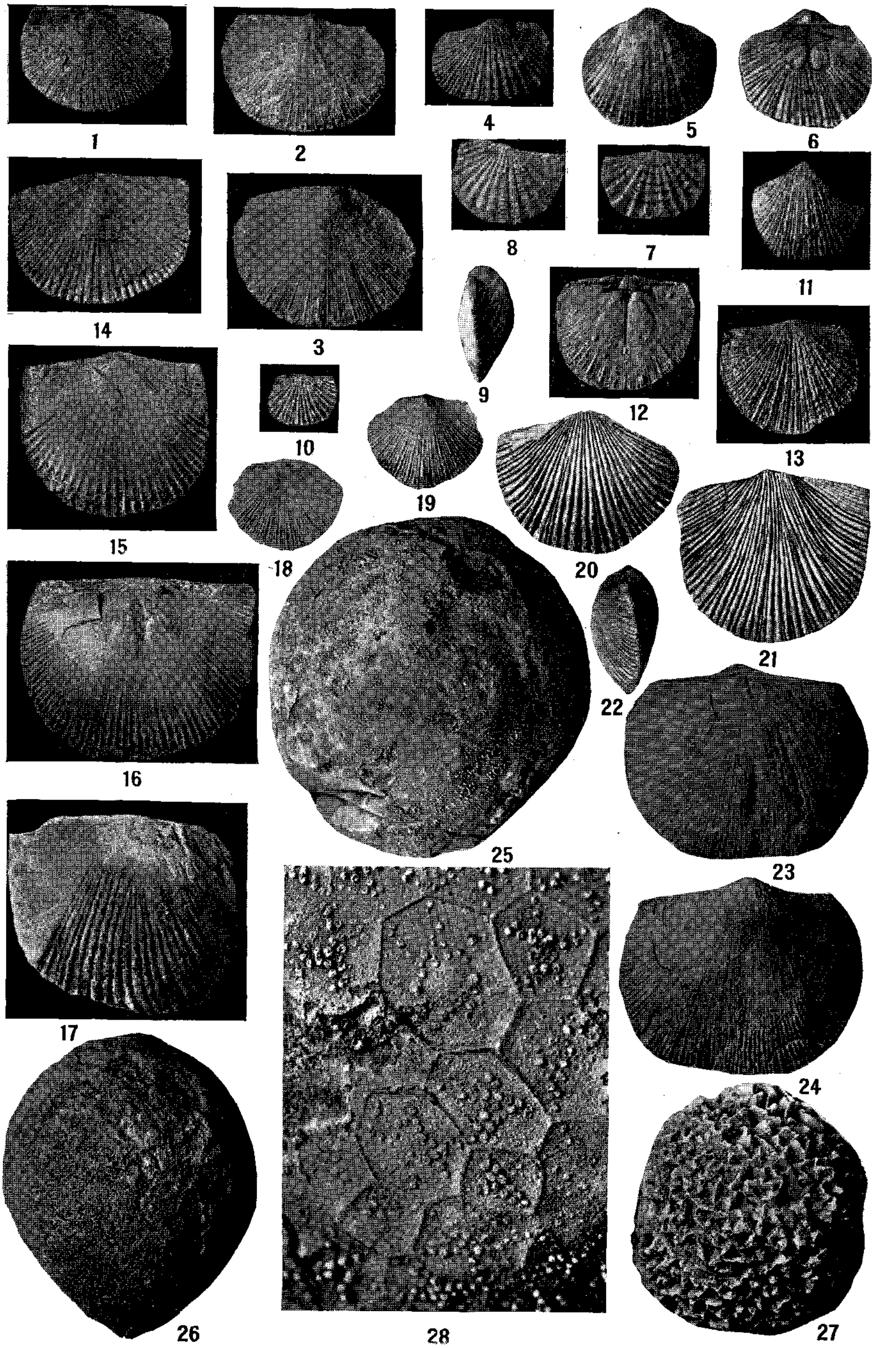
12, 13, profile and dorsal views of a head; 14, dorsal view of a tail. Whitesburg limestone; Grayson farm about 4 miles southwest of Bland, Bland County. 12, 13, U. S. N. M. 97419a; 14, 97419b.

15. *Hyboaspis shuleri* Raymond.

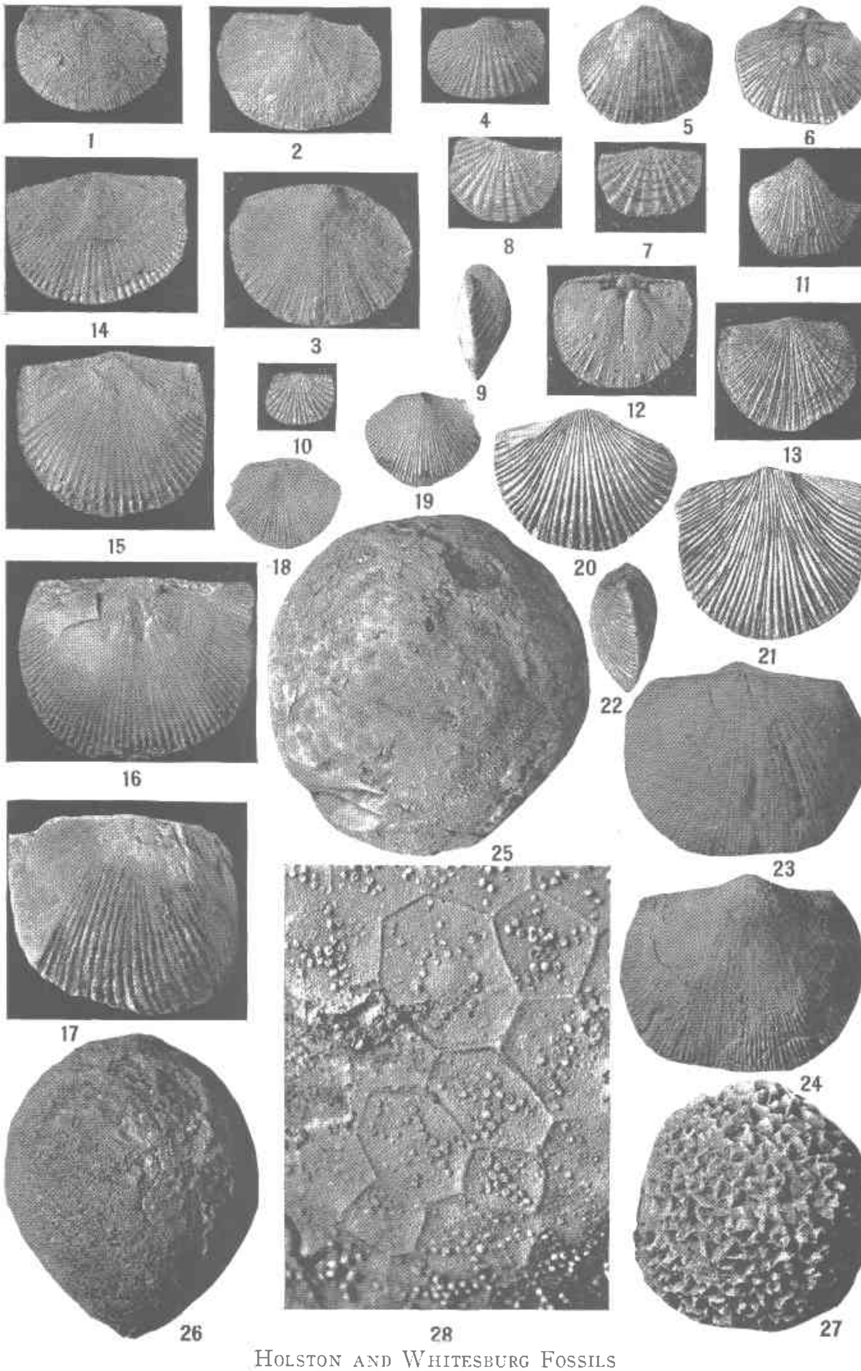
Dorsal view of a tail. Head and thorax apparently unknown. Occurrence as 1. U. S. N. M. 97420.

16–18. *Acrolichas prominulus* Raymond.

16, 17, head, dorsal and profile views of a plaster cast of the type. (See Bull. Mus. Comp. Zool., vol. 67, no. 1, pl. 8, figs. 11, 12, 1925.) 18, dorsal view of tail. Occurrence as 4. U. S. N. M. 78348.



HOLSTON AND WHITESBURG FOSSILS



Holston and Whitesburg Fossils

PLATE 80.—HOLSTON AND WHITESBURG FOSSILS

FIGURE

1–3. Undetermined genus, related to *Rafinesquina?*

1, dorsal valve; 2, 3, ventral valves; 3, × 2. Holston limestone; quarry of the Mathieson Alkali Works at Porterfield 5 miles east of Saltville, Smyth County. U. S. N. M. 99256a, 99256b, 99256c.

4–10. *Productorthis agilera* (Willard).

5, 6, 9, ventral, dorsal, and profile views of the same specimen; 4, 7, 8, 10, doubtfully referred to this species, probably a *Glyptorthis*. Occurrence as 1. 5, 6, 9, U. S. N. M. 99257; 4, 99258a; 7, 99258b; 8, 99258c; 10, 99258d.

11–13. *Paurorthis catawbaensis* Butts, n. sp., × 2.

Characterized by its convex valves and the fasciculation of its striae; differs from *P. parva* (Pander) by its finer ornamentation. 11, impression of an external mold of a ventral valve; 12, internal mold of a dorsal valve; 13, impression of the external mold of the same specimen as 12, showing the actual exterior of the shell. Holston? limestone, shaly facies near bottom; along State Route 311 about 6½ miles northwest of Salem and half a mile southwest of Catawba post office, Roanoke County. Horizon doubtful; is just above Mosheim limestone and may be Lenoir or Whitesburg. Cotypes: U. S. N. M. 99259a, 99259b, 99259c.

14–17. *Multicostella whitesburgensis* Butts, n. sp.

Distinguished by its large, robust size and coarse, simple ribs, and biconvex valves. Ribs 10 to 11 in 10 millimeters. Whitesburg limestone. 14, 15, half a mile west of Lexington, Rockbridge County; 16, 17, near the south base of Big Butt Mountain 6½ miles northwest of Lexington, Rockbridge County. Cotypes: U. S. N. M. 99260a, 99260b, 99261a, 99261b.

18, 19. *Dinorthis?* sp.

Dorsal and ventral valves of same specimen. Occurrence as 1. U. S. N. M. 99262.

20, 21. *Cyrtonotella virginiensis* Butts, n. sp.

Ventral valve very convex; dorsal valve concave; main ribs extending to beak, 10 in 10 mm.; secondary ribs intercalated in anterior half. 20, ventral valve; 21, dorsal valve

FIGURE

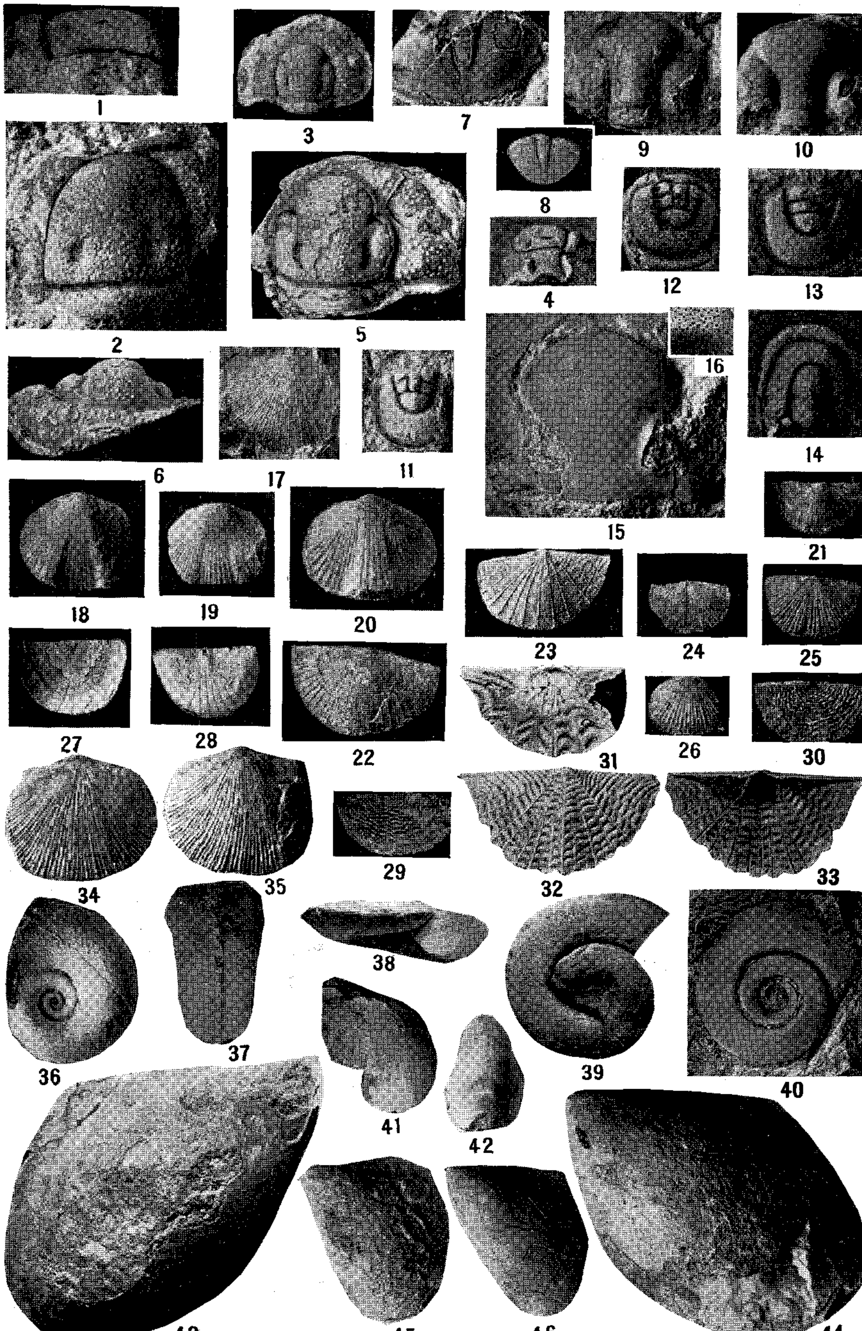
of different individuals. Holston limestone?, shaly phase; one-third of a mile southwest of Catawba, Roanoke County. Cotypes: U. S. N. M. 99263a, 99263b.

22–24. *Doleroides?* sp.

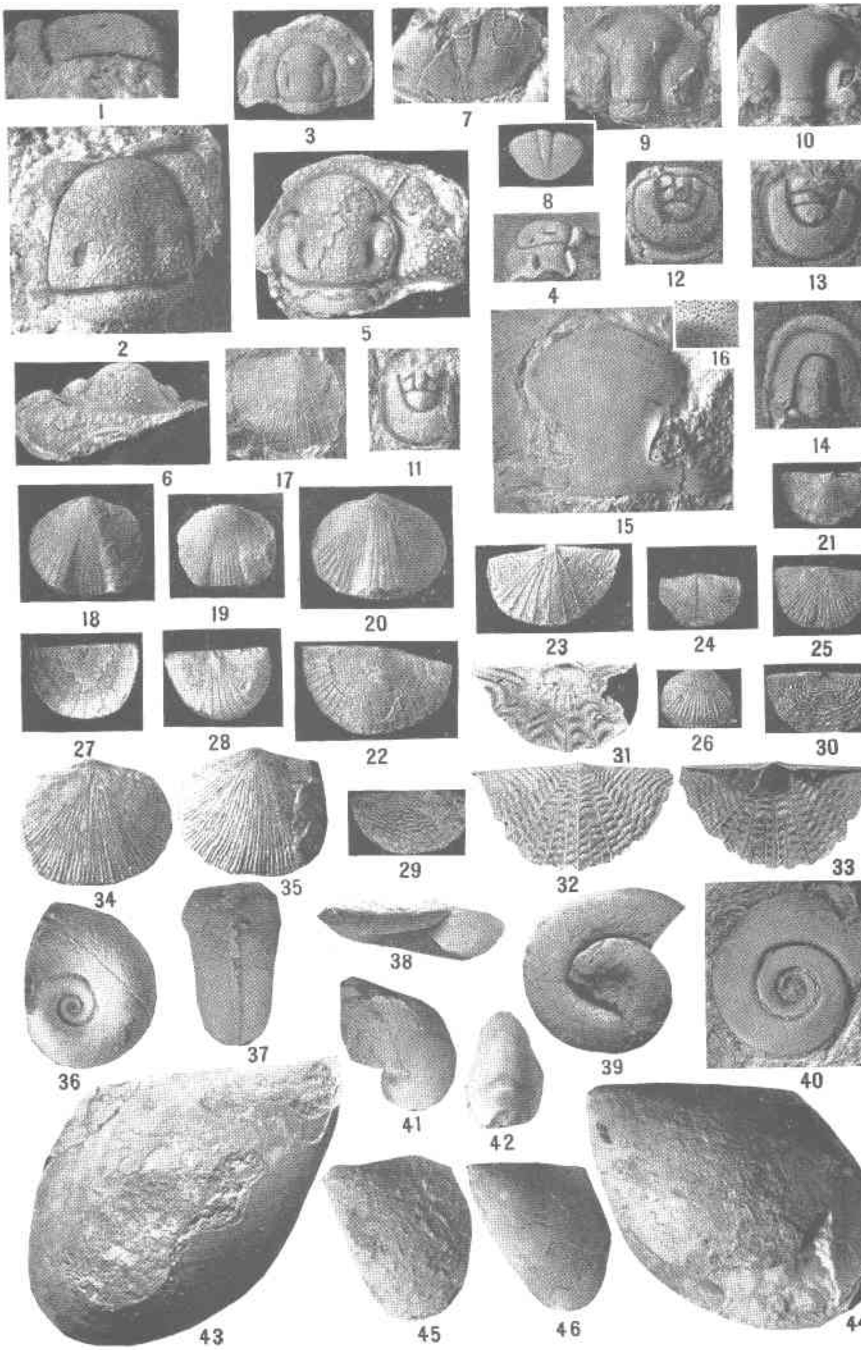
22, profile of specimen of Pl. 81, figs. 34 and 35; 23, 24, dorsal and ventral views of another and larger specimen. Occurrence as 1. 22, U. S. N. M. 98225a; 23, 24, 98225b.

25–28. *Echinosphaerites* cf. *E. aurantium* (Gyllenhal).

25, internal mold, test exfoliated, showing the fillings of the pores; 28, part of surface of 25, × 4, showing more plainly the fillings of the pores; 26, an exfoliated specimen; 27, an exfoliated specimen showing crystalline calcite common in fossil echinoderms. Whitesburg limestone. 25, 27, 28, base of the northeast slope of Green Hill about 2 miles southwest of Collierstown, Rockbridge County; 26, from field half a mile north of State Route 4 and 2½ miles east of Dale Enterprise, Rockingham County. 25, 28, U. S. N. M. 97421a; 27, 97421b; 26, 97422.



HOLSTON AND WHITESBURG FOSSILS



HOLSTON AND WHITESBURG FOSSILS

PLATE 81.—HOLSTON AND WHITESBURG FOSSILS

FIGURE

1, 2. [a]*Glaphurina brevicula* Ulrich, × 2.

Dorsal and side views of a head. Holston limestone; 2 miles northwest of Lexington, Rockbridge County. U. S. N. M. 80549.

3, 4. [a]*Glaphurus* sp.

Dorsal and side views of a head. Holston limestone; quarry of the Mathieson Alkali Works at Porterfield 5 miles east of Saltville, Smyth County. U. S. N. M. 97423.

5, 6. [a]*Glaphurus latior* Ulrich, × 2.

Dorsal and front views of a head. Whitesburg limestone; 6 miles southwest of Bland, Bland County. U. S. N. M. 80552.

7–10. *Bronteopsis gregaria* Raymond.

7, 8, tails; 9, 10, heads, dorsal views. 8, × 2. Whitesburg limestone. 7-9, Cedar Grove Church 1 mile east of Harrisonburg, Rockingham County; 10, Hoge farm 6 miles southwest of Bland, Bland County. U. S. N. M. 97424a, 97424b, 97424c, 97425.

11–14. *Arthrorhachis elspethi* Raymond, × 4.

11-13, tails; 14, head. Whitesburg limestone. 11, 12, 14, locality as 10; 13, Swoope 7 miles west of Staunton, Augusta County. U. S. N. M. 97426a, 97426b, 97427, 97426c.

15, 16. *Homotelus* sp.

16, a small part of the carapace of 15 to show punctation, × 4. Whitesburg limestone?; source uncertain. U. S. N. M. 97428.

17. *Rafinesquina* sp.?

Occurrence as 3. U. S. N. M. 98222.

18–20. *Oxoplecia* sp.

18, 19, ventral valves; 20 dorsal valve, all different individuals. Whitesburg limestone; Cedar Grove Church 1 mile east of Harrisonburg, Rockingham County. U. S. N. M. 98227a, 98227b, 98227c.

---

[a] After Ulrich, E. O., Proc. U. S. Nat. Mus., vol. 76, pp. 1-101, pls. 1-8, 1929.

FIGURE

21, 22. *Sowerbyella?* sp.

Ventral valves. 22, × 2. Rare. Whitesburg limestone; Lexington, Rockbridge County. U. S. N. M. 98228a, 98228b.

23. *Sowerbyella?* sp., × 2.

Whitesburg limestone; locality as 3. Associated with *Ptychoglyptus*. (See Figs. 29 and 30.) U. S. N. M. 98229.

24–26. *Hebertella?* sp.

24, 25, ventral valves; 26, dorsal valve, doubtfully referred to this form. Occurrence as 3. U. S. N. M. 98223a, 98223b, 98223c.

27, 28. *Leptellina elegantula* Butts, n. sp.

Distinguished by its small size and fine regular alternating striae, 6 large ones in 5 mm., with 10-15 finer striae between. 27, external mold; 28, internal mold of the same specimen. Occurrence as 23. Holotype: U. S. N. M. 98224.

29–33. *Ptychoglyptus virginiensis* Willard.

29, 32, exteriors of ventral valves; 30, exterior of dorsal valve; 33, interior of 32; 31, interior of a dorsal valve. 31-33, × 2. Whitesburg limestone. 29, 30, locality as 3; 31-33, etched from a slab collected on the crest of a low ridge 1½ miles west of Lairds Knob and 6 miles east of Harrisonburg, Rockingham County. U. S. N. M. 98230a, 98230b, 98231a, 98231b.

34, 35. *Doleroides?* sp.

Dorsal and ventral valves. Occurrence as 3. (See Pl. 80, fig. 22, for profile view.) U. S. N. M. 98225a.

36, 37. *Bucania* sp.

Dorsal and side views of a specimen. Ornamented by transverse scalloped lines which do not show here. Occurrence as 3. U. S. N. M. 97429.

38–40. *Liospira* sp.

Internal molds. 38, 39, side and apical views of a specimen; 40, apical view of another specimen. Occurrence as 21. U. S. N. M. 97430a, 97430b.

41, 42. *Sinuites* sp.

Side and dorsal views. Occurrence as 21. U. S. N. M. 97431.

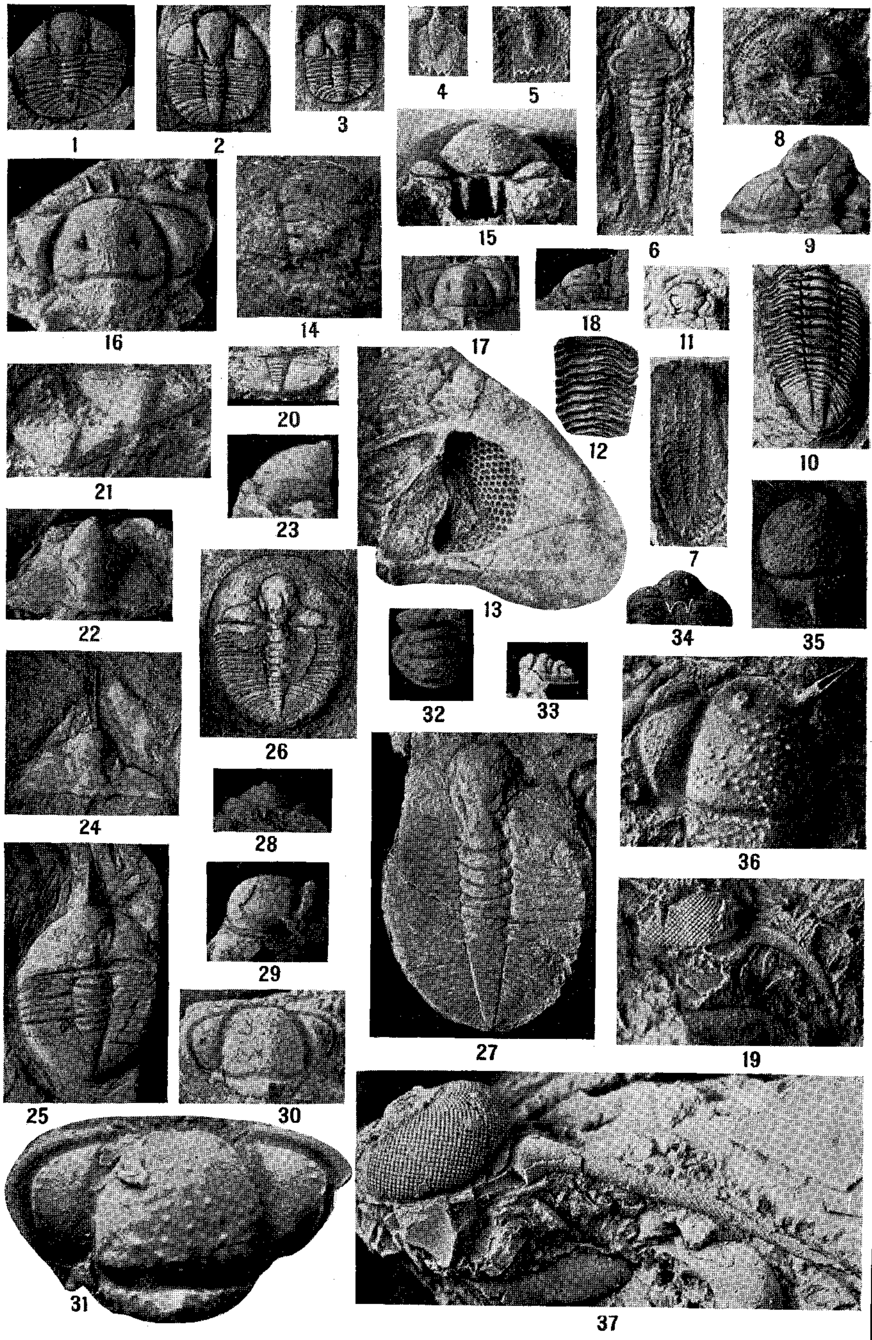
FIGURE

43, 44. *Clionychia* sp.?

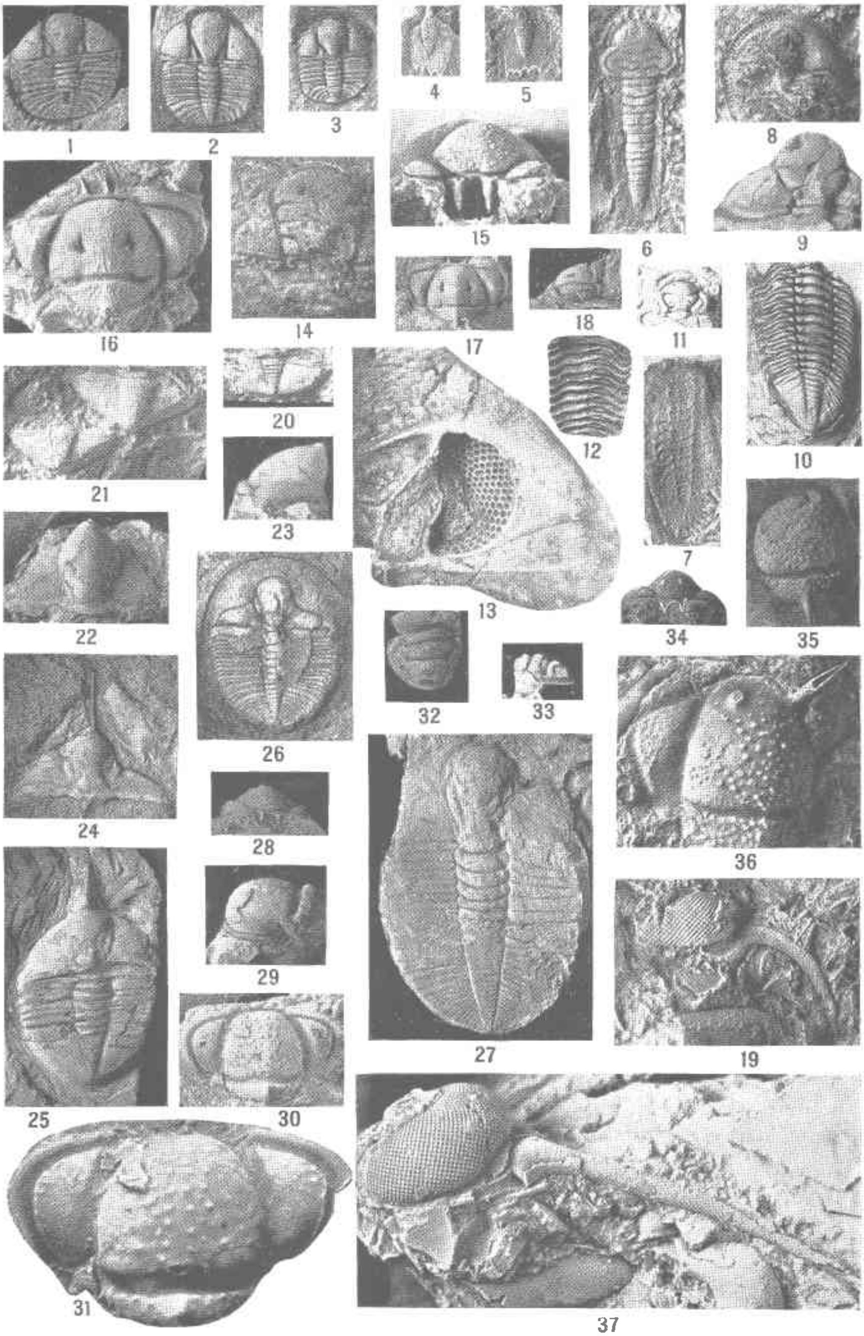
Right and left valves. Occurrence as 3. U. S. N. M. 97432a, 97432b.

45, 46. *Clionychia* cf. *C. nitida* Ulrich.

Two left valves. Occurrence as 3. The undulating growth lines on 45 are probably abnormal, for on the opposite valve they are nearly regular, and on 46, they are regular and even, but so faint that they do not show here. This species closely resembles *C. nitida* Ulrich from the Platteville (Lowville) limestone of Minnesota. U. S. N. M. 97433a, 97433b.



WHITESBURG, ATHENS, AND OTTOSEE FOSSILS



Whitesburg, Athens, and Ottosee Fossils

PLATE 82.—WHITESBURG, ATHENS, AND OTTOSEE FOSSILS

FIGURE

1–3. *Ampyxina scarabeus* Butts, n. sp., × 2.

Dorsal views of three individuals. The glabella is more narrowly obovate, the furrows on the thoracic segments are slightly narrower and more nearly parallel to the sutures, and the lateral lobes on the pygidium are more sharply flexed downward at the outer extremities than in *A. bellatula* (Savage), the only other described species. Athens shale; along State Route 114, 4 to 5 miles southwest of Catawba Sanatorium, Roanoke County. Cotypes: U. S. N. M. 97434a, 97434b, 97434c.

4–7. *Robergia major* Raymond.

4, 5, tails. (The posterior extremities have been retouched to bring out the scalloped margins.) 6, internal mold of a nearly complete specimen, dorsal view; 7, external mold of a thorax, dorsal view. (A few of the lateral lobes of the thorax have been strengthened by retouching.) Athens shale. 4, 7, west end of bridge 1 mile west of Front Royal, Warren County; 5, 6, old quarry of Mathieson Alkali Works 2 miles southeast of Saltville, Smyth County. Raymond's types were obtained here. U. S. N. M. 97435a, 72145a, 72145b, 97435b.

8. *Tretaspis reticulata* Ruedemann?

Dorsal view of an exfoliated head. The reticulation is faintly shown on the right fixed cheek in the specimen and very plainly shown on a fragment in the same collection preserving the original exterior of the carapace. Limestone in the Athens; 1½ miles east of Tenth Legion, Rockingham County. U. S. N. M. 97436.

9–13. *Pterygometopus* sp.?

9, 11, internal molds of two heads lacking the free cheeks; 10, internal mold of a thorax with tail; 12, internal mold of part of another thorax; 13, external mold of part of a head, × 4, preserving part of the glabella and free cheek with a perfect facetted compound eye common to trilobites. Athens shale; 5 miles northwest of Roanoke and three-fourths of a mile northeast of Kingstown, Roanoke County. U. S. N. M. 97437a, 97437b, 97437c, 97437d, 97437e.

FIGURE

14. *Ceraurus* or *Ceraurinus* sp.?, × 2.
Dorsal view of a partly preserved head. Ottosee limestone; Rye Cove, Scott County. U. S. N. M. 97438.

15. [a]*Telephus gelasinosus* Butts, × 4.
Anterior view to show vertical frontal spines or teeth characteristic of the genus. Whitesburg limestone; Pratts Ferry, Bibb County, Ala. U. S. N. M. 71468.

16–19. [a]*Telephus bipunctatus* Ulrich.
16, dorsal view of a head, × 4; 17, 18, dorsal and profile views of a head, × 2; 19, free cheek with eye and spine, × 4. The two pits on the glabella are the most distinctive feature of this species. Whitesburg limestone; Lexington, Rockbridge County. Occurs south to Pratts Ferry, Bibb County, Ala. Ulrich states that this is the most abundant and widely distributed of American species of *Telephus*. 16, U. S. N. M. 80543b; 17, 18, 80543a; 19, 80543d.

20. *Ampyx* sp.
Tail. Whitesburg limestone; 1½ miles north of Seven Mile Ford, Smyth County. U. S. N. M. 97439.

21–23. *Ampyx* sp.
21, tails; 22, 23, dorsal and profile views of a head. Occurrence as 16. 21, U. S. N. M. 72102a; 22, 23, 72102b.

24, 25. *Ampyx americanus* Safford and Vogdes.
24, head with frontal spine; 25, entire specimen, dorsal view. Athens shale. 24, Riverton, Warren County; 25, Southern Railway bridge east of Bulls Gap, Tenn. U. S. N. M. 72104, 97440.

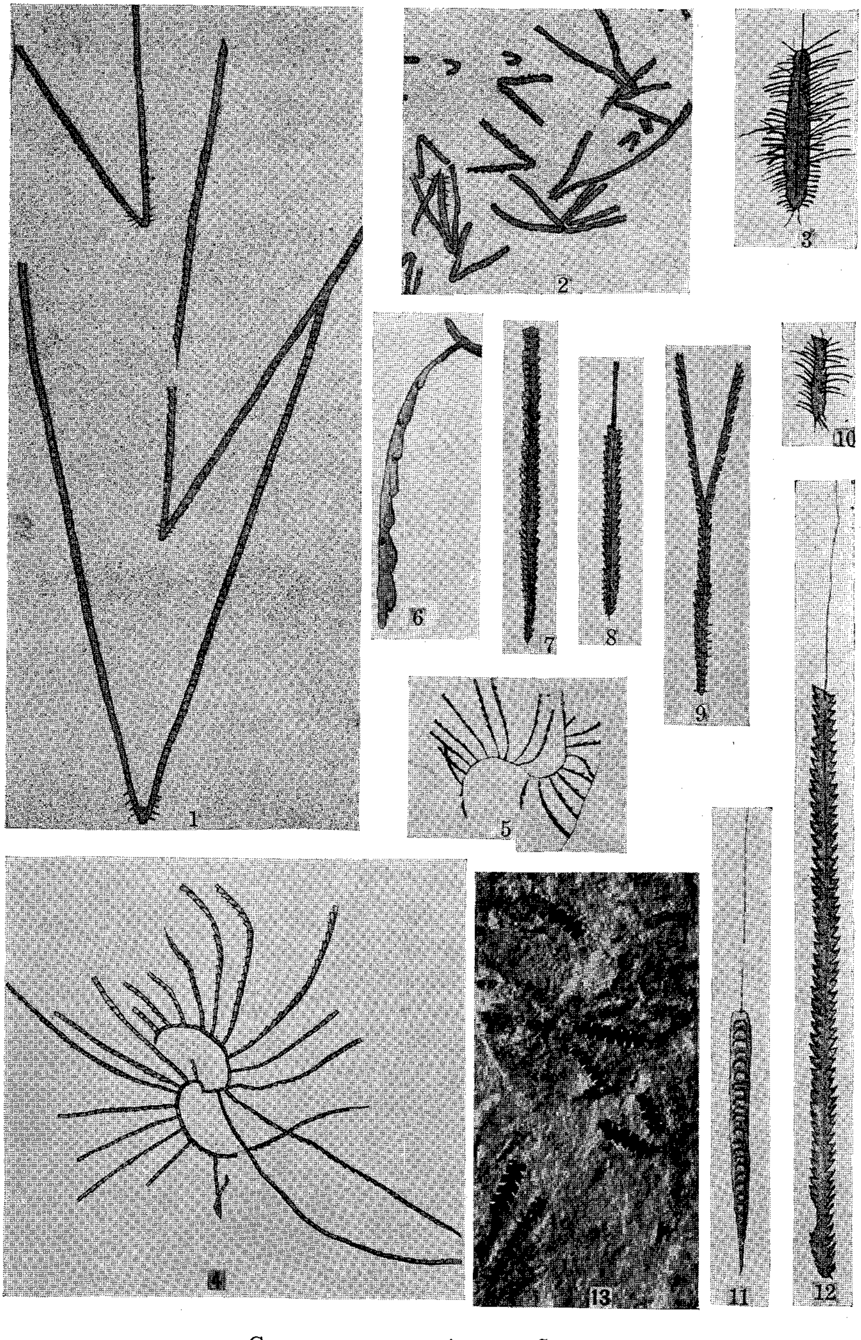
26, 27. *Dionide holdeni* Raymond.
Nearly entire specimens, dorsal views. 26, × 4, occurrence as 1; 27, occurrence as 24. U. S. N. M. 97441, 97442.

28–31. [a]*Telephus pustulatus* Ulrich.
28-30, anterior, profile, and dorsal views of a head, × 2; 31, same as 30, × 4. Occurrence as 16. U. S. N. M. 80536.

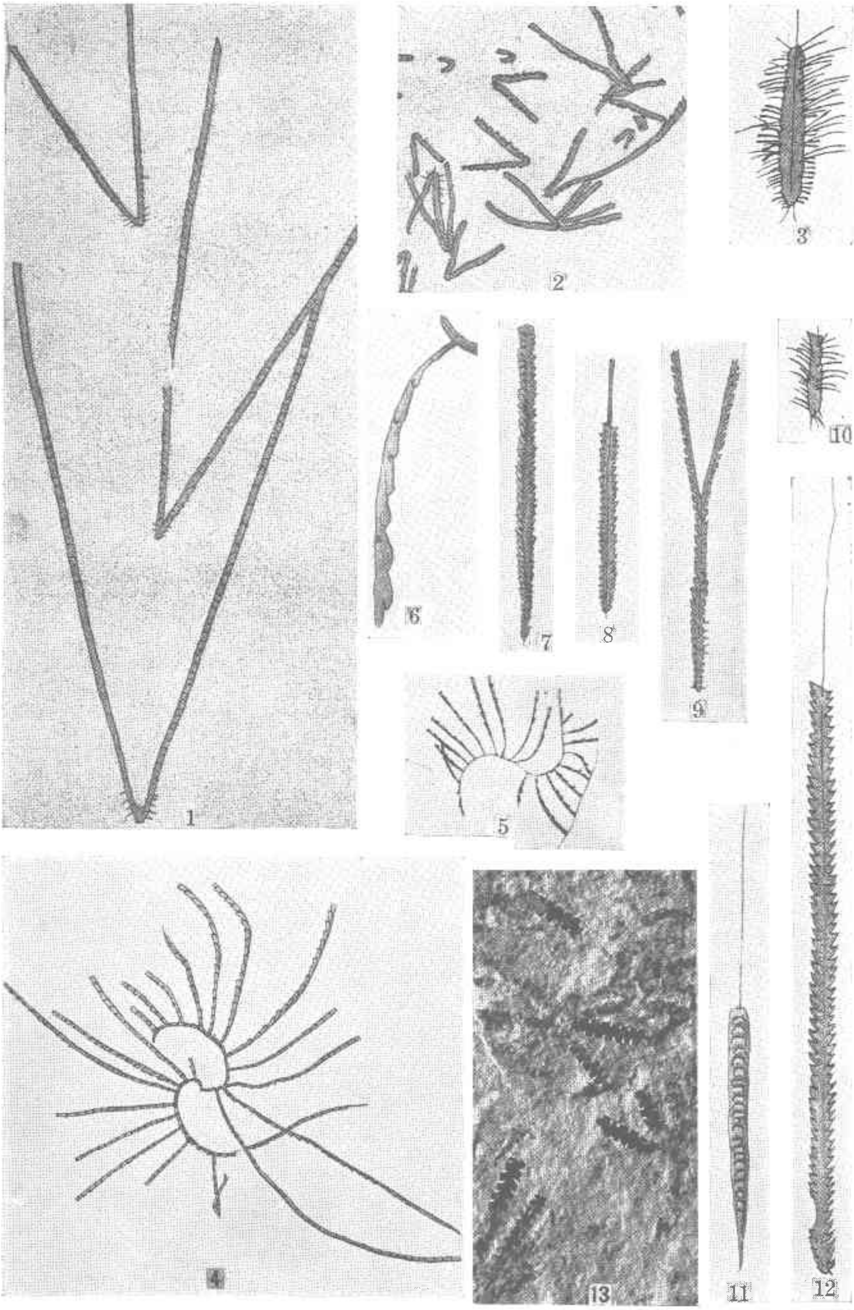
32–37. [a]*Telephus bicornis* Ulrich, × 4.
32, 33, dorsal and profile views of a tail; 34, anterior view of a head showing the bases of two occipital spines; 35, dorsal

[a] After Ulrich, E. O., Proc. U. S. Nat. Mus., vol. 76, pp. 1-101, pls. 1-8, 1929.

view of a head showing a complete posterior occipital spine; 36, dorsal view of a head preserving base of the left frontal spine and a larger part of the right spine which is restored; 37, eye with long spine. Whitesburg limestone; Grayson farm 4 miles southwest of Bland, Bland County. 32, 33, U. S. N. M. 80535j; 34-37, 80535f, 80535d, 80535h, 80535a.



GRAPTOLITES FROM ATHENS SHALE



Graptolites from Athens Shale

PLATE 83.—GRAPTOLITES FROM ATHENS SHALE

All the figures on this plate, except Figs. 4 and 13, are reproduced from Ruedemann, "The Graptolites of New York," New York State Museum, Mem. 11, 1908. The specimens figured, except that of Fig. 4, were collected outside of Virginia, but all the species occur in the Athens of Virginia.

FIGURE

1. *Dicellograptus moffatensis alabamensis* Ruedemann.
   Athens shale; Pratts Ferry, Ala.

2. *Dicellograptus smithi* Ruedemann.
   Athens shale; Pratts Ferry, Ala.

3. *Glossograptus ciliatus* Emmons.
   Normanskill shale; Glenmont, N. Y.

4–6. *Nemagraptus gracilis* (Hall).
   4, along road about half a mile south of Lusters Gate and 2½ miles east of Blacksburg, Montgomery County. Camera lucida drawing by R. Ruedemann. Athens shale. U. S. N. M. 97443. 5, 6, Normanskill shale, Kenwood, N. Y. (after Ruedemann.)

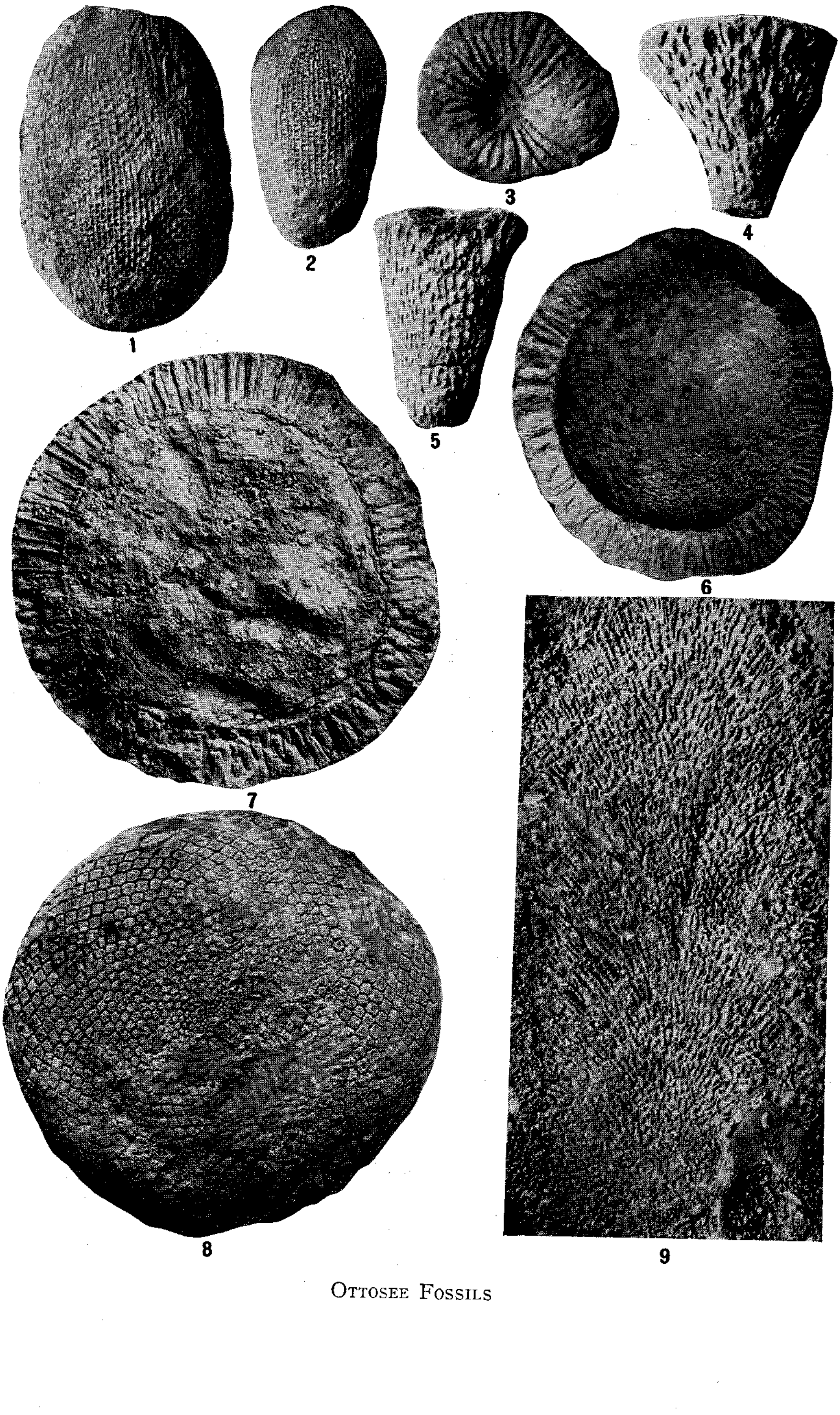
7, 8. *Diplograptus foliaceus* (Murchison).
   7, Utica shale; Cohoes, N. Y.; 8, Normanskill shale, Glenmont, N. Y.

9. *Dicranograptus spinifer* Lapworth.
   Normanskill shale; Glenmont, N. Y.

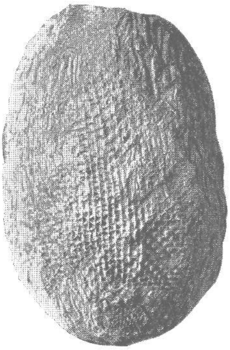
10. *Glossograptus ciliatus* mutation *horridus* Ruedemann.
   Graptolite shale; Summit, Nev.

11, 12. *Diplograptus foliaceus* (Murchison).
   Normanskill shale; Glenmont, N. Y.

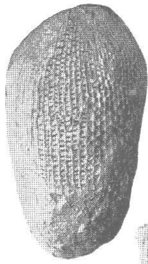
13. *Climacograptus scharenbergi* Lapworth.
   Limestone in the Athens shale; Cahaba River 4 miles northeast of Centerville, Bibb County, Ala. U. S. N. M. 71489.



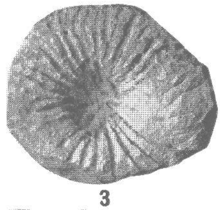
OTTOSEE FOSSILS



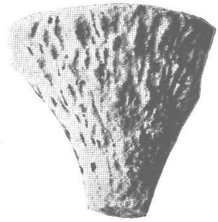
1



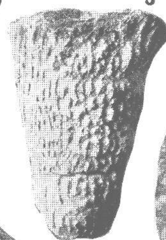
2



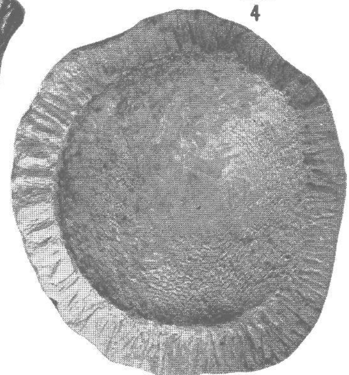
3



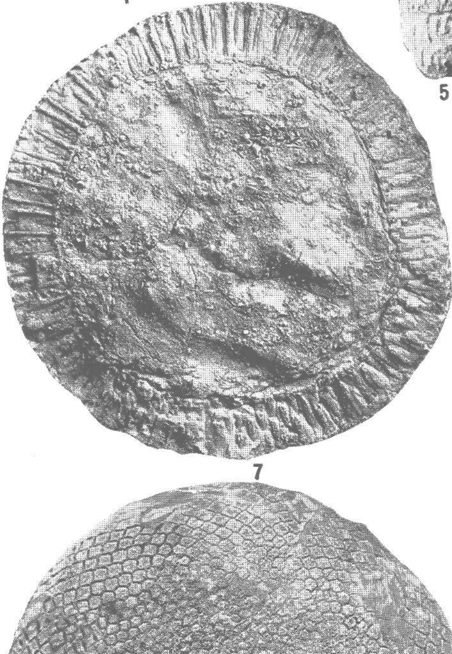
4



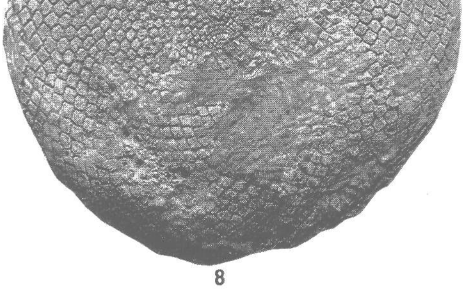
5



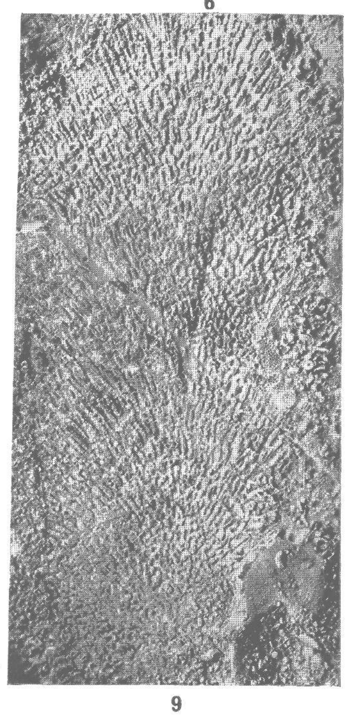
6



7



8



9

OTTOSEE FOSSILS

PLATE 84.—OTTOSEE FOSSILS

FIGURE

1, 2. Sponge; genus and species undetermined.

Ottosee limestone; Rye Cove, Scott County. U. S. N. M. 97444a, 97444b.

3–5. Sponge; genus and species undetermined.

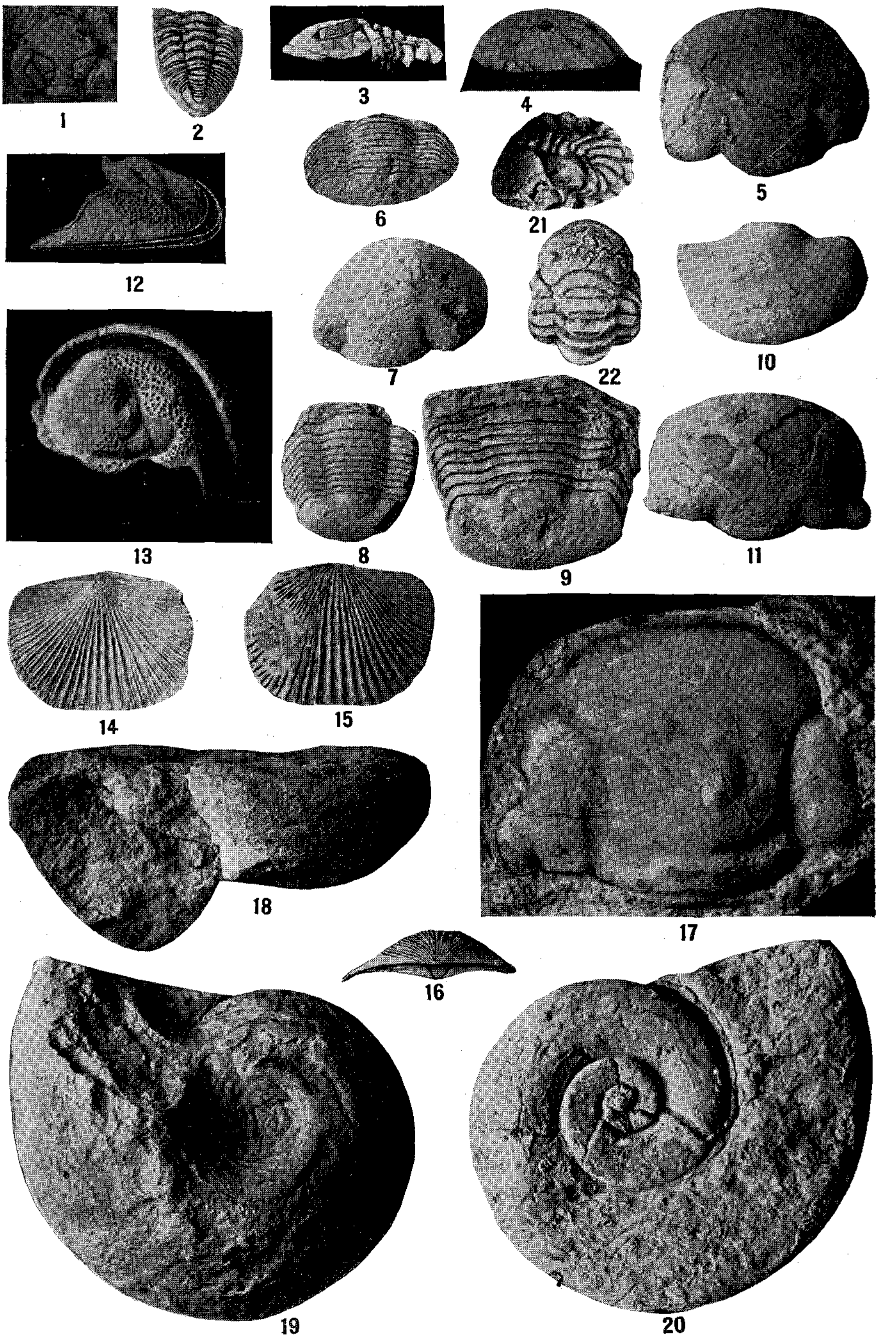
3, 4, calycinal and lateral views of a specimen; 5, lateral view of another specimen. Occurrence as 1. 3, 4, U. S. N. M. 97445a; 5, 97445b.

6–8. *Receptaculites* sp.

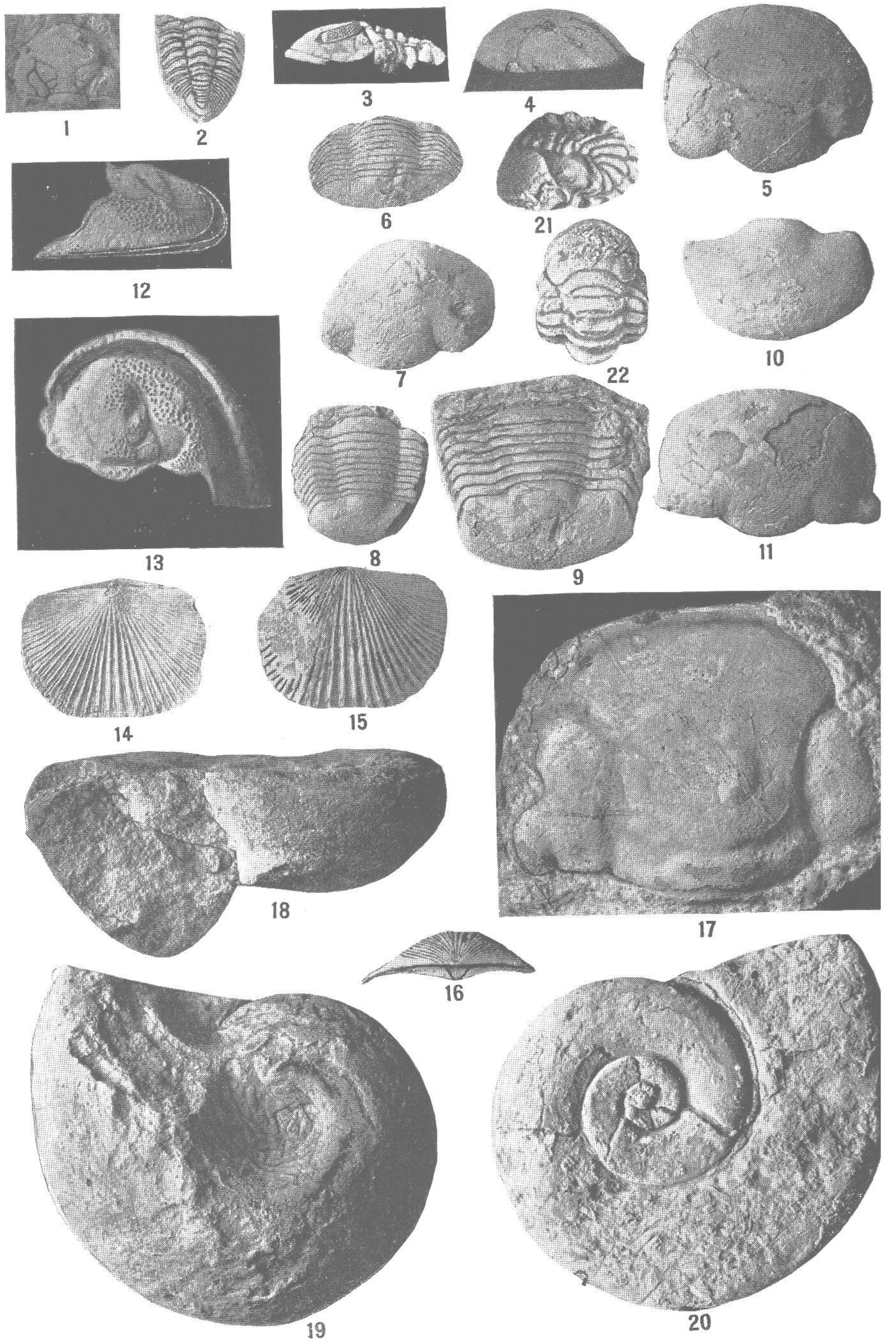
6, under side, showing concavity; 7, under side of another specimen with concavity filled and showing thickness of wall and upright pillars; 8, top view of the same specimen showing external ends and quincuncial arrangement of pillars. A common Ottosee fossil. Occurrence as 1. 6, U. S. N. M. 97446a; 7, 8, 97446b.

9. *Dystactospongia* sp. undetermined.

Ottosee limestone; along State Route 71, 500 feet southeast of Dickensonville, Russell County. U. S. N. M. 97447.



Ottosee Fossils



Ottosee Fossils

PLATE 85.—OTTOSEE FOSSILS

FIGURE

1–3. *Pterygometopus* sp.

1, head; 2, tail and thorax; 3, side view of head showing the faceted eye and part of thorax; a broken, and somewhat distorted specimen. Ottosee limestone; Rye Cove, Scott County. U. S. N. M. 97448a, 97448b, 97448c.

4–11. *Illaenus fieldi* Raymond.

4, 5, side and dorsal views of a head; 6, 8, 9, tail and thorax of different specimens; 10, dorsal view of a tail; 7, 11, dorsal view of two heads. Ottosee limestone. 4, 5, 11, about three-fourths of a mile northeast of Rye Cove, Scott County; 6-10, 1 mile west of Rye Cove, Scott County. 4, 5, U. S. N. M. 97449a; 6-11, 97450a, 97450b, 97450c, 97450d, 97450e, 97449b.

12, 13. *Eoharpes* sp., × 2.

Side and dorsal views of head. The reticulate ornamentation consists of deep pits and their dividing walls. Occurrence as 1. U. S. N. M. 97451.

14–16. *Dinorthis transversa* Willard.

Dorsal, ventral, and posterior views of a specimen. Occurrence as 1. U. S. N. M. 98038.

17. *Basilicus?* sp.

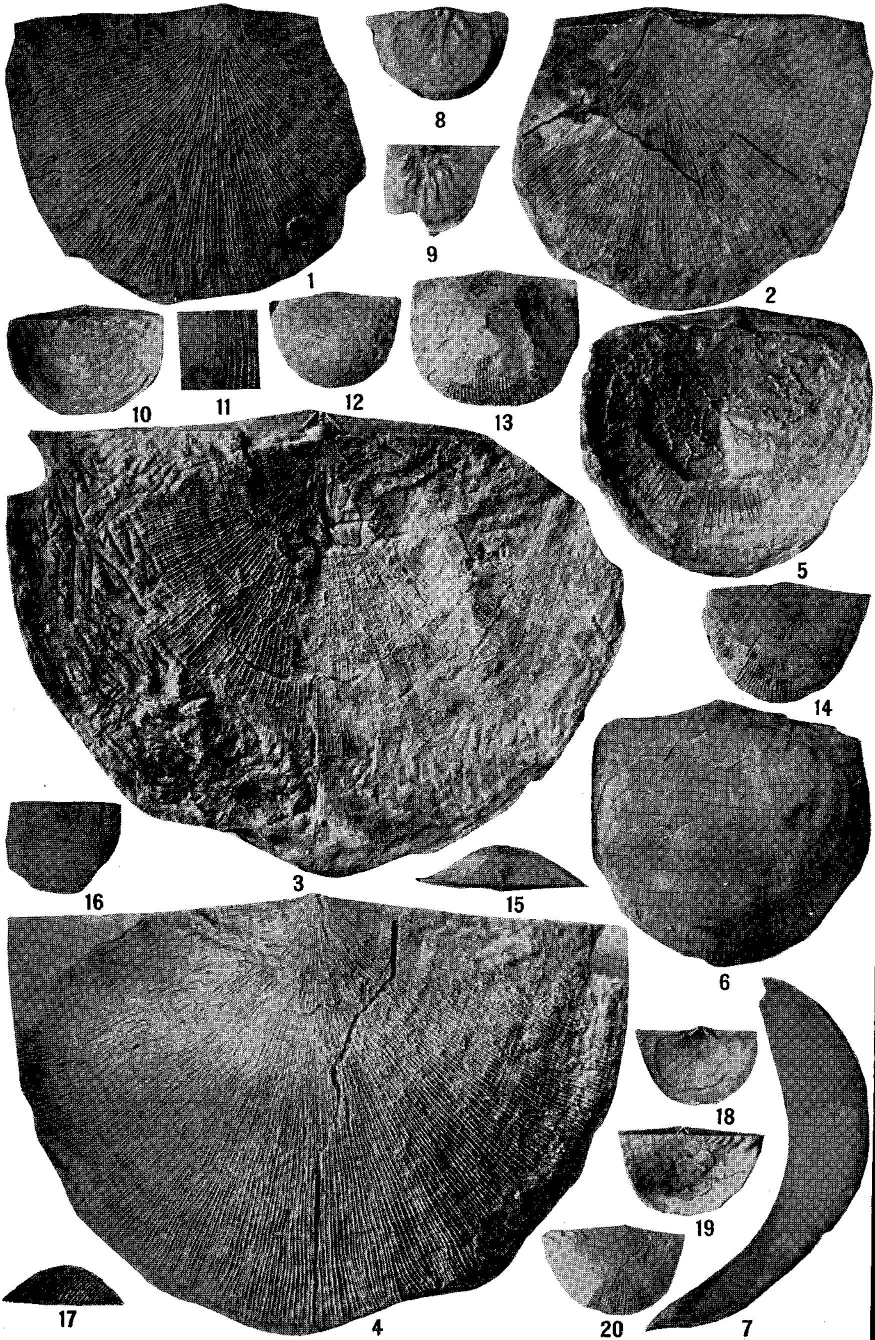
Dorsal view of a head. Occurrence as 1. U. S. N. M. 97452.

18–20. *Maclurites* aff. *M. bigsbyi* (Hall).

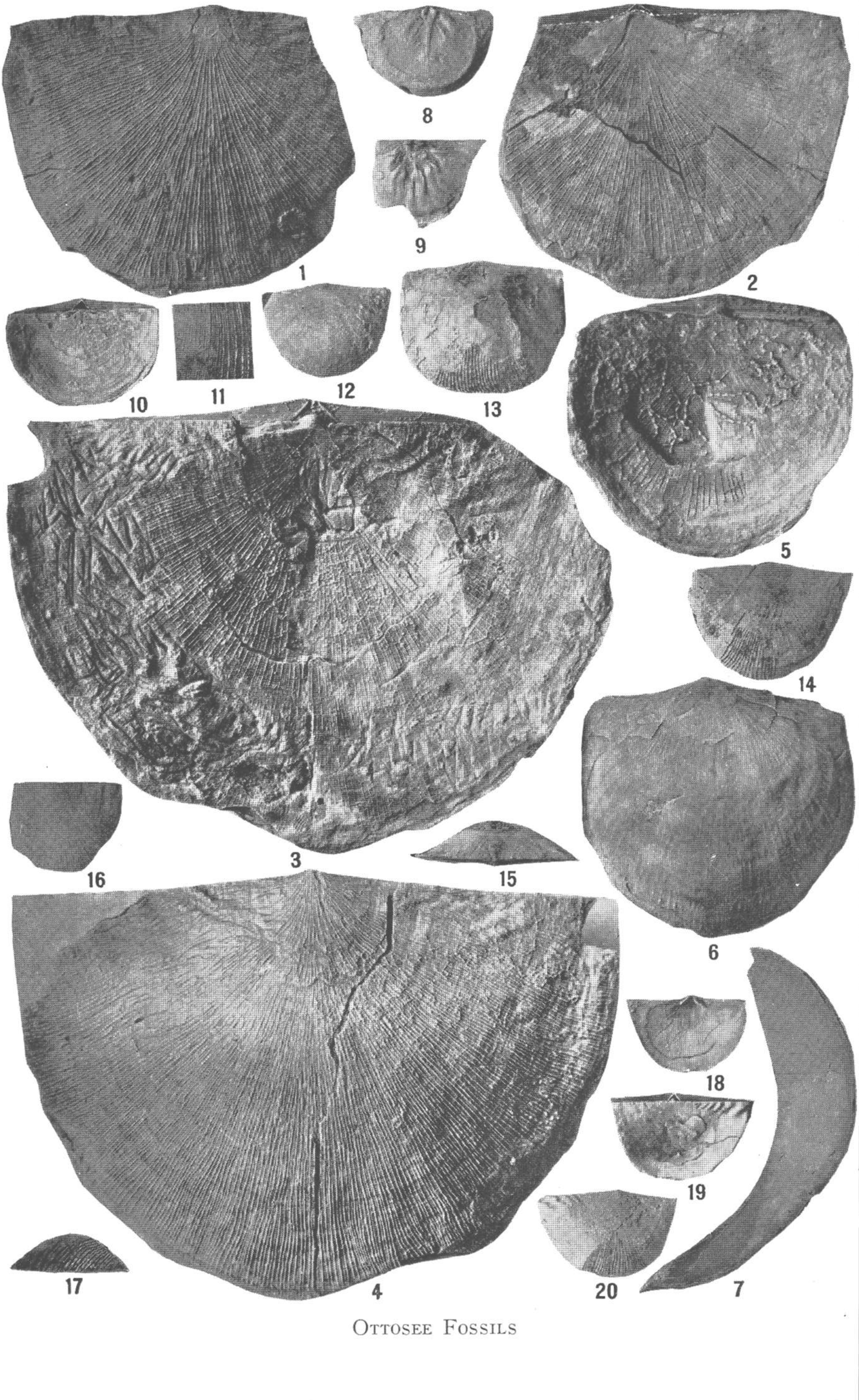
18, side view of a specimen; 19, upper view; 20, basal view of another specimen. Occurrence as 1. 18, U. S. N. M. 97453a; 19, 20, 97453b.

21, 22. *Sphaerexochus* sp., × 3.

Side and dorsal views. Occurrence as 1. U. S. N. M. 97454.



OTTOSEE FOSSILS



OTTOSEE FOSSILS

PLATE 86.—OTTOSEE FOSSILS

FIGURE

1–4. *Rafinesquina magna* Butts, n. sp.

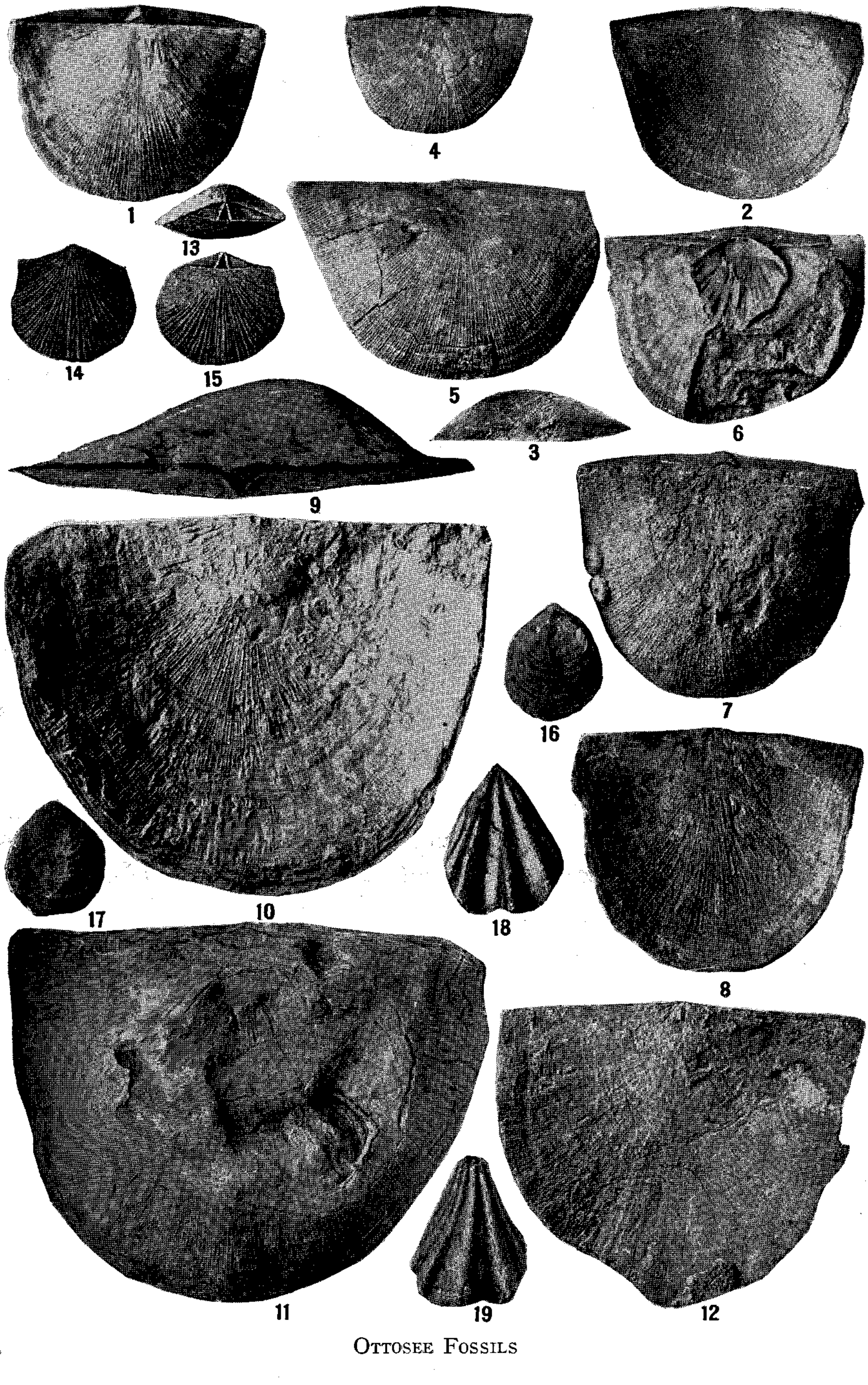
Distinguished by its large size and low convexity. Large striae, 20 in 10 mm., with one or two fine striae between. Specimen of 3, 4, width on hinge line, 3¼ inches; beak to front, 2⅓ inches. So far as known one of the largest species of the genus. 1, 2, ventral and dorsal views of a medium sized specimen; 3, 4, dorsal and ventral views of the largest specimen found. Ottosee limestone; Rye Cove, Scott County. Cotypes: 1, 2, U. S. N. M. 98198; 3, 4, 98199.

5–7. *Rafinesquina* cf. *R. champlainensis* Raymond.

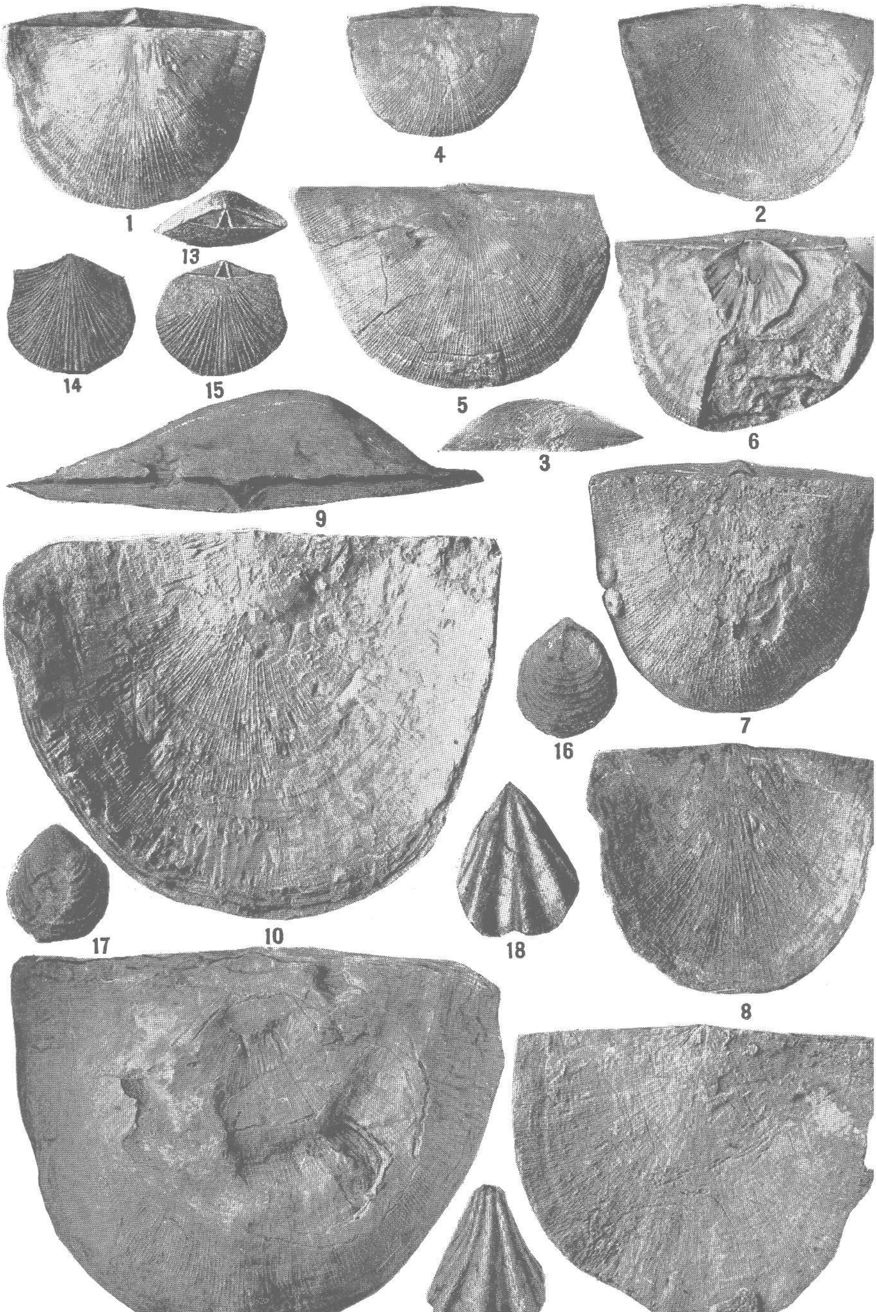
5, 6, dorsal and ventral views of a specimen; 7, sectional view of another specimen showing the convex curvature of the ventral valve (right) and concave curvature of the dorsal valve (left). In *Strophomena* (Pl. 87, figs. 1-12) the relative curvature of the valves is just the reverse. 5, has a network of the stoloniferous bryozoon, *Stomatopora,* upon it. Ottosee limestone; Green Valley 3 miles southeast of Lebanon, Russell County. 5, 6, U. S. N. M. 98200a; 7, 98200b.

8–20. *Rafinesquina* aff. *R. minnesotensis* (N. H. Winchell).

8, 9, interiors of dorsal valves; 9, shows the five digitate muscular impressions characteristic of the dorsal valve of *R. minnesotensis;* 10, 19, dorsal valves of different individuals; 12-14, 20, ventral valves of four individuals; 13, an especially convex specimen; 15, posterior view; 17, profile view of 14; 18, interior of a ventral valve; 11, 16, surfaces of specimens preserving the striae better than the average; 11, × 2. Occurrence as 1. Very abundant. 8-13, U. S. N. M. 98226a, 98226b, 98226c, 98226d, 98226e, 98226f; 14, 15, 17, 98226g; 16, 98226h; 18-20, 98226i, 98226j, 98226k.



OTTOSEE FOSSILS



Ottosee Fossils

PLATE 87.—OTTOSEE FOSSILS

FIGURE

1–6. *Strophomena medialis* Butts, n. sp.

Distinguished by its medium size, low convexity, and regular alternating coarse and fine striae, 30 in 10 mm. Intermediate fine ones inconstant. 1-3, dorsal, ventral, and profile views of a specimen; 4, dorsal view of a small specimen with more irregular striae; 5, ventral view of a specimen with typical striae; 6, interior of a ventral valve. Ottosee limestone; Rye Cove, Scott County. Cotypes: 1-3, U. S. N. M. 98201a; 4-6, 98201b, 98201c, 98201d.

7–12. *Strophomena amploides* Butts, n. sp.

Larger than *S. medialis,* dorsal valve flat in front of the umbo; striae more irregular than in *S. medialis;* about 20 coarse striae in 10 mm. with 1 to 3 finer ones between. 7, 8, dorsal and ventral valves of a specimen; 9-11, posterior, ventral, and dorsal views of the largest specimen found; 12, ventral valve of a specimen. Occurrence as 1. Cotypes: 7, 8, U. S. N. M. 98202a; 9-11, 98202b; 12, 98202c.

13–15. *Pionodema* sp., × 2.

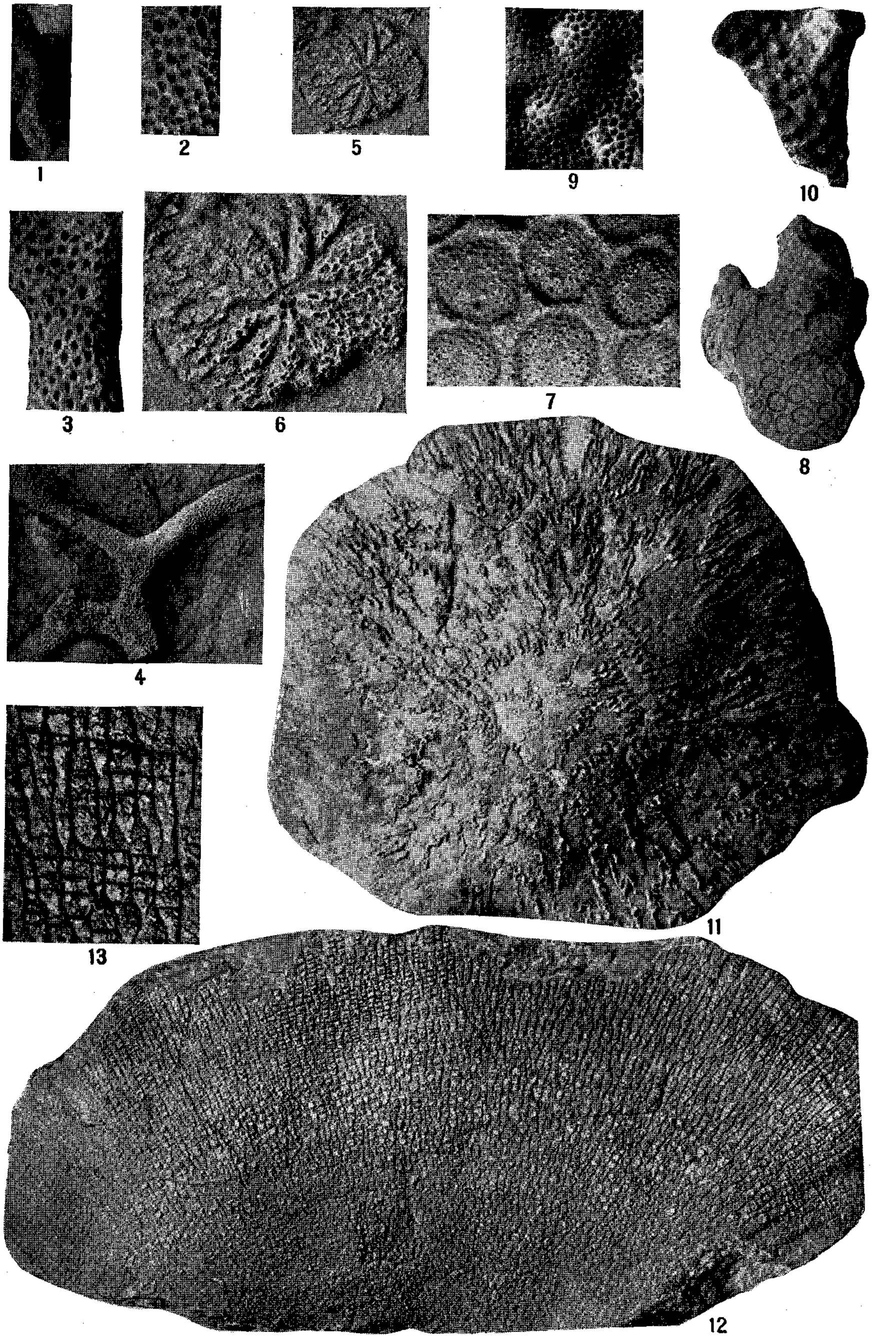
Posterior, ventral, and dorsal views. Occurrence as 1. U. S. N. M. 98203.

16, 17. *Schizambon cuneatus* Willard.

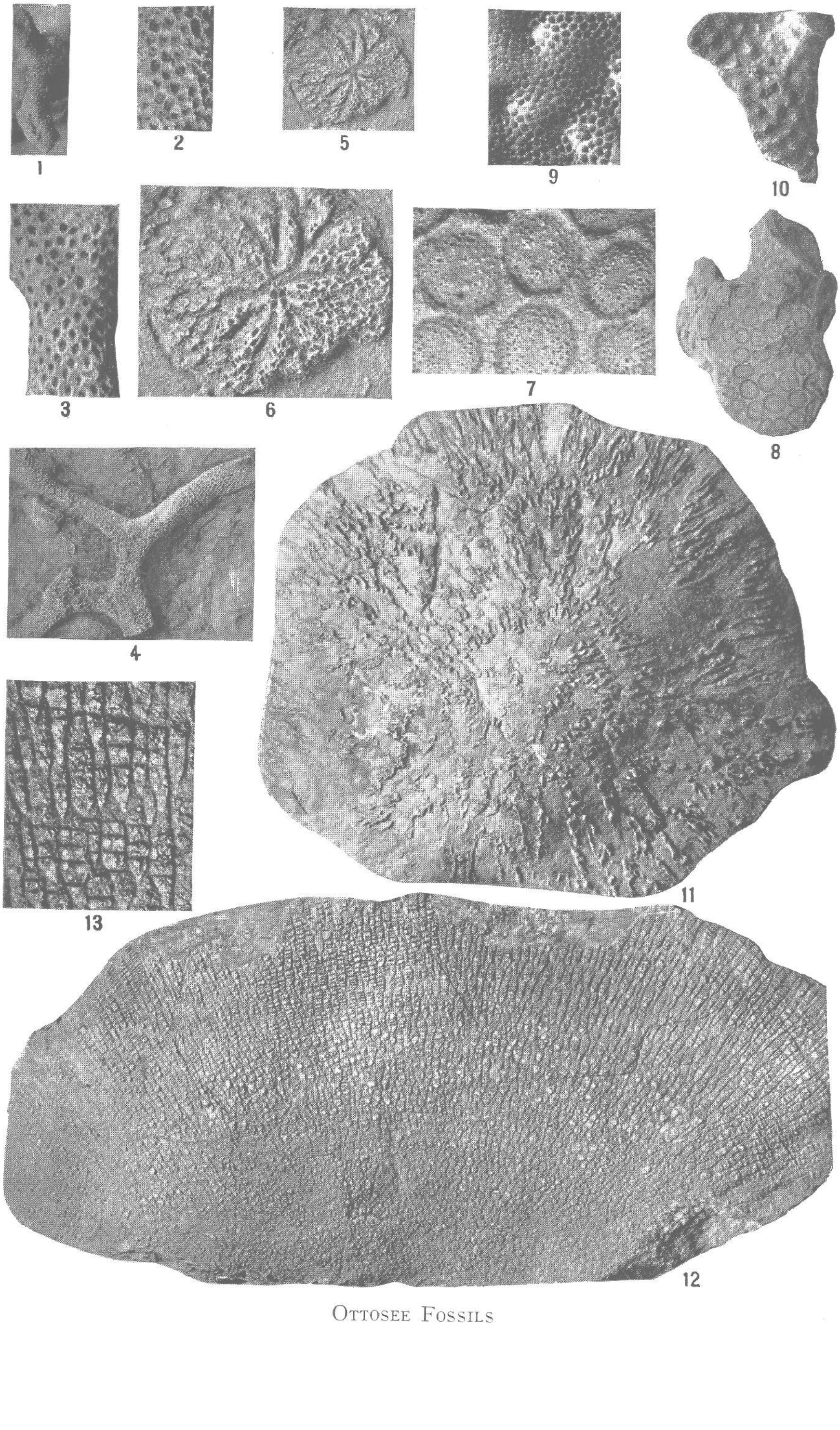
16, dorsal valve; 17, ventral valve. Two specimens. Ottosee limestone; three-fourths of a mile northeast of Rye Cove School, Scott County. U. S. N. M. 98204a, 98204b.

18, 19. *Oligorhynchia* sp., × 4.

Dorsal and ventral valves. Ottosee limestone; Miller farm on northwest slope of Wallen Ridge about 2 miles southeast of Olinger, Lee County. *Oligorhynchia* is very rare in Virginia and so far found only at this place and in Rye Cove. U. S. N. M. 98205.



OTTOSEE FOSSILS



Ottosee Fossils

PLATE 88.—OTTOSEE FOSSILS

FIGURE

1–4. *Anolotichia* sp.

3, an enlargement from 1, × 4; 2, an enlargement from 4, × 4. Ottosee limestone; Rye Cove, Scott County. U. S. N. M. 97455, 97456.

5, 6. *Scenellopora radiata* Ulrich.

5, a macula, × 2; 6, the same, × 4. Occurrence as 1. U. S. N. M. 97457. The holotype, U. S. N. M. 43289, is supposed to be from the type Ottosee at Knoxville, Tenn.

7, 8. *Ceramaporella* sp.

7, part of 8, × 4. Occurrence as 1. U. S. N. M. 97461.

9, 10. Bryozoan; genus and species undetermined. Occurrence as 1.

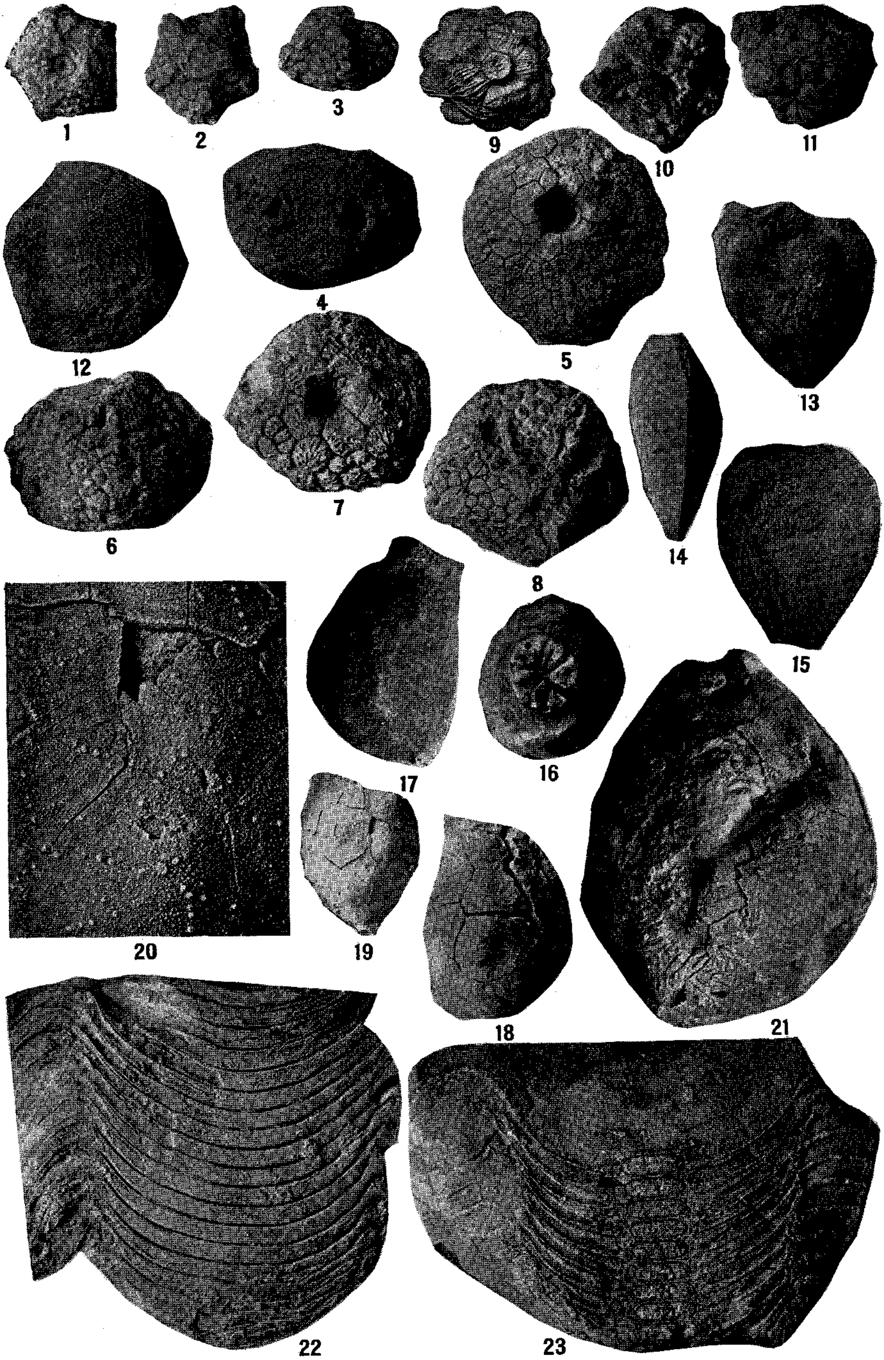
9, part of 10, × 4. U. S. N. M. 97458.

11. *Tetradium* sp.

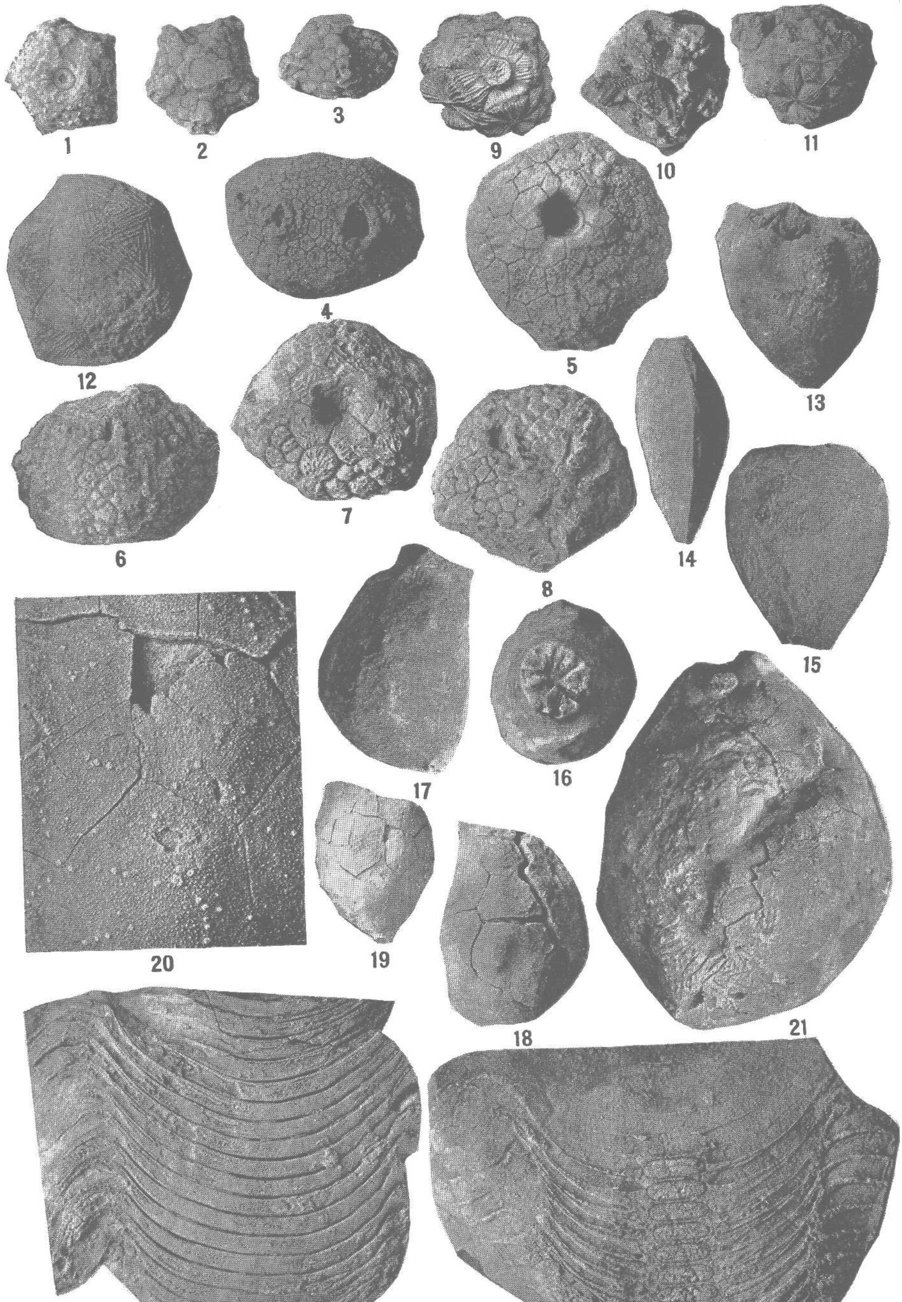
Very common and characteristic form in the Ottosee of Rye Cove, Scott County. U. S. N. M. 97459.

12, 13. *Lichenaria* cf. *L. carterensis* (Safford).

13, part of 12, × 2. Like *Favosites* but lacks radiating septa. Ottosee limestone; along Sinking Creek, 1½ miles northwest of Newport, Giles County. U. S. N. M. 97460.



OTTOSEE FOSSILS



Ottosee Fossils

PLATE 89.—OTTOSEE FOSSILS

FIGURE

1–3. *Diabolocrinus perplexus* Wachsmuth and Springer.

Dorsal, ventral, and lateral views. Ottosee limestone; half a mile west of Rye Cove School, Scott County. U. S. N. M. 97462.

4–8. *Diabolocrinus asperatus* (Miller and Gurley)?.

4, 5, lateral and basal views of a specimen; 6-8, lateral, basal, and ventral views of another specimen, possibly a different species from *D. asperatus*. Ottosee limestone; Rye Cove, Scott County. U. S. N. M. 97463, 97464.

9–11. *Palaeocrinus* aff. *P. striatus* Billings.

Basal, ventral and lateral views. Occurrence as 4. U. S. N. M. 97465.

12. *Echinosphaerites* sp.

Occurrence as 4. U. S. N. M. 97466.

13. *Holocystites?* sp.

Shape and ornamentation like *Holocystites*. Ottosee limestone; 1½ miles southwest of Rye Cove School, Scott County. U. S. N. M. 97467.

14, 15. *Platycystites faberi* Miller.

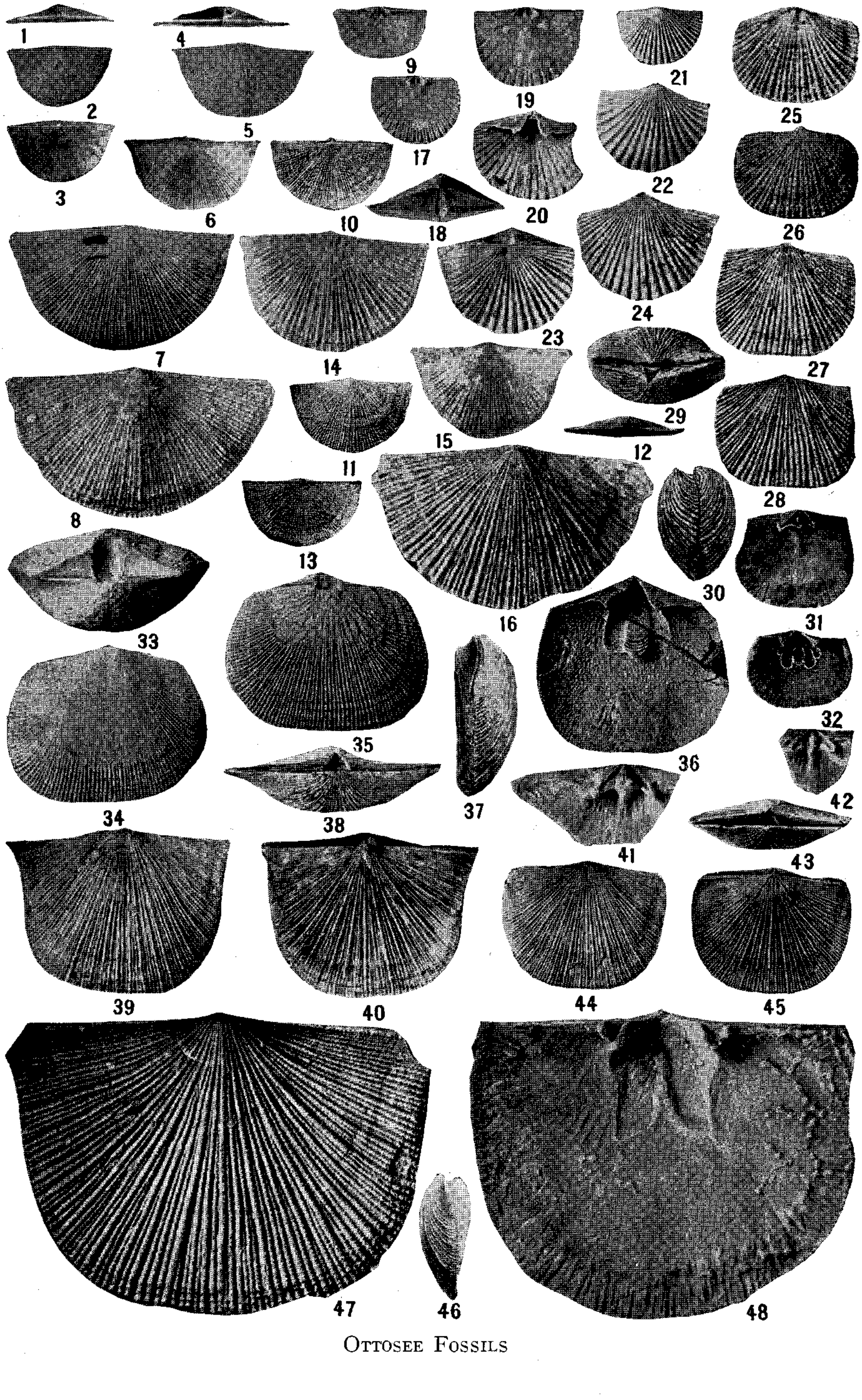
Edge and side views. Occurrence as 13. U. S. N. M. 97468.

16–21. Cystid; genus and species undetermined.

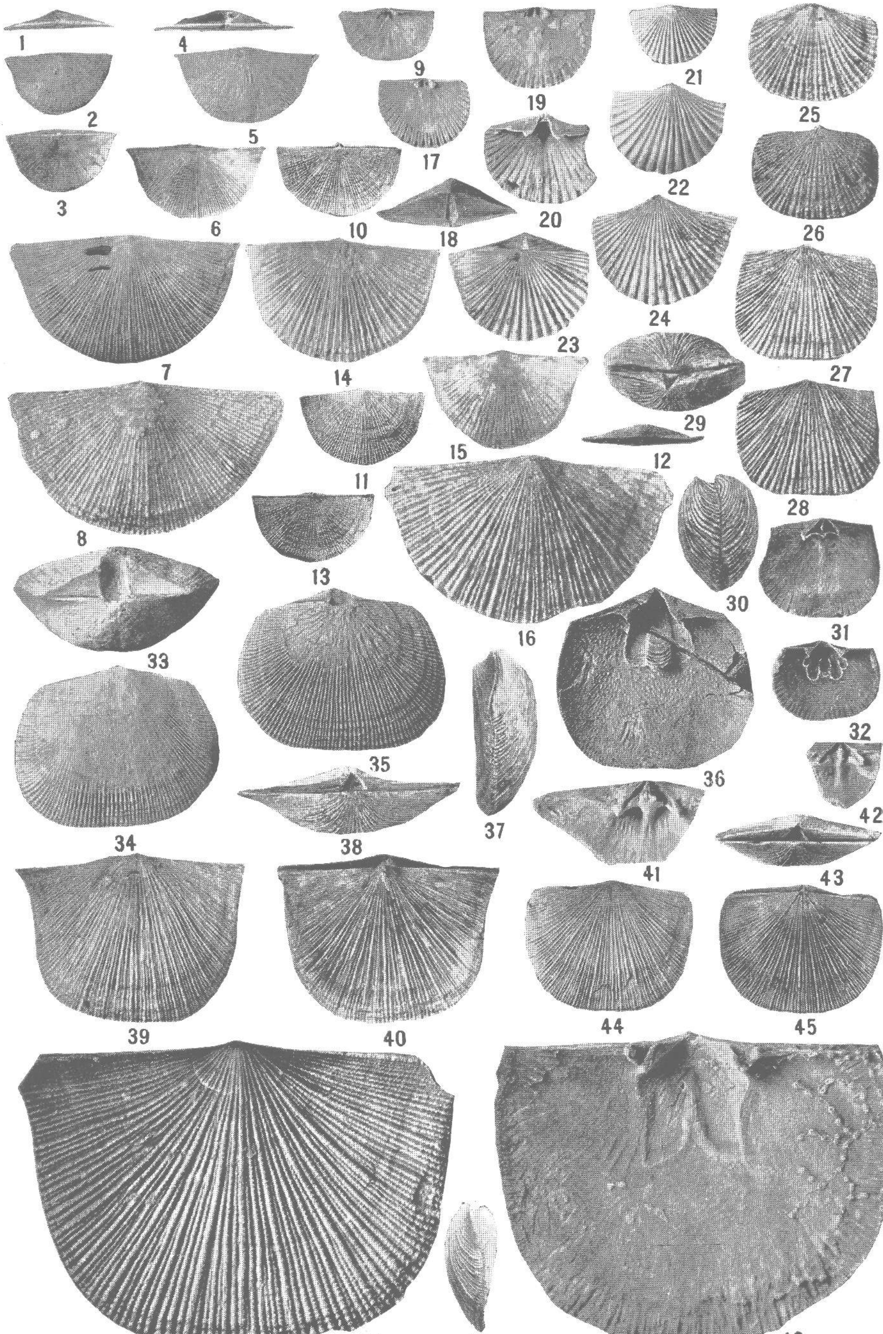
17-19, 21, lateral views; 16, summit view of 17; 20, part of 19, × 4; 21, posed with shadow on left. Occurrence as 4. 16, 17, U. S. N. M. 97469a; 18, 97469b; 19, 20, 97469c; 21, 97469d.

22, 23. *Gonioceras* sp.?

Near *G. anceps* Hall of the Lowville limestone of New York. 23, natural section showing part of siphuncle. Occurrence as 4. U. S. N. M. 97470a, 97470b.



Ottosee Fossils



Ottosee Fossils

PLATE 90.—OTTOSEE FOSSILS

(From Rye Cove, Scott County)

FIGURE

1–8. *Sowerbyella* sp.

2, 5, 7, 8, ventral valves; 7, × 2; 8, × 4; 3, 6, dorsal valves of 2, 5; 1, posterior view of 2; 4, posterior view of 5. 1-3, U. S. N. M. 98206a; 4-6, 98206b; 7, 8, 98206c, 98206d.

9–16. *Sowerbyella* sp.

9, interior of a ventral valve; 10-12, dorsal, ventral, and posterior views of a specimen; 13, darker print of 10 showing the transverse lines more plainly; 10, shows better the cardinal process of the dorsal valve; 14-16, ventral valves of 3 specimens; 14, × 2; 16, specimen of the same size as that of 8, × 4. The differences in the striae of the two species is plainly shown in 7, 14, and in 8, 16. 9, U. S. N. M. 98207a; 10-13, 98207b; 14-16, 98207c, 98207d, 98207e.

17–24. *Hesperorthis* aff. *H. tricenaria* (Conrad).

17, 19, interiors of dorsal valves; 20, interior of ventral valve; 18, 23, 24, posterior, dorsal, and ventral views of the same specimen; 21, 22, ventral views of smaller specimens. 17, 19, U. S. N. M. 98208a, 98208c; 20, 98208d; 18, 23, 24, 98208b; 21, 22, 98208e, 98208f.

25–32. *Glyptorthis* aff. *G. bellarugosa* (Conrad).

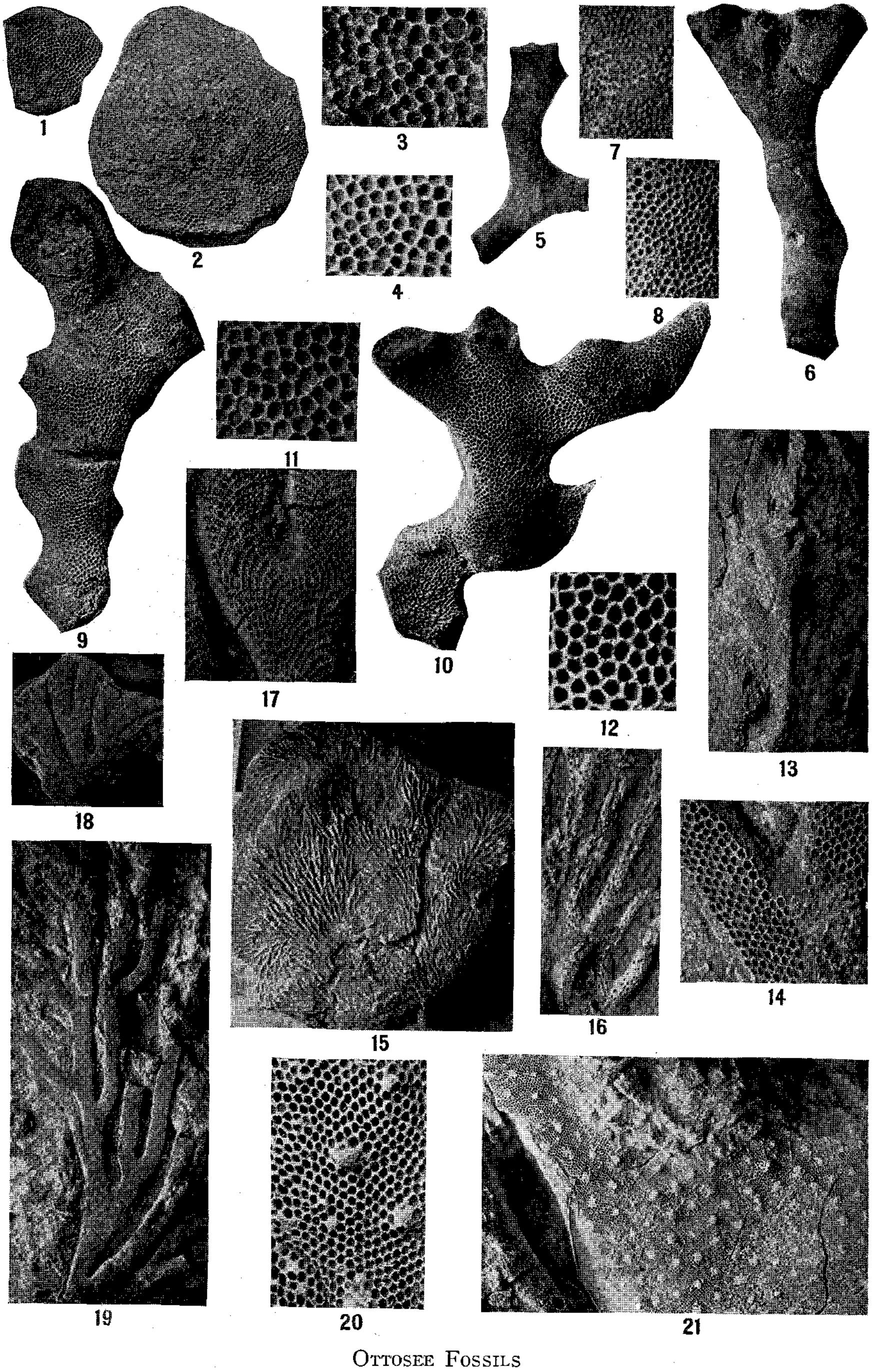
25, 26, dorsal and ventral valves of a specimen; 27-30, ventral, dorsal, posterior, and lateral views of a specimen; 31, interior of a dorsal valve; 32, interior of a ventral valve. 25, 26, U. S. N. M. 98209a; 27-30, 98209b; 31, 32, 98209c, 98209d.

33–36. *Mimella superba* Butts, n. sp.

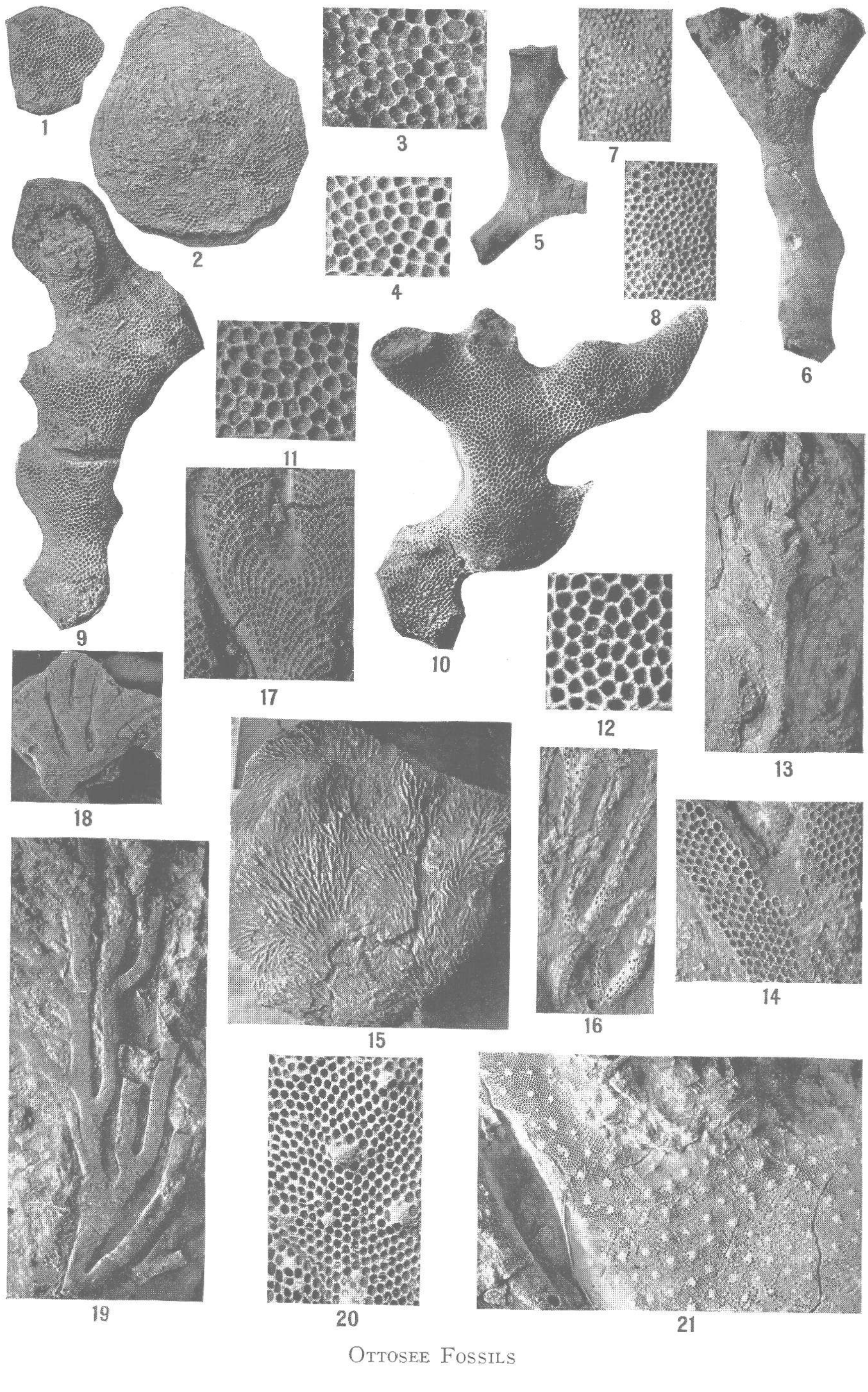
Distinguished from *M. melonica* Willard by its larger size and more subquadrate form. 33-35, posterior, ventral, and dorsal views of a large specimen; 36, interior of a ventral valve. Holotype: 33-35, U. S. N. M. 98210; Paratype: 36, 98211.

37–48. *Multicostella* aff. *M. platys* (Billings).

37-40, lateral, posterior, ventral, and dorsal views of a specimen of average size; 41, 42, interiors of two dorsal valves; 43-46, posterior, ventral, dorsal, and lateral views of a slightly smaller specimen; 47, ventral valve of a specimen, × 2; 48, interior of ventral valve, × 2, with chain of the coral *Stomatopora* on right margin. 37-40, U. S. N. M. 98212a; 41, 42, 98212b, 98212c; 43-46, 98212d; 47, 48, 98212e, 98212f.



Ottosee Fossils



OTTOSEE FOSSILS

Plate 91.—Ottosee Fossils
(From Rye Cove, Scott County)

Figure

1–4. *Mesotrypa* sp.
3, part of 2, × 4; 4, part of 1, × 4. U. S. N. M. 97471a, 97471b.

5–8. *Dekayella?* sp.
5, 6, two individuals; 7, surface of 5, × 4; 8, surface of 6, showing shape and size of cells, × 4. U. S. N. M. 97472a, 97472b.

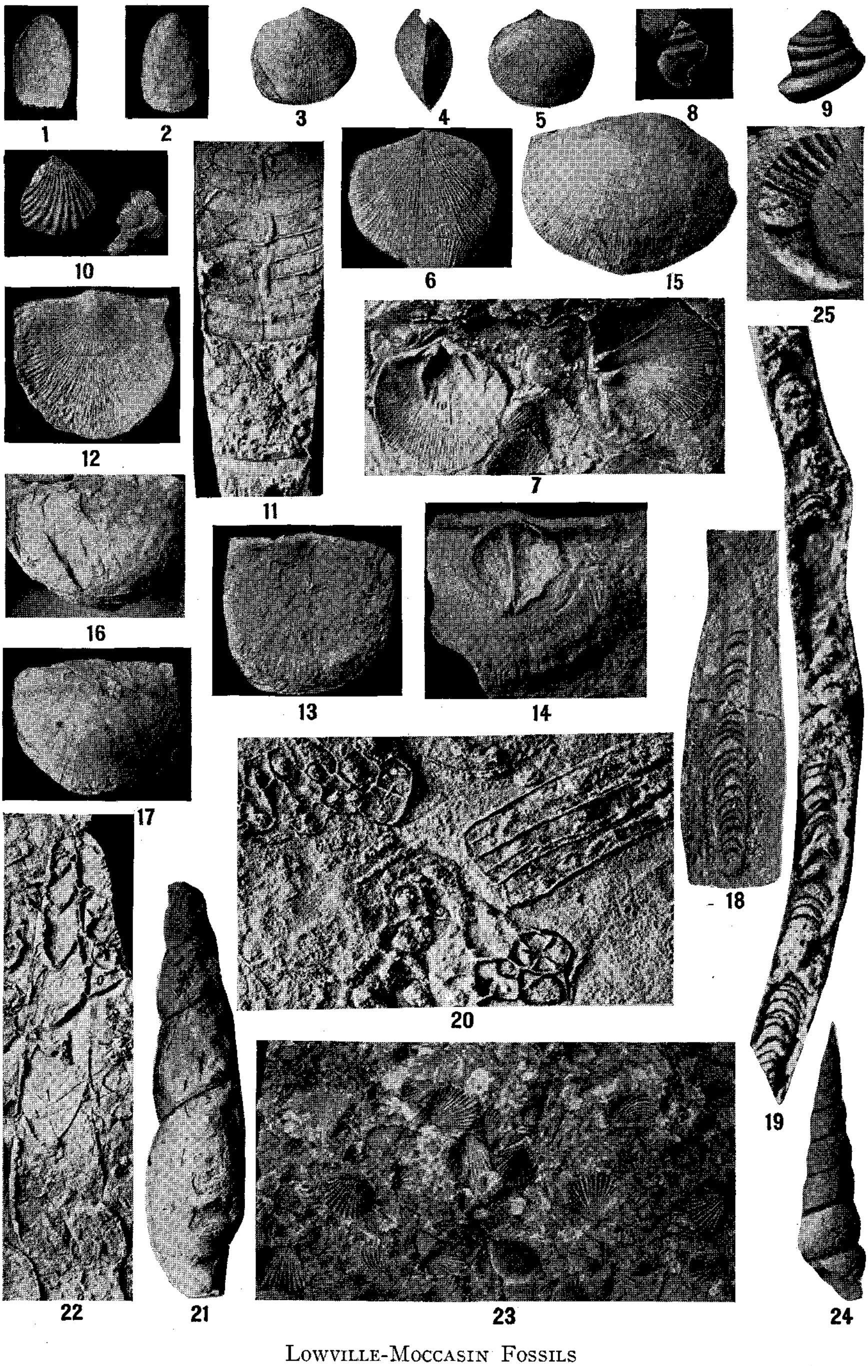
9–12. *Batostoma sevieri* Bassler.
9, 10, two specimens; 11, surface of 9, × 4; 12, surface of 10, × 4. U. S. N. M. 97473a, 97473b.

13, 14. *Phaenopora* sp.
Distinguished by its branching arborescent manner of growth. 14, part of 13, × 4. U. S. N. M. 97474.

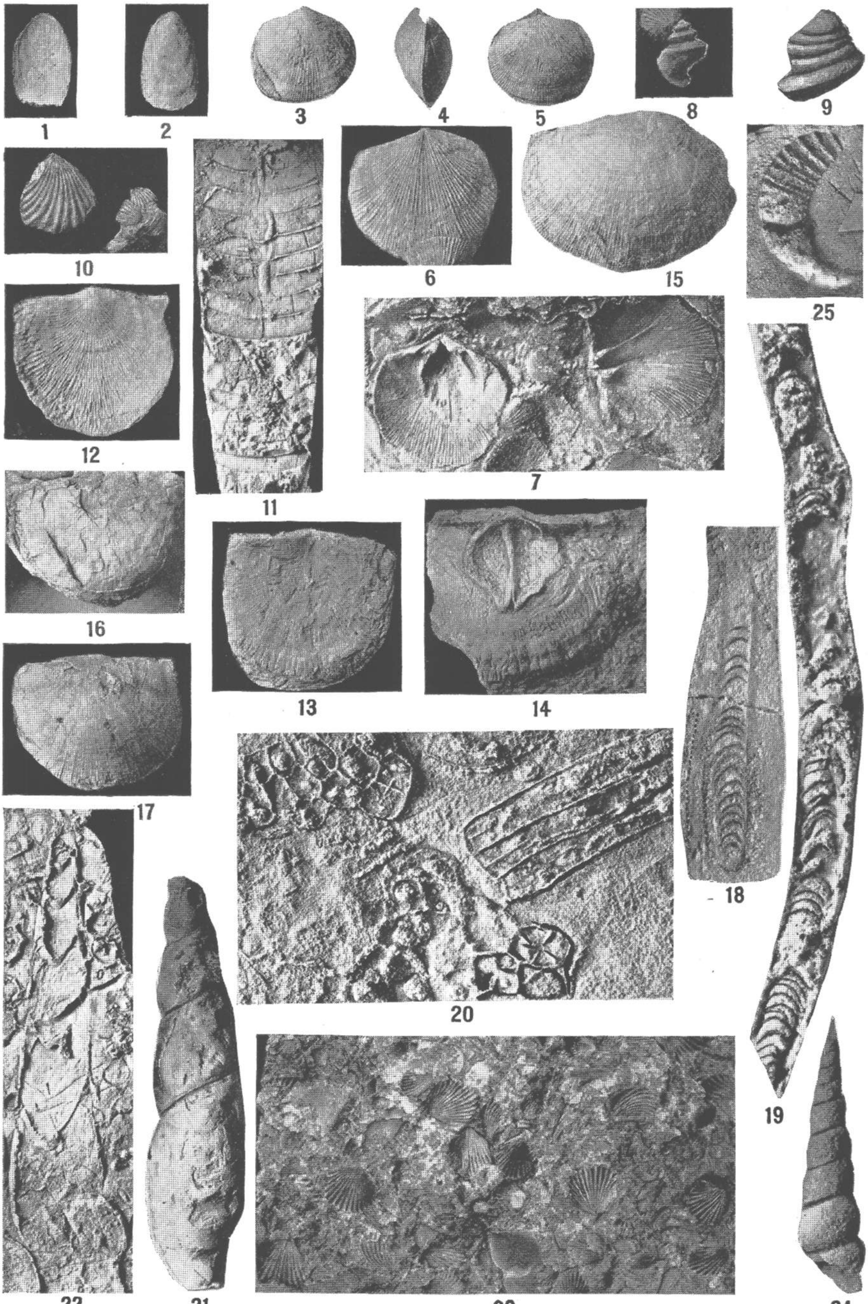
15, 16. *Chasmatopora* sp.
15, noncelluliferous side; 16, celluliferous face of a few branches of another individual, × 4. U. S. N. M. 97475a, 97475b.

17–19. *Graptodictya* sp.
Distinguished by its parallel branching and U-shaped bifurcation. 17, part of 18, × 4. U. S. N. M. 97476a, 97476b.

20, 21. *Pachydictya* sp.
Distinguished by its large expanded frond. 20, part of 21, × 4. U. S. N. M. 97477.



Lowville-Moccasin Fossils



LOWVILLE-MOCCASIN FOSSILS

PLATE 92.—LOWVILLE-MOCCASIN FOSSILS

FIGURE

1, 2. *Lingula* sp.

External and internal molds of a ventral valve. Sandstone in the top of the Moccasin formation; northwest foot of Catawba Mountain along State Route 311 in the angle just southeast of Catawba Creek and 1 mile southeast of Catawba Sanitorium, Roanoke County. U. S. N. M. 97478a, 97478b.

3–7. *Pionodema subaequata* (Conrad).

3-5, ventral, profile, and dorsal views of a specimen; 6, ventral view of a specimen from the same slab as shown in 7; 7, interior of a ventral (left), and of a dorsal (right), valve. Lowville limestone. 3-5, along U. S. Route 58 about 3½ miles east of Cumberland Gap village, Tenn.; 6, 7, slab collected near Franks Run 2 miles northwest of Crabbottom, Highland County. 3-5, U. S. N. M. 97479; 6, 7, 97480a, 97480b.

8. *Lophospira oweni* Ulrich and Scofield.

Lowville limestone; half a mile east of Olinger, Lee County. U. S. N. M. 97481.

9. *Eotomaria dryope* (Billings).

Lowville limestone; along U. S. Route 19 half a mile south of St. Clair station and 3 miles southwest of Bluefield, Tazewell County. U. S. N. M. 97483.

10. *Camarotoechia plena* (Hall)? Also several specimens of *Zygospira recurvirostris* (Hall).

Limestone in the Moccasin formation; 3 miles northeast of Sweet Chalybeate Springs, Alleghany County. U. S. N. M. 97482.

11. *Orthoceras multicameratum* Emmons.

Dove-colored limestone in the base of the Moccasin (red) formation; about 50 feet above the Ottosee limestone in Ward Cove 3½ miles southwest of Snapp, Tazewell County. (See Tazewell sheet). U. S. N. M. 97484.

12–14. *Strophomena incurvata* (Shepard).

12, ventral valve; 13, dorsal valve; 14, interior of another ventral valve. Lowville limestone; northwest slope of Wallen Ridge southeast of Olinger, Lee County. U. S. N. M. 97485a, 97485b, 97485c.

FIGURE

15. *Strophomena?* sp.

A very convex or hemispherical dorsal valve with striae-like *Strophomena* or *Rafinesquina.* Several specimens. Lowville limestone; on slope just south of Gate City, Scott County. U. S. N. M. 97486.

16, 17. *Rafinesquina?* sp.

16, exfoliated dorsal valve; 17, ventral valve. Occurrence as 12. U. S. N. M. 97487a, 97487b.

18, 19. *Cryptophragmus antiquatus* Raymond. (*Beatricea gracilis* Foerste.)

One of the main guide fossils of the Lowville limestone. 18, shows two layers of spongy tissue outside of the septate internal chambers. 18, northwest slope of Peters Mountain 3½ miles southwest of Gap Mills on road to Waiteville, W. Va.; 19, Rye Cove, Scott County, about 50 feet above Ottosee limestone. U. S. N. M. 97489, 97488.

20. *Tetradium cellulosum* (Hall), × 4.

Shows both cross and longitudinal sections of dividing corallites. Lowville limestone; just northwest of Powell River about 6 miles southeast of Rose Hill, Lee County. Another main guide fossil of the Lowville limestone. U. S. N. M. 97490.

21, 22. *Subulites cf. S. regularis* Ulrich and Scofield.

21, exterior; 22, longitudinal section. Lowville limestone. 21, locality as 3; 22, in Ward Cove 2 miles southwest of Snapp, Tazewell County. (See Tazewell sheet.) U. S. N. M. 97491, 97492.

23. Slab crowded with *Zygospira recurvirostris* (Hall).

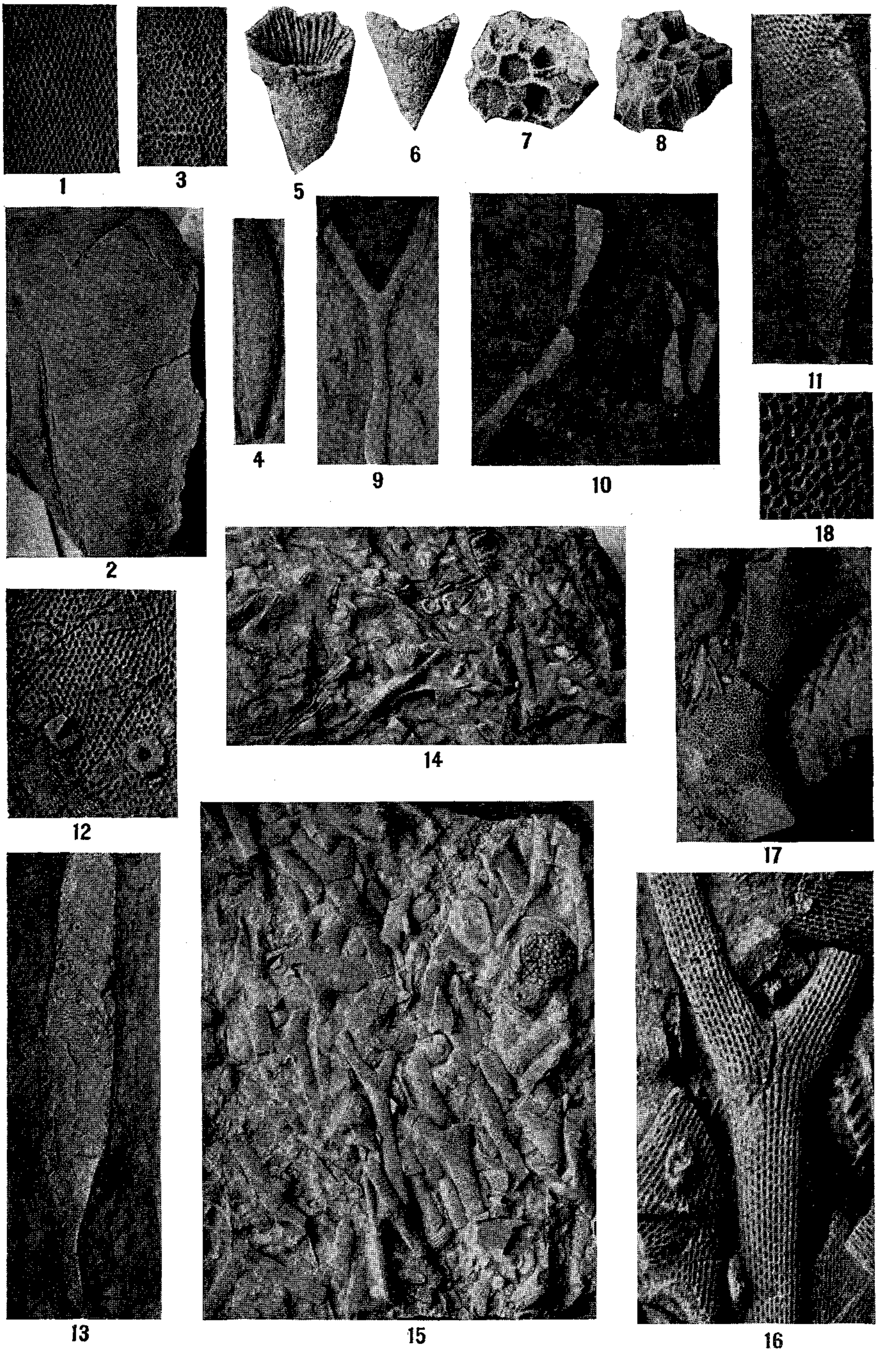
Lowville limestone; 3 miles northeast of Sweet Chalybeate Springs, Alleghany County. Occurs also in older limestone but most commonly in the Lowville. U. S. N. M. 97493.

24. *Hormotoma gracilis* (Hall).

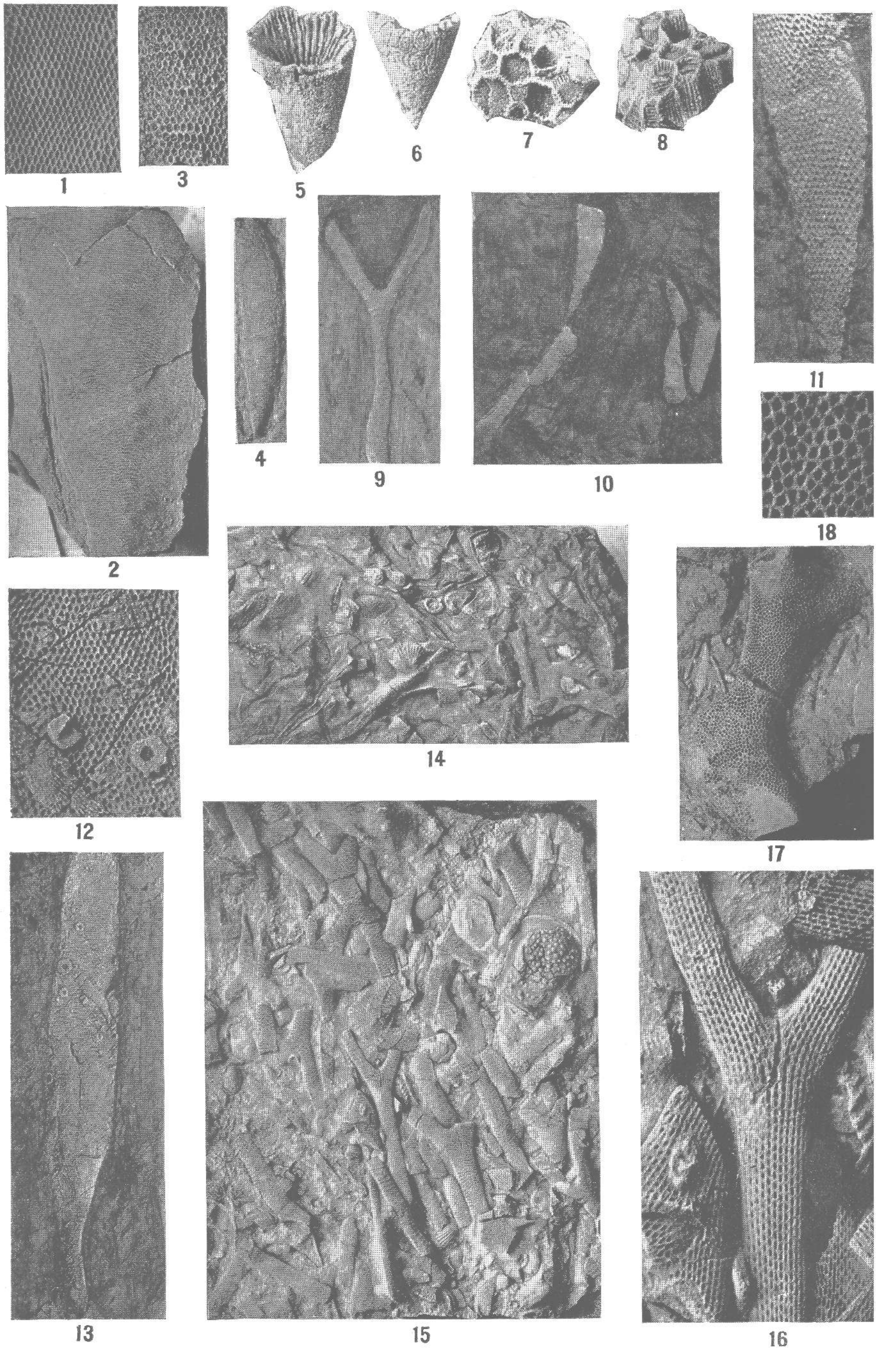
Occurrence as 3. U. S. N. M. 97494.

25. *Centrocyrtoceras annulatus* (Hall).

Occurrence as 22. U. S. N. M. 97495.



LOWVILLE FOSSILS



LOWVILLE FOSSILS

PLATE 93.—LOWVILLE FOSSILS

FIGURE

1, 2. *Escharopora* sp.

1, part of 2, × 4. Lowville limestone; Warm Springs, Bath County. U. S. N. M. 97497.

3, 4. *Escharopora* sp.

3, part of 4, × 4. Lowville limestone; cut on the Virginian Railway along east bluff of New River one-fourth of a mile north of Walker Mountain, Giles County. U. S. N. M. 97498.

5, 6. *Streptelasma profundum* (Conrad).

Lowville limestone; along U. S. Route 58 about 3½ miles east of Cumberland Gap village, Tenn. U. S. N. M. 97499a, 97499b.

7, 8. *Columnaria halli* Nicholson.

Occurrence as 5. U. S. N. M. 97500.

9. *Rhinidictya nicholsoni* Ulrich.

Lowville limestone; along railroad 600 feet south of Speers Ferry railroad station, Scott County. U. S. N. M. 97501.

10, 11. *Escharopora subrecta* (Ulrich).

11, upper specimen on 10, × 4. Lowville limestone; Wheeler quarry 1 mile northeast of Walnut Hill, Lee County. U. S. N. M. 97504.

12, 13. *Escharopora confluens* Ulrich.

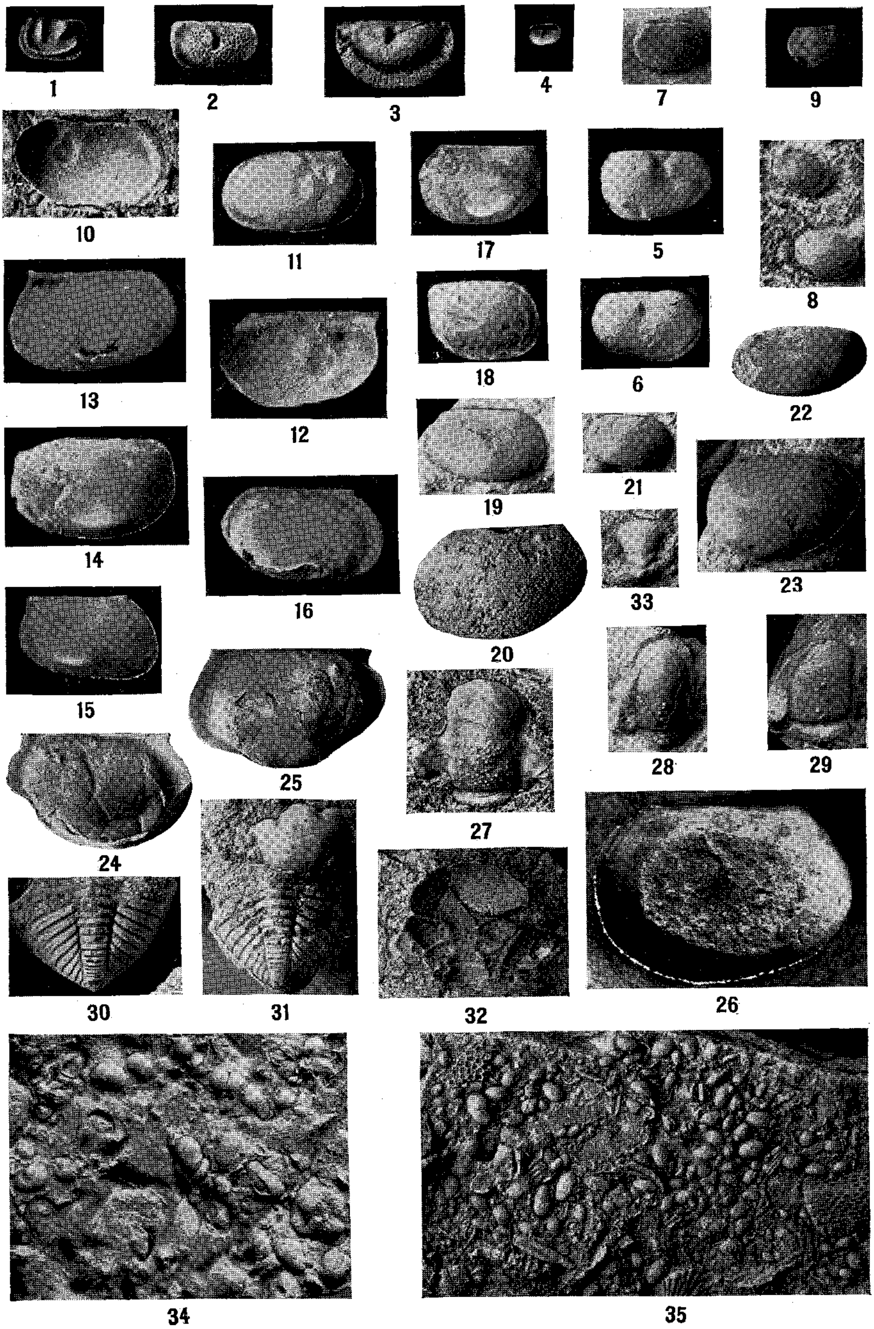
12, part of 13, × 4. Occurrence as 9. U. S. N. M. 97505.

14–16. *Rhinidictya nicholsoni* Ulrich.

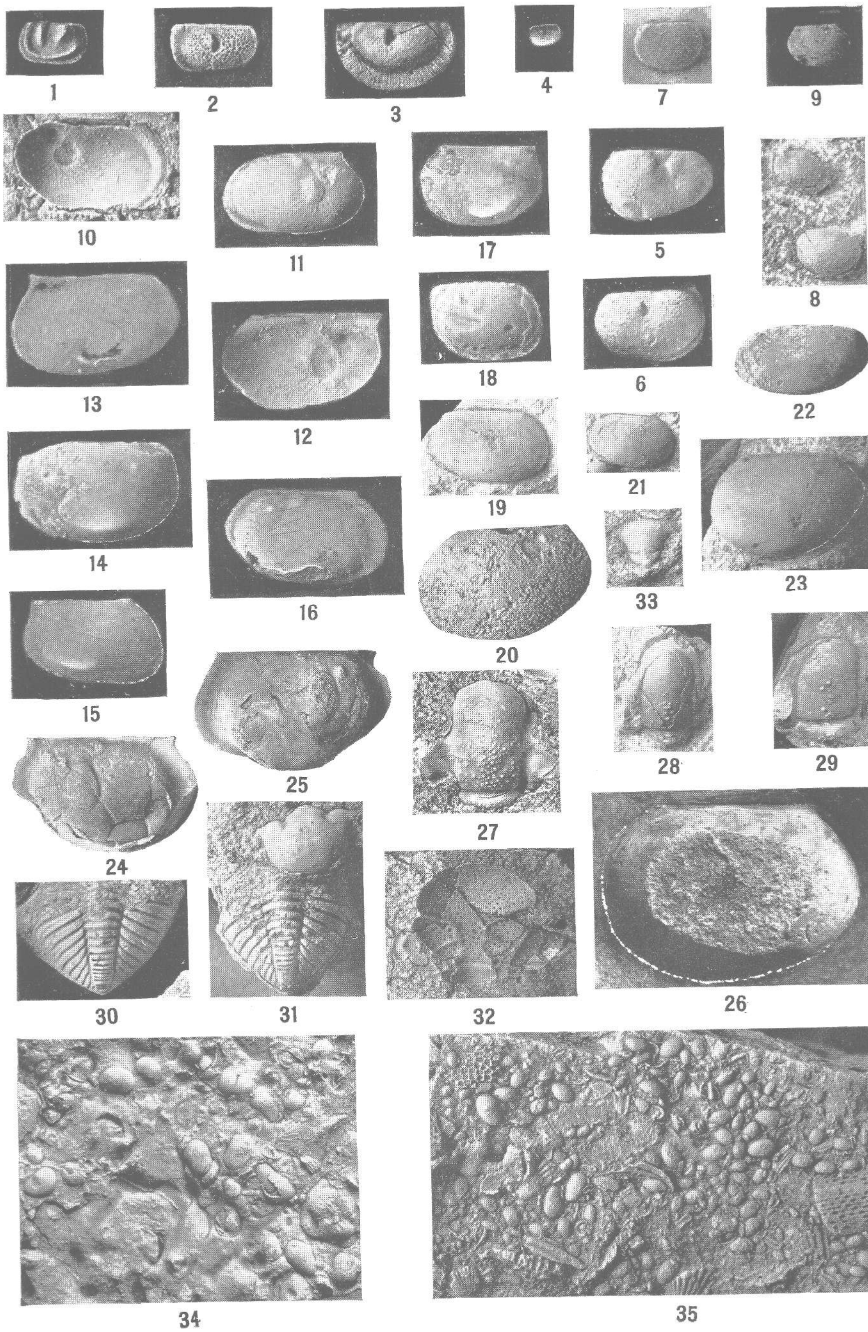
Lowville limestone. 16, central specimen of 15, × 4; 14, northwest slope of Wallen Ridge 2 to 3 miles southeast of Dryden, Lee County; 15, locality as 5. 14, U. S. N. M. 97502; 15, 16, 97503.

17, 18. *Batostoma magnopora* Ulrich.

18, part of 17, × 4. Lowville limestone; cut on Virginian Railway on New River 1 mile south of Goodwins Ferry, Giles County. U. S. N. M. 97506.



LOWVILLE AND EGGLESTON FOSSILS



LOWVILLE AND EGGLESTON FOSSILS

PLATE 94.—LOWVILLE AND EGGLESTON FOSSILS

FIGURE

1\. *Drepanella* aff. *D. crassinodo* Ulrich, × 4.

Left valve. Lowville limestone; Wheeler quarry 1 mile northeast of Walnut Hill, Lee County. U. S. N. M. 97507.

2, 3. *Eurychilina reticulata* Ulrich, × 4.

Right valves. 2, with flange broken away but preserving the reticulated surface; 3, exfoliated. Eggleston limestone (upper Black River); along road on northwest slope of Peters Mountain 3½ miles southwest of Gap Mills, Monroe County, W. Va. U. S. N. M. 97508a, 97508b.

4–6. *Haploprimitia minutissima* (Ulrich) ?.

5, 6, × 6. 4, left valve natural size; 5, right valve; 6, enlargement of 4. Eggleston formation (upper Black River); northwest slope of Wallen Ridge 3½ miles southeast of Dryden, Lee County. 4, 6, U. S. N. M. 97509a; 5, 97509b.

7–9. *Leperditella tumida* (Ulrich), × 4.

7, left valve; 8, 9, right valves. Lowville limestone; locality as 2. U. S. N. M. 97510a, 97510b, 97510c.

10–12. *Isochilina* sp., × 4.

10, external mold of right valve; 12, external mold of left valve; 11, internal mold of right valve. Lowville limestone; southwest base of Elk Knob, 13½ miles southwest of Big Stone Gap, Lee County. U. S. N. M. 97512a, 97512b, 97512c.

13–17. *Isochilina armata* (Walcott), × 4.

13, 14, 17, right valves; 15, 16, left valves. Lowville limestone. 13, 15, 17, northwest slope of Wallen Ridge 2 miles southeast of Olinger, Lee County; 14, slope to Powell River 1 mile southwest of mouth of Yellow Branch, Lee County; 16, Little Indian Creek 2 miles northeast of Belfast Mills, Russell County. U. S. N. M. 97513a, 97514, 97513b, 97515, 97513c.

18\. *Isochilina* sp.

Left valve. Occurrence as 10. U. S. N. M. 97516.

19–23. *Leperditia fabulites* (Conrad).

20, 23, × 2. 19, 21, left valves; 20, 22, 23, right valves; 22, may be compressed vertically; 20, 23 are possibly of a different species. Lowville limestone. 19, 22, 23, along U. S.

FIGURE

Route 19 half a mile south of St. Clair railroad station and at road intersection 3 miles southwest of Bluefield, Virginia; 20, along U. S. Route 58, 3½ miles northeast of Cumberland Gap village, Tenn.; 21, along road in Thompsons Valley 2 miles southeast of Tazewell, Tazewell County. U. S. N. M. 97518a, 97517, 97519, 97518b, 97518c.

24, 25. *Isochilina* sp.

Left and right valves. Eggleston limestone (upper Black River); Ward Cove along northwest slope of ridge 2 miles due south of Snapp, Tazewell County. (See Tazewell sheet.) U. S. N. M. 97520a, 97520b.

26. *Leperditia* sp.

Eggleston limestone (upper Black River); northwest slope of Wallen Ridge 2½ miles southeast of Dryden, Lee County. U. S. N. M. 97521.

27. *Bathyurus* aff. *B. johnstoni* Raymond.

Lowville limestone about 30 feet above the Ottosee limestone; Rye Cove, Scott County. U. S. N. M. 97522.

28, 29. *Bathyurus?* sp.

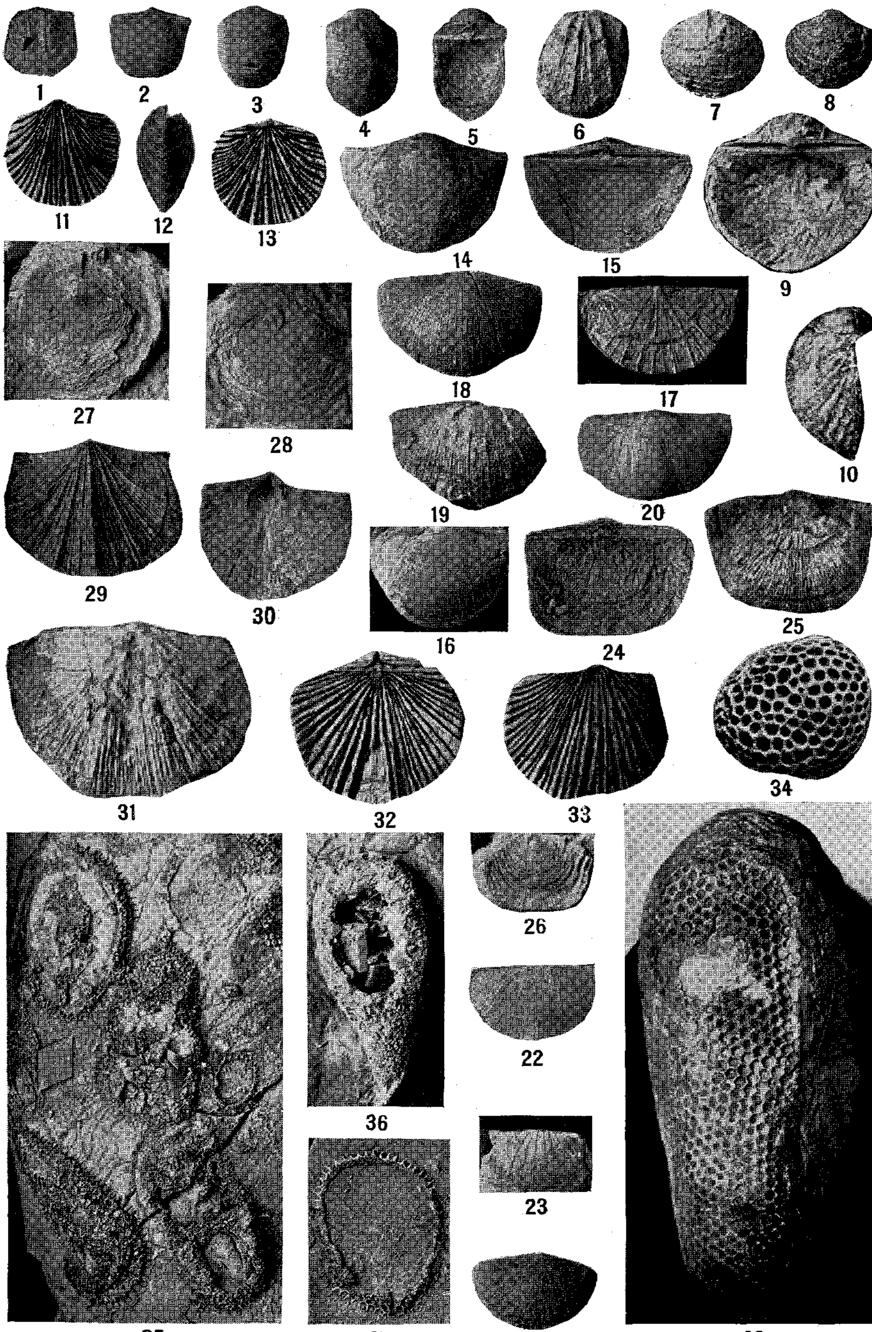
Lowville limestone; northwest base of Clinch Mountain just south of Gate City, Scott County. U. S. N. M. 97523a, 97523b.

30–33. *Calliops* cf. *C. callicephala* (Hall).

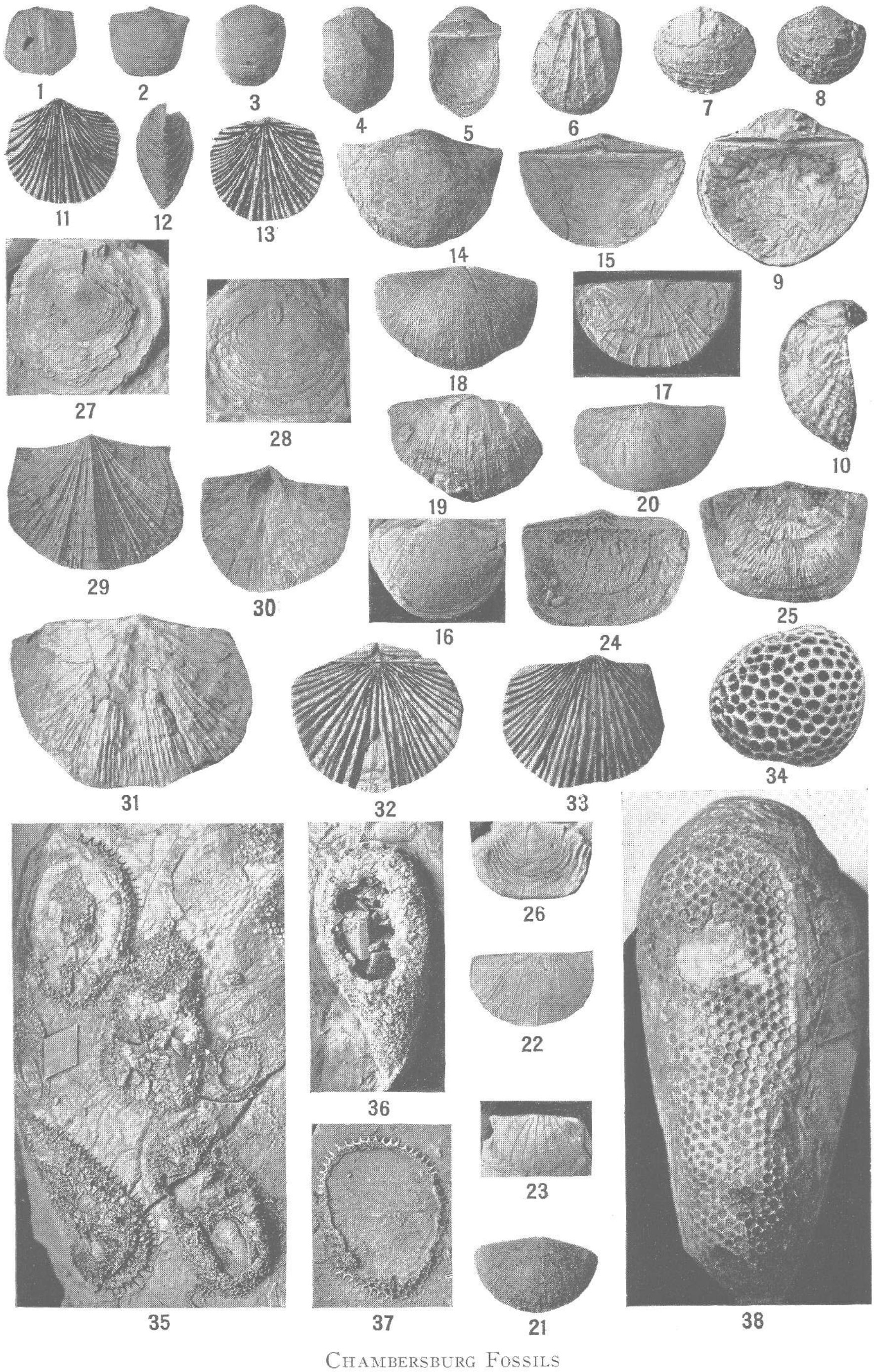
33, associated labrum. Occurrence as 27. U. S. N. M. 97524a, 97524b, 97524c, 97524d.

34, 35. *Leperditella sulcata* (Ulrich).

34, × 4; 35, × 2. A few individuals show a faint dorsal sulcus, but most of them do not, and it may be doubted whether all are *L. sulcata*. Lowville limestone; along road near State Route 64 about 2 miles northeast of Olinger, Lee County. U. S. N. M. 97511a, 97511b.



CHAMBERSBURG FOSSILS



CHAMBERSBURG FOSSILS

PLATE 95.—CHAMBERSBURG FOSSILS

FIGURE

1–3. *Christiania trentonensis brevis* Butts, n. var.

Distinguished from typical *C. trentonensis* Ruedemann by its shorter length:—young individuals or shorter forms?. Chambersburg limestone; Strasburg, Shenandoah County. Cotypes: U. S. N. M. 97536a, 97536b, 97536c.

4–6. *Christiania* cf. *C. trentonensis* Ruedemann.

4, 5, dorsal and ventral views of a specimen; 6, interior of a ventral valve. Occurrence as 1. 4, 5, U. S. N. M. 97537a; 6, 97537b.

7–10. *Christiania lamellosa* Bassler.

7, 8, ventral valves; 9, 10, dorsal and profile views of 8, × 2. Occurrence as 1. 7, U. S. N. M. 97538a; 8, 9, 10, 97538b.

11–13. *Dalmanella?* sp, × 2.

Occurrence as 1; also about one-third of a mile north of Green Mount Church and 4 miles north of Harrisonburg, Rockingham County. U. S. N. M. 97539.

14–16. *Sowerbyella* cf. *S. pisum* (Ruedemann), × 2.

14, 15, ventral and dorsal views of a specimen; 16, ventral view of another specimen. Occurrence as 1. 14, 15, U. S. N. M. 97540a; 16, 97540b.

17. *Sowerbyella platys* Butts, n. sp., × 2.

Distinguished from *S. pisum* (Ruedemann) by the nearly plane or flat surface of its ventral valve. Occurrence as 1. Holotype: U. S. N. M. 97541.

18–21. *Sowerbyella* sp.?

Ventral valves. 19-21, × 2. 19, 20, occurrence as 1; 18, 21, one-third of a mile north of Green Mount Church, Rockingham County. U. S. N. M. 97542a, 97543a, 97543b, 97542b.

22, 23. *Sowerbyella alternata* Butts, n. sp.

Ventral valves. 23, × 2. Distinguished by the strongly alternating striae. Slightly broader on the hinge line than *S. pisum* which it most resembles. Occurrence as 1. Cotypes: U. S. N. M. 97544a, 97544b.

FIGURE

24, 25. *Leptaena homostriata* Butts, n. sp., × 2.
Dorsal and ventral valves of a specimen. Distinguished from *L. unicostata* (Meek and Worthen) by its regular striae. Occurrence as 1. Holotype: U. S. N. M. 97545.

26. *Leptaena* aff. *L. rhomboidalis* (Wilckens).
Ventral valve. Occurrence as 1. U. S. N. M. 97546.

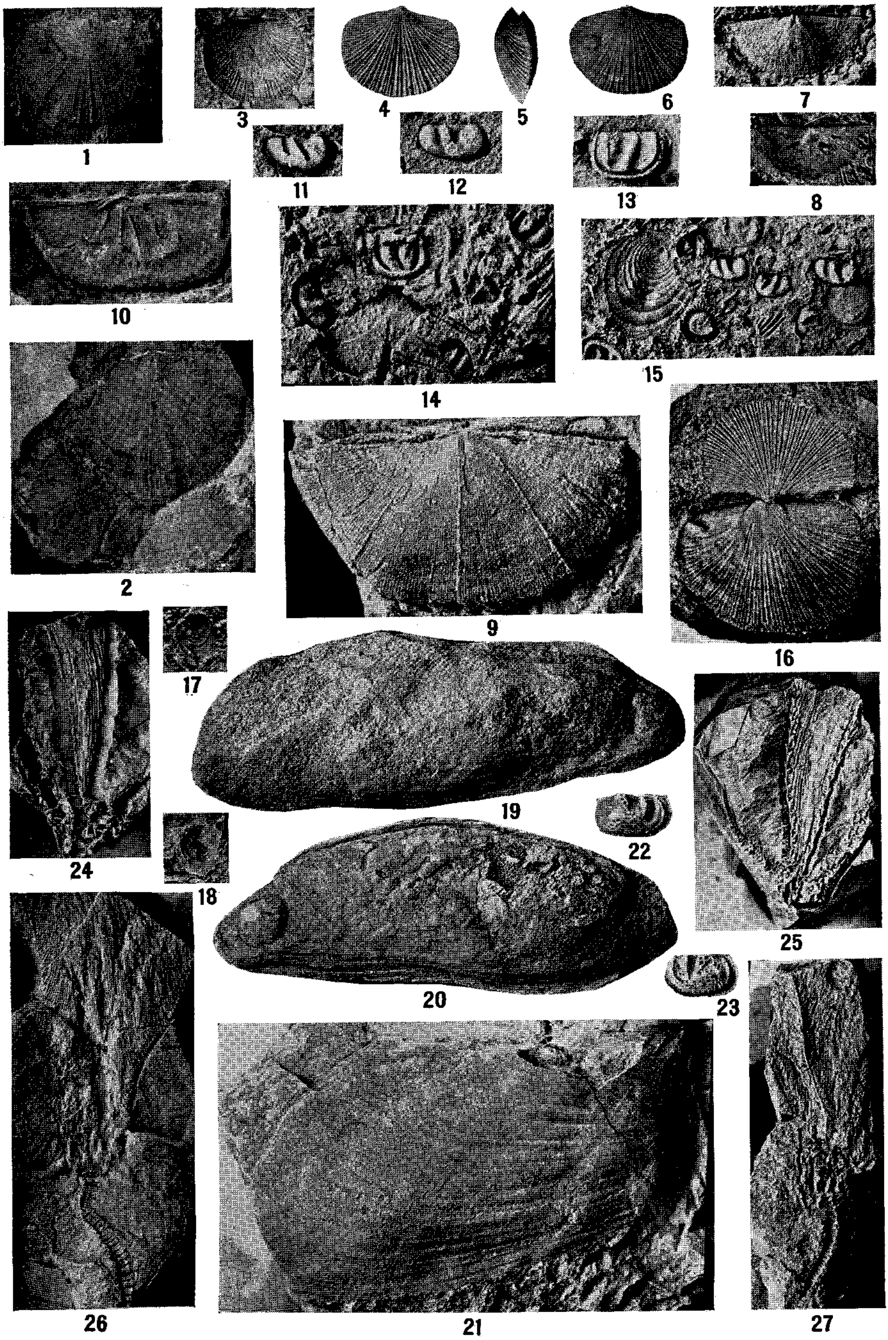
27, 28. *Orbiculoidea* sp.
Occurrence as 1. U. S. N. M. 97547a, 97547b.

29–31. *Dalmanella edsoni* Bassler.
29, ventral valve; 31, dorsal valve; 30, interior of a ventral valve. Occurrence as 1. U. S. N. M. 97548a, 97548b, 97548c.

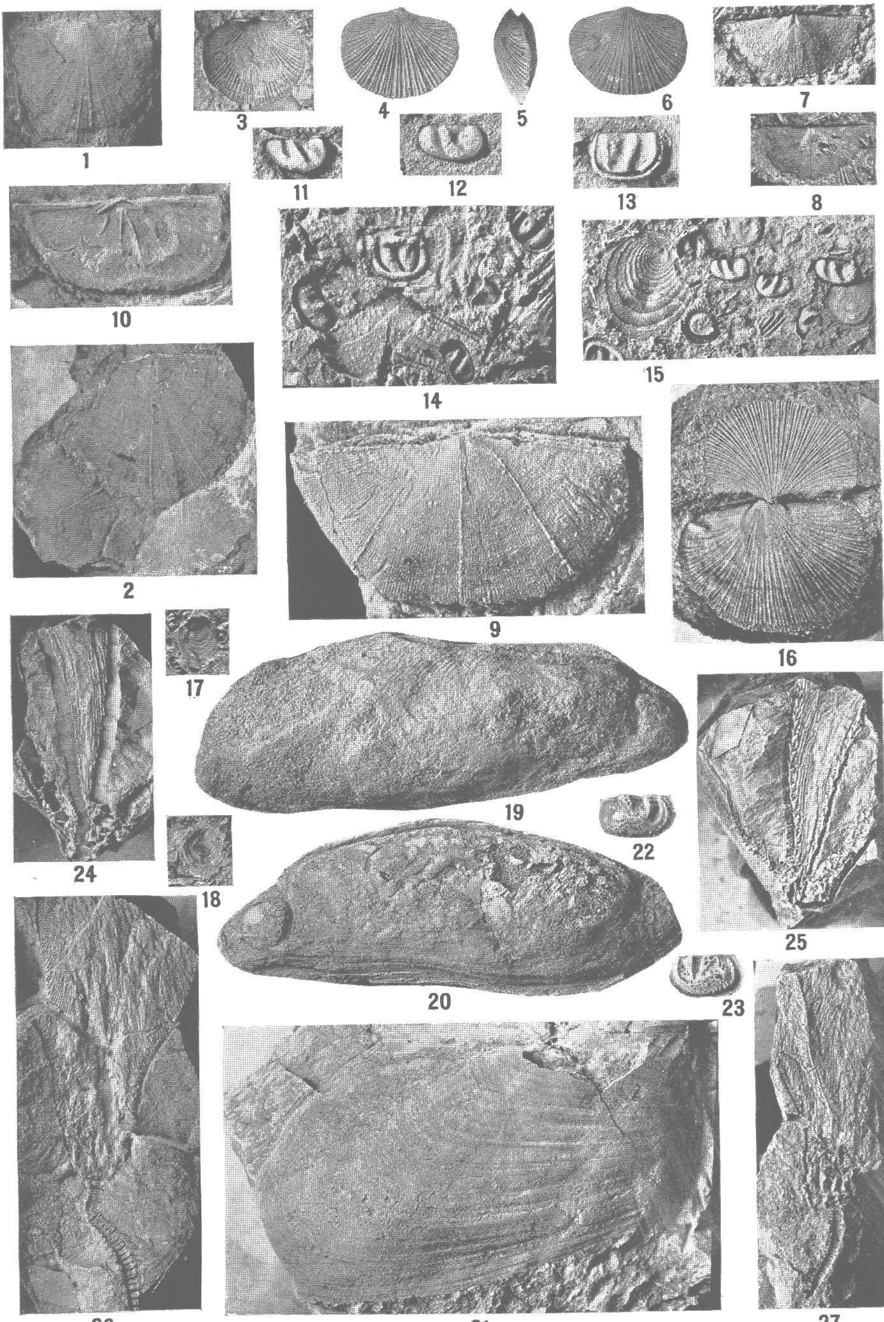
32, 33. *Nicolella strasburgensis* Butts, n. sp.
Dorsal and ventral valves. Distinguished from *N. actoniae*, the type of the genus, by its finer costae. Rare in America. Occurrence as 1. Cotypes: U. S. N. M. 97549a, 97549b.

34. *Bolboporites americanus* Billings(?), × 4.
Occurrence as 1. U. S. N. M. 97550.

35–38. *Nidulites pyriformis* Bassler.
38, × 2. Occurrence as 1. A highly characteristic fossil of the Chambersburg limestone but occurs also in the base of the Ottosee limestone in Clinch River Valley east of Blackford and on Little Indian Creek, Russell County. U. S. N. M. 97551.



CHAMBERSBURG, MARTINSBURG, AND SEQUATCHIE FOSSILS



Chambersburg, Martinsburg, and Sequatchie Fossils

PLATE 96.—CHAMBERSBURG, MARTINSBURG, AND SEQUATCHIE FOSSILS

FIGURE

1, 2. *Rafinesquina alternata* (Emmons).

Ventral valves, exteriors. Chambersburg limestone; three-fourths of a mile northeast of Collierstown (present location), Rockbridge County. U. S. N. M. 97578a, 97578b.

3–6. *Dalmanella fertilis* Bassler.

3, external mold of a ventral valve; 4-6, dorsal, profile, and ventral views of a whole specimen. 3, Martinsburg shale, Trenton horizon; along State Route 311 at the northwest base of Catawba Mountain, about three-fourths of a mile southeast of Catawba Sanatorium, Roanoke County; 4-6, along State Route 63 about three-fourths of a mile southeast of Dickerson Ford (bridge), Lee County. 3, U. S. N. M. 97580; 4-6, 97579.

7, 8. *Sowerbyella rugosa* (Meek), × 2.

7, internal mold of a ventral valve; 8, external mold of a dorsal valve. Martinsburg shale; along the northwest slope of Catawba Mountain about 1¼ miles southeast of Catawba Sanatorium, Roanoke County. U. S. N. M. 97581a, 97581b.

9. *Sowerbyella rugosa* var. *triradiatus* Butts, n. var., × 4.

Distinguished from *S. rugosa* by 3 equally spaced strong striae with many fine striae between. Chambersburg limestone; Strasburg, Shenandoah County. Holotype: U. S. N. M. 97582.

10. *Sowerbyella* sp.

Interior of a dorsal valve of unusual form and size. Martinsburg shale, Trenton horizon; along road on Buffalo Creek half a mile northwest of Zollmans and 1½ miles northwest of Buffalo Mills, Rockbridge County. U. S. N. M. 97583.

11. *Ceratopsis chambersi* (Miller), × 6⅓.

Internal mold of a left valve. Martinsburg shale, Trenton horizon; along southeast slope of Smith Ridge about three-fourths of a mile southwest of Carvin Creek gorge at reservoir of Roanoke Waterworks, Roanoke County. U. S. N. M. 97584.

12. *Ctenobolbina ciliata* (Emmons), × 6⅓.

Internal mold of left valve showing ciliated margin. (One of specimens in fig. 15.) Occurrence as 7. U. S. N. M. 97585a.

FIGURE

13, 14. *Tetradella* aff. *T. quadrilirata* (Hall and Whitfield).

13, wax impression of an external mold of a right valve, × 6⅓; 14, slab with several specimens, × 4. Martinsburg shale, Trenton horizon. 13, along State Route 311 at northwest base of Catawba Mountain 1 mile southeast of Catawba Sanatorium, Roanoke County; 14, near locality and bed of 11. U. S. N. M. 97587, 97586.

15. *Ctenobolbina ciliata* (Emmons), × 4.

Slab with several specimens, also *Pholidops*. Occurrence as 7. U. S. N. M. 97585.

16. *Dalmanella emacerata* (Hall)?

Martinsburg shale, Maysville horizon; along Cub Run just east of Catharine Furnace at the southeast foot of Massanutten Mountain and 12 miles southwest of Luray, Page County. U. S. N. M. 97588.

17, 18. *Pholidops cincinnatiensis* Hall.

Occurrence as 7. U. S. N. M. 97589a, 97589b.

19, 20. *Orthodesma* sp.?

Martinsburg shale, Maysville horizon; along State Route 16 just northwest of crest of Walker Mountain and 5 miles north of Marion, Smyth County. U. S. N. M. 97590a, 97590b.

21. *Cuneamya?* sp.

Martinsburg shale, Maysville horizon; same locality as 7. U. S. N. M. 97591.

22, 23. *Drepanella richardsoni* (Miller), × 4.

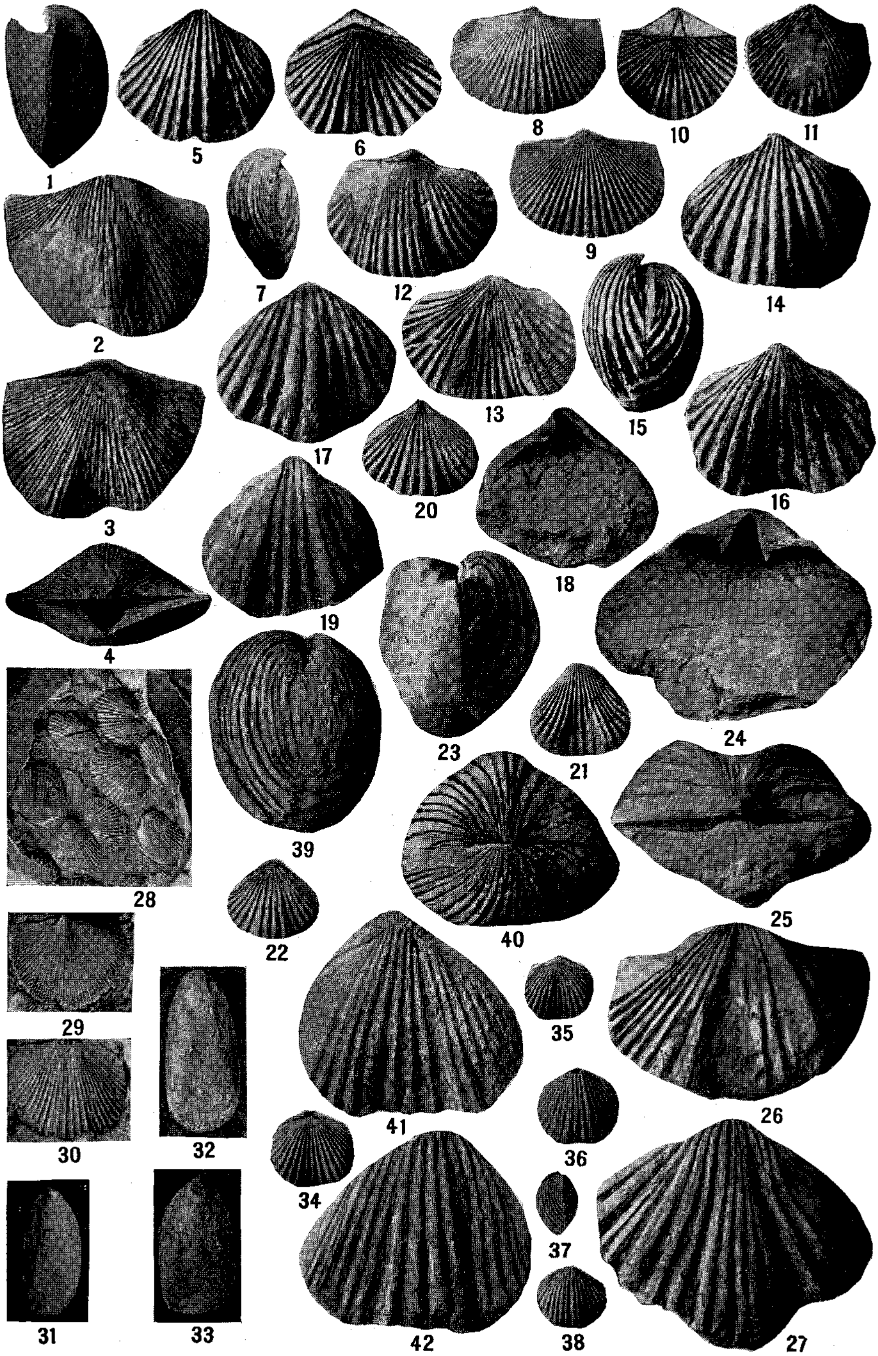
Right and left valves. Whitewater formation; Upper Cowan Creek, Clinton County, Ohio. Occurs in the Sequatchie (Juniata-Richmond) formation three-fourths of a mile southeast of Cumberland Gap village, Tenn., but no specimens suitable for illustration were obtained. U. S. N. M. 97592a, 97592b.

24, 25. *Ectenocrinus simplex* (Hall).

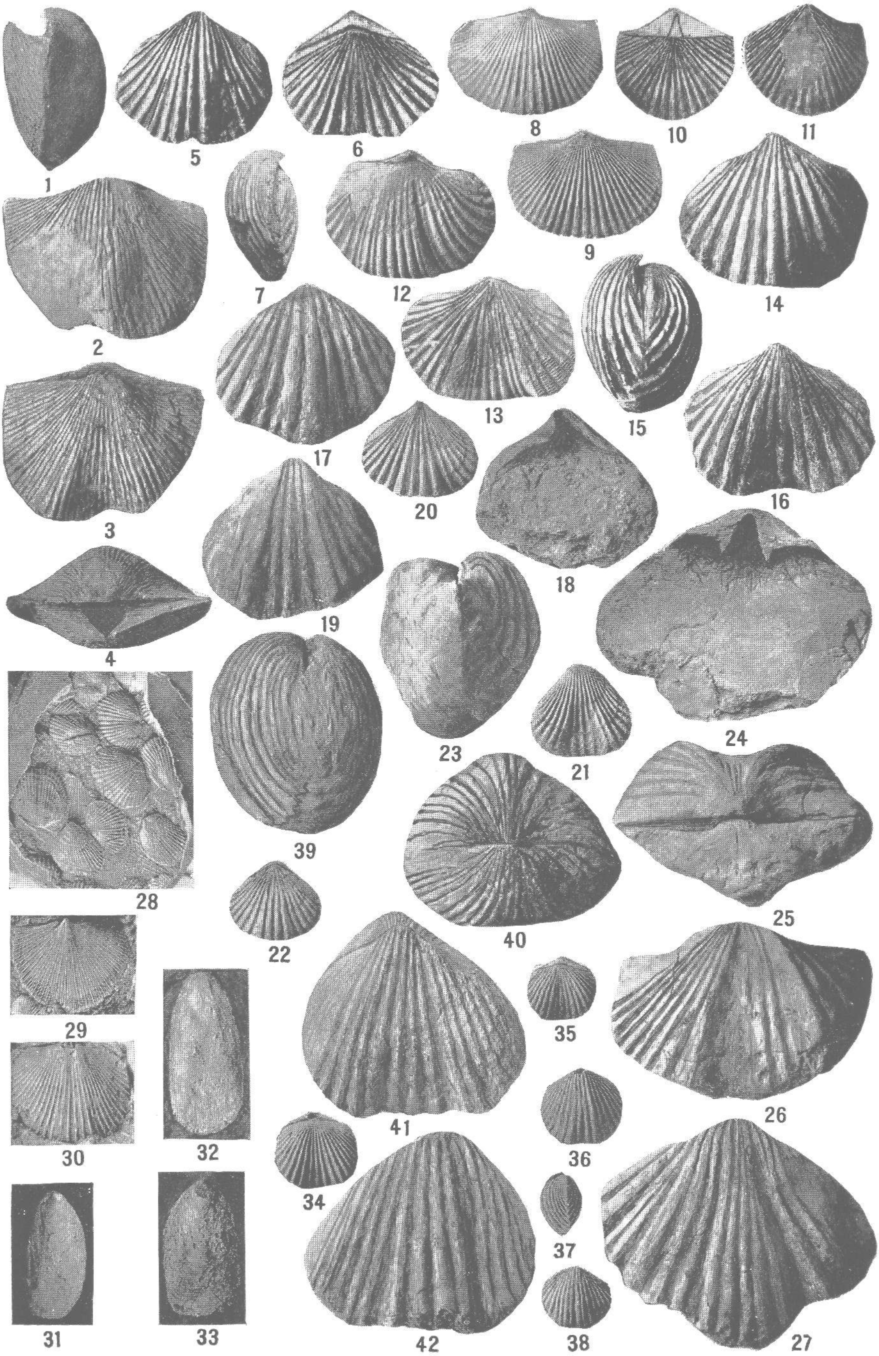
Martinsburg shale, probably Eden horizon; quarry on Lee Highway about half a mile southeast of New Market Gap, Massanutten Mountain, Page County. U. S. N. M. 97593a, 97593b.

26, 27. *Glyptocrinus pattersoni* Miller.

Occurrence as 24. U. S. N. M. 97594a, 97594b.



CHAMBERSBURG, MARTINSBURG, TRENTON, AND REEDSVILLE FOSSILS



CHAMBERSBURG, MARTINSBURG, TRENTON, AND REEDSVILLE FOSSILS

PLATE 97.—CHAMBERSBURG, MARTINSBURG, TRENTON, AND REEDSVILLE FOSSILS

FIGURE

1–4. *Hebertella sinuata* Hall and Clarke.

Profile, dorsal, ventral, and posterior views of an entire specimen. Reedsville shale, Maysville horizon; along road three-fourths of a mile southeast of Cumberland Gap village, Tenn. U. S. N. M. 97595.

5–7. *Zygospira kentuckiensis* James, × 2.

Dorsal, ventral, and profile views of a whole specimen. Reedsville shale, Maysville horizon; Fourmile fenster 3 miles south of Ewing, Lee County. U. S. N. M. 97596.

8, 9. *Hebertella frankfortensis* Foerste.

Dorsal and ventral views of a specimen. Trenton limestone; southeast slope of Big A Mountain about three-fourths of a mile southeast of the summit, Russell County. U. S. N. M. 97597.

10, 11. *Hesperorthis tricenaria* (Conrad).

Dorsal and ventral views of a whole specimen. Chambersburg limestone; one-third of a mile north of Green Mount Church and 5 miles north of Harrisonburg, Rockingham County. U. S. N. M. 97598.

12, 13. *Oxoplecia* sp.

Dorsal and ventral views of a specimen. Occurrence as 10. U. S. N. M. 97599.

14–19. *Orthorhynchula linneyi* (James).

14-16, dorsal, profile, and ventral views of a specimen; 17, dorsal view of another specimen; 18, 19, internal and ventral views of another specimen; 18, partly filled with matrix but shows the absence of an area like that of *Platystrophia* (Fig. 24); Martinsburg shale, Maysville horizon. 14-16, Cumberland Gap, Tenn.; 17-19, along U. S. Route 58 on the west slope of Wallen Ridge one-fourth of a mile northwest of the summit and 1½ miles northwest of Stickleyville, Lee County. 14-16, U. S. N. M. 97601; 17, 97602a; 18, 19, 97602b.

FIGURE

20–22. *Rhynchotrema increbescens* (Hall).

20, 22, dorsal views of two specimens; 21, ventral view of 22. Trenton limestone; along State Route 63 three-fourths of a mile southeast of Dickerson Ford (bridge) on Powell River, Lee County. U. S. N. M. 97603a, 97603b.

23–27. *Platystrophia laticosta* (Meek).

23, 25, 26, profile, posterior, and ventral views of a specimen; 27, dorsal view of another specimen; 24, interior of 27, showing hinge area. Occurrence as 17. 23, 25, 26, U. S. N. M. 97604a; 24, 27, 97604b.

28. *Zygospira modesta* Hall.

Clay impression from an external mold of several specimens in fine-grained sandstone. Martinsburg shale, Eden horizon?; along State Route 311 on the northwest slope of Catawba Mountain 1 mile southeast of Catawba Sanatorium, Roanoke County. U. S. N. M. 97605.

29. *Rafinesquina alternata* (Emmons).

Occurrence as 28. U. S. N. M. 97606.

30. *Catazyga* cf. *C. erratica* (Hall).

Internal mold of a dorsal valve. Occurrence as 28. U. S. N. M. 97607.

31–33. *Lingula nicklesi* Bassler.

Internal molds of ventral valves; 33, preserves part of the shell. Martinsburg shale, Maysville horizon; just east of Miller Creek at the northwest foot of Ramsay Mountain, Max Meadows, Wythe County. Common in association with *Orthorhynchula linneyi* in the top of the Martinsburg shale (*Orthorhynchula* zone) throughout Virginia. U. S. N. M. 97608a, 97608b, 97608c.

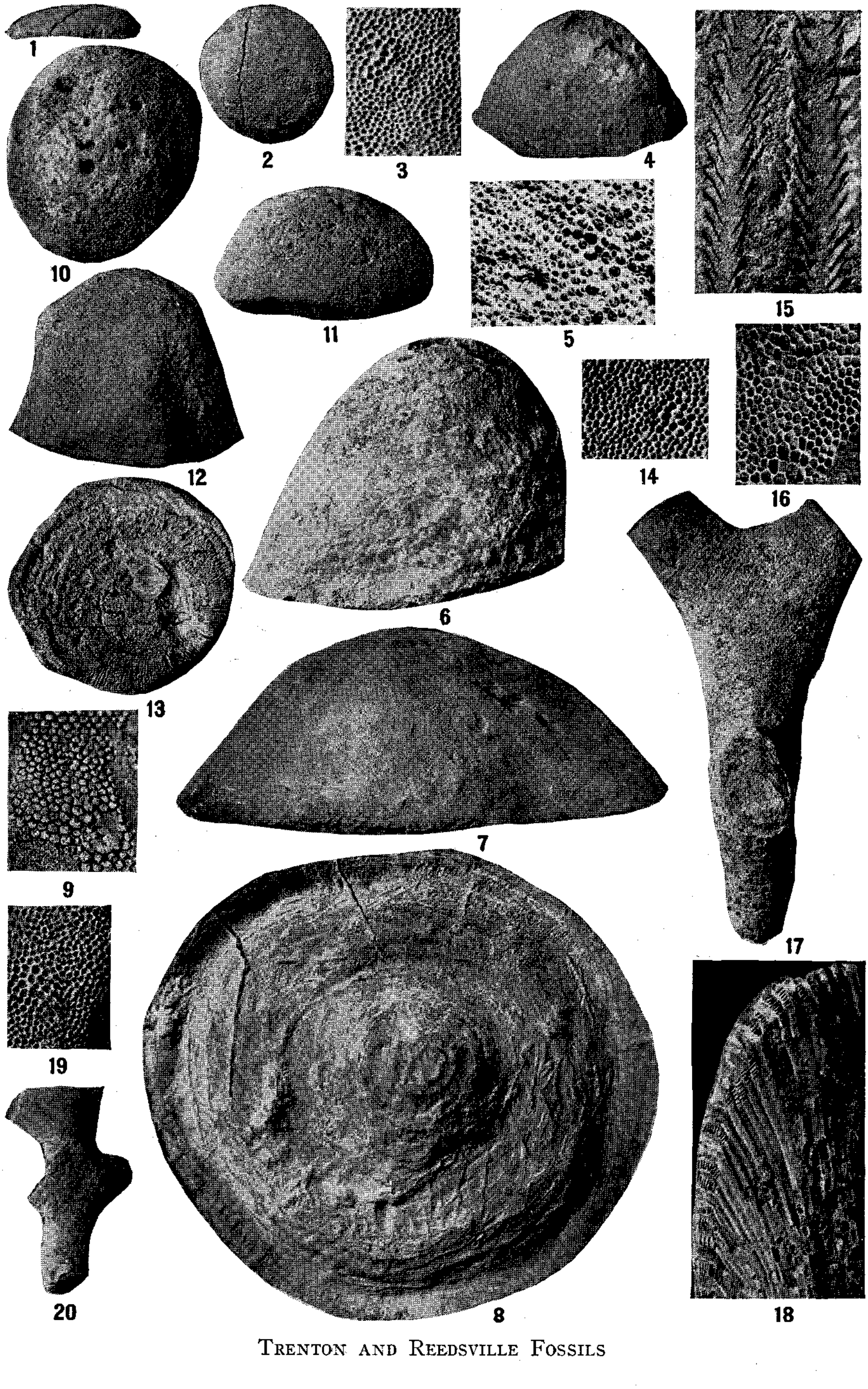
34–38. *Zygospira recurvirostris* (Hall), var. approaching *Z. kentuckiensis* James.

34, 36, dorsal and ventral views of a specimen; 35, 37, 38, dorsal, profile, and ventral views of another specimen. Martinsburg shale, about top of Trenton horizon; along State Route 80 on the northwest slope of Clinch Mountain about half a mile northwest of the summit, Russell County. 34, 36, U. S. N. M. 97609a; 35, 37, 38, 97609b.

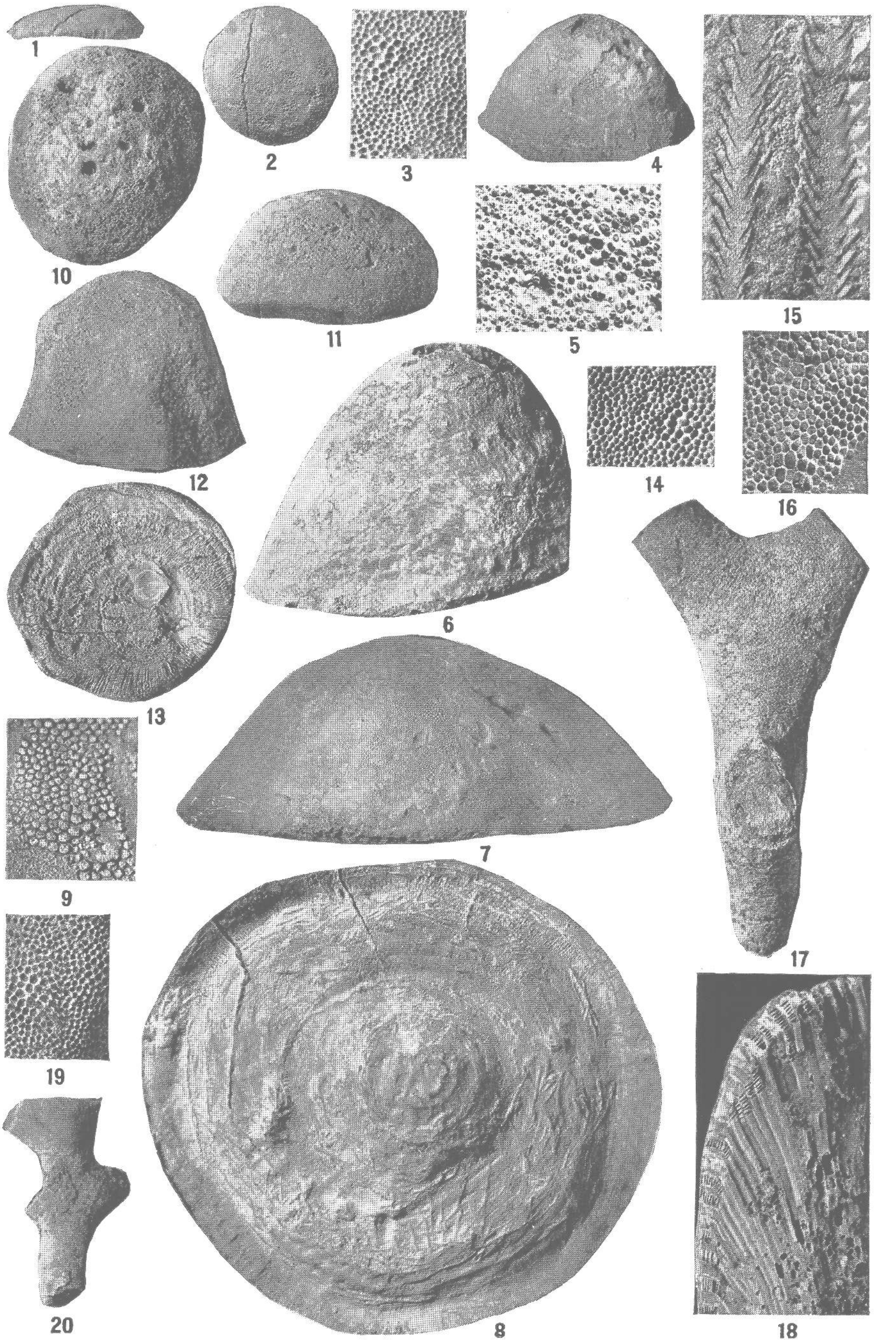
FIGURE

39–42. *Orthorhynchula linneyi* (James).

Profile, posterior, ventral, and dorsal views of a large specimen. Martinsburg shale, Maysville horizon; along State Route 91 in McCall Gap through Walker Mountain between Saltville and Glade Springs, Washington County. U. S. N. M. 97600.



TRENTON AND REEDSVILLE FOSSILS



Trenton and Reedsville Fossils

PLATE 98.—TRENTON AND REEDSVILLE FOSSILS

FIGURE

1–3. *Monotrypa* sp.

Distinguished by its lenticular shape and large maculae. 1, side view; 2, zooecial surface showing maculae; 3, surface of 2, × 4. Trenton limestone; along State Route 64 about three-fourths of a mile southeast of Dickerson Ford on the Powell River, Lee County. U. S. N. M. 97552.

4–9. *Prasopora simulatrix* Ulrich.

4, 6, 7, side views of 3 specimens; 5, part of exfoliated surface of 6, × 4, showing cystiphragms; 8, view of epithecal surface of 7; 9, part of the weathered surface of 7, × 4, showing the matrix filling the zooecial tubes. Martinsburg shale, Trenton zone; along State Route 80 on northwest slope of Clinch Mountain about half a mile northwest of summit and about 1 mile south of Rockdell, Russell County. 4, 6, 7, U. S. N. M. 97553a, 97553b, 97553c.

10–14. *Mesotrypa quebecensis* (Ami).

10, 11, top and side views of a specimen; 12, 13, side and epithecal views of another specimen; 14, part of surface of another specimen, × 4, to show cells. Occurrence as 1. 10, 11, U. S. N. M. 97554a; 12, 13, 97554b; 14, 97554c.

15. *Diplograptus amplexicaulis* (Hall).

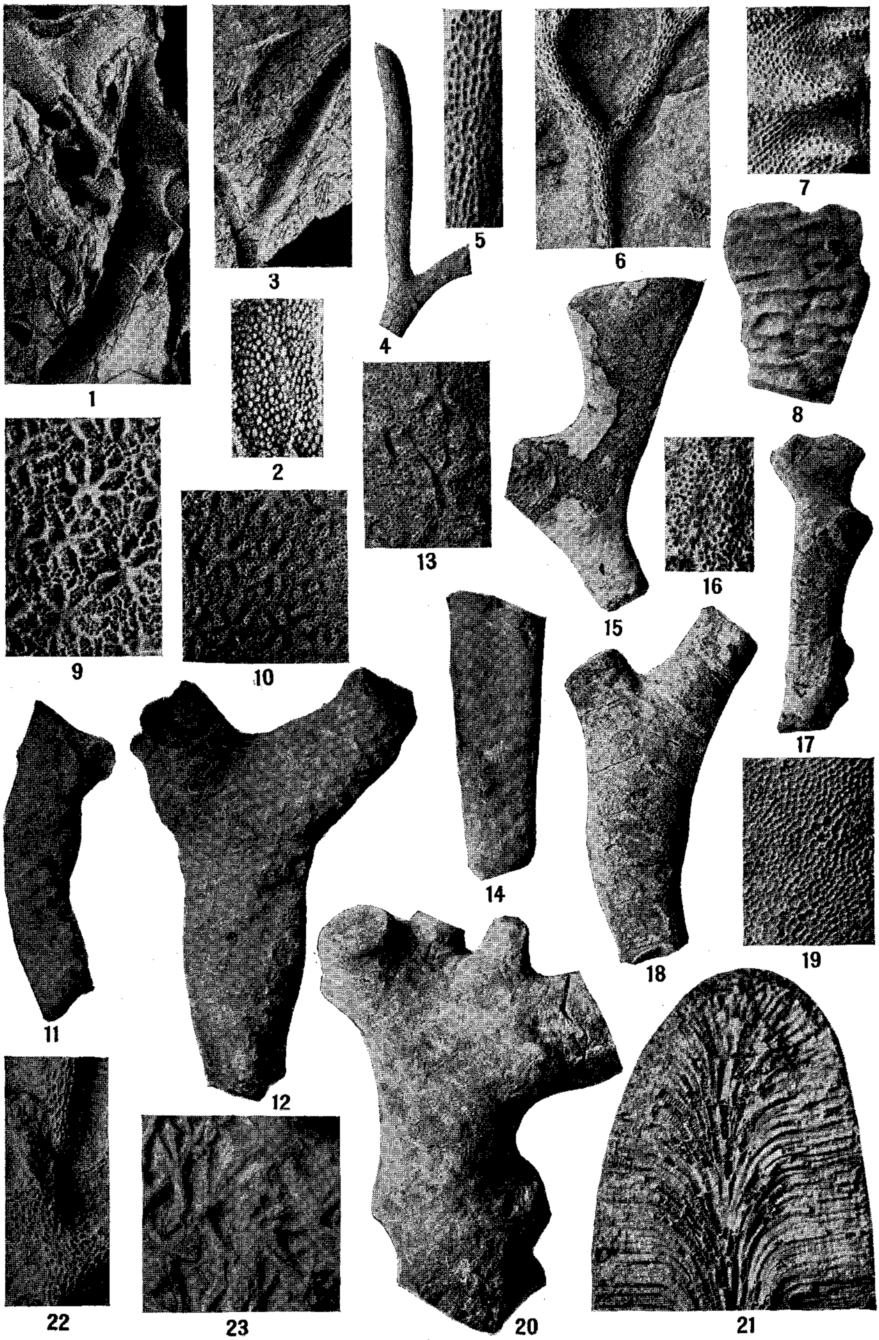
Martinsburg shale, Trenton zone; 1½ miles south of summit of Little House Mountain west of Lexington, Rockbridge County. U. S. N. M. 97555.

16–18. *Hallopora ampla* (Ulrich).

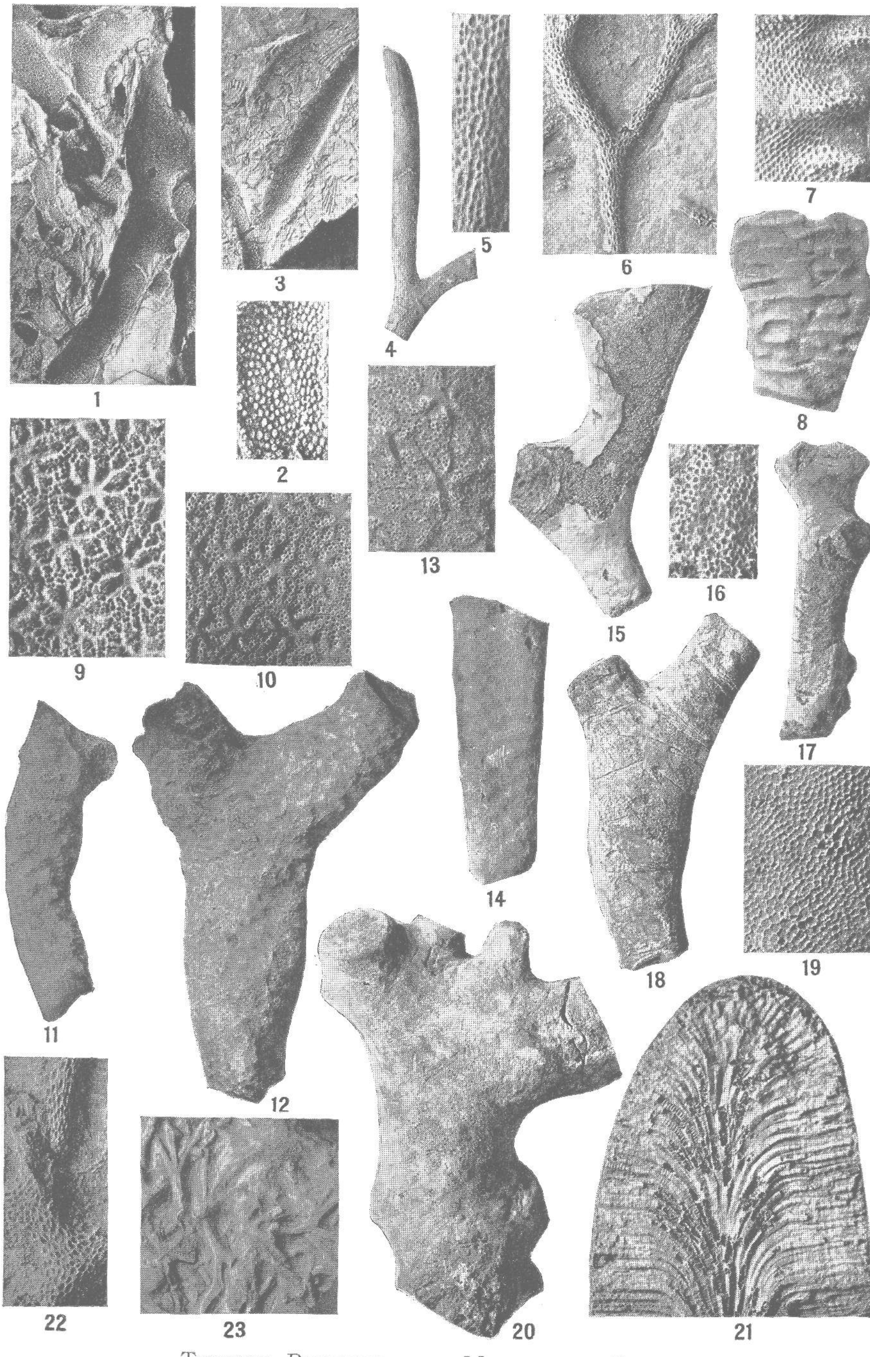
16, part of surface of a specimen to show cells, × 4; 17, nearly whole specimen; 18, part of a vertical section through the center of a specimen, × 4, showing the internal structure and manner of growth of the zooecial tubes and the closely packed diaphragms at the sharply flexed extremities. Occurrence as 4. U. S. N. M. 97556a, 97556b, 97556c.

19, 20. *Amplexopora pustulosa* Ulrich?

19, part of surface of a specimen to show cells, × 4. Reedsville shale, Maysville horizon?; three-fourths of a mile southeast of Cumberland Gap village, Tenn. U. S. N. M. 97557a, 97557b.



TRENTON, REEDSVILLE, AND MARTINSBURG FOSSILS



TRENTON, REEDSVILLE, AND MARTINSBURG FOSSILS

PLATE 99.—TRENTON, REEDSVILLE, AND MARTINSBURG FOSSILS

FIGURE

1, 2. *Hallopora andrewsi* (Nicholson)?

1, external mold; 2, part of 1, × 4, to show cells. The elevations are the matrix filling the cells or pits (zooecial apertures) of the original specimen. Martinsburg shale, Maysville horizon; along State Route 311 on the northwest slope of Catawba Mountain about 1 mile southeast of Catawba Sanatorium, Roanoke County. U. S. N. M. 97558.

3, 4. *Hallopora sigillarioides* (Nicholson).

3, external mold; 4, wax impression of same. Martinsburg shale, Eden horizon; same locality as 1. U. S. N. M. 97559.

5, 6. *Eridotrypa?* sp.

5, part of 6, × 4, to show cells. Martinsburg shale, probably Trenton horizon; Blue Spring Creek about 11 miles northwest of Eagle Rock, Botetourt County. A common slender bryozoon in the Trenton. U. S. N. M. 97560.

7, 8. *Escharopora hilli* (James).

7, part of 8, × 4, to show cells. Reedsville shale, Maysville zone; along road about three-fourths of a mile southeast of Cumberland Gap village, Tenn. A highly characteristic Maysville fossil. U. S. N. M. 97561.

9–12. *Constellaria teres* Ulrich and Bassler.

11, 12, two specimens natural size to show exteriors; 9, 10, parts of surfaces of two other specimens, × 4, to show arrangement of cells. Trenton limestone; along southeast slope of Big A Mountain about three-fourths of a mile southeast of summit, Russell County. U. S. N. M. 97562a, 97562b, 97562c, 97562d.

13, 14. *Constellaria florida* Ulrich.

13, part of 14, × 4. Occurrence as 7. U. S. N. M. 97563.

15–17. *Dekayia?*

16, part of surface of a specimen, × 4. Martinsburg shale; along State Route 80 on the northwest slope of Clinch Mountain and 800 feet northwest of the summit, Russell County. U. S. N. M. 97564a, 97564b, 97564c.

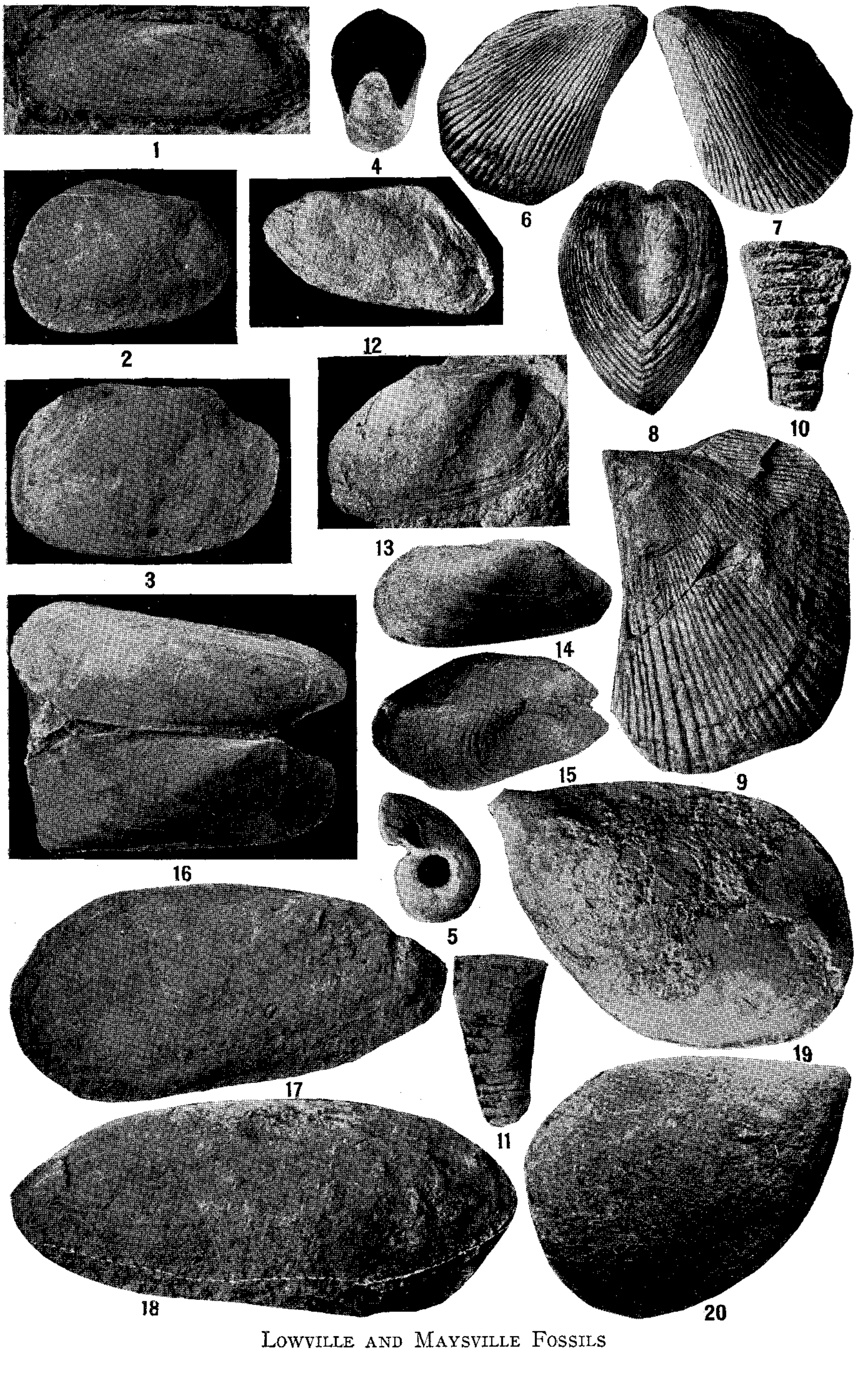
FIGURE

18–21. *Amplexopora cingulata* Ulrich.

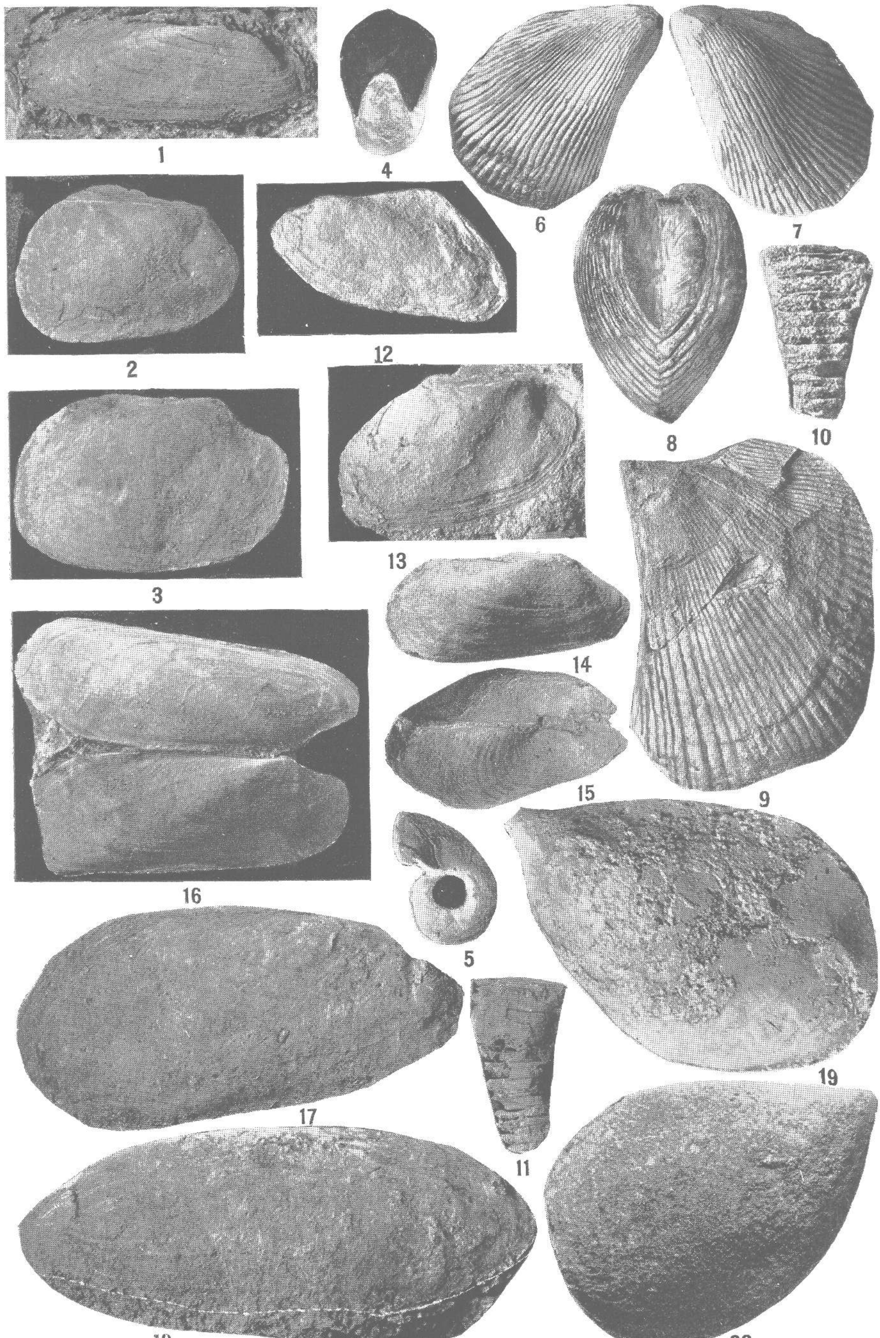
19, surface of a specimen, × 4, to show cells; 21, natural longitudinal section through a branch, × 4, to show manner of growth. The inner tubes and the outer ends of the zooecia at right angles to the surface are closely packed with diaphragms which show only faintly in the photograph of the broken surface but are plainly visible on a polished surface. Some of these are strengthened by retouching. Reedsville shale; Fourmile fenster about 3 miles southeast of Ewing, Lee County. U. S. N. M. 97565a, 97565b, 97565c, 97565d.

22, 23. *Eridotrypa?*

22, part of 23, × 4. Fragments of *Cryptolithus* on 23. Compare with 5, 6. These slender bryozoa are rather common and distinctive Trenton fossils. Martinsburg shale, Trenton zone; along road cut on Buffalo Creek half a mile northwest of Zollmans and 1½ miles northwest of Buffalo Mills, Rockbridge County. U. S. N. M. 97566.



LOWVILLE AND MAYSVILLE FOSSILS



LOWVILLE AND MAYSVILLE FOSSILS

PLATE 100.—LOWVILLE AND MAYSVILLE FOSSILS

FIGURE

1. *Rhytimya* sp.?

   Right valve. Martinsburg shale, Maysville horizon; along State Route 311 on the northwest slope of Catawba Mountain 1¼ miles southeast of Catawba Sanatorium, Roanoke County. U. S. N. M. 97567.

2, 3. *Modiolodon truncatus* (Hall).

   Right valves. Reedsville shale, Maysville horizon; along Louisville & Nashville Railroad about three-fourths of a mile southeast of Cumberland Gap village, Tenn., and about 175 feet east of east portal of tunnel. U. S. N. M. 97568a, 97568b.

4, 5. *Sinuites* cf. *S. cancellatus* (Hall).

   4, apertural view; 5, side view of a specimen. Occurrence as 2. U. S. N. M. 97569.

6–8. *Byssonychia radiata* (Hall).

   Right and left valves and byssal view of a whole specimen. Martinsburg shale, Maysville horizon; along U. S. Route 58 on the northwest slope of Wallen Ridge about one-fourth of a mile northwest of summit and 1½ miles northwest of Stickleyville, Lee County. U. S. N. M. 97570.

9. *Byssonychia vera* Ulrich.

   Left valve of a whole specimen. Martinsburg shale, Maysville horizon; along road on North Fork of Roanoke River at south end of Paris Mountain about one-fourth of a mile west of Fagg Station, Montgomery County. U. S. N. M. 97571.

10, 11. *Wetherbyoceras conoidale* (Wetherby).

   Dorsal and lateral views showing curvature. Martinsburg shale, Maysville horizon; along State Route 80 on the northwest slope of Clinch Mountain about one-fourth of a mile northwest of the summit, Russell County. U. S. N. M. 97572.

12, 13. *Modiolopsis* sp.?

   Left and right valves. Martinsburg shale, Maysville horizon; along State Route 88 a few hundred feet northwest of summit of Walker Mountain and 5 miles north of Marion, Smyth County. U. S. N. M. 97573a, 97573b.

FIGURE

14, 15. *Rhytimya* sp.?

14, right valve; 15, hinge view, showing both valves of the same specimen. Occurrence as 12. U. S. N. M. 97574.

16. *Whiteavesia* sp.?

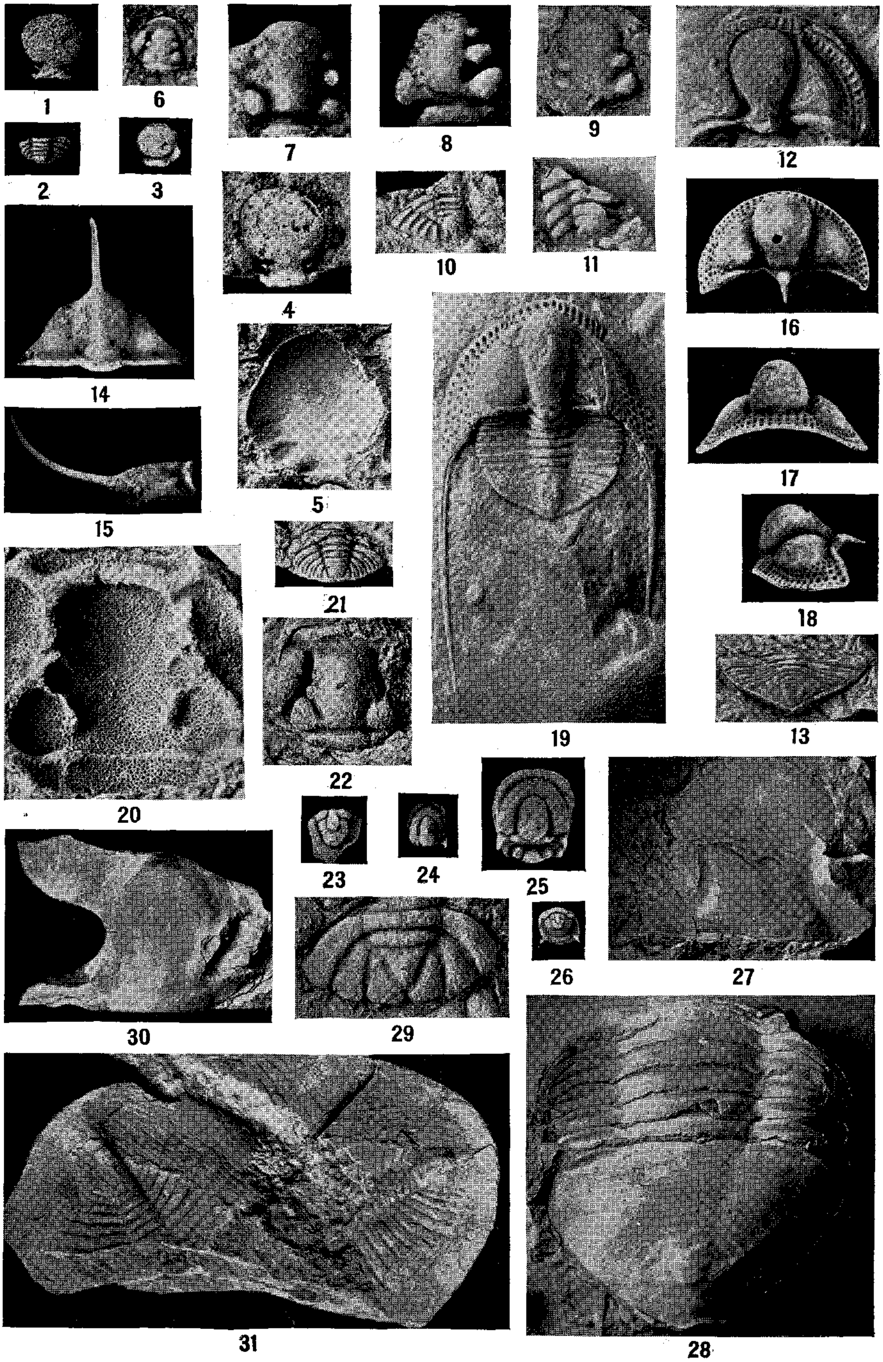
Hinge view of both valves of a whole specimen. Occurrence as 1. U. S. N. M. 97575.

17, 18. *Modiodesma modiolare* (Conrad).

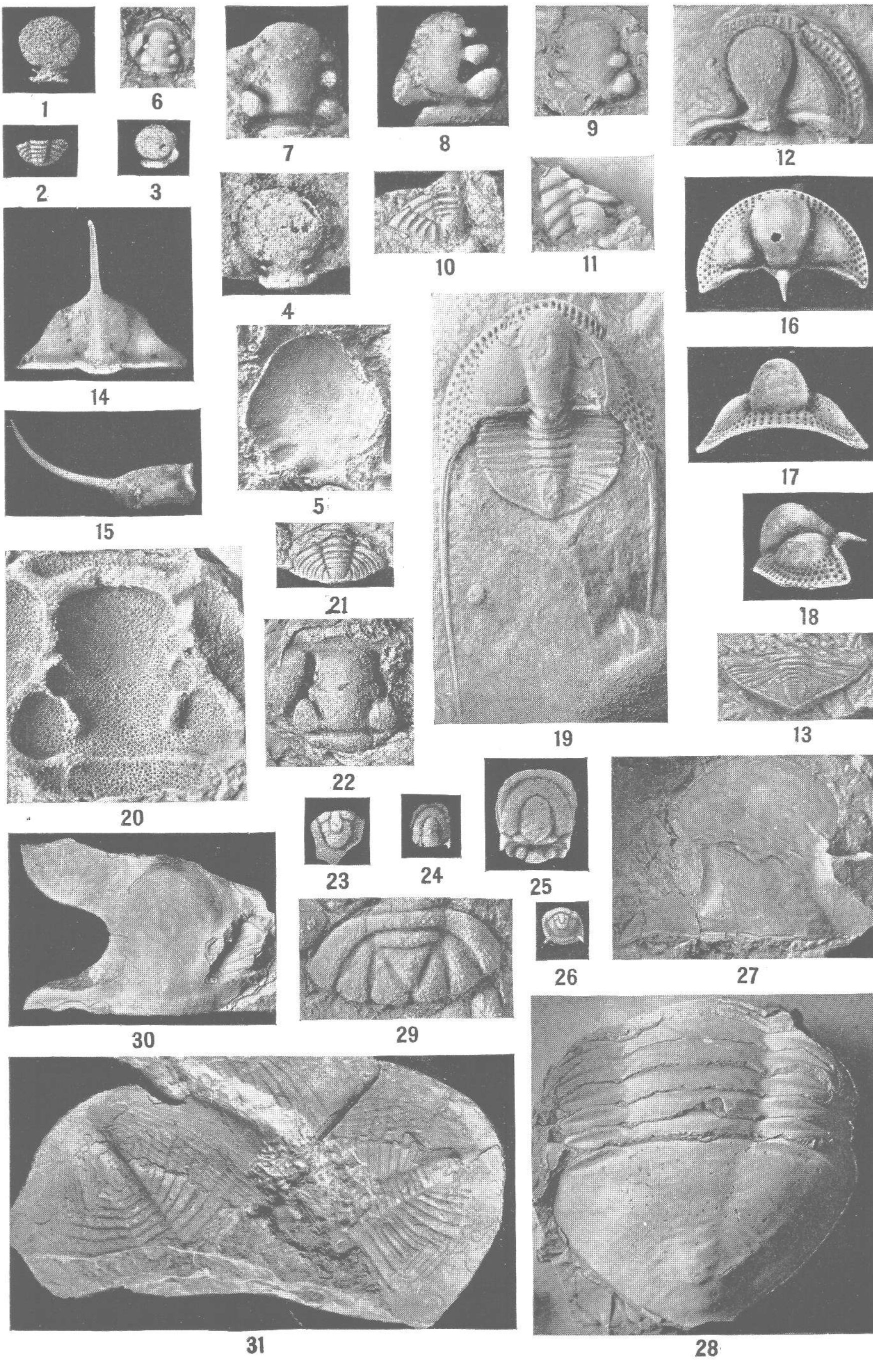
Right and left valves. In 18 the white line marks about the lower margin of the shell. Occurrence as 2. U. S. N. M. 97576a, 97576b.

19, 20. *Clionychia* sp.

Left and right valves. Lowville limestone, 30-50 feet above Ottosee limestone; in Rye Cove about three-fourths of a mile southwest of Rye Cove School, Scott County. U. S. N. M. 97577a, 97577b.



ATHENS, CHAMBERSBURG, MARTINSBURG, BRASSFIELD, AND CLINTON FOSSILS



ATHENS, CHAMBERSBURG, MARTINSBURG, BRASSFIELD, AND CLINTON FOSSILS

PLATE 101.—ATHENS, CHAMBERSBURG, MARTINSBURG, BRASSFIELD, AND CLINTON FOSSILS

FIGURE

1–5. *Phacops pulchellus* Foerste.

1-4, × 2; 5, × 4; 1, 3, 4, internal molds of heads; 5, external mold of head; 2, internal mold of a tail. Brassfield formation; along Louisville & Nashville Railroad half a mile southeast of Cumberland Gap, Tenn. 1-4, from sandstone at base of formation; 5, from ferruginous limestone at top of formation. (See Part I, Pl. 60B.) U. S. N. M. 97525a, 97525b, 97525c, 97525d, 97526.

6, 9. *Calymene niagarense* of authors.

According to Foerste not typical *C. niagarense*. Internal molds of heads. Clinton formation, ore bed; Fourmile fenster about 2 miles south-southeast of Ewing, Lee County. U. S. N. M. 97527a, 97527b.

7, 8, 10, 11. *Calymene vogdesi* Foerste.

All fragmentary. 7, 8, internal molds of heads; 10, 11, internal molds of tails. Occurrence as 5. U. S. N. M. 97528a, 97528b, 97528c, 97528d.

12, 13. *Tretaspis reticulata* Ruedemann, × 2.

Head and tail. Chambersburg limestone; vicinity of Strasburg, Shenandoah County. U. S. N. M. 97529a, 97529b.

14, 15. *Ampyx hastatus* Ruedemann, × 2.

Dorsal and profile views of a head. Specimens etched out of limestone. Chambersburg limestone; Tumbling Run 1½ miles southwest of Strasburg, Shenandoah County. U. S. N. M. 97530.

16–19. *Cryptolithus tessellatus* Green, × 2.

16-18, dorsal, front, and profile views of a head, etched out of limestone; 19, wax impression from an external mold of a whole specimen including the tail. Pleural furrows on lobes of tail faintly shown. Martinsburg shale, Trenton horizon. 16-18, 3 miles northeast of Long Glade, Augusta County; 19, Swatara Gap, northwest of Lebanon, Lebanon County, Pa. 16-18, U. S. N. M. 97531; 19, 90061.

FIGURE

20–22. *Calymene granulosa* (Foerste).

20, external mold of a head, × 4; 21, internal mold of a tail; 22, internal mold of a head. Martinsburg shale, Eden horizon; along State Route 311 on the northwest slope of Catawba Mountain and about 1 mile southeast of Catawba Sanatorium, Roanoke County. U. S. N. M. 97532a, 97532b, 97532c.

23–26. *Arthrorhachis* cf. *A. elspethi* Raymond, × 2.

24, 25, heads; 23, tail; 26, entire specimen rolled up and showing only the tail with the spines. All etched from limestone. Occurrence as 14. This is the only known occurrence of *Arthrorhachis* in formations younger than the Athens shale. 23, U. S. N. M. 97533a; 24, 25, 97533b; 26, 97533c.

27, 28. *Homotelus simplex* (Raymond and Narraway).

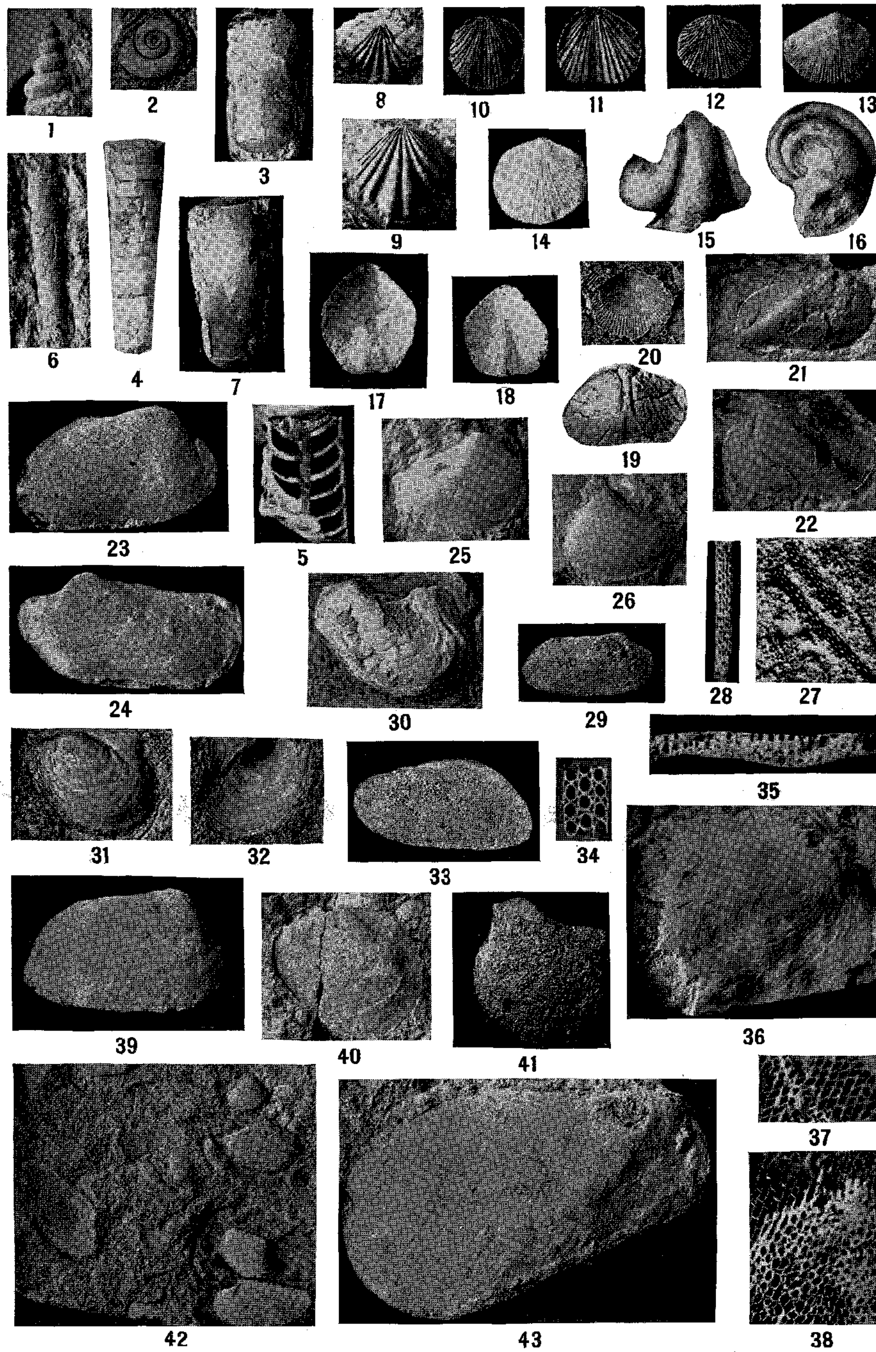
27, head; 28, thorax and tail. Occurrence as 14. U. S. N. M. 97534a, 97534b.

29. *Sphaerexochus?* sp., × 4.

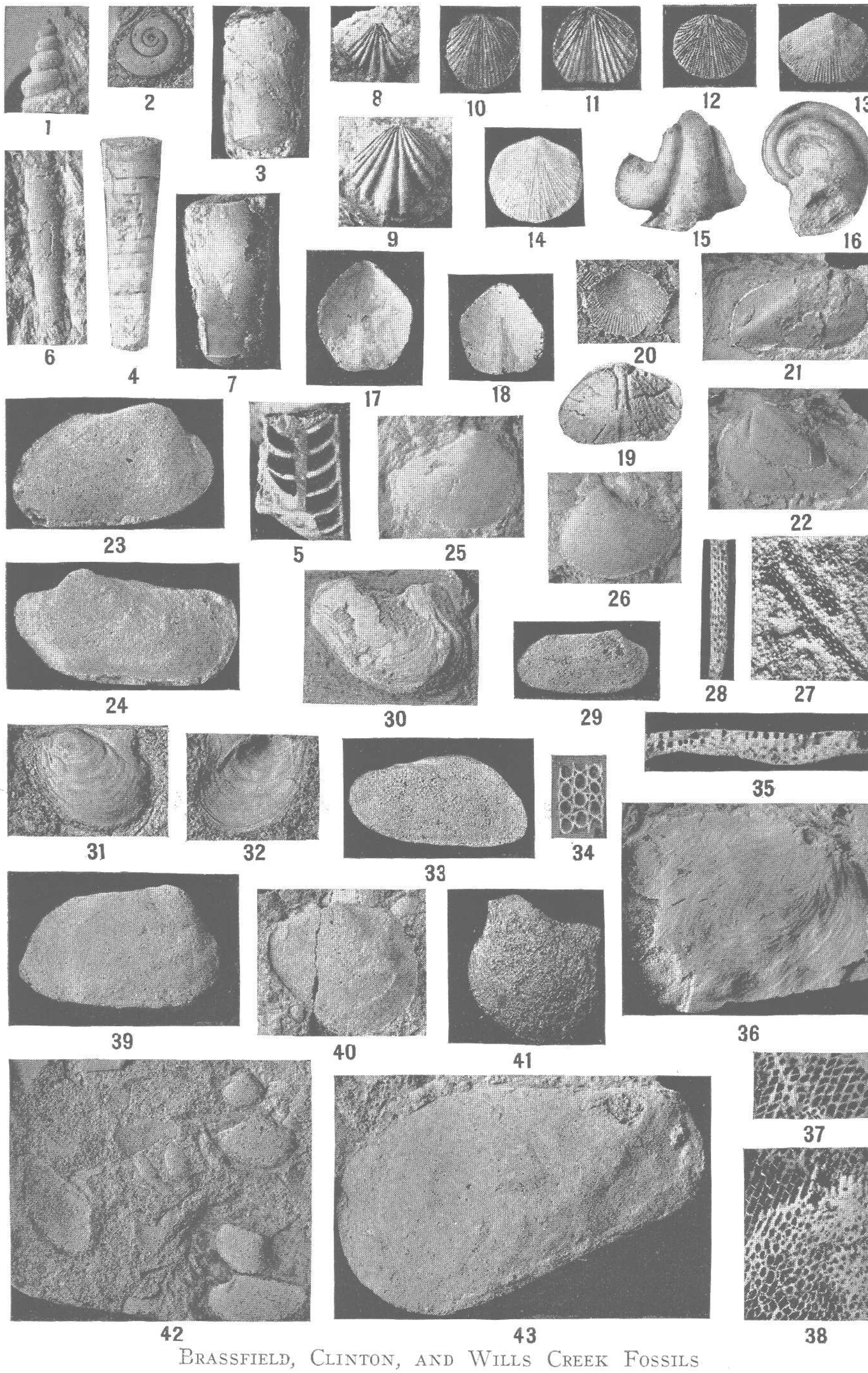
Tail. Occurrence as 12. U. S. N. M. 97535.

30, 31. *Basilicus* cf. *B. marginalis* (Hall).

Part of head and two tails. Athens limestone; 1½ miles south-southwest of Murat, Rockbridge County. U. S. N. M. 102308.



BRASSFIELD, CLINTON, AND WILLS CREEK FOSSILS



BRASSFIELD, CLINTON, AND WILLS CREEK FOSSILS

PLATE 102.—BRASSFIELD, CLINTON, AND WILLS CREEK FOSSILS

FIGURE

1. *Hormotoma subulata* (Conrad).
   Limestone at top of Brassfield horizon; near west end of tunnel on the Louisville and Nashville Railroad about half a mile east of Cumberland Gap village, Tenn. U. S. N. M. 97611.

2. *Straparollus* cf. *S. incarinatum* Foerste.
   Clinton formation near top; railroad cut on Wolf Creek 1 mile south of Rocky Gap village, Bland County; on same piece with *Bonnemaia obliqua* (Pl. 104, figs. 31 and 33). U. S. N. M. 97612.

3–5. *Cycloceras inceptum* (Foerste).
   5, vertical section showing septae and siphuncle. Occurrence as 1. U. S. N. M. 97614a, 97614b, 97614c.

6, 7. *Orthoceras? (Coleolus) clintonensis* Foerste, × 2.
   Marked with about 10 very fine revolving lines between the septae. Occurrence as 1. U. S. N. M. 97615a, 97615b.

8, 9. *Camarotoechia* cf. *C. decemplicata* (Sowerby), × 2.
   Occurrence as 1. U. S. N. M. 97616a, 97616b.

10, 11. *Hebertella?* sp., × 2.
   Dorsal and ventral valves. Occurrence as 1. U. S. N. M. 97617a, 97617b.

12–13. *Rhipidomella* sp.
   Occurrence as 1. U. S. N. M. 97618a, 97618b.

14. *Rhipidomella hybrida* (Sowerby).
   Occurrence as 1. U. S. N. M. 97610.

15, 16. *Bucanella trilobata* (Conrad), × 4.
   Occurrence as 1. U. S. N. M. 97619.

17–19. *Meristina maria* (Hall)?
   17, 18, external molds probably of dorsal valves; 19, internal mold of the rostral cavity of a dorsal valve, showing faintly the vascular scars. Clinton formation, Rochester horizon; along State Route 284 about 2 miles southeast of Crabbottom, Highland County. U. S. N. M. 97620a, 97620b, 97620c.

FIGURE

20. *Parmorthis* sp.
    Occurrence as 17. U. S. N. M. 97622.

21, 22. *Clidophorus?* sp.
    Right and left valves. Occurrence as 1. U. S. N. M. 97623a, 97623b.

23, 24. Cf. *Modiolopsis orthonota* (Conrad).
    Right and left valves. Sandstone in base of Brassfield; about half a mile southeast of Cumberland Gap village, Tenn. (Pl. 60B) U. S. N. M. 97624a, 97624b.

25, 26. *Ctenodonta* sp.?
    Occurrence as 1. U. S. N. M. 97625a, 97625b.

27, 28. *Helopora fragilis* Hall, × 4.
    27, poorly preserved external mold in sandstone, in which it is abundant. The white spots are the projecting matrix filling the pores that are shown in 28, which is a specimen in limestone showing the external characters. Brassfield horizon. 27, basal sandstone, same locality as 23; 28, Cataract formation; forks of Credit River, Ontario, Canada. A very widespread fossil at this horizon. U. S. N. M. 97626, 71553.

29. *Orthonota?* sp.
    Sandstone in Wills Creek formation. Associated with *Leperditia elongata willsensis* (Pl. 104, figs. 27, 28 and 32). Along Grannys Run half a mile southeast of Craig Healing Springs, Craig County. U. S. N. M. 97627.

30. *Pterinea* sp.
    Wills Creek formation; 1 mile east of Monterey, Highland County. U. S. N. M. 97628.

31, 32. *Pterinea* sp.
    Internal and external molds of the same specimen. Occurrence as 30; may be same species. U. S. N. M. 97629.

33. *Modiolopsis* sp.
    Left valve. Occurrence as 30. U. S. N. M. 97631.

34-38. *Phaenopora expansa* Hall and Whitfield.
    34, × 8, diagrammatic enlargement of the surface of another species to show external character of *Phaenopora;* 35, × 4, edge view of a fragment of a lamina; 36, one surface

FIGURE

of the bilaminar frond on which the specimen split. 37, 38, × 4, enlargement of parts of the exfoliated surface in lower left of 36. The rest of the surface of 36 is occupied by lozenge-shaped cells like those in 37. Occurrence as 1. 35, 36, U. S. N. M. 97632a, 97632b.

39, 40. *Cyrtodonta?*, 2 species.

Occurrence as 1. U. S. N. M. 97633, 97634.

41. *Pterinea* sp.?

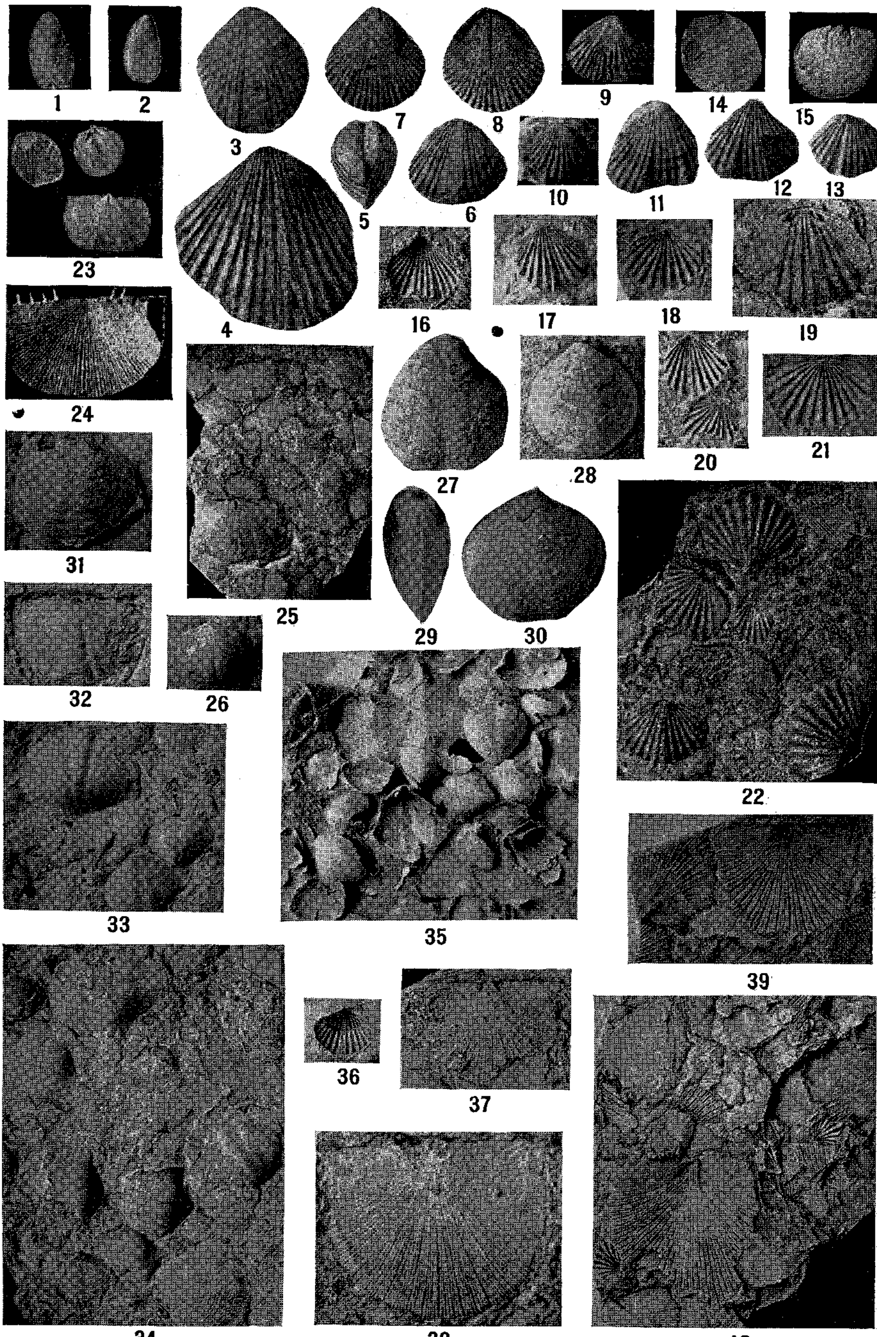
Clay impression from an external mold of a left valve. Occurrence as 29. U. S. N. M. 97635.

42. *Clidophorus* sp.

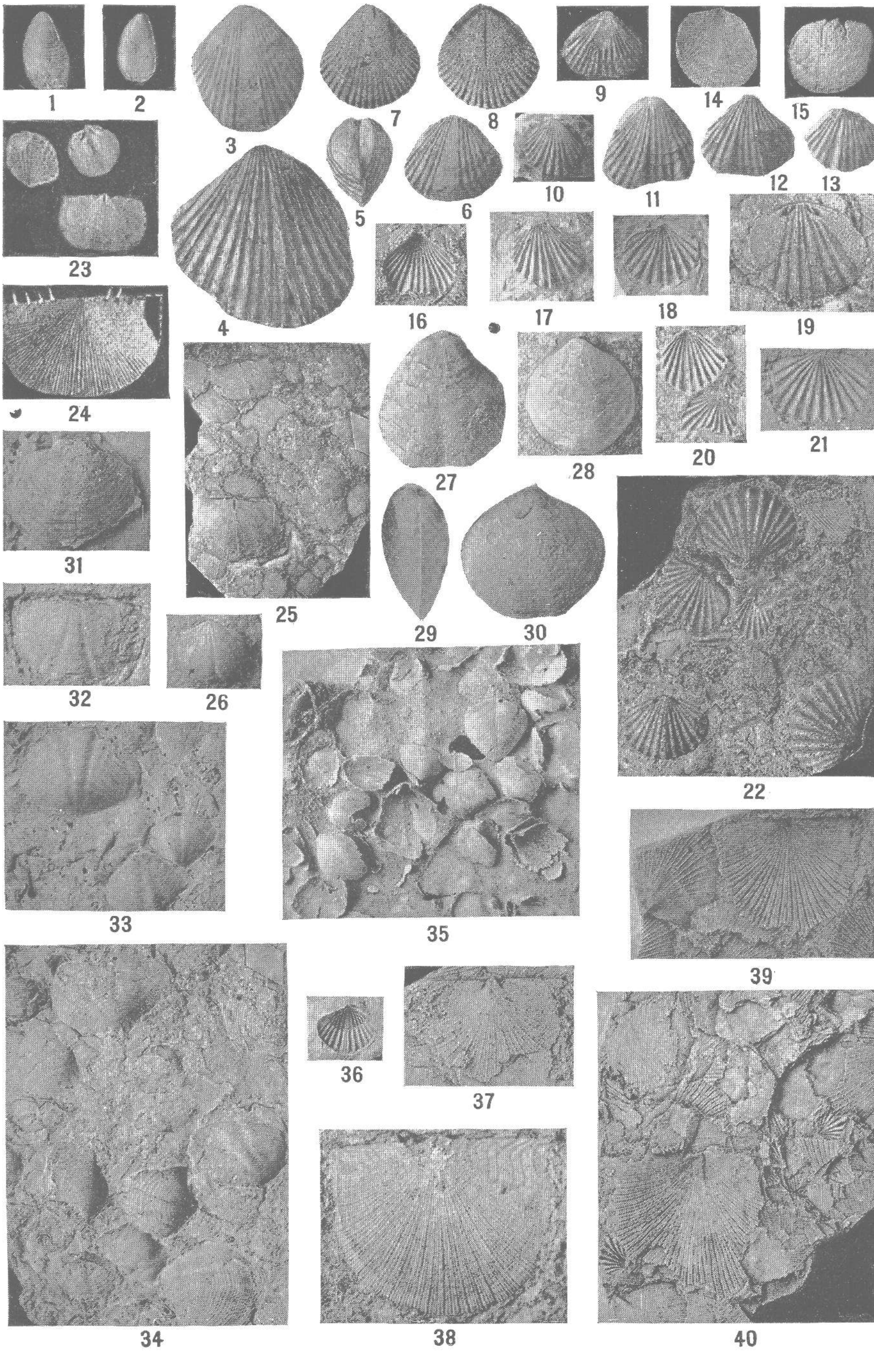
Right and left valves. Sandstone in base of Brassfield formation; half a mile southeast of Cumberland Gap, Tenn. U. S. N. M. 97636. (See part I, plate 60B.)

43. *Modiolopsis* sp.

Occurrence as 42. U. S. N. M. 97630.



Brassfield, Clinton, and Tonoloway Fossils



Brassfield, Clinton, and Tonoloway Fossils

PLATE 103.—BRASSFIELD, CLINTON, AND TONOLOWAY FOSSILS

FIGURE

1, 2. *Lingula cuneata* Conrad.

Brassfield formation, sandstone at base; half a mile southeast of Cumberland Gap, Tenn. U. S. N. M. 97637a, 97637b.

3–6. *Homeospira evax* (Hall).

3, ventral valve of a specimen; 4-6, ventral, profile, and dorsal views of a nearly whole specimen; 4, × 2. Clinton formation, Rochester horizon; along State Route 284 about 2 miles southeast of Crabbottom, Highland County. 3, U. S. N. M. 97638a; 4-6, 97638b.

7, 8. *Uncinulus?* sp.

Ventral and dorsal views of a specimen. Clinton formation; 2 miles north of Blackwater, Lee County. U. S. N. M. 97639.

9–13. *Camarotoechia tonolowayensis* Swartz.

9, 11, 12, ventral valves; 10, 13, dorsal valves. Tonoloway limestone? 9, 10, Tumbling Run 4 miles southwest of Saltville, Smyth County; 11-13, Flat Top Mountain about 1 mile east of Hollybrook, Bland County. U. S. N. M. 97640a, 97640b, 97641a, 97641b, 97641c.

14, 15. *Parmorthis?* sp., commonly called *Dalmanella elegantula* (Dalman).

14, impression of an external mold of a ventral valve; 15, internal mold of the same valve. Clinton formation; along road on southeast slope of Jack Mountain about 2½ miles west of Doe Hill, Highland County. U. S. N. M. 97621.

16, 17. *Camarotoechia neglecta* (Hall).

Ventral and dorsal valves. 16, Clinton formation; same locality as 3; 17, Brassfield limestone; same locality as 1. U. S. N. M. 97642, 97643.

18–22. *Anoplotheca hemispherica* (Sowerby).

18, external mold of a ventral valve; 19, internal mold of ventral valve, × 2; 20, external mold of a ventral valve (above), and of a dorsal valve (below); 21, external mold of a dorsal valve; 22, internal molds of 3 ventral valves and external mold of 1 dorsal valve. (See also Fig. 23.) Clinton formation. This fossil is apparently the only constant

FIGURE

member of the Clinton fauna from New York to Georgia and Alabama. 18, iron ore mine dump in Fourmile fenster about 2 miles south-southeast of Ewing, Lee County; 19, about 2½ miles northwest of Star Tannery post office, Frederick County; 20-22, southeast slope of Powell Mountain on U. S. Route 58 about 1 mile due north of Pattonsville, Scott County. U. S. N. M. 97644, 97645, 97646a, 97646b, 97646c.

23–25. *Chonetes novascoticus* Hall.

23, lower right, internal mold of a ventral valve; upper left, external mold of the ventral valve of *Anoplotheca hemispherica* showing ornamentation; upper right, small orthoid; 24, × 2, external mold of a ventral valve which preserves a few hinge spines; 25, slab with several internal molds of ventral valves. Clinton formation; about 1¾ miles northwest of Star Tannery post office, Frederick County. U. S. N. M. 97647a, 97647b, 97647c.

26–30. *Hindella (Greenfieldia) congregata* Swartz.

27-30, × 2. 26, 27, 30, ventral valves; 28, dorsal valve; 29, profile of the whole specimen of 30. Tonoloway limestone. 27, 28, same locality as 9; 26, 29, 30, along road near north end of Bolar Valley and 1 mile northwest of Trimble, Bath County. U. S. N. M. 97649a, 97648a, 97648b, 97649b.

31–34. *Reticularia bicostata* (Vanuxem).

31, ventral valve; 32, dorsal valve; 33, 34, parts of slabs with several specimens of ventral and dorsal valves. Occurrence as 3. U. S. N. M. 97650a, 97650b, 97650c, 97650d.

35. *Hindella (Greenfieldia) congregata* Swartz.

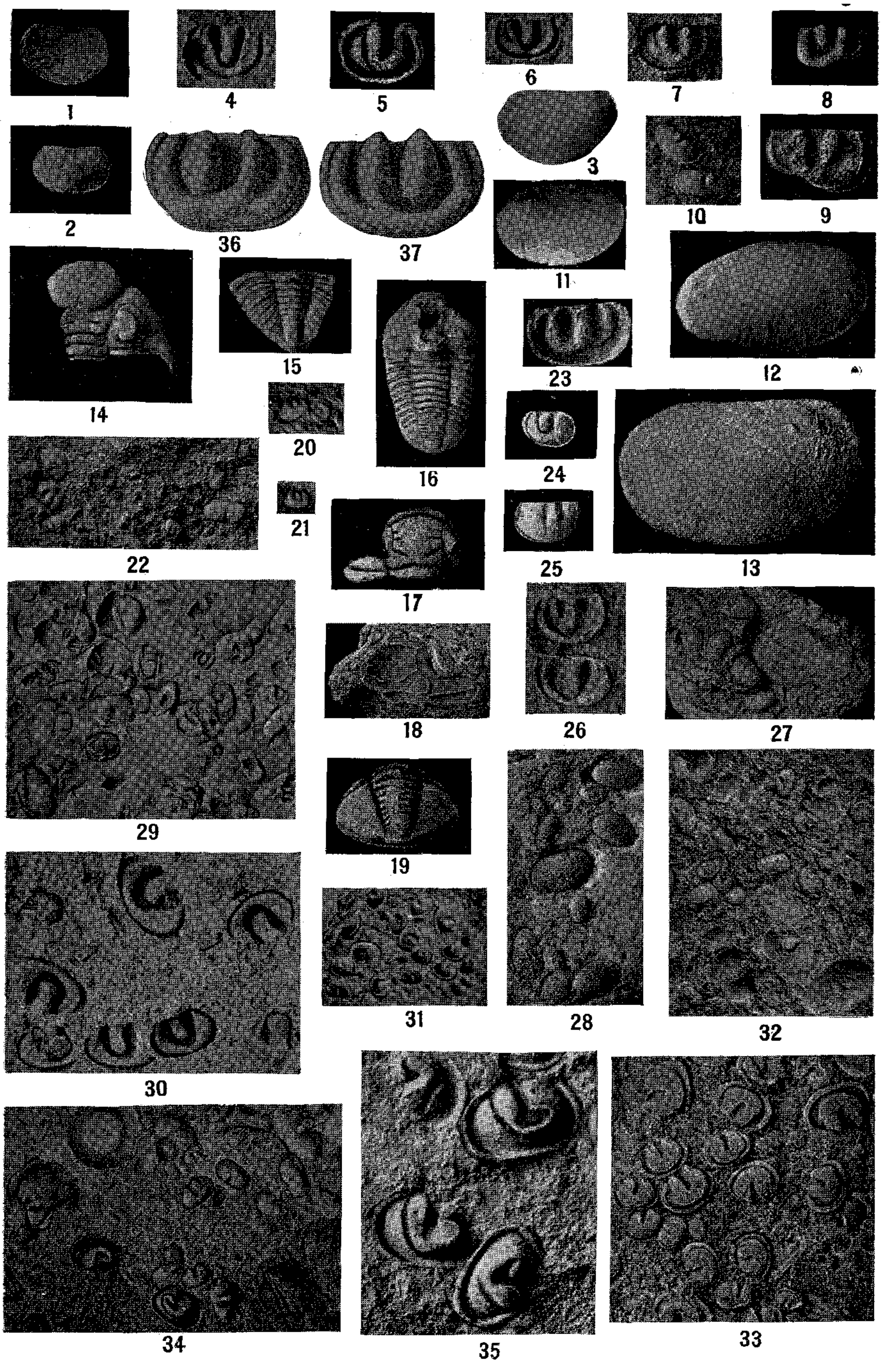
Etched slab with several specimens of both valves, some showing interiors. Occurrence as 26. U. S. N. M. 97649c.

36. *Trematospira camura* Hall.

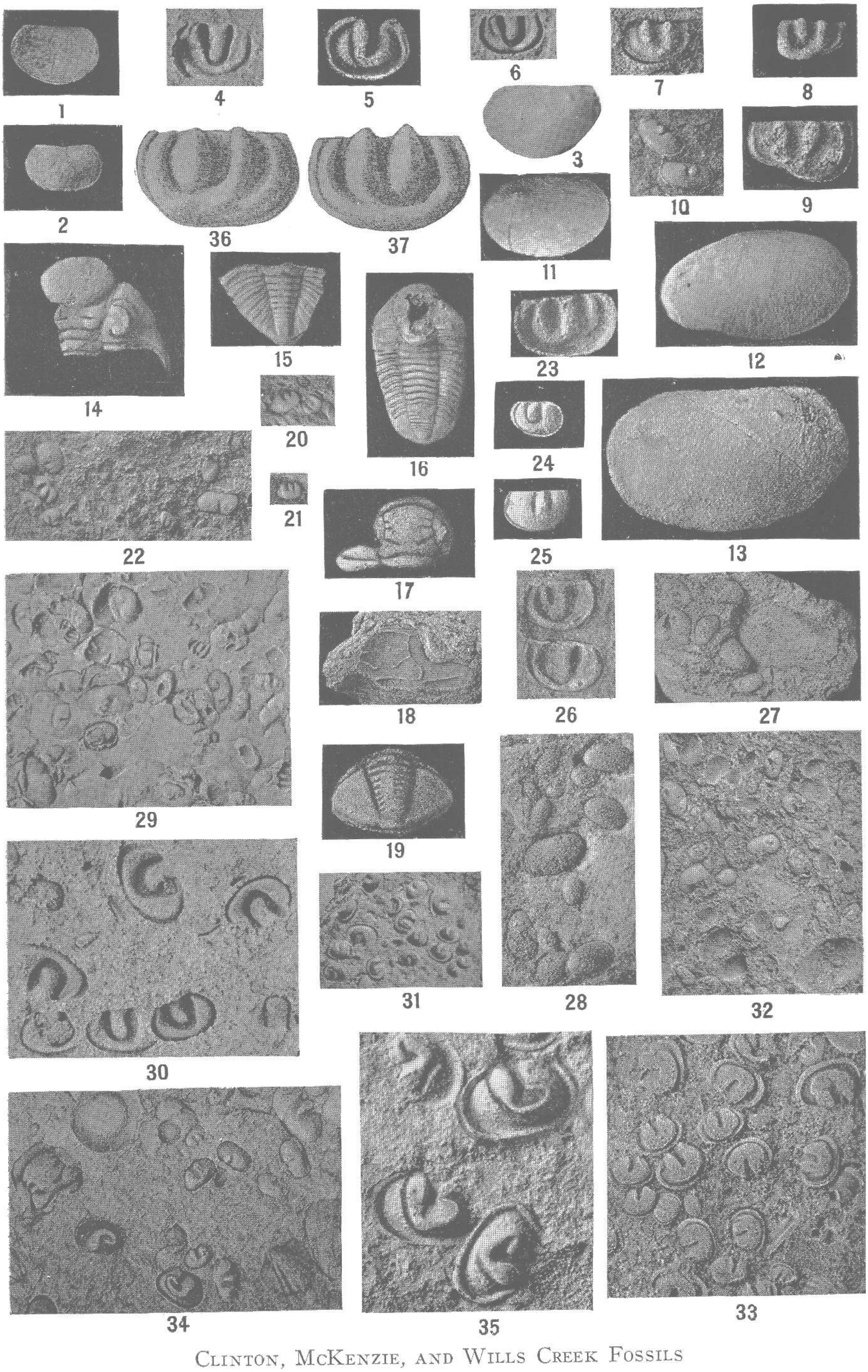
External mold of a ventral valve. Occurrence as 3. U. S. N. M. 97651.

37–40. *Brachyprion corrugata* (Conrad).

37, internal mold of a ventral valve; 38-40, probably all external molds of ventral valves. 39, 40, show how thickly the shells are crowded together in the rock; 38, shows the crenulations in the upper right corner that suggest the specific name. Clinton formation; along U. S. Route 58 about half a mile northeast of Cumberland Gap village, Tenn. U. S. N. M. 97652a, 97652b, 97652c, 97652d.



CLINTON, MCKENZIE, AND WILLS CREEK FOSSILS



CLINTON, MCKENZIE, AND WILLS CREEK FOSSILS

PLATE 104.—CLINTON, MCKENZIE, AND WILLS CREEK FOSSILS

FIGURE

1. *Leperditia alta* (Conrad), × 2.
   Interior of a left valve. Wills Creek limestone; along U. S. Route 50 just west of the north end of Great North Mountain, Frederick County. U. S. N. M. 97653.

2. *Leperditia scalaris praecedens* Ulrich and Bassler.
   Left valve. Tonoloway limestone?, along Chesapeake and Ohio Railway between Gala and Haden, Botetourt County. U. S. N. M. 97654.

3. *Leperditia altoides* Weller.
   Right valve. Occurrence as 2. U. S. N. M. 97655.

5. *Zygosella cristata* Ulrich and Bassler?
   Impression of an external mold of a right valve. Clinton formation, near top; along U. S. Route 58 on the east slope of Powell Mountain 1 mile due north of Pattonsville, Scott County. U. S. N. M. 97658.

4, 6–9. *Zygobolba decora* (Billings), × 4.
   4, 6, external molds of left valves; 7, internal mold of right valve; 8, 9, females, right and left internal molds. Horizon, low in the middle Clinton or lower Clinton near the top. 4, waste from mining of iron ore bed in Fourmile fenster 3 miles south of Ewing, Lee County; 6-9, same locality as 5. U. S. N. M. 97656a, 97657a, 97657b, 97657c, 97657d.

10. *Kloedenia longula* Ulrich and Bassler, × 4.
   Right and left valves. Wills Creek formation?, argillaceous limestone in bed of small creek not far above the top of the Bloomsburg sandstone; Harshberger Gap near south end of east ridge of Massanutten Mountain, Rockingham County. U. S. N. M. 97659.

11. *Isochilina?* sp.
   Slab with *Kloedenia longula* and *Leperditia*. Occurrence as 10. U. S. N. M. 97660.

12, 13. *Leperditia elongata willsensis* Ulrich and Bassler, × 4.
   12, left valve, crushed or abnormal?; 13, right valve. Wills Creek formation; same locality as 10. U. S. N. M. 97661a, 97661b.

FIGURE

14, 15. *Dalmanites limulurus* (Green).

Head and tail. Clinton formation, Rochester member; along State Route 284 about 2 miles southeast of Crabbottom, Highland County. U. S. N. M. 97664a, 97664b.

16–19. *Liocalymene clintoni* (Vanuxem).

16, a nearly entire individual; 17, internal mold of a head, × 2; 18, external mold of another head; 19, internal mold of a tail. Clinton formation. 16, in gap through Rich Patch Mountain about 1½ miles south of Rich Patch, Botetourt County; 17-19, along road about 2 miles northeast of Blackwater, Lee County. One of the commonest Clinton fossils in Va. U. S. N. M. 97665, 97666a, 97666b, 97666c.

20–22. *Kloedenia normalis* Ulrich and Bassler, × 4.

Also *Eukloedenella simplex,* U. S. N. M. 97692, in 22 on right. 20, 21, right valves; 22, left valve. McKenzie limestone; along State Route 284 about 2 miles southeast of Crabbottom, Highland County. U. S. N. M. 97667a, 97667b, 97667c.

23. *Drepanellina clarki* Ulrich and Bassler, × 4.

External mold of left valve. Characteristic fossil of the Rochester horizon of the Clinton formation; same locality as 20. U. S. N. M. 97670.

24, 25. *Kloedenia normalis* Ulrich and Bassler, × 4.

Left and right valves. 24, occurrence as 20; 25, Tonoloway or Wills Creek limestone; along Tumbling Run 4 miles southwest of Saltville, Washington County. U. S. N. M. 97668, 97669.

26. *Zygobolba decora* (Billings).

External mold of right valve. Occurrence as 4. U. S. N. M. 97656b.

27, 28. *Leperditia elongata willsensis* Ulrich and Bassler.

Internal molds of both valves. Wills Creek formation; along Grannys Run half a mile southeast of Craig Healing Springs, Craig County. U. S. N. M. 97662a, 97662b.

FIGURE

29. *Eukloedenella sinuata* Ulrich and Bassler.
Dizygopleura swartzi Ulrich and Bassler.

E. sinuata, the elongate forms with two low ridges; *D. swartzi,* the short forms with prominent lobes. Small piece of shale thickly covered with specimens, × 4. McKenzie formation; immediately beneath the Bloomsburg formation along U. S. Route 50 at north end of Great North Mountain, Frederick County. U. S. N. M. 97671, 97691.

30. *Zygobolbina conradi* Ulrich and Bassler, × 4.

External molds of both valves, thickly scattered on a small piece of sandstone. Clinton formation; on southeast slope of Jack Mountain 2 miles west of Doe Hill, Highland County. A good index fossil of the middle Clinton horizon. U. S. N. M. 97672.

32. *Leperditia elongata willsensis* Ulrich and Bassler.

Internal mold of both valves. Wills Creek formation; along State Route 284 about 2½ miles southeast of Crabbottom, Highland County. U. S. N. M. 97663.

31, 33. *Bonnemaia obliqua* Ulrich and Bassler.

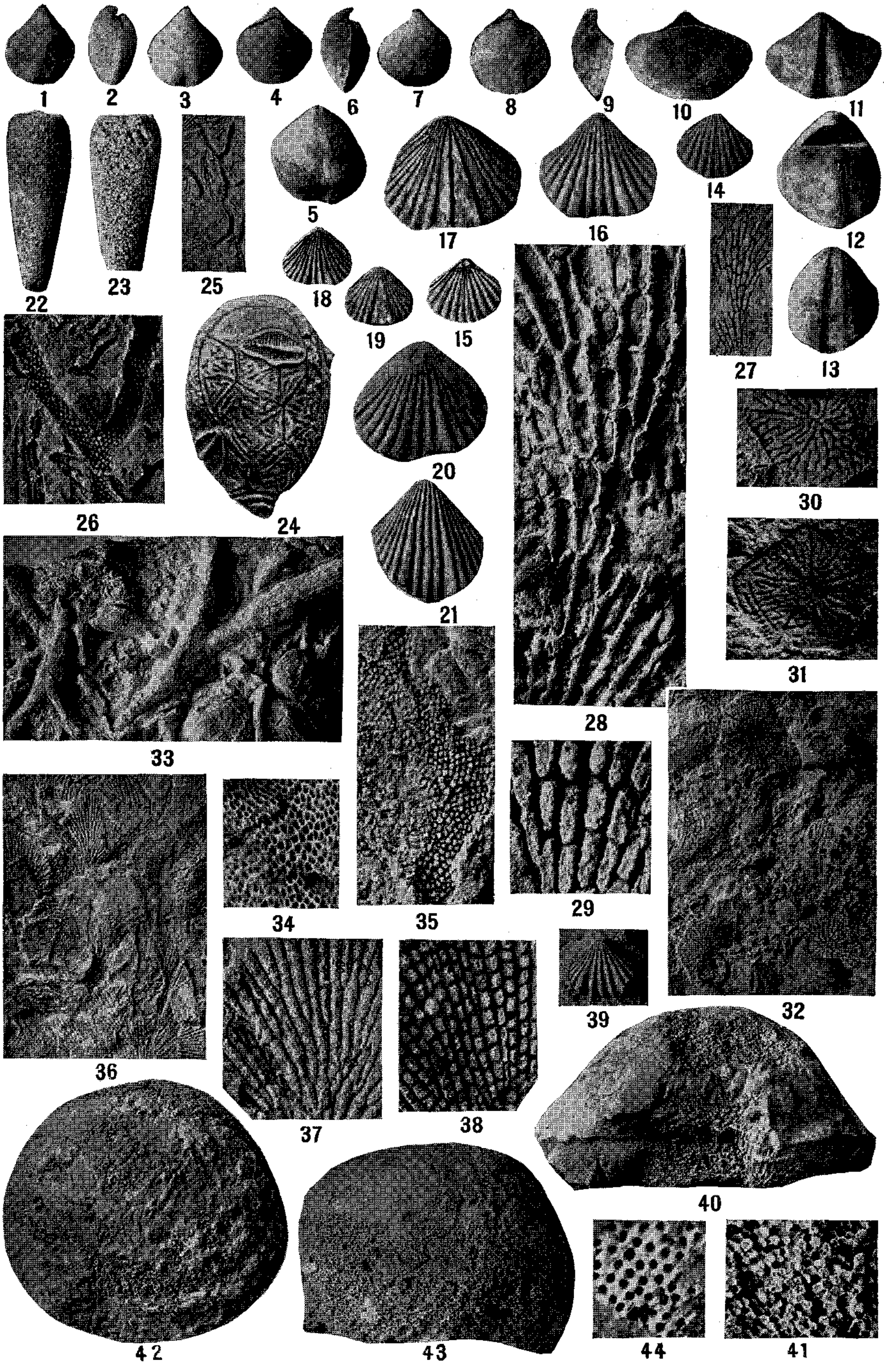
31, part of a small slab thickly strewn with internal molds; 33, wax impression of 31, × 2. Clinton formation, upper part; along railroad cut on Wolf Creek 1 mile south of Rocky Gap village, Bland County. U. S. N. M. 97613.

34, 35. *Mastigobolbina typus* Ulrich and Bassler.

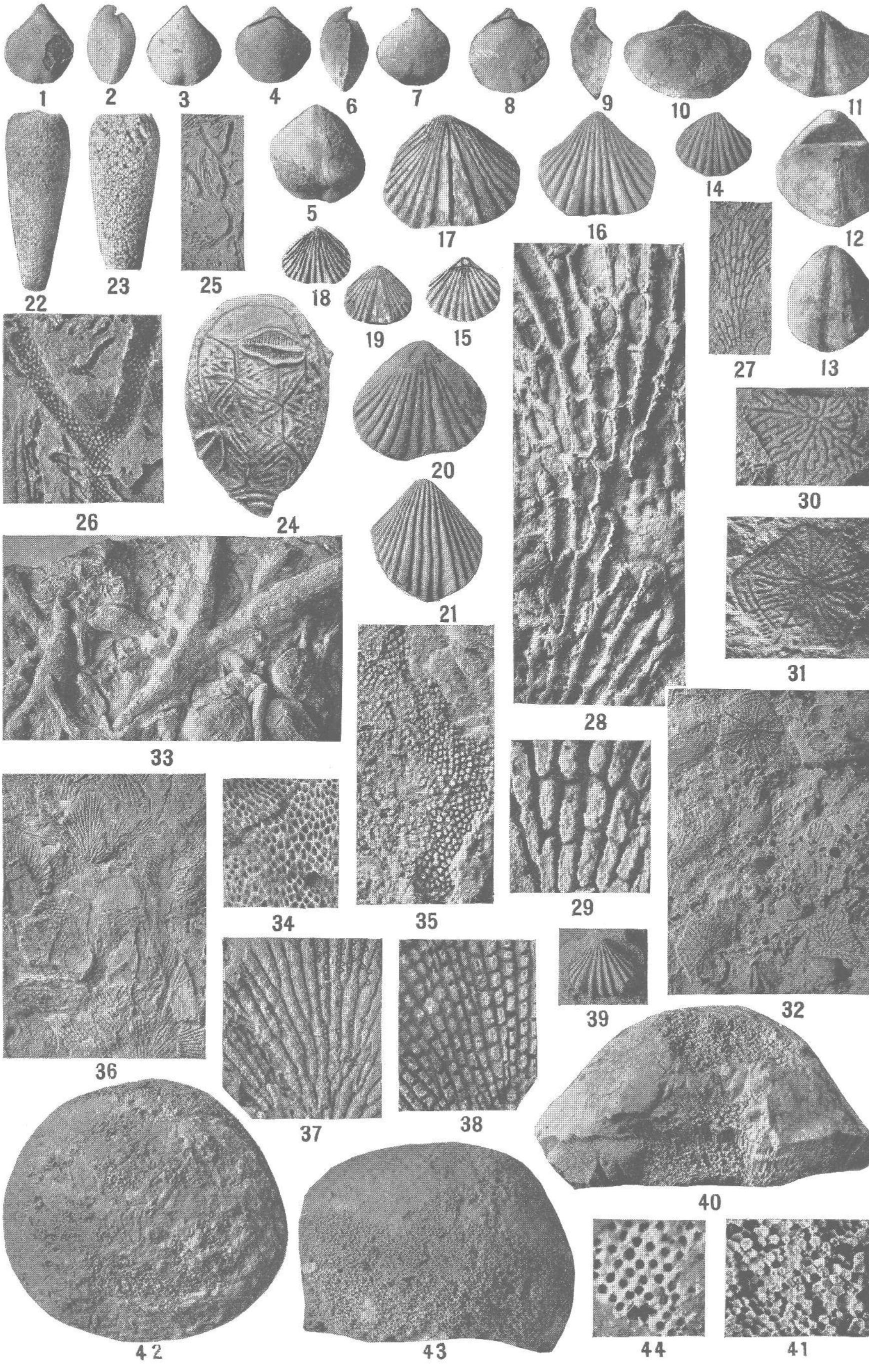
Wax impressions of external molds. 34, × 2; 35, × 4. In 35, the upper two are right valves and the lower a left valve. Clinton formation, near top; along State Route 284 about 2 miles southeast of Crabbottom, Highland County. A good index fossil of the upper Clinton. U. S. N. M. 97673a, 97673b.

36, 37. *Drepanellina clarki* Ulrich and Bassler, × 8.

Right and left valves. Enlarged drawings of perfect specimens to show actual character, Cumberland, Maryland. Characteristic fossils of the Rochester horizon of the Clinton formation. U. S. N. M. 83478.



KEYSER FOSSILS



KEYSER FOSSILS

PLATE 105.—KEYSER FOSSILS

FIGURE

1–3. *Whitfieldella nucleolata* Hall.

Dorsal, profile, and ventral views of a whole specimen. Keyser limestone; about 1½ miles northwest of Palo Alto, Highland County. U. S. N. M. 97675.

4–8. *Hindella* (*Greenfieldia*) *congregata* Swartz?

4, 6, 7, dorsal, profile, and ventral views of a whole specimen. 5, 8, ventral and dorsal views of other specimens. Keyser limestone; along U. S. Route 250 about 1 mile southeast of McDowell, Highland County. 4, 6, 7, U. S. N. M. 97676a; 5, 97676b; 8, 97676c.

9–11. *Spirifer modestus* Hall.

Profile, dorsal, and ventral views of a whole specimen. Keyser limestone; about 2 miles northwest of Palo Alto, Highland County. U. S. N. M. 97677.

12, 13. *Spirifer modestus plicatus* Maynard.

Dorsal and ventral views of a whole specimen, with obscure ribs barely visible on the ventral valve. Occurrence as 9. U. S. N. M. 97678.

14, 15. *Trematospira* cf. *T. camura* Hall.

Ventral and dorsal views of a whole specimen. Keyser limestone; southeast slope of Peters Hill about 2 miles west of Newcastle, Craig County. U. S. N. M. 97679.

16–21. *Camarotoechia litchfieldensis* (Schuchert).

16, 21, ventral valves of 2 specimens, × 2; 18, 19, ventral and dorsal views of a specimen; 19, exfoliated; 17, 20, dorsal, and ventral views of the same specimen as 18, 19, × 2; Keyser limestone. 16, 21, same locality as 1; 17-20, about 2 miles northeast of Van Buren Furnace, Shenandoah County. (See Pl. 109, figs. 8-10.) 16, 21, U. S. N. M. 97681a, 97681b; 17-20, 97680.

22–24. *Lepocrinites manlius* Schuchert.

22, 23, stems; 24, head, retaining the upper part of the stem. Keyser limestone. 22, same locality as 14; 23, along road 2½ miles west of Newcastle, Craig County; 24, Keyser, W. Va. (courtesy of Maryland Geological Survey, Lower Devonian, Pl. 32, fig. 8). 22, 23, U. S. N. M. 97674, 97725.

FIGURE

25, 26. *Orthopora rhombifera* (Hall).
26, part of 25, × 4. Occurrence as 17. U. S. N. M. 97682.

27–29. *Fenestrellina altidorsata* (Ulrich and Bassler).
27, external mold of the celluliferous side; 28, impression of 27, × 4; 29, part of 27, × 4. Occurrence as 17. U. S. N. M. 97683.

30-32. Cystid plates, probably *Pseudocrinites abnormalis* Schuchert, 30, 31, × 2.
Occurrence as 9. U. S. N. M. 97684a, 97684b, 97684.

33, 34. *Eridotrypa parvulipora* Ulrich and Bassler.
34, × 4. Occurrence as 4. U. S. N. M. 97685a, 97685b.

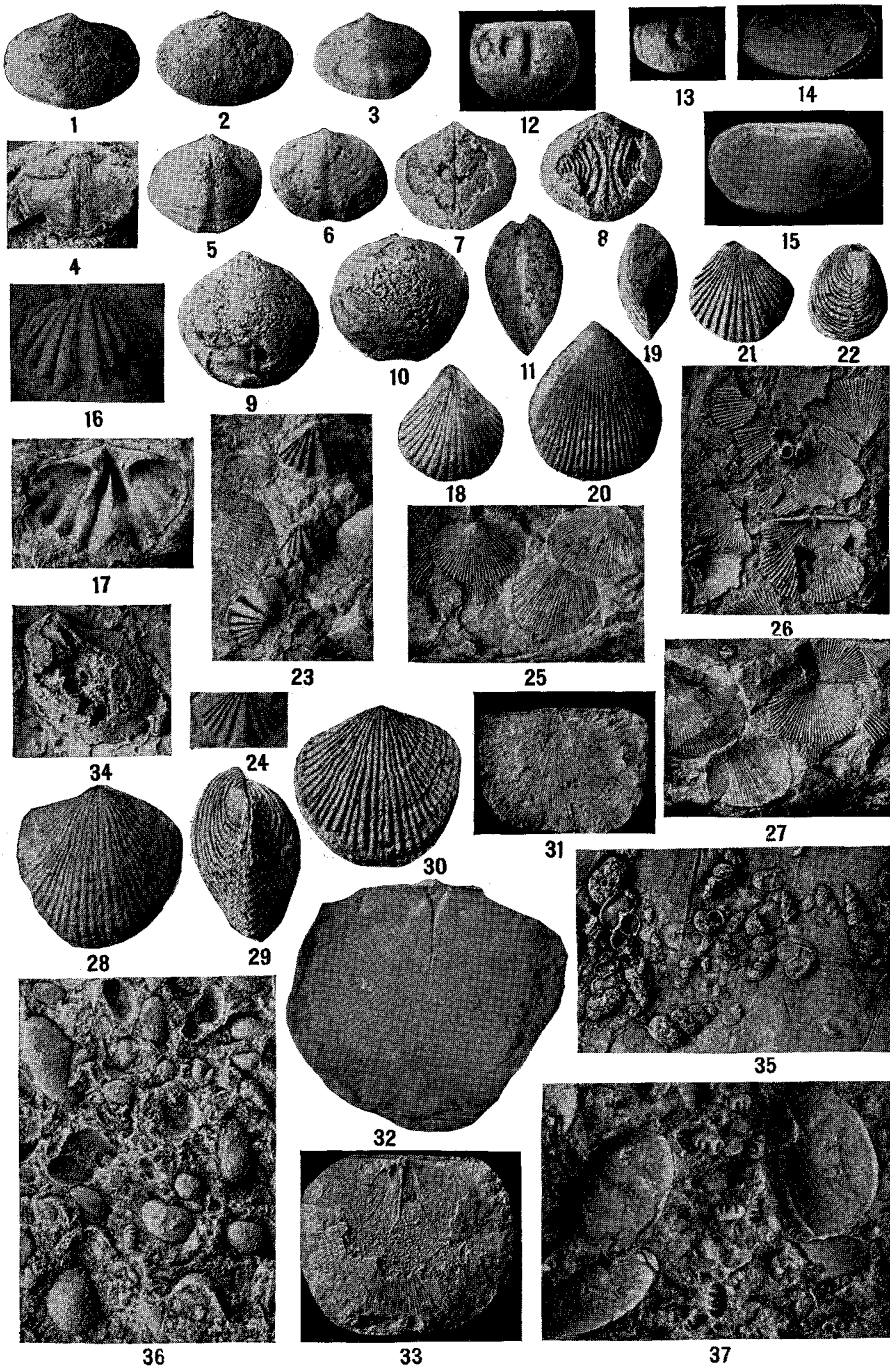
35. *Diplostenopora siluriana* (Weller), × 4.
Poorly preserved, external mold in limestone. Occurrence as 17. U. S. N. M. 97686.

36–38. *Fenestrellina cumberlandica* (Ulrich and Bassler).
36, slab with a mat of fossils; 37, 38, celluliferous and non-celluliferous surface, × 2. Occurrence as 17. U. S. N. M. 97687.

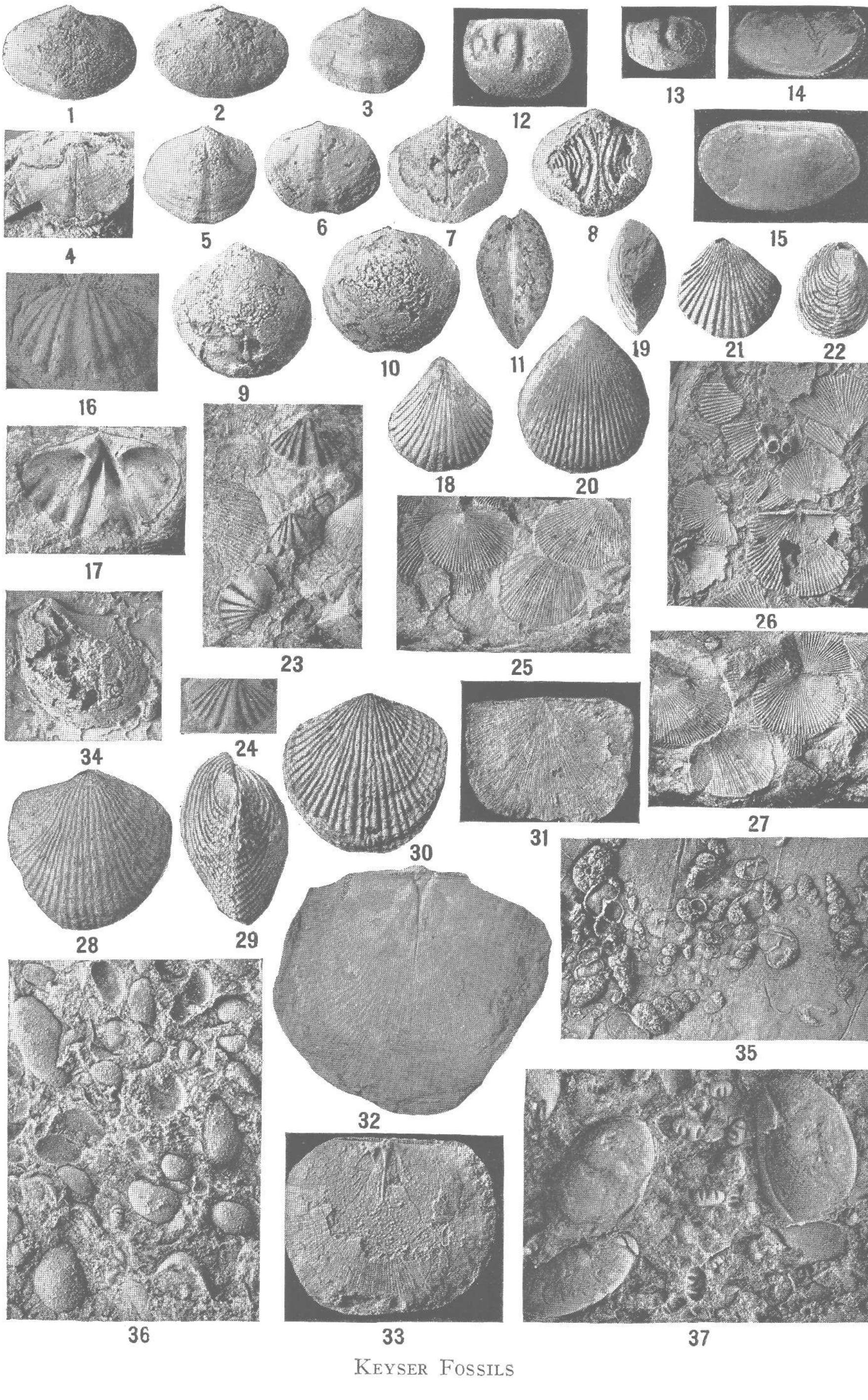
39. *Camarotoechia* cf. *C. altiplicata* (Hall).
Ventral valve, apparently representing the silicified shell. Occurrence as 9. U. S. N. M. 97688.

40, 41. *Cyphotrypa corrugata* (Weller).
41, × 4. Occurrence as 9. U. S. N. M. 97689.

42–44. *Stromatotrypa globularis* Ulrich and Bassler.
42, 43, summit and lateral views; 44, part of surface, × 4. Keyser limestone; along U. S. Route 250 in Back Creek Valley on the northwest slope of Lantz Mountain, Highland County. U. S. N. M. 97690.



Keyser Fossils



KEYSER FOSSILS

PLATE 106.—KEYSER FOSSILS

FIGURE

1–6. *Nucleospira elegans* Hall.

1, 2, ventral and dorsal views of a whole specimen; 3, ventral valve of another specimen; 4, internal mold of a ventral valve showing the narrow furrow made by the low septum in that valve; 5, 6, dorsal and ventral views of a narrower specimen. Keyser limestone; Peters Hill 2 miles west of Newcastle, Craig County. U. S. N. M. 97693a, 97693b, 97693c, 97693d.

7–11. *Nucleospira swartzi* Maynard?, × 2.

7, 8, ventral and dorsal views of a partially exfoliated specimen; 8, showing the spiral arm supports; 9-11, ventral, dorsal and profile views of another specimen. Keyser limestone; 2 miles northeast of Van Buren Furnace, Shenandoah County. U. S. N. M. 97694a, 97694b.

12, 13. *Kloedenia* sp., × 4.

Left and right valves of different specimens. Keyser limestone; 1 mile southeast of McDowell, Highland County. U. S. N. M. 97695a, 97695b.

14, 15. *Leperditia elongata* Weller, × 4.

Left and right valves. Occurrence as 12. U. S. N. M. 97696, 97697.

16, 17. *Delthyris perlamellosus praenuntius* F. M. Swartz.

Exterior and interior of different ventral valves. Occurrence as 1. U. S. N. M. 97698a, 97698b.

18, 19. *Uncinulus convexorus* Maynard.

Dorsal and profile views of a whole specimen. The ventral valve is almost the same as the dorsal. Occurrence as 7. U. S. N. M. 97699.

20. *Uncinulus* cf. *U. globulus* Schuchert.

Ventral valve. Keyser limestone?; about 800 feet southeast of Bells Valley, Augusta County. U. S. N. M. 97700.

21, 22. *Uncinulus nucleolatus* (Hall)?

Dorsal and profile views of a nearly whole specimen. Keyser limestone; about 2 miles northwest of Palo Alto, Highland County. U. S. N. M. 97701.

FIGURE

23, 24. *Spirifer vanuxemi* Hall.

23, slab with two ventral valves (upper), and one dorsal valve (lower); 24, dorsal valve. Associated with *Chonetes jerseyensis* (25-27). Keyser limestone; on Sand Ridge 2½ miles southwest of Gore, Frederick County. U. S. N. M. 97702a, 97702b.

25–27. *Chonetes jerseyensis* Weller.

Small pieces of rock covered with many specimens, some in fragmentary condition; mostly ventral valves, some showing interiors. 25, 27, counterparts. This fossil is highly diagnostic of the lowermost part of the Keyser limestone. 25, 27, same locality as 23; 26, same locality as 1. 25, 27, U. S. N. M. 97703; 26, 97704.

28–30. *Atrypa reticularis* (Linné).

28, 30, dorsal and ventral views of a specimen; 29, profile view of another specimen. Keyser limestone. 28, 30, same locality as 1; 29, 1¾ miles west of Palo Alto, Highland County. 28, 30, U. S. N. M. 97705; 29, 97706.

31–33. *Stropheodonta bipartita* (Hall).

31, partly exfoliated ventral valve showing internal mold of beak; 32, internal mold of a dorsal valve; 33, partly exfoliated ventral valve showing the interior of the dorsal valve below. All show the hinge denticles. 31, occurrence as 23; 32, occurrence as 21; 33, occurrence as 1. U. S. N. M. 97707, 97708, 97709.

34. *Pterinea?* sp.

Left valve. Keyser limestone; along U. S. Route 250 on the southeast slope of Bullpasture Mountain, Highland County. U. S. N. M. 97710.

35. *Hormotoma?* sp.

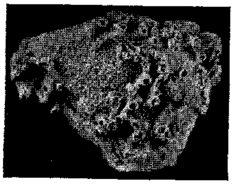
A small piece of limestone crowded with these high-spired gastropods. Keyser, or perhaps Tonoloway, limestone; same locality as 12. U. S. N. M. 97711.

36. *Leperditia* and other small ostracodes.

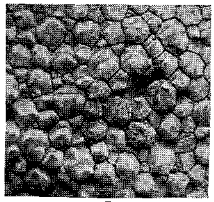
Of common occurrence in the Keyser limestone; Buffalo Gap, Augusta County. U. S. N. M. 97712.

FIGURE

37. Small piece of argillaceous limestone crowded with ostracodes; *Leperditia* (large) and probably species of *Dizygopleura* (small). Occurrence as 12. 36, 37 are good examples of the prolific occurrence of these small ostracodes peculiarly characteristic of the Tonoloway and Keyser limestones. U. S. N. M. 97713.

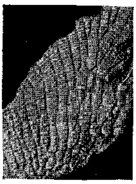


1

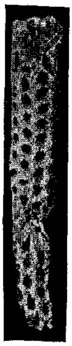


2

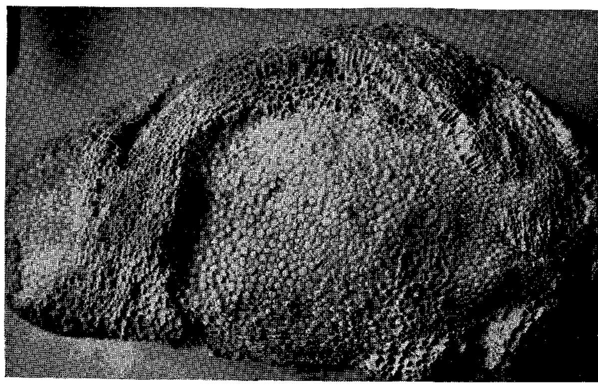
6



3



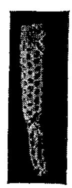
7



5

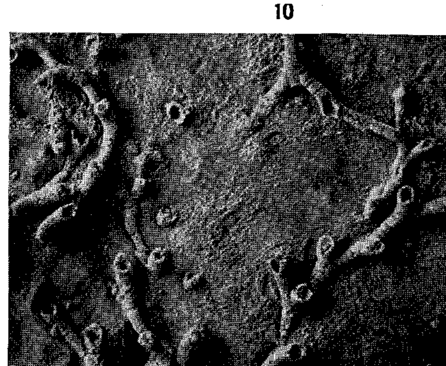
4

9



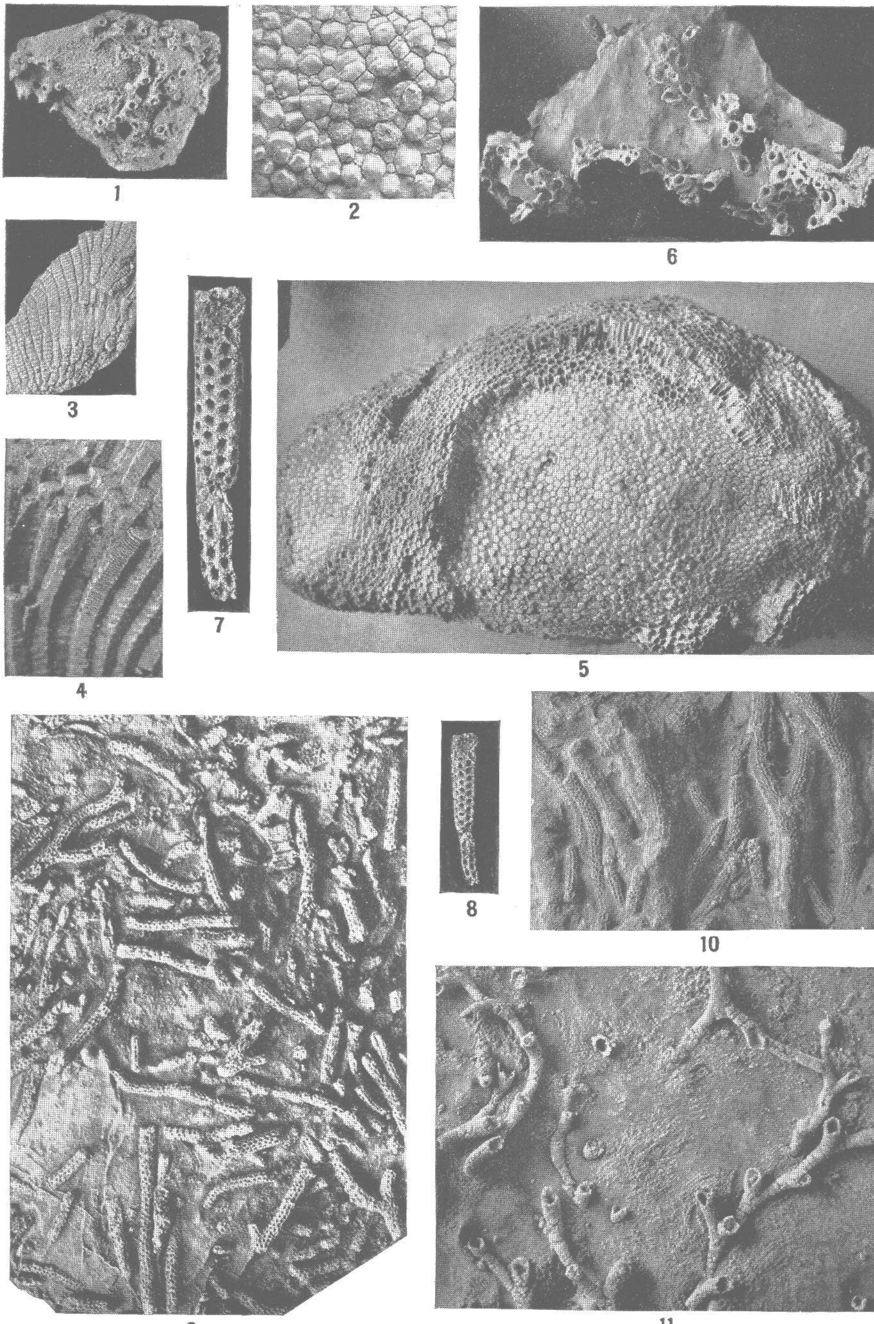
8

10



11

KEYSER FOSSILS



Keyser Fossils

PLATE 107.—KEYSER FOSSILS

FIGURE

1. *Aulopora* cf. *A. schohariae* Hall.

   Attached to a massive bryozoon. Keyser limestone; 1½ miles northwest of Palo Alto, Highland County. U. S. N. M. 97714.

2–5. *Favosites helderbergiae* Hall.

   2, 4, × 2. 5, whole head; 2, direct view of 5, to show size and shape of coralites in transverse section; 4, side view of 5, to show radial coralites with tabulae; 3, side view of another specimen. Keyser limestone. 5, Paddy Run about 5 miles southwest of Star Tannery post office, Frederick County; 3, about 2 miles northeast of Van Buren Furnace, Shenandoah County. 2, 4, 5, U. S. N. M. 97715; 3, 97716.

6. *Ceratopora?* sp.

   Probably undescribed species. Keyser limestone; along U. S. Route 250 on the northwest slope of Lantz Mountain, Highland County. U. S. N. M. 97717.

7–9. *Cladopora rectilineata* Simpson.

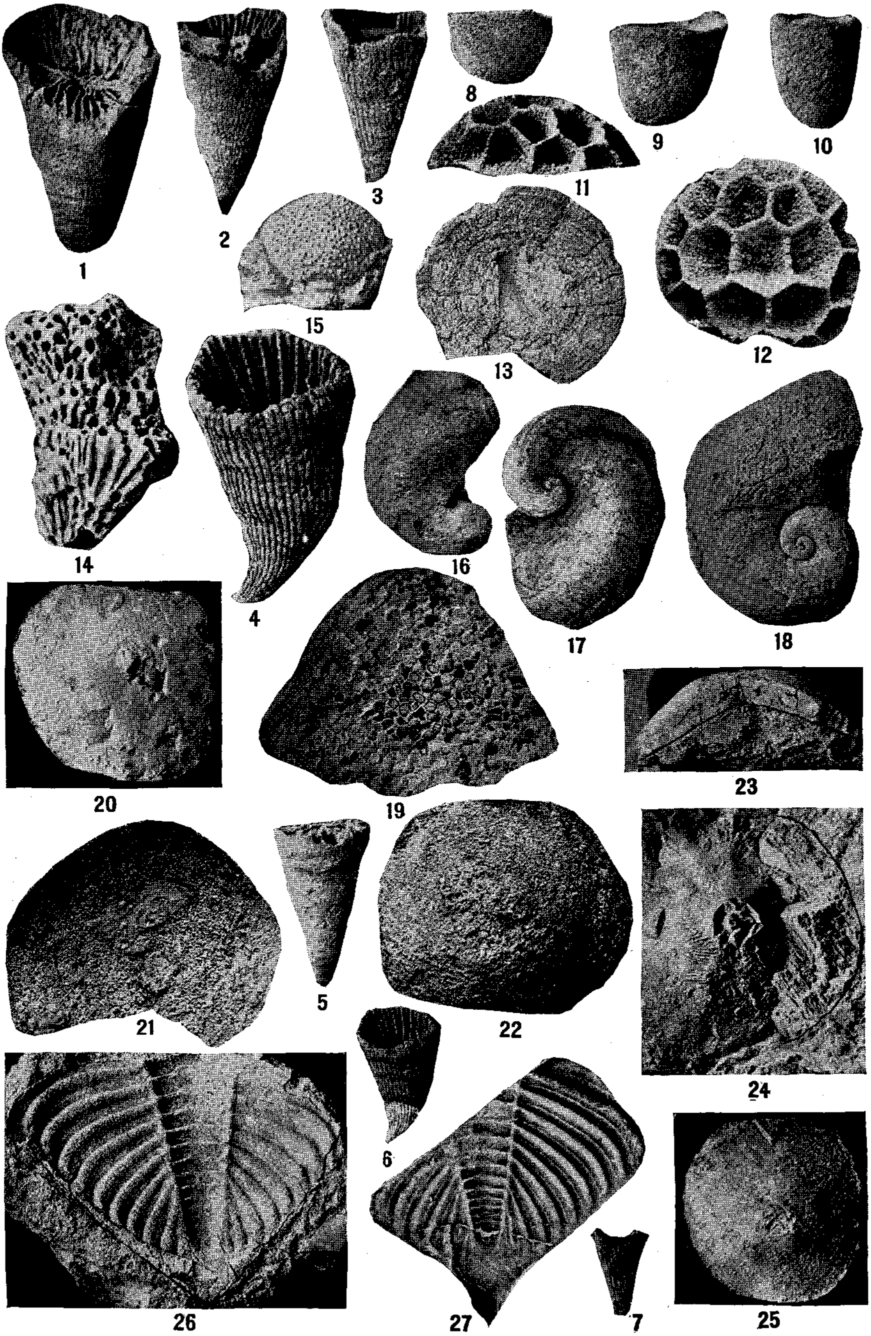
   7, × 4; 8, × 2, of same specimen. Keyser limestone. 7, 8, same locality as 6. 9, Keyser, W. Va. (courtesy of Maryland Geol. Survey, Lower Devonian, Pl. 25, fig. 4). Perhaps the best guide fossil of the Keyser. 7, 8, U. S. N. M. 97718.

10. *Cladopora multiseriata* Weller.

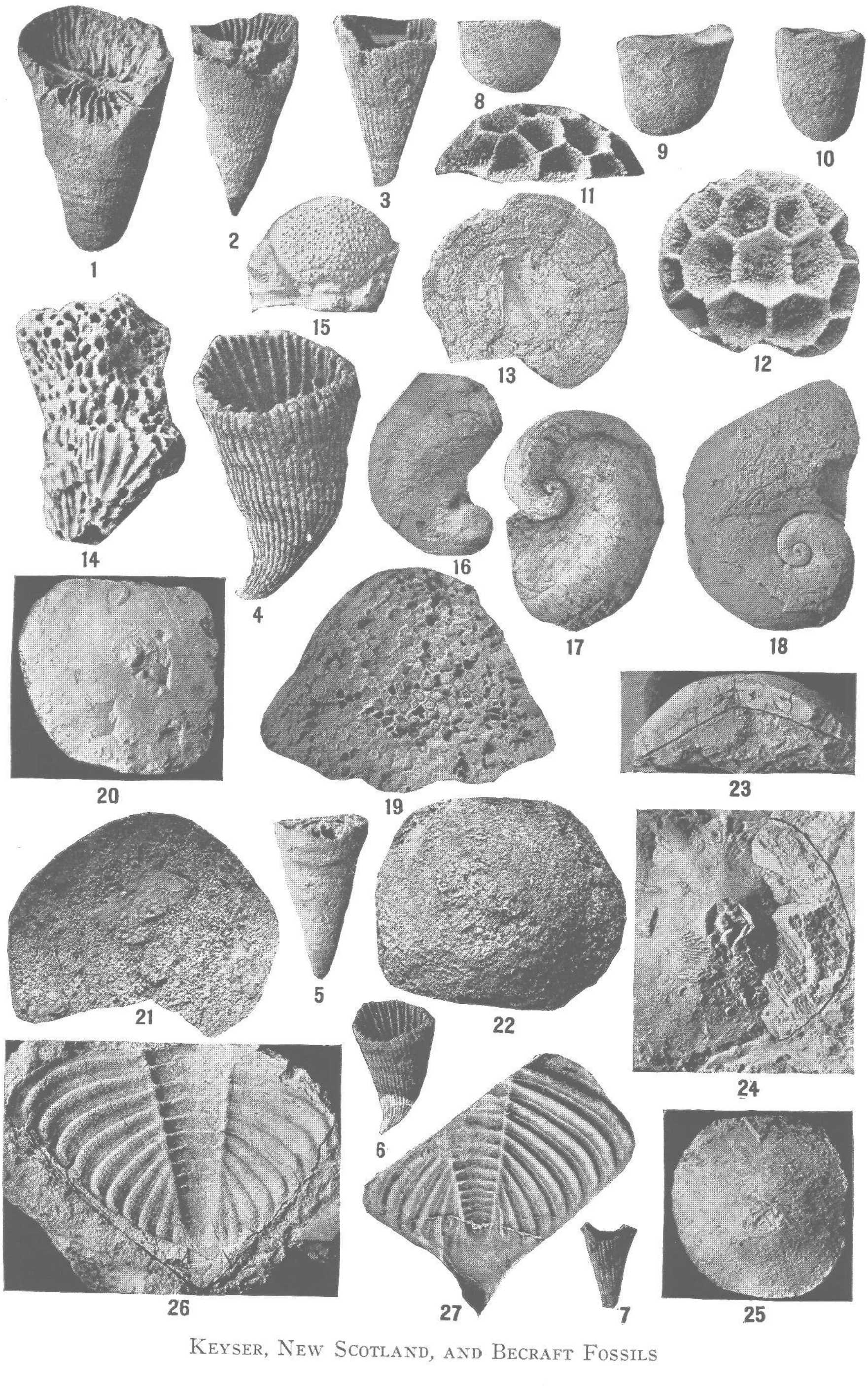
   Keyser limestone; Island Ford along U. S. Route 60 about 3½ miles southeast of Covington, Alleghany County. U. S. N. M. 97719.

11. *Ceratopora?* cf. *C.? marylandica* C. K. Swartz, × 2.

   Occurrence as 7. U. S. N. M. 97720.



KEYSER, NEW SCOTLAND, AND BECRAFT FOSSILS



Keyser, New Scotland, and Becraft Fossils

PLATE 108.—KEYSER, NEW SCOTLAND, AND BECRAFT FOSSILS

FIGURE

1–7. *Streptelasma strictum* Hall.

3, same as 7, × 2; 4, same as 6, × 2. Helderberg, New Scotland member; along U. S. Route 250 on southeast slope of Bullpasture Mountain, Highland County. U. S. N. M. 97726a, 97726b, 97726c, 97726d, 97726e.

8–10. *Edriocrinus pocilliformis* Hall.

Three bases of different size and proportions. Helderberg, New Scotland member; along U. S. Route 220 about 8 miles southwest of Monterey, Highland County. One of the most distinctive New Scotland fossils. U. S. N. M. 97727a, 97727b, 97727c.

11–13. *Pleurodictyum lenticulare* (Hall).

Lateral, calycinal, and basal views of a specimen. Helderberg, New Scotland member; along U. S. Route 60 just east of Covington, Alleghany County. U. S. N. M. 97728.

14. *Striatopora* or *Cladopora* sp., × 3.

Helderberg, probably Keyser member; at Island Ford along U. S. Route 60 about 4 miles east of Covington, Alleghany County. U. S. N. M. 97729.

15. *Phacops logani* Hall.

Helderberg, Becraft member; along State Route 311 about 1 mile south of Newcastle, Craig County. U. S. N. M. 97730.

16, 17. *Platyceras trilobatum* Hall.

16, occurrence as 1; 17, occurrence as 8; U. S. N. M. 97731, 97934.

18. *Platyceras gebhardi* Conrad.

Occurrence as 1. U. S. N. M. 97732.

19. *Favosites conicus* Hall.

Occurrence as 1. U. S. N. M. 97733.

20–25. *Aspidocrinus scutelliformis* Hall.

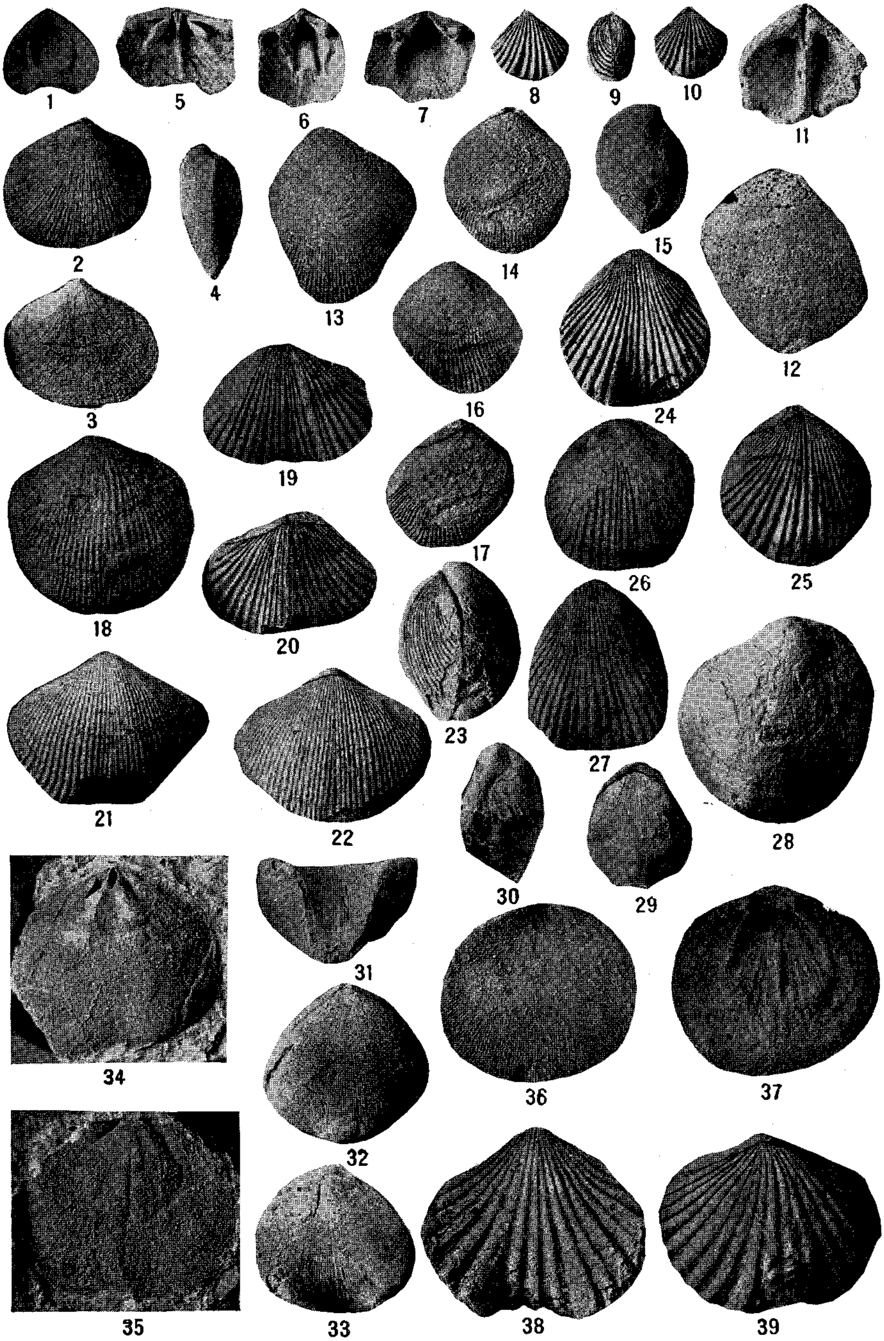
20, 22, 24, 25, external molds of the lower side of basal discs; 21, external mold of the upper side of a basal disc, concave toward the observer; 23, transverse section of

FIGURE

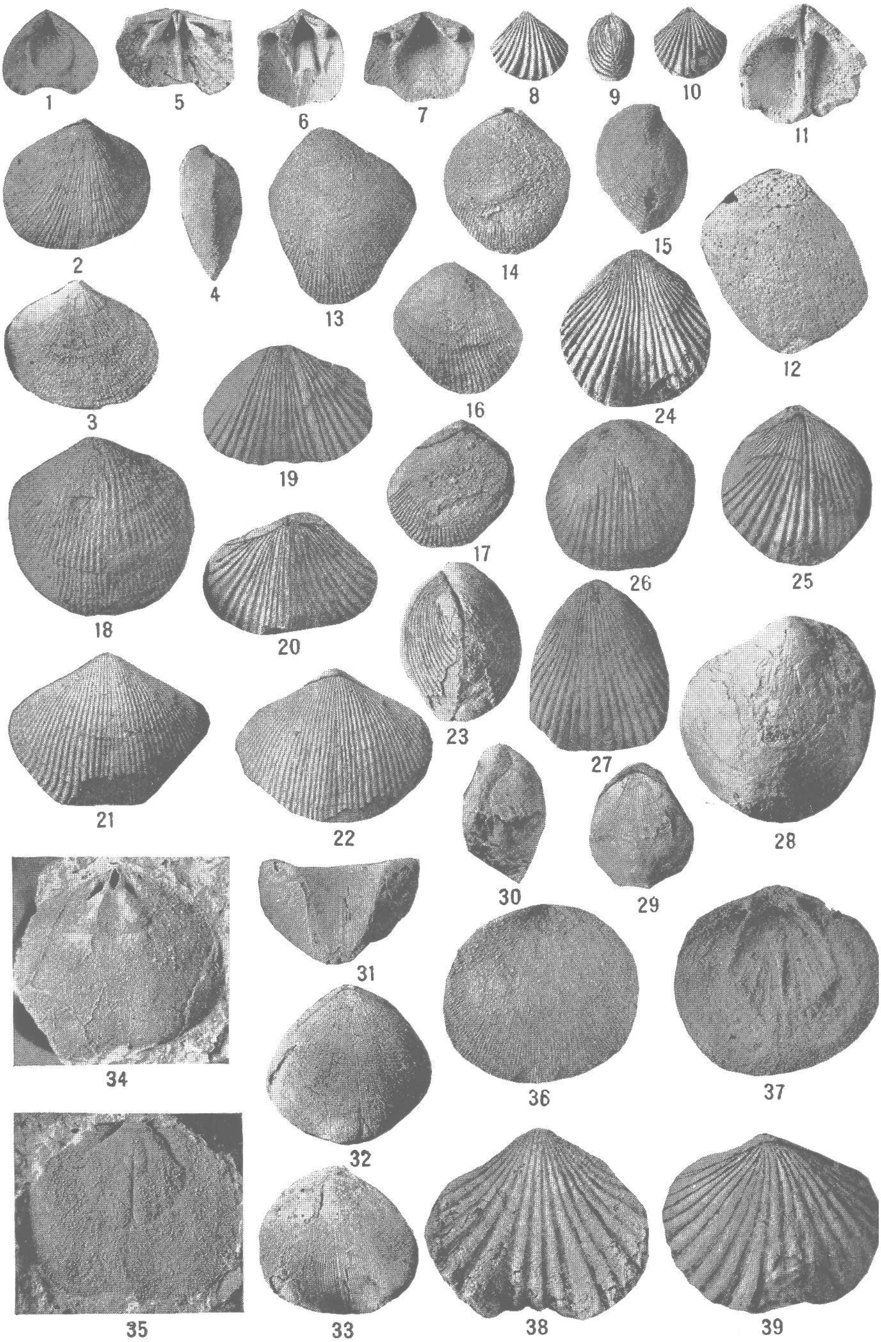
a basal disc filled with matrix. The specimen of 24 retains part of the basal disc (on the right). Helderberg limestone, Becraft member. 21, 22, from sandstone boulders at base of southeast slope of Wolf Creek Mountain and just east of junction of Wilderness Creek with Hunting Camp Creek, Bland County; 20, 23-25, northeast slope of Stone Mountain about 5 miles northeast of Honaker, Russell County. The specimens of 21, 22, may be another species which F. M. Swartz has named *Aspidocrinus caroli.* They are in coarse-grained sandstone and coated with manganese or iron oxide. This fossil is so abundant in the Becraft limestone of the Helderberg Mountains in New York that the Becraft was originally named the Scutella limestone. U. S. N. M. 97734a, 97735a, 97735b, 97734b, 97734c, 97734d.

26, 27. *Dalmanites pleuroptyx* (Green).

External molds of two tails. Concave toward the observer. Helderberg, New Scotland member. 26, along road in gorge of Jackson River through Morris Hill-Coles Mountain, Alleghany County; 27, same locality as 8. Fragments of this trilobite are common in the New Scotland. U. S. N. M. 97736, 97737.



KEYSER, NEW SCOTLAND, AND BECRAFT FOSSILS



KEYSER, NEW SCOTLAND, AND BECRAFT FOSSILS

PLATE 109.—KEYSER, NEW SCOTLAND, AND BECRAFT FOSSILS

FIGURE

1. *Eatonia peculiaris* (Conrad).
Ventral interior. Helderberg, New Scotland member; along U. S. Route 250 on the southeast slope of Bullpasture Mountain, Highland County. U. S. N. M. 97738.

2–7. *Rhipidomella oblata* (Hall).
2-4, dorsal, ventral, and profile views of a whole specimen; 5, dorsal interior; 6-7, ventral interiors. Helderberg, New Scotland member; along U. S. Route 220 half a mile north of Pinckney and 8 miles southwest of Monterey, Highland County. 2-4, U. S. N. M. 97740a; 5, 6, 7, 97740b, 97740c, 97740d.

8–10. *Camarotoechia litchfieldensis* (Schuchert).
Ventral, profile, and dorsal views of a whole specimen. Keyser limestone; 1½ miles northwest of Palo Alto, Highland County. (See Pl. 105, figs. 16-21.) U. S. N. M. 97681c.

11, 12. *Gypidula coeymanensis* var. *prognostica* Maynard.
11, interior of a ventral valve; 12, exterior of a fragment of another ventral valve. Keyser limestone?; along U. S. Route 250 on the northwest slope of Lantz Mountain, Highland County. U. S. N. M. 97741a, 97741b.

13–17. *Rensselaeria subglobosa* Weller.
13, 14, ventral and dorsal valves of different specimens; 15-17, profile, ventral, and dorsal views of a nearly whole but slightly distorted specimen. Occurrence as 2. 13, 14, U. S. N. M. 97742a, 97742b; 15-17, 97742c.

18. *Atrypa reticularis* (Linné).
Ventral valve. Helderberg, Becraft member; entrance to fair grounds and airport, Bluefield, W. Va. U. S. N. M. 97743.

19, 20. *Trematospira multistriata* (Hall).
Ventral and dorsal views of a specimen. Helderberg, New Scotland member; along U. S. Route 250 about 2 miles northwest of McDowell, Highland County. U. S. N. M. 97744.

FIGURE

21–23. *Trematospira equistriata* Hall and Clarke.
Ventral, dorsal, and profile views of a specimen. Occurrence as 2. U. S. N. M. 97935.

24, 25. *Uncinulus abruptus* (Hall).
Ventral and dorsal views of a specimen. Occurrence as 1. U. S. N. M. 97745.

26, 27. *Uncinulus,* species not determined.
Dorsal and ventral valves of different specimens; may be two species. Helderberg, Becraft member; along State Route 311 about 1 mile south of Newcastle, Craig County. U. S. N. M. 97746a, 97746b.

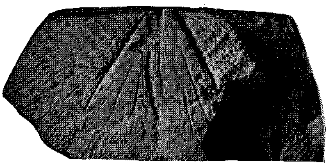
28. *Meristella lata* (Hall).
Ventral valve. Occurrence as 26. U. S. N. M. 97747.

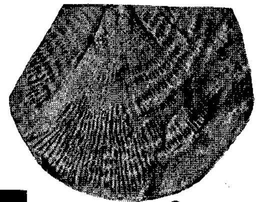
29, 30. *Eatonia peculiaris* (Conrad).
Dorsal and profile views of a narrow and partly exfoliated specimen. Occurrence as 26. U. S. N. M. 97739.

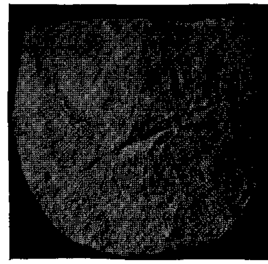
31–33. *Eatonia singularis* (Vanuxem).
Anterior, dorsal, and ventral views of a large, well preserved specimen. Helderberg, New Scotland member; along U. S. Route 60 just east of Covington, Alleghany County. U. S. N. M. 97748.

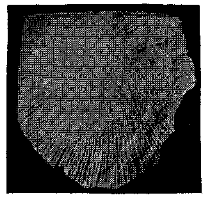
34–37. *Rhipidomella assimilis* (Hall)?
34, internal mold of a dorsal valve; 35, internal mold of a ventral valve; 36, external mold of a ventral valve; 37, interior of a ventral valve. Helderberg, Becraft member. 34-36, manganese ore pit on Flat Top Mountain 1 mile northwest of Hollybrook, Giles County; 37, locality as 2. U. S. N. M. 97749a, 97749b, 97749c, 97751.

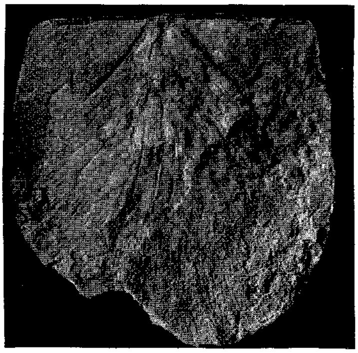
38, 39. *Eatonia medialis* (Vanuxem).
Ventral and dorsal views of two specimens. Helderberg, New Scotland member. 38, Pinckney, 4 miles southwest of Vanderpool, Highland County; 39, same locality as 1. Common fossil of the New Scotland member. U. S. N. M. 97936, 97750.

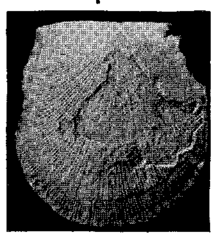

1

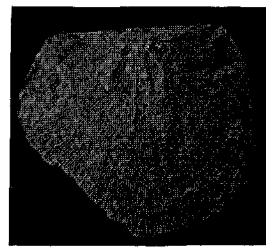

2

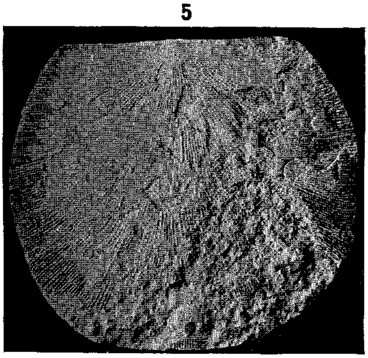

3

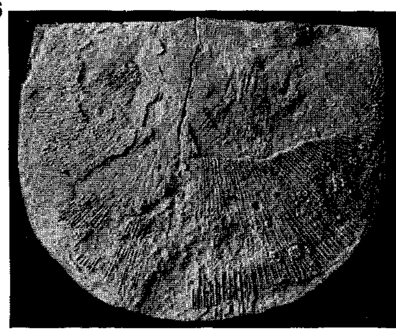

4

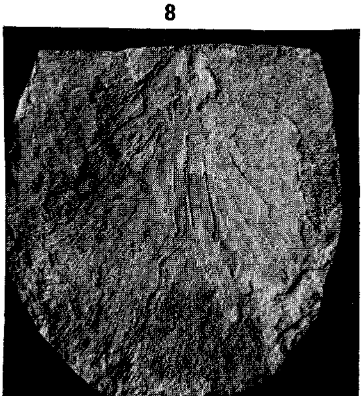

5

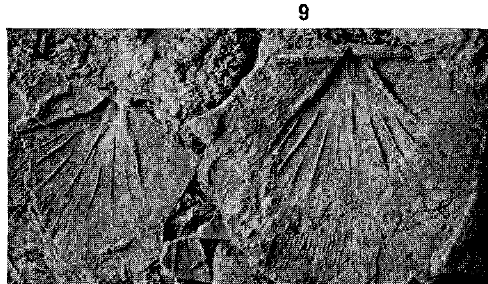

6


7

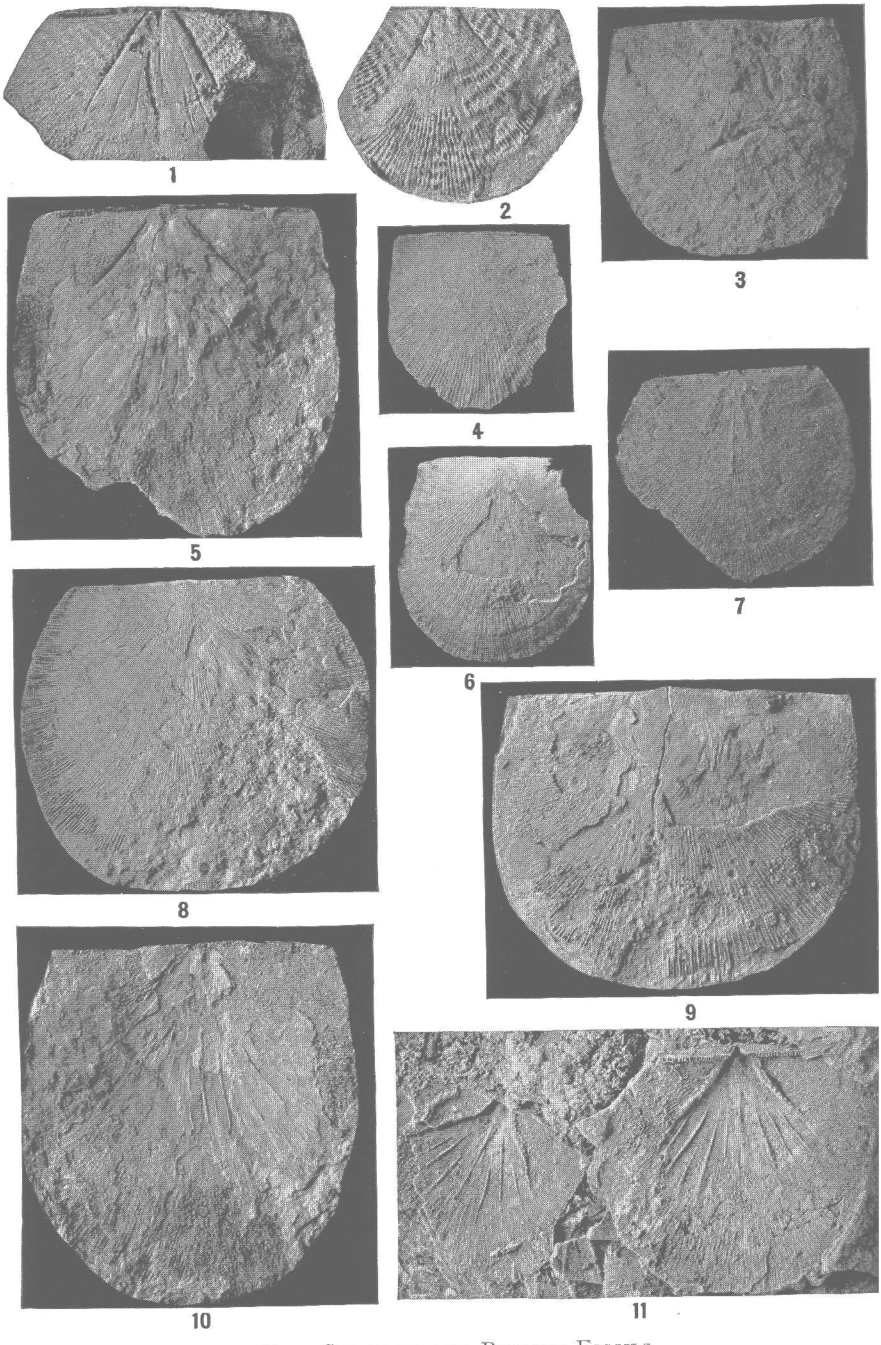

8


9


10


11

NEW SCOTLAND AND BECRAFT FOSSILS



New Scotland and Becraft Fossils

PLATE 110.—NEW SCOTLAND AND BECRAFT FOSSILS

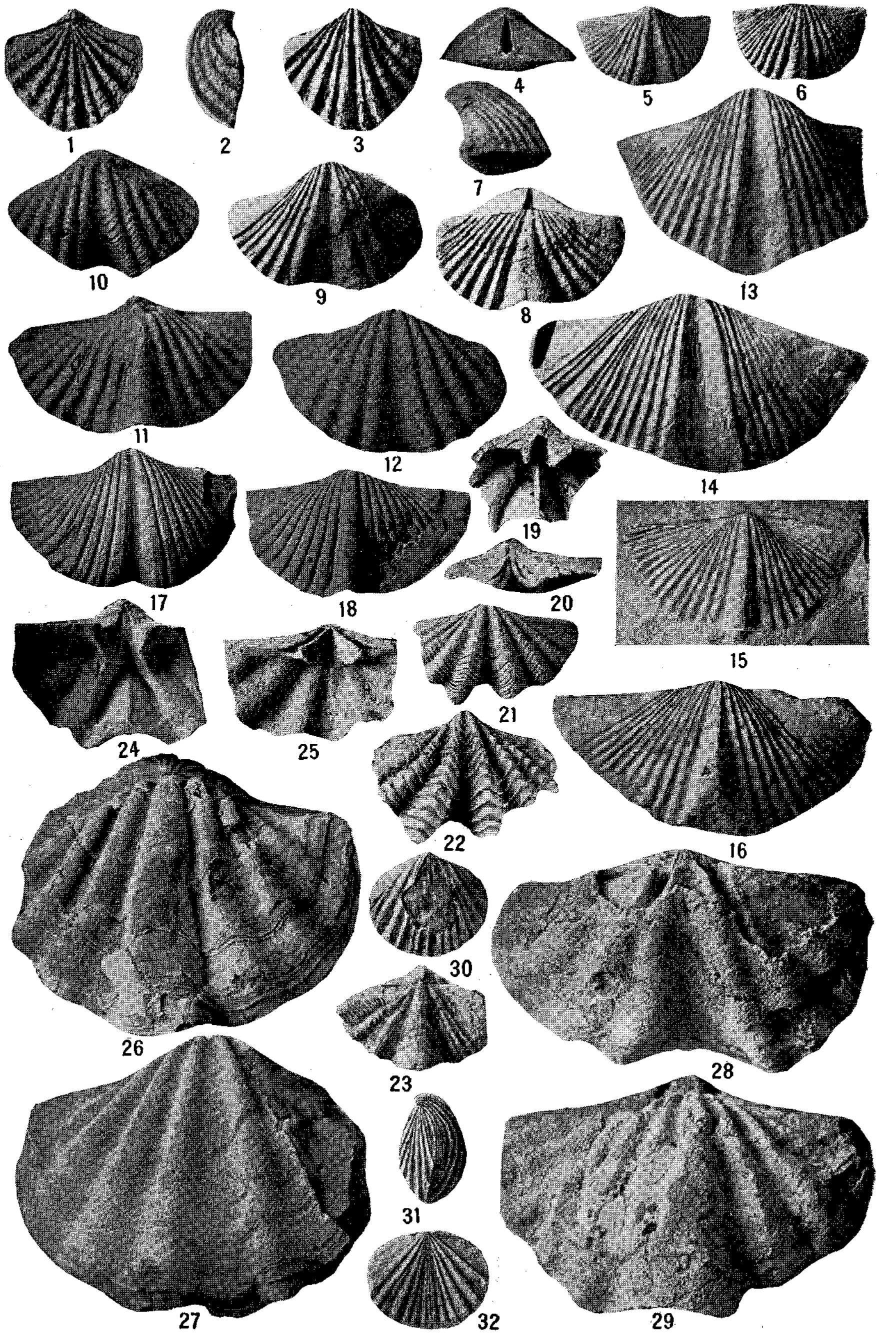
FIGURE

1, 2. *Leptostrophia becki* (Hall).

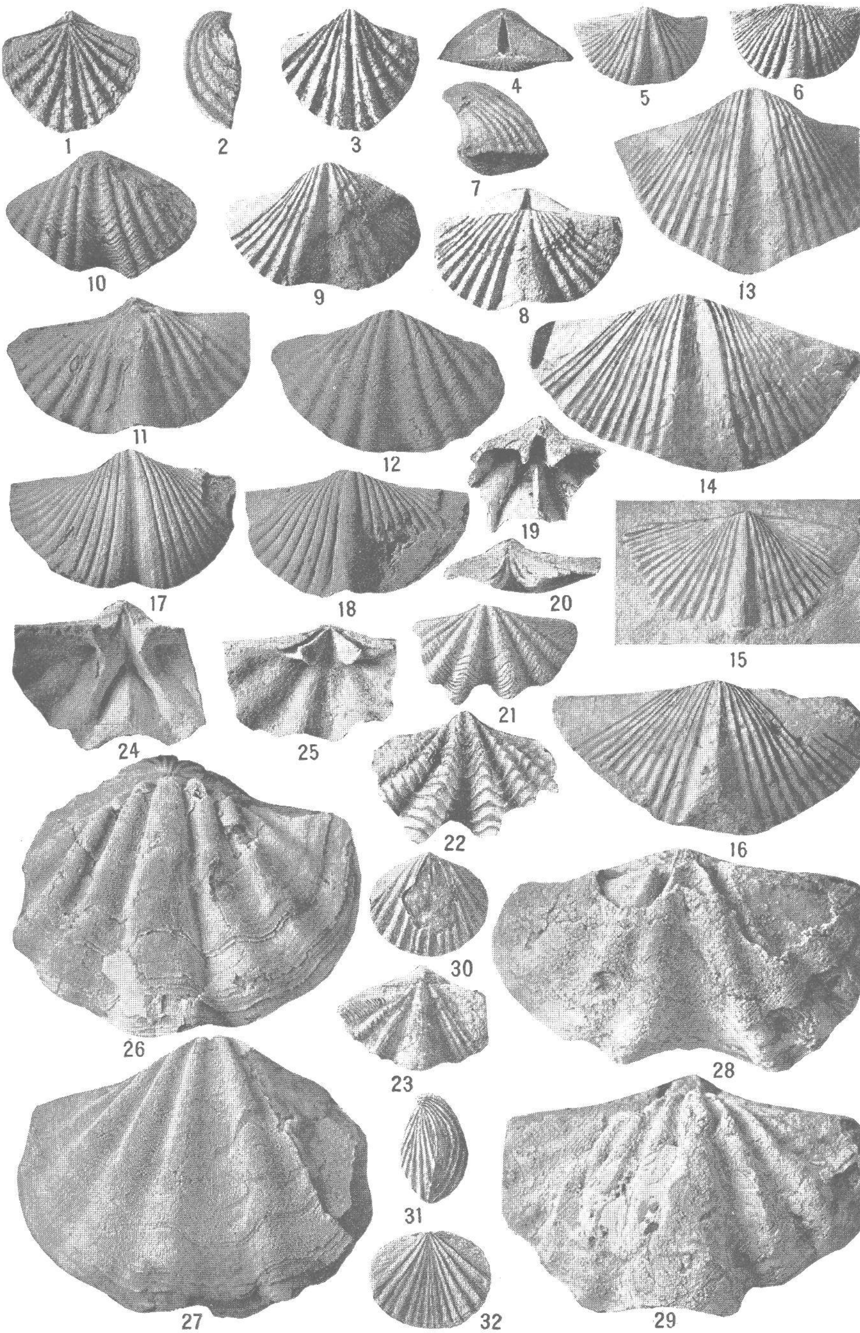
1, internal mold of ventral valve; 2, partially exfoliated ventral valve showing the characteristic concentric ridges below the beak. Helderberg, New Scotland member; along U. S. Route 250 on the southeast slope of Bullpasture Mountain, Highland County. U. S. N. M. 97721a, 97721b.

3–11. *Stropheodonta planulata* (Hall).

3, 4, 6, 8, 9, ventral valves; 5, internal mold of ventral valve shown in 10; 7, interior of dorsal valve; 10, 11, interiors of ventral valves. The identification of the specimen of 9, and its reference to the Becraft are doubtful. It is a broader form than the other specimens referred to *S. planulata* and the striae are coarse and fine alternating. Helderberg limestone, Becraft member. 3, 6, 7, 8, along State Route 311 about 1 mile south of Newcastle, Craig County; 4, 5, 10, 11, manganese ore pit on Flat Top Mountain about 1 mile northeast of Hollybrook, Giles County; 9, road along Narrow Passage Creek, 1½ miles southwest of gap at northeast end of Massanutten Mountain, Shenandoah County. 3, 4, 6, 8, 9, U. S. N. M. 97722a, 97723a, 97722b, 97722d, 97724; 5, 10, 97723b; 7, 11, 97722c, 97723c.



NEW SCOTLAND AND BECRAFT FOSSILS



NEW SCOTLAND AND BECRAFT FOSSILS

PLATE 111.—NEW SCOTLAND AND BECRAFT FOSSILS

FIGURE

1–3. *Atrypina imbricata* (Hall), × 2.

Dorsal, profile, and ventral views of a whole specimen. Helderberg limestone, New Scotland member; along U. S. Route 250 on the southeast slope of Bullpasture Mountain, Highland County. U. S. N. M. 97752.

4–9. *Cyrtina varia* Clarke.

4-6, posterior, ventral, and dorsal views of a whole specimen; 7-9, profile, dorsal, and ventral views of a whole specimen. Helderberg limestone, New Scotland member. 4-6, Pinckney, 8 miles southwest of Monterey, Highland County; 7-9, along U. S. Route 60 just east of Covington, Alleghany County. 4-6, U. S. N. M. 97753; 7-9, 97754.

10–12. *Spirifer cyclopterus* Hall.

10, 12, ventral valves; 11, dorsal valve. Different individuals. Helderberg limestone, New Scotland member. 10, 11, along State Route 42 about 2 miles northwest of Newcastle, Craig County; 12, same locality as 7. U. S. N. M. 97755a, 97755b, 97856.

13. *Spirifer concinnus* Hall.

Ventral valve. Helderberg limestone, Becraft member; along State Route 311 about 1 mile south of Newcastle, Craig County. U. S. N. M. 97857.

14–16. *Spirifer concinnus progradius* Swartz.

14, ventral valve; 15, 16, dorsal valves. Occurrence as 13. U. S. N. M. 97858a, 97858b, 97858c.

17, 18. *Spirifer* cf. *S. concinnus* Hall.

Ventral and dorsal views of the only specimen found. Occurrence as 7. U. S. N. M. 97859.

19–23. *Delthyris* (*Spirifer*) *perlamellosus* (Hall).

19, 22, × 2. 19, 20, interiors of ventral valves; 21, 22, ventral valves; 23, dorsal valve. This fossil and the next, *Spirifer macropleurus,* are the most distinctive fossils of the New Scotland. Occurrence as 1. U. S. N. M. 97860a, 97860b, 97860c, 97860d, 97860e.

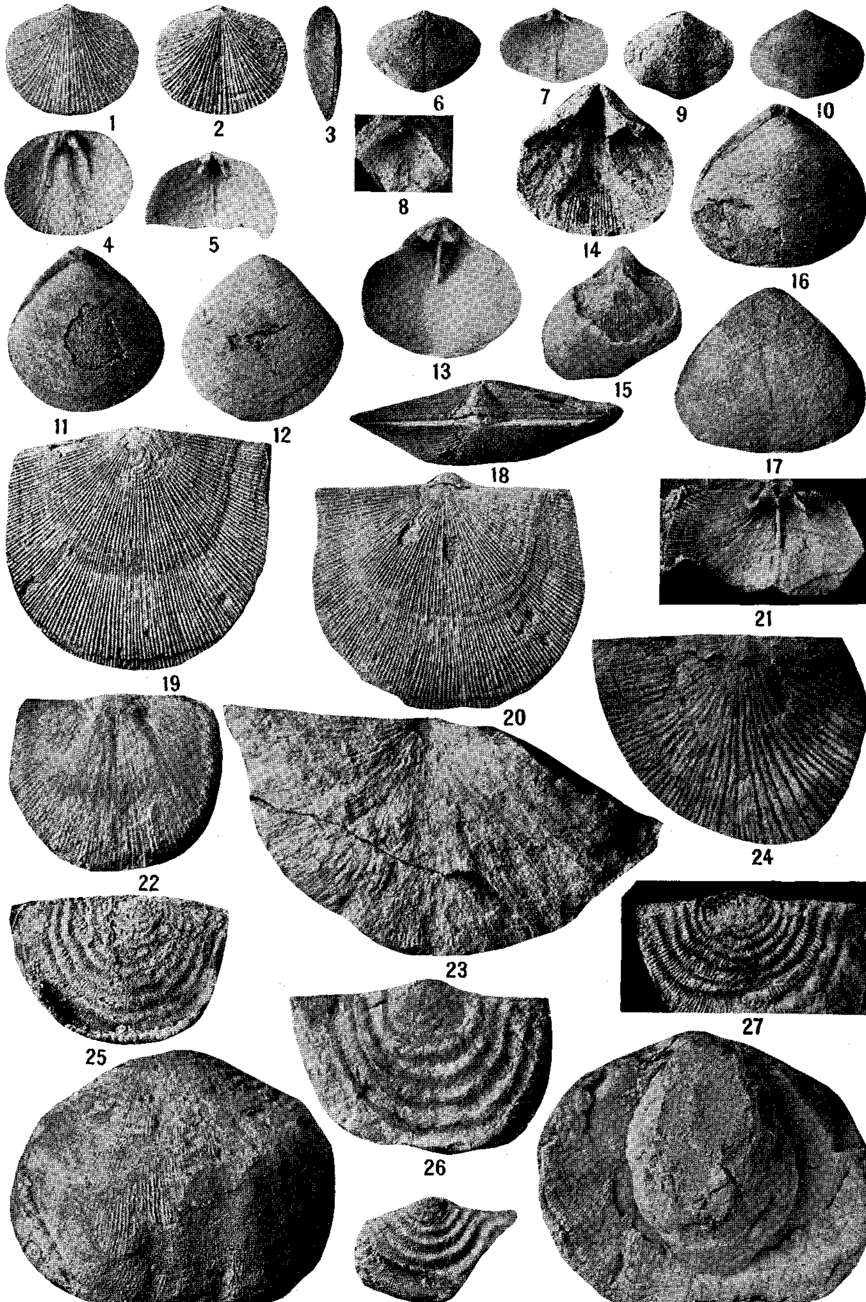
FIGURE

24–29. *Spirifer macropleurus* (Conrad).

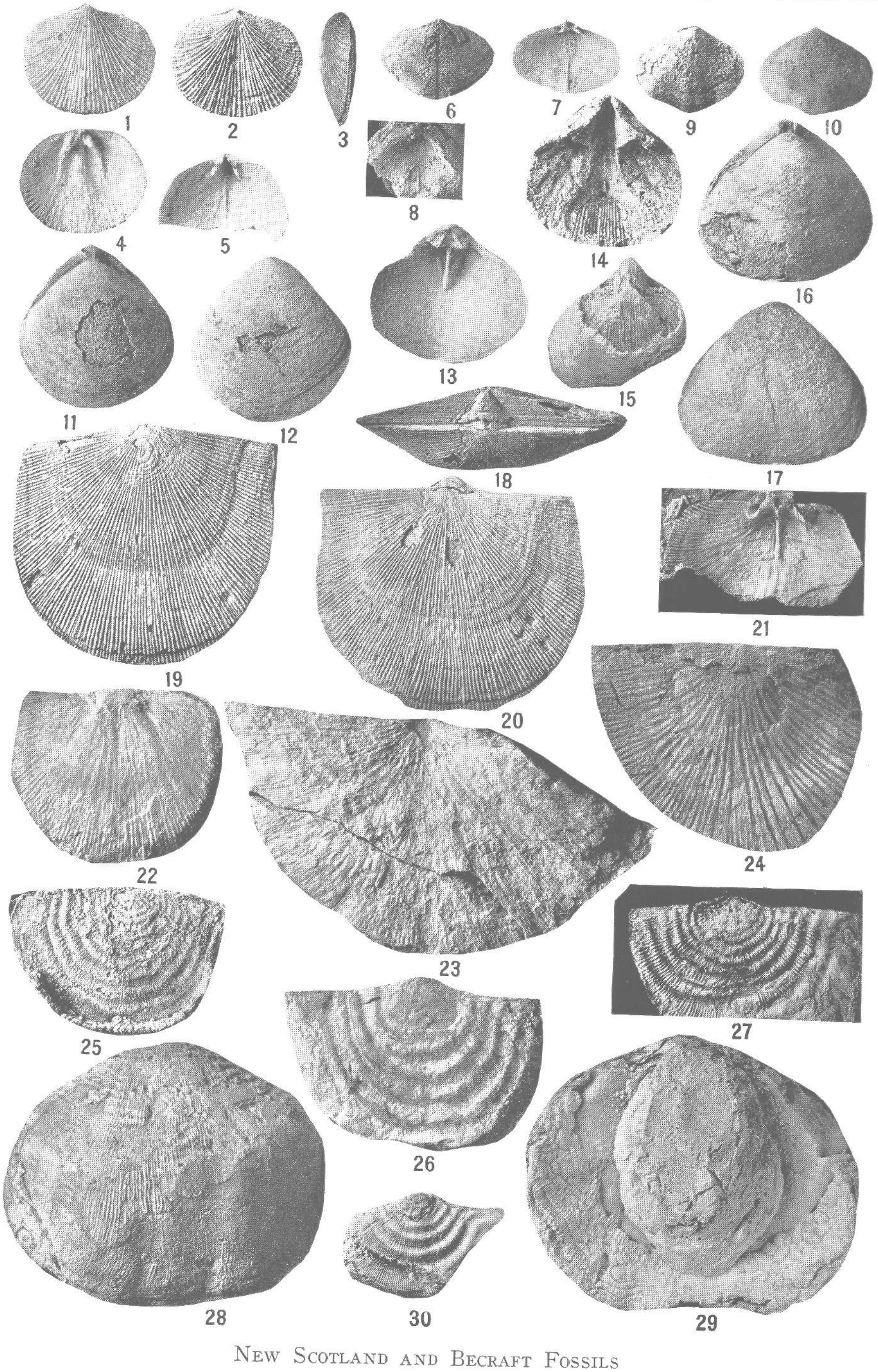
24, interior of a ventral valve; 25, interior of a dorsal valve; 27, 28, ventral valves; 26, 29, dorsal exteriors of two nearly complete individuals. Occurrence as 1. 24, 25, U. S. N. M. 97861a, 97861b; 26, 27, 97861c; 28, 29, 97861d.

30–32. *Anoplotheca concava* (Hall), × 2.

Ventral, profile, and dorsal views of an entire silicified specimen. Occurrence as 1. U. S. N. M. 97862.



New Scotland and Becraft Fossils



NEW SCOTLAND AND BECRAFT FOSSILS

PLATE 112.—NEW SCOTLAND AND BECRAFT FOSSILS

FIGURE

1–5. *Platyorthis planoconvexa* (Hall).

1-3, ventral, dorsal, and profile views of a specimen; 4, dorsal interior; 5, ventral interior. Helderberg limestone, New Scotland member; along U. S. Route 60 just east of Covington, Alleghany County. 1-3, U. S. N. M. 97863a; 4, 5, 97863b, 97863c.

6–10. *Nucleospira elegans* Hall?

6, internal mold of a ventral valve, showing the impression of the median septum; 7, interor of a dorsal valve; 8, interior of a broken ventral valve showing the low thin septum extending nearly to the front; 9, 10, dorsal and ventral views of a whole specimen. Helderberg limestone, New Scotland member; along railroad about half a mile northwest of Hot Springs, Bath County. 6-8, U. S. N. M. 97864a, 97864b, 97864c; 9, 10, 97864d.

11–15. *Meristella symmetrica* Schuchert.

11, 12, dorsal and ventral views of a specimen; 13, interior of a dorsal valve; 14, ventral interiors of different specimens; 14, shows the striated surface of the large rostral cavity characteristic of *Meristella;* 15, ventral valve exfoliated on the umbo and showing the mold of the large striated rostral cavity. Helderberg limestone, New Scotland member. 11-13, 15, same locality as 1; 14, along U. S. Route 250 on the southeast slope of Bullpasture Mountain, Highland County. 11, 12, U. S. N. M. 97865a; 13-15, 97865b, 97866, 97865c.

16, 17. *Meristella lata* (Hall).

Dorsal and ventral valves. 16, occurrence as 14; 17, Becraft limestone, along State Route 311 about 1 mile south of Newcastle, Craig County. U. S. N. M. 97867, 97868.

18–22. *Schellwienella woolworthana* (Hall).

18-20, posterior, ventral, and dorsal views of a complete individual; 21, interior; 22, mold of interior of dorsal valve. Helderberg limestone. 18-20, locality as 1; 21, locality as 17; 22, Becraft member, along State Route 42 about 1 mile northeast of Newcastle, Craig County. 18-20, U. S. N. M. 97869; 21, 22, 97870, 97871.

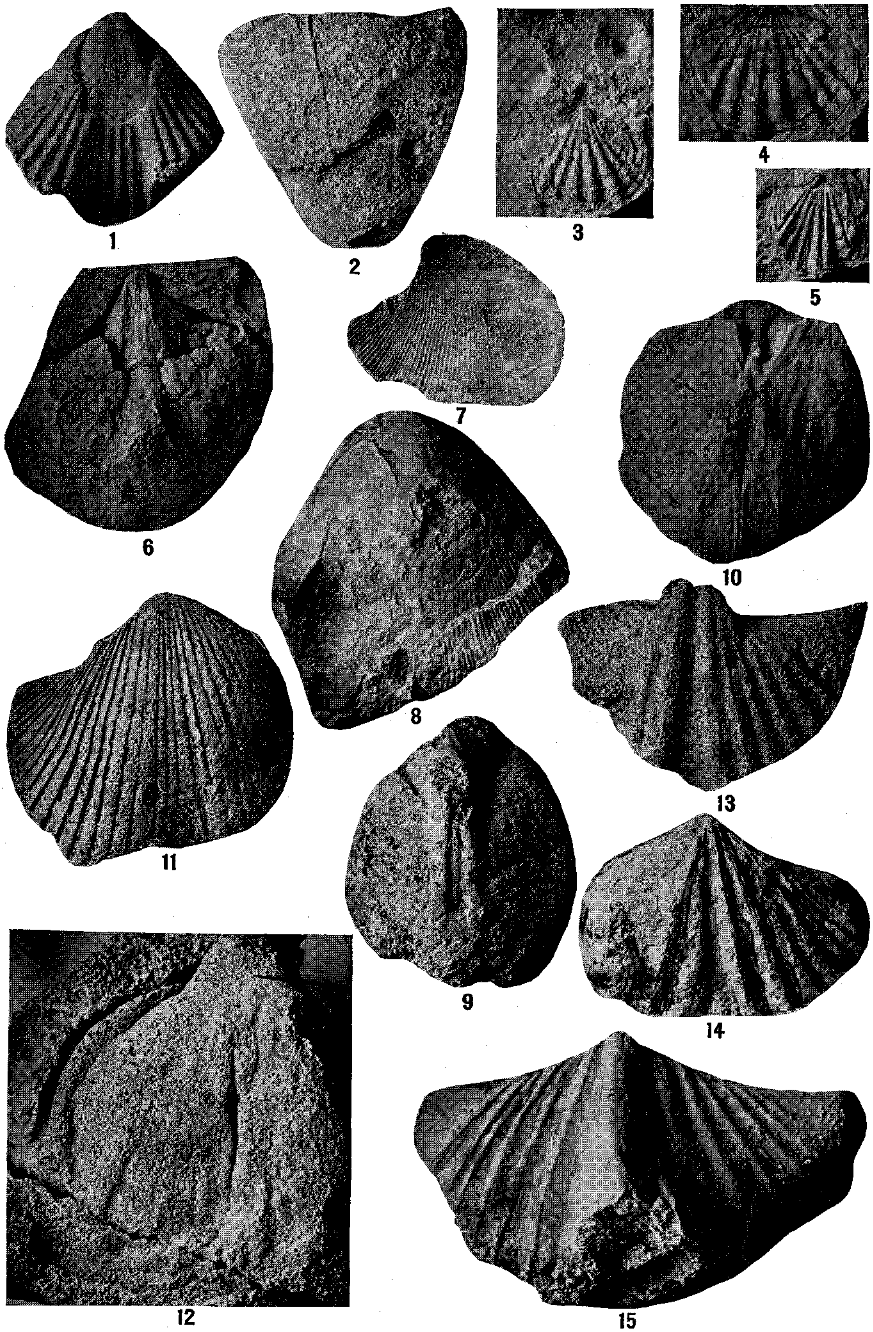
FIGURE

23, 24. *Strophonella punctulifera* (Conrad).

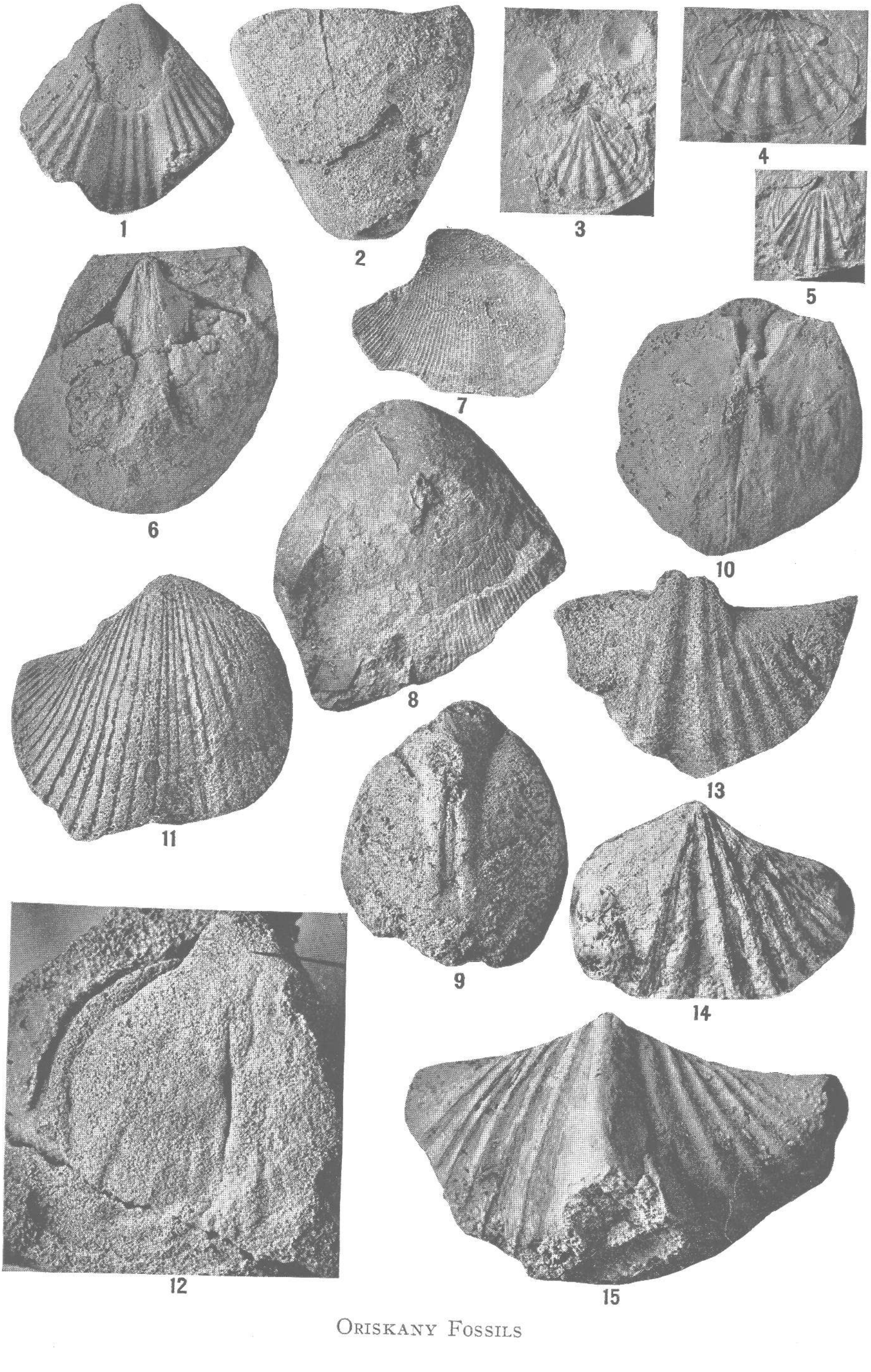
23, internal mold of a dorsal valve; 24, interior of a dorsal valve showing a small area of the external mold of the valve where the shell is exfoliated. Helderberg limestone, New Scotland member; along U. S. Route 220 at Pinckney, 8 miles southwest of Monterey, Highland County. U. S. N. M. 97872a, 97872b.

25–30. *Leptaena rhomboidalis* (Wilckens).

25-27, 30, ventral valves; 28, oblique view of a ventral valve of a large individual; 29, dorsal view of the same specimen. (The hump in 29 is encrusting chert.) 25, 27, 30, occurrence as 14; 26, occurrence as 23; 28-29, occurrence as 1. 25-27, U. S. N. M. 97873a, 97874, 97873b; 28, 29, 97875; 30, 97873c.



ORISKANY FOSSILS



Oriskany Fossils

PLATE 113.—ORISKANY FOSSILS

FIGURE

1. *Uncinulus* aff. *U. pyramidatus* (Hall).
   Internal mold of a ventral valve. Oriskany sandstone; along old road to Shannon Gap on Walker Mountain 5 miles northwest of Marion, Smyth County. U. S. N. M. 97876.

2. *Edriocrinus sacculus* Hall.
   Base. Oriskany sandstone; between Monterey and Straight Creek, Highland County (exact locality unknown). U. S. N. M. 97877.

3–5. *Anoplotheca flabellites* (Conrad)?
   4, × 2. Dorsal valves. Associated with *Orbiculoidea* and *Styliolina*. In 3 feet of shale near middle of 35 feet of Oriskany sandstone. Northwest slope of Morris Hill about 1½ miles south of Greenwood, Alleghany County. U. S. N. M. 97878a, 97878b, 97878c.

6. *Meristella lata* (Hall).
   Internal mold of ventral valve. Oriskany sandstone; along State Route 16 about 5 miles north of Marion, Smyth County. U. S. N. M. 97879.

7–9. *Rensselaeria marylandica* var. *symmetrica* Schuchert?
   7, external mold of part of a ventral (?) valve concave toward the observer; 8, ventral valve; 9, internal mold of a dorsal valve. Oriskany sandstone; along U. S. Route 60 at Island Ford about 4 miles east of Covington, Alleghany County. U. S. N. M. 97880a, 97880b, 97880c.

10. *Rensselaeria?* sp.
   Associated with *Spirifer arenosus*. Occurrence as 6. U. S. N. M. 97881.

11. *Spirifer arenosus* (Conrad).
   Impression of an external mold of a ventral valve. This is one of the most common and characteristic Oriskany fossils. Occurrence as 6. U. S. N. M. 97882.

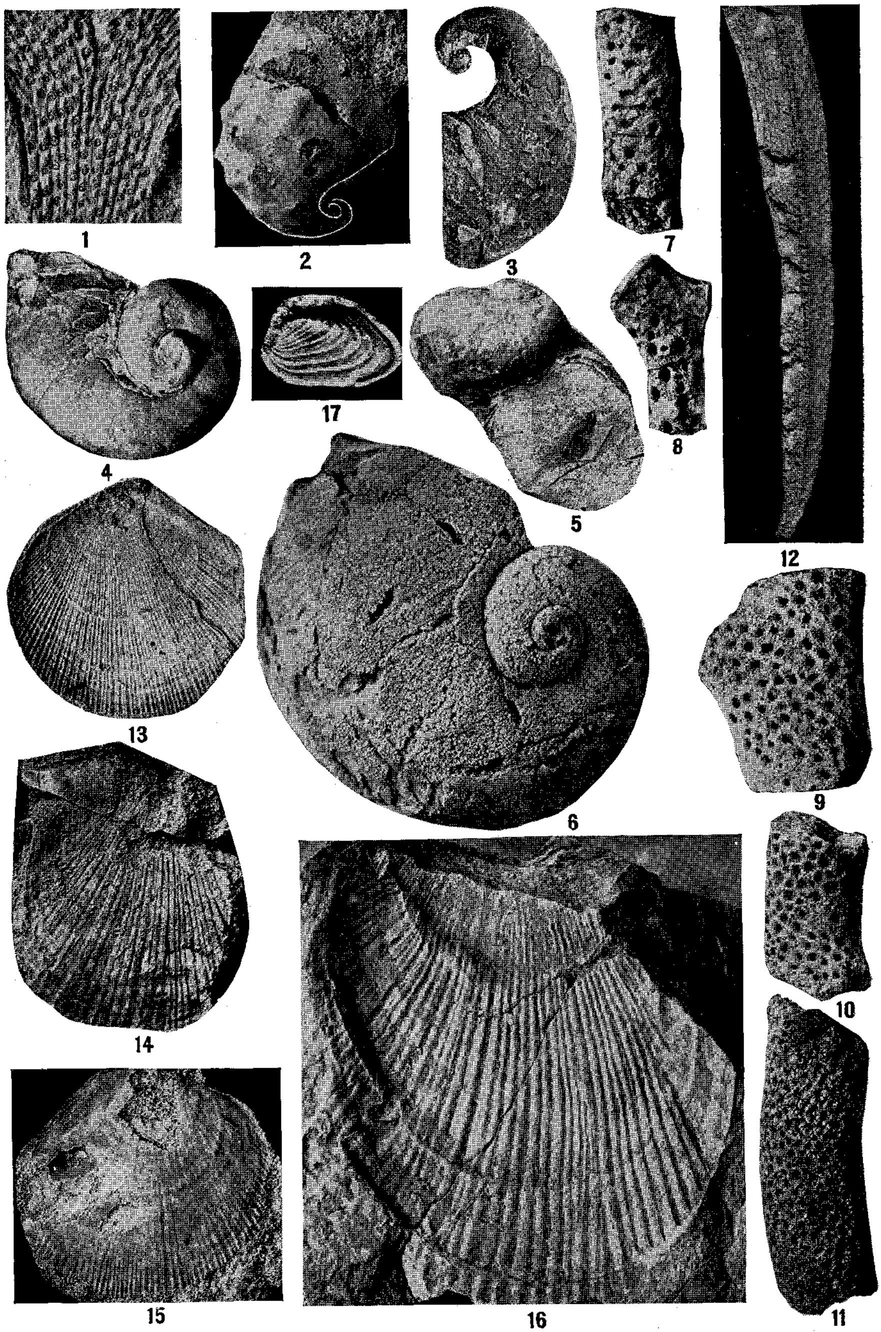
12. *Hipparionyx proximus* Vanuxem?
   Internal mold of a ventral valve. This may be *Rhipidomella musculosa*. Oriskany sandstone; along southeast slope

FIGURE

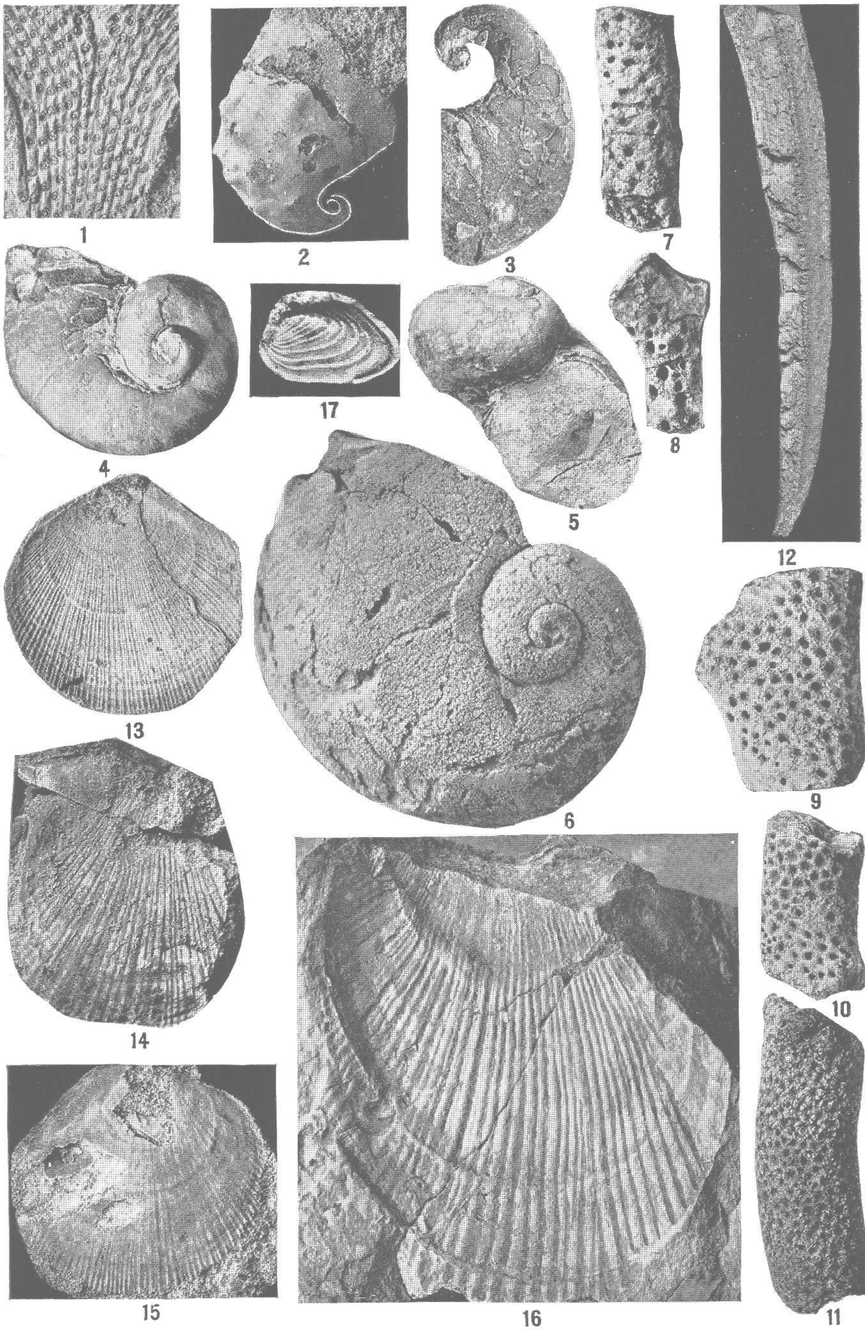
of Walker Mountain on Bear Creek road about 5 miles northeast of Marion, Smyth County. U. S. N. M. 97883.

13–15. *Spirifer murchisoni* Castelnau.

Oriskany sandstone. 13, along U. S. Route 21 at summit of Walker Mountain, Wythe County; 14, same locality as 6; 15, same locality as 1. U. S. N. M. 97884, 97885, 97886.



ONONDAGA FOSSILS



ONONDAGA FOSSILS

PLATE 114.—ONONDAGA FOSSILS

FIGURE

1. *Cystodictya ovatipora* (Hall), × 4.

   Onondaga limestone; southeast slope of Clinch Mountain about 500 feet north of State Route 42 and one-fourth of a mile east of U S. Route 19, Washington County. U. S. N. M. 97887.

2. *Platyceras dumosum* Conrad.

   Onondaga limestone; Seven Springs, Washington County. U. S. N. M. 97888.

3. *Platyceras dumosum rarispinum* Hall.

   Occurrence as 2. U. S. N. M. 97889.

4, 5. *Platystoma lineatum* Conrad.

   Apical and aperatural views. Onondaga limestone; just northwest of gap at northwest entrance of Burkes Garden, Tazewell County. U. S. N. M. 97890.

6. *Strophostylus?* cf. *S. varians* Hall.

   Onondaga limestone; along State Route 91 at McCall Gap through Walker Mountain, Washington County. U. S. N. M. 97891.

7, 8. *Dendropora neglecta* Rominger.

   Onondaga limestone; on southeast slope of Walker Mountain about 2 miles northeast of Lyons Gap, Smyth County. U. S. N. M. 97892a, 97892b.

9. *Favosites* cf. *F. proximus* Davis.

   Onondaga limestone; along southeast slope of Clinch Mountain, near base, on Locust Branch 2 miles north of Saltville, Smyth County. U. S. N. M. 97893.

10, 11. *Favosites* cf. *F. limitaris* Rominger.

   Occurrence as 9. U. S. N. M. 97894a, 97894b.

12. *Machaeracanthus peracutus* Newberry.

   Fin spine of a sharklike fish. Occurrence as 1. U. S. N. M. 97895.

13. *Aviculopecten pecteniformis* (Conrad).

   External mold of right valve. (For internal mold, see fig. 15.) Onondaga limestone; along southeast slope of Flat Top Mountain, near base, 2 miles southwest of Tannersville, Tazewell County. U. S. N. M. 97896.

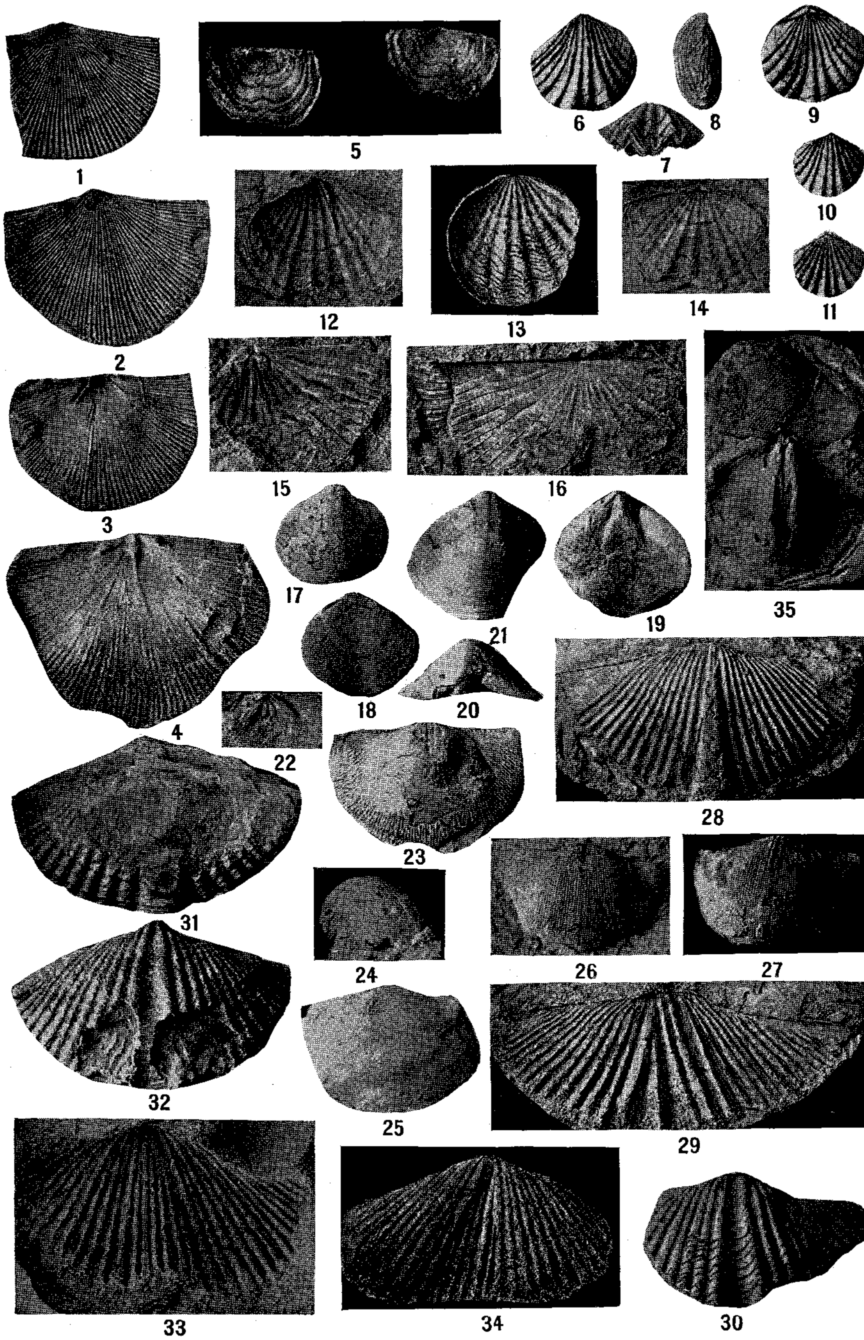
FIGURE

14. *Lyriopecten* cf. *L. parallelodontus* Hall.
External mold of a left valve. Occurrence as 13. U. S. N. M. 97897.

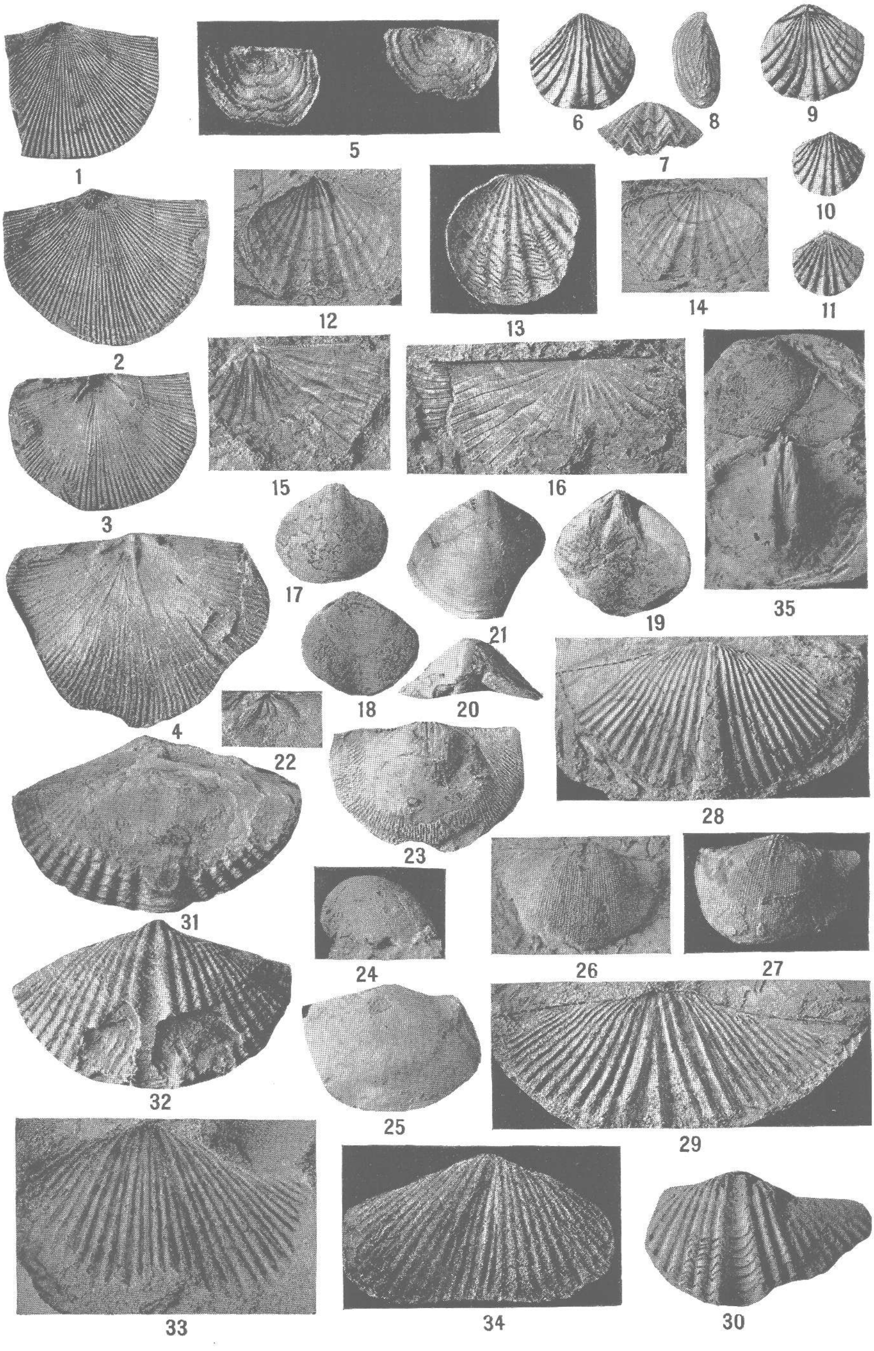
15. *Aviculopecten pecteniformis* (Conrad).
Internal mold of right valve of 13. Occurrence as 13. U. S. N. M. 97896.

16. *Panenka* cf. *P. multiradiata* Hall.
External mold of a left valve. Onondaga limestone; along road to Fetzer Gap about 2 miles east of Van Buren Furnace, Shenandoah County. U. S. N. M. 97898.

17. *Cypricardinia indenta* (Conrad), × 4.
Internal mold of a left valve. Occurrence as 1. U. S. N. M. 97899.



ONONDAGA FOSSILS



ONONDAGA FOSSILS

PLATE 115.—ONONDAGA FOSSILS

FIGURE

1–4. *Schuchertella pandora* (Billings).

1, 2, external molds of ventral valves; 3, 4, impressions of internal molds of ventral and dorsal valves. Onondaga limestone; at Seven Springs, Washington County. U. S. N. M. 97900a, 97900b, 97900c, 97900d.

5. *Ambocoelia?*, × 2.

External molds of dorsal valves. Onondaga limestone; at southeast entrance to Iron Gate Gorge about 1½ miles southeast of Clifton Forge, Alleghany County. U. S. N. M. 97901.

6–14. *Anoplotheca acutiplicata* (Conrad).

6-9, ventral, anterior, profile, and dorsal views of a whole specimen; 10, 11, ventral and dorsal views of a small specimen; 12, 14, external molds of ventral and dorsal valves of the common size; 13, external mold of a ventral valve, concave to the observer. Onondaga limestone. Universally distributed and one of the principal guide fossils of the Onondaga in Virginia. 6-11, southeast slope of Clinch Mountain on Locust Branch about 2 miles northeast of Saltville, Smyth County; 12, 14, same locality as 1; 13, along State Route 311 about 1 mile southeast of Newcastle, Craig County. 6-9, U. S. N. M. 97902a; 10, 11, 97902b; 12, 97903a; 13, 97904; 14, 97903b.

15, 16. *Stropheodonta* cf. *S. patersoni* (Hall).

Internal and external molds of a dorsal valve. 4 to 8 fine striae between the coarse ones. Onondaga limestone; along southeast slope of Clinch Mountain about 500 feet north of State Route 42 and one-fourth of a mile east of U. S. Route 19, Washington County. U. S. N. M. 97905.

17–21. *Pentagonia unisulcata* (Conrad).

17, 18, dorsal and ventral valves, internal molds of a specimen; 19-21, ventral, posterior, and dorsal views of an internal mold. Onondaga limestone. 17, 18, about 2 miles west of Tannersville, Tazewell County; 19-21, Locust Branch about 2 miles northeast of Saltville, Smyth County. 17, 18, U. S. N. M. 97906; 19-21, 97907.

FIGURE

22–27. *Eodevonaria* (*Chonetes*) *arcuata* (Hall).

22, internal mold of a dorsal valve; 23, internal mold of a ventral valve; 24, 27, profile and ventral views of a specimen; 25, 26, ventral views of two specimens. Onondaga limestone. 22, 24, 27, same locality as 17; 23, same locality as 15; 25, same locality as 6; 26, southeast slope of Clinch Mountain along road on Rich Creek, 6 miles due west of Saltville, Smyth County. This is another guide fossil of the Onondaga. 22, 23, U. S. N. M. 97909a, 97916; 24, 27, 97909b; 25, 26, 97910, 97911.

28–30. *Spirifer macrus* Hall.

28, dorsal valve; 29, external mold of dorsal valve; 30, ventral valve retaining the characteristic growth lines. These lines are faintly preserved on 28, 29. Onondaga limestone. 28, 30, along State Route 80 about 2 miles northeast of Hayter Gap village, Washington County; 29, southeast slope of Walker Mountain, 2 miles northeast of Lyons Gap, Smyth County. U. S. N. M. 97912a, 97913, 97912b.

31, 32. *Spirifer macrus* Hall?

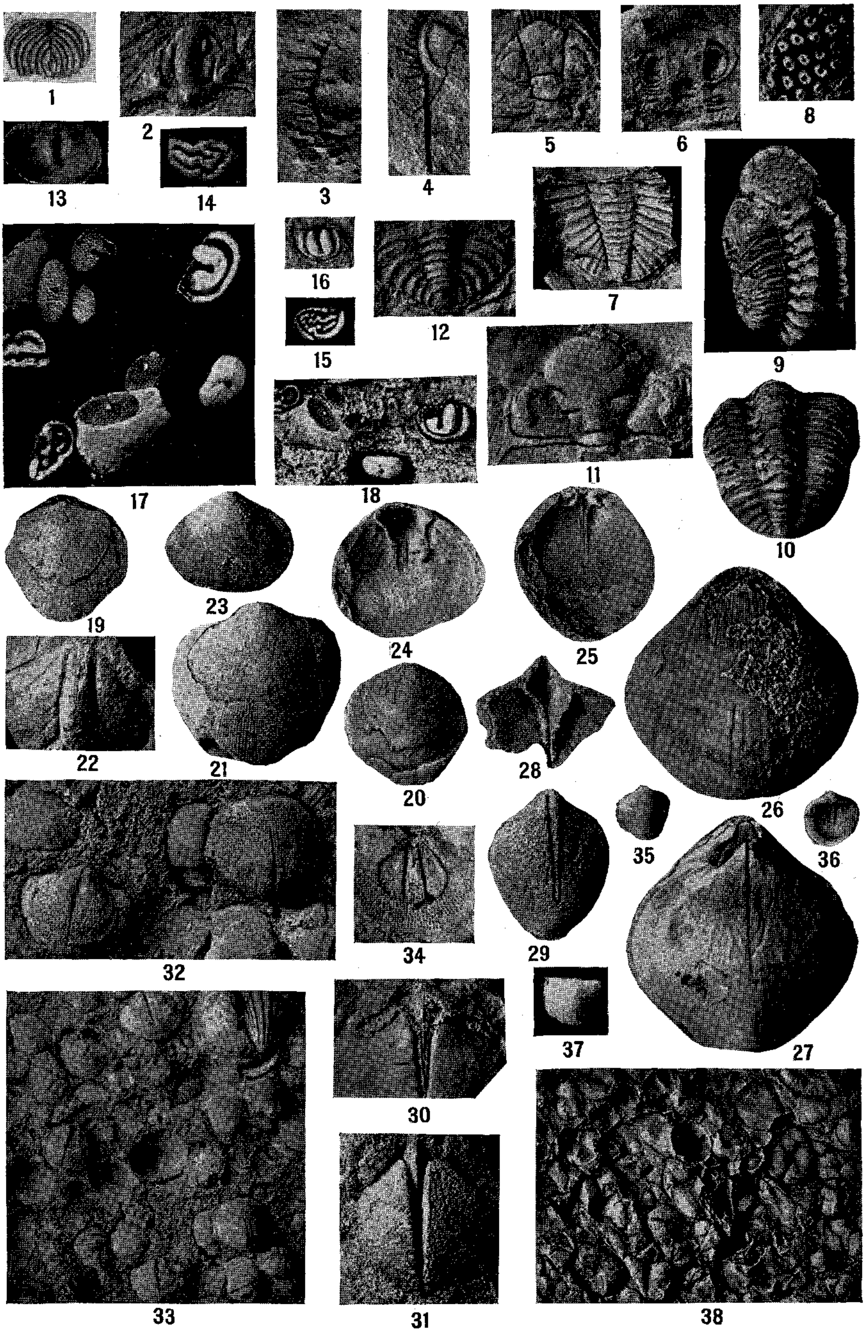
Probably a variant of *S. macrus* like the specimen figured by Hall (Paleon. N. Y., vol. 4, pl. 27, figs. 26 and 27). Onondaga limestone; vicinity of Hayter Gap village, Washington County. U. S. N. M. 97914.

33, 34. *Spirifer divaricatus* Hall.

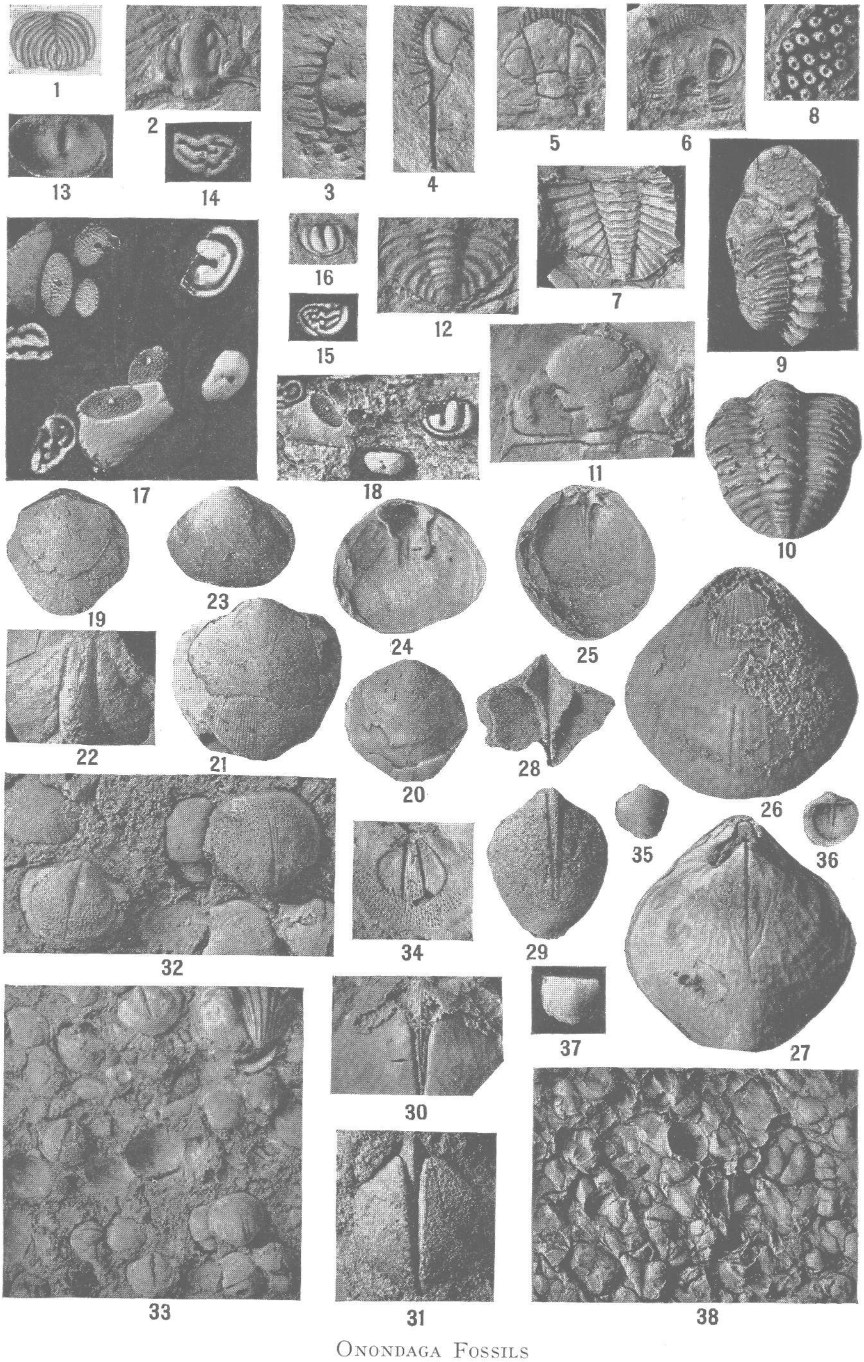
33, external mold of a ventral valve; 34, clay impression from the same. Occurrence as 1. Strongly marked by zigzag transverse growth lines that do not show distinctly in the figures. U. S. N. M. 97915.

35. *Pentagonia unisulcata* (Conrad).

Internal mold of dorsal valve. Onondaga limestone; half a mile northeast of the intersection of U. S. Route 19 and State Route 42, Washington County. U. S. N. M. 97908.



Onondaga Fossils



Onondaga Fossils

PLATE 116.—ONONDAGA FOSSILS

FIGURE

1–4. *Acidaspis callicera* Hall and Clarke.

1, drawing of a tail from a photograph, × 8; 2, internal mold of a head with the notched anterior border plainly visible under a magnifier; 3, 4, fragments of free cheeks. Onondaga limestone; along road to Fetzer Gap 2 miles east of Van Buren Furnance, Shenandoah County. U. S. N. M. 97917a, 97917b, 97917c, 97917d.

5–7. *Odontocephalus aegeria* Hall.

5, 6, internal and external molds of a head; 7, tail. Onondaga limestone. 5, 6, along U. S. Route 220 about 1½ miles southeast of Clifton Forge, Alleghany County; 7, along State Route 311 about 1 mile south of Newcastle, Craig County. 5, 6, U. S. N. M. 97918; 7, 97919.

8–10. *Phacops cristata* Hall?

8, part of eye, × 4; 9, thorax and head; 10, thorax and tail. Onondaga limestone; along southeast slope of Clinch Mountain at Locust Branch about 2 miles northeast of Saltville, Smyth County. U. S. N. M. 97920a, 97920b, 97920c.

11, 12. *Dalmanites aspectans* Conrad?

Head and tail. Occurrence as 1. U. S. N. M. 97921a, 97921b.

13. *Kloedenia?*, × 3.

On slab with *Acidaspis callicera*. Occurrence as 1. U. S. N. M. 97922.

14, 15. *Octonaria stigmata* Ulrich?

Right valve. 14, impression of 15, × 6⅔; 15, external mold, × 4. Onondaga limestone; Seven Springs, Washington County. U. S. N. M. 97923.

16. *Bollia ungula* Jones, × 4.

The same species also on 17, 18. Occurrence as 14. U. S. N. M. 97924.

17, 18. *Favulella* (*Amphissites?*, *Bythocypris*) *favulosa* (Jones).

The punctate specimens. 17, right specimen, × 6¾; 18, lower specimen, internal molds of the same left valve, × 4; 17, lower center, and 18, left, external molds show-

FIGURE

ing a central pustule that is the mold of the central pit shown in the impression; 17, upper left, wax impression of group in 17, lower center, showing the external appearance of *Favulella* which has a distinct pit in the center; 17, upper right, *Bollia ungula;* left corner, *Octonaria stigmata.* Occurrence as 14. These three ostracodes together with *Anoplotheca acutiplicata* occur on the same slab. The assemblage is persistent from Pennsylvania to southern Virginia and any one of the species is an index of the Onondaga. U. S. N. M. 97925.

This fossil was described as *Bythocypris favulosa* by Jones in 1886. *Amphissites*? was suggested orally to the author while Part I of this volume was being prepared, and that name was used. After Part I had gone to press, the genus was named *Favulella* by F. M. Swartz and F. M. Swain, Bull. Geol. Soc. of America, vol. 52, pp. 438-439, 1941.

19–22. *Beachia suessana* (Hall)?

19, 20, dorsal and ventral views of a specimen; 21, ventral valve of another specimen; 22, internal mold of the umbonal cavity of a ventral valve. Occurrence as 8. 19, 20, U. S. N. M. 97926a; 21, 22, 97926b, 97926c.

23–25. *Charionella scitula* Hall.

23, clay impression of the external mold of a ventral valve; 24, same of the internal mold of a ventral valve; 25, same of the dorsal valve. Onondaga limestone; in gap in Little North Mountain about 3½ miles northwest of Forestville, Shenandoah County. U. S. N. M. 97927a, 97927b, 97927c.

26, 27. *Meristella nasuta* (Conrad).

Ventral and dorsal views of a nearly complete specimen. Onondaga limestone. Specimen was given by a man who lives on the outcrop of the Onondaga half a mile east of U. S. Route 19 and just north of State Route 42, Washington County. U. S. N. M. 97928.

28–31. *Amphigenia curta* (Meek and Worthen).

28, interior of a ventral valve; 29-31, internal molds of ventral valves. Onondaga limestone. 28, 30, 500 feet north of State Route 42 and one-fourth of a mile east of U. S. Route 19, Washington County; 29, 31, Big Stone Gap,

FIGURE

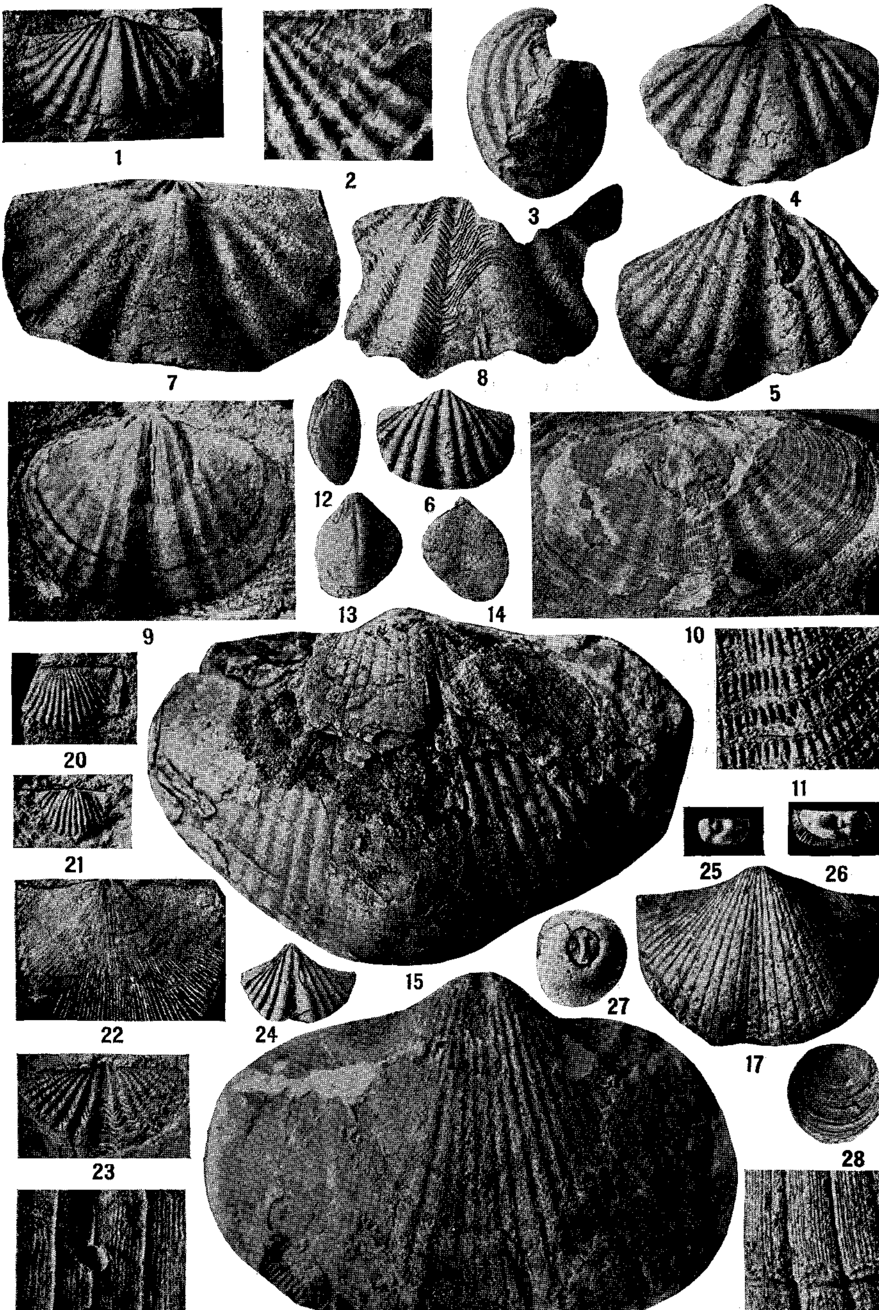
Wise County. U. S. N. M. 97930a, 97929a, 97930b, 97929b.

32–37. *Anoplia nucleata* (Hall).

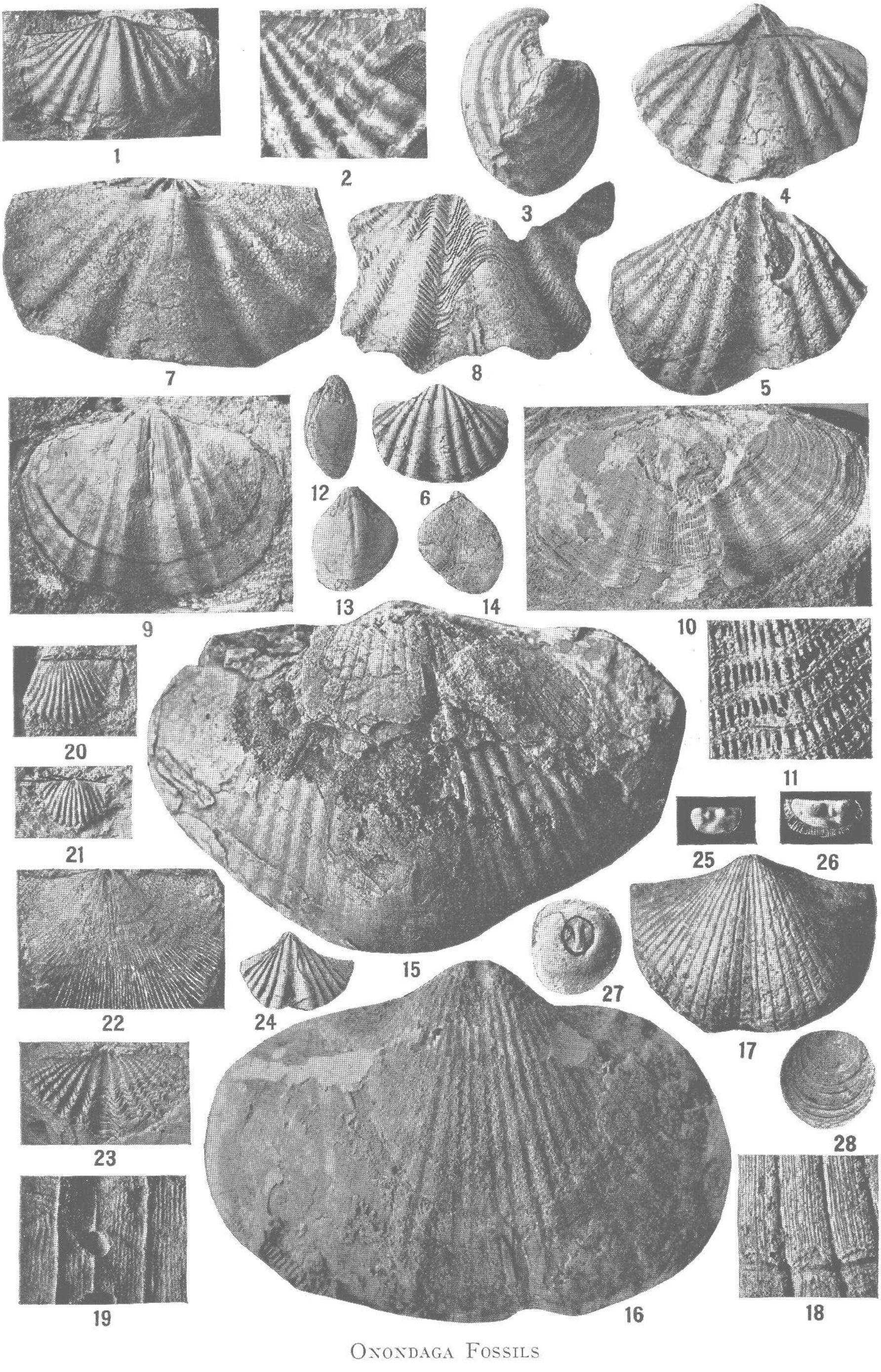
33, part of a slab with many individuals, mainly internal molds of ventral valves; 32, part of 33, × 2; 34, internal mold of a dorsal valve on the rock of which 33 is a part, × 2; 35, ventral valve; 36, interior of 35; 37, external mold of a concave dorsal valve. Onondaga limetsone. 32-34, along southeast slope of Clinch Mountain on road along Rich Creek 6 miles due west of Saltville, Smyth County; 35-37, same locality as 8. *Anoplia nucleata* is common in the Onondaga in southwestern Virginia, and is not known in any other formation in the State. 32-34, U. S. N. M. 97932; 35, 36, 97931a; 37, 97931b.

38. *Ambocoelia* sp., × 2.

Small piece of shale crowded with these minute shells. So far as observed, this species occurs only in crowded aggregates as shown in this figure. Onondaga limestone; along U. S. Route 21 half a mile south of Hicksville, Bland County. Common in southwestern Virginia. Very plentiful in top of the Onondaga at Hayfield, Frederick County. U. S. N. M. 97933.



Onondaga Fossils



ONONDAGA FOSSILS

PLATE 117.—ONONDAGA FOSSILS

FIGURE

1–6. *Spirifer duodenarius* (Hall).

1, internal mold of a dorsal valve; 2, part of external mold of a dorsal valve, × 4, showing ornamentation of fine cancellated lines, not reproduced in figure; 3, 4, profile and dorsal views of the same specimen; 5, 6, ventral valves of other specimens. Onondaga limestone. 1, 3, 4, 6, Locust Branch about 2 miles north of Saltville, Smyth County; 2, 5, Webb farm just north of State Route 42 ahd half a mile east of U. S. Route 19, Washington County. 1, 2, U. S. N. M. 97937a, 97938a; 3, 4, 97937b; 5, 6, 97938b, 97937c.

7, 8. *Delthyris raricosta* Conrad.

7, internal mold of a dorsal valve; 8, impression of the external mold of 7. Sandstone in Onondaga; Big Stone Gap, Wise County. U. S. N. M. 97939.

9–11. *Elytha fimbriata* (Conrad).

9, internal mold of a ventral valve; 10, exterior of a dorsal valve preserving the shell; 11, part of the external mold of 10, × 3, showing the pits made by the projecting, elongate nodes ornamenting the exterior of the shell. Onondaga limestone; at Seven Springs, Washington County. 9, U. S. N. M. 97940a; 10, 11, 97940b.

12–14. *Centronella glansfagea* Hall.

Profile, ventral, and dorsal views of an internal mold of a whole specimen. Occurrence as 9. U. S. N. M. 97941.

15–19. *Spirifer planicostatus* (F. M. Swartz).

Swartz[a] described this species as *S. arenosus* var. *planicostatus,* but as *S. arenosus* lacks the linear striae and differs in other respects, this is plainly a different species.

15, partly exfoliated silicified dorsal valve; 16, impression of an external mold of a ventral valve; 17, slightly exfoliated silicified ventral valve of a smaller specimen; 18, part of the exterior of a valve preserving the fine lineation, × 4; 19, part of the external mold of a valve showing the fine lineation, × 4. Onondaga limestone. 15, 17, 18,

[a] Swartz, F. M., U. S. Geol. Survey Prof. Paper 158C, p. 56, Pl. 9, figs. 13-15, 1929.

FIGURE

same locality as 1. 16, 19, along southeast slope of Clinch Mountain about 1 mile northwest of Hayter Gap village, Washington County. U. S. N. M. 97942a, 97943a, 97942b, 97942c, 97943b.

20, 21. *Chonetes mucronatus* Hall, × 2.

Internal molds of two ventral valves, the smaller showing at the left cardinal angle the long spine parallel to the hinge line, characteristic of the species. Onondaga limestone; one-fourth of a mile north of State Route 42 and half a mile east of U. S. Route 19, Washington County. U. S. N. M. 97944a, 97944b.

22. *Stropheodonta perplana* (Conrad).

Internal mold of a dorsal valve. Onondaga limestone; 2 miles southwest of Tannersville, Tazewell County. U. S. N. M. 97945.

23. *Spirifer varicosus* Hall.

External mold of a dorsal valve showing the imprints of the strongly imbricating growth lines. Onondaga limestone; in gap of Little North Mountain 3½ miles northwest of Forestville, Shenandoah County. U. S. N. M. 97946.

24. *Cyrtina hamiltonensis* Hall.

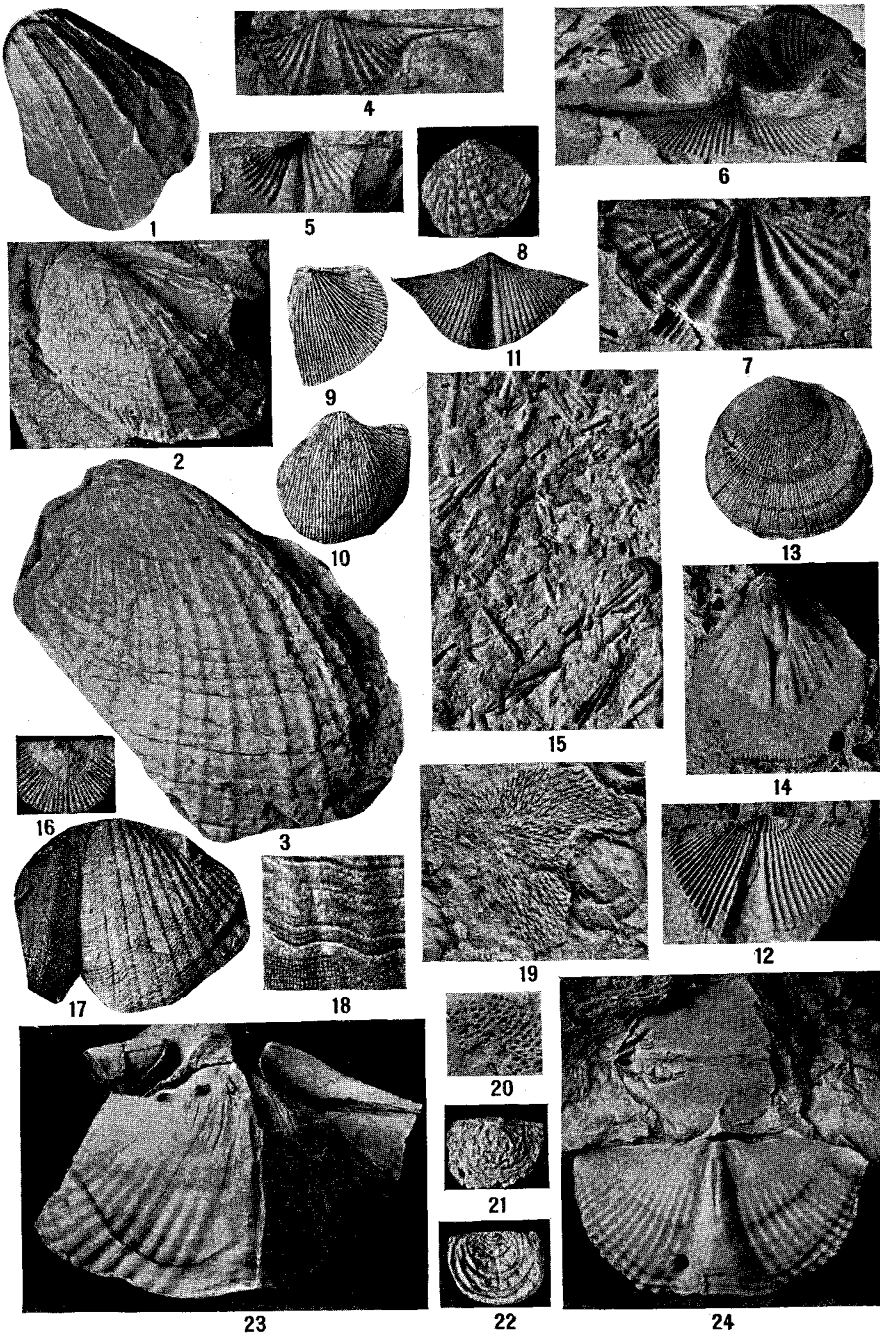
A silicified ventral valve. Occurrence as 1. U. S. N. M. 97947.

25, 26. *Hollina armata* (Ulrich), × 4.

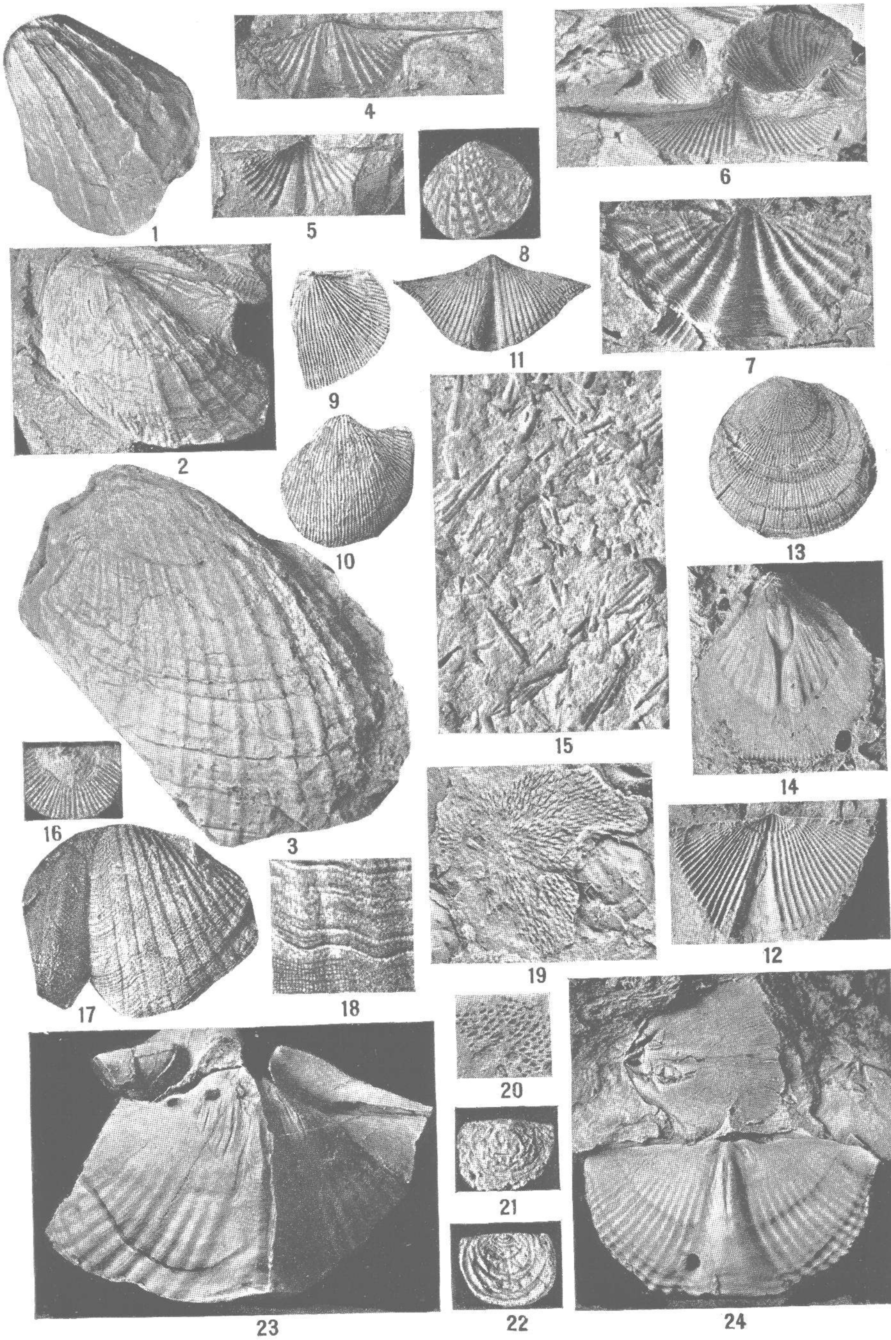
Right and left valves. Onondaga limestone; half a mile northeast of intersection of U. S. Route 19 and State Route 42, Washington County. U. S. N. M. 97948a, 97948b.

27, 28. *Pholidops areolata* Hall, × 1⅓.

Internal and external molds of a ventral valve. Occurrence as 25. U. S. N. M. 97949a, 97949b.



MARCELLUS AND HAMILTON FOSSILS



MARCELLUS AND HAMILTON FOSSILS

PLATE 118.—MARCELLUS AND HAMILTON FOSSILS

FIGURE

1–3. *Pterinea flabellum* (Conrad).

Fragments of 3 left valves. Hamilton member of the Romney shale; Green Springs, Frederick County. U. S. N. M. 97950a, 97950b, 97950c.

4–7. *Spirifer mucronatus* (Conrad).

4, internal mold of a ventral valve; 5, 6, external molds of ventral valves; 6, shows the normal expression of the species; 7, external mold of a dorsal valve; the mucronate extension of the hinge line on the left has been broken off. The transverse growth lines shown on this specimen are present on all the other specimens but are too faint to show in the photographs. Hamilton shale. 4, 5, Cedar Grove, Frederick County; 6, Dietrich in the Passage Creek Valley of Massanutten Mountain, Shenandoah County; 7, same locality as 1. U. S. N. M. 97951a, 97951b, 97952, 97953.

8. *Buchiola halli* Clarke.

Right valve. Marcellus shale; along State Route 42 half a mile northeast of Hayter Gap village, Washington County. U. S. N. M. 97955.

9, 10. *Chonetes coronatus* (Conrad).

9, internal mold of a ventral valve, left half broken away; 10, impression from the external mold of the same specimen. Hamilton shale; at the intersection of roads about 2 miles northeast of Liberty Furnace, Shenandoah County. U. S. N. M. 97956.

11, 12. *Spirifer audaculus* (Conrad).

11, impression of an external mold of a ventral valve; 12, external mold of a dorsal valve. Occurrence as 9. U. S. N. M. 97958a, 97958b.

13, 14. *Rhipidomella vanuxemi* (Hall).

13, impression of an external mold of a ventral valve; 14, internal mold of a ventral valve. Occurrence as 9. U. S. N. M. 97959a, 97959b.

15. *Styliolina fissurella* (Hall), × 4.

Small piece of shale thickly covered with this fossil. Several specimens show the median fissure in the surface

FIGURE

of the shell. A guide for Middle and lower Upper Devonian formations (Onondaga to upper Millboro) in which it is abundant and universally distributed. Marcellus shale?; along road on west side of New River about 1 mile northeast of Narrows, Giles County. U. S. N. M. 97960.

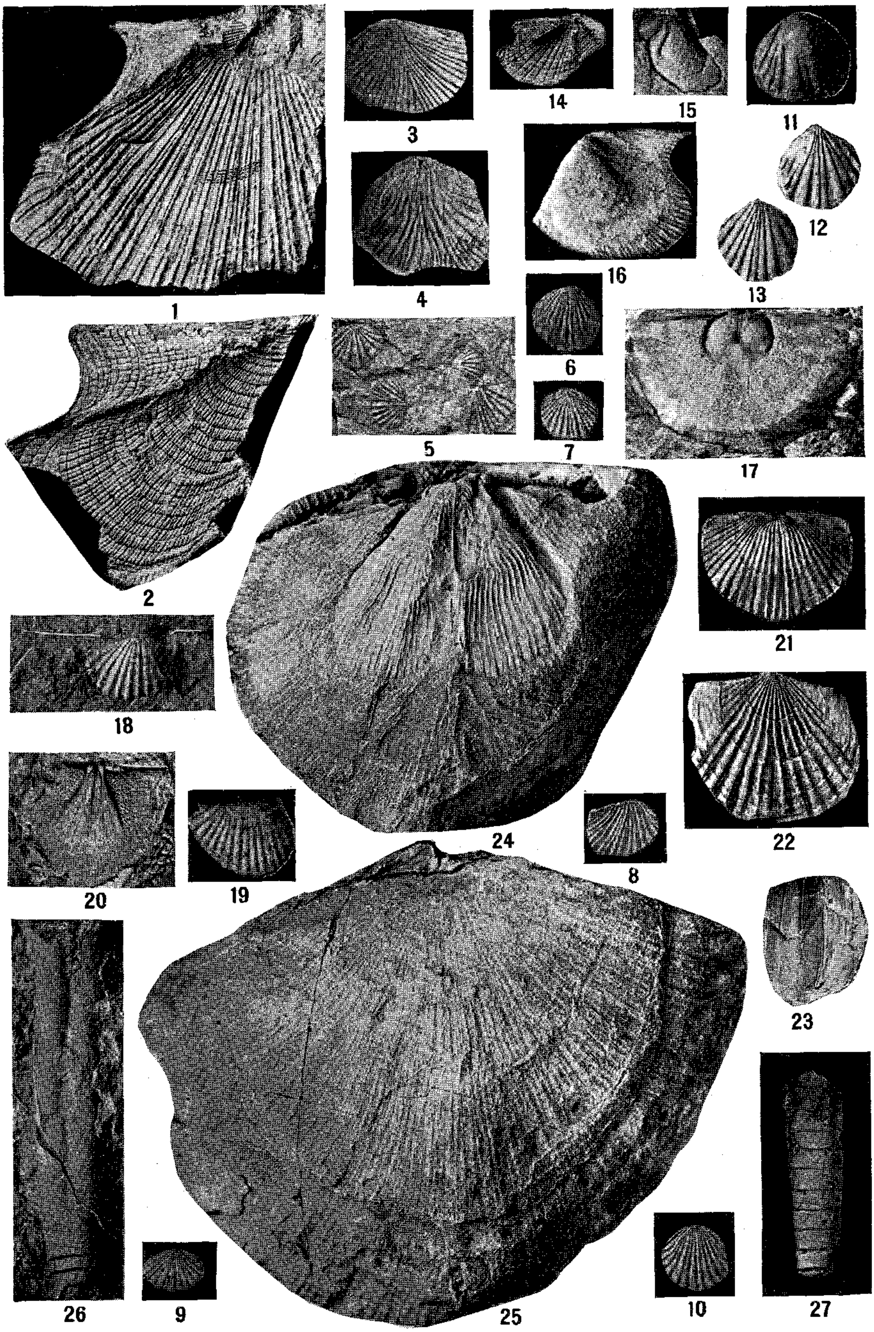
16. *Chonetes lepidus* Hall, × 4.
Occurrence as 8. U. S. N. M. 97957.

17, 18. *Spirifer granulosus* (Conrad).
17, impression of an external mold of a ventral valve; 18, part of 17, × 4, to show granulated surface. Occurrence as 9. U. S. N. M. 97961a. (See also figs. 23, 24.)

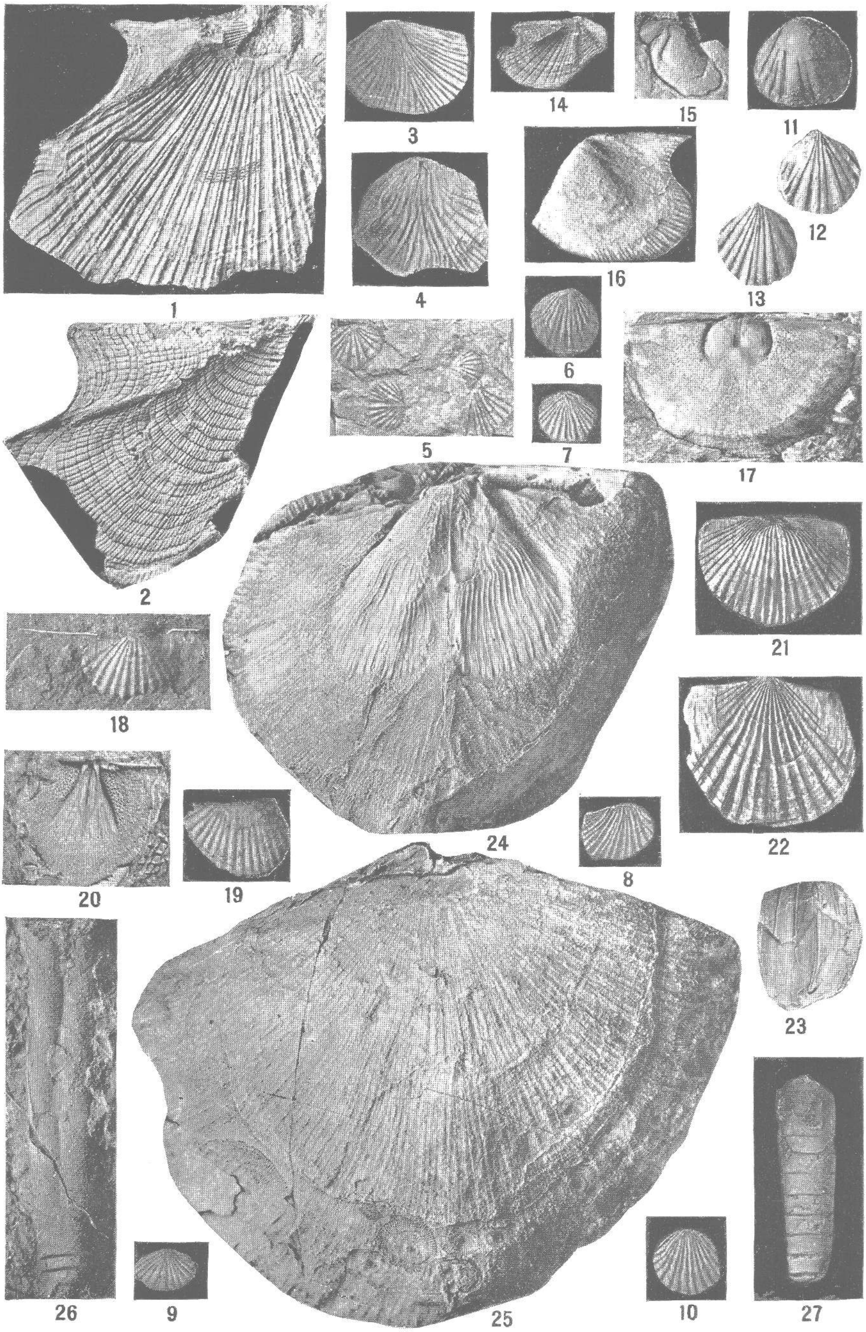
19, 20. *Paleschara* sp., × 4.
A lamellar bryozoon. Marcellus shale. Rare but widely distributed fossil of the Marcellus. 19, same locality as 8; 20, along road half a mile southeast of Waiteville, Monroe County, W. Va., just above Onondaga chert. U. S. N. M. 97962, 97963.

21, 22. *Strophalosia truncata* (Hall), × 2.
21, internal mold of a ventral valve; 22, exterior of the concave dorsal valve preserving the shell substance. Occurrence as 8. U. S. N. M. 97964a, 97964b.

23, 24. *Spirifer granulosus* (Conrad).
Internal molds of two dorsal valves. Occurrence as 9. U. S. N. M. 97961b, 97961c. (See also figs. 17, 18.)



MARCELLUS AND HAMILTON FOSSILS



MARCELLUS AND HAMILTON FOSSILS

PLATE 119.—MARCELLUS AND HAMILTON FOSSILS

FIGURE

1. *Lyriopecten interradiatus* Hall.

   External mold of a left valve. Hamilton shale; Green Springs, Frederick County. U. S. N. M. 97965.

2. *Actinopteria decussata* Hall.

   External mold of a left valve. Hamilton shale; along road 2 miles northeast of Liberty Furnace, Shenandoah County. U. S. N. M. 97966.

3–10. *Leiorhynchus limitare* (Vanuxem)?

   Romney or Millboro shale, Marcellus horizon. 3, 4, along U. S. Route 21 about 3 miles southeast of the summit of Walker Mountain, Wythe County; 5, 7-10, along road at southeast base of Ingles Mountain about 1½ miles south of Radford, Pulaski County; 6, road on Hughes Creek about one-fourth of a mile north of the mouth and 12 miles north of Covington, Alleghany County. This species shows considerable variation in number and size of ribs. A collection from the Marcellus near Central City (Milesburg), Center County, Pa., includes the same forms which are there associated with *Paleschara,* as found at a number of places in Virginia as far south as Hayter Gap, Washington County. U. S. N. M. 97967a, 97967b, 97968a, 97969, 97968b, 97968c, 97968d, 97968e.

11–13. *Leiorhynchus mysia* Hall, × 2.

   12, 13, dorsal and ventral views of a whole specimen; 11, ventral view of a slightly larger specimen. Associated with *Tornoceras uniangulare?* and *Schizobolus truncatus.* Marcellus shale; along State Route 42 half a mile northeast of village of Hayter Gap, Washington County. U. S. N. M. 97970a, 97970b.

14–16. *Actinopteria muricata* Hall.

   14, external mold of left valve; 15, internal mold of a left valve, × 2; 16, internal mold of the posterior part of a left valve, × 4. Marcellus shale; half a mile south of Waiteville, Monroe County, W. Va. U. S. N. M. 97971a, 97971b, 97971c.

FIGURE

17. *Douvillina? inequistriata* (Conrad)?
Internal mold of a ventral valve. Occurrence as 2. U. S. N. M. 97972.

18, 19. *Chonetes mucronatus* Hall.
Ventral valves. 18, shows the characteristic long hinge spine extending parallel to the hinge line. Occurrence as 11. U. S. N. M. 97973a, 97973b.

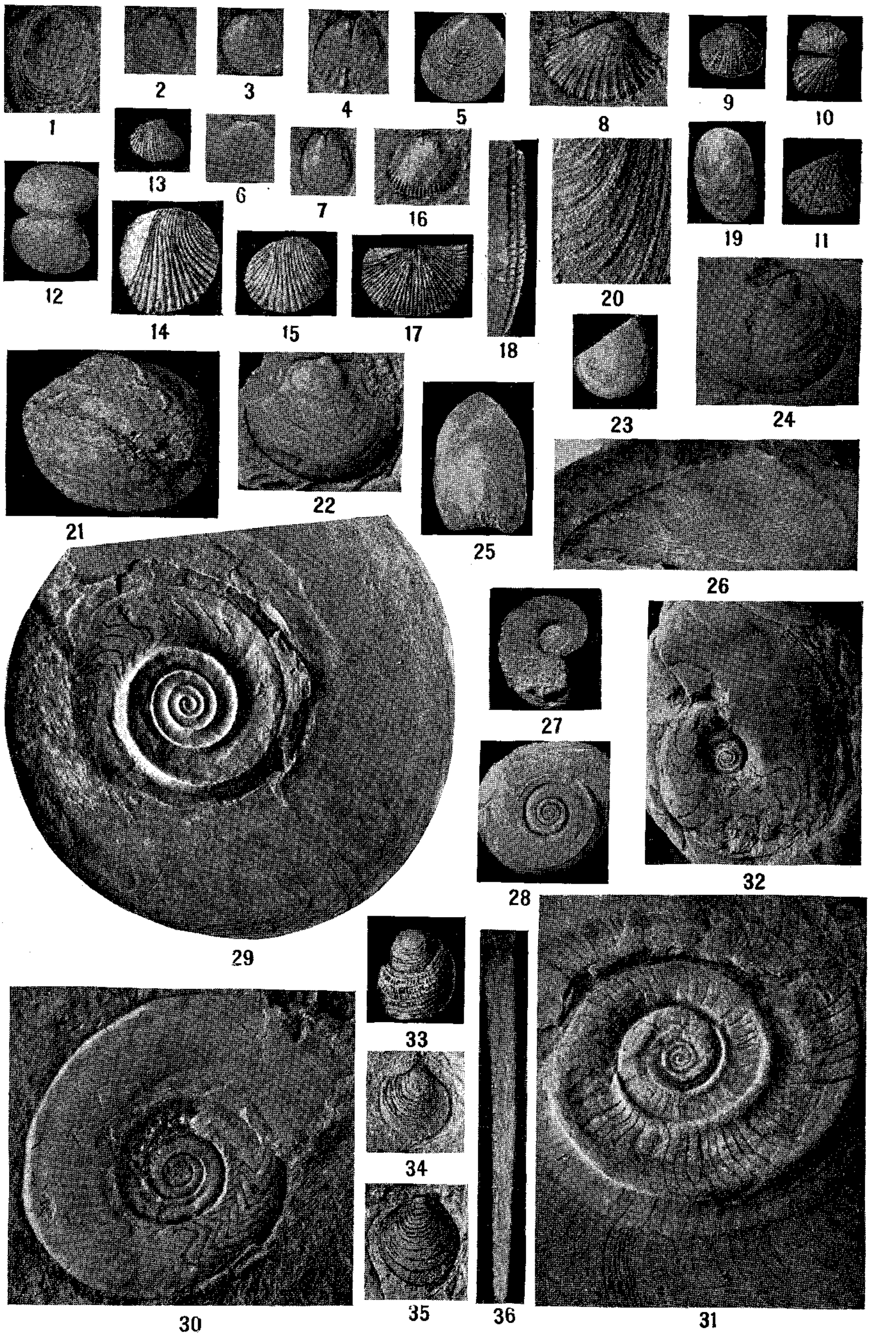
20. *Stropheodonta perplana* (Conrad).
Internal mold of a dorsal valve. Occurrence as 2. U. S. N. M. 97974.

21, 22. *Tropidoleptus carinatus* (Conrad).
Internal molds of two ventral valves. Occurrence as 2. U. S. N. M. 97975a, 97975b. (See Plate 123, figs. 11-13.)

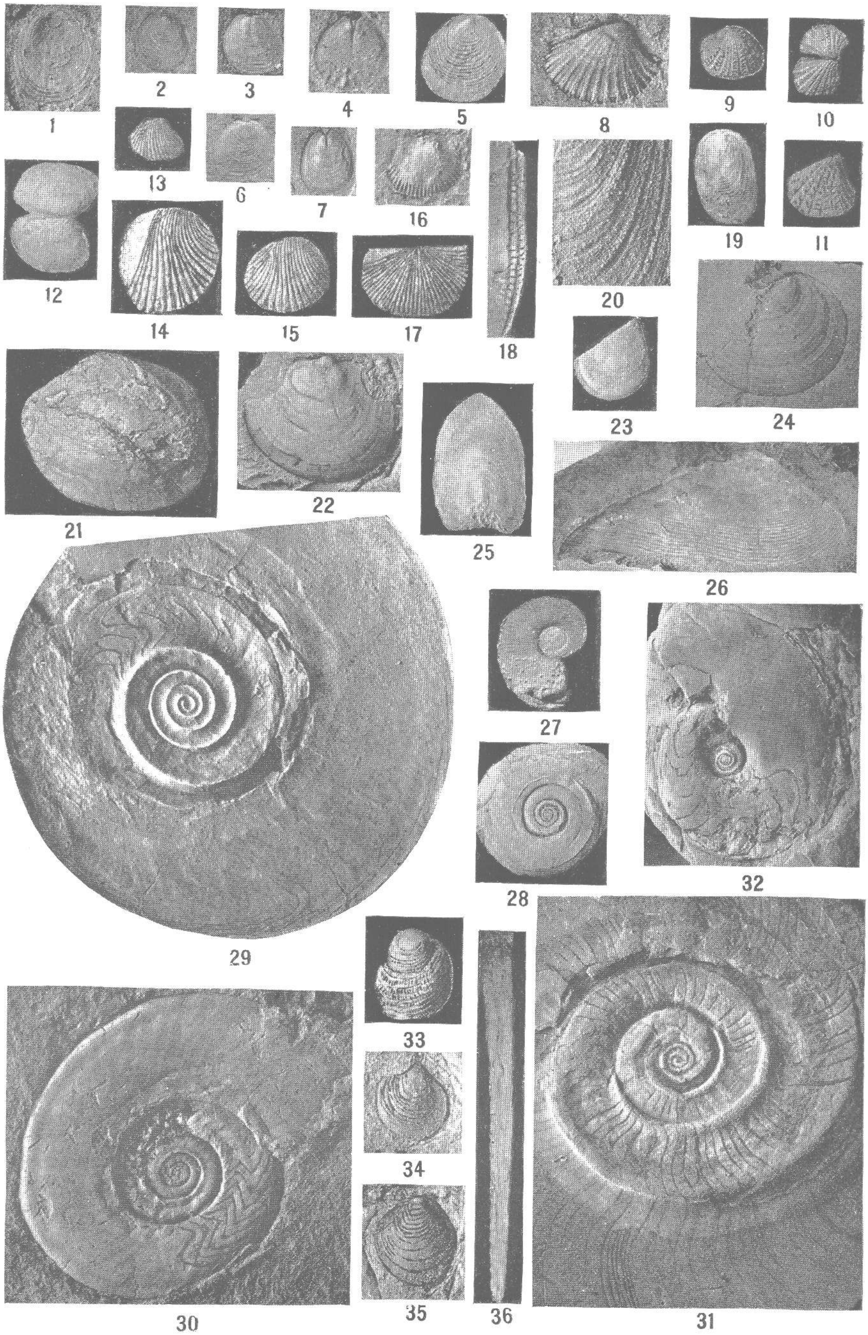
23. *Nucleocrinus strichteri* Rowley?
Hamilton shale; half a mile northwest of Dietrich in the Passage Creek valley of Massanutten Mountain, Shenandoah County. U. S. N. M. 97976.

24, 25. *Stropheodonta concava* Hall.
24, internal mold of a ventral valve; 25, internal mold of a dorsal valve. Occurrence as 2. U. S. N. M. 97977a, 97977b.

26, 27. *Orthoceras* sp., $\times$ 2.
Pyritized. 26, exterior of living chamber crushed in middle. Occurrence as 8. U. S. N. M. 98000a, 98000b.



MARCELLUS, NAPLES, AND BRALLIER FOSSILS



MARCELLUS, NAPLES, AND BRALLIER FOSSILS

PLATE 120.—MARCELLUS, NAPLES, AND BRALLIER FOSSILS

FIGURE

1–7. *Schizobolus concentricus* (Vanuxem), × 2.

1, external mold of a dorsal valve; 2, 5, internal molds of dorsal valves; 3, 4, 6, 7, internal molds of ventral valves. Millboro shale. 1, 3, 5, 6, Marcellus horizon; about 2½ miles southwest of village of Hayter Gap, Washington County; 2, 7, basal Portage, Naples horizon; along State Route 42 half a mile northeast of the village of Hayter Gap, Washington County; 4, Marcellus horizon; same locality as 2, but just below bed with *Leiorhynchus mysia* (Pl. 119, figs. 11-13). U. S. N. M. 97978a, 97979a, 97978b, 97980, 97978c, 97978d, 97979b.

8. *Honeoyea* cf. *H. erinacea* Clarke.

Slightly longer and of less height than *H. erinacea.* Millboro shale, Naples horizon; along southeast slope of Rich Mountain just below sharp angle in State Route 87 and about 1 mile north of the entrance to Burkes Garden, Tazewell County. U. S. N. M. 97981.

9, 10. *Buchiola retrostriata* (von Buch), × 2.

9, internal mold of left valve; 10, internal mold of both valves. 9, Brallier shale, near bottom; along road on Beaver Fork ¾ of a mile south of Bluefield, Va.; 10, occurrence as 8. U. S. N. M. 97982, 97983.

11. *Buchiola halli* Clarke.

Internal mold of a right valve. Millboro shale, probably Marcellus horizon; along the Lee Highway just northwest of the crest of Draper Mountain and about 1 mile south of Pulaski, Pulaski County. U. S. N. M. 97954.

12. *Palaeoneilo* cf. *P. petilla* Clarke.

Occurrence as 9. U. S. N. M. 97984.

13–15. *Paracardium doris* Hall, × 2.

13, left valve; 14, 15, right valves. Millboro shale, Naples horizon. 13, along Bennetts Run 2 miles northwest of Bergton, Shenandoah County; 14, 15, along U. S. Route 50 half a mile west of Burlington, Mineral County, W. Va. These specimens are from a good collection made

FIGURE

by G. W. Stose. They are evidently from the bed designated Genesee by the West Virginia Geological Survey. (See Geology of Mineral County.) As this fossil is apparently not reported from the Genesee, as restricted by Clarke, it is believed that the black shale, designated "Genesee" by the Maryland and West Virginia geological surveys, is not Genesee but Portage, and representative of the Naples beds of Clarke. *Paracardium doris* is probably the most common and most persistently distributed fossil of the Naples beds and is a guide fossil of those beds from New York to Tennessee. 13, U. S. N. M. 97985.

16, 17. *Chonetes lepidus* Hall, × 4.

Ventral valves. Occurrence as 8. U. S. N. M. 97986a, 97986b.

18. *Pteridichnites biseriatus* C. K. Swartz.

Brallier shale, base; along road on Beaver Fork at the right angle, three-fourths of a mile southeast of Bluefield, Va. Most common fossil of the Brallier. U. S. N. M. 97987.

19, 20. *Lingulipora williamsana* Girty.

19, part of a valve; 20, part of same to show punctuate shell structure, × 4. Brallier shale; along railroad one-fourth of a mile south of Raven, Tazewell County. U. S. N. M. 97988.

21, 22. *Ontaria halli* Clarke.

Left and right valves. Occurrence as 8. U. S. N. M. 97989a, 97989b.

23. *Lunulicardium* cf. *L. eriense* Clarke.

Marked by very fine radiating lines. Brallier shale; Gala station on Chesapeake and Ohio Railway about 5 miles northwest of Eagle Rock, Botetourt County. U. S. N. M. 97990.

24. *Lunulicardium* cf. *L. pilosum* Clarke.

Marked by very fine radiating lines. Occurrence as 8. U. S. N. M. 97991.

25, 26. *Spathiocaris emersoni* Clarke?

Occurrence as 8. U. S. N. M. 97992a, 97992b.

FIGURE

27–31. *Probeloceras lutheri* Clarke.

27, 31, external molds showing the fine curving lines of ornamentation, × 4. Between the coarser lines shown are several fine hairlike lines not shown except by retouching in the lower part of 31. 28, external mold (?) showing faint surface markings; 29, 30, internal molds showing the zigzag sutures of the plicated septae, × 2. 28, Brallier shale along Walker Creek 5 miles west of Marion, Smyth County; 27, occurrence as 2; 29-31, occurrence as 8. U. S. N. M. 97993, 97994, 97995a, 97995b, 97995c.

32. *Manticoceras patersoni* (Hall).

Internal mold. Occurrence as 8. U. S. N. M. 97996.

33. *Palaeotrochus praecursor* Clarke.

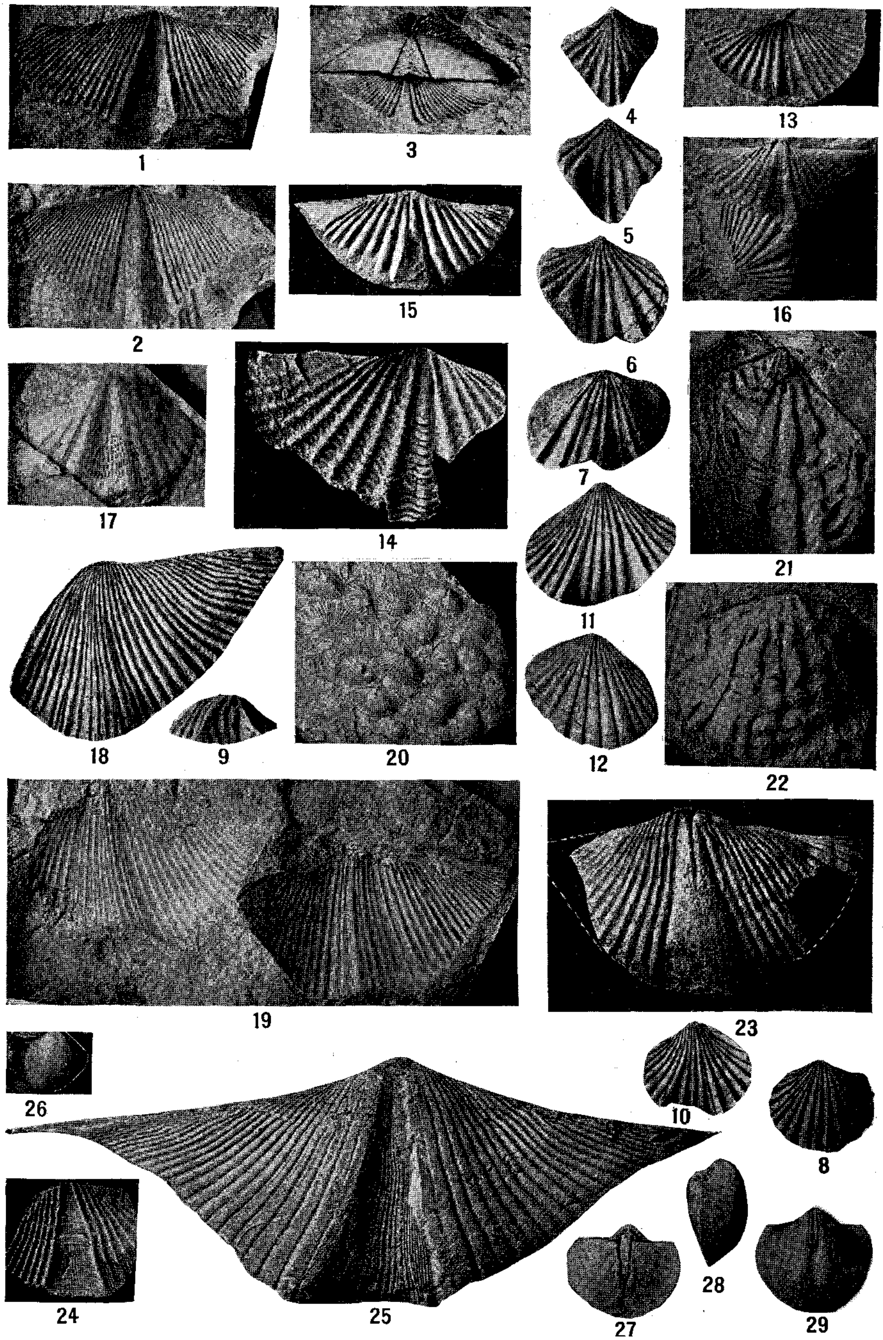
Occurrence as 8. U. S. N. M. 97997

34, 35. *Pterochaenia fragilis* (Hall), × 2.

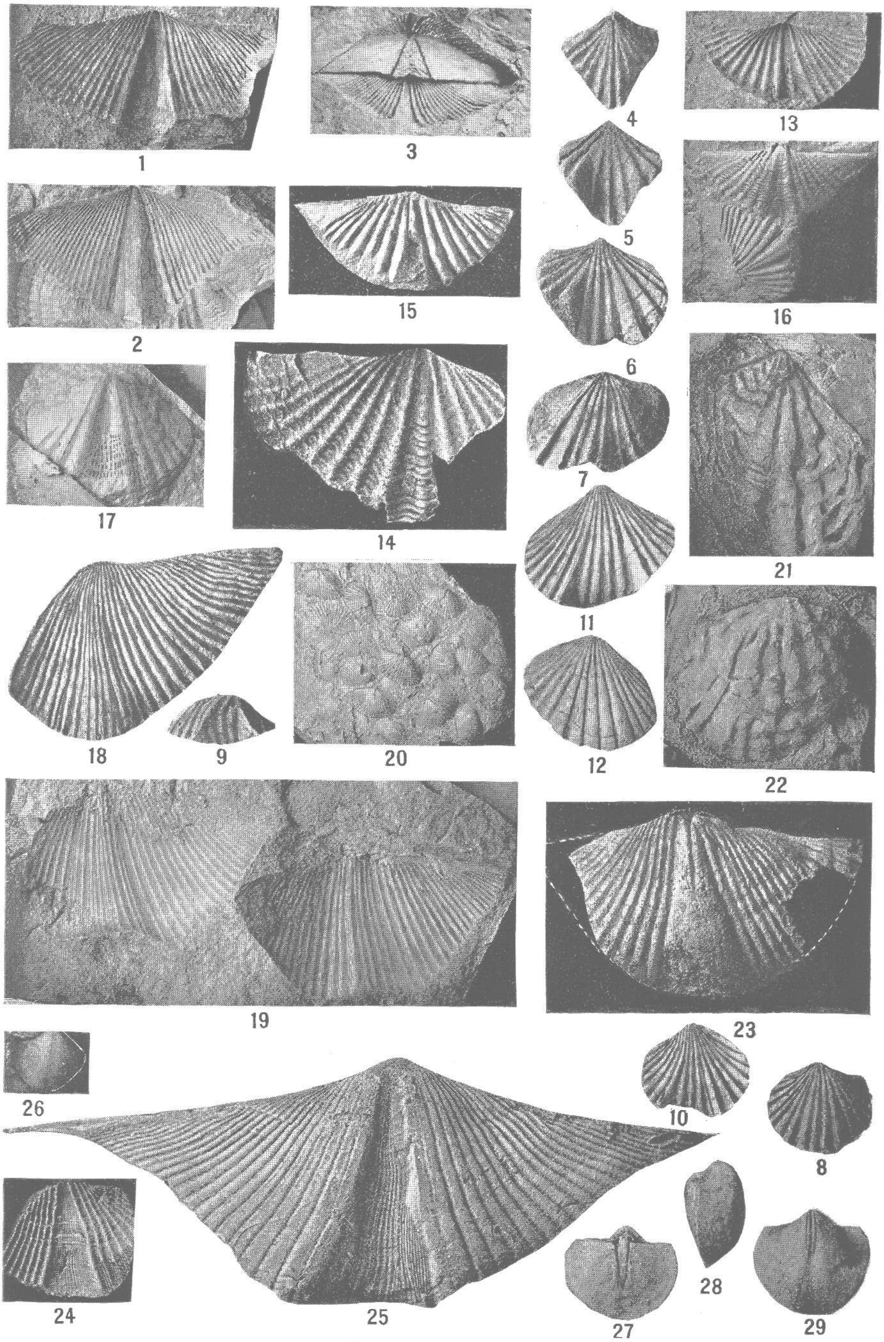
34, left valve, not correctly posed; 35, right valve. Millboro shale, Naples horizon; 1 mile northeast of White Sulphur Springs, W. Va. U. S. N. M. 97998a, 97998b.

36. *Bactrites gracilior* Clarke.

One of the most common fossils of the Naples horizon. Occurrence as 8. U. S. N. M. 97999.



Chemung Fossils



CHEMUNG FOSSILS

PLATE 121.—CHEMUNG FOSSILS

FIGURE

1–3. *Spirifer marcyi* Hall?

1, external mold of a dorsal valve, concave toward the observer; 2, external mold of a ventral valve, also concave toward the observer; 3, external mold of the area of the ventral valve showing the delthyrium, the dorsal valve, and the overhanging posterior margin of the ventral valve. It should be viewed from the left side. This species was originally described as from the Hamilton, but Williams and Tarr[a] cite it from the Chemung in the Ithaca region, New York. Chemung formation, near bottom; along Little Back Creek 750 feet above its junction with State Route 501 and 2½ miles northwest of Mountain Grove, Bath County. U. S. N. M. 98001a, 98001b, 98001c.

4–10. *Camarotoechia contracta* (Hall).

4, 5, dorsal and ventral views of an internal mold; 6, 7, ventral and dorsal views of another specimen; 8-10, dorsal, front, and ventral views of another specimen. Chemung formation. 4-7, gorge of Reed Creek through Brushy Mountain about 3 miles northwest of Blacklick, Wythe County; 8-10, top of Chemung along U. S. Route 21 about 1½ miles north of Bland, Bland County. 4, 5, U. S. N. M. 98002a; 6, 7, 98002b; 8-10, 98003.

11, 12. *Camarotoechia congregata* (Conrad).

Ventral and dorsal valves. Chemung formation; along U. S. Route 21 about 2 miles north of Bland, Bland County. U. S. N. M. 98004a, 98004b.

13–16. *Spirifer* (*Delthyris*) *mesicostalis* (Hall).

13, 14, external molds of dorsal valves; 14, × 2, to show zigzag transverse lamellae; 15, internal mold of the dorsal valve preserving an inner film of the shell; 16, internal mold of a ventral valve (upper) and of a dorsal valve (lower) showing the rib in the sinus of the ventral valve and the furrow on the fold of the dorsal valve. This is the most characteristic feature of the species. These two specimens have unusually long mucronate extensions of the hinge line. Ranges from the Portage (Brallier)

---

[a] Williams, H. S. and Tarr, R. S., U. S. Geol. Survey Geol. Atlas, Watkins Glen-Catatonk folio (No. 169), 1909.

FIGURE

through the Chemung. Chemung formation. 13, 14, State line at head of Lick Run about 10 miles northeast of Durbin, W. Va.; 15, same locality as 1; 16, about 1½ miles northeast of Orkney Springs, Shenandoah County. U. S. N. M. 98005a, 98005b, 98006, 98007.

17. *Elytha fimbriata* (Conrad).
Impression of the external mold of the ventral valve. Occurrence as 1. U. S. N. M. 98008.

18, 19. *Spirifer disjunctus* Sowerby.
18, impression from an external mold of part of a dorsal valve; 19, external molds of ventral valves. Note ribs on fold of 18 and in sinus of 19, and compare with 1, 2, 23. Chemung formation. 18, along U. S. Route 60 about 2 miles east of White Sulphur Springs, W. Va.; 19, along State Route 91 half a mile north of Broadford, Smyth County. Probably the most abundant Chemung fossil, but good specimens are rare in Virginia. U. S. N. M. 98009, 98010a, 98010b.

20. *Chonetes scitulus* Hall.
Slab with several specimens. Chemung formation; at Red Mill 1½ miles north of Gap Mills, Monroe County, W. Va. U. S. N. M. 98011.

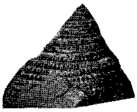
21, 22. *Atrypa spinosa* Hall.
Clay impressions of external molds. 21, ventral valve; 22, dorsal valve. Coarser and more strongly nodose ribs than in the common and normal examples. Occurrence as 18. U. S. N. M. 98012a, 98012b.

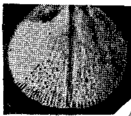
23–25. *Spirifer mesistrialis* Hall.
23, internal mold of a dorsal valve; 24, external mold of a dorsal valve; 25, impression of an external mold of a ventral valve. All show the absence of ribs on the fold and in the sinus. 24, shows the fine striae on both ribs and folds, and 25 those on the fold that suggest the name. Both features are characteristic of the species. Chemung formation. 23, 24, along road midway between Little North Mountain and Supin Lick Mountain about 4 miles southeast of Orkney Springs, Shenandoah County; 25, Tioga County, N. Y. U. S. N. M. 98013a, 98013b, 4251.

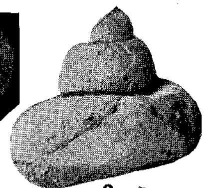
FIGURE

26–29. *Ambocoelia umbonata* (Conrad).

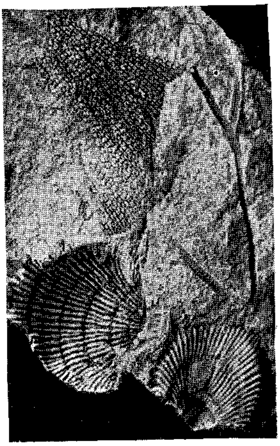
26, impression of an external mold of a ventral valve; 27-29, dorsal, profile, and ventral views of an internal mold of a whole specimen, × 2. Chemung formation; float from Shenandoah Mountain in deep ravine 2½ miles northeast of Williamsville, Bath County. 26, U. S. N. M. 98014a; 27-29, 98014b.

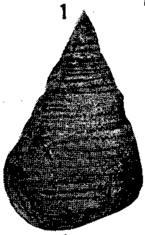

1

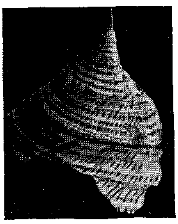

5

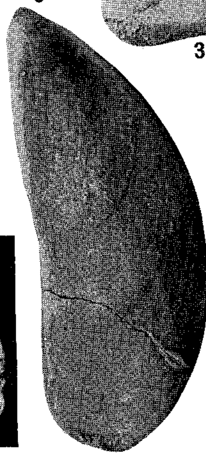

3


6

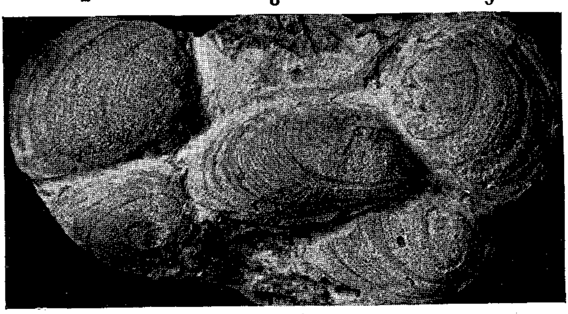

7

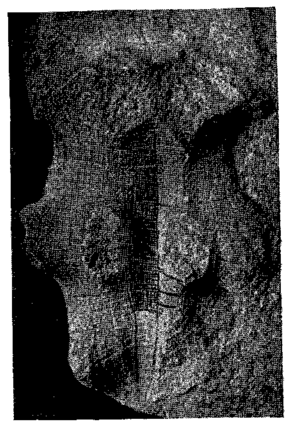

4

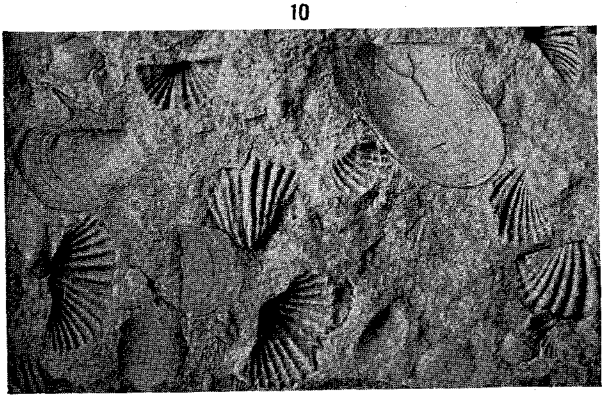

2

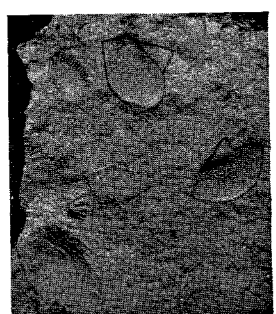

8


9

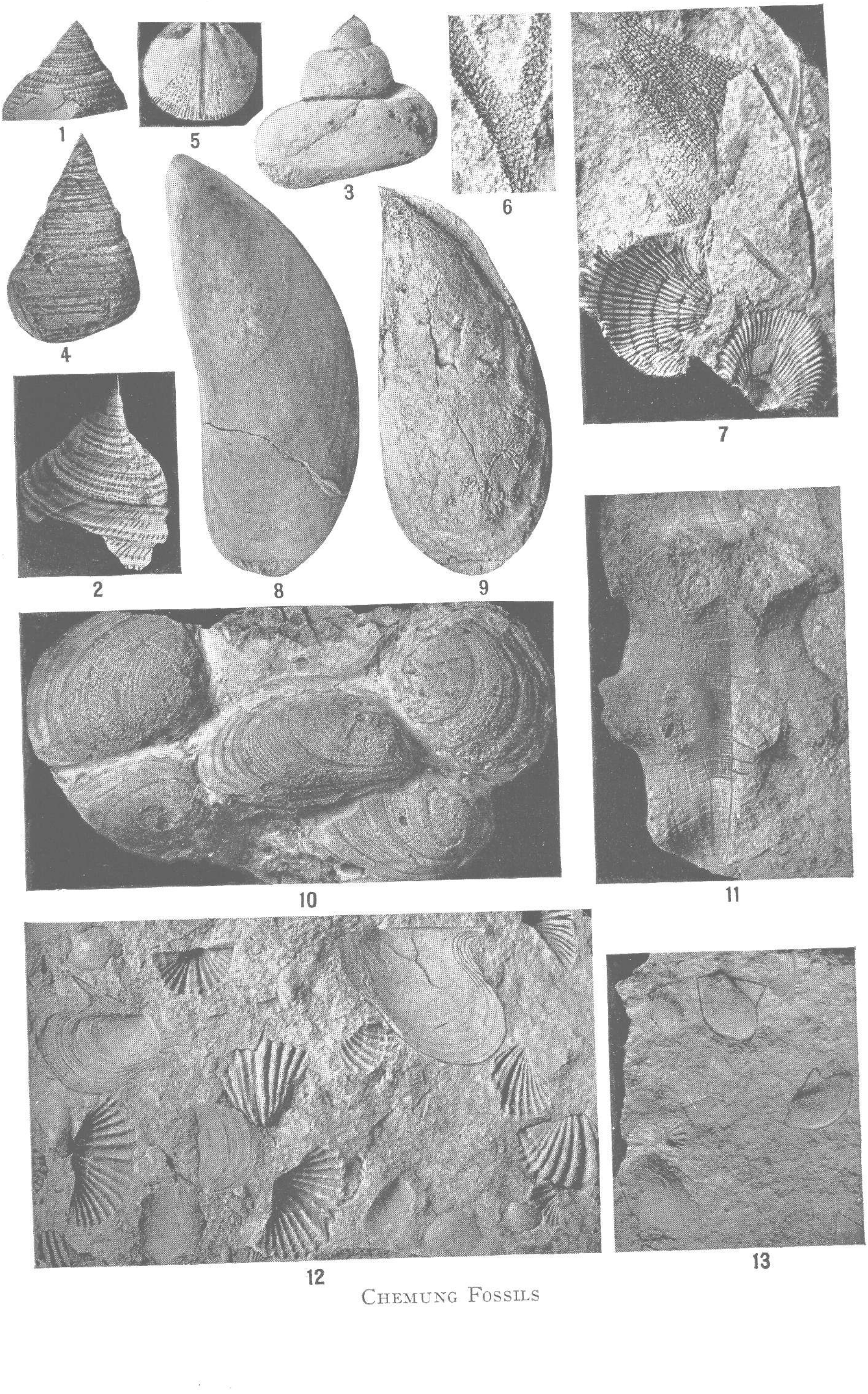

10


11


12


13

Chemung Fossils



Chemung Fossils

PLATE 122.—CHEMUNG FOSSILS

FIGURE

1–3. *Cyclonemina multistriata* Clarke and Swartz.

1, impression from an external mold; 2, external mold of another specimen, concave toward the observer, to show ornamentation; 3, internal mold of a third specimen. Chemung formation; along U. S. Route 250 about 3 miles west of Jennings Gap, Augusta County. U. S. N. M. 98015a, 98015b, 98015c.

4. *Cyclonemina crenulistriata* Clarke and Swartz.

Impression from an external mold. Occurrence as 1. U. S. N. M. 98016.

5. *Rhipidomella vanuxemi* (Hall) ?

Internal mold of dorsal valve. Chemung formation; near mouth of Little Back Creek about 2½ miles northwest of Mountain Grove, Bath County. (See Pl. 123, figs. 9 and 10.) U. S. N. M. 98017a.

6, 7. *Rhombopora* sp.

7, external mold of a branching specimen on right; 6 part of 7, × 4. The *Rhombopora* is the most common and widely distributed bryozoan in the Chemung. Shows also species of *Fenestrellina* and two specimens of *Atrypa reticularis*. Chemung formation; along U. S. Route 60 about 2 miles east of White Sulphur Springs, W. Va. U. S. N. M. 98018.

8. *Modiola praecedens* Hall.

Left valve. Chemung formation; Brushy Mountain 6 miles west of Marion, Smyth County. U. S. N. M. 98019.

9. *Mytilarca chemungensis* (Conrad).

Left valve. Associated with *Spirifer disjunctus*. Chemung formation; half a mile west of Broadford, Smyth County. U. S. N. M. 98020.

10. *Edmondia subovata* Hall.

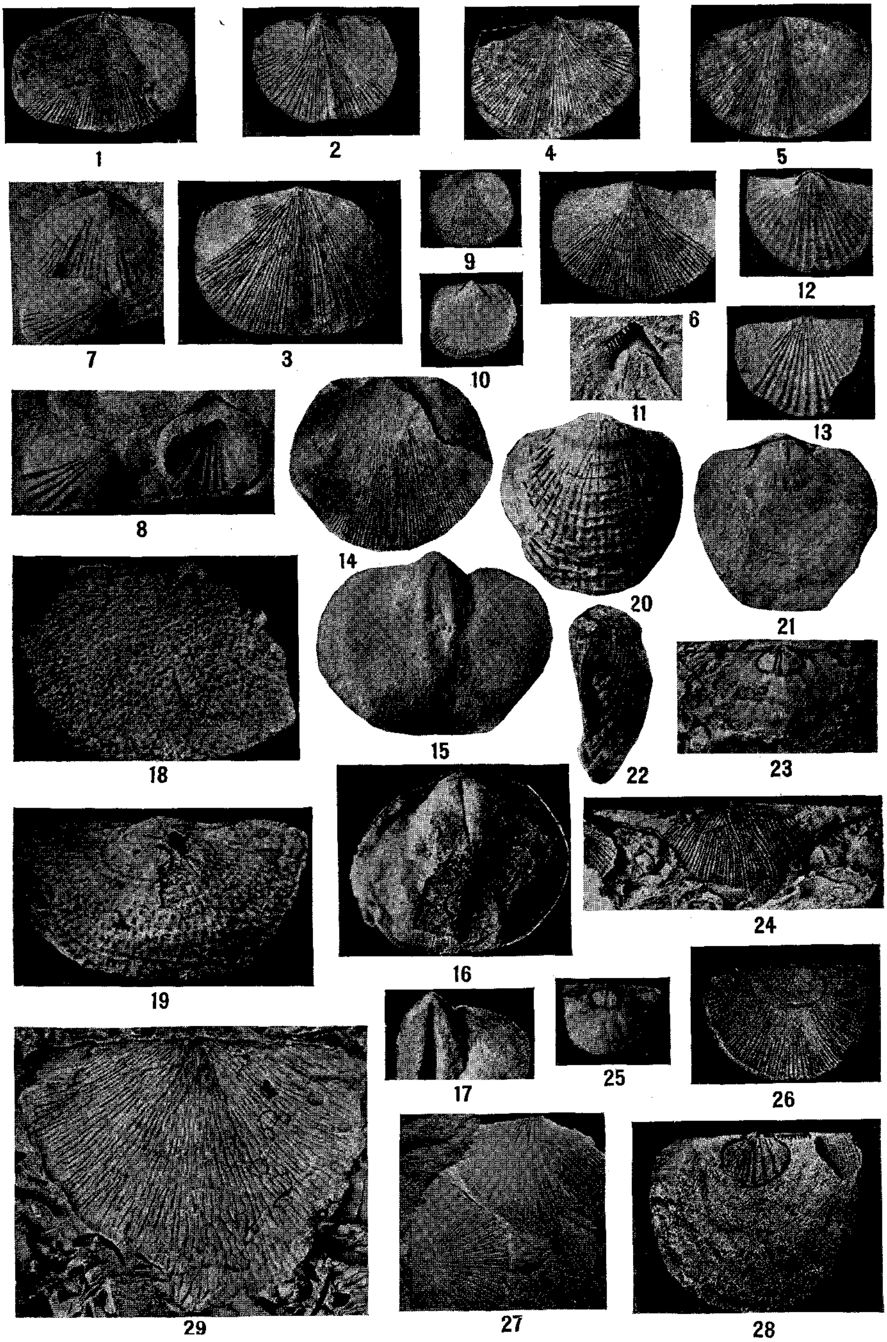
Left valve (upper left corner) and right valves. Chemung formation; along old Staunton-Parkersburg pike 5 miles northwest of Buffalo Gap, Augusta County. U. S. N. M. 98021.

FIGURE

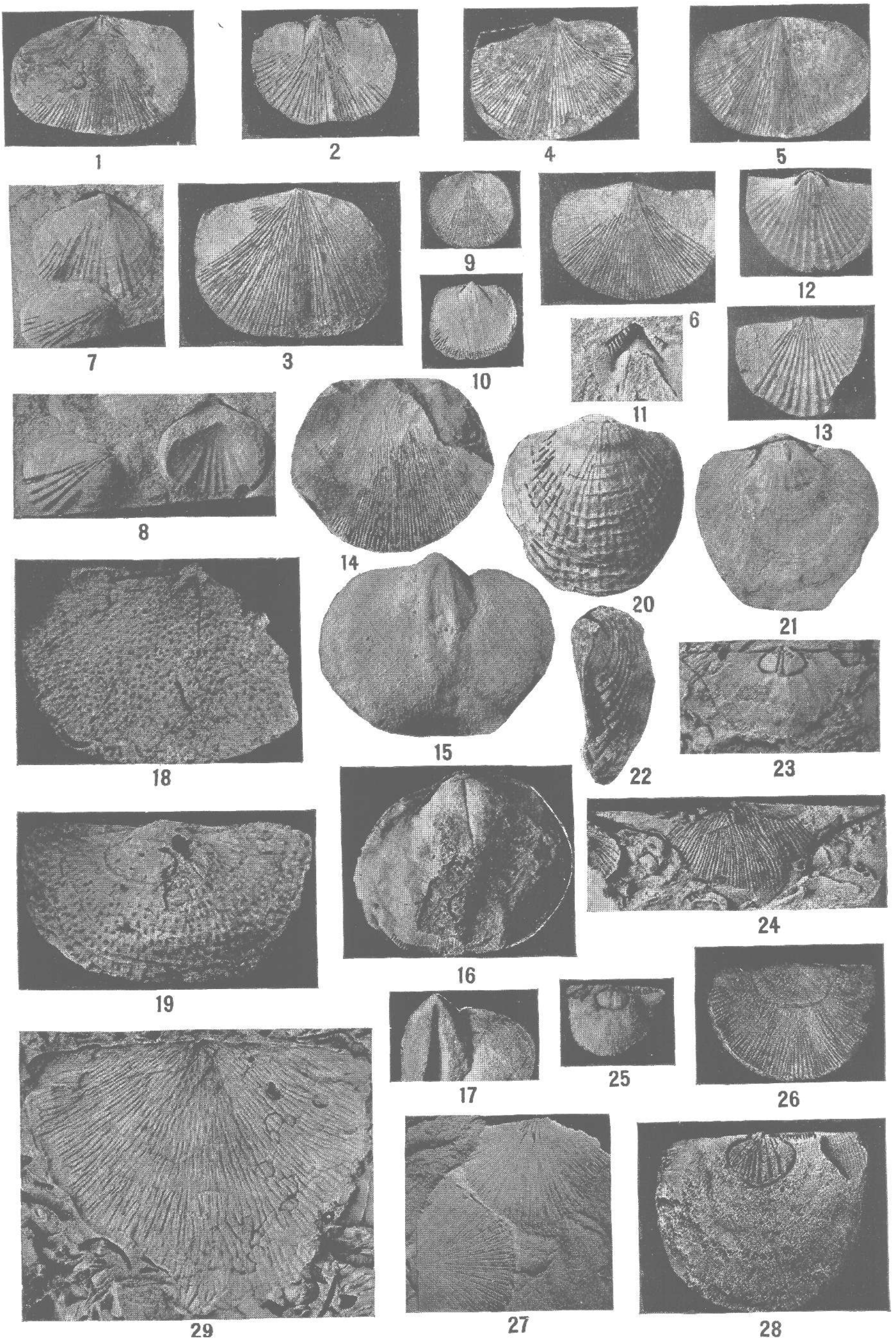
11. *Hydnoceras tuberosum* Conrad.
Occurrence as 6. U. S. N. M. 98022.

12. Slab with *Leptodesma potens* Hall (right); *L. agassizi* Hall (left); and molds of *Spirifer* (*Delthyris*) *mesicostalis* Hall. Chemung formation; State line at head of Spring Run in the northwest corner of Highland County. U. S. N. M. 98023, 98024, 98025.

13. *Leptodesma sociale* Hall.
Occurrence as 12. U. S. N. M. 97079.



Chemung Fossils



CHEMUNG FOSSILS

PLATE 123.—CHEMUNG FOSSILS

FIGURE

1–6. *Carniferella carinata* or *C. tioga* (Hall)?

These two species closely resemble each other, as noted by Hall. 1, internal mold of a dorsal valve; 2, internal mold of a ventral valve; 3, impression of an external mold of a dorsal valve; 4, external mold of a ventral valve; 5, external mold of a dorsal valve; 6, impression of 4, showing the actual exterior of the shell. Chemung formation, near base; along road on Little Back Creek about 750 feet north of State Route 501 and 2½ miles northwest of Mountain Grove, Bath County. This genus is apparently confined to the Chemung formation. U. S. N. M. 98026a, 98026b, 98026c, 98026d, 98026e.

7, 8. *Leiorhynchus mesicostale* (Hall).

7, (upper), internal mold of a ventral valve; 8, (left), internal mold of a dorsal valve. Occurrence as 1. U. S. N. M. 98027a, 98027b.

9, 10. *Rhipidomella vanuxemi* (Hall)?

9, ventral valve; 10, internal mold of a ventral valve. Occurrence as 1. (See Pl. 122, fig. 5.) U. S. N. M. 98017b, 98017c.

11–13. *Tropidoleptus carinatus* (Conrad).

11, internal mold of a dorsal valve showing the pits made by the teeth of the crenulated socket plates characteristic of the genus. 12, internal mold of a ventral valve; 13, external mold of a dorsal valve. Occurrence as 1. (See Plate 119, figs. 21, 22.) U. S. N. M. 98028a, 98028b, 98028c.

14–17. *Schizophoria striatula* Schlotheim?

14, impression from an external mold of a ventral valve; 15, internal mold of a ventral valve; 16, internal mold of a dorsal valve; 17, internal mold of a fragment of a ventral valve showing the strong muscular impression of the umbonal cavity. Presumably owing to this, the specific name *impressa* was given by Hall. Occurrence as 1. U. S. N. M. 98029a, 98029b, 98029c, 98029d.

FIGURE

18, 19. *Productella hirsuta* Hall.

Internal molds of dorsal and ventral valves. Chemung formation; one-fourth of a mile northwest of summit of Price Mountain in the southwest corner of the Eagle Rock quadrangle, Craig County. U. S. N. M. 98030a, 98030b.

20–22. *Atrypa reticularis* (Linné).

Ventral, dorsal, and profile views. Occurrence as 1. U. S. N. M. 98031.

23, 24. *Douvillina extensa* Butts, n. sp.

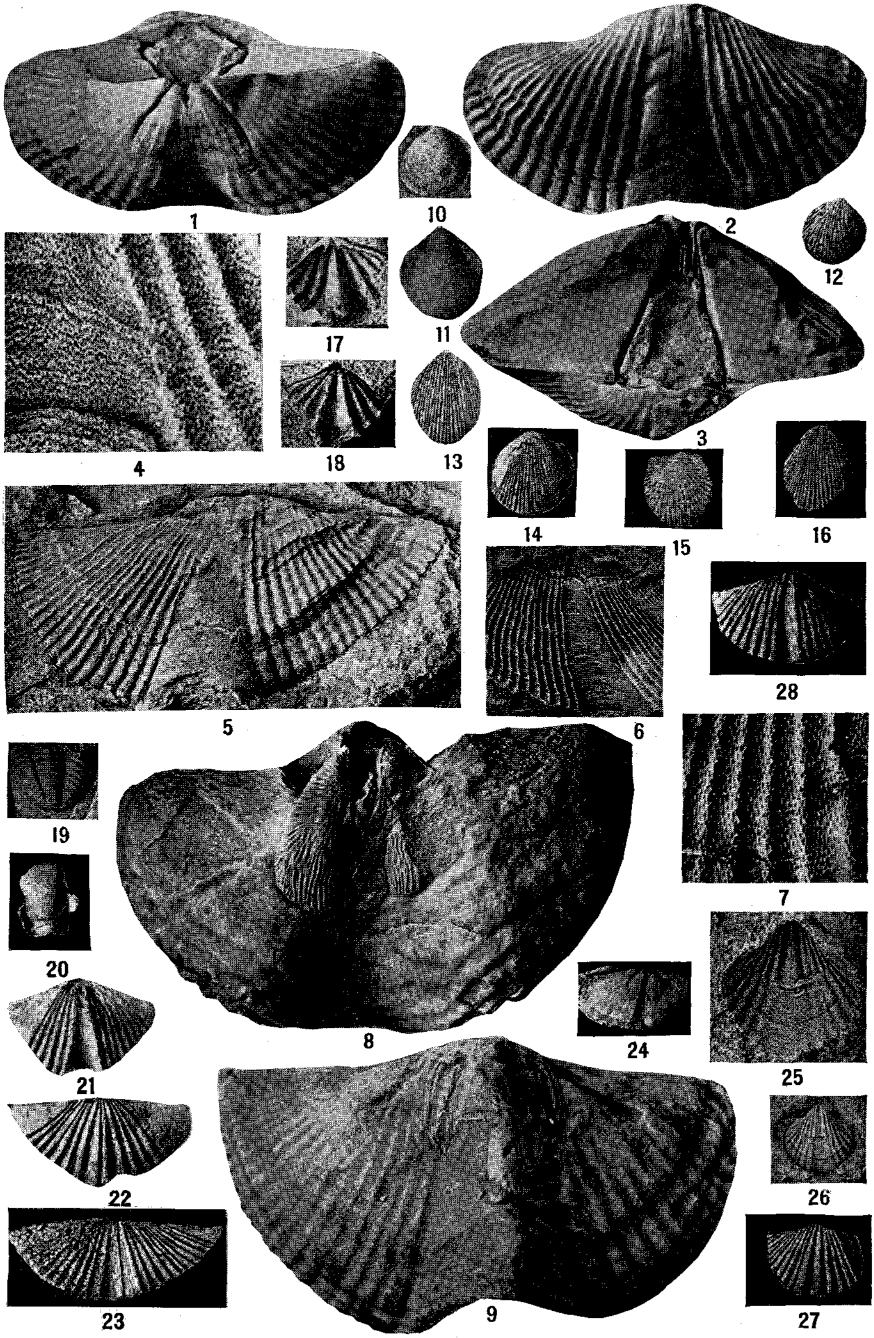
Distinguished by very extended cardinal extremities, coarser and more numerous primary costae than in *D. mucronata,* and by only one or two intermediate, fine striae instead of four or five as in *D. mucronata* (cf. Fig. 27). 23, internal mold of a ventral valve, with mucronate extremities broken off; 24, impression from an external mold of a ventral valve. Chemung formation; along U. S. Route 60 about 1 mile west of State line and 2 miles east of White Sulphur Springs, W. Va. Cotypes: U. S. N. M. 98032a, 98032b.

25–28. *Douvillina mucronata* (Hall) ?.

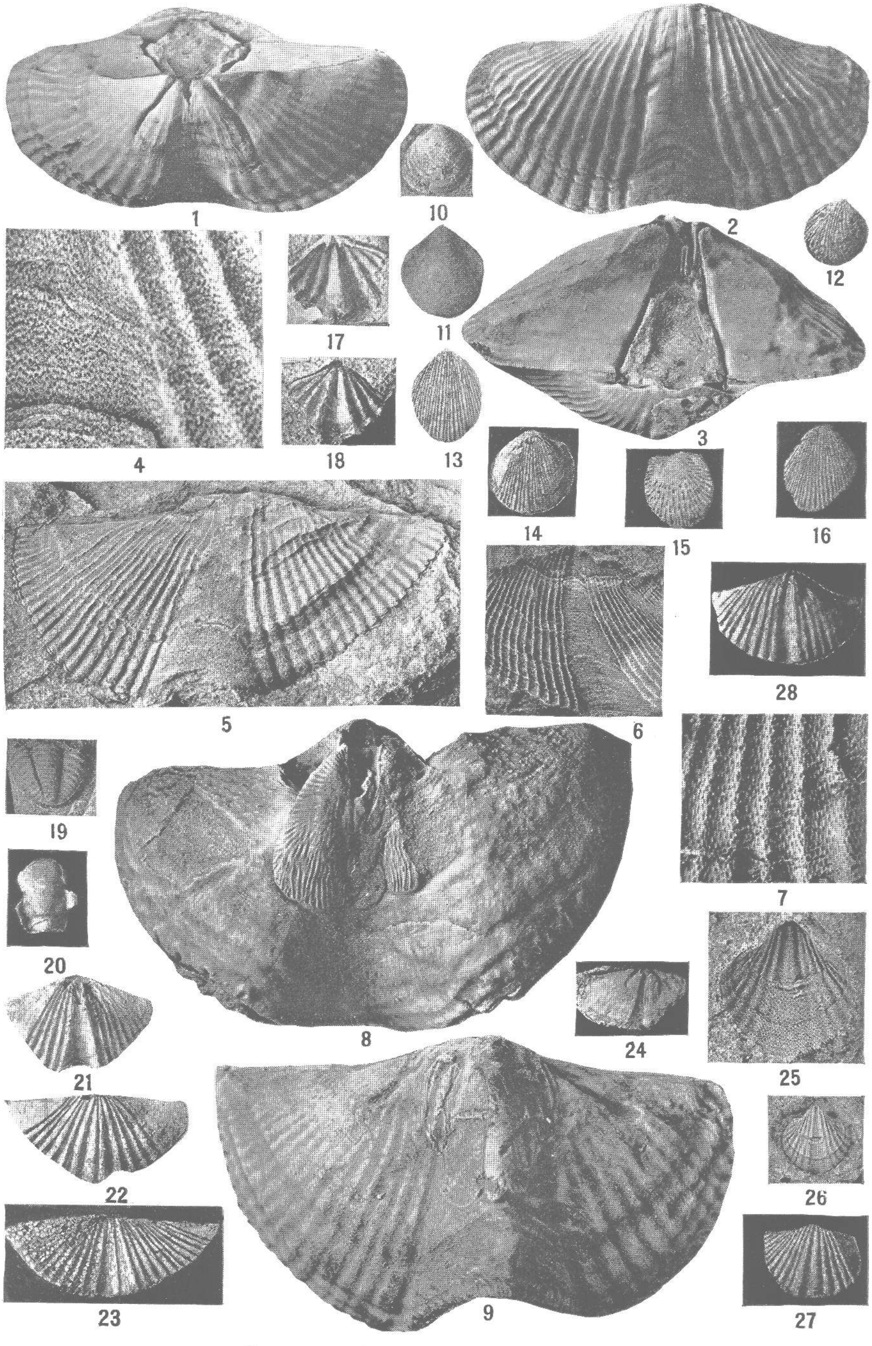
25, 28, internal molds of ventral valves; 26, external mold of a ventral valve showing the muscle scar; 27, internal mold of a ventral valve (left) and of the dorsal valve (right). Chemung formation. 25, same locality as 23; 26, along U. S. Route 250 on southeast slope of Shenandoah Mountain, Augusta County; 27, occurrence as 1. Supposed to be about 200 feet below the horizon of 1; 28, at State line 5 miles east of Frost, W. Va. 25, 28, U. S. N. M. 98037, 98033; 26, 98034; 27, 98035.

29. *Stropheodonta perplana* Conrad, var. *nervosa* Hall.

External mold of a ventral valve. Occurrence as 23. U. S. N. M. 98036.



PRICE AND NEW PROVIDENCE FOSSILS



PRICE AND NEW PROVIDENCE FOSSILS

PLATE 124.—PRICE AND NEW PROVIDENCE FOSSILS

FIGURE

1–9. *Syringothyris texta* (Hall).

1, 8, internal molds of ventral valves; 2, 9, internal molds of dorsal valves; 3, posterior view of an internal mold showing the syrinx and the filling of its internal tube; 5, internal mold of a dorsal valve; 6, external mold of part of a dorsal valve; 4, 7, views of small parts of the surface of two specimens to show "twilled cloth" pattern of ornamentation, × 4; 4, external mold; 7, impression of an external mold showing the actual surface of the shell. 1-3, New Providence formation; along Monon Railroad half a mile north of Farrabee Station, Washington County, Ind.; 4-9, Price formation. 4-6, along U. S. Route 21 about 6 miles northwest of Wytheville, Wythe County; 7, railroad cut in gap through Pine Mountain 2 miles east of Cassard, Scott County; 8, 9, exact locality unknown, donated by a person living at Raven, Tazewell County. *Syringothyris* can be distinguished from *Spirifer* by the "twilled cloth" ornamentation shown in 4, 6, 7, and by the syrinx shown in 3. It is also differentiated from *Spirifer disjunctus* by the lack of ribs on the fold and in the sinus. 1-3, U. S. N. M. 98039; 4, 98040a; 5, 6, 98040b; 8, 9, 90666.

10. *Athyris ohioensis* (Winchell).

Price formation; along road 1¾ miles southwest of Bandy, Tazewell County. U. S. N. M. 98041.

11. *Centronella?* sp.

Price formation; shale pit half a mile south of Richlands, Tazewell County. U. S. N. M. 98042.

12–16. *Productus,* one or more species.

12, impression from an external mold of a ventral valve; 13, 14, 16, internal molds of ventral valves; 15, external mold of a dorsal valve. These seem to correspond to small species occurring in the Cuyahoga formation of Ohio and named by Herrick *P. rushvillensis* and *P. nebrascensis.* Certain specific identification is hardly possible with the material at hand and without Ohio material for comparison. The Virginia species seem certainly to be the same as those of Ohio. Price formation. 12, 13, 16, along

FIGURE

railroad through Pine Mountain 2 miles east of Cassard, Scott County; 14, 15 (Maccrady shale?), 500 feet west of Sunbright station (Hortons Summit) on the Southern Railway at the south end of Powell Mountain, Scott County. U. S. N. M. 98044a, 98044b, 98043a, 98043b, 98045.

17, 18. *Spiriferina solidirostris* (White).

18, interior of a ventral valve; 17, impression from the same showing the slit made by the septum. Occurrence as 10. U. S. N. M. 98046.

19, 20. *Phillipsia meramecensis* Shumard.

Tail and head. Price (Maccrady?); same locality as 14. U. S. N. M. 98047a, 98047b.

21–24. *Spirifer winchelli* Herrick?.

21, 24, internal molds of ventral valves; 22, internal mold of a dorsal valve; 23, external mold of the same valve. Occurrence as 10. 21, 24, U. S. N. M. 98049a, 98048; 22, 23, 98049b.

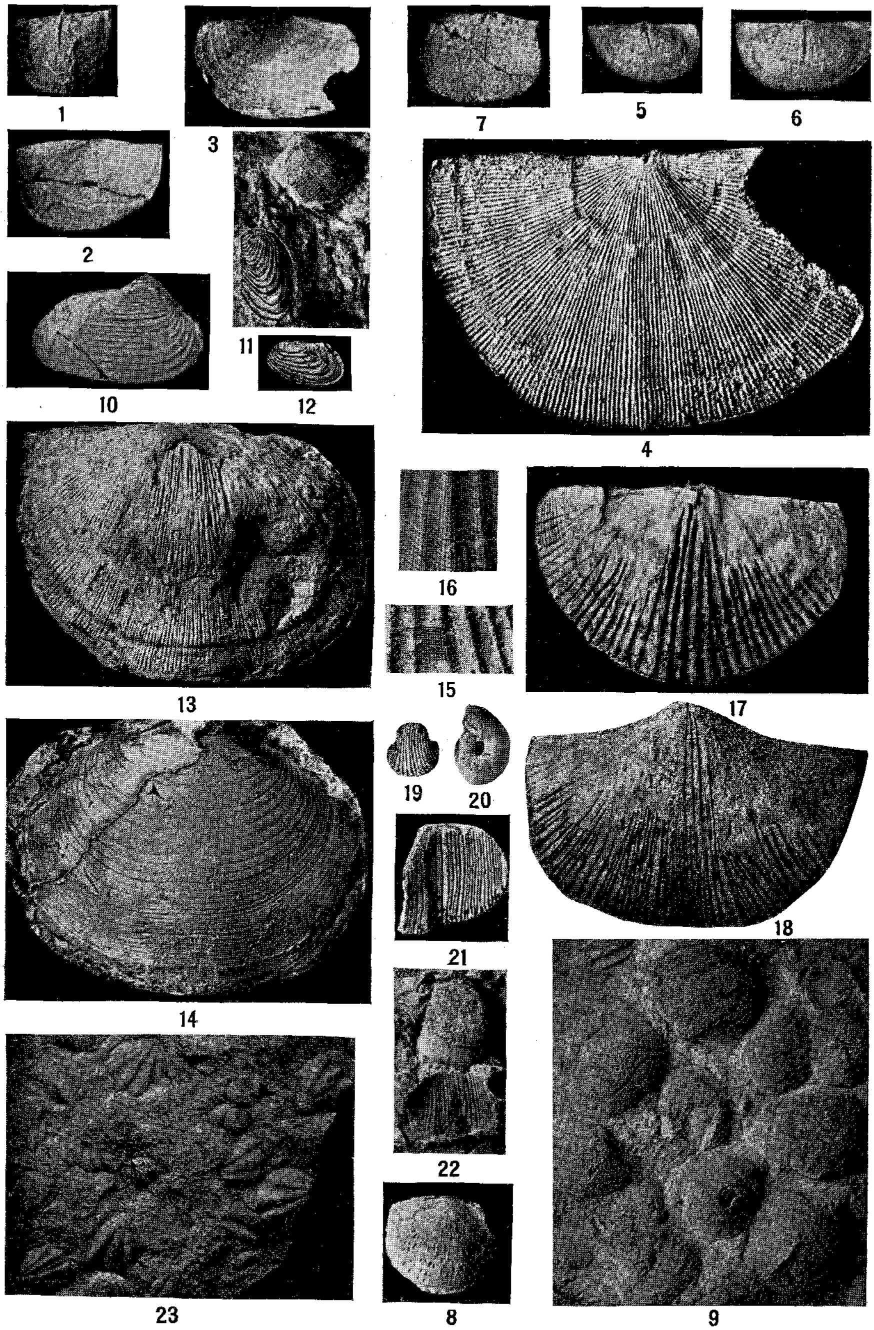
25, 26. *Spiriferella? schucherti* (Rowley).

25, external mold of a ventral valve, × 2; 26, impression from the same specimen; 25 shows fine pits made by low spines or pustules on the exterior of the shell. This form was described from specimens obtained in the lower Burlington limestone of Missouri, and referred by Weller with doubt to *Spiriferella.* He had no specimens showing the internal characters, but remarked that if a median septum were present, the form would be referred to *Spiriferina.* As shown in both figures, a very low median septum is present indicating *Spiriferina.* Price (Maccrady?); same locality as 14. U. S. N. M. 98050.

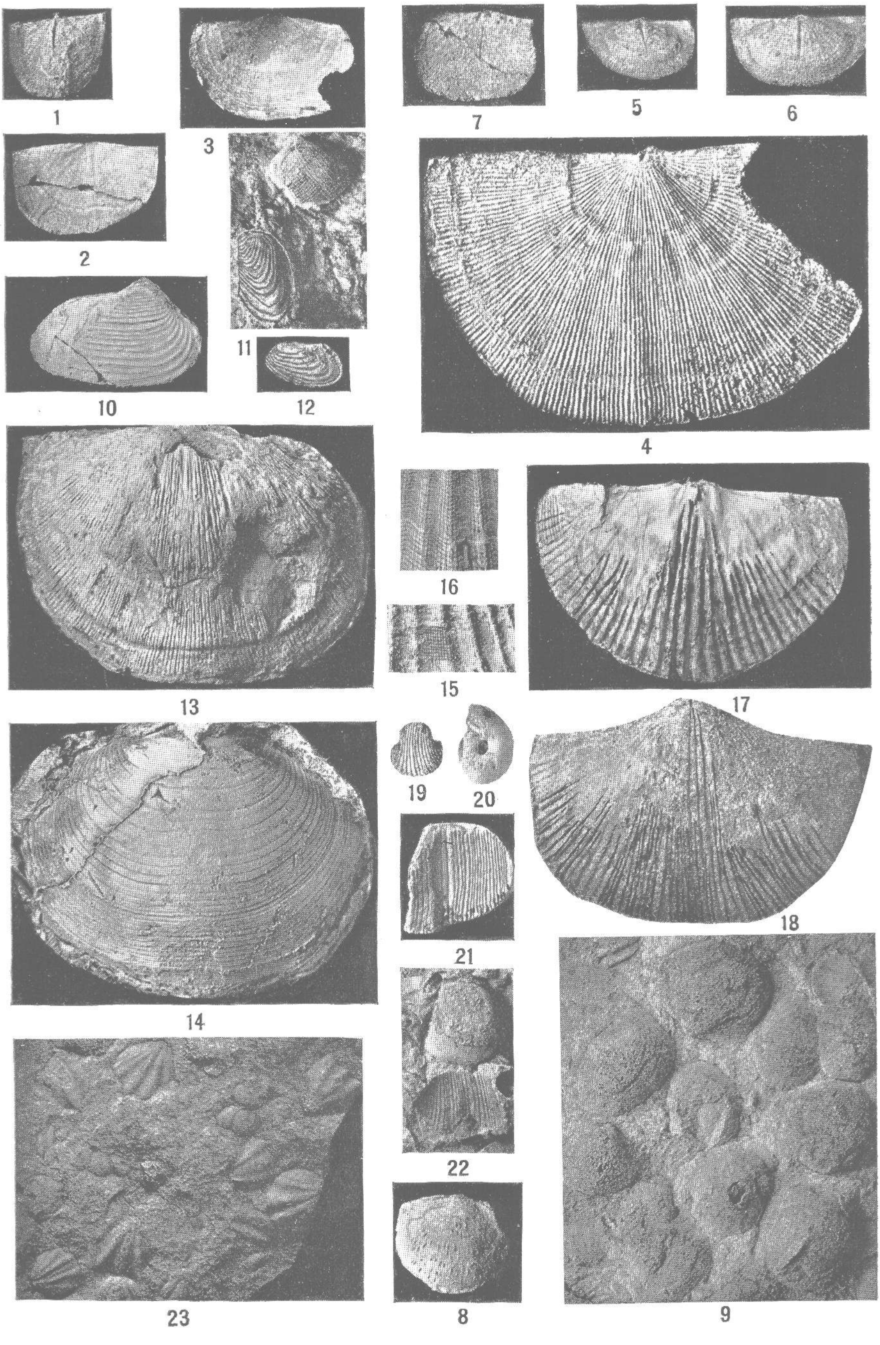
27, 28. *Spirifer* cf. *S. striatiformis* as figured by Herrick[a].

27, impression of an external mold of a ventral valve; 28, internal mold of a ventral valve. Occurrence as 10. U. S. N. M. 98051a, 98051b.

[a] Denison Univ. Bull., Jour. Sci. Labs., vol. 3, pl. 3, fig. 23, 1888.



PRICE AND NEW PROVIDENCE FOSSILS



PRICE AND NEW PROVIDENCE FOSSILS

PLATE 125.—PRICE AND NEW PROVIDENCE FOSSILS

FIGURE

1. *Chonetes* sp.?
   Internal mold of a ventral valve. Price formation; along U. S. Route 21 on Stony Creek 6 miles northwest of Wytheville, Wythe County. U. S. N. M. 98052.

2–4. *Chonetes shumardanus* De Koninck.
   2, 3, external molds of ventral valves; 4, external mold of a dorsal valve showing the extremely fine striae, × 4. Price formation. 2, (Maccrady?), 500 feet west of Sunbright station (Hortons Summit) on the Southern Railway at south end of Powell Mountain, Scott County; 3, 4, along State Route 84 about 1 mile southeast of Richlands, Tazewell County. U. S. N. M. 98053, 98054a, 98054b.

5, 6. *Chonetes illinoisensis* Worthen?
   Ventral valves, internal molds. Occurrence as 1. U. S. N. M. 98055a, 98055b.

7–9. *Productella concentrica* (Hall)?
   7, internal mold of a dorsal valve; 8, external mold of a dorsal valve showing spine bases; 9, slab with several molds, mostly external, of dorsal valves. Price formation; north slope of Brushy Mountain 1½ miles north of Ceres, Bland County. U. S. N. M. 98056a, 98056b, 98056c.

10. *Allorisma consanguinatum* Herrick?
   Price formation; shale pit 1 mile west of railroad station at Richlands, Tazewell County. U. S. N. M. 98057.

11, 12. *Cypricardinia scitula* Herrick.
   11, also with *Bucanopsis* sp.? Price formation. 11, cut on north slope of Pine Mountain 2 miles east of Cassard, Scott County; 12, along State Route 82 about 1 mile northwest of Cleveland, Russell County. U. S. N. M. 98058, 98059.

13, 14. *Reticularia pseudolineata* (Hall).
   13, internal mold of a ventral valve; 14, clay impression of the external mold of a ventral valve. Occurrence as 11. U. S. N. M. 98060a, 98060b.

FIGURE

15–18. *Spirifer striatiformis* Meek.

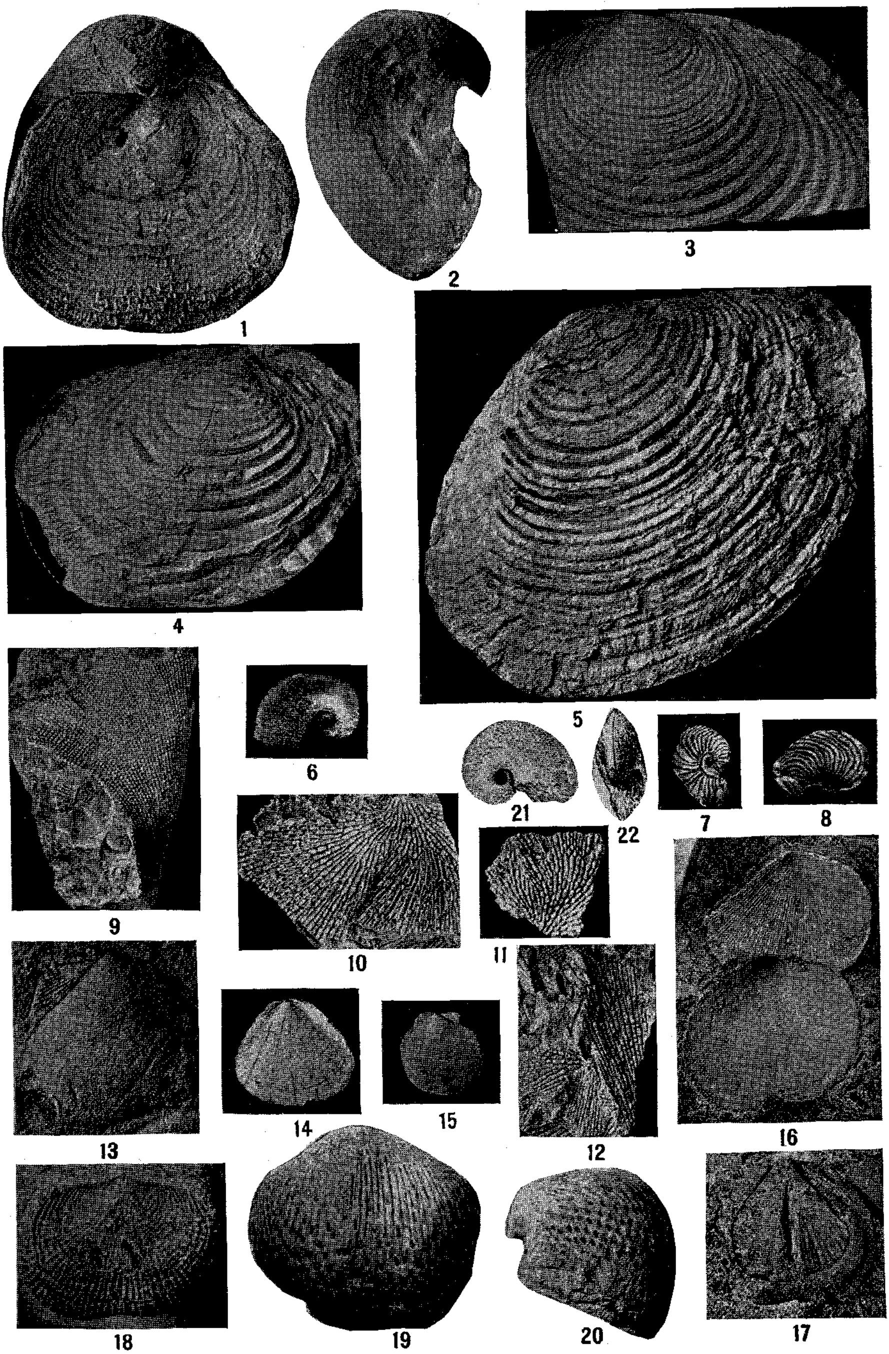
15, 16, × 4. 15, part of an external mold to show striae; 16, impression of the external mold of another specimen; 17, internal mold of a dorsal valve; 18, impression of the external mold of a ventral valve. 16, New Providence formation; about 1 mile south of Morehead, Rowan County, Ky.; 15, 17, 18, Price formation; 1¾ miles southwest of Bandy, Tazewell County. U. S. N. M. 98065, 98061a, 98061b, 98061c.

19–22. *Euphemites galericulatus* (Winchell).

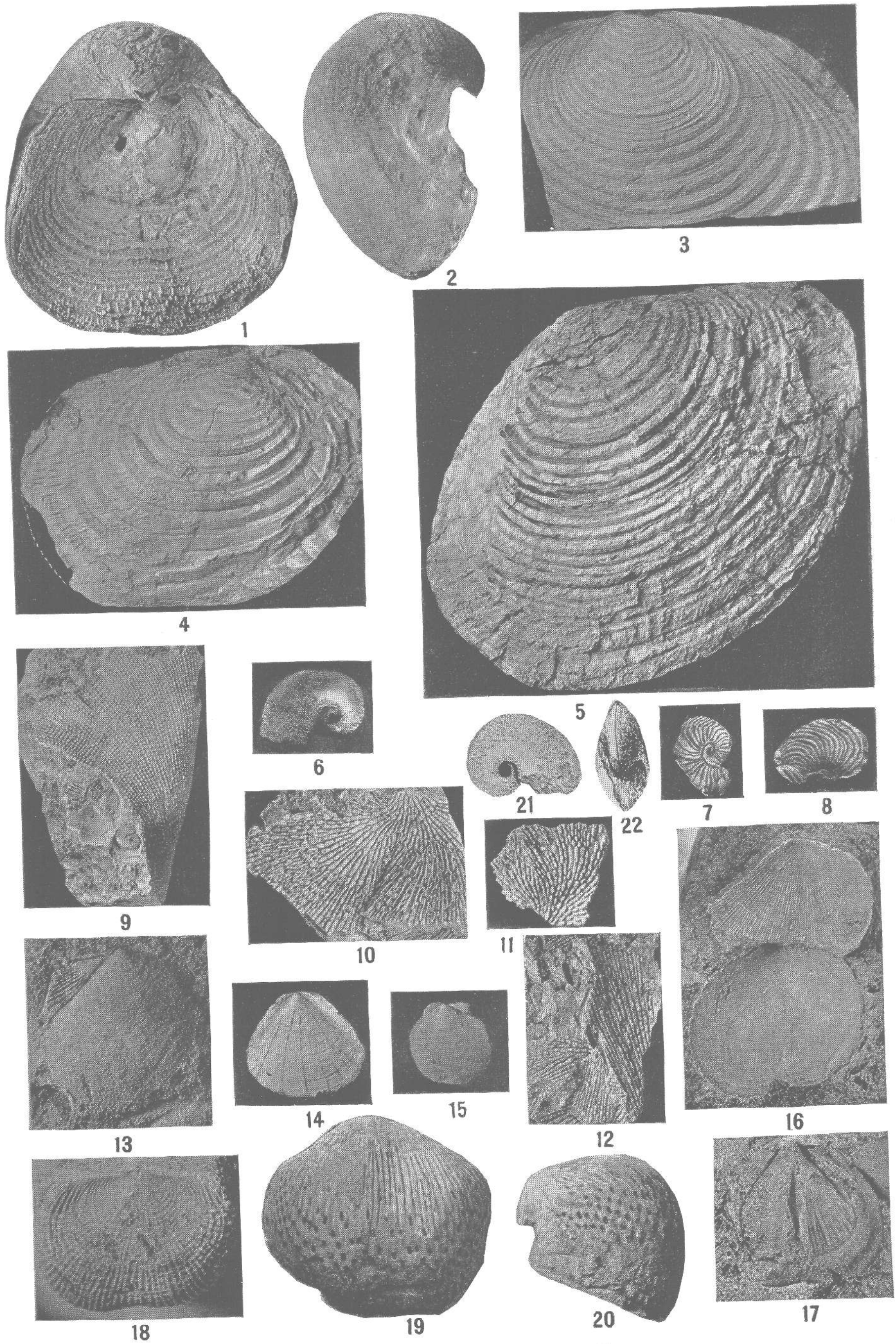
19, drawing representing the external shape and markings, dorsal view. (After Herrick, Bull. Denison Univ., Jour. Sci. Labs., vol. 3, pl. 9, fig. 32a, 1888); 20, internal mold, side view, preserves faint lines as in 19; 21, external mold, dorsal view, concave toward the observer, × 2. The parallel lines are furrows made by ridges on the outside of the shell. 22, internal mold (above) and external mold (below). 19, Cuyahoga formation; Licking County, Ohio; 20-22, Price formation. 20, 21, along Lee Highway about three-fourths of a mile south of the Norfolk and Western Railway station at Pulaski; 22, same locality as 12. This species is fairly common in the marine Price of southwestern Virginia. It is also said to be common in Licking County, Ohio. The type specimens were obtained from the Marshall group of Michigan. 20-22, U. S. N. M. 98062a, 98062b, 98063.

23. *Leiorhynchus?*, apparently an undescribed species.

Occurrence as 7. U. S. N. M. 98064.



PRICE, WARSAW, AND ST. LOUIS FOSSILS



PRICE, WARSAW, AND ST. LOUIS FOSSILS

PLATE 126.—PRICE, WARSAW, AND ST. LOUIS FOSSILS

FIGURE

1. *Echinoconchus alternatus* (Norwood and Pratten).
   Dorsal view. Warsaw formation; 3 miles east of Union, Monroe County, W. Va. U. S. N. M. 98066.

2. *Productus* (*Dictyoclostus*) *inflatus* McChesney?
   Profile view. St. Louis limestone; Little Stone Gap, Wise County. (See pl. 128, figs. 1-8.) U. S. N. M. 98067a.

3–5. *Posidonomya* or *Caneyella?* sp.
   3, left valve; 4, 5, right valves. Warsaw formation; along railroad about half a mile south of Mathieson Alkali Works, Saltville, Smyth County. U. S. N. M. 98068a, 98068b, 98068c.

6–8. *Oxydiscus cyrtolites* (Hall).
   6, internal mold, side view; 7, 8, impressions of external molds. Price formation; shale pit 1 mile west of railroad station at Richlands, Tazewell County. This is another characteristic Cuyahoga fossil occurring commonly in the Price of southwestern Virginia but generally in a fragmentary condition. U. S. N. M. 98069a, 98069b, 98069c.

9. *Fenestrellina tenax* (Ulrich).
   External mold of the non-celluliferous surface. Price formation; Pine Mountain 2 miles east of Cassard, Scott County. U. S. N. M. 98070.

10, 11. *Fenestrellina regalis* (Ulrich)?
   External molds of the non-celluliferous surface. Occurrence as 9. U. S. N. M. 98071a, 98071b.

12. *Fenestrellina herrickana* (Ulrich).
   External mold of the non-celluliferous surface. Occurrence as 9. U. S. N. M. 98072.

13–15. *Streblopteria media* Herrick?
   13, left valve; 14, 15, right valves, anterior ears partly broken away. Price formation (Maccrady?); 500

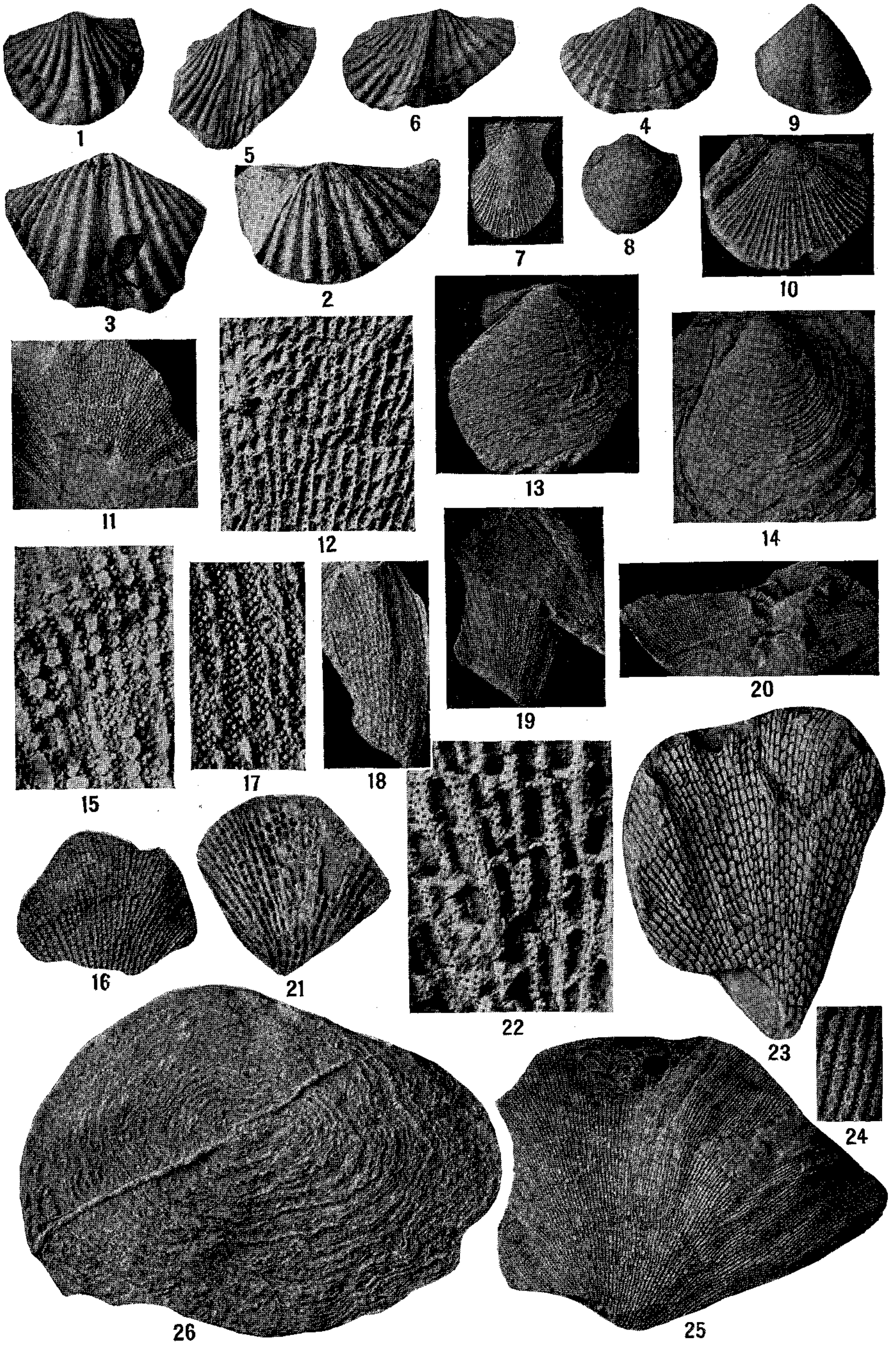
FIGURE

feet west of Sunbright station (Hortons Summit) on the Southern Railway at south end of Powell Mountain, Scott County. U. S. N. M. 98073a, 98073b, 98073c.

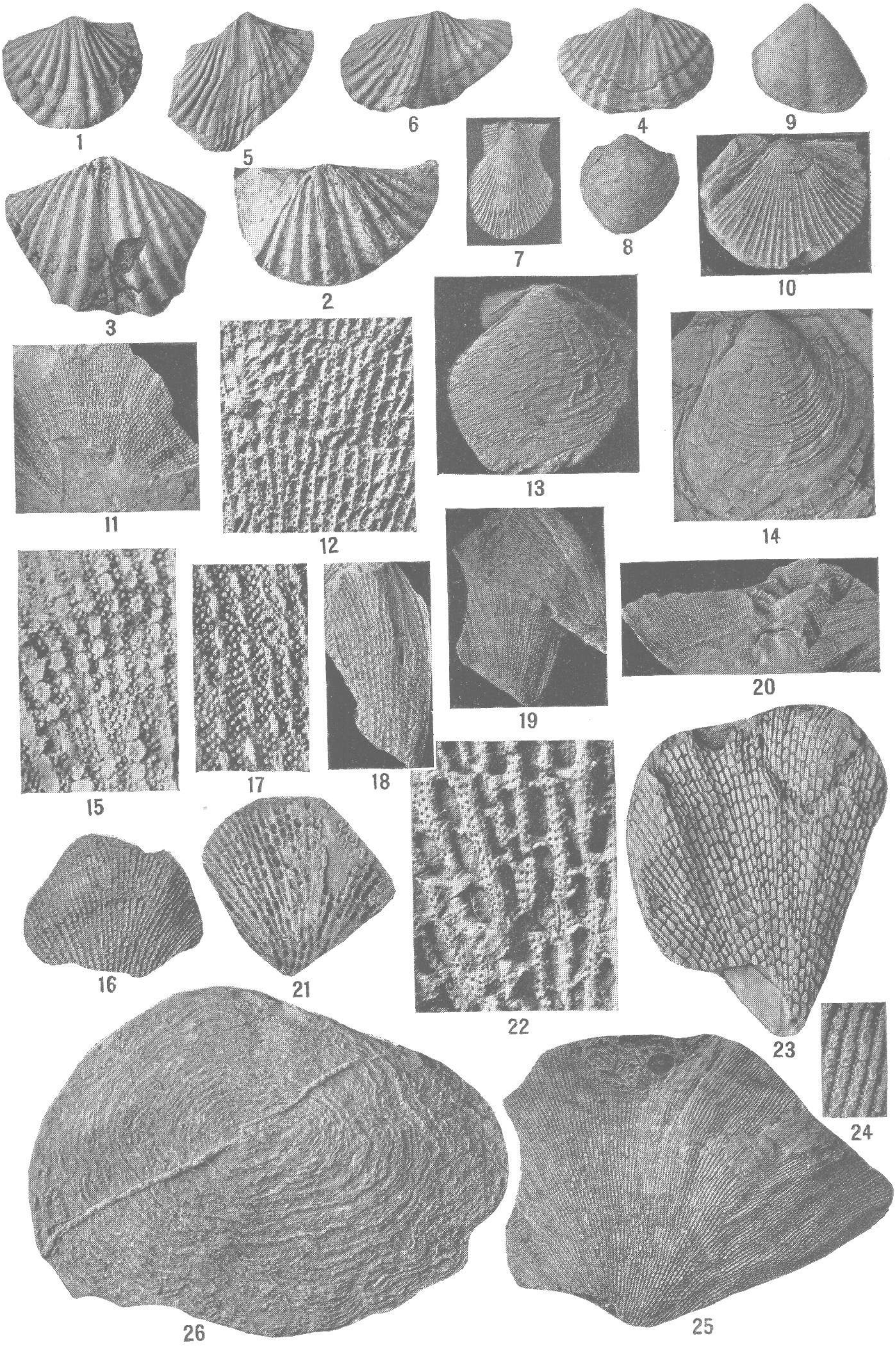
16, 17. *Rhipidomella oweni* Hall and Clarke.
16, external molds of ventral valves; 17, internal mold of a ventral valve. Price formation; along U. S. Route 19 about 2 miles west of Bluefield, Va. 16, U. S. N. M. 98074a, 98074b; 17, 98074c.

18–20. *Productus* (*Dictyoclostus*) *burlingtonensis* Hall.
18, external mold of a dorsal valve; 19, 20, ventral and profile views of an internal mold of a ventral valve. Occurrence as 16. 18, U. S. N. M. 98075a; 19, 20, 98075b.

21, 22. *Oxydiscus cyrtolites* (Hall).
Side and edge views. Cuyahoga formation; Licking County, Ohio. (After Herrick, Denison University Bull., Jour. Sci. Labs., vol. 3, pl. 2, fig. 27, 1888.)



WARSAW AND ST. LOUIS FOSSILS



Warsaw and St. Louis Fossils

PLATE 127.—WARSAW AND ST. LOUIS FOSSILS

FIGURE

1–4. *Spirifer bifurcatus* Hall.

1, dorsal valve; 2-4, ventral valves. 1-3, St. Louis limestone. 1, 2, about 2 miles southwest of Bandy, Tazewell County; 3, one-fourth of a mile south of Adria, Tazewell County; 4, Warsaw limestone; along river bluff 1 mile east of Saltville, Smyth County. U. S. N. M. 98076a, 98076b, 98077, 98078.

5, 6. *Spirifer leidyi* Norwood and Pratten.

Ventral and dorsal valves. Occurrence as 4. U. S. N. M. 98079a, 98079b.

7. *Aviculopecten?* sp.

Warsaw limestone; near river about 1½ miles northwest of Blackwell, Washington County. U. S. N. M. 98080.

8. *Cliothyridina hirsuta* (Hall).

Warsaw limestone; about 1 mile west of Ravens Nest and 3 miles northeast of Mendota, Washington County. U. S. N. M. 98081.

9. *Composita trinuclea* (Hall).

Occurrence as 8. U. S. N. M. 98082.

10. *Aviculopecten monroensis* Worthen?

Occurrence as 7. U. S. N. M. 98083.

11, 12. *Fenestrellina serratula* (Ulrich).

11, external mold of the celluliferous surface in shale; 12, impression of part of 11, × 4. Occurrence as 4. U. S. N. M. 98084a.

13. cf. *Aviculopecten?* sp.; possibly *Crenipecten,* × 2.

Internal mold of a ventral valve. Another small specimen shows faint radiating striae. Occurrence as 7. U. S. N. M. 98085.

14. *Aviculopecten?* sp.; possibly *Crenipecten.*

Warsaw limestone; along railroad half a mile southwest of Mathieson Alkali Works, Saltville, Smyth County. U. S. N. M. 98086.

FIGURE

15, 16. *Polypora biseriata* Ulrich.

External mold of the celluliferous face. 15, part of 16, ×4. Occurrence as 4. U. S. N. M. 98087.

17, 18. *Polypora varsoviensis* Prout.

External mold of the celluliferous face. 17, part of 18, × 4. Contains more rows of pores than *P. biseriata*. Occurrence as 4. U. S. N. M. 98088.

19. *Fenestrellina serratula* (Ulrich)?

Seems to vary slightly from *F. serratula* in size of fenestrules. Occurrence as 4. U. S. N. M. 98089.

20. *Fenestrellina tenax* (Ulrich).

Also *F. serratula* (right). The difference in the size of the fenestrules in *F. tenax* and *F. serratula* is shown by these figures. Occurrence as 4. U. S. N. M. 98090.

21–23. *Fenestralia sancti-ludovici* Prout.

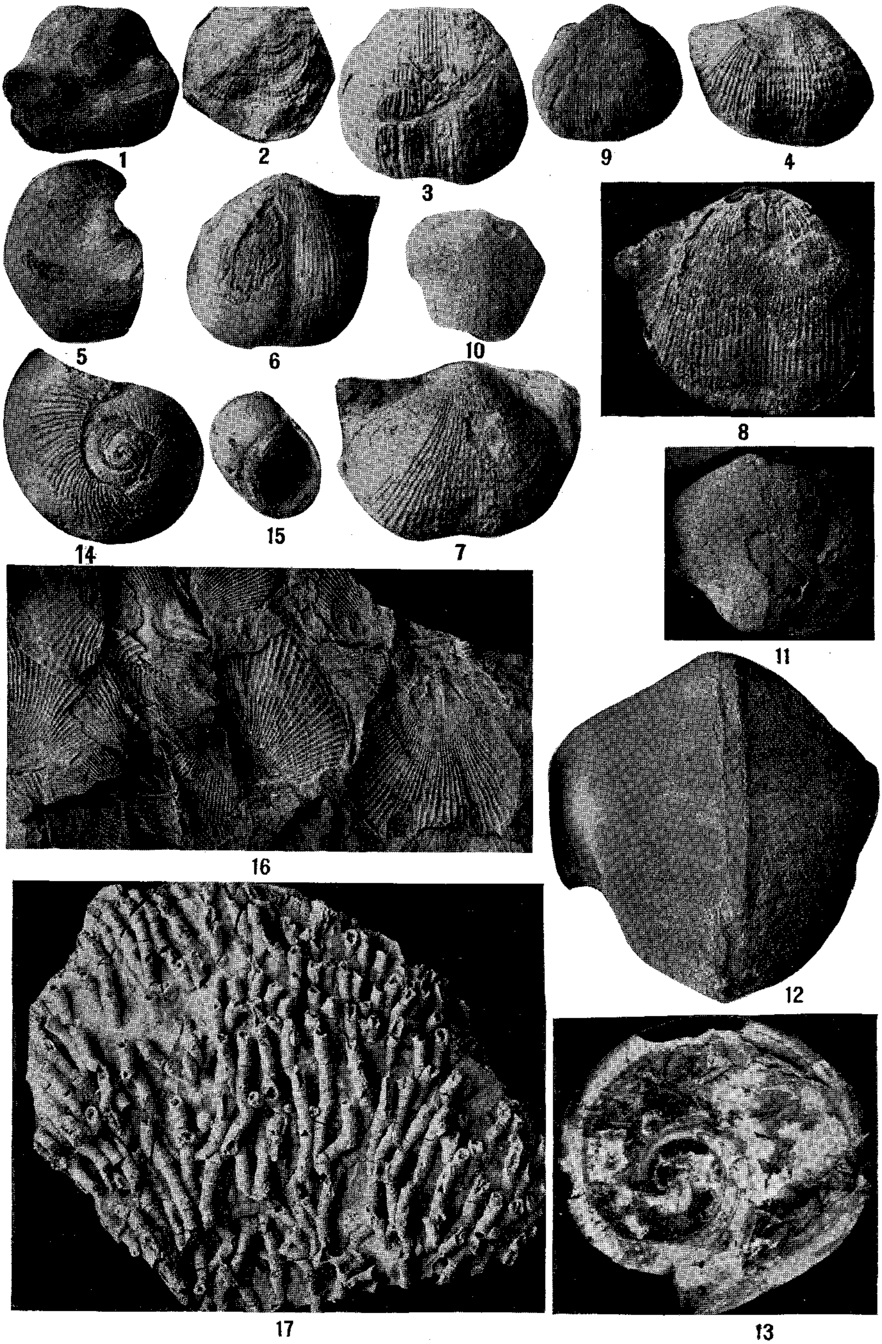
21, impression of an external mold of the celluliferous surface; 22, part of the same, × 4; 23, external mold of the noncelluliferous surface. Distinguished from *Fenestrellina* by having two rows of cells on each side, and from *Polypora* by having a distinct crest, or carina (shown faintly in 22) separating the pairs of cell rows. A guide fossil of the Warsaw limestone. Occurrence as 4. 21, 22, U. S. N. M. 98091a; 23, 98091b.

24, 25. *Fenestrellina serratula* (Ulrich).

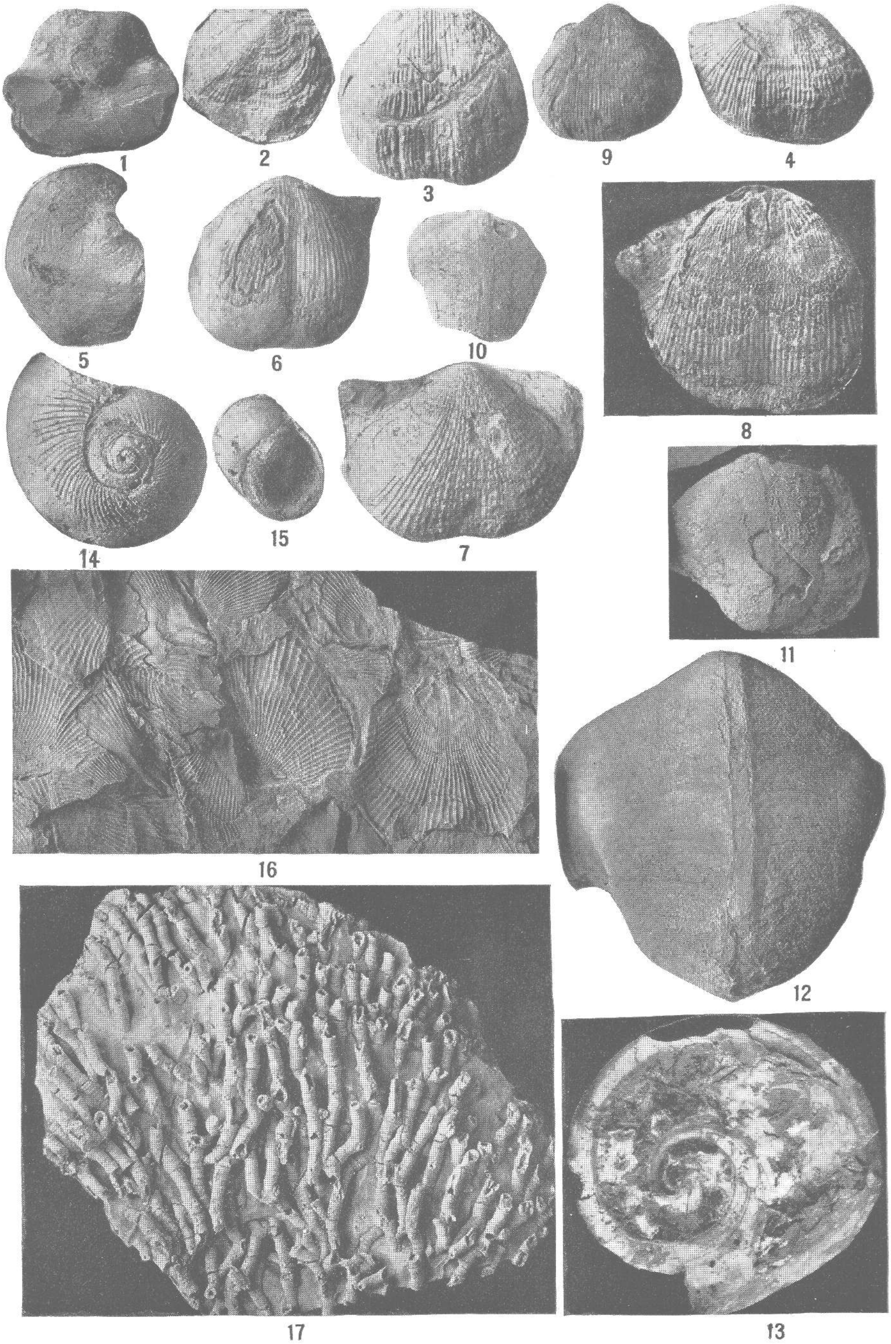
External molds of the celluliferous surface in shale. 24, part of 25, × 4. Occurrence as 4. U. S. N. M. 98084b.

26. Calcareous algae; genus and species undetermined.

St. Louis limestone; along State Route 82 about 1¼ miles northwest of Cleveland, Russell County. Common, locally abundant, in the St. Louis in southwestern Virginia. A layer several inches thick in the quarry at the Mathieson Alkali Works, Saltville, is made up largely of these forms. U. S. N. M. 40248.



WARSAW AND ST. LOUIS FOSSILS



WARSAW AND ST. LOUIS FOSSILS

PLATE 128.—WARSAW AND ST. LOUIS FOSSILS

FIGURE

1–8. *Productus* (*Dictyoclostus*) *inflatus* McChesney?

1, posterior view of a ventral valve; 2, external mold of a dorsal valve; 3, 4, 6-8, ventral valves; 5, profile view of 6. 1-7, St. Louis limestone. 1-4, along State Route 80 just south of Holston River and 1½ miles northwest of Lindell, Washington County; 5, 6, 1⅛ miles south of Big Moccasin Gap, Scott County; 7, Little Stone Gap, Wise County; 8, Warsaw limestone; along road just north of Holston River opposite the mouth of Finley Creek and 2 miles southwest of Hayter Gap village, Washington County. 1-4, U. S. N. M. 98093a, 98093b, 98093c, 98093d; 5, 6, 98094; 7, 8, 98067b, 98095.

9. *Productus* (*Linoproductus*) *altonensis* Norwood and Pratten?

Ventral valve. St. Louis limestone; 2 miles southwest of Bandy, Tazewell County. U. S. N. M. 98096.

10–13. *Bellerophon sublaevis* Hall.

10, fragment of a specimen of about the usual size; 11, fragment of a larger specimen; 12, a very large, nearly complete specimen; 13, section through the middle of a specimen. All completely silicified. St. Louis limestone; along road about 1 mile northwest of Bandys Chapel (Baptist Valley), Tazewell County. U. S. N. M. 98097a, 98097b, 98097c, 98097d.

14, 15. *Strophostylus carleyanus* (Hall).

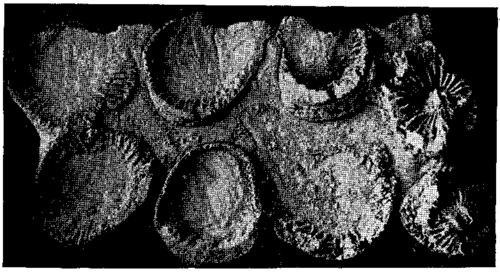
14, × 2. Apical and apertural views of the same specimen. Occurrence as 10. U. S. N. M. 98098.

16. *Tetracamera?* sp.

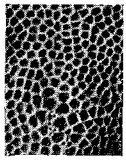
Slab with several specimens. In bed of black shale about 20 feet thick in the Warsaw limestone, 100 feet below the St. Louis limestone; along U. S. Route 19 about one-eighth of a mile south of bridge over Holston River and 2 miles northwest of Greendale, Washington County. U. S. N. M. 98099.

17. *Syringopora virginica* Butts, n. sp.

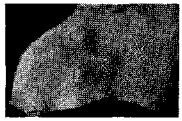
Moderately dense, somewhat irregularly branching corallites 1.5 mm. in diameter. In the mature portions the corallites are subparallel and separated from each other by about twice the width of the individual coralites. They commonly send out a branch every 4 to 6 mm. Very similar to a specimen in the National Museum labeled as *S. ramulosa* (name preoccupied), from the St. Louis limestone at Glasgow Junction, Ky. This is the most common fossil in the St. Louis limestone in Virginia, occurring on the weathered surface of the black limestone in most exposures, often in the same layers with *Lithostrotionella,* and also where *Lithostrotionella* is absent. As no *Syringopora* has been noted in any other formation in Virginia, it is a guide fossil of the St. Louis in the State. St. Louis limestone; along State Route 82 about 1¼ miles northwest of Cleveland, Russell County. Holotype: U. S. N. M. 98100. Description by Josiah Bridge.



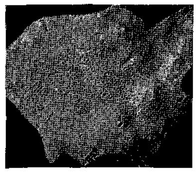
1



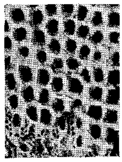
4



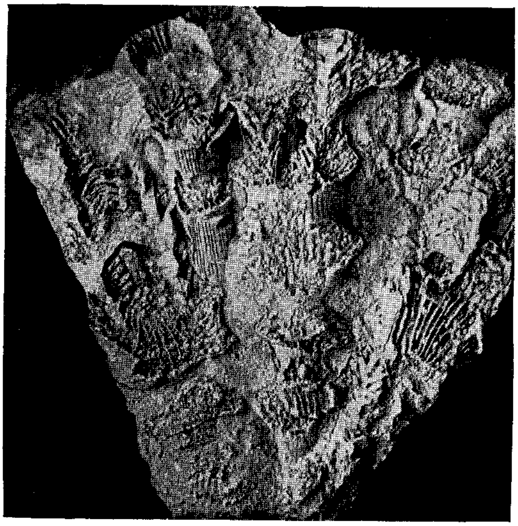
5



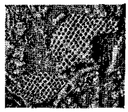
10



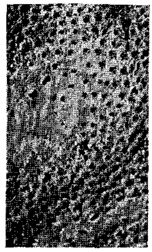
7



2

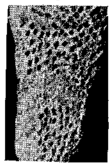


6

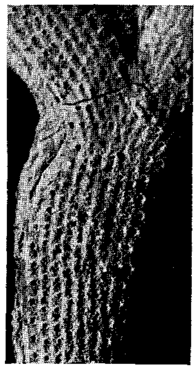


11

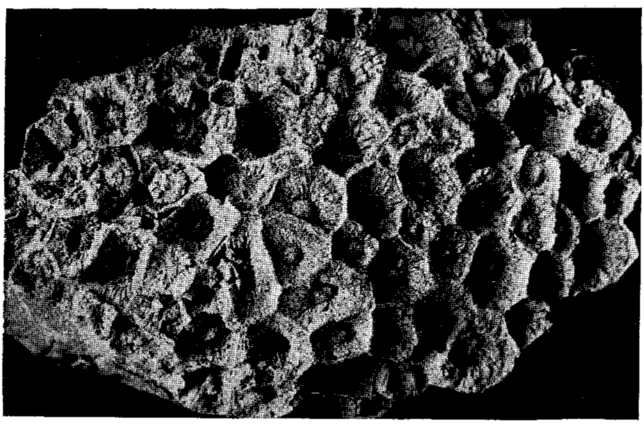
8



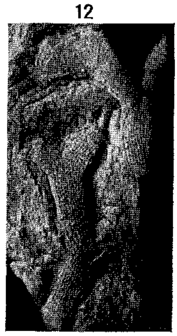
9



12

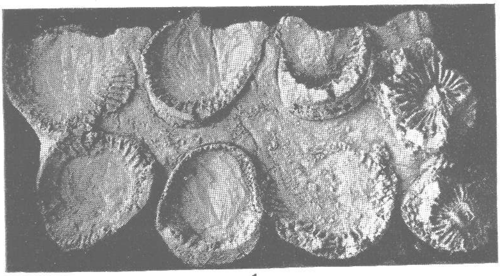


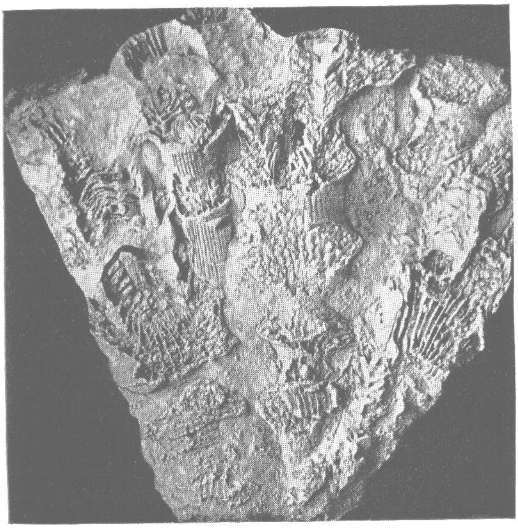
3

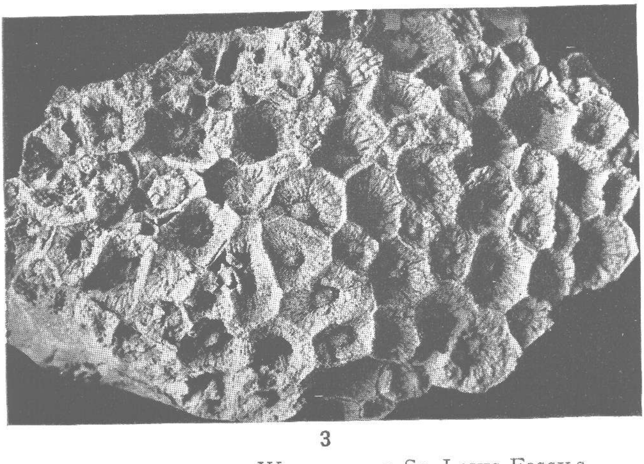


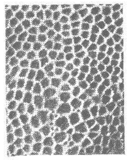
13

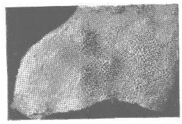
Warsaw and St. Louis Fossils

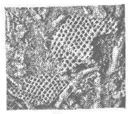

1

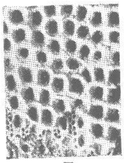

2

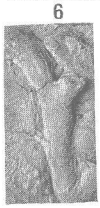

3

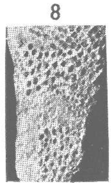

4

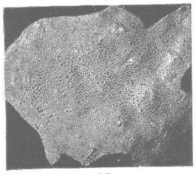

5

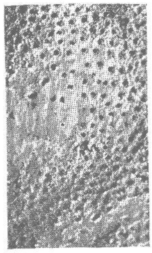

6

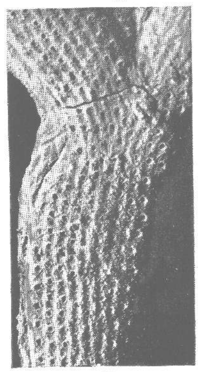

7

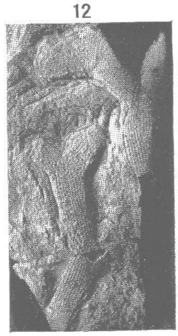

8


9


10


11


12


13

Warsaw and St. Louis Fossils

PLATE 129.—WARSAW AND ST. LOUIS FOSSILS

FIGURE

1, 2. *Lithostrotionella prolifera* (Hall).

1, calycinal view; 2, side and sectional view. Note that the cylindrical coralites are not in contact. St. Louis limestone; just south of Adria and 4 miles north of Tazewell, Tazewell County. U. S. N. M. 98101a, 98101b.

3. *Lithostrotionella "canadensis"* (Castelnau).

Calycinal view. Note that the polygonal coralites are in contact. St. Louis limestone; along State Route 82 about 1¼ miles north of Cleveland, Russell County. *Lithostrotionella prolifera* and *L. "canadensis"* are the chief guide fossils of the St. Louis limestone. U. S. N. M. 98102.

4, 5. *Tabulipora tuberculata* (Prout).

4, part of 5, × 4. Warsaw limestone; one-fourth of a mile east of Ravens Nest and 4 miles northeast of Mendota, Washington County. U. S. N. M. 98103.

6, 7. *Hemitrypa proutana* Ulrich.

6, noncelluliferous side; 7, part of 6, × 4, showing cells at bottom. Occurrence as 4. U. S. N. M. 98104.

8, 9. *Rhombopora simulatrix* Ulrich?

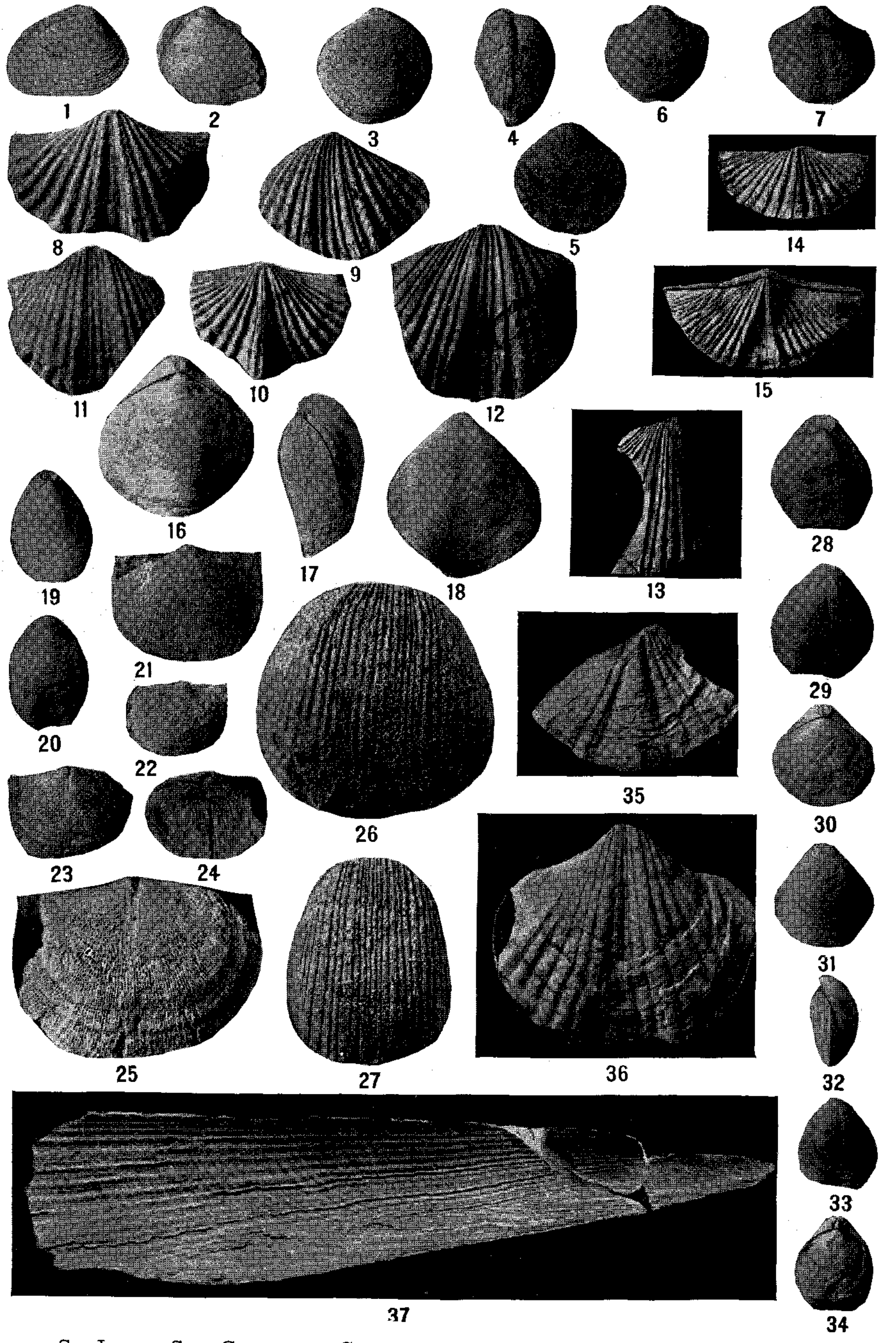
9, part of 8, × 4. Warsaw limestone; along U. S. Route 19 just south of bridge over Holston River and 2 miles northwest of Greendale, Washington County. U. S. N. M. 98105.

10, 11. *Dichotrypa flabellum* (Rominger).

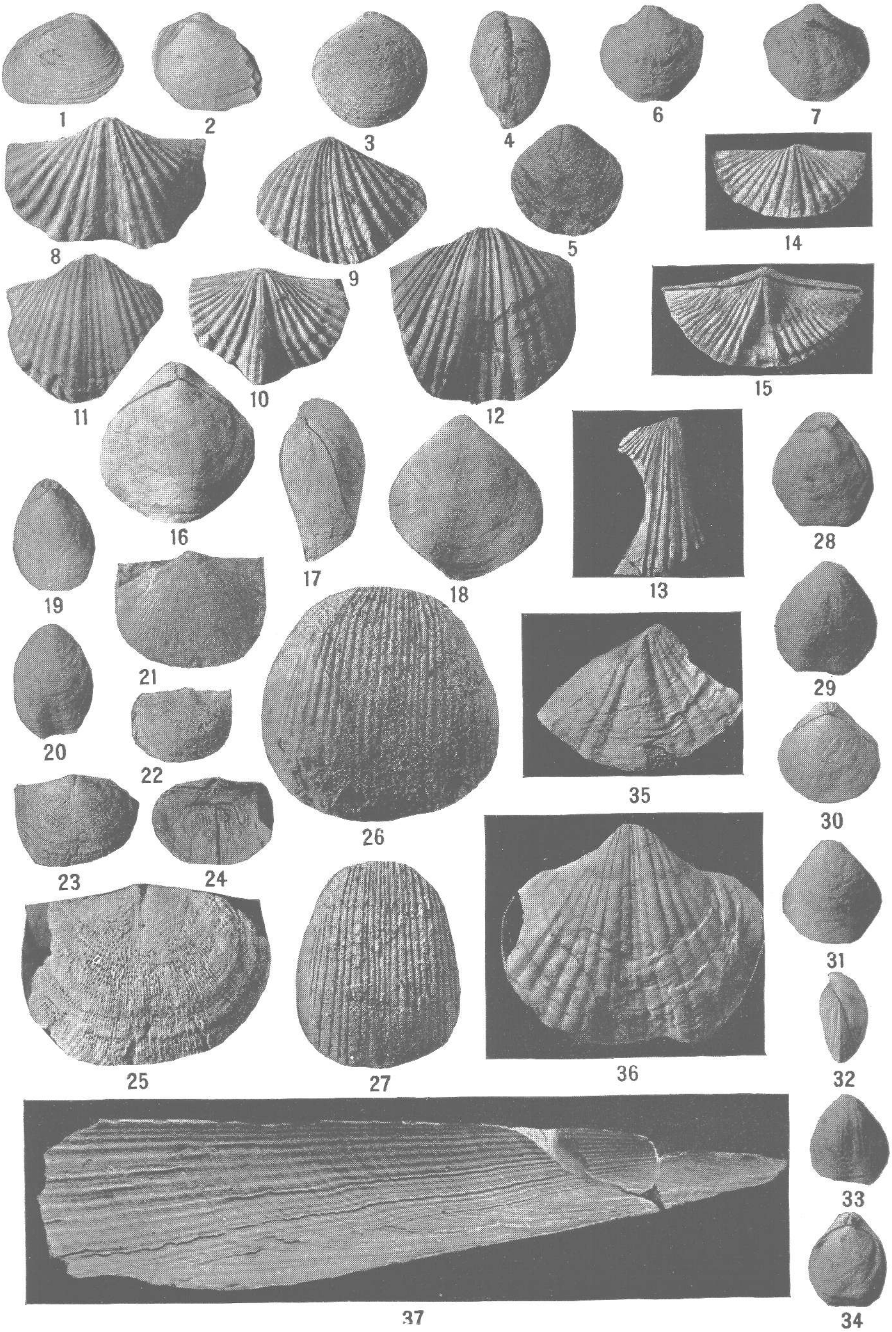
11, part of 10, × 4. St. Louis limestone; along State Route 80 just south of Holston River and 1½ miles northwest of Lindell, Washington County. U. S. N. M. 98106.

12, 13. *Cystodictya lineata* Ulrich.

12, part of 13, × 4. Warsaw limestone; along bluff by riverside about 1 mile northeast of the railroad station at Saltville, Smyth County. U. S. N. M. 98107.



ST. LOUIS, STE. GENEVIEVE, GASPER, GLEN DEAN, AND PENNINGTON FOSSILS



ST. LOUIS, STE. GENEVIEVE, GASPER, GLEN DEAN, AND PENNINGTON FOSSILS

PLATE 130.—ST. LOUIS, STE. GENEVIEVE, GASPER, GLEN DEAN, AND PENNINGTON FOSSILS

FIGURE

1, 2. *Astartella?* sp.

Right and left valves. St. Louis limestone; 1⅛ miles south of Big Moccasin Gap, Scott County. U .S. N. M. 98108a, 98108b.

3–7. *Cliothyridina sublamellosa* (Hall).

3-5, dorsal, profile, and ventral views of a specimen; 6, 7, dorsal and ventral views of another specimen. 3-5, Gasper limestone; three-fourths of a mile south of Union, Monroe County, W. Va.; 6, 7, Pennington formation; along U. S. Route 19 half a mile northwest of Greendale, Washington County. 3-5, U. S. N. M. 98109; 6, 7, 98110.

8–10. *Spirifer leidyi* Norwood and Pratten.

8, 9, ventral valves; 10, dorsal valve. St. Louis limestone; along road about 1 mile northwest of Baptist Valley, Tazewell County. Associated with *Lithostrotionella prolifera*. U. S. N. M. 98111a, 98111b, 98111c.

11–13. *Spirifer increbescens* Hall.

11, 12, ventral valves; 13, fragment of a dorsal valve. Glen Dean limestone; along Southern Railway in the gorge of Powell River about 1 mile northwest of the town of Big Stone Gap, Wise County. U. S. N. M. 98112a, 98112b, 98112c.

14, 15. *Spiriferina transversa* (McChesney).

Dorsal and ventral valves. Occurrence as 11. U. S. N. M. 98113, 98114.

16–18. *Composita subquadrata* (Hall).

Dorsal, profile, and ventral views of a whole specimen. Occurrence as 11. U. S. N. M. 98115.

19, 20. *Dielasma arkansanum* Weller.

Dorsal and ventral views of a whole specimen. Occurrence as 6. U. S. N. M. 98116.

21–25. *Chonetes chesterensis* Weller.

21, ventral valve preserving the shell, × 2; 22, internal mold of a ventral valve; 23, 24, ventral and dorsal views of an internal mold of a whole specimen; 25, same as

FIGURE

23, × 2. 21, 23-25, occurrence as 11; 22, Gasper limestone; about 1½ miles west of Bluefield, Va. 21, 22, U. S. N. M. 98119a, 98117; 23, 25, 98119b.

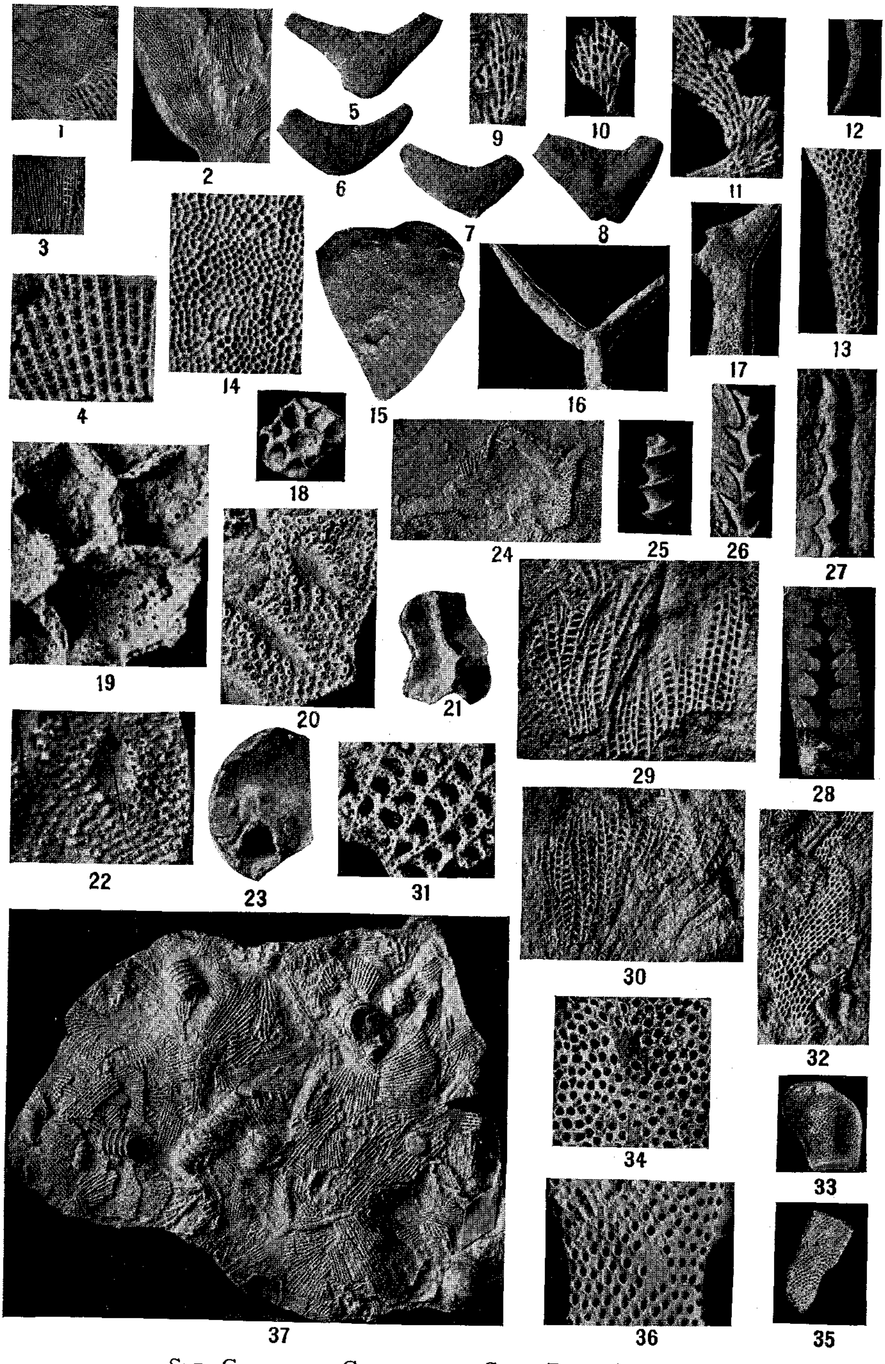
26. *Productus (Dictyoclostus) parvus* Meek and Worthen, × 2. Ventral valve. Ste. Genevieve limestone; along U. S. Route 19 about 1½ miles west of Bluefield, Va. *Platycrinus penicillus* in the same bed. U. S. N. M. 98118.

27. *Productus (Dictyoclostus) scitulus* Meek and Worthen, × 2. Ventral valve. St. Genevieve limestone; along U. S. Route 19 about one-third of a mile south of bridge over Holston River and 1½ miles northwest of Greendale, Washington County. Associated with *Platycrinus penicillus*. U. S. N. M. 98120.

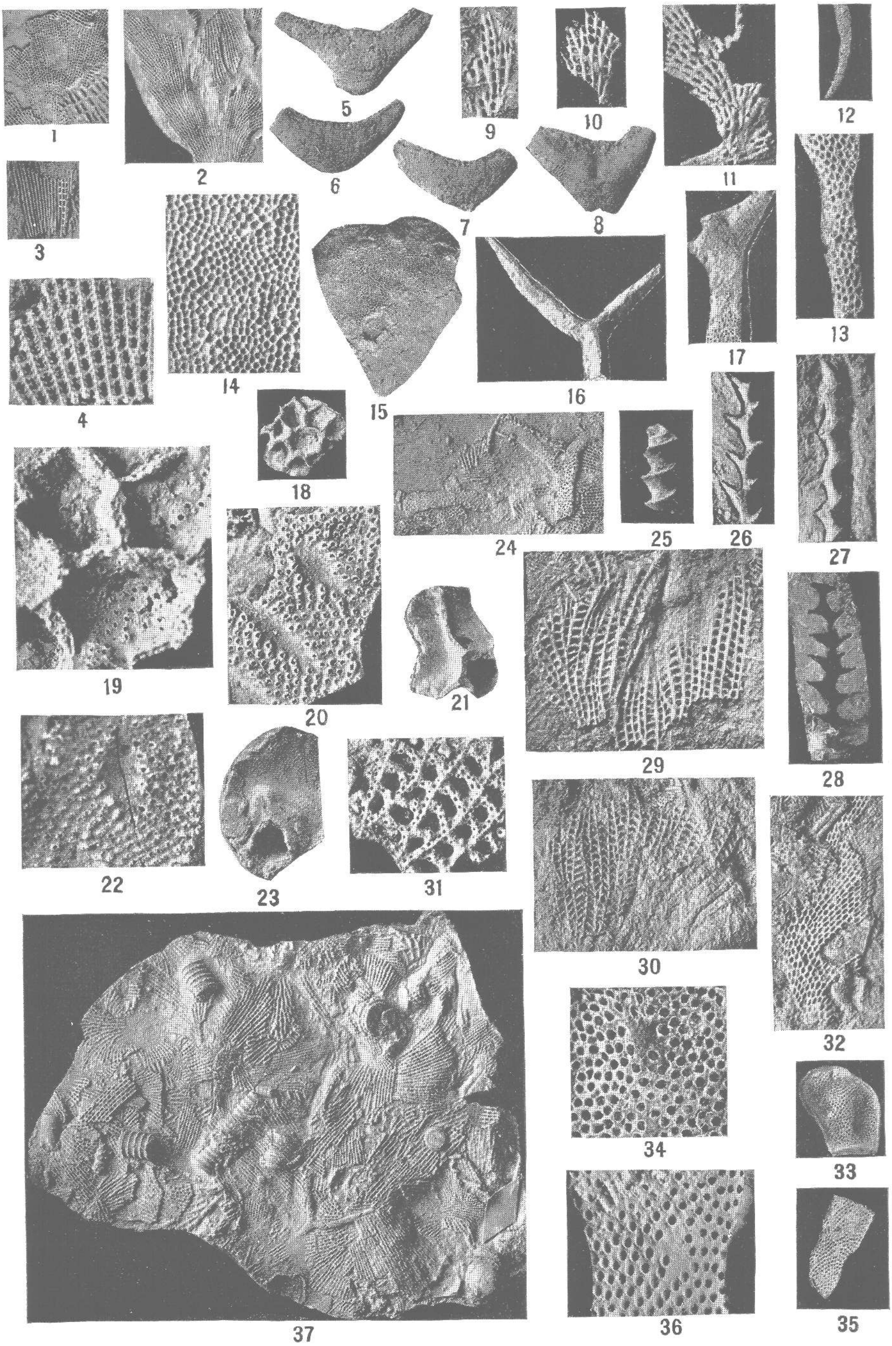
28–34. *Girtyella indianensis* (Girty)? 28-31, dorsal and ventral views of two whole specimens; 32-34, profile, ventral, and dorsal views of another specimen. Occurrence as 6. 28, 29, U. S. N. M. 98121a; 30, 31, 98121b; 32-34, 98121c.

35, 36. *Brachythyris chesterensis* Butts. 35, fragment of a dorsal valve; 36, ventral valve. Gasper limestone; Abbs Valley 1 mile east of Pocahontas, W. Va. U. S. N. M. 98122a, 98122b.

37. *Sulcatopinna missouriensis* (Swallow). External mold of a left valve. Pennington formation; railroad cut in gorge of Opossum Creek about 5 miles southwest of Gate City, Scott County. It also occurs on the Southern Railway one-fourth of a mile northeast of Benham, and at locality of 6. Washington County. U. S. N. M. 98123.



STE. GENEVIEVE, GASPER, AND GLEN DEAN FOSSILS



STE. GENEVIEVE, GASPER, AND GLEN DEAN FOSSILS

PLATE 131.—STE. GENEVIEVE, GASPER, AND GLEN DEAN FOSSILS

FIGURE

1, 2. *Fenestrellina tenax* (Ulrich).

Noncelluliferous and celluliferous surfaces. The smaller size of the fenestrules in this species than those in *F. serratula* can be seen by comparison with the retouched right side of 3. A small part of a species with larger fenestra, probably *F. cestriensis,* on lower margin. Gasper limestone; along U. S. Route 19 about 3 miles northeast of Bluefield, W. Va. U. S. N. M. 98124a, 98124b.

3, 4. *Fenestrellina serratula* (Ulrich).

External molds of the celluliferous surface showing the proximal parts of the matrix filling the cells. 4, part of 3, × 4. Occurrence as 1. U. S. N. M. 98125.

5–8. *Lyropora ranosculum* Ulrich.

Portions of the noncelluliferous U-shaped supporting arms of 4 specimens. The fenestrelinid network enclosed by the arms has been broken away. Gasper limestone; along U. S. Route 58 in the Greendale syncline near Gaines Chapel about 2 miles southeast of Hilton, Scott County. U. S. N. M. 98126a, 98126b, 98126c, 98126d.

9–11. *Polypora cestriensis* Ulrich.

9, 10, parts of the noncelluliferous sides of two specimens; 11, celluliferous side of another specimen. Occurrence as 1. U. S. N. M. 98127a, 98127b, 98127c.

12, 13. *Rhombopora* cf. *R. minor* Ulrich.

13, part of 12, × 2. Occurrence as 1. U. S. N. M. 98128.

14, 15. *Tabulipora tuberculata* (Prout).

14, part of 15, × 4. Glen Dean limestone; in face of the Pinnacle northwest of Cumberland Gap village, Tennessee. U. S. N. M. 98129.

16, 17. *Prismopora serrulata* Ulrich.

Two poorly preserved specimens but showing the characteristic cross section, and the celluliferous surface very faintly in 17. The triangular cross section is shown at the lower end of the specimen of 16. Occurrence as 14. Associated with *Pentremites canalis* and *Pentremites brevis.* U. S. N. M. 98130a, 98130b.

FIGURE

18, 19. *Glyptopora michelinia* (Prout).
19, part of 18, × 4. Gasper limestone; 1 mile east of Shrader, Tazewell County. U. S. N. M. 98131.

20–23. *Glyptopora punctipora* Ulrich?
21, 23, silicified fragments. Possibly specimen 21 is *G. michelinia*. 20, × 4; 22, part of 23, × 4. Gasper limestone. 20, along U. S. Route 19 (old location) 3 miles northeast of Bluefield, W. Va.; 21-23, same locality as 5. 20, U. S. N. M. 98133; 21, 98132a; 22, 23, 98132b.

24. *Cystodictya labiosa* Weller.
Occurrence as 1. U. S. N. M. 98134.

25. *Archimedes communis* Ulrich.
Occurrence as 14. U. S. N. M. 98135.

26, 27. *Archimedes distans* Ulrich, or *A. meekanus* (Hall).
Glen Dean limestone. 26, along Southern Railway in gorge of Powell River about 1 mile north of Big Stone Gap, Wise County; 27, same locality as 14. U. S. N. M. 98136, 98138.

28. *Archimedes proutanus* Ulrich.
Section through center of axis. Gasper? limestone; along Norfolk and Western Railway half a mile northeast of Bluefield, Va. U. S. N. M. 98139.

29, 30. *Septopora subquadrans* Ulrich.
Noncelluliferous and celluliferous surfaces. Occurrence as 26. U. S. N. M. 98140a, 98140b.

31. *Septopora cestriensis* Prout, × 4.
Gasper limestone; along U. S. Route 19 (old location) 3 miles northeast of Bluefield, W. Va. U. S. N. M. 98092.

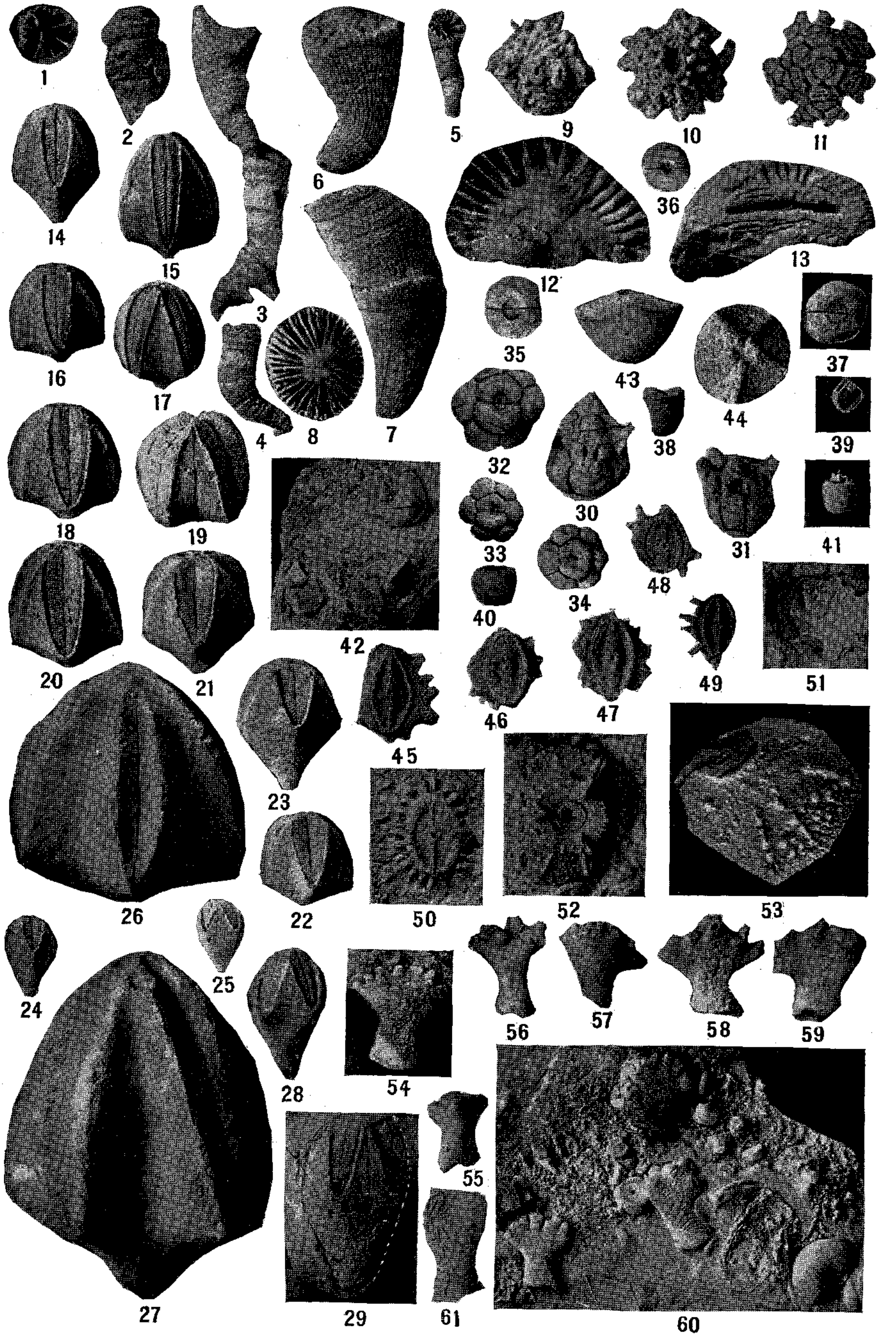
32. *Fenestrellina cestriensis* (Ulrich).
Noncelluliferous surface. Occurrence as 26. U. S. N. M. 98137.

33, 34. *Meekopora eximia* Ulrich.
34, part of 33, × 4. Gasper limestone; 3 miles northeast of Bluefield, W. Va. U. S. N. M. 98141.

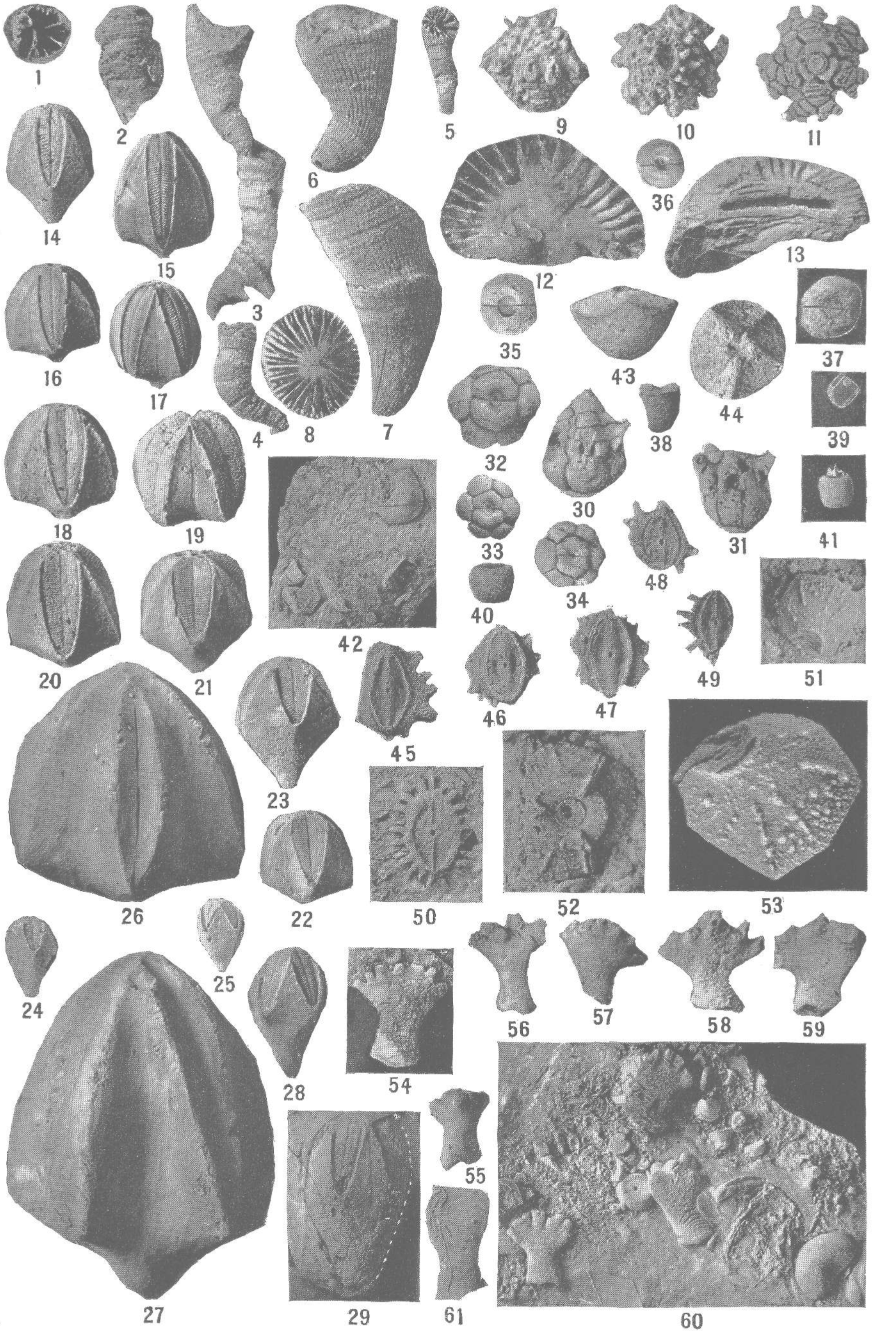
FIGURE

35, 36. *Meekopora clausa* Ulrich.
36, part of 35, × 4. Occurrence as 26. U. S. N. M. 98142.

37. Slab with *Fenestrellina,* mostly *F. tenax* and *F. serratula.* Occurrence as 33. U. S. N. M. 98143.



GASPER AND GLEN DEAN FOSSILS



GASPER AND GLEN DEAN FOSSILS

PLATE 132.—GASPER AND GLEN DEAN FOSSILS

FIGURE

1–5. *Cystelasma quinqueseptatum* Ulrich.

1, 5, calycinal views showing the principal septae; 5, calycinal view of 4; 2-4, side views of several specimens. Ste. Genevieve limestone; along road on Toole Creek 1¾ miles north of Whites Mill, Washington County. 1-3, U. S. N. M. 98144a, 98144b, 98144c; 4, 5, 98144d.

6–8. *Zaphrentis spinulosa* Milne-Edwards and Haime.

Gasper limestone; along U. S. Route 58 near Gaines Chapel, 2 miles southeast of Hilton, Washington County. U. S. N. M. 98145a, 98145b, 98145c.

9–11. *Globocrinus unionensis* (Worthen).

Side, dorsal, and basal views. Occurrence as 6. U. S. N. M. 98146.

12, 13. *Campophyllum? gasperense* Butts.

12, calycinal view; 13, side view of a fragment preserving a few tabulae and part of the calyx. Rare in Virginia. Gasper limestone; 1 mile east of Shraders, Tazewell County. U. S. N. M. 98147.

14. *Pentremites welleri* Ulrich.

Gasper limestone; quarry at Nemours, Mercer County, W. Va. U. S. N. M. 98148.

15. *Pentremites biconvexus* Ulrich.

Occurrence as 14. U. S. N. M. 98149.

16, 17. *Pentremites planus* Ulrich (*P. godoni* De France?)

Occurrence as 14. U. S. N. M. 98150a, 98150b.

18–20. *Pentremites "godoni"* Ulrich, not De France.

Gasper limestone. 18, same locality as 14; 19, 20, along road about 1 mile northwest of Bandys Chapel (Baptist Valley), Tazewell County. Depressed ambulacral areas, such as occur in this species, are practically absent from all *Pentremites* occurring below the Gasper limestone. As *P. "godoni"* is common and easily identifiable, it is a guide fossil of the Gasper. U. S. N. M. 98151, 98152a, 98152b.

FIGURE

21. *Pentremites canalis* Ulrich.
Glen Dean limestone; in face of the Pinnacle just northwest of the village of Cumberland Gap, Tenn. U. S. N. M. 98153.

22. *Pentremites brevis* Ulrich.
Occurrence as 21. U. S. N. M. 98154.

23. *Pentremites patei* Ulrich.
Occurrence as 14. U. S. N. M. 98155.

24, 25. *Pentremites pyriformis* Say?
Occurrence as 6. U. S. N. M. 98156a, 98156b.

26, 27. *Pentremites macalleyi* Schuchert.
Lower one-fourth of the Bluefield shale (Golconda horizon?); about 1 mile southwest of Glenlyn in Mercer County, W. Va. U. S. N. M. 98157a, 98157b.

28. *Pentremites pyramidatus* Ulrich.
Occurrence as 21. U. S. N. M. 98158.

29. *Pentremites gemmiformis* Hambach?
Gasper limestone; in Abbs Valley about 1 mile southwest of Boissevain, Tazewell County. U. S. N. M. 98159.

30–34. *Talarocrinus cornigerus* (Shumard).
30, 31, two crowns without the arms; 32-34, basal views of three specimens that may belong to this species showing row of six radial plates. The two semicircular, basal plates should be noted. Gasper limestone. 30-32, same locality as 14; 33, same locality as 29; 34, just north of U. S. Route 58 and 2 miles southwest of Fido, Scott County. U. S. N. M. 98160a, 98160b, 98160c, 98161, 98162.

35–42. *Talarocrinus,* species undetermined.
35-37, bases; 38-42, radial plates; 39, 42, (lower left), interior surfaces of radial plates. 41 retains the base of the arm. Gasper limestone. 35, 36, same locality as 29; 37, 42, along U. S. Route 19 (old location) 3 miles northeast of Bluefield, W. Va.; 38, 39, 41, along U. S. Route 19 about 1 mile northwest of Greendale, Washington County; 40, same locality as 14.

FIGURE

The genus *Talarocrinus* is not known to occur in beds as old as the Ste. Genevieve (Fredonia) limestone of Virginia and central and eastern Kentucky, nor in beds younger than the Gasper limestone anywhere. As the genus can be identified by the scattered U-shaped, radial plates or by single basal plates, it is a dependable guide fossil of the Gasper limestone east of central Kentucky. U. S. N. M. 98163a, 98163b, 98164a, 98165a, 98165b, 98166, 98165c, 98164b.

43, 44. *Agassizocrinus* cf. *A. ovalis* Miller and Gurley?

Side and ventral views of the infrabasal disc. Occurrence as 19. U. S. N. M. 98167.

45–53. *Platycrinus penicillus* Meek and Worthen=*P. huntsvillea* Wachsmuth and Springer.

All × 2 except 53. 45-50, stem plates; 51-53, parts of bases. 53, same as 51, × 4, differently posed. The elliptical, spiny stem plates and tricarinate bases are characteristic of this species. Ste. Genevieve (Fredonia) limestone. 45-49, along U. S. Route 19 about 1½ miles west of Bluefield, Va.; 50, top of Newman Ridge just west of Blackwater, Lee County; 51-53, slab along State Route 80 about 1 mile north of Lindell, Washington County. This is the main guide fossil of the Ste. Genevieve. The separated stem plates can commonly be found on weathered surfaces of limestone and are sufficient evidence of its Ste. Genevieve age. U. S. N. M. 98168a, 98168b, 98168c, 98168d, 98168e, 98169, 98170a, 98170b.

54–60. *Pterotocrinus serratus* Weller.

54-60, detached wing plates; 60 has also half of a base of *Talarocrinus*. Occurrence as 37. Widely distributed in the Gasper of southwest Virginia. It is another good guide fossil of the formation. U. S. N. M. 98171a, 98171b, 98171c, 98171d, 98171e, 98171f, 98172.

61. *Pterotocrinus spatulatus* Wetherby.

A detached wing plate. Occurrence as 21. U. S. N. M. 98173.

Price Plant Fossil

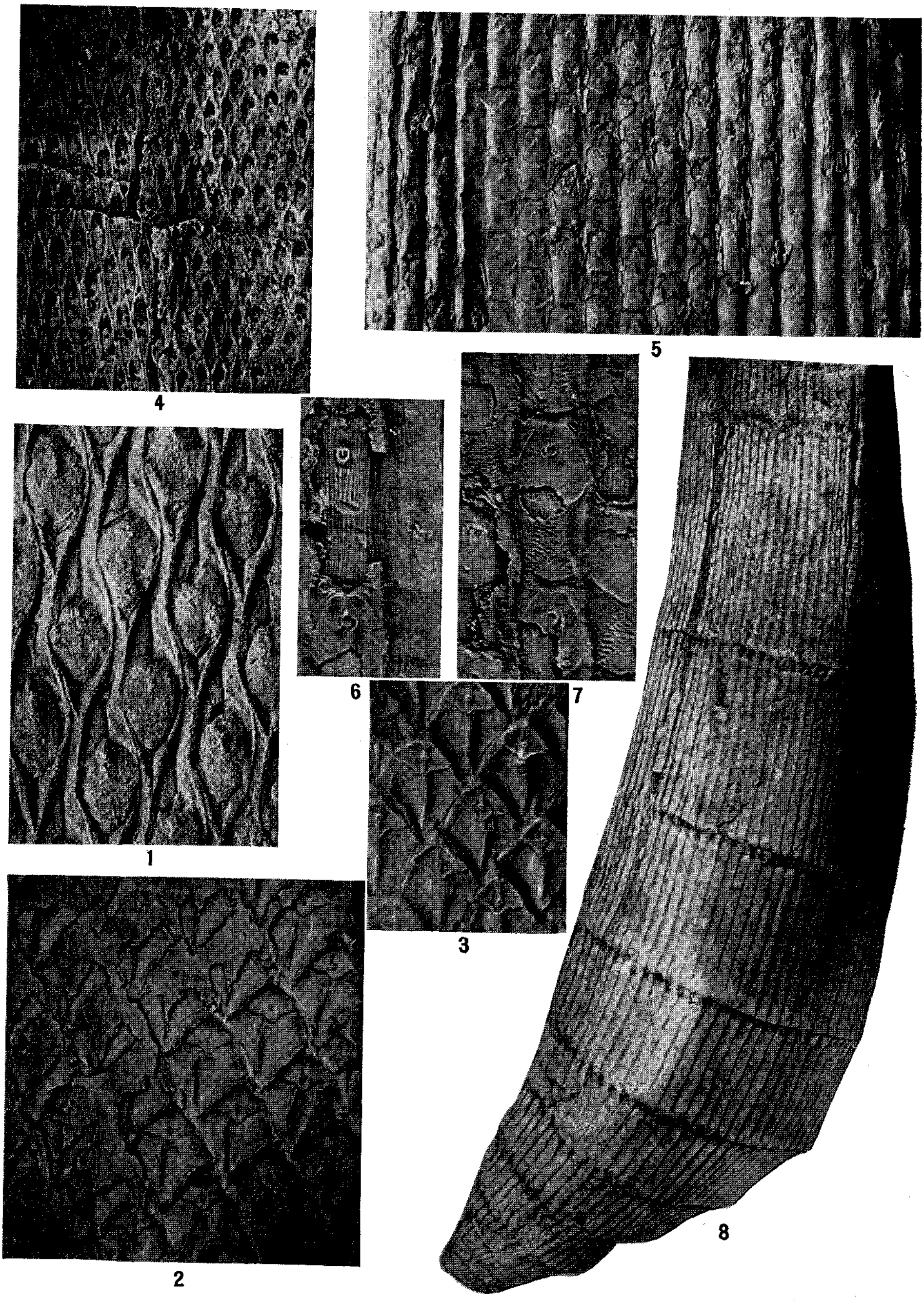
PRICE PLANT FOSSIL

PLATE 133.—PRICE PLANT FOSSIL

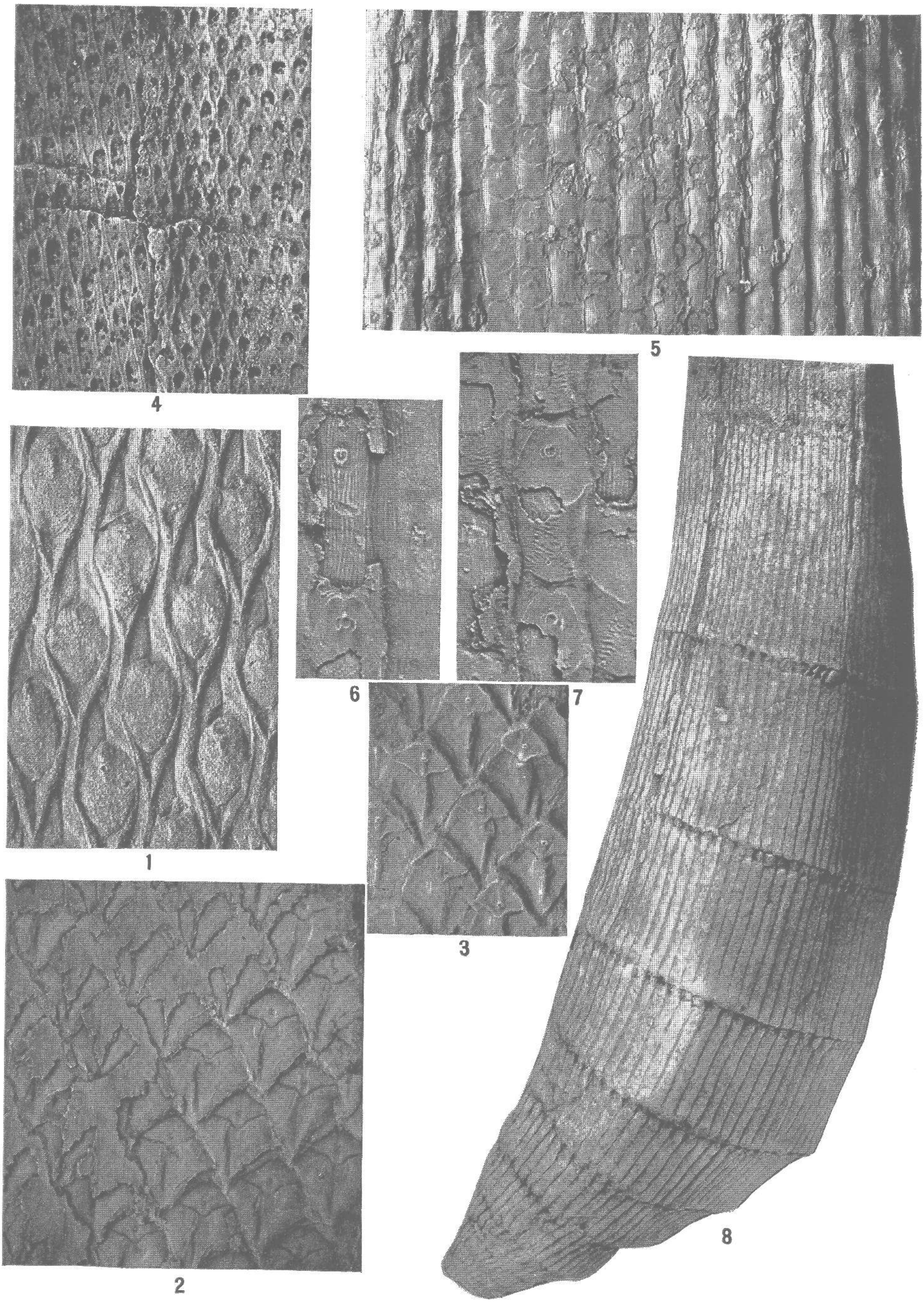
FIGURE

1. *Triphyllopteris lescuriana* (Meek).

Photograph of the type specimen, × ⅔; inset in upper left hand corner is a trilobate punule, × 4. Price formation; Lewis tunnel, three-fourths of a mile east of Alleghany Station, Alleghany County. U. S. N. M. 1447.



MISSISSIPPIAN AND PENNSYLVANIAN PLANT FOSSILS



Mississippian and Pennsylvanian Plant Fossils

PLATE 134.—MISSISSIPPIAN AND PENNSYLVANIAN PLANT FOSSILS

FIGURE

1. *Lepidodendron* sp.

The name means scale tree. Mold in sandstone of inside of stem showing the form and oblique arrangement of leaf bases characteristic of the genus. Compare this with the stem or branch of a pine tree and note the similarity to the diagonal rows of scars on the pine where the leaves have been shed. *Lepidodendron* has no relation to the pine; its nearest living relative is the common club moss (*Lycopodium*). The large oval bodies in the centers of the rhombic leaf cushions are produced by the adhesion of portions of the leaf cushions to the rock.

2, 3. *Lepidodendron obovatum* Sternberg.

2, external mold of a branch after the leaves had been shed. In places thin films of the carbonized bark, or cortex, are adhering. 3, wax squeeze of part of 2. This shows the actual external appearance of the stem after shedding the leaves. The small point in each leaf scar marks the spot where the midrib or central nerve emerged from the stem and entered the leaf.

4. *Lepidodendron scobiniforme* Meek.

External mold of a part of a stem. Price formation, Merrimac coal bed; Brushy Mountain north of Price Forks, Montgomery County. The small leaf scars are characteristic of the Pocono-Price species of *Lepidodendron*. U. S. N. M. 20348.

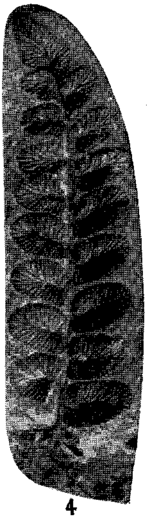
5–7. *Sigillaria mamillaris* Brongniart.

5, part of stem; 6-7, parts of 5, showing form and arrangement of the leaf bases, × 2. *Sigillaria* means seal tree from the resemblance of the leaf base scars to a seal. The distinguishing feature of this tree is the vertical parallel flutings of the stem and the arrangement of the leaves upon them in vertical rows instead of in oblique rows as in *Lepidodendron*. Other species of *Sigillaria* occur in the Coal Measures of Virginia.

8. *Calamites suckowi* Brongniart.

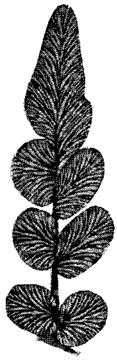
Internal mold of a hollow stem filled with sand. These are among the commonest of Coal Measures plants. They are related to the modern horsetails and scouring rushes (*Equisetum*). The characteristic features are the joints or nodes and the narrow fluting of the internodes. The small round impressions on the ribs just below the nodes are the scars left by the slender, and in some cases needle-like, leaves.

1

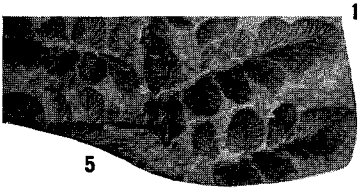


4

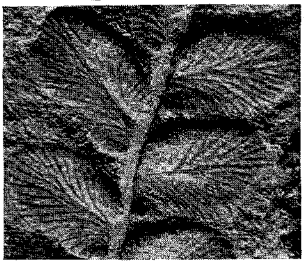
2



7



5

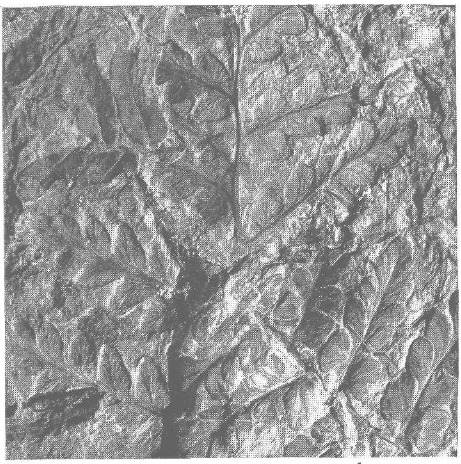


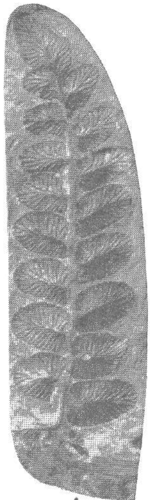
8

3

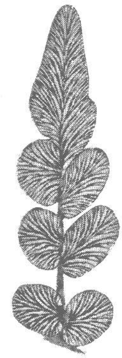
6

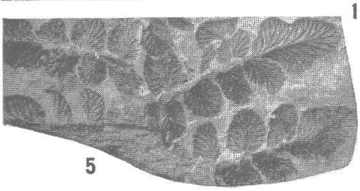
POTTSVILLE PLANT FOSSILS

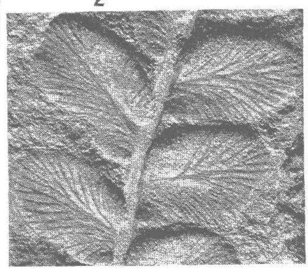

1

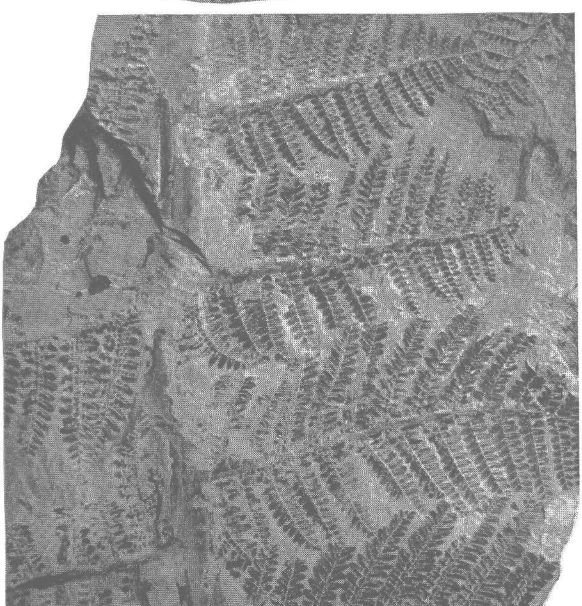

4

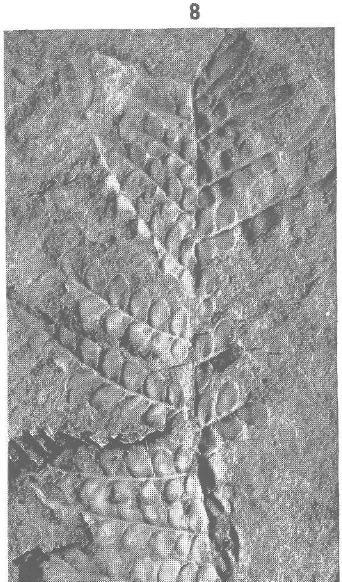

2


7


5


8


3


6

Pottsville Plant Fossils

PLATE 135.—POTTSVILLE PLANT FOSSILS

FIGURE

1, 2. *Mariopteris pottsvillea* D. White.

1, impression of a part of a frond in shale; 2, diagrammatic drawing (by David White) of a pinna, × 2. (From U. S. Geol. Survey 20th Ann. Rept., Pt. 2, pl. 190, fig. 3a.) Lower Pottsville. 1, Welch formation; three-fourths of a mile south of Squire Jim, McDowell County, W. Va.; 2, Lykens No. 4 coal, at Lincoln colliery in the southern anthracite coal basin, Pennsylvania. 1, U. S. N. M. 40247.

3–5. *Neuropteris smithii* Lesquereux.

3, × ⅓, part of a slab with an unusually large and well-preserved part of a frond; 4, × 2, enlargement of two pinnae showing the nervation of the pinnules; 5, × 2, enlargement of a small part to show the lobation of the pinnnules in some parts of the fronds. Black Creek coal bed; Warrior, Jefferson County, Ala. (University of Alabama collection.) Occurs in the lower and middle Coal Measures of Virginia.

6–8. *Neuropteris pocahontas* D. White.

6, impression of a part of a frond in shale; 7, diagrammatic drawing (by David White) of a pinna, × 2. (From U. S. Geol. Survey 20th Ann. Rept., Pt. 2, pl. 191, fig. 5a.) 8, part of a pinna of the original of 6 with several leaflets, × 4. Lower Pottsville. 6, 8, Fire Creek coal, Sewell, W. Va.; 7, Pocahontas coal, Gillam, W. Va. Reported in the Lee formation near Little Stone Gap, Wise County, Va. 6, 8, U. S. N. M. 40246.

INDEX

R

Z