COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE LEXINGTON QUADRANGLE VIRGINIA

KENNETH F. BICK

REPORT OF INVESTIGATIONS 1

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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Commonwealth of Virginia
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1960

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GEOLOGY OF THE LEXINGTON QUADRANGLE, VIRGINIA

By

KENNETH F. BICK

ABSTRACT

The rocks of the Lexington quadrangle, Virginia (bounded by parallels 37° 45′ and 38° 00′ and meridians 79° 15′ and 79° 30′) range in age from Precambrian to Middle Devonian. The metamorphic and igneous Precambrian basement is overlain by 2,500 feet of clastic rocks that contain interbedded volcanic material in the basal part; these rocks, Precambrian and Early Cambrian in age, represent a westward transgression of a sea across the area. This sequence is overlain by 10,000 feet of Early Cambrian to Middle Ordovician rocks, chiefly carbonate rocks that represent a period of offshore shallow water deposition. The Middle Ordovician to Middle Devonian sequence is composed largely of clastic rocks about 4,500 feet thick; the lower half of this sequence is chiefly sandstone and the upper half is chiefly shale. These clastic rocks represent debris eroded from mountainous areas east of the Lexington quadrangle.

Deformation of the rocks of the Lexington quadrangle occurred during the Appalachian orogeny of Permian age. The area may be conveniently divided into 3 structural units which correspond closely to the physiographic divisions: the Blue Ridge belt is characterized by folding and faulting of the Precambrian basement rocks; the central belt is characterized by low angle overthrust faulting of sedimentary rocks; and the northwestern belt is characterized by folding of the sedimentary rocks. The Blue Ridge belt is in fault contact with the rocks of the central belt along the Midvale fault and the previously unmapped South River fault. The major thrust faults of the central belt are the North Mountain fault, the Pulaski fault, and the Pulaski-Staunton fault. The North Mountain fault divides into 3 branches in the northern part of the quadrangle and a large window in the upper plate is present southwest of Brownsburg. The Pulaski fault branches southwest of Fairfield; the west branch is continuous with the Staunton fault and is herein named the Pulaski-Staunton fault; the minor east branch, formerly thought to be the main Pulaski fault, is named the Fairfield fault. The major structures of the northwestern belt are folds;

one fold is overturned and thrust northwestward along the previously unmapped Zack fault in the northern part of the quadrangle. The structural history is a record of long continued deformation that progressed from folding of sedimentary rocks to overthrust faulting of sedimentary rocks, and finally to faulting of the Blue Ridge anticlinorium over the earlier formed structures.

Iron ore and manganese ore have been mined in the quadrangle from residual accumulations overlying the Rome formation and the Ridgeley sandstone; undiscovered deposits may exist, but they are likely to be small. The quadrangle contains ample supplies of carbonate rocks that may be used for many industrial purposes.

INTRODUCTION

LOCATION AND ACCESS

The Lexington quadrangle, in west-central Virginia, is an area of 240 square miles bounded by parallels 37° 45′ and 38° 00′ and meridians 79° 15′ and 79° 30′. Most of the quadrangle is in Rockbridge County; the northeastern and southeastern "corners" are, respectively, in Augusta and Amherst counties. The major town in the area is Lexington, from which the quadrangle takes its name; Lexington lies in the southwest corner of the area and is approximately 50 miles north of Roanoke and 160 miles west of Richmond. Buena Vista is the largest town in the vicinity, though only the northern edge of the city is noted on the map. Some of the larger communities in the quadrangle are Goshen in the extreme northwestern corner, Brownsburg in the northeast, and Fairfield in the east-central part of the area.

The quadrangle is laced by a network of roads that provide easy access to most portions of the area. The major highways are U. S. Highway 11, which crosses the quadrangle from northeast to southwest, and U. S. Highway 60, which crosses the southwestern corner of the quadrangle. State highways and roads, paved and unpaved, connect with the United States highways and lead into all parts of the area except the high mountains.

GEOGRAPHY

The Lexington quadrangle lies wholly within the Appalachian Highlands and includes portions of two physiographic provinces. The southeastern corner of the area is part of the Blue Ridge province and the remainder of the quadrangle lies within the Valley and Ridge province.

Topographically, the area may be divided into three parts; the Blue Ridge on the southeast, the Shenandoah Valley which comprises most of the quadrangle, and the Appalachian Mountain ridges on the northwest. All of these features have a marked northeasterly trend. Only the first ridge of the Appalachian chain is present in the quadrangle. This ridge known as Little North Mountain, loses its identity about 2½ miles north of Goshen Pass and becomes a complex of ridges including Jump Mountain, Hogback Mountain, and Forge Mountain. Altitudes average about 2,700 feet along the Blue Ridge, about 1,300 feet in the Shenandoah Valley, and about 3,200 feet on the northwestern ridges. Big Butt, at the south end of Hogback Mountain, reaches a height of 3,451 feet and is the highest point in the quadrangle. Total relief in the area is 2,591 feet.

The quadrangle is drained by three major streams. The largest of these is the Maury River (North River) which flows through the area from the northwest corner to the southern boundary and thence into the James River about 10 miles further south. The major tributaries to the Maury River are the Calfpasture River in the northwest and the South River which joins the Maury about 4 miles east of Lexington. With the exception of the Maury River, the quadrangle has a poorly defined trellis drainage pattern; the Maury River flows in an entrenched meandering channel that is transverse to the structural grain of the area.

PURPOSE

The present work was undertaken in order to map the geology of the Lexington quadrangle at a scale of 1:62,500 and to study the structural and economic geology. In line with this, the stratigraphy was not studied in detail and the mapped units are those used previously in reconnaissance mapping and stratigraphic studies.

PREVIOUS WORK

The record of geologic studies in the Lexington quadrangle goes well back into the 1800's. The bulk of these reports pertain to the small iron, manganese, and tin ore deposits in the Blue Ridge area and the remainder deals chiefly with stratigraphic nomenclature. The first work of major importance, involving reconnaissance mapping with stratigraphic and structural studies, was by Butts (1933, 1940). This work was concerned with the entire Appalachian Valley region. Cooper (1946) noted several localities in the quadrangle where breccias may be observed along the Pulaski fault and suggested that the Pulaski and Staunton faults as shown by Butts might be one and the same. Cooper and Cooper (1946) worked in the quadrangle in connection with a regional study of Middle Ordovician stratigraphy and report in some detail the characteristics of the Middle Ordovician rocks of the Lexington area. Bloomer and Werner (1955) mapped the part of the quadrangle that lies in the Blue Ridge, and studied the stratigraphy and structure, as part of a larger study of the Blue Ridge area. Edmundson (1958) measured many stratigraphic sections in the Lexington quadrangle during his study for the report "Industrial Limestones and Dolomites in Virginia: James River District West of the Blue Ridge." Edmundson also indicated that the Pulaski and Staunton faults are the same, and suggested that a structurally complex area near Brownsburg is a window in the North Mountain fault.

PRESENT WORK AND ACKNOWLEDGEMENTS

The field work for the present report was done in the summer of 1959 by the writer. The writer gratefully acknowledges the aid given to him by numerous residents of the area and by the Virginia Division of Mineral Resources. The writer is especially indebted to Robert O. Bloomer who generously allowed his work on the Blue Ridge portion of the quadrangle to be incorporated into the writer's map of the Lexington area.

GEOLOGIC FORMATIONS

INTRODUCTION

In the following sections are described in chronologic order the 23 geologic formations shown on the geologic map. Of these formations, 20 are composed of sedimentary rocks, 2 of sedimentary and volcanic rocks, and one of an igneous and metamorphic complex. The formations range in age from Precambrian to Devonian.

PRECAMBRIAN SYSTEM

PEDLAR FORMATION

The Pedlar formation is part of the igneous and metamorphic complex upon which the younger sediments were deposited. The formation is exposed in the Blue Ridge in the southeastern corner of the Lexington quadrangle and is named for exposures on the upper reaches of the Pedlar River in northwestern Amherst County, Virginia (Bloomer and Werner, 1955).

The Pedlar formation consists of a heterogeneous assemblage of granitic, granodioritic, syenitic, quartz dioritic, anorthositic, and unakitic rocks that cannot be easily separated from one another during field mapping (Bloomer and Werner, 1955). The formation is variable in color, ranging from green to red to white, and is mainly comprised of coarse-grained granular rock. In many areas the rock is deeply weathered and crumbles readily. These characteristics are easily seen in outcrops along U. S. Highway 60. The rock is indistinctly foliated and contains porphyroblasts up to 4 inches in long dimension at some localities (Bloomer and Werner, 1955).

PRECAMBRIAN AND CAMBRIAN SYSTEMS

DISCUSSION

The age and regional relationships of the rocks overlying the Precambrian Pedlar formation and underlying the Lower Cambrian Shady dolomite are unclear. The complete sequence of formations occupying this interval in central Virginia, in ascending order, is the Swift Run formation, Catoctin greenstone, Unicoi formation, Hampton formation and Erwin quartzite, the last two called the Harpers formation and Antietam quartzite which together with the Unicoi form the Chilhowee group (Bloomer and Werner, 1955). The formational names used in this report are shown in Table 1, together with formational names used by other writers.

Table 1. Precambrian and Cambrian formations.

Butts 1940	Bloomer and Werner, 1955	Edmundson 1958	This Report
Elbrook dolomite		Elbrook formation	Elbrook formation
Waynesboro formation		Waynesboro formation	Rome formation
Tomstown dolomite	Tomstown dolomite	Shady-Tomstown dol.	Shady dolomite
Antietam sandstone	Antietam quartzite	basal quartzites	Erwin quartzite
Harpers shale	Harpers formation		Hampton formation
Weverton sandstone	Unicoi formation		Unicoi formation
Loudoun formation			

The type locality of the Chilhowee group is Chilhowee Mountain in east-central Tennessee (Safford, 1856). Here the Chilhowee unconformably overlies the Ocoee series and is conformably overlain by the Shady dolomite of Early Cambrian age (King, 1949); the Shady is the same formation known as the Tomstown dolomite in central Virginia (Butts, 1940). From the unconformable relations and a few fossils, the Chilhowee group has been considered of Early Cambrian age and the Ocoee series of Precambrian age (King, 1949).

A sequence of rocks similar in gross lithology to the Chilhowee group, and also conformably overlain by the continuous Shady dolomite of Early Cambrian age, has been recognized by various workers over the entire length of the Blue Ridge. King (1949, 1950b) has suggested that this sequence be known as the Chilhowee group wherever found. Many local formation names are in use for this sequence of strata and detailed lithologic equivalence cannot be demonstrated between all these formations, but in gross aspect the sequence is very similar to the Chilhowee group of the type locality. Bloomer and Werner (1955) have adopted Chilhowee group for use in central Virginia.

Stose and Stose (1949) recognize that the Chilhowee group is unconformable on the Catoctin greenstone in northern Virginia. The relations are quite similar to those reported from Tennessee and can be interpreted to mean that the Swift Run formation and Catoctin are essentially correlative with the Ocoee series and are of probable Late Precambrian age while the Chilhowee group is of Early Cambrian age. Bloomer and Werner (1955) maintain that the Chilhowee group is conformable with the Catoctin in central Virginia and, further, that the lower part of the Chilhowee intertongues with the upper part of the Catoctin. The overall relations between the Swift Run formation, the Catoctin greenstone, and Chilhowee group in central Virginia indicate to Bloomer and Werner that the entire sequence is time transgressive and overlaps the Precambrian crystalline basement from east to west.

The major features of the stratigraphy of this sequence have been outlined; but the actual ages of the rocks concerned is not fully known. Stose and Stose (1949) and Bloomer and Werner (1955) have considered the Swift Run formation and the Catoctin greenstone to be Late Precambrian in age and the Chilhowee group to be Early Cambrian in age. King (1949) concurs in assigning the Chilhowee group an Early Cambrian age. Because of a general lack of fossils and the transgressive nature of the entire sequence, the writer prefers to withhold judgement on the ages of these formations. This is clearly necessary because of the demonstrated intertonguing of the Catoctin greenstone and the Chilhowee group; these units are partially contemporaneous, yet one has been considered Precambrian and the other Early Cambrian. Lower Cambrian fossils are known from the Erwin quartzite and Hampton formation; but the Unicoi formation, Catoctin greenstone, and Swift Run formation are still undated (Bloomer and Werner, 1955). Until more work is done on this problem, the writer does not feel it proper to assign a more specific age than Precambrian and Cambrian to the rocks between the Pedlar formation and the Shady dolomite.

In the Lexington area, the normal stratigraphic succession cited above for central Virginia is not present. The Chilhowee group lies directly on the Pedlar formation along the crest of the Blue Ridge; the Swift Run formation and Catoctin greenstone are absent. In the extreme southeastern corner of the quadrangle, however, the Swift Run formation overlies the Pedlar in normal stratigraphic succession. Part of the Swift Run has been removed during recent erosion and it is not possible to ascertain if the full sequence of formations was originally present. The close juxtaposition of these two areas of different sequence is the result of overlapping of the older rocks by westward transgression at the time of deposition. The two areas are also separated by a thrust fault which has telescoped the original distance between the rocks now exposed and this tends to give the false impression of an abrupt overlap.

SWIFT RUN FORMATION

The Swift Run formation, composed of arenaceous sediments and interbedded lava flows, nonconformably overlies the Pedlar formation in the exteme southeastern corner of the quadrangle. The upper contact of the formation is not present as it has been removed by recent erosion.

The Swift Run formation consists of graywacke, andesite, tuff, and greenstone. The basal part of the formation is a conglomeratic graywacke, with boulders up to 5 feet in diameter, that grades upward into

fine-grained, thin-bedded subgraywacke (Bloomer and Werner, 1955). Near the middle of the formation is a dark gray, fine-grained andesite flow about 85 feet thick (Bloomer and Werner, 1955).

CATOCTIN GREENSTONE

The Catoctin greenstone, which underlies the Unicoi formation in central Virginia, is not present in the Lexington quadrangle as discussed above.

UNICOI FORMATION

The basal formation of the Chilhowee group in the Lexington area is known as the Unicoi formation (Bloomer and Werner, 1955). The Unicoi nonconformably overlies the Pedlar formation of the Precambrian crystalline basement rocks and is conformably overlain by the Harpers formation. The lower part of the Unicoi contains tuff, greenstone, and basalt that are indistinguishable from that in the Catoctin greenstone and this lower part of the formation intertongues with the Catoctin (Bloomer and Werner, 1955). The upper contact is located at the top of the uppermost pebbly quartzite bed encountered in the section.

The Unicoi formation is comprised of about 500 feet of graywacke, subgraywacke, pebbly arkose, pebbly quartzite, and volcanic rocks. The base of the formation is marked by a saprolite several feet thick (Bloomer and Werner, 1955), and overlying this is 100 feet or more of graywacke conglomerate containing fragments of granite, quartz, and feldspar. The volcanic rocks, reddish brown tuff, greenstone, and basalt, occur in the basal part of the formation as lens-shaped bodies. (Bloomer and Werner, 1955). The remainder of the formation is comprised of fine-grained, dark colored subgraywacke with subordinate interbedded pebbly arkose and pebbly quartzite. The Unicoi, like the rest of the Chilhowee group, is essentially unmetamorphosed.

HAMPTON (HARPERS) FORMATION

The Hampton formation is conformable with the underlying Unicoi formation and overlying Erwin quartzite. The lower contact is variable, being taken at the highest locally exposed pebbly quartzite bed in the section; the upper contact is sharp and is at the base of a thick sequence of white and gray quartzite (Bloomer and Werner, 1955).

The Hampton formation is transitional in lithology between the heterogeneous subgraywacke of the Unicoi formation and the massive, pure quartzite of the Erwin. The lower part of the formation is predominantly gray to green, thin-bedded, fine-grained subgraywacke with

a subordinant amount of white quartzite. The subgraywacke decreases in abundance upward, and the quartzite increases, until the upper part of the formation is 75 percent quartzite. Three distinct quartzite members are present in the Hampton, but only the lower member is delineated and named on the map (Bloomer and Werner, 1955). This quartzite is called the Snowden member, and has been distinguished because of greater thickness and the presence of *Scotholithus sp.* (Bloomer and Werner, 1955). These fossils are the only ones found in the Hampton and are the earliest ones known from the stratigraphic section of the Lexington quadrangle.

ERWIN (ANTIETAM) QUARTZITE

The Erwin quartzite conformably overlies the Hampton formation and is conformably overlain by the Shady dolomite. The lower contact is at the base of the thick quartzite sequence (Bloomer and Werner, 1955). The upper contact is not exposed in the Lexington area as it is covered by many feet of "slope wash" from the Erwin. Exposures at the southwestern end of Sallings Mountain, several miles south of the Lexington quadrangle, show the contact to be a transition zone of dolomitic sandstone about 25 feet thick (Bloomer and Werner, 1955). The Erwin is resistant to erosion and forms bold hogbacks along the northwestern front of the Blue Ridge.

The Erwin quartzite is a remarkably homogeneous formation, consisting of about 600 feet of quartzite. The quartzite is white to bluish-gray and occurs in beds up to 20 feet thick with local cross-stratification. Quartz comprises 99 percent of the rock (Bloomer and Werner, 1955). Clayey partings in the basal zone of the formation and some calcareous cement in the upper part are the major exceptions to the uniformity of the Erwin. Lower Cambrian fossils have been collected from the Erwin in Virginia and Maryland (Bloomer and Werner, 1955).

CAMBRIAN SYSTEM

SHADY (TOMSTOWN) DOLOMITE

The upper and lower contacts of the Shady dolomite are covered by slope wash in the Lexington quadrangle. However, as seen in the vicinity of Sallings Mountain south of the quadrangle, the formation conformably overlies the Erwin quartzite and is conformably overlain by the Rome formation (Bloomer and Werner, 1955). The contacts are gradational and the limits are drawn at the bottom of the first

pure dolomite beds and at the top of the uppermost pure dolomite bed beneath the red shale of the Rome (Bloomer and Werner, 1955).

The Shady dolomite is almost wholly composed of pinkish-tan to dark bluish-gray, medium-grained dolomite. The formation is largely covered in the Lexington area and the nearest good exposures are near Natural Bridge Station, about 10 miles south. Edmundson (1958) has studied this section and reports that the lower 900 feet, with the exception of one 200-foot unit, is light gray to pinkish-tan, medium-grained, vuggy dolomite; the remainder of the formation is bluish-gray, fine to medium-grained dolomite. The section of the Shady at Natural Bridge Station is incomplete and about 1200 feet thick (Edmundson, 1958).

The Shady dolomite is the same lithologic unit referred to as the Tomstown dolomite in northern Virginia (Butts, 1940). This widespread dolomite unit is an excellent stratigraphic marker from Pennsylvania to Alabama, and faunas of Early Cambrian age have been collected from several widely separated localities (Butts, 1940).

ROME (WAYNESBORO) FORMATION

The Rome formation outcrops in two parts of the quadrangle. One outcrop belt lies at the foot of the Blue Ridge where the Rome overlies the Shady dolomite in normal stratigraphic sequence; the other outcrop area is in the northeastern part of the quadrangle where the Rome is exposed on the overthrust plate of the North Mountain fault. The Rome is conformable with both the underlying Shady and the overlying Elbrook formation (Butts, 1940; Edmundson, 1958), but neither contact is exposed in the Lexington quadrangle.

The Rome formation is a heterogeneous mixture of red and green shale, brown sandstone, and impure limestone and dolomite. The red shale is the most distinctive feature of the formation although the green shale and carbonate rocks are more abundant; the more abundant rock types are usually masked by reddish mantle derived from the red shale members. The formation is so covered and structually distorted that the actual sequence of beds is undetermined for the Lexington area and the thickness is not accurately known. The Rome appears to be on the order of 1,500 to 2,000 feet thick, a figure that compares favorably with a measured section near Buchanan (Butts, 1940).

The Rome formation is the same lithologic unit referred to as the Waynesboro formation in northern Virginia (Butts, 1940). The Rome formation is scantily fossiliferous in Virginia, but collections from

several localities show it to be of Early and Middle Cambrian age (Butts, 1940).

ELBROOK FORMATION

The Elbrook formation is conformable with the underlying Waynesboro formation and the overlying Conococheague limestone. The formation crops out in three distinct belts in the Lexington quadrangle. The easternmost belt parallels the valley of the South River at the foot of the Blue Ridge; here the Elbrook is in normal stratigraphic sequence above the Rome formation. The second belt about 4 miles to the west, is exposed along the Pulaski, Pulaski-Staunton, and Fairfield faults and is continuous from the southern to northeastern boundaries of the quadrangle. The third belt of outcrop is another 3 to 4 miles to the west where the Elbrook is exposed on the overthrust plate of the North Mountain fault; this belt extends from the vicinity of Bethany Church to McClung Mill.

The lower contact of the Elbrook formation is not exposed in the quadrangle and is mapped on the distribution of float from the Elbrook and Rome formations. The contact between the Elbrook and the overlying Conococheague limestone is not well defined in the literature pertaining to central Virginia, and the writer has attempted to map it at the lowest locally exposed sandstone bed in the carbonate sequence. This contact has not proved entirely satisfactory because of extensive covered areas.

The Elbrook formation is composed dominantly of dolomite with minor interbedded limestone; parts of the formation consist largely of limestone. The carbonate rocks are mostly of two quite different types and occur in alternating units. One type is thick-bedded, medium to dark gray, medium to fine-grained dolomite that weathers light gray and sometimes white. The other chief type is thin-bedded dolomite with shale partings on the bedding planes, and this rock weathers to slabby and shaly plates. Either of these types may locally be limestone, but limestone appears chiefly in the thin-bedded units. The Elbrook formation is approximately 2,300 feet thick in the Lexington quadrangle (Edmundson, 1958).

The Elbrook formation is only sparingly fossiliferous in Virginia (Butts, 1940), the chief fossil being *Cryptozooan*. On the basis of stratigraphic position and facies relations, the Elbrook is probably correlative with the Rutledge limestone, Rogersville shale, Maryville limestone and Nolichucky shale of southwestern Virginia (Butts, 1940). These formations are dated as Middle and Late Cambrian (Butts, 1940).

CONOCOCHEAGUE LIMESTONE

The Conococheague limestone conformably overlies the Elbrook formation and is conformably overlain by the Chepultepec limestone. The formation outcrops in two belts in the quadrangle. The first outcrop area is in the southeastern part of the quadrangle east of the Pulaski, Pulaski-Staunton, and Fairfield faults and the second is in the central part of the quadrangle east of the North Mountain fault. The lower contact of the formation is placed at the base of the first locally exposed sandstone bed in the carbonate sequence, and the upper contact is at the base of the thick-bedded, dark bluish limestone of the Chepultepec limestone.

The Conococheague limestone is actually composed of two facies in the Lexington area, one predominately limestone and the other predominately dolomite; the formation is mainly limestone in the eastern outcrop belt, but is 75 to 80 per cent dolomite in the western belt. The Conococheague is difficult to distinguish from the Elbrook formation in the western belt and isolated outcrops are also easily confused with the Beekmantown formation.

The Conococheague limestone has two characteristics that almost always serve to identify it readily if 20 to 30 feet of section are visible. The first is the presence of sandstone layers interbedded with the carbonate rocks and the second is the common occurrence of thin siliceous laminae that stand out as irregular ribs on weathered surfaces. The rocks of the Conococheague are mainly thick-bedded, although several units of thin-bedded shale-parted rock tend to compound the confusion with the Elbrook formation. The rock is usually blue-gray in the limestone belt; in the dolomite belt, the rocks are light to dark gray and some weather very dark gray. The Conococheague, as scaled from the map, is approximately 2,000 feet thick in the Lexington quadrangle. Edmundson (1958) lists several sections in and about the area that confirm this thickness.

A few fossils have been found in the Conococheague limestone in Virginia and they indicate its age to be Late Cambrian (Butts, 1940). The Conococheague is continuous with, and correlative with, the Copper Ridge dolomite to the south (Butts, 1940). In fact, on the basis of lithology, the western outcrop belt of the formation is more similar to the Copper Ridge than to the Conococheague limestone.

ORDOVICIAN SYSTEM

CHEPULTEPEC LIMESTONE

The Chepultepec limestone conformably overlies the Conococheague limestone and is conformably overlain by the Beekmantown formation. The formation has two major outcrop belts. One is in the southeastern part of the area and the other extends from southwest to northeast across the quadrangle. In both cases, the Chepultepec is exposed on the upper plate of a thrust fault. The lower contact is at the base of a sequence of thick-bedded, blue, laminated limestone and the upper contact is at the base of a thick sequence of light gray, fine-grained dolomite.

The Chepultepec limestone is a homogeneous formation composed of limestone with only minor amounts of dolomite. The limestone is thick-bedded, dark bluish-gray, and fine-grained. Many beds exhibit laminated weathered surfaces. The formation is between 400 and 600 feet thick in the Lexington quadrangle.

The Chepultepec limestone contains a characteristic Lower Ordovician fauna that correlates with the Tribes Hill formation, the basal unit of the standard Lower Ordovician section in New York State (Butts, 1940). The Chepultepec is also correlative with the Stonehenge limestone of Pennsylvania.

BEEKMANTOWN FORMATION

The Beekmantown formation conformably overlies the Chepultepec limestone and is disconformably overlain by the New Market limestone. The Beekmantown is found in 4 major outcrop belts. One belt lies in the southeastern part of the area about one mile west of the South River. The longest outcrop belt extends from the southwestern corner to the northeastern corner of the quadrangle, and is paralleled by a third belt 2 to 3 miles to the west. A large area of Beekmantown is also exposed southwest of Brownsburg in a window through the North Mountain fault. The lower contact of the formation is located at the base of a thick sequence of medium to light gray fine-grained dolomite. The upper contact is sharp, although seldom well exposed, and is at the base of an aphanitic dark gray limestone. This contact is a disconformity that can be seen along Whistle Creek where exposures are particularly good.

The Beekmantown formation is composed of dolomite with a few interbedded limestone beds. The dolomite is rather heterogeneous and facies changes seem to be common within the formation; a great deal of

work will be necessary to obtain a detailed picture of the Beekmantown lithologies. Notwithstanding this, however, the formation is usually easily recognized. The most abundant rock type appears to be light to medium gray, fine-grained, thick-bedded dolomite. This rock weathers medium to dark gray and has the distinctive feature of intersecting grooves or furrows that occur on weathered surfaces. Much of the Beekmantown contains chert, as nodules and as small grains in the dolomite matrix. This is a distinctive feature; if the dolomite is weathered out, a whitish to brownish gnarly mass of chert may be left. Although chert seems most abundant in the upper half of the formation, it occurs locally in most parts of the Beekmantown. Dark gray dolomite that weathers very dark gray was observed in abundance along Kerrs Creek but nowhere else. About one mile north of Pisgah Chapel, the formation contains a 10-foot unit of limestone identical to the overlying New Market, but about 150 feet stratigraphically below the New Market. The Beekmantown is estimated to be about 1,500 feet thick in the vicinity of Lexington (Edmundson, 1958).

Fossils occur in the Beekmantown in many areas of Virginia, including Brushy Hill west of Lexington (Butts, 1940). The faunas indicate that the formation is of Early Ordovician age and correlative with the Nittany dolomite, Axeman limestone, and Bellefonte dolomite of central Pennsylvania, and the upper part of the Knox group of the southern Appalachians.

NEW MARKET LIMESTONE

The New Market limestone (Cooper and Cooper, 1946) disconformably overlies the Beekmantown formation and is conformably overlain by the Lincolnshire limestone. The New Market is best exposed in an outcrop belt extending from the southwestern corner of the quadrangle to the vicinity of Timber Ridge where the formation is truncated by the Pulaski fault. A second, less well exposed belt, extends from the vicinity of Zack to Kerrs Creek where it is truncated by the North Mountain fault. The lower contact is a disconformity as discussed. The upper contact is gradational with the Lincolnshire limestone and is placed at the top of the uppermost thick-bedded aphanitic limestone.

The New Market limestone is composed of a very distinctive thick-bedded, medium to dark gray, aphanitic limestone that breaks with conchoidal fracture. A few thin-bedded rocks are present in the formation and black chert nodules are locally abundant, but neither of these features is widespread. The New Market ranges in thickness from about

10 to 75 feet and reflects the topography of the erosion surface upon which it was deposited.

The New Market limestone contains fossils of Middle Ordovician age (Chazyan) and correlates with the Blackford formation of southwestern Virginia and the Lenoir limestone of Tennessee (Cooper and Cooper, 1946). The New Market is essentially the same unit mapped as Mosheim limestone by Butts (1933, 1940).

LINCOLNSHIRE LIMESTONE

The Lincolnshire limestone (Cooper and Cooper, 1946) conformably overlies the New Market limestone and is conformably overlain by the Botetourt member of the Edinburg formation. Cooper and Cooper (1946) have recognized the Whistle Creek limestone as a distinct unit between the New Market and Lincolnshire, and have designated Whistle Creek in the Lexington quadrangle as the type area of the formation. The Whistle Creek formation is too thin to be mapped satisfactorily at a scale of 1: 62,500 over most of the quadrangle, and has been included within the Lincolnshire in this report. The Lincolnshire outcrops in two belts, one extending from Timber Ridge to the southwest corner of the quadrangle, and the other from Zack to Kerrs Creek. The lower contact is at the base of an impure limestone that contrasts sharply with the underlying New Market lithology. The upper contact is at the base of a sequence of impure, reddish weathering limestone that breaks down to an ocherous soil.

The lower part of the Lincolnshire limestone is commonly thin-bedded, dark bluish to brownish, cherty limestone that is irregularly bedded. The upper parts of the formation are characterized by light gray, coarse-grained, massively bedded limestone that is known as the Murat limestone facies of the Lincolnshire. In contrast to many areas, the Murat facies is common in the Lexington quadrangle, but is locally replaced by dark gray, cherty limestone that is generally similar to that often found in the lower part of the formation. The thickness of the Lincolnshire limestone varies between 200 and 400 feet in the Lexington quadrangle. The faunas of the Lincolnshire limestone are Middle Ordovician and of probable Late Chazyan age (Twenhofel, et al, 1954).

EDINBURG FORMATION

The Edinburg formation (Cooper and Cooper, 1946) conformably overlies the Lincolnshire limestone and is conformably overlain by the Martinsburg shale. The Collierstown limestone (Cooper and Cooper,

1946), which occurs between the Edinburg and Martinsburg, has not been mapped and is included with the Edinburg in this report. The writer feels that there is no significant lithologic difference between these formations and has not attempted to define their limits. The Edinburg outcrops in a belt that passes through the town of Lexington and in a second belt extending from Zack to Kerrs Creek. The lower contact is at the base of a sequence of reddish weathering limestone and the upper contact is at the base of the yellowish shales of the Martinsburg.

The Edinburg is composed largely of argillaceous limestone and interbedded shale. The basal 40 to 80 feet is composed of irregularly bedded, coarse-grained, nodular limestone that weathers reddish and breaks down to an ocherous soil. This unit is an excellent mapping guide and has been differentiated as the Botetourt member of the Edinburg formation (Cooper and Cooper, 1946). The overlying rocks are chiefly interbedded fine-grained, black thin-bedded limestone and dark gray to black shale. The shale occurs as partings between the limestone beds and also as separate units. These rock types form the Liberty Hall facies of the Edinburg formation (Cooper and Cooper, 1946). Thirty miles and more to the north of the quadrangle, the Edinburg formation is composed chiefly of cobbly to nodular black limestone with no shale; this is known as the Lantz Mills facies of the Edinburg (Cooper and Cooper, 1946). A few tongues of the Lantz Mills facies extend into the Lexington area and one is well exposed in the Barger Quarry on the eastern outskirts of the town of Lexington. The thickness of the Edinburg is difficult to determine because of cover and structural conditions. However, it is believed to be about 1,000 feet thick.

The faunas of the Edinburg formation are Middle Ordovician in age, ranging from Black River to Middle Trenton (Cooper and Cooper, 1946). The formation corresponds to the Whitesburg limestone, Athens formation and Chambersburg limestone of Butts (1940).

MARTINSBURG SHALE

The Martinsburg shale is conformable with the underlying Edinburg formation and is disconformably overlain by the Clinch sandstone. The lower contact is at the base of a thick sequence of yellow to brown weathering shale and the upper contact is at the base of a thick sequence of gray thick-bedded quartzite. The chief outcrop belt of the Martinsburg is along the eastern flanks of Hogback Mountain and Little North Mountain in the northwestern part of the area. A smaller outcrop belt is present in the south central part of the quadrangle, but the formation is incomplete and eventually is truncated by the Pulaski fault.

The Martinsburg shale is a distinctive unit and good mapping guide even though mostly covered. The major constitutent of the Martinsburg is gray calcareous shale that weathers yellow to light brown. The formation also contains a few thin beds of limestone and a few beds of sandstone. The Martinsburg is structurally weak and is folded and cleaved wherever found in the area. The thickness is estimated to be on the order of 1,000 to 2,000 feet.

The Martinsburg shale contains fossils of Middle and Late Ordovician age. Approximately the lower one-third of the formation is late Trenton and the remainder is Edenian and Maysvillian (Butts, 1940; Twenhofel, et al, 1954).

SILURIAN SYSTEM

CLINCH SANDSTONE

The Clinch sandstone disconformably overlies the Martinsburg shale and is conformably overlain by the Clinton formation. The lower contact is taken at the base of a sequence of thick-bedded gray quartzite. There is little evidence to show that this contact is unconformable, but the Juniata formation which usually overlies the Martinsburg is not present in the Lexington quadrangle. The Juniata has an irregular distribution in Virginia (Butts, 1940) and this implies a regional disconformable relationship at the base of the Clinch. The upper contact is taken at the base of a sequence of red-brown siltstone. The Clinch outcrops near the crests of Hogback Mountain, Jump Mountain, and Little North Mountain in the northwestern part of the quadrangle.

The Clinch sandstone is composed entirely of quartz grains cemented by quartz. The color is white to light gray and the beds are 1 to 5 feet thick. The Clinch may be confused with some of the quartzite in the Clinton formation but the Clinton rocks have a definite yellowish hue that is not present in the Clinch. The formation is about 200 feet thick in the Lexington area and is well exposed in Goshen Pass.

Fossils are scarce in the Clinch sandstone of the Lexington area, but good collections have been made near Cumberland Gap, Tennessee. Here, the Clinch is Early Silurian (Albion) in age (Butts, 1940). The Clinch is continuous with the Tuscorora sandstone of Pennsylvania.

CLINTON FORMATION

The Clinton formation is conformable with the underlying Clinch sandstone and the overlying Tonoloway limestone may be disconformable with it. The lower contact is located at the base of a sequence of red-

brown siltstone and the upper contact is at the base of a dark gray, laminated limestone. The upper contact is largely covered, and in a few exposures the Tonoloway is noted to overlie an orangish-brown thin-bedded sandstone. This type of sandstone is not typical of the Clinton and perhaps it represents the Wills Creek shale which underlies the Tonoloway in other parts of Virginia. The Clinton formation is so covered by slope wash that the writer was not able to locate the lower contact of this orange-brown sandstone and has grouped it with the Clinton for the present. The Clinton outcrops in the northwestern part of the area, occuping a particularly broad belt in the vicinity of Goshen Pass where the formation is folded into a series of anticlines and synclines.

The Clinton formation may be divided into 2 members, the Cacapon and Keefer (Butts, 1940). The Cacapon overlies the Clinch sandstone and is distinctive for the deep red color of many of its beds. This member is composed of siltstone, sandstone, and shale that range in color from brownish-red to dark gray. The sandstone is commonly cemented by hematite and has been mined locally as iron ore, but the grade of ore is too low for extensive operations. The Keefer member forms the upper half of the Clinton and is sometimes hard to distinguish from the Clinch. The most common rock type is thick-bedded quartzite that is medium to dark gray on fresh surfaces and weathers to a yellowish-gray; a few dark green shales are interbedded with the quartzite. The uppermost part of the formation is thin-bedded, orangish-brown sandstone that may be part of the Wills Creek shale rather than the Clinton. The formation is estimated to be 600 to 700 feet thick in the Lexington area. Fossils from the Clinton are of early Middle Silurian age (Butts, 1940).

TONOLOWAY LIMESTONE

The Tonoloway limestone disconformably (?) overlies the Clinton formation and is conformably overlain by the Keyser limestone. The lower contact is located at the base of a sequence of dark gray laminated limestone, and this contact may represent a disconformity as discussed. The upper contact is at the base of a light gray, coarse-grained limestone. The Tonoloway outcrops in the northwestern part of the quadrangle but is largely covered by slope wash from the Clinton and is only partially exposed in a few stream valleys and roadcuts.

The Tonoloway limestone is homogeneous and composed of dark gray, fine-grained limestone. Portions of the formation are thinly parted and the remainder is medium-bedded and commonly regularly laminated. The thickness of the Tonoloway is probably about 75 feet,

but exposures are too poor for accurate determination. The Tonoloway limestone is Late Silurian (Cayugan) in age (Butts, 1940).

KEYSER LIMESTONE

The Keyser limestone conformably overlies the Tonoloway limestone and is conformably overlain by the Helderberg group. The lower contact is at the base of a coarse-grained, light gray limestone and the upper contact is at the base of a sequence of thick-bedded very coarse-grained limestone. The Keyser is partially exposed in a few stream valleys and roadcuts, but is covered elsewhere. The formation outcrops in the northwestern part of the area.

The Keyser limestone is a heterogeneous formation composed of limestone, sandstone, and shale. The lower part of the formation is medium to thick-bedded, light to medium gray, coarse-grained limestone. The middle part of the Keyser is an interbedded shale and sandstone known as the Clifton Forge sandstone member of the Keyser limestone. The sandstone is a thick-bedded gray rock that weathers tan to white and is often calcareous. The shale is dark gray and calcareous. The upper part of the formation is comprised of a thin-bedded shaly limestone interbedded with limestone similar to the thick-bedded rocks at the base of the formation. The formation is between 80 and 100 feet thick in the Lexington quadrangle. The Keyser limestone is Upper Silurian (Cayugan) in age (Swartz, et al, 1942).

DEVONIAN SYSTEM

HELDERBERG GROUP

The Helderberg group conformably overlies the Keyser limestone and is conformably overlain by the Ridgeley sandstone. The Helderberg is comprised of 3 formations, the Coeymans limestone, New Scotland limestone, and Licking Creek limestone; these formations could not be distinguished on the present mapping scale. The lower contact is at the base of a very coarse crystalline, gray and pink mottled limestone.The upper contact is gradational and is located at the base of the first thick-bedded brown weathering sandstone. The Helderberg is almost completely covered by slope wash from the Clinton formation.

The basal formation of the Helderberg group is the Coeymans limestone. The Coeymans is not well exposed, but appears to be only 10 to 20 feet thick and is composed of very coarse-grained, gray and pink mottled limestone. The overlying New Scotland formation is about 20 to 30 feet thick and composed of limestone and calcareous

sandstone. The limestone is light to medium gray and medium to coarse-grained, commonly containing "floating" quartz grains. The New Scotland changes facies southward into the Healing Springs sandstone (Swartz, 1929) and the sandstones in the Lexington area are probably "tongues" of the Healing Springs. The uppermost formation of the group, the Licking Creek limestone, is medium to dark gray, medium-grained, cherty limestone. The black chert occurs as stringers and nodules and is a characteristic feature of the formation. The upper few feet of the Licking Creek are sandy and grade into the overlying Ridgeley sandstone. The total thickness of the Helderberg group is about 100 to 150 feet. The group is Early Devonian (Ulsterian) in age (Cooper, et al, 1942).

RIDGELEY SANDSTONE

The Ridgeley sandstone conformably overlies the Helderberg group and is conformably overlain by the Millboro shale. The lower contact is gradational and is located at the first thick-bedded sandstone. The upper contact is not exposed and is only approximately mapped. The Ridgeley outcrops in the northwestern part of the quadrangle, but is almost completely covered by slope wash.

The Ridgeley is comprised of medium to coarse-grained, thick-bedded, red-brown weathering sandstone. The thickness is about 20 feet in the Lexington area. The Ridgeley is Early Devonian (Ulsterian) in age (Cooper, et al, 1942).

MILLBORO SHALE

The Millboro shale conformably overlies the Ridgeley sandstone and is conformably overlain by the Brallier shale. The lower part of the formation is not exposed in the Lexington area because of the great amount of slope wash. The Onondaga formation is probably included in the unit mapped as Millboro. The upper contact is at the base of a thick sequence of brown and green shale and siltstone. The Millboro outcrops in isolated patches in the northwestern part of the quadrangle.

The Millboro shale is a black fissile shale that weathers light gray and gray-brown. On a typical outcrop, the shale is broken up into thin slivers and flakes. The only outcrops seen were of this rock type, but as discussed, the lower part of the formation is not exposed and the shaly, sandy, and cherty Onondaga formation (Butts, 1940) is also probably present. The thickness of the Millboro is difficult to determine

because of internal deformation, but is probably at least 1,000 feet (Butts, 1940). The age of the Millboro shale is Middle Devonian (both Erian and Senecan) according to Cooper, et al (1942).

BRALLIER SHALE

The Brallier shale is well exposed in roadcuts northwest of the town of Goshen. The Brallier conformably overlies the Millboro shale; the upper contact of the Brallier is not present in the Lexington quadrangle. The formation is conformably overlain by the Chemung formation in other Virginia localities (Butts, 1940). The Brallier outcrops in the extreme northwestern corner of the quadrangle. The formation may also be present in the area between Little North Mountain and Knob Mountain; this latter area is covered and the writer could not determine whether the Brallier was present.

The Brallier shale is a distinctive unit comprised of non-fissile shale, siltstone, and some sandstone. The shale and siltstone are dark gray to green and weather shades of brown. The sandstone beds are greenish and commonly well jointed. The part of the Brallier exposed in the quadrangle is about 600 to 1,000 feet thick. The formation is Middle Devonian (Senecan) in age (Cooper, et al, 1942).

GEOLOGIC STRUCTURE

INTRODUCTION

The Lexington quadrangle contains three belts of contrasting structure that may be conveniently grouped into a Blue Ridge belt, a central belt, and a northwestern belt (Plate 1). The Blue Ridge belt extends from the eastern boundary of the quadrangle to the South River fault, and is characterized by folds, high and low angle thrust faults, and transverse faults. The central belt extends from the South River fault to the North Mountain fault and is characterized by low angle thrust faults and minor folds. The northwestern belt extends from the North Mountain fault to the western boundary of the quadrangle and is characterized by folds and minor low angle thrust faults. These structures were probably formed during the period known as the Appalachian orogeny (King, 1950a). Although there is no direct evidence of the age within the Lexington quadrangle, the structures are believed to be post-Middle Devonian.

BLUE RIDGE BELT

The major structures of the Blue Ridge belt are the Buena Vista anticline, the South River syncline, and the Midvale and South River faults. These structures all appear to be related and have resulted from the same deformational forces.

BUENA VISTA ANTICLINE

The northwestern limb of the Buena Vista anticline (cross-sections CC′ and DD′) is the dominant structural element of that part of the Blue Ridge belt lying in the Lexington area. The structure extends several miles east, north, and south from the quadrangle (Bloomer and Werner, 1955). The Buena Vista anticline is the northwestern-most fold of the Blue Ridge anticlinorium. One of its most interesting features is the structural continuity between it and the typical Valley and Ridge structure. Except for the small segment between Irish Creek and Glasgow, 8 miles south of the quadrangle, the Blue Ridge is bounded by thrust faults for many miles to the north and south.

The Buena Vista anticline is modified by thrust and transverse faults. The thrust faults do not appear to have displacements of more than a few miles at most (Bloomer and Werner, 1955). The transverse faults have only minor displacements and progressively offset the anticline to the west as it is traced northward. The presence of thrust and

transverse faults indicates that the anticline, after its formation, probably resisted further folding and yielded by fracturing as deformation continued.

MIDVALE FAULT

The Midvale fault is named for a small community near the foot of the Blue Ridge. The fault is significant because it separates the Blue Ridge province from the Valley and Ridge province up to its termination near Irish Creek (cross-section CC′). The northern termination of the fault is several miles northeast of the quadrangle where the Buena Vista anticline plunges and disappears (Bloomer and Werner, 1955). This characteristic further supports the idea that the anticline, once formed, resisted later folding and was thrust northwestward as deformation continued.

SOUTH RIVER FAULT

The South River fault (cross-section CC′ and DD′) generally parallels the South River, from which it takes its name, in the southeastern part of the quadrangle. The fault splits into two branches west of Midvale. The South River fault dips 70 to 85 degrees southeast, a much steeper angle than the thrust faults to the west. The fault also parallels the foot of the Blue Ridge, a fact that is most noticeable near Marlbrook where the Blue Ridge swings sharply northeast. These facts suggest that the fault is more closely related to the Blue Ridge belt structure than to the central belt.

The South River fault is considered similar to the Midvale fault in that it is a fracture along which the Buena Vista anticline was thrust northwestward. The Blue Ridge is bounded by faults on the northwest side in central Virginia except for a 10 mile interval between Irish Creek and Glasgow (Bloomer and Werner, 1955). The South River fault, previously unmapped, is probably the connecting link between the northwestward displacements shown by the Midvale fault and the fault south of Glasgow.

SOUTH RIVER SYNCLINE

The South River occupies the axial portion of a syncline that parallels the Buena Vista anticline. The syncline is probably caused more by faulting than by folding. The southeast limb is continuous with the Buena Vista anticline, but the northwest limb was probably formed by uplift along the South River fault. North of Cornwall, the

southeast limb of the syncline is overturned and dipping southeast because of drag along the Midvale fault.

CENTRAL BELT

Thrust faults, the major structures of the central belt, are the Pulaski and Pulaski-Staunton faults, the Fairfield fault, and the North Mountain fault. Only minor folds are present in the central belt and most of them are intimately related to the thrust faults.

PULASKI, PULASKI-STAUNTON, AND FAIRFIELD FAULTS

These faults are considered as a group because they are closely related; in fact, the Pulaski and Pulaski-Staunton faults are the same, but the name Staunton is well known in the literature (Butts, 1933; 1940) and it might lead to confusion if the writer were to abandon the term altogether.

The Pulaski fault as mapped by Butts (1933) extended to the vicinity of Fairfield where its direction turned sharply northeast, continued several miles, and terminated near Greenville; the Staunton fault (Butts, 1933) extended into the quadrangle from the north and merged with the North Mountain fault near Brownsburg. The Pulaski fault and the Staunton fault are actually continuous and the writer has given the name Fairfield fault to the branch that extends northeastward to Greenville. The main fault is here (cross-sections CC′ and DD′) called the Pulaski fault south of the junction and the Pulaski-Staunton fault (cross-sections AA′ and BB′) north of the junction. The merger of the Pulaski and Staunton faults, a possibility first suggested by Cooper (1946), considerably extends the known length of the fault zone.

The Pulaski and Pulaski-Staunton faults extend from the southern boundary of the quadrangle, about 3 miles east of Lexington, to the eastern boundary, about ½ mile north of the Augusta County line. The fault strikes about N30°E, but is irregular in detail, and dips 20 to 40 degrees southeast. The fault plane is poorly exposed, but a few outcrops show two general characteristics in the fault zone; in some areas the break is very clean and in others the fault plane is obscured by breccia.

The Elbrook formation forms the hanging wall of the thrust fault along its entire extent in the area, but several formations of the lower plate are truncated by the fault. The Beekmantown dolomite forms the footwall in the northern two-thirds of the quadrangle and minor deformation of the rocks adjacent to the fault occurs along this segment. The Middle Ordovician limestones and Martinsburg shale form the footwall

in the southern one-third of the area and here the rocks of the lower plate are mashed, folded, and in some instances overturned. Folds occur in the vicinity of Timber Ridge where a minor anticline and syncline are outlined by the Middle Ordovician limestone formations. The structure of the lower plate appears to be a broad, northeastward plunging syncline that is truncated by the fault.

In many parts of Virginia, the Pulaski fault is apparently a zone of faults rather than one major break (Cooper, 1946); however, only one break occurs along most of its extent in the Lexington quadrangle. A minor associated fault is present and extends from the southern boundary of the quadrangle to the vicinity of Grassy Ridge where it merges with the main fault. The displacement of this subsidiary break is much less than that of the Pulaski fault.

The rocks of the upper plate of the Pulaski and Pulaski-Staunton faults are little deformed. The dip of the rocks is to the southeast and varies between 25 and 60 degrees, but minor folds and some overturned beds are present immediately adjacent to the South River fault; this can probably be attributed to the drag effect along the fault zone. An exception to this general picture occurs in the area southeast of Fairfield. Here there are two infolded remnants of the Chepultepec limestone, one of which is bounded on the southeast by a minor thrust fault. The Conococheague limestone is abnormally thin in this region and is probably faulted, although the actual break was not located. This locally disturbed area is just southeast of the junction of the Fairfield and Pulaski faults and may be attributed to adjustments of the rocks at the branching of the faults. On the other hand, this area is just northwest of the abrupt change in trend of the Blue Ridge belt and could be a reflection of this structure. The effect of the deformational forces was possibly concentrated here at the time the Buena Vista anticline was thrust northwestward and rocks of the Valley and Ridge province were affected more than at other places along the front of the Blue Ridge. It is further possible that the occurrence of the Fairfield fault is evidence of the same active forces and is later, rather than contemporaneous with, the Pulaski fault. Faulting of the Buena Vista anticline is later than thrusting in the central belt because the structures under consideration are in the upper plate of the Pulaski fault. The relations of the South River fault, discussed above support this conclusion because that fault breaks across the upper plate of the Pulaski fault.

The amount of displacement along the Pulaski and Pulaski-Staunton faults is unknown in the Lexington area. The stratigraphic

throw varies between 3,500 and 6,000 feet, but these are low angle thrust faults and the actual displacement is probably much more than this. Butts (1940) estimates that the displacement may be as great as 20 miles in the region around Pulaski, Virginia.

NORTH MOUNTAIN FAULT

The North Mountain fault forms the northwestern boundary of the central belt. The fault is present as a single break from the vicinity of Kerrs Creek to McClung Mill (cross-sections BB′ and CC′), but divides into three branches north of the latter locality (cross-section AA′). The three branches continue to the northern boundary of the quadrangle; the middle branch is the main fault.

The thrust fault plane of the North Mountain fault is very poorly exposed but the break is easily traced by noting the distribution of the sedimentary formations. The dip of the fault is about 30 degrees southeast around Kerrs Creek, and may locally be as high as 50 degrees judging by the dip of the rocks immediately adjacent to the fault on the upper plate.

The Elbrook formation and Conococheague limestone form the hanging wall of the fault for most of its extent. In the northeastern part of the area, the Rome formation is faulted over the Beekmantown formation along the main branch of the thrust fault, and the Conococheague is thrust over the Rome along the east branch. The east branch of the fault is unusual in that the younger Conococheague limestone has been faulted over the older Rome formation. Edmundson (1958) reports that the Elbrook formation is present beneath the Conococheague a few miles north of the quadrangle, so these relations along the east branch of the North Mountain thrust are apparently only a local complication.

The footwall of the North Mountain fault is Beekmantown dolomite except in the area around Kerrs Creek. Here, the Middle Ordovician limestones form the footwall; a subsidiary thrust fault and an overturned syncline are present in these incompetant rocks adjacent to the main fault. The North Mountain thrust overrides a broad doubly plunging anticline, the northern half of which is overturned. The entire anticline is well outlined by the outcrop belt of Middle Ordovician limestone.

The rocks of the upper plate of the North Mountain fault are more structurally complex than those described from the upper plate of the Pulaski fault. The two major structures are a window through the fault southwest of Brownsburg (cross-section BB′) and a northwest trending syncline (cross-section DD′) west of Lexington. In the Brownsburg area,

the North Mountain fault has been folded subsequent to its formation and one anticline has been eroded through to expose the Beekmantown in the lower plate. The rocks of the lower plate were also folded before the thrust fault developed. The syncline west of Lexington trends at right angles to the other structures in the quadrangle. The structural development of this syncline appears to be an accommodation of the rocks to a "sag" developed between the noses of two plunging folds. The northwest limb of the syncline parallels the southward plunging anticline near Kerrs Creek and the southwest limb of the syncline parallels a northward plunging anticline that is present to the southwest (Butts, 1933). These two anticlines are slightly offset from one another so that, as folding progressed, a structural low was developed between the noses of the folds. Thus the syncline is a side effect of the northwesterly deformational forces rather than evidence of a change in direction of deformational forces.

NORTHWESTERN BELT

The northwestern belt is characterized by folds and faults; the faults are intimately related to the folds. The major structures are the anticline adjacent to the North Mountain fault, the Little Calfpasture syncline, the Knob Mountain anticline, folds in the Goshen Pass area, and the Zack fault and associated structures.

The structure immediately northwest of the North Mountain fault is an anticline. The southwestern half of this fold is broad, open, and plunges to the southwest in the Kerrs Creek area. The northwestern limb of the anticline steepens to the northeast and is faulted about 4 miles north of Rockbridge Baths. From this point northward, the northwestern limb of the anticline is overturned and thrust over the Martinsburg shale. This thrust fault has been named the Zack fault from the village of Zack in the northern part of the quadrangle (cross-section AA′ and BB′). Northeast of Zack, the anticline plunges northward and several minor folds are superimposed on the major anticline (cross-section AA′).

The Zack fault dips 15 to 30 degrees eastward, and probably does not have a large displacement. Near the mouth of Hays Creek, a small block splinters off the Zack fault and the western limb of the overturned anticline (cross-section BB′) is repeated. The transverse fault bordering this block on the northeast probably has more dip-slip than strike-slip movement because the North Mountain fault is only slightly displaced near McClung Mill. Much of the movement of this fault may predate the development of the North Mountain fault, however.

The Little Calfpasture syncline is named for the Little Calfpasture River which occupies the axial part of the fold and the Knob Mountain anticline is named for Knob Mountain (cross-section BB′). The Knob Mountain anticline extends across the northwestern corner of the quadrangle. The southeast limb of the Little Calfpasture syncline is structurally complicated south of Jump Mountain. Between Jump Mountain and Big Butt, the southeast limb of the syncline is corrugated into a series of steep plunging folds (cross-section CC′). The structure is best exposed in Goshen Pass. The Clinton formation underlies the entire folded area. North of Jump Mountain, the southeast limb of the Little Calfpasture syncline dips to the northwest. The change in structure on the southeast limb of the Little Calfpasture syncline is probably related to the Zack fault which terminates near the point where the limb of the syncline becomes structurally complicated. The deformational shortening represented by the fault and the folds on the southeast limb of the syncline are about equal. This indicates that as the displacement decreased near the termination of the fault, the shortening was accomplished by more intense folding of the rocks northwest of the fault.

SUMMARY OF STRUCTURAL DEFORMATION

From the above cited facts, a general structural history of the Lexington area may be deduced. The North Mountain fault is the westernmost thrust fault in the central Virginia region; the rocks northwest of the fault are folded, but are not thrust faulted (Butts, 1933). Thus, the rocks of the northwestern belt probably allow the closest approximation to the earliest deformation affecting the Lexington area.

The early deformation appears to have been characterized chiefly by broad open folds. These folds were overturned to the northwest and the overturned limbs were thrust westward over the adjacent synclines. Following this early deformation, the sedminentary rocks were broken and thrust westward over the previously folded rocks. Two of these major breaks, the Pulaski fault and the North Mountain fault, are present in the Lexington quadrangle. Later, the competent rocks of the Blue Ridge area were also broken by faults and thrust westward over the earlier formed structures. Concomitant with this, perhaps, the sedimentary rocks were again folded and the thrust planes were warped.

The evidence from the Lexington area does lend itself to this interpretation of 3 periods of deformation, but the writer considers it probable that these are progressive stages of a single deformation and probably overlap considerably in time. The fact that the deforming forces were oriented northwest-southeast suggests a single period of deformation

building gradually from processes of folding to those of thrust faulting of sedimentary beds to a climax during which the competent rocks of the Precambrian crystalline basement were broken and faulted. This deformation was post-Middle Devonian in the Lexington area. In consideration of the regional geology of the Appalachian Highlands King (1950a) suggests that the deformation was part of the Appalachian orogeny of Permian age.

ECONOMIC GEOLOGY

INTRODUCTION

At present, the only operation in which rock and mineral resources of the Lexington quadrangle are utilized is the Barger Quarry on the eastern environs of the town of Lexington. The following materials have been produced from the area, chiefly in the latter part of the 1800's and the early part of the 1900's: iron ore, manganese ore, brick clay, crushed stone (both quartzite and carbonates). The history, mode of occurrence, and further possibilities for each of these materials are noted in the following sections.

MINERAL RESOURCES

IRON ORE

The major iron ore deposits of the area are found along the western slope of the Blue Ridge. These deposits are part of the limonite belt that extends the length of the Blue Ridge in Virginia. Major production in the vicinity of the Lexington quadrangle was from the Buena Vista mine which lay at the foot of the Blue Ridge about one-quarter mile south of the quadrangle. This mine was one of the leaders in Virginia iron ore production (Watson, 1907) and was in operation until about the time of the First World War. The ruins of the furnace used for smelting the ore may be seen near the South River. Ore was produced from only one prospect in this belt in the Lexington quadrangle. This was known as the Midvale mine and was located about ½ mile east of Midvale on the flank of South Mountain (the writer has been unable to ascertain if this is the same Midvale mine referred to by Watson (1907) in connection with manganese ores); he reports that 20,000 tons of ore were produced from this mine in 1895 and 1896.

The ores of the Blue Ridge belt in the Lexington quadrangle are limonite; they contained approximately 35 to 50 percent metallic iron (Watson, 1907). The deposits are residual accumulations derived from weathering of the Lower Cambrian rocks. Mines have been worked in material overlying the Erwin quartzite, Shady dolomite, and Rome formation. As there is a great deal of slope wash in the area, it is difficult to say whether a limonite-rich weathered residue was produced from each of these formations or whether the material was derived from one formation and later spread over the surface exposures of the others. The Rome formation is probably the source of the limonite because the Erwin and Shady contain little or no iron.

Residual limonite deposits derived from the Oriskany, or Ridgeley, sandstone and associated formations occur in many parts of Virginia.

Watson (1909) notes the presence of a limonite deposit near the junction of the Little Calfpasture and Maury rivers, and it is likely that this deposit was one that contained "Oriskany ores." He also notes the presence of one limonite deposit east of Moffat's Creek in the northern part of the quadrangle; this was located in the outcrop area of the Waynesboro formation.

There may be two general areas favorable for exploration in the Lexington quadrangle area. One is the area underlain by the Rome formation and its immediately adjacent formations, and the other is the area underlain by the Ridgeley sandstone and its adjacent formations. These areas are closely associated with the most covered areas in the quadrangle and possibly other limonite deposits exist. Deposits are likely to be small and difficult to locate.

MANGANESE ORES

Manganese ores are related to the limonite ores of the quadrangle and have been mined in two localities. The first is on the Blue Ridge east of Midvale and the second is at the eastern foot of Bratton Mountain in the northwest corner of the quadrangle.

Manganese ore was first discovered east of Midvale and a mine was opened in the early 1880's. This mine was known as the Midvale mine (the writer has been unable to ascertain if this is the same Midvale mine referred to above in connection with iron ores). Only small amounts of manganese ore were produced at the Midvale mine (Stose, et al, 1919). The deposit was a residual concentration relatively rich in psilomelane and minor manganite (Stose, et al, 1919). The manganese nodules were separated from the matrix by washing and the washed ore was about 80 percent manganese oxide. Several closely spaced deposits of residual manganese ore were also worked along the eastern foot of Bratton Mountain (Watson, 1907 and 1909) and a sample analysed by Watson was 65 percent manganese. These ores were closely associated with the limonite that was derived from the Ridgeley sandstone.

There may be two general areas favorable for manganese ore exploration in the Lexington quadrangle. One is the area underlain by the Rome formation and its immediately adjacent formations along the foot of the Blue Ridge; the other is the area underlain by the Ridgeley sandstone and its adjacent formations. These areas are closely associated with the most covered areas in the quadrangle and possibly other manganese ore deposits exist. Deposits are likely to be small and difficult to locate.

CLAY DEPOSITS

No clay deposits are presently being worked in the Lexington quadrangle, but recent stream clays and Devonian shales were once utilized for brick manufacture at Goshen (Ries and Somers, 1920). The Dickinson Fire Brick Company operated a clay pit north of Buena Vista, about one-quarter mile south of the quadrangle, but operations ceased in 1929.

The area at the foot of the Blue Ridge is largely covered by many feet of mantle in which some exposures of clay have been reported by Ries and Somers (1920). Exploration for such deposits would of necessity be detailed. Three of the sedimentary formations of the quadrangle furnish fair possibilities of clay deposits. From the weathered Elbrook and Conococheague formations large amounts of clay may develop and occur locally as workable deposits of clay that may be satisfactory for common-brick manufacture. Ries and Somers (1920) report that the Martinsburg shale can be used satisfactorily in the manufacture of brick materials. The Martinsburg outcrops over several large areas, and possibilities for development may be favorable. Some recent stream clays, especially along the Little Calfpasture River, also present possibilities, but further testing of their extent and useability is necessary.

CARBONATE ROCKS

The entire region between the Blue Ridge and Little North Mountain is largely underlain by carbonate rocks of varied types. These rocks meet the qualifications for most industrial uses for carbonate rocks and are present in large amounts, but probably cannot be usefully exploited until transportation facilities within the region are improved. Edmundson (1958) discusses the carbonate rocks that are present in the quadrangle and includes chemical analyses in his report. The interested reader is referred to Edmundson's work for details.

The carbonate rocks of the area may be divided into four major groups based on chemical composition. The New Market limestone and most of the Murat facies of the Lincolnshire limestone are included in the *high calcium limestones* (over 95 percent calcium carbonate); minor parts of the Tonoloway limestone and Helderberg group also have this approximate composition. These limestones are used in industry for the manufacture of fertilizers, dye, fluxes, glass, lime, mineral feeds, paper, Portland cement, and many other products.

The Edinburg formation, and most of the Tonoloway and Helderberg rocks are included in the *limestones* (chiefly calcium carbonate, less than 10 percent magnesium carbonate) and *impure limestones* (more than 5 percent non-carbonate material). The Conococheague and Chepultepec limestones contain many rocks of this classification but also much magnesian limestone and dolomite that would have to be separated. These limestones are used for the manufacture of agricultural limestone, explosives, natural cement, hydraulic lime, and many other products.

The Elbrook and Beekmantown formations and large parts of the Conococheague and Chepultepec limestones are included in the *magnesian limestones* (10 to 30 percent magnesium carbonate) and *dolomites*. These rocks may be used as agricultural limestone, in explosives manufacture, as blast furnace flux, and for many other purposes.

The Shady dolomite is the only example of the fourth category, *high-magnesium dolomite* (over 40 percent magnesium carbonate and less than 4 percent non-carbonate material). This rock type is used for the manufacture of dolomite refractories, dye, fertilizers, paper, and many other products.

Thus the Lexington quadrangle contains large supplies of almost all types of industrial carbonate rocks. At present only one quarry is operating in the quadrangle. This is the Barger Quarry that produces crushed stone from the Edinburg formation. The quarry produces about 110,000 tons of crushed stone per year, 100,000 tons of which is used in road building and the remainder as concrete aggregate. There are several inactive quarries in the area. Two long-abandoned quarries in the Lincolnshire limestone (Murat) facies are present near Lexington; one is immediately west of the Lexington water tower, and the other is about 1½ miles southwest of the town along State Highway 251. The State Highway Department had opened a quarry, presently inactive, about ½ mile southwest of Timber Ridge Church on the east side of U. S. Highway 11; this quarry from which rock was crushed for aggregate used in highway construction is in the Elbrook formation. The city of Buena Vista has quarried the Erwin quartzite along the Jordan Road at the foot of the Blue Ridge for road material, but has presently abandoned the operation.

Several locations in the quadrangle are favorable sites for quarrying operations and three locations of high-calcium limestone warrant special mention. These are the areas immediately northeast of Zack where tight folds expose the New Market and Lincolnshire limestones over areas that are wider than usual, the folded belt southeast of the

village of Timber Ridge, and the area of wide exposure of the Lincolnshire from Limekiln Bridge southward. In this latter area the rocks are almost flat-lying and extensive shallow quarrying operations would be possible. Detailed surveys of the chemical composition of the rocks in these three locations will be necessary before a quarry could be established.

From analyses of the Liberty Hall facies of the Edinburg formation (Bassler, 1909; Edmundson, 1958) there is an indication that large parts of this facies have the chemical composition of natural cement rock. The wide area of exposure of the formation in the central part of the quadrangle promises large reserves and the opportunity of large scale operations. The Middle Ordovician limestones are sources of materials that could be extensively utilized in the manufacture of Portland cement.

SUMMARY

In summary of the potential use of rock and mineral resources in the Lexington quadrangle, it would appear that the carbonate rocks furnish the best possibilities for development. The area contains carbonates of different types that can be used in many industries; reserves are ample. The major obstacle to development at present is the distance from a market and lack of transportation facilities.

Iron ore, manganese ore, and clay deposits may be present in the quadrangle. Judging from the size and quality of known deposits, there is reasonable doubt that large deposits are present.

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VIRGINIA DEPARTMENT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver, Commissioner of Mineral Resources
and State Geologist

Base from U.S. Geological Survey topographic map.

Geology by K. F. Bick, in part by R. O. Bloomer.

EXPLANATION

MIDDLE DEVONIAN	Db — Brallier Shale	DEVONIAN	ORDOVICIAN
	Dm — Millboro Shale		LOWER ORDOVICIAN: Ob — Beekmantown dolomite; Och — Chepultepec limestone
LOWER DEVONIAN	Dri — Ridgeley sandstone		CAMBRIAN
	Dhl — Helderberg group		UPPER CAMBRIAN: Ꞓco — Conococheague limestone
UPPER SILURIAN	Sk — Keyser limestone	SILURIAN	MIDDLE CAMBRIAN: Ꞓe — Elbrook formation
	St — Tonoloway limestone		LOWER CAMBRIAN: Ꞓr — Rome (Waynesboro) formation; Ꞓs — Shady (Tomstown) dolomite; Ꞓer — Erwin (Antietam) quartzite; Ꞓh — Hampton (Harpers) formation, Ꞓhs - Snowden member
MIDDLE SILURIAN	Scl — Clinton formation		
LOWER SILURIAN	Sc — Clinch sandstone		
UPPER ORDOVICIAN	Omb — Martinsburg shale	ORDOVICIAN	CAMBRIAN OR PRECAMBRIAN: pꞒCu — Unicoi formation; pꞒCs — Swift Run formation
MIDDLE ORDOVICIAN	Oe, Oeb — Edinburg formation, Oeb - Botetourt member		PRECAMBRIAN: pꞒp — Pedlar formation
	Ol — Lincolnshire limestone		
	On — New Market limestone		

CONTACTS
exposed
approximate
covered

FAULTS
NORMAL AND REVERSE
U/D exposed
U/D approximate
U - upthrown side
D - downthrown side

THRUST
exposed
approximate
covered
(T - overthrust side)

TRANSVERSE
exposed
approximate
arrows show direction of relative movement

ATTITUDE OF ROCKS
40 Strike and dip of rocks
40 Strike and dip of overturned rocks
Strike of vertical beds
Horizontal beds

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE LEXINGTON QUADRANGLE, VIRGINIA

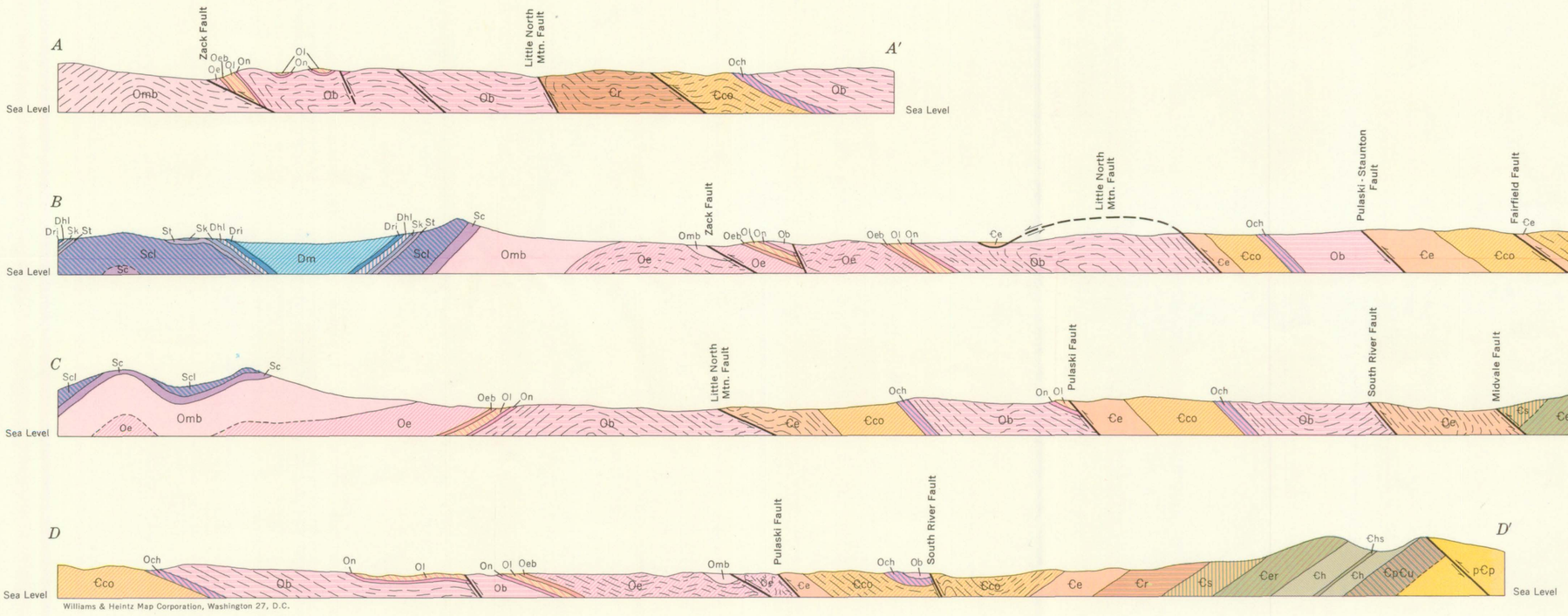
Scale 1/62500

1 ½ 0 1 2 3 4 Miles

Contour interval 20 feet
Datum is mean sea level

1960

K. F. Bick
R. O. Bloomer



No vertical exaggeration

Williams & Heintz Map Corporation, Washington 27, D.C.