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

Bulletin 65

Industrial Limestones and Dolomites in Virginia: Northern and Central Parts of Shenandoah Valley

By
RAYMOND S. EDMUNDSON

UNIVERSITY, VIRGINIA
1945

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COMMONWEALTH OF VIRGINIA
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1945

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., July 12, 1945.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit for publication as Bulletin 65 of the Virginia Geological Survey, the text and illustrations of a report on *Industrial Limestones and Dolomites in Virginia: Northern and Central Parts of Shenandoah Valley,* by Dr. Raymond S. Edmundson, Associate Geologist of the Virginia Geological Survey.

This report is the second in a series on the limestones and dolomites of present and future industrial value in the State. As the investigations are completed, additional reports in the series will be issued until all of the industrial limestones and dolomites of Virginia have been discussed.

Bulletin 65 contains a discussion of these carbonate rocks in seven counties in Shenandoah Valley, exclusive of the southern part of the valley which will be described in a forthcoming report. These counties are Clarke, Frederick, Shenandoah, Warren, Page, Rockingham and Augusta. The geologic data given in the report are primarily those of industrial significance, with sufficient scientific discussion of the stratigraphy and structure of the formations. The measured geologic sections and the chemical analyses of representative field samples are of particular value. The high quality of many of the limestones and dolomites is notable.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, July 20, 1945.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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Industrial Limestones and Dolomites in Virginia: Northern and Central Parts of Shenandoah Valley

By Raymond S. Edmundson

ABSTRACT

The area described in this report includes the northern and central parts of Shenandoah Valley in Virginia, extending from the West Virginia line southwestward to the vicinity of Greenville, Augusta County. It contains extensive deposits of high-calcium limestone averaging more than 97 per cent calcium carbonate. The Mosheim limestone, composed largely of high-calcium limestone, is the important "quarry rock" of the area. Other formations containing high-calcium limestone include locally a part of the Lenoir, the upper part of the Chambersburg in the western belts of Shenandoah County, and relatively thin units in the Beekmantown along the eastern side of the Massanutten Mountain syncline north of Rockingham County. Some of the thickest deposits of high-calcium limestone near railroads are in Frederick, Shenandoah, Rockingham, and Augusta counties.

Extensive exposures of the Tomstown (Shady) dolomite, containing more than 42 per cent magnesium carbonate, occur in the eastern part of Clarke County. Locally near the North Mountain fault in parts of Shenandoah and Rockingham counties, 80 feet or more of brecciated dolomite in the Elbrook formation contains about 43.5 per cent magnesium carbonate and generally less than 2 per cent silica. Most of the sampled dolomite units in the Elbrook, Conococheague, and Beekmantown formations contain less than 40 per cent magnesium carbonate.

Special study was made of the carbonate rocks suitable for chemical use and favorably located near railroads. Limestones, containing less than 95 per cent calcium carbonate, were studied locally in some detail. Descriptions of the belts of industrial limestone and dolomite are supplemented by geologic maps and sections, and chemical analyses.

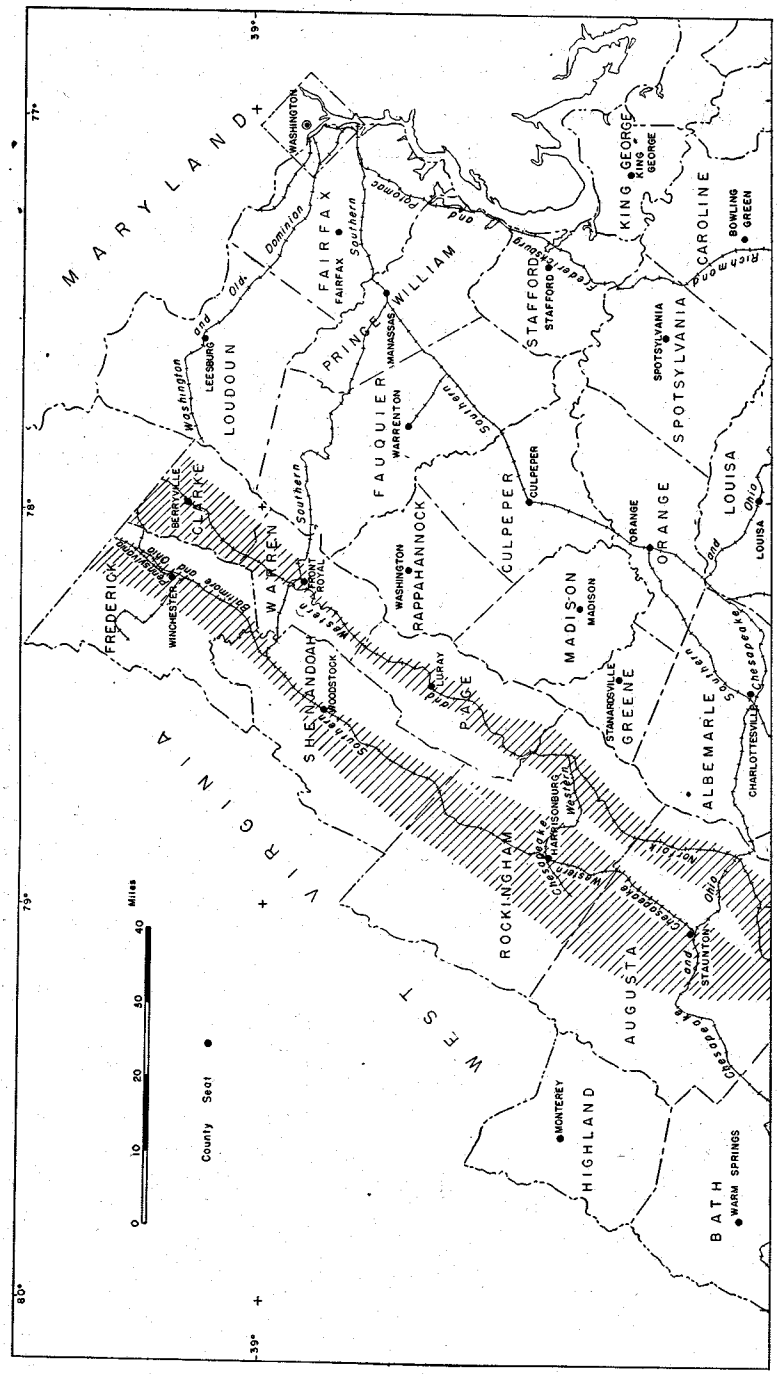


FIGURE 1.—Index map of northern Virginia showing distribution of limestones and dolomites in the northern and central parts of Shenandoah Valley.

INTRODUCTION

LOCATION OF THE AREA

The most important deposits of limestone and dolomite in Virginia are in the Valley and Ridge province. This natural division of the State, west of the Blue Ridge, may be defined as a long relatively narrow belt of valleys and ridges underlain by folded Paleozoic strata. It is divided longitudinally into two parts: an eastern broad almost flat valley with local ridges and hills, and a western belt of narrow parallel ridges and valleys (Valley Ridges). The eastern belt, known as the Valley of Virginia, is further subdivided,[15] from north to south, into Shenandoah, Fincastle, Salem, Dublin, and Abingdon valleys. The area described in this report (Fig. 1) extends from Greenville, Augusta County, northeastward to the West Virginia line at the northeastern boundary of Frederick County, a distance of 105 miles. The width ranges from about 12 to 20 miles.

PURPOSE AND SCOPE OF REPORT

It is the purpose of this report to give accurate information on the location, thickness, and chemical composition of the important occurrences of industrial limestones and dolomites in the northern and central parts of Shenandoah Valley, Virginia. This information should be helpful to quarry operators and others interested in the expansion of the stone industry. Special study was made of those formations which contain high-calcium limestone and high-magnesium dolomite. The physical character and chemical composition of the other carbonate rocks at a few selected localities, exclusive of local occurrences remote from railroads along the western edge of the valley, are discussed. Wartime limitations on field work made it necessary to generalize some of the geologic mapping and to suggest only tentative correlations of the formations, except in areas where there had been previous detailed study. It is thought that the data in this paper are adequate to define the most important belts of carbonate rocks and to serve as a guide in selecting particular localities for more detailed geologic investigation and testing.

Although the physical properties of the different rocks were not determined, it is evident, from their general lithologic character and from current commercial operations, that some of the limestones and dolomites are well suited for general construction uses.

FIELD WORK AND ACKNOWLEDGMENTS

In 1942 a study of the industrial limestones and dolomites in the Appalachian Valley of Virginia was planned by the State Geologist. The area northeast of Roanoke was assigned to the writer and the area southwest of Roanoke to Dr. Byron N. Cooper, also of the Virginia Geological Survey. This report covers the northern and central parts, approximately two-thirds, of Shenandoah Valley.

During the summer of 1942 the writer was capably assisted in the field, in the northern part of the valley, by Mr. Vincent E. Shainin, then a student at Columbia University. The remaining part of the area was surveyed jointly by Dr. Byron N. Cooper and the writer during the summers of 1943 and 1944. The report, including the geologic sections and maps, was prepared by the writer. Samples collected during field work were analyzed by Froehling and Robertson, Inc., Richmond, Va., and by Dr. John H. Yoe of the University of Virginia, also chemist of the Virginia Geological Survey. Wherever possible, chips for analyses were collected from fresh material at stratigraphic intervals of 1 to 2 feet. This is believed to yield the average composition of the full thickness of the rock sampled.

The geologic map of the Appalachian Valley of Virginia, which was published in Virginia Geological Survey Bulletin 42, served as a guide for the field investigations. Slight changes in the geologic interpretations shown on this map were made locally along the belts of high-calcium limestone that were studied in detail. Stratigraphic names and many salient features of the geology discussed in this report are taken from Virginia Geological Survey Bulletin 52, which is complementary to the geologic map of the Appalachian Valley of Virginia.

The geologic maps of the carbonate rocks in Frederick and Clarke counties, beginning with the top of the Tomstown (Shady) dolomite, were compiled from field maps by Charles Butts and the writer. The eastern boundary of the carbonate rocks in Clarke County was taken from a manuscript map made by G. W. Stose and Anna Jonas Stose for the Virginia Geological Survey. The geology in Page County between parallels 38° 30′ and 38° 45′ and east of meridian 78° 30′ is modified from a manuscript map made by H. P. Woodward for the Virginia Geological Survey. These maps are in the files of the Virginia Geological Survey. Maps in published reports[11, 16] on manganese deposits furnished the boundary between carbonate and noncarbonate rocks along most of the eastern side of Shenandoah Valley south of Warren County. Other published reports which were consulted during the

preparation of this manuscript are referred to in the text. The base maps used include county maps prepared by the Virginia State Planning Board and quadrangle topographic maps of the U. S. Geological Survey.

The writer is indebted to members of the Virginia Geological Survey for suggestions concerning the preparation of this report and for editing the manuscript and illustrations for publication. Special acknowledgment is due quarry operators for assistance in field investigations and for valuable information on special uses of limestone and dolomite. Many other citizens of the area have helped in the collection of data and have extended every courtesy to the writer

DEFINITION OF TERMS

Carbonate rocks are of sedimentary origin and are composed essentially of calcium carbonate or calcium and magnesium carbonates. They range in color from white through pale shades of gray, blue, and brown to black. In this report, particularly in the geologic sections, the term *limestone* is used in the general geologic sense of applying to rocks composed predominantly of calcium carbonate ($CaCO_3$). *Dolomite* is used in the same sense for those rocks composed chiefly of the double carbonate of calcium and magnesium ($CaCO_3.MgCO_3$). A pure dolomite contains about 46 per cent magnesium carbonate and 54 per cent calcium carbonate, whereas pure limestone is composed entirely of calcium carbonate. None of the carbonate rocks in Virginia have this theoretical purity. Rocks containing about 10 to 30 per cent magnesium carbonate are referred to in this report as *magnesian* or *dolomitic* limestone. If sufficient chemical data are available, the rocks are further subdivided into *high-calcium limestone,* containing more than 95 per cent calcium carbonate, and *high-magnesium dolomite,* containing more than 40 per cent magnesium carbonate and generally less than 4 per cent noncarbonates. Since the noncarbonate constituents are important for certain uses, the heading *impure limestone* is used in the text to describe those limestone formations which are commonly low in magnesium carbonate and contain more than 5 per cent noncarbonates. These noncarbonates, or impurities, include chiefly silica, alumina, and iron oxide. Phosphorus, sodium, and potassium are generally present in very small amounts.

The descriptive terms *fine-, medium-,* and *coarse-grained* refer to the texture of the rocks. *Fine-grained* varieties are composed of mineral grains too small to be distinguished without magnification. The *coarse-grained* rocks are composed largely of particles, perhaps aver-

aging not less than 2 millimeters in diameter, which are readily distinguished by the naked eye. Other rocks which show intermediate granularity are described as *medium grained*. The term *compact* refers to a very fine-grained, dense, homogeneous rock which breaks with a smooth fracture, similar to glass.

USES OF LIMESTONE AND DOLOMITE

Certain uses of limestone and dolomite are dependent upon their chemical composition, whereas other uses are largely controlled by their physical character. Uses[2] in which physical properties are most important include dimension stone, concrete aggregate, road stone, railroad ballast, asphalt filler, riprap, sewage filter beds, stucco and terrazzo, poultry grit, sand, roofing gravel, yard and playground surfacing, concrete-block manufacture, whiting, and whiting substitute.

The important uses of carbonate rocks which are determined chiefly by their chemical composition are given in Table 1 compiled from a report[13] of the Illinois State Geological Survey. The classification of

TABLE 1.—*Important chemical uses of limestone and dolomite*

USES	High-calcium limestone	Limestone and impure limestone	Magnesian limestone and dolomite	High-magnesium dolomite
Agricultural limestone	x	x	x	x
Alkalies	x			
Aluminum oxide	x			
Ammonia (cyanamide process)	x			
Baking powders	x			
Calcium carbide	x			
Calcium nitrate	x			
Carbon dioxide	x	?	?	x
Coal-mine dusting	x		x	x
Dolomite refractories			?	x
Dye works	x			
Epsom salts				x
Explosives	x	x	x	x
Fertilizers	x			x
Flux:				
Open-hearth furnace	x			
Blast furnace	x		x	x
Nonferrous metals	x			
Glass manufacture	x			x

TABLE 1.—*Important chemical uses of limestone and dolomite—Continued*

USES	High-calcium limestone	Limestone and impure limestone	Magnesian limestone and dolomite	High-magnesium dolomite
Lime:				
High-calcium lime	x			
Low-magnesium lime			x	
High-magnesium lime				x
Hydraulic lime		x		
Magnesium				x
Mineral feeds	x			
Natural cement		x		
Paper:				
Sulphite pulp (Tower system)	x			x
Sulphite pulp (milk-of-lime system)				x
Soda pulp and sulphate pulp	x			
Portland cement	x	x		
Rock wool	x	x	x	x
Salt refining	x			
Soap purification	x			
Sugar refining	x			
Technical carbonate				x
Whiting substitute[a]	x			x

[a] Physical properties more important for certain uses.

limestones and dolomites given in this table is used in the general sense described under the definition of terms.

The value of limestone, including crushed and broken stone and lime produced in Virginia in 1943, as given by the U. S. Bureau of Mines, is summarized in Tables 2 and 3.

TABLE 2.—*Limestone (crushed and broken stone) sold or used by producers in Virginia in 1943*[3]

	Short tons	Value
Riprap	14,040	$ 20,525.00
Fluxing stone	473,110	502,318.00
Crushed stone:		
Concrete and road metal	1,639,870	1,645,761.00
Railroad ballast	612,760	512,887.00
Agriculture	896,520	918,347.00
Other uses	726,270	694,669.00
Total	4,362,570	$ 4,294,507.00

TABLE 3.—*Lime sold or used by producers in Virginia in 1943*[14]

	Short tons	Value
Agricultural	37,099	$ 273,774.00
Building	8,384	59,676.00
Metallurgical	53,978	359,140.00
Paper mills	14,116	97,041.00
Tanneries	1,000	6,247.00
Water purification	28,373	202,673.00
Other uses	52,024	340,124.00
Total	194,974	$ 1,338,675.00

GEOGRAPHY

RELIEF AND DRAINAGE

The area described in this report (Fig. 1) includes parts of Frederick, Shenandoah, Rockingham, Augusta, Page, Warren, and Clarke counties. It is the broad generally flat valley, lying between the Blue Ridge on the east and the Valley Ridges on the west, which is drained by Shenandoah River and its tributaries. The geography of the Valley of Virginia has been described by Stose. That part of his description pertaining to the area included in this report is as follows:[17]

"The northern part of the Valley of Virginia is drained by Shenandoah River. At the Maryland State line it is 20 miles wide and its floor is relatively even and little dissected except near the large streams. Its altitude here is between 500 and 600 feet, but it rises gradually southwestward. It has approximately the same width to the vicinity of Strasburg and Riverton, at the forks of Shenandoah River, beyond which the valley is divided lengthwise by Massanutten Mountain, a bold, high mountain ridge 45 miles long. North Fork of Shenandoah River drains the part northwest of the mountain and South Fork the part to the southeast. The valley southeast of Massanutten Mountain has an average width of about 5 miles, expanding to 6 or 8 miles in width near Luray and at Elkton and locally narrowing to 3 miles in width near Compton and south of Alma. The floor of this eastern part of the valley rises from about 700 feet in altitude at its north end to 1,200 feet at its south end. The valley northwest of Massanutten Mountain has a general width of 6 to 10 miles, and its floor rises from about 800 feet altitude near Strasburg to about 1,500 feet at Harrisonburg. Beyond the southwest end of Massanutten Mountain the valley is again 20 miles wide, but narrows to about 14 miles near Greenville. This wider part of the valley is drained by North, Middle, and South rivers, which coalesce to form South Fork of Shenandoah River. Its floor rises southwestward from between 1,200 and 1,500 feet to 1,800 and 2,000 feet altitude near Lofton and Middlebrook on the Shenandoah-James divide, the higher levels prevailing on the northwest side of the valley."

TRANSPORTATION FACILITIES

The Norfolk and Western Railway extends northward across the eastern part of the area, passing through Stuarts Draft, Waynes-

boro, Luray, Riverton, and Berryville. The main east-west line of the Chesapeake and Ohio Railway serves the southern portion of the area, extending through Waynesboro, Staunton, and Clifton Forge, and crossing the Norfolk and Western at Waynesboro. Harrisonburg near the geographical center of Shenandoah Valley in Virginia is connected with Staunton, Elkton, and Bridgewater by branch lines of the Chesapeake Western Railway. A branch line of the Southern Railway extends from Harrisonburg northeastward to Strasburg Junction and thence eastward through Riverton to connect with the main line at Manassas. From Strasburg Junction, the Valley Division of the Baltimore and Ohio Railroad extends northward through Winchester and Wadesville to connect with the main line at Harpers Ferry, W. Va. A branch line of the Pennsylvania Railroad from Harrisburg, Pennsylvania, terminates at Winchester. That part of western Frederick County between Gore and Winchester is served by the Winchester and Western Railroad.

U. S. Highway 11, the main thoroughfare through the Valley of Virginia, extends southwestward through Winchester, Woodstock, Harrisonburg, Staunton, and Greenville. State Highway 12, passing through Berryville, Front Royal, Luray, and Waynesboro, serves the eastern part of the area. Among the main thoroughfares crossing the area from east to west are U. S. Highway 50, through Millwood and Winchester; State Highway 55, through Riverton and Strasburg; U. S. Highway 211, through Luray and New Market; U. S. Highway 33, through Elkton and Harrisonburg; and U. S. Highway 250, through Waynesboro, Staunton, and Churchville. Numerous hard-surfaced roads connecting with the main highways offer ready accessibility to most of the limestone and dolomite belts.

GEOLOGY

GENERAL STATEMENT

The land forms, rocks, and soils in the Appalachian Valley are the results of a succession of events through a long period of geologic time. These natural changes are continuing today but so slowly that they are not generally observed.

The history of the Appalachian Valley began with the subsidence of a narrow belt in the eastern part of North America, extending at least from Newfoundland into Alabama. This gradual subsidence resulted in the formation of a large trough (Appalachian geosyncline) which was gradually flooded many times by interior seas. Streams flowing from neighboring land areas transported and deposited sediments in this ancient seaway throughout most of the Paleozoic era. The deposits of mud, silt, sand, and gravel were compacted and cemented into stratified shale, sandstone. and conglomerate. The limestones and dolomites were formed from limy materials. Many of the rocks show shallow-water features, such as mud cracks, cross bedding, and ripple marks. Approximately 15,000 feet of sedimentary rocks, chiefly limestone and dolomite, are now exposed in the northern and central parts of Shenandoah Valley.

The extremely long period of deposition in the geosynclinal trough was followed by intense crustal movements which compressed the thick mass of sedimentary rocks and elevated them above sea level. During this period of orogeny, the rocks were folded, fractured and faulted. In some areas the rocks were broken into large segments and thrust northwestward one upon the other, overlapping much like shingles on a roof.

Erosion has been active since the strata which became the old mountains began to rise above sea level, having been renewed and intensified from time to time by vertical uplifts of the region. The structure and relative resistance to erosion of bedrock play an important rôle in shaping the landscape. Resistant rocks, such as firm sandstones, form ridges; whereas less resistant rocks, such as limestone and shale, become valleys.

STRATIGRAPHY

The carbonate rock units, or formations, in the northern and central parts of Shenandoah Valley are shown in Table 4. The

TABLE 4.—*Carbonate formations in the northern and central parts of Shenandoah Valley, Virginia*
(After Charles Butts[4])

ERA	PERIOD AND SYSTEM	FORMATION
Paleozoic	Ordovician	Chambersburg limestone Athens formation Whitesburg limestone[a] Lenoir limestone Mosheim limestone Beekmantown formation Chepultepec limestone
	Cambrian	Conococheague formation Elbrook formation Waynesboro (Rome) formation Tomstown (Shady) dolomite

[a] The Whitesburg was observed locally in the belts mapped as Athens and Chambersburg in Augusta and Rockingham counties.

following summary of these formations includes a brief description of the character and thickness of the rocks. Since the field investigation on which this report is based did not include the study of fossils, the boundaries of the formations shown on the geologic maps and sections, except in areas where there has been detailed geologic work, are subject to revision.

Tomstown dolomite.—The thick succession of clastic Lower Cambrian rocks which crop out mainly on the lower northwestern flanks and spurs of the Blue Ridge is overlain in normal geologic sequence by the Tomstown (Shady) dolomite, the oldest carbonate formation in Shenandoah Valley. The belt of Tomstown at the western foothills of the Blue Ridge is concealed locally by overthrusting and, between Rockbridge County and northern Warren County, is almost entirely covered by material washed down from the mountain. The presence of the Tomstown beneath this mantle of unconsolidated material, exclusive of the localities which are faulted, is indicated chiefly by the occurrence of white to varicolored residual clays exposed in several manganese and iron-ore pits and by unweathered dolomite encountered in several recent test holes for manganese.[12] The Tomstown dolomite, although not fully displayed in any exposure, crops out at several localities near Shenandoah River in Clarke County and near the southwestern end of Shenandoah Valley in Rockbridge and Botetourt counties. In Clarke County its thickness is estimated at 1000 to 1500 feet. In

general, the upper part of the formation in the northern part of the area is composed predominantly of light- to dark-gray, fine- to medium-grained dolomite that averages more than 40 per cent, and locally contains more than 42 per cent, magnesium carbonate. Some beds, for example those which crop out along State Highway 7 west of Castleman Ferry Bridge, are cream-colored and have a saccharoidal texture. Partial exposures, probably within the lower part of the formation, observed along a tributary of Shenandoah River about three-fourths of a mile northeast of State Highway 7, in a field one-fourth of a mile west of Parker Island, and just southwest of Shepherd Ford, are composed of bluish-gray limestone or magnesian limestone, dolomite, and thin silty beds. Although exposures are inadequate for detailed descriptions of the lithology, thickness, and structure, it is thought that the upper part of the Tomstown which crops out in Clarke County contains large reserves of high-magnesium dolomite.

Waynesboro formation.—The Waynesboro (Rome) formation directly overlies the Tomstown dolomite and crops out in a relatively broad belt near the northwest base of the Blue Ridge. This belt, except where it is crossed by large streams, commonly is deeply weathered, covered by slope wash over large areas, and is locally concealed by overthrusting. At other localities along the western side of Shenandoah Valley, north of Staunton, Augusta County, erosion has not extended to sufficient depths to expose the formation.

The Waynesboro is a heterogeneous formation. It is composed of maroon-drab and green shaly mudrock, fine-grained brownish sandstone, and impure limestone and dolomite. Intercalations of maroon-drab shales and layers of impure dolomites, which weather to ochreous rocks, are distinctive features of the formation. Although no complete sections of the Waynesboro were observed in this area, it is probable that the measured thickness[5] of about 2000 feet in the vicinity of Buchanan, Botetourt County, at the southwestern end of Shenandoah Valley, may apply in other parts of the Valley.

Elbrook formation.—The Elbrook formation, in normal sequence above the Waynesboro, crops out in one belt along the southeastern side of Shenandoah Valley. It is continuous, except for a faulted area southwest of Front Royal. Another belt occurs along a major

overthrust near the western edge of the valley. Other smaller outcrops occur along faults or occupy the crests of anticlines.

In Frederick County the Elbrook is composed essentially of interbedded clayey limestone and minor amounts of impure dolomite. It contains a few layers of flesh-colored limestone of apparently good quality. The thickness is estimated at about 2000 feet. The impure parts of the formation are generally thin bedded and weather to rusty-looking slabs and thin plates. Although no samples were collected for chemical analysis, it is thought that there are no quarriable thicknesses of either high-grade limestone or dolomite in the Elbrook in the county.

The Elbrook formation, near the North Mountain fault in parts of Shenandoah and Rockingham counties, contains zones, 80 feet or more thick, of dark-gray, brecciated, mealy weathering dolomite, which average about 43.5 per cent magnesium carbonate and generally less than 2 per cent silica. Other massively bedded units of Elbrook dolomite sampled in Augusta County and adjoining Rockbridge County generally contain less than 41 per cent magnesium carbonate and more than 5 per cent noncarbonates. Partial exposures of the Elbrook formation along the eastern side of the valley, although not sampled or studied in any detail, are briefly described under each county as being composed largely of impure limestone and dolomite.

Conococheague formation.—The Conococheague formation crops out in a belt east of the Massanutten Mountain syncline, and in one or more belts along the western side of the valley. In the northeastern part of the area, particularly in Frederick, Clarke, and Warren counties, the Conococheague is predominantly a bluish-gray limestone containing beds of dolomite of variable thickness. Farther southwest, dolomite becomes more abundant, and in Augusta County it probably represents about half of the estimated thickness of 2500 feet. The formation is marked by two distinctive features: thin laminae, containing siliceous material, which stand out as crinkly ribs on weathered surfaces of limestone (Pl. 1A); and beds of coarse-grained, friable sandstone (Pl. 1B). The siliceous banded limestones are generally more abundant near the top of the formation. Sampled units of limestone commonly show from 65 to 90 per cent calcium carbonate; those of dolomite, less than 40 per cent magnesium carbonate.

Chepultepec limestone.—The Chepultepec limestone, at the base of the Ordovician system between the Beekmantown and the Conococheague, crops out in a narrow belt east of Massanutten Mountain and in one or more belts west of Massanutten Mountain. It is composed largely of thick-bedded, bluish-gray, slightly laminated limestone with a few intercalated layers of dolomitic limestone. The thickness of the formation is estimated at 300 to 500 feet. Sampled units commonly contain from about 80 to 90 per cent calcium carbonate, depending upon the relative amounts of siliceous laminae and intercalated magnesian layers present.

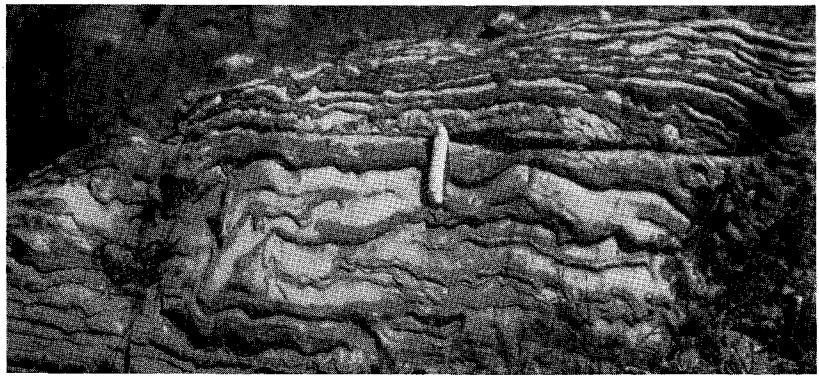
Beekmantown formation.—The Beekmantown formation, like the Chepultepec, crops out in one belt along the eastern limb of the Massanutten Mountain syncline and in one or more belts in the western part of the area. It shows wide variations in composition and thickness. In Augusta and Rockingham counties, the Beekmantown is composed chiefly of fine-grained, gray dolomite with minor amounts of bluish-gray limestone. Farther northeast along the strike limestone becomes more abundant, and in Frederick County probably comprises slightly more than half of the formation. Limestone also becomes more abundant southeastward across the strike of the belts; thus in Clarke County the Beekmantown is largely bluish-gray limestone with minor amounts of dolomite. In places the formation contains relatively thin beds of high-calcium limestone (Pl. 1C) intercalated in dolomitic limestone and dolomite. The layers of dolomite are commonly characterized by distinct intersecting furrows on weathered surfaces (Pl. 2A). The sampled units of Beekmantown dolomite contain about 30 to 41 per cent magnesium carbonate. Chert, although generally not abundant, occurs locally at several horizons in the formation. Field observations indicate that the thickness of the Beekmantown increases northeastward, probably ranging from 2000 feet in Augusta County to about 3000 feet in northern Frederick and Clarke counties.

Mosheim limestone.—The Mosheim limestone, occurring in several narrow belts, is the principal "quarry rock" in Shenandoah Valley. This formation is described in considerable detail in this report, since it contains extensive potential reserves of high-calcium limestone. It is composed chiefly of thick bedded, compact to glassy, bluish-gray to dove-gray limestone. Among distinguishing characteristics are specks of transparent calcite scattered through many

of the layers and thin films of chalklike material on weathered surfaces. At a few localities the generally dense texture of the Mosheim is supplanted by a rock composed of subangular to rounded grains of compact limestone in a matrix of colorless calcite.

In the belts west of Massanutten Mountain the Mosheim ranges in thickness from about 40 to 240 feet, averaging more than 100 feet at many localities. East of Massanutten Mountain, except in the small area southwest of Fishersville, the Mosheim generally is less than 50 feet thick and locally absent. Field studies indicate that many of the local variations in thickness are due to the deposition of the Mosheim upon an irregular surface at the top of the Beekmantown formation. The formation in the western belts is commonly divided into two parts: an upper division, including more than half of the total thickness, containing about 97 to 98.5 per cent calcium carbonate; and a lower slightly impure part averaging about 96 per cent calcium carbonate. A few exceptions to this high calcium carbonate content are given in the detailed descriptions of the Mosheim under various counties.

Lenoir limestone.—The Lenoir in a complete geologic sequence overlies the Mosheim and crops out in a number of narrow belts in the western part of the area and generally in one belt east of Massanutten Mountain. At a few localities in the eastern part of Shenandoah Valley, where the Mosheim is absent, it rests directly upon Beekmantown dolomite. Throughout most of the valley the Lenoir is composed of dark-gray, fine- to medium-grained, cherty limestone (Pl. 2B). It commonly contains pinkish partings along irregular bedding surfaces and thin clay seams. A part of the formation is distinctly nodular. It contains high-calcium limestone at a few places. East and south of Staunton, Augusta County, thick deposits of light-gray, coarse-grained limestone, tentatively correlated as a part of the Lenoir, contain from about 96 to 98 per cent calcium carbonate. At a few other localities, where chert is not present, the typical dark-gray, fine-grained limestones, particularly in the lower part of the formation, contain from about 95 to 97 per cent calcium carbonate. The Lenoir is generally impure and rarely could the full thickness be quarried as high-calcium limestone. The Lenoir is thought to be persistent throughout the northern and central parts of Shenandoah Valley, ranging in thickness from about 40 feet to a possible maximum of 250 feet.



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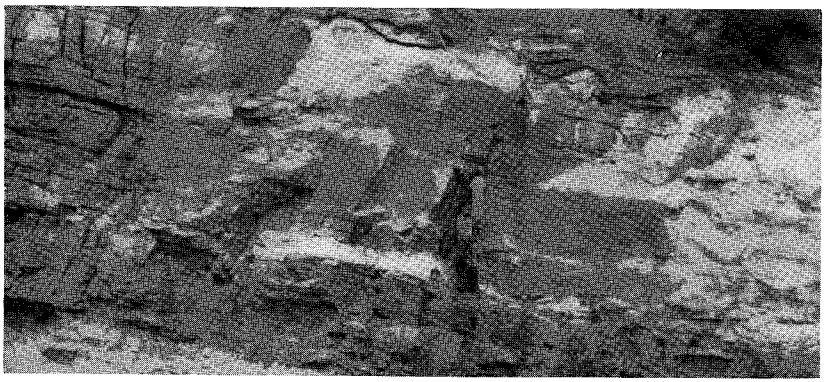

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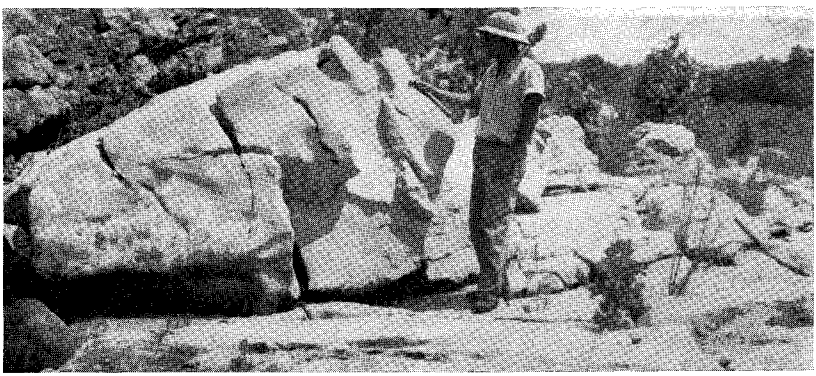
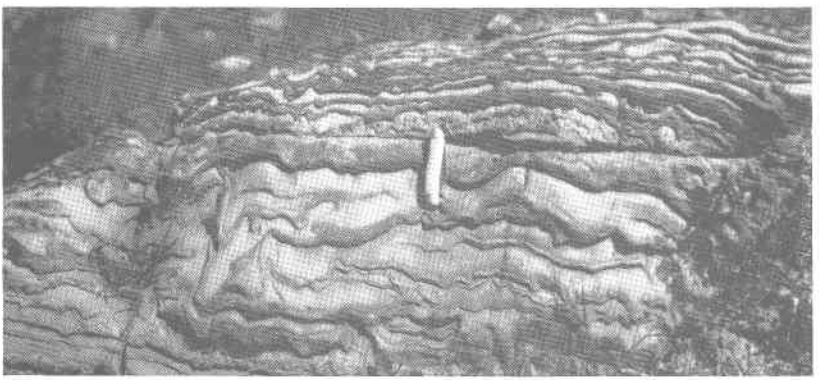
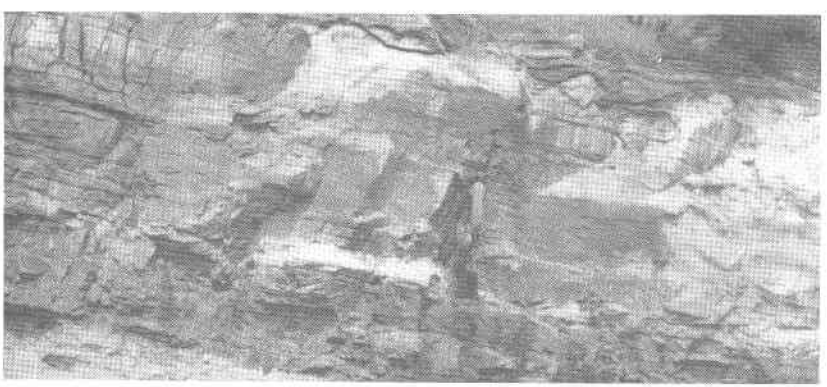


C.

A, Laminae containing siliceous material in Conococheague limestone near Staunton, Va. B, Five-foot sandstone bed in Conococheague limestone three-fourths of a mile southeast of Luray, Va. C, High-calcium limestone in upper part of Beekmantown formation at power dam northwest of Luray, Va.



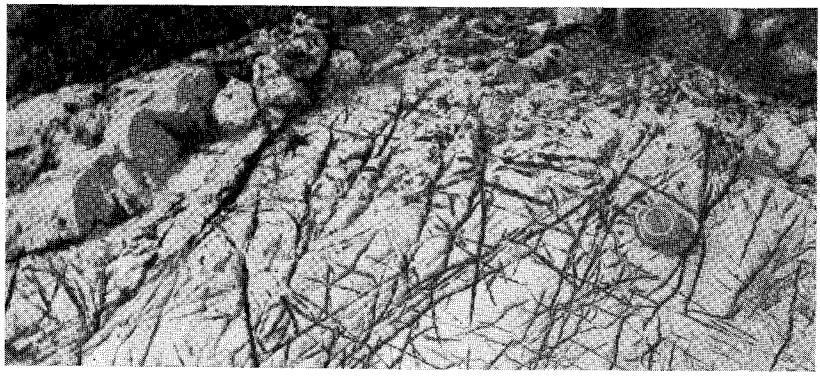
A.



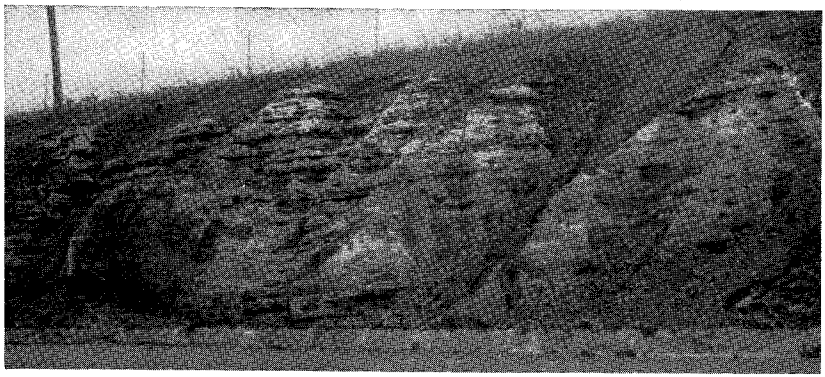
B.

C.

A, Laminae containing siliceous material in Conococheague limestone near Staunton, Va. B, Five-foot sandstone bed in Conococheague limestone three-fourths of a mile southeast of Luray, Va. C, High-calcium limestone in upper part of Beekmantown formation at power dam northwest of Luray, Va.



A.



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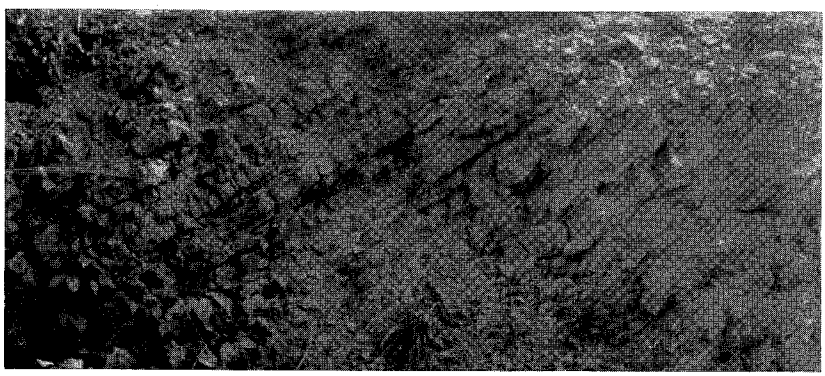
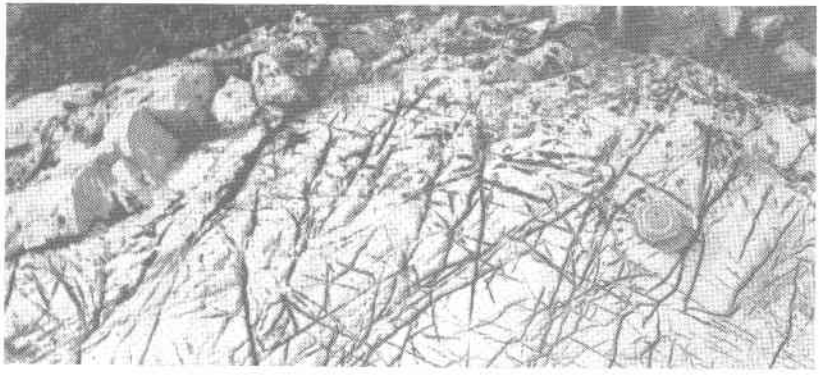


C.

A, Furrows in weathered Beekmantown dolomite in Burkes Garden, Tazewell County, Va. (Photograph by B. N. Cooper.) B, Cherty Lenoir limestone one mile northwest of Broadway, Va. C, Cobbly weathering Chambersburg limestone 4 miles northeast of New Market, Va.



A.

B.

C.

A, Furrows in weathered Beekmantown dolomite in Burkes Garden, Tazewell County, Va. (Photograph by B. N. Cooper.) B, Cherty Lenoir limestone one mile northwest of Broadway, Va. C, Cobbly weathering Chambersburg limestone 4 miles northeast of New Market, Va.

Whitesburg limestone.—Limestone tentatively referred to the Whitesburg was observed locally in central Rockingham County and northeast of Staunton in Augusta County. The Whitesburg is composed chiefly of impure, dark-gray, medium- to coarse-grained limestone that weathers rusty brown. The thickness probably averages between 10 and 30 feet.

Athens and Chambersburg formations.—The beds between the Whitesburg limestone and Martinsburg shale, or between the Lenoir and Martinsburg in areas where the Whitesburg is absent in the northern and central parts of Shenandoah Valley, are composed chiefly of variable proportions of gray to black shale and compact impure black limestone, with a few interbedded fine-grained sandstones or siltstones. On the geologic map of the Appalachian Valley in Virginia these beds include both Athens and Chambersburg in parts of Shenandoah Valley, whereas in other parts only one of these formations is present. Northwest of the Massanutten Mountain syncline the Athens has recently been mapped as extending northeastward to the general vicinity of Mount Jackson in Shenandoah County[9]. On the eastern side of the syncline, the Athens extends northeastward through Clarke County into West Virginia[4]. The Chambersburg is present in one belt in parts of Clarke and Page counties along the eastern side of the Massanutten Mountain syncline; on the northwestern side of the syncline, in one belt extending from the West Virginia line southwestward to Endless Caverns, and in several belts west of Woodstock, Harrisonburg, and Staunton.

In the vicinity of Staunton and generally along the eastern side of the valley the Athens is chiefly shale with thin intercalations of black limestone, whereas in the vicinity of Harrisonburg and in the western belts, limestones are prominently developed. The Chambersburg, exclusive of the upper 60 to 90 feet of high-calcium limestone in the northwestern part of Shenandoah County, is largely black, in part nodular weathering limestone (Pl. 2C), which contains less than 90 per cent calcium carbonate. Since most of the Chambersburg closely resembles the limestone facies of the Athens, the two formations in some areas can not, at present, be distinguished with certainty from each other by their lithology. The combined thickness of the formations is estimated to be about 1350 feet in Rockingham County, 400 to 600 feet in Shenandoah County, and about 500 feet near the West Virginia line in Clarke County.

The carbonate rocks in Shenandoah Valley are overlain in places by a thick succession of shales and fine-grained sandstones comprising the Martinsburg formation. These rocks were originally overlain by still younger formations, all of which, except in Massanutten Mountain, have been eroded from the area here described.

STRUCTURE

The sedimentary rocks in Shenandoah Valley are now generally inclined at angles to the almost horizontal position in which they were deposited. The present attitude and distribution of these rocks indicate that they have been bent into upfolds, or anticlines, and downfolds, or synclines, and subsequently deeply eroded. Most of the axes of these folds and the truncated edges of the strata which crop out along the limbs of the structures are approximately parallel and trend northeastward. In many places the normal geologic sequence of formations is modified by great fractures (faults) along which the strata are displaced. A few of the larger structures[8] in the area are briefly described below.

One of the major structures in Shenandoah Valley is the Massanutten Mountain syncline, which extends from the vicinity of Greenville, Augusta County, on the southwest, northeastward into Berkeley County, West Virginia. The main area of the syncline, occupied by Martinsburg shale and sandstone, lies east of Staunton, Harrisonburg, and Winchester. In a broad sense, the syncline includes also the carbonate rocks which crop out on the flanks of the structure east and west of the belt of Martinsburg shale. The bold ridges of Massanutten Mountain, underlain chiefly by resistant Silurian sandstone, begin at the north near the middle of the fold in the vicinity of Strasburg, Shenandoah County, and continue southwestward to the general vicinity of McGaheysville, Rockingham County. Minor folds and faults within the Martinsburg formation and in the associated limestones (Pls. 3A and 3B) show that this structure is not a single symmetrical fold.

The belt of country between the Massanutten Mountain syncline on the west and the Blue Ridge on the east is the eastern part of Shenandoah Valley, known locally as Page Valley. This area is underlain chiefly by Cambrian and Ordovician limestones and dolomites. At certain localities these formations occur in normal geologic sequence overlying the Lower Cambrian clastic rocks along the northwestern base of the Blue Ridge, whereas in other areas crystalline rocks of the Blue Ridge have been thrust westward onto these limestones and dolo-

mites. The broad belts of carbonate rocks in this part of Shenandoah Valley generally trend northeastward. They are locally modified by gently pitching folds which have produced sinuous outcrop patterns. The common southeast dip of the strata and the great width of outcrop of some of the formations suggest a number of small folds overturned toward the northwest. Minor folding and faulting are well displayed by narrow belts of Ordovician limestone along the Martinsburg formation, particularly in parts of Clarke, Warren, and Page counties.

The formations of limestone and dolomite west of Massanutten Mountain syncline, except for relatively small local occurrences along the western edge of the area, are bounded on the northwest side by the North Mountain fault. Locally, along the trace of this fault there are faulted slices and diverging branches which constitute a faulted zone.

Another major overthrust of the valley is the Staunton fault. It enters Augusta County west of Greenville and extends northeastward to the vicinity of Endless Caverns, in northern Rockingham County. One of the interesting features of this fault is a detached mass of the overthrust sheet (klippe) resting upon younger rocks along the Augusta-Rockingham County line west of Burketown.[4]

The structure of the rocks between the Massanutten Mountain syncline and the North Mountain fault near the western side of the valley generally consists of a number of relatively long, narrow overlapping folds. Along a traverse extending southeast of Brocks Gap in northwestern Rockingham County the high-calcium limestone (Mosheim) is repeated five times by folding; whereas at Winchester, in Frederick County, it is limited to one narrow belt along the western broad expanse of Martinsburg shale in the Massanutten Mountain syncline. Outlying belts of the Martinsburg are confined to synclinal troughs west of Woodstock, Broadway, and southwest of Harrisonburg. Cambrian limestones and dolomites, exclusive of the principal belt along the western side of the valley, are exposed along the crest of an anticline between the latitude of Woodstock and Lacey Spring, southwest of Endless Caverns, and west of Staunton. Minor folding, resulting in sinuous boundaries between formations, and small faults have been observed in local areas which have been mapped in detail.

FREDERICK COUNTY

GENERAL STATEMENT

Frederick County, the most northerly county in Virginia, is bounded on the northeast and northwest by West Virginia, on the east by Clarke County, and on the south by Warren and Shenandoah counties (Fig. 1). It is separated from Clarke County chiefly by Opequon Creek and its important tributary, Wright Run, and from Shenandoah County by Cedar Creek. The county has an approximate area of about 432 square miles or 276,480 acres. The longest dimension, which is 32 miles, extends from the northern apex of the State boundary southeastward to Zion Church near Nineveh, Warren County.

That part of the county (Pl. 5), between Little North Mountain on the northwest and Opequon Creek on the southeast, between 8 and 10 miles wide and about 20 miles long, lies in Shenandoah Valley. Exposed bedrock includes limestone and dolomite in the western half of the valley and shale and fine-grained sandstone east of a line passing southwestward near Stephenson, Winchester, and Middletown. The area underlain by carbonate rocks is characterized by low discontinuous northeasterly trending ridges, rising from about 50 to 150 feet above the bordering valleys, whereas in the shale belt there are no conspicuous knobs or ridges. Altitudes range from about 450 feet along Opequon Creek at the West Virginia line to 900 feet along the southeast base of Little North Mountain, and average about 750 feet in the vicinity of Winchester, Stephens City, and Middletown. That part of the county, southwest of a line extending northwest through Stephens City, is drained into Shenandoah River by streams tributary to Cedar Creek and Crooked Run, whereas the northeastern part of the county is drained northeastward to the Potomac by Opequon and Back creeks.

The county is served by a branch line of the Baltimore and Ohio Railroad which closely parallels U. S. Highway 11 from Shenandoah County northeastward to Stephenson; by a branch line of the Pennsylvania Railroad north of Winchester; and by the Winchester and Western Railroad between Winchester and Gore.

GEOLOGY

The carbonate rocks which crop out in the Shenandoah Valley part of Frederick County are described in this report as high-calcium limestone; impure limestone; and interbedded limestone, magnesian limestone, and dolomite. A summary of these rocks, including lithologic

character, general range in chemical composition, and approximate thickness, is given in Table 5.

TABLE 5.—*Summary of carbonate rocks in the Shenandoah Valley portion of Frederick County, Virginia*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Chambersburg	Shaly and nodular black limestone with thin layers of brownish siltstone. Sampled units contain less than 91 per cent calcium carbonate.	400–575
Lenoir	Granular, medium-bedded, dark-gray limestone; commonly cherty. Sampled units generally contain less than 90 per cent calcium carbonate, but locally, where chert free, about 96 per cent.	50–100
Mosheim	Compact, medium- to thick-bedded, dove-gray limestone. Sampled units, representing in most instances the full thickness of the formation, contain from about 96 to 98 per cent calcium carbonate.	50–220
Beekmantown	Interbedded, fine-grained, dark-colored limestone and gray finely crystalline dolomite, in the ratio of about 3 to 2. Chert, although not abundant, occurs throughout the formation. Sampled units of dolomite in the upper part of the formation contain from about 38 to 41 per cent magnesium carbonate.	2500–3000[a]
Chepultepec	Thick-bedded, slightly laminated, bluish-gray limestone with thin layers of magnesian limestone. Sampled units, representing the full thickness of the formation, average about 89 per cent calcium carbonate.	300±
Conococheague	Bluish-gray limestone with minor amounts of interbedded gray dolomite. Distinctive features are thin laminae, containing siliceous material, which weather out on the surface as crinkly ribs, and a few beds of coarse-grained, friable sandstone. Sampled units of limestone and magnesian limestone, mainly in the upper part of the formation, contain from 65 to 90 per cent calcium carbonate and from 6 to 22 per cent silica.	2500[a]
Elbrook	Predominantly thin-bedded impure limestone and dolomite which commonly weather on the surface to rusty-looking slabs and thin plates. Also contains some thin layers of flesh-colored limestone of apparently good quality.	2000[a]

[a] Estimated.

The major structures in the eastern part of Frederick County (Pl. 5) are briefly discussed below. Massanutten Mountain syncline, a great trough occupied by Martinsburg shale in the eastern two-fifths of the county, is the principal fold. The western boundary of this shale belt roughly parallels U. S. Highway 11, passing just east of Stephenson and Winchester, through the northwestern environs of Stephens City, and near the eastern limits of Middletown. The eastern boundary of the shale belt closely follows Opequon Creek from the West Virginia line southwestward to the general latitude of Stephens City. To give only the boundaries of the shale belt would minimize the width of the Massanutten Mountain syncline. In a broad sense, this structure includes the carbonate rocks which crop out east and west of the shale belt. This broad syncline is not a single symmetrical trough, but includes also several subordinate anticlines and synclines and minor faults. The minor structures have produced a somewhat sinuous boundary between the limestones and shales along the western limb of the syncline in Frederick County. Locally, the thin belts of Ordovician limestone along the Martinsburg shale are repeated by close folding and offset by faulting (Pl. 5).

Another major geologic structure in the county is the North Mountain fault which crosses U. S. Highway 50 about 800 feet east of the school building at Chambersville. The trace of this fault marks the western boundary of the carbonate rocks described in this report.

The broad area between the shale belt east of Winchester and Little North Mountain in the vicinity of Chambersville is occupied by formations ranging from the Chambersburg limestone on the east to the Elbrook along the western boundary. A normal geologic sequence is modified by the repetition of a part of the Elbrook, Conococheague, and Chepultepec along minor faults which cross U. S. Highway 50 between Winchester and Chambersville (Pl. 5). Small flexures, showing reversals in the direction of the dip of the rocks, are also common in the area, but apparently they are not of sufficient magnitude to cause a repetition of any of the formations.

HIGH-CALCIUM LIMESTONE

High-calcium limestone, containing more than 95 per cent calcium carbonate, in Frederick County includes the Mosheim limestone and locally the basal part of the Lenoir. The Mosheim is a compact, dove-gray limestone containing relatively large specks of transparent calcite. The prevailing thickness of the formation in the central part of the county between Winchester and Kernstown, is estimated to be 50 feet

or less, whereas the thickness along the strike to the northeast and southwest ranges from about 80 feet to a maximum of about 200 feet. It probably averages about 110 feet over much of the county. Exclusive of a few relatively impure layers near the base, the Mosheim is 97 to 98 per cent calcium carbonate.

The overlying dark-gray, finely crystalline Lenoir limestone is medium bedded, nodular weathering and commonly cherty. It is 50 to 100 feet thick. Analyses of a part of the Lenoir at a few localities where chert is not prominently developed show 95 to 96 per cent calcium carbonate. Generally, the formation is high in silica, and for that reason it is mapped (Pl. 5) with overlying impure limestones.

The principal deposits of high-calcium limestone in the county are described under the Clearbrook-Middletown and the Cedar Creek belts. Other small occurrences are found locally along the North Mountain fault (Pl. 5, loc. 30) and in the extreme southeastern part of the county near Nineveh (Pl. 5, loc. 31).

Clearbrook-Middletown belt.—This narrow band of high-calcium limestone enters Virginia about half a mile southeast of Rest and continues southwestward across the county, passing through or near Clearbrook, Stephenson, Winchester, Kernstown, Stephens City, Vaucluse, and Middletown. It is sinuous, due to minor folding, and locally is offset and overlapped by faulting.

The thickness and composition of the rocks comprising this high-calcium limestone belt in the extreme northeastern part of Frederick County (Pl. 5, loc. 1) are as follows:

Geologic Section 1.—Near the Virginia-West Virginia line, half a mile east of Rest, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (110 feet): strike N. 18° E.; dip 70° SE.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.10; Fe_2O_3, 0.08; Al_2O_3, 0.34; $CaCO_3$, 98.32; $MgCO_3$, 0.80; total, 99.64	80
1. Limestone, dove-gray, compact; few impure beds; SiO_2, 0.06; Fe_2O_3, 0.04; Al_2O_3, 0.62; $CaCO_3$, 97.72; $MgCO_3$, 1.05; total, 99.49	30
Beekmantown formation	

An analysis of a separate sample of unit 2 in the above section shows 0.009 per cent phosphorus pentoxide (P_2O_5). The approximate

boundaries of this high-calcium limestone belt can be traced southwest of the State line for about half a mile, although there are no complete exposures for precise determination of thickness. About 100 yards northeast of Road 669, the total thickness of the Mosheim is estimated to be 140 feet, the upper 115 feet seemingly of good quality (Pl. 5, loc. 2). Observations at four places along the belt of Mosheim between Rest and a point about one mile northeast of Clearbrook (Pl. 5, loc. 3) indicate that the formation has thickened in a southwestward direction.

Geologic Section 2.—Along Road 671 about 1 mile northeast of Clearbrook, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (169 feet): strike N. 31° E.; dip 48° SE.	
2. Limestone, dove-gray, compact; partly covered	113
1. Limestone, dove-gray, compact; a few impure beds	56
Beekmantown formation	

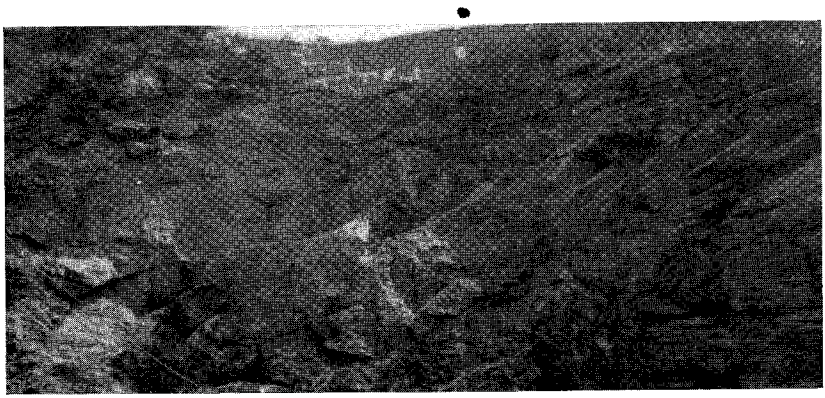
The Mosheim is well displayed in a small area about half a mile southeast of Clearbrook where the high-calcium limestones are repeated by close folding along the strike for about half a mile. The thickness and composition of the rocks which crop out near the southwestern end of a small gently pitching anticline (Pl. 5, loc. 4) are as follows:

Geologic Section 3.—Along Road 666 about four-tenths of a mile southeast of Clearbrook, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (219± feet): strike N. 48° E.; dip 30° SE.	
3. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.04; Fe_2O_3, 0.04; Al_2O_3, 0.52; $CaCO_3$, 98.02; $MgCO_3$, 0.97; total, 99.59	130±
2. Limestone, dove-gray, compact; a few impure beds	89
Beekmantown formation (upper part)	
1. Dolomite and limestone	100+

Between Clearbrook and Stephenson, a distance of 1½ miles, the belt of high-calcium limestone is largely covered. Observations in the vicinity of Stephenson show that the Mosheim here is similar in thickness and composition to the localities described in the northeastern part

A.



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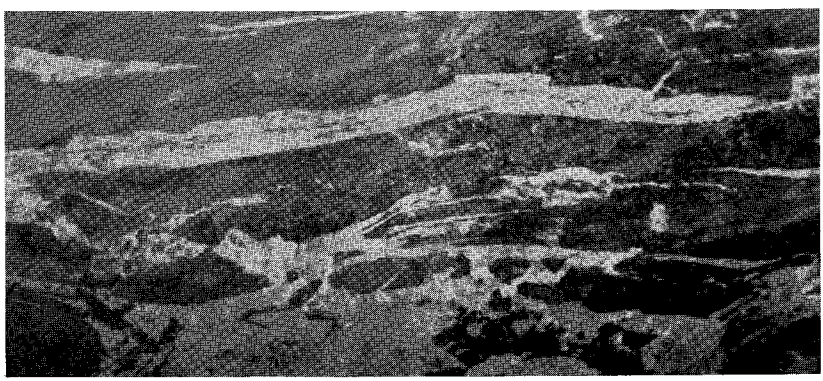

C.

A, Anticline and fracture cleavage in shaly Athens limestone near Bixler Bridge, Page County, Va. B, Recumbent folds in Athens limestone at Woodward stone quarry, southwest of Luray, Va. C, Calcite veins in Conococheague limestone 2 miles northeast of Berryville, Va.

A.

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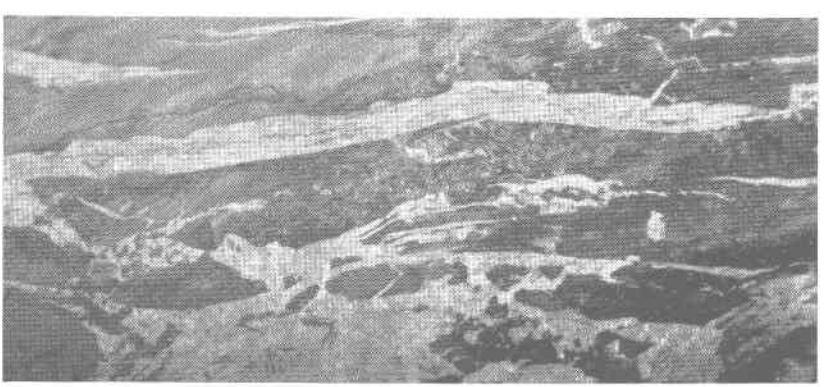
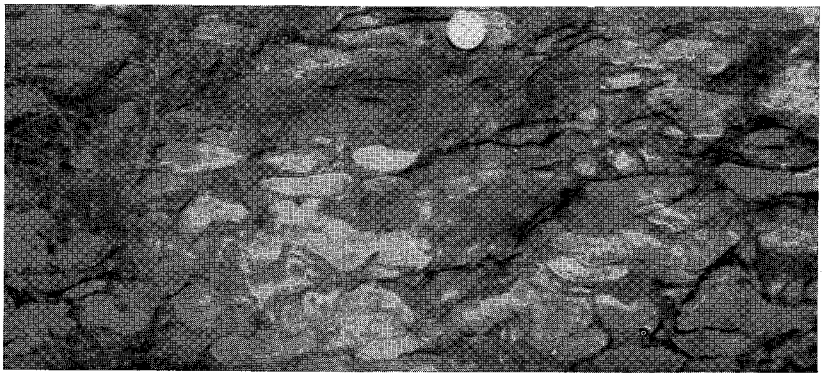


C.

A, Anticline and fracture cleavage in shaly Athens limestone near Bixler Bridge, Page County, Va. B, Recumbent folds in Athens limestone at Woodward stone quarry, southwest of Luray, Va. C, Calcite veins in Conococheague limestone 2 miles northeast of Berryville, Va.



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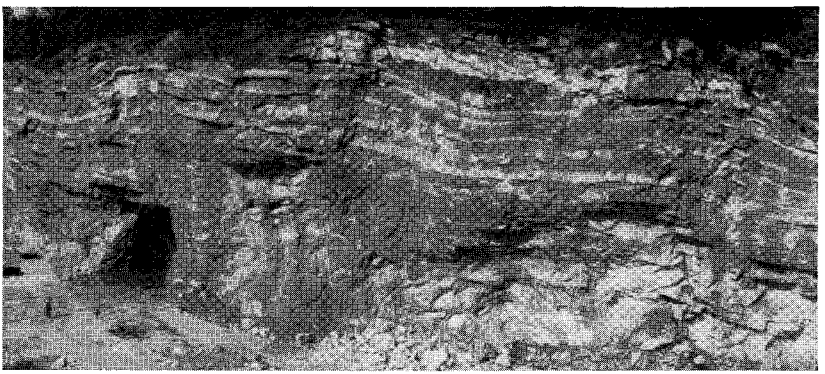

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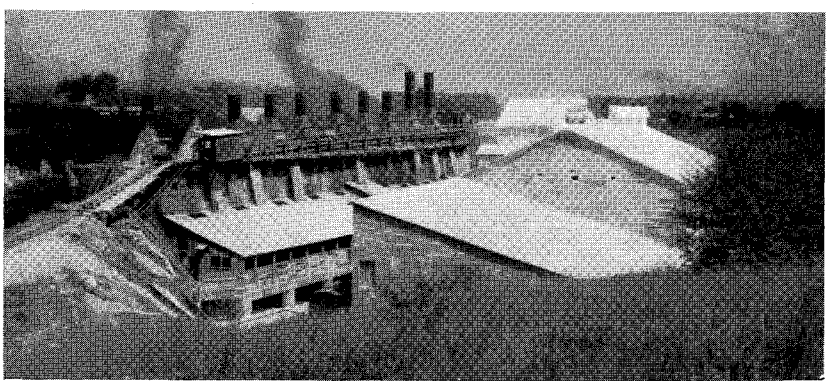
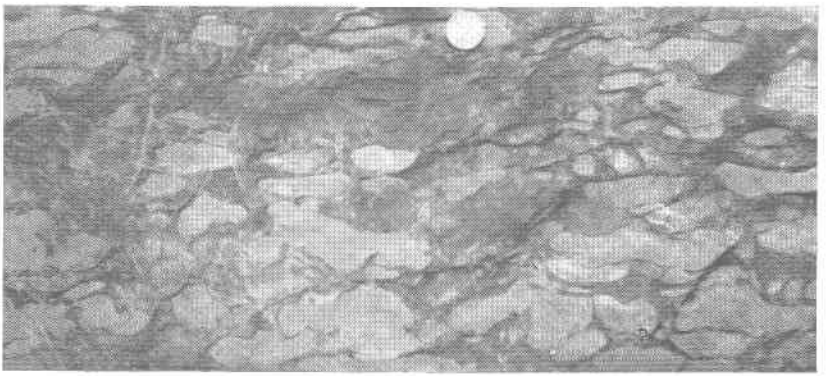


C.

A, Pebble-like limestone masses near top of Beekmantown dolomite north of Leaksville, Page County, Va. B, Beekmantown limestone (dark) and dolomite (light) in Limeton Lime Company quarry, Warren County, Virginia. C, Plant of M. J. Grove Lime Company near Stephens City, Va.



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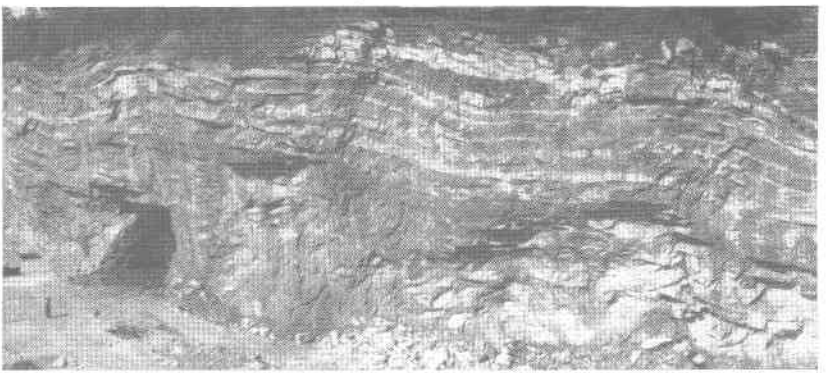

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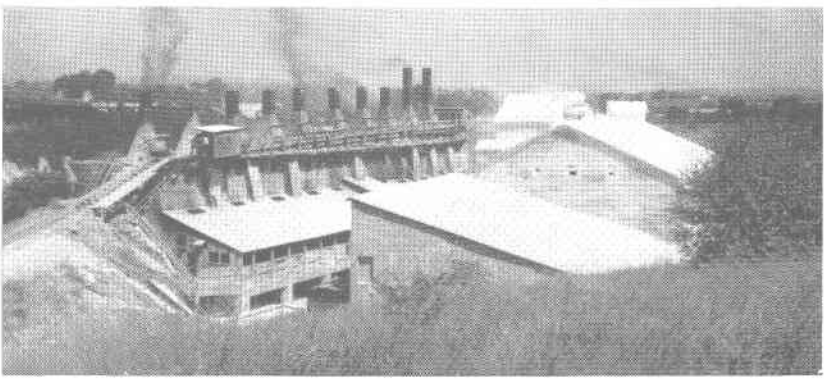


C.

A, Pebble-like limestone masses near top of Beekmantown dolomite north of Leaksville, Page County, Va. B, Beekmantown limestone (dark) and dolomite (light) in Limeton Lime Company quarry, Warren County, Virginia. C, Plant of M. J. Grove Lime Company near Stephens City, Va.

of the county, but thinner than in the small area southeast of Clearbrook. A fully displayed section in the vicinity of Stephenson (Pl. 5, loc. 5) is as follows:

Geologic Section 4.—About 500 feet east of U. S. Highway 11 and four-tenths of a mile northeast of Stephenson, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (118 feet): strike N. 25° E.; dip 45° SE.	
3. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.22; Fe_2O_3, 0.08; Al_2O_3, 0.82; $CaCO_3$, 97.44; $MgCO_3$, 1.24; total, 99.80	88
2. Limestone, dove- to bluish-gray, compact to fine grained	30
Beekmantown formation (upper part)	
1. Dolomite, gray, fine grained	335

The Mosheim belt continues southwestward through Stephenson to locality 6, near the crossing of State Highway 274 and the Baltimore and Ohio Railroad. In this area the thickness of the dove-gray limestone, with impure layers near the base, is estimated to be 130 feet. Bedrock exposures are generally poor between State Highway 274 and locality 7, about 500 feet east of a diagonal fault that offsets the limestone belt. The geologic sequence and character of the rocks west of the fault (Pl. 5, loc. 8) are as follows:

Geologic Section 5.—Along Road 663 about 1000 feet southeast of U. S. Highway 11 and 1 mile southwest of Stephenson, Frederick County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, medium grained; thickness estimated	75
Mosheim limestone (78 feet): strike N. 33° E.; dip 40° SE.	
2. Limestone, dove-gray, compact, thick bedded	43
1. Limestone, dove-gray; a few impure beds	35
Beekmantown formation	

Although the exposures are not complete it is assumed that the character and thickness of the rocks shown in the above section are maintained southwestward along the strike for about 2 miles, since at locality 9 the thickness of the Mosheim is almost identical. Generally, the Mosheim formation along this part of the belt is thinner and contains more impurities than at any of the other localities studied north of State Highway 274. A complete exposure of the Mosheim at a locality about half a mile northeast of the corporate limits of Winchester (Pl. 5, loc. 9) is as follows:

Geologic Section 6.—About 1 mile east of U. S. Highway 11 and half a mile northeast of Winchester, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (82 feet): strike N. 55° E.; dip 30° SE.	
2. Limestone, dove-gray, compact; SiO_2, 0.40; Fe_2O_3, 0.12; Al_2O_3, 0.72; $CaCO_3$, 96.09; $MgCO_3$, 2.33; total, 99.66	73
1. Limestone, dove-gray, impure, striped	9
Beekmantown formation	

The high-calcium limestone belt is largely covered in the general vicinity of Winchester. It is estimated that there is less than 50 feet of Mosheim exposed in two small abandoned quarries located in the southeastern environs of the city (Pl. 5, locs. 10 and 11). Near Kernstown (Pl. 5, loc. 12), about 3 miles southwest of Winchester, the rocks immediately succeeding the Beekmantown are as follows:

Geologic Section 7.—Along Road 652 about half a mile southeast of Kernstown, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (82 feet): strike N. 47° E.; dip 75° SE.	
2. Limestone, dove-gray, compact	45
1. Limestone, dove-gray, impure; few laminated beds	37
Analysis of units 1 and 2, sampled thickness 82 feet: SiO_2, 0.46; R_2O_3, 1.47; $CaCO_3$, 95.33; $MgCO_3$, 2.53; total, 99.79.	
Beekmantown formation	

The geologic map (Pl. 5) showing the closely folded belts of Mosheim limestone between Kernstown and Bartonville is somewhat generalized, since the bedrock in a part of this area is largely covered. The Mosheim exposed along U. S. Highway 11, about half a mile southeast of Bartonville, is within 200 feet of a narrow belt of Martinsburg shale; thus it is probable that the belt of Mosheim (Pl. 5, loc. 14) is faulted along the northwest side. The general southwestward trend of the high-calcium limestones between Bartonville and Vaucluse is modified by close folding. A small anticline and syncline, both pitching gently southwestward, are well displayed along this belt about half a mile northwest of Stephens City. The quarry and mine (Pls. 4C and 6A) of the M. J. Grove Lime Company are located near the southwestern end of this plunging anticlinal structure. The average thickness of the Mosheim in this area (Pl. 5, loc. 15) is about 110 feet. Locally, the lower part of the overlying Lenoir is practically free of chert and may be quarried as high-calcium limestone. A fully exposed section of the limestone belt in the vicinity of Vaucluse (Pl. 5, loc. 16) is as follows:

Geologic Section 8.—Along U. S. Highway 11 at Vaucluse, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (137 feet): strike N. 35° E.; dip vertical	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.18; Fe_2O_3, 0.08; Al_2O_3, 0.44; $CaCO_3$, 97.52; $MgCO_3$, 0.92; total, 99.14	80
1. Limestone, dove-gray, thin bedded, impure	57
Beekmantown formation	

The belt of high-calcium limestone continues southwestward through Middletown, paralleling closely the Valley Branch of the Baltimore and Ohio Railroad. The Mosheim has a thickness of 84 feet in a small exposure (Pl. 5, loc. 17) about half a mile southwest of Middletown. In the vicinity of Meadow Mills, limestones crop out on the limbs of a small anticline which pitches gently southwestward. They are well displayed in an abandoned quarry (Pl. 5, loc. 18) near Road 625 and in a steep hillside exposure (Pl. 5, loc. 19) along Road 624 about 300 feet west of the Baltimore and Ohio Railroad.

Cedar Creek belt.—This belt, although limited in extent, is thought to contain some of the largest reserves of high-calcium limestone in the

northern part of Shenandoah Valley in Virginia. It extends from Cedar Creek, at the southwestern boundary of Frederick County, northeastward for about 3 miles (Pl. 5). The structure of this belt is a long narrow syncline, locally containing minor flexures and small faults. Mosheim, Lenoir, and Chambersburg limestones occupy the trough of the fold in the southwestern part of the belt, whereas near the northeastern end of the structure, except for small isolated patches of cherty Lenoir, the Mosheim is well displayed. Beekmantown dolomite crops out along the crest of a small anticline within the belt of Mosheim north of Road 627. Since these minor structures are of such small extent they are not shown on the geologic map.

The width of the belt of limestone, crossing Road 627 about 1½ miles northwest of Middletown (Pl. 5, loc. 20), is approximately 900 feet. Although the thickness of the Mosheim was not determined accurately, it is assumed that at least 100 feet, containing 98.02 per cent calcium carbonate and 1.26 per cent magnesium carbonate, were included in the sampled beds (Table 6). An analysis of a separate sample representing all of the beds exposed at this locality shows 0.009 per cent phosphorus pentoxide (P_2O_5).

The quarry of the M. J. Grove Lime Company, located about 1½ miles west of Middletown, is being developed across the strike of the beds in the syncline. The operations are about 800 feet long and vary in width from a few feet at the western end to about 200 feet near the eastern side. Other openings, now abandoned, are located along the strike of the rocks just south of the road leading from the quarry to the spur railroad. The thickness and character of the Mosheim along the western side of the quarry (Pl. 5, loc. 21) are as follows:

Geologic Section 9.—In quarry of the M. J. Grove Lime Company, 1½ miles west of Middletown, Frederick County, Virginia

	Thickness Feet
Mosheim limestone (154 feet): strike N. 48° E.; dip 27°-42° SE.	
2. Limestone, dove-gray, compact, thick-bedded; SiO_2, 0.08; Fe_2O_3, 0.12; Al_2O_3, 0.48; $CaCO_3$, 97.72; $MgCO_3$, 0.94; total, 99.34	100
1. Limestone, dove-gray, compact; a few impure layers; lower boundary uncertain	54
Beekmantown formation	

Natural exposures of the Mosheim and Lenoir are prominently displayed in vertical cliffs along Cedar Creek about 2000 feet southwest of the M. J. Grove Lime Company quarry. Another exposure of approximately 88 feet of Mosheim limestone, near the southwestern end of the Cedar Creek belt, is along Road 624, just east of the bridge over Cedar Creek (Pl. 5, loc. 22).

IMPURE LIMESTONE

In Frederick County impure limestone formations include the Chepultepec, the Chambersburg, and the Lenoir at most localities. Other relatively impure limestones which are interbedded with dolomites are described under "Limestone, magnesian limestone, and dolomite."

The Chepultepec, with an average thickness of about 300 feet, is composed essentially of thick-bedded, slightly laminated, bluish-gray limestone with a few thin layers of magnesian limestone. It crops out in a narrow sinuous belt that extends northeastward across the county, passing about 1 mile west of Bartonville, Kernstown, and Clearbrook. There is also a narrow belt about 4 miles west of Rest and a small lozenge-shaped exposure across U. S. Highway 50, about 2½ miles west of Winchester. The composition, thickness, and character of the Chepultepec in the vicinity of Winchester (Pl. 5, loc. 25) are as follows:

Geologic Section 10.—Along the southwest slope of Star Fort Hill, half a mile north of Winchester, Frederick County, Virginia

	Thickness Feet
Chepultepec limestone	
1. Limestone, bluish-gray, thick bedded, laminated; a few covered intervals	280±
Average of 8 analyses (Table 6) of unit 1, each representing about 35 feet of beds: SiO_2, 5.07; R_2O_3, 1.48; $CaCO_3$, 89.69; $MgCO_3$, 3.48; total, 99.72.	
Conococheague limestone	

One of the best exposures of the Chepultepec in Frederick County is about 1 mile southwest of the intersection of Roads 631 and 625, and 2½ miles east of Marlboro (Pl. 5, loc. 29). Here the thickness of the formation is estimated to be 300 feet. The average of eight analyses, each representing about 35 feet of beds, shows

88.70 per cent calcium carbonate and 4.83 per cent magnesium carbonate, a total of 93.53 per cent carbonates (Table 6). The Chepultepec sampled at another locality in the southwestern environs of Winchester (Pl. 5, loc. 27) has an almost identical composition.

The Lenoir, which succeeds the Mosheim, is composed of fine- to medium-grained, dark-gray limestone. It is 50 to 100 feet thick and commonly is characterized by abundant nodules and stringers of black chert. The Lenoir is mapped (Pl. 5) with the overlying impure Chambersburg limestone. The Chambersburg consists chiefly of shaly and nodular black limestone with thin layers of brownish siltstone. The thickness, except for one section which is probably thinned by faulting, ranges from about 400 to 575 feet. The principal belt of the Lenoir and Chambersburg limestones in Frederick County extends northeastward through the central part of Shenandoah Valley, paralleling the narrow belt of high-calcium limestone. The impure limestones overlying the Lenoir along the southeastern boundary of the county appear to be Athens (Pl. 5). The general character of the Chambersburg and Lenoir limestones near the Virginia-West Virginia line (Pl. 5, loc. 2) is as follows:

Geologic Section 11.—About 100 yards northeast of Road 669, three-fourths of a mile southeast of Rest, Frederick County, Virginia

	Thickness Feet
Chambersburg limestone (391 feet): strike N. 13° E.; dip 80° SE.	
6. Limestone, bluish-gray, clayey	203
5. Limestone, blue, fine-grained, impure	49
4. Limestone, black, medium bedded	20
3. Limestone, black; brown clayey partings; weathers gray	68
2. Limestone, black, nodular weathering	51
Analysis of units 2 to 6, sampled thickness 391 feet: SiO_2, 5.18; Fe_2O_3, 0.34; Al_2O_3, 1.26; $CaCO_3$, 90.89; $MgCO_3$, 2.58; total, 100.25.	
Lenoir limestone	
1. Chiefly covered; a few exposures of medium-grained, dark-gray limestone	98
Mosheim limestone	

The Chambersburg and Lenoir limestones are well displayed in the general vicinity of Kernstown (Pl. 5, locs. 12 and 13), although the thickness of the Chambersburg at locality 12 is less than that observed at other localities in the county. Whether this is due to local variations in sedimentation or to minor faulting was not determined.

Geologic Section 12.—Along Road 652 about half a mile southeast of Kernstown, Frederick County, Virginia

	Thickness Feet
Chambersburg limestone (271 feet): strike N. 47° E.; dip 74° SE.	
4. Limestone, black, fine grained, clayey; SiO_2, 6.92; R_2O_3, 2.84; $CaCO_3$, 87.70; $MgCO_3$, 2.75; total, 100.21	268
3. Siltstone or fine-grained, dark-brown sandstone	3
Lenoir limestone (94 feet)	
2. Limestone, fine to coarse grained; some cobbly beds; upper boundary uncertain	54
1. Limestone, dark-gray, fine grained, cherty	40
Analysis of units 1 and 2, exclusive of chert, sampled thickness 94 feet: SiO_2, 1.09; R_2O_3, 0.98; $CaCO_3$, 95.77; $MgCO_3$, 2.29; total, 100.13.	

Another good exposure (Pl. 5, loc. 16) of the Lenoir and Chambersburg limestones is in the vicinity of Vaucluse.

Geologic Section 13.—Along U. S. Highway 11 at Vaucluse, Frederick County, Virginia

	Thickness Feet
Chambersburg limestone (577 feet): strike N. 35° E.; dip vertical	
7. Limestone, black, mealy, clayey	55
6. Limestone, black, nodular	85
5. Limestone, black, regularly bedded	68
4. Limestone, black; some nodular beds	288
3. Covered interval	79
2. Siltstone or fine-grained sandstone	2±

	Thickness Feet
Lenoir limestone	
1. Limestone, dark-gray, medium grained, sparsely cherty; upper boundary uncertain	106
Mosheim limestone	

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

The formations composed principally of interbedded limestone, magnesian limestone, and dolomite include the Elbrook, Conococheague and Beekmantown. The Chepultepec, previously described as impure limestone, separates the Beekmantown from the Conococheague.

The Elbrook, although containing a few layers of limestone and dolomite of apparently good quality, is composed essentially of impure limestone and minor amounts of dolomite interbedded throughout the entire thickness estimated at about 2000 feet. The impure parts of the formation are generally thin bedded and weather on the surface to rusty-looking slabs and thin plates. The main outcrop belt of the Elbrook is near the southeast base of Little North Mountain, beginning about 1 mile south of Nain and extending southwestward into Shenandoah County. A second belt of outcrop begins as a narrow wedge near Road 622, about 2 miles southwest of Winchester, and continues northward through the village of White Hall into West Virginia. A smaller, lozenge-shaped belt lies about midway between the two main belts, crossing U. S. Highway 50 about 2½ miles west of Winchester.

In Frederick County, the Conococheague, overlying the Elbrook, is predominantly a limestone, but like most of the older limestones of Shenandoah Valley, it contains variable but generally thin beds of dolomite throughout the formation. It is marked by two distinctive features: (1) beds up to 10 feet thick, containing siliceous material, which stand out as crinkly ribs on weathered surfaces of the limestone, and (2) beds of coarse-grained, friable sandstone. The crinkly ribs are more abundant near the top of the formation, whereas the sandstones apparently are not confined to any particular horizon. Some of the sandstone beds may be as much as 25 feet thick. These beds commonly make distinct ridges along their outcrop and reveal their presence by many boulders of sandstone. These sandstones can be everywhere recognized and

serve as horizon markers for revealing the structure of the whole mass of limestone. The Conococheague occupies a wide belt extending from Cedar Creek, 4 miles northwest of Middletown northeast across the county into West Virginia, 2½ miles northeast of White Hall. North of the latitude of Winchester, the Conococheague is split into two belts by a narrow wedge of Elbrook which is faulted along the northwest side. Minor folding within the broad belt of Conococheague is clearly indicated by the sinuous outcrop pattern of the interbedded sandstone layers. As none of these beds are well displayed over large areas, structural details which would permit accurate thickness determinations are lacking. About 2500 feet is thought to be a reasonable estimate of the thickness of the Conococheague. The following section, measured along the southeast slope of Apple Pie Ridge (Pl. 5, loc. 24), shows the principal constituents of the Conococheague. The abnormal thickness of 3733 feet measured at this locality is most likely the result of structural irregularities not recognized along the line of traverse.

Geologic Section 14.—Along Road 672 about 2½ miles west of Clearbrook, Frederick County, Virginia

	Thickness Feet
Conococheague limestone (3733 feet)	
43. Limestone, light bluish-gray, banded	67
42. Limestone containing siliceous and crinkly laminae	140
41. Chert float	10
40. Limestone, bluish-gray, banded	111
39. Mostly covered; a few layers of dolomite and abundant chert and sandstone float	290
38. Limestone, banded; partly covered	220
37. Mostly covered; sandstone float	80
36. Limestone, bluish-gray, banded	108
35. Mostly covered; abundant sandstone float	103
34. Limestone, banded; partly covered; some sandstone float	102
33. Sandstone, brownish-gray, coarse grained	8
32. Limestone, cherty, banded	53
31. Sandstone; partly covered	12
30. Limestone containing crinkly siliceous laminae	163

	Thickness Feet
29. Dolomite, gray, fine grained	8
28. Limestone, bluish-gray, banded	110
27. Dolomite, gray, fine grained	34
26. Limestone, banded	82
25. Dolomite, gray, fine grained	28
24. Limestone, bluish-gray, banded; one-foot bed of edgewise conglomerate at base	95
23. Limestone, bluish-gray, banded; chert in upper part	272
22. Dolomite, gray	2
21. Limestone, light-gray, medium grained; one-foot bed of siltstone at base	18
20. Limestone, bluish-gray, banded	43
19. Mostly covered; a few thin beds of sandstone, sandy dolomite, and chert	180
18. Sandstone and sandy dolomite	12
17. Limestone containing crinkly siliceous laminae; partly covered, abundant shale chips in soil	330
16. Dolomite, gray, fine grained	162
15. Limestone, bluish-gray; partly covered	8
14. Dolomite, gray	66
13. Limestone and dolomite	36
12. Mostly covered; a few beds of dolomite	245
11. Dolomite, gray, fine grained	38
10. Limestone, mottled light- and dark-gray	38
9. Dolomite with a few thin beds of bluish-gray limestone; partly covered	269
8. Mostly covered; a few beds of dolomite	43
7. Limestone and dolomite, gray, fine grained	126
6. Sandstone	1
5. Dolomite and limestone	10
4. Dolomite, medium-gray, medium grained	5
3. Limestone, dark-gray; contains irregular ramifying veins of dolomite	5
Elbrook formation (upper part, 285 feet)	
2. Dolomite and siltstone; dolomite weathers rusty-brown	72
1. Dolomite, gray, laminated, silty; weathers shaly	213

Generally, the sampled units of limestone and magnesian limestone, mainly in the upper part of the Conococheague, show from 65 to 90 per cent calcium carbonate and from about 6 to 22 per cent silica. A part of the formation, consisting of banded limestone, magnesian limestone and thin layers of dolomite and sandstone, is exposed in the Stuart M. Perry quarry, just south of U. S. Highway 50 and about 2½ miles west of Winchester (Pl. 5, loc. 28). An average of two samples from this quarry, each representing about 100 feet of rock, shows 68.36 per cent calcium carbonate, 16.10 per cent magnesium carbonate, and 14.10 per cent silica.

The upper 150 feet of the formation, cropping out on the southwest slope of Star Fort Hill about half a mile north of Winchester (Pl. 5, loc. 25), contains 90.21 per cent total carbonates and 9.59 per cent impurities, chiefly silica, alumina and iron oxide. It is quite apparent from the above analyses that the Conococheague is not suited for chemical use, but a large part of the formation is composed of tough resistant rock that is well adapted for general construction purposes (Pl. 5, loc. 28).

The Beekmantown formation is composed of interbedded fine-textured dark bluish-gray limestone and finely crystalline gray dolomite. Chert, although not abundant, occurs throughout the formation. The absence of intercalated coarse-grained sandstones in the Beekmantown is one of the striking differences between this formation and the underlying Conococheague. An estimate based on several incompletely exposed sections indicates that the ratio of limestone or magnesian limestone to dolomite for the full thickness of the formation is about 3 to 2, although dolomite predominates in the upper part. Assuming the beds to be vertical, the possible maximum thickness along Road 631 west of Stephens City is about 2500 feet. The formation appears to be much thicker in northern Frederick County (Pl. 5, loc. 23), but the measurements of exposures there may be inaccurate as a result of minor folding or faulting which was not evident in the field. The general character of the Beekmantown which crops out on both sides of U. S. Highway 11, about 1½ miles southwest of the Virginia-West Virginia line (Pl. 5, loc. 23), is as follows:

Geologic Section 15.—About 1½ miles southwest of Rest, Frederick County, Virginia

	Thickness Feet
Beekmantown formation (3478± feet)	
23. Largely covered; a few beds of gray dolomite	300±
22. Dolomite, gray, fine grained; a few bluish-gray limestone beds in lower part	153
21. Limestone and dolomite	130
20. Dolomite, gray, fine grained	79
19. Dolomite with thin beds of bluish-gray limestone	95
18. Dolomite with thin beds of bluish-gray limestone	95
17. Limestone, bluish-gray, banded	258
16. Dolomite and limestone	108
15. Limestone, bluish-gray, fine grained, banded	175
14. Limestone, light bluish-gray, medium grained	80
13. Dolomite, gray, fine grained	7
12. Limestone, bluish-gray, medium grained, banded	65
11. Dolomite, gray, fine grained	80
10. Covered interval	235
9. Limestone and dolomite; largely limestone	400
8. Dolomite and limestone; largely dolomite	97
7. Limestone, bluish-gray; a few thin beds of dolomite	245
6. Largely covered; a few thin beds of dolomite	137
5. Limestone, bluish-gray	32
4. Limestone with thin magnesian layers	205
3. Dolomite and limestone	58
2. Limestone, bluish-gray, banded	230
1. Limestone and dolomite; abundant chert float; lower boundary uncertain	214
Chepultepec limestone	

One of the best exposures of the upper 1050 feet of the Beekmantown formation, consisting almost entirely of finely granular gray dolomite, is in a field about half a mile southwest of the intersection of U. S. Highways 50 and 522 about half a mile south of Winchester (Pl. 5, loc. 26). The average of three samples from

this locality, each representing about 350 feet of dolomite, shows 5.34 per cent silica, 0.49 per cent iron oxide (Fe_2O_3), 0.69 per cent alumina, 54.41 per cent calcium carbonate, and 40.05 per cent magnesium carbonate. The upper 100 feet of the Beekmantown near Meadow Mills in southwestern Frederick County (Pl. 5, loc. 19) has an almost identical composition.

TABLE 6.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Frederick County, Virginia (Pl. 5)*

(Froehling & Robertson, Inc., and John H. Yoe, Analysts)

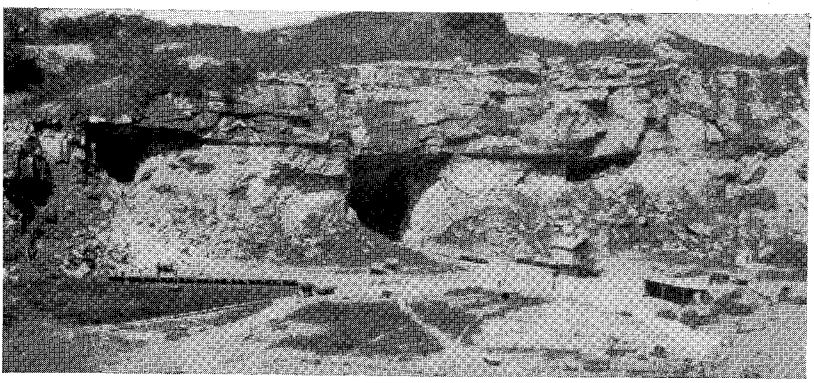
Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
1	1	2	Mosheim	80	98.32	0.80	0.10	0.08	0.34	99.64	Near Virginia-West Virginia line about half a mile east of Rest.
		1		30	97.72	1.05	0.06	0.04	0.62	99.49	
2	11	2–6	Chambersburg	391	90.89	2.58	5.18	0.34	1.26	100.25	Near Road 669, three-fourths of a mile southeast of Rest.
4	3	3	Mosheim	130±	98.02	0.97	0.04	0.04	0.52	99.59	Along Road 666, fourth-tenths of a mile southeast of Clearbrook.
4			Mosheim	100	98.06	1.53	0.50	0.12	0.16	100.37	About 100 yards northeast of Geologic Section 3.
				22	93.22	4.27	1.89	0.17	0.35	99.90	
5	4	3	Mosheim	88	97.44	1.24	0.22	0.08	0.82	99.80	Fourth-tenths of a mile northeast of Stephenson.
9	6	2	Mosheim	73	96.09	2.33	0.40	0.12	0.72	99.66	About 1 mile east of U. S. Highway 11 and half a mile northeast of Winchester.
12	7	1–2	Mosheim	82	95.33	2.53	0.46	1.47[a]		99.79	Along Road 652, half a mile southeast of Kernstown.
	12	4	Chambersburg	268	87.70	2.75	6.92	2.84[a]		100.21	
		1–2	Lenoir	94	95.77	2.29	1.09	0.98[a]		100.13	

16	8	2	Mosheim	80	97.52	0.92	0.18	0.08	0.44	99.14	Along U. S. Highway 11 at Vaucluse.
19			Beekmantown	100	51.62	40.91	5.88	0.49	0.56	99.46	Along Road 624 near Meadow Mills.
20			Mosheim	100±	98.02	1.26	0.14	0.08	0.34	99.84	Along Road 627 about 1½ miles northwest of Middletown.
21	9	2	Mosheim	100	97.72	0.94	0.08	0.12	0.48	99.34	M. J. Grove Lime Company quarry, 1½ miles west of Middletown.
25	10	1	Chepultepec	35±	92.84	1.92	4.57	0.76[a]		100.09	Star Fort Hill, half a mile north of Winchester.
				35±	86.38	6.60	6.64	0.91[a]		100.53	
				35±	86.86	3.68	5.55	2.54[a]		98.63	
				35±	85.75	5.39	5.15	1.87[a]		98.16	
				35±	90.57	3.57	4.31	1.87[a]		100.32	
				35±	87.04	2.34	5.59	2.60[a]		97.57	
				35±	94.32	2.87	4.85	0.59[a]		102.68	
				35±	93.80	1.48	3.91	0.69[a]		99.88	
			Conococheague	50±	80.97	7.69	8.67	2.77[a]		100.10	
				50±	89.43	4.85	5.98	0.69[a]		100.95	
				50±	79.47	8.24	7.23	3.46[a]		98.40	

TABLE 6.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Frederick County, Virginia (Pl. 5)—Continued*

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
26			Beekmantown	350±	53.23	41.14	5.30	0.54	0.58	100.79	Half a mile south of Winchester.
				350±	54.58	40.59	5.71	0.44	0.63	101.95	
				350±	55.41	38.42	5.01	0.50	0.86	100.20	
27			Chepultepec	100	90.24	1.41	8.04	1.47[a]		101.16	Along U. S. Highway 11, half a mile southwest of Winchester.
			Conococheague	50	72.76	2.00	22.30	2.35[a]		99.41	
28			Conococheague	100	65.11	16.79	16.42	1.49	1.79	101.60	Stuart M. Perry quarry, 2½ miles west of Winchester.
				100	71.61	15.42	11.79	1.10	1.02	100.94	
29			Chepultepec	35±	88.62	5.01	6.36	0.96[a]		100.95	About 2½ miles east of Marlboro.
				35±	83.86	3.97	8.69	2.27[a]		98.79	
				35±	90.54	8.47	2.65	0.91[a]		102.57	
				35±	88.93	5.77	6.96	1.38[a]		103.04	
				35±	84.59	5.12	6.78	1.24[a]		97.73	
				35±	91.72	3.59	3.83	0.90[a]		100.04	
				35±	89.90	3.66	4.85	1.04[a]		99.45	
				35±	91.45	3.05	4.31	0.49[a]		99.30	

[a] Reported as R_2O_3.



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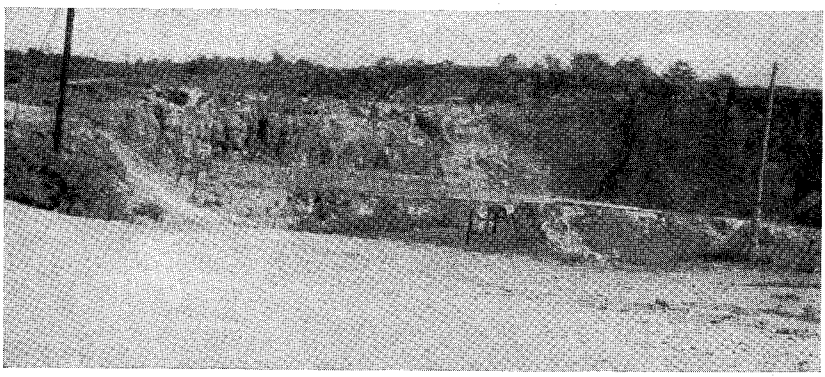
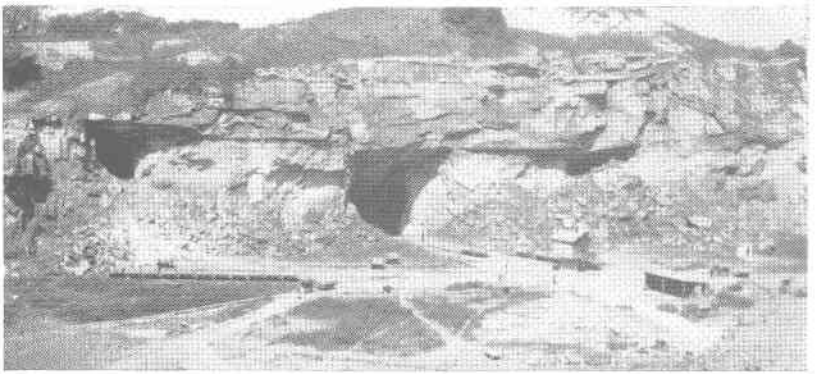


C.

A, Quarry and mine of the M. J. Grove Lime Company near Stephens City, Va. B, Central Chemical Lime Corporation quarry 2 miles northeast of Strasburg, Va. Looking northeast. C, Standard Lime and Stone Company quarry about one mile north of Strasburg. Looking northeast.



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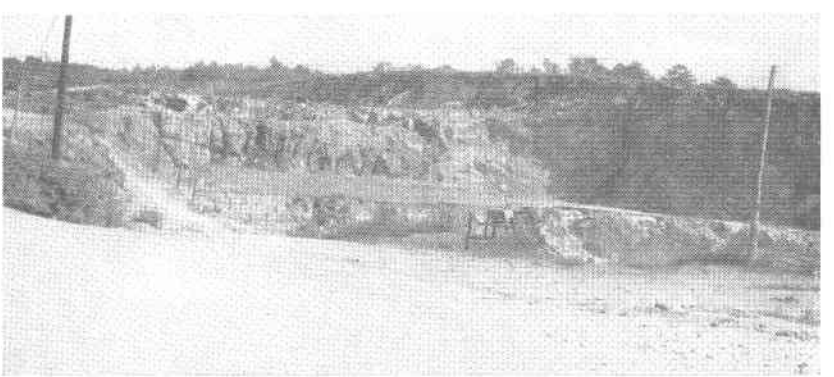

C.

A, Quarry and mine of the M. J. Grove Lime Company near Stephens City, Va. B, Central Chemical Lime Corporation quarry 2 miles northeast of Strasburg, Va. Looking northeast. C, Standard Lime and Stone Company quarry about one mile north of Strasburg. Looking northeast.

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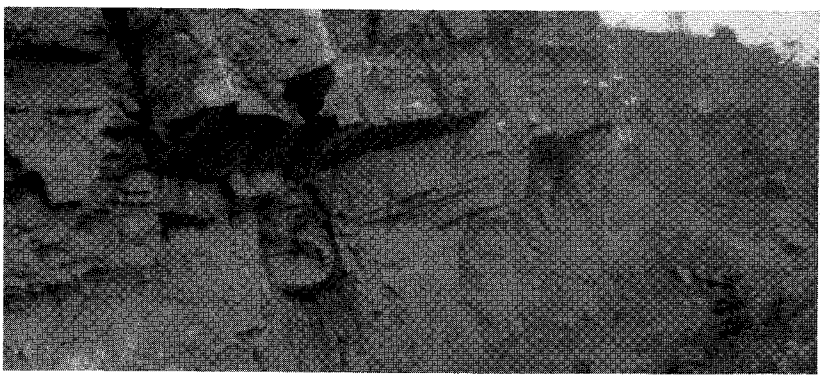

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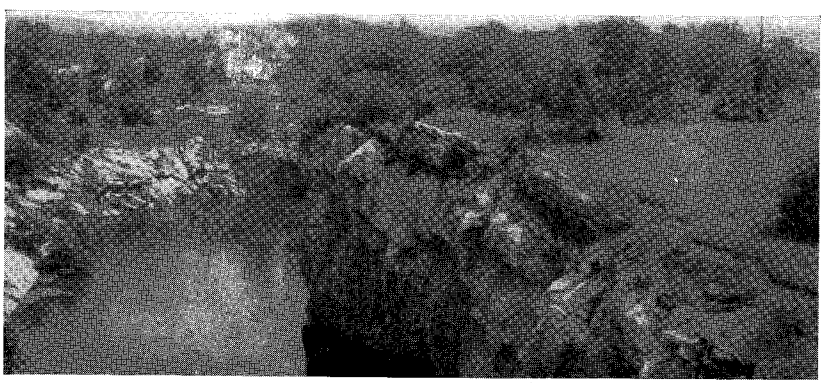
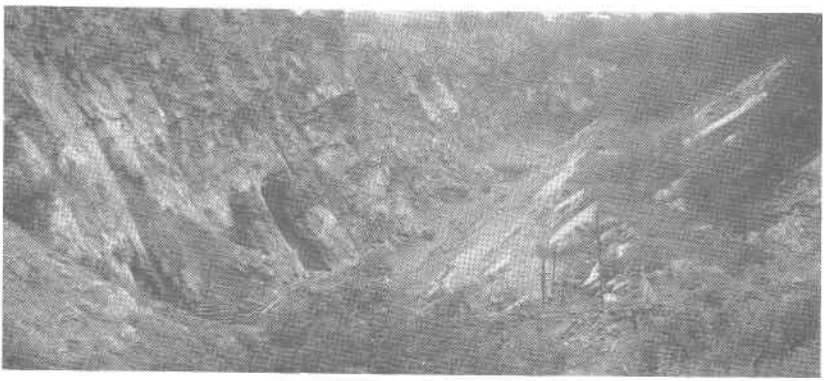


C.

A, Powhatan Lime Company quarry northeast of Strasburg Junction, Shenandoah County, Va. Looking southwest. B, Shenandoah Lime Company quarry just east of Strasburg Junction. Looking southwest. C, Abandoned quarry half a mile southwest of Strasburg Junction. Looking northeast.



A.

B.

C.

A, Powhatan Lime Company quarry northeast of Strasburg Junction, Shenandoah County, Va. Looking southwest. B, Shenandoah Lime Company quarry just east of Strasburg Junction. Looking southwest. C, Abandoned quarry half a mile southwest of Strasburg Junction. Looking northeast.

SHENANDOAH COUNTY

GENERAL STATEMENT

Shenandoah County, with an area of 510 square miles, lies between the West Virginia line and the eastern ridge of Massanutten Mountain.. It is bounded on the northeast by Frederick County, on the east and southeast by Warren and Page counties, and on the southwest by Rockingham County (Fig. 1). About half of the area of the county, extending from Massanutten Mountain northwest to the vicinity of Little North Mountain, is in Shenandoah Valley (Pl. 8). Altitudes vary from 500 feet along the North Fork of Shenandoah River east of Strasburg to about 1200 feet on some of the low ridges and rounded hills in the western part of the valley. The general average for most of the valley floor is about 1000 feet. The principal streams are North Fork of Shenandoah River, which flows northeastward along the western side of Massanutten Mountain, and Cedar Creek which forms a natural boundary between Frederick and Shenandoah counties.

Woodstock, the county seat, is located about 3 miles west of Massanutten Mountain and slightly northeast of the geographical center of Shenandoah County. The county is served by the Valley Branch of the Southern Railway, which parallels Shenandoah Valley from New Market northeastward to Strasburg, and by the Valley Branch of the Baltimore and Ohio Railroad north of Strasburg Junction. Important roads include U. S. Highway 11, which traverses the valley from the vicinity of Strasburg to New Market, and several State highways which cross the county north of Strasburg; west of Woodstock, Mount Jackson, and Quicksburg; and southwest of Columbia Furnace.

GEOLOGY

That part of Shenandoah County within Shenandoah Valley contains several narrow belts of high-calcium limestone separated by broader belts of limestone, magnesian limestone, dolomite, and shale (Pl. 8). A summary of the carbonate rocks is given in Table 7.

TABLE 7.—*Summary of carbonate rocks in the Shenandoah Valley portion of Shenandoah County, Virginia*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Chambersburg and Athens	Chambersburg, mainly black impure limestone, in part nodular weathering; in western belts upper 60 to 90 feet contains 96.34 to 97.56 per cent calcium carbonate. Athens, chiefly shaly black limestone.	400–600
Lenoir	Chiefly medium-grained, cherty, dark-gray limestone. Locally, a part of the formation, where free of chert, contains about 96 to 97 per cent calcium carbonate.	75–200
Mosheim	Compact, thick-bedded, dove-gray limestone. Commonly, the lower part of the formation is thinner bedded and slightly impure. Sampled units, representing in most instances the full thickness of the formation, contain about 96 to 98.5 per cent calcium carbonate, averaging about 97.5 per cent.	40–240
Beekmantown	Composed largely of fine-grained, gray dolomite, with conspicuous intercalated beds of bluish-gray limestone. Sampled limestone units contain less than 90 per cent calcium carbonate and the dolomite units, from about 36 to 41 per cent magnesium carbonate.	2500±
Chepultepec	Bluish-gray limestone with a few thin beds of dolomite. Generally contains less than 90 per cent calcium carbonate.	300–500
Conococheague	Chiefly limestone, magnesian limestone, and dolomite. Distinctive features are thin laminae containing siliceous material, which weather as distinct ribs, and a few layers of coarse-grained, friable sandstone.	2500±
Elbrook	Chiefly shaly weathering dolomite and limestone; locally, near the North Mountain fault, contains quarriable zones of brecciated dolomite averaging about 43.5 per cent magnesium carbonate.	2000±

Structure sections showing the major folds and faults along lines extending southeast of Conicville and Saint Luke are given on the geologic map (Pl. 8). The largest geologic structure in Shenandoah County is the Massanutten Mountain syncline. The area of this syncline in the eastern part of the county, exclusive of Massanutten Mountain, is occupied by Martinsburg shale. The western boundary of the shale extends from Strasburg southwestward to

New Market, passing east of Toms Brook, Woodstock, Edinburg, and New Market.

The next structure to the west is a well-defined anticline, here named the Mount Jackson anticline for the town of Mount Jackson which is located near the axis of the fold. The Conococheague flanked by the Chepultepec and Beekmantown formations is exposed along this anticline southwest of Woodstock, whereas to the northeast of Woodstock the Conococheague is bounded on the northwest side by a fault. Between the Mount Jackson anticline and the Saumsville fault, south of the latitude of Woodstock, is a complexly folded area in which are exposed beds of Beekmantown, Mosheim, and the overlying impure limestones and shales. Some of the largest deposits of high-calcium limestone in Shenandoah County occur in this area.

Rocks ranging from the Elbrook to the Martinsburg underlie a broad area between the North Mountain and Saumsville faults. A synclinal structure in the eastern part of this area is well shown by the repetition of the Mosheim and a part of the Beekmantown (Pl. 8), north of Lantz Mills. Between the latitude of Columbia Furnace and Rockingham County the rocks forming the east limb of the syncline are largely concealed by faulting.

Along the western side of the valley from the vicinity of Saumsville southwestward to a point about 3 miles southwest of Saint Luke (Pl. 8), a thick occurrence of high-calcium Mosheim limestone crops out. This belt of limestone, within an area underlain by formations ranging from Conococheague to Martinsburg, is interpreted tentatively as a faulted slice.

HIGH-CALCIUM LIMESTONE

Strasburg-New Market belt.—The Strasburg-New Market belt of high-calcium Mosheim limestone crops out west of the Martinsburg shale in the Massanutten Mountain syncline and closely parallels U. S. Highway 11 and the Southern Railway from the general vicinity of Strasburg southwestward to New Market. Except for a covered interval between Edinburg and a point about 3 miles northeast of New Market, the high-calcium limestone is well displayed and offers many complete sections for detailed study.

Several quarries producing high-calcium limestone are located in the general vicinity of Strasburg and Toms Brook in the northern part of Shenandoah County. In 1944 quarries were operated in this belt by the Central Chemical Lime Corporation, Shenandoah Valley Lime

and Stone Corporation, Standard Lime and Stone Company, Powhatan Lime Company, Shenandoah Lime Company, Strasburg Lime Company, and the Toms Brook Lime and Stone Company. Data regarding these quarries, which accompany the following brief geologic descriptions, are based on information obtained by the writer in 1942.

Along the belt between Cedar Creek and locality 32 (Pl. 8), the truncated edges of the limestone are about 100 feet above Cedar Creek. The main quarry of the Central Chemical Lime Corporation (Pl. 8, loc. 32), about three-fourths of a mile southwest of Meadow Mills, is approximately 500 feet long, 250 feet wide, and ranges in depth from a few feet at the southwestern end to about 80 feet near the northeastern end (Pl. 6B). In the main part of the quarry the rocks are Mosheim; those high on the southeast face Lenoir. A small quarry in the lower part of the Mosheim (Pl. 8, loc. 33) is located along Road 629, just south of the Company's plant. This locality contains the thickest body of high-calcium limestone observed in the Strasburg area, as shown in the following section.

Geologic Section 16.—Along Road 629 about 2 miles northeast of Strasburg, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (225± feet): strike N. 75° E.; dip 29° SE.	
4. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.10; Fe_2O_3, 0.04; Al_2O_3, 0.42; $CaCO_3$, 98.25; $MgCO_3$, 0.80; total, 99.61	160±
3. Limestone, dove-gray, compact; partly covered	60
2. Conglomerate; limestone and dolomite pebbles in an impure taupe-gray limestone matrix; lower boundary uncertain	5
Beekmantown formation	
1. Dolomite mainly; several hundred feet. (See Geologic Section 43.)	

Between localities 33 and 35 the belt of high-calcium limestone crops out along the northwest slope of a low ridge, the summit of which is underlain by cherty Lenoir limestone. Most of the Mosheim and the lower part of the Lenoir in this belt are well displayed in the Shenandoah Valley Lime and Stone Corporation quarry (Pl. 8, loc. 35) along Road 630. This quarry is approximately 800 feet long, 250 feet

wide, and 30 to 80 feet deep along the eastern side. In 1942 the quarry was being enlarged in a southeasterly direction down the gentle dip of the Mosheim limestone. Because of the similarity of the rocks at this locality to those shown in Geologic Section 16, no samples for analysis were taken here. The Mosheim is overlain by a few feet of chert-free, dark limestone in the lower part of the Lenoir, which probably could be quarried together with the Mosheim as high-calcium limestone.

The general southwestward trend of the high-calcium limestone belt between localities 35 and 37 is modified by two folds, an anticline at locality 36 pitching gently southward and a syncline east of Capon Road that "spoons out" to the northeast. The quarry of the Standard Lime and Stone Company (Pl. 8, loc. 36), located along the crest of the broad gently pitching anticline, is approximately 1400 feet long, 200 to 300 feet wide, and about 125 feet deep at the western end. The quarry has been developed as several broad benches, arranged steplike along the general eastward strike of the rocks, which can be worked simultaneously (Pl. 6C). Approximately 100 feet of Mosheim limestone sampled along the western side of the quarry contains 98.15 per cent calcium carbonate and 0.95 per cent magnesium carbonate, a total of 99.10 per cent carbonates (Table 8). It should be noted that the beds sampled probably do not represent the full thickness of the Mosheim limestone, since at no place in the quarry was the base of the formation observed. The Mosheim is overlain in normal geologic sequence by beds of cherty Lenoir limestone which are well displayed along the south face of the quarry.

The thickness and character of the rocks comprising the high-calcium limestone belt about 100 yards (Pl. 8, loc. 37) northeast of the Powhatan Lime Company quarries are as follows:

Geologic Section 17.—Near the Powhatan Lime Company quarries about half a mile northeast of Strasburg Junction, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (162 feet): strike N. 51° E.; dip 38° SE.	
3. Limestone, dove-gray, fine grained	33
2. Limestone, dove-gray, compact, thick bedded	100
1. Limestone, dove-gray, compact; a few impure beds	29
Beekmantown formation	

The quarries of the Powhatan Lime Company (Pl. 8, loc. 38) are between locality 37 and the Southern Railway east of Strasburg Junction. The largest, near the southwestern end of the belt of high-calcium limestone, is approximately 800 feet long, 300 feet wide, and about 100 feet deep (Pl. 7A). The Mosheim is not fully exposed in the quarry, but it is assumed that the rocks quarried are similar to those described in Geologic Section 17. The overlying Lenoir formation which crops out along the east face of the quarry (Pl. 7A) and the adjacent low ridge is approximately 178 feet thick. It consists of medium- to fine-grained, dark-gray limestone. Cherty horizons are particularly abundant in the upper part of the formation. Two smaller quarries, each about 200 to 300 feet long and 20 to 50 feet deep, are located at intervals of about 500 feet northeast of the main quarry. The belt of high-calcium limestone appears to thin southwest of the Powhatan Lime Company quarries. In the quarry of the Shenandoah Lime Company (Pl. 8, loc. 40) the character and thickness of the rocks are as follows:

Geologic Section 18.—Shenandoah Lime Company quarry, 500 feet south of Strasburg Junction, Shenandoah County, Virginia

	Thickness Feet
Lenoir limestone (75 feet)	
4. Limestone, dark-gray, granular; very cherty; top not included	25
3. Limestone, dark-gray, medium grained; pinkish partings; sparsely cherty; SiO_2, 0.92; Fe_2O_3, 0.08; Al_2O_3, 0.56; $CaCO_3$, 96.97; $MgCO_3$, 1.21; total, 99.74	50
Mosheim limestone (88 feet): strike N. 45° E.; dip 45° SE.	
2. Limestone, dove-gray, compact, thick bedded	73
1. Limestone, dove-gray, compact, thin bedded; a few impure layers	15
Beekmantown formation	

The Shenandoah Lime Company quarry has a length of about 700 feet, width of 150 feet, and a maximum depth of 100 feet. Cherty Lenoir limestone is conspicuously displayed in an overhanging ledge forming the southeast rim of the quarry (Pl. 7B). The lower part of the Lenoir at this locality is relatively free of chert and meets the specifications of high-calcium limestone as used in this report.

One large quarry (Pl. 7C), now filled with water, is located along the belt of limestone between Strasburg Junction and the Strasburg Lime Company quarry (Pl. 8, loc. 41). The present quarry of the Strasburg Lime Company (Pl. 10A) is approximately 600 feet long, 150 feet wide, and 40 to 50 feet deep. The rock in the main part of the quarry is Mosheim; that along the southeast face Lenoir.

Geologic Section 19.—Strasburg Lime Company quarry, half a mile southwest of Strasburg Junction, Shenandoah County, Virginia

	Thickness Feet
Lenoir limestone (lower part, 35 feet)	
4. Limestone, dark-gray, granular, cherty	25
3. Limestone, dark-gray, medium grained	10
Mosheim limestone (85 feet): strike N. 50° E.; dip 32° SE.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.18; Fe_2O_3, 0.08; Al_2O_3, 0.40; $CaCO_3$, 98.45; $MgCO_3$, 0.91; total, 100.02	64
1. Limestone, dove-gray, banded, impure	21
Beekmantown formation	

One of the best exposed sections of the Ordovician limestone sequence from the top of the Beekmantown dolomite to the base of the overlying Martinsburg shale in northern Shenandoah County is along Tumbling Run, about 1½ miles southwest of Strasburg. The character of the rocks in the lower part of this section (Pl. 8, loc. 42) is as follows:

Geologic Section 20.—Along Road 601 and Tumbling Run, 1½ miles southwest of Strasburg, Shenandoah County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, granular, cherty	132
Mosheim limestone (56 feet): strike N. 35° E.; dip 30° SE.	
2. Limestone, dove-gray, compact, thick bedded	35
1. Limestone, dove-gray, compact, thin bedded; a few impure beds; lower boundary uncertain	21
Beekmantown formation	

All of the measurements of the Mosheim north of Tumbling Run in Shenandoah County indicate that there is an appreciable thickening of the limestone northeastward along the strike. Generally, the part of the Mosheim quarried along this belt, exclusive of the slightly impure beds near the base of the formation, ranges from about 75 to 125 feet in thickness.

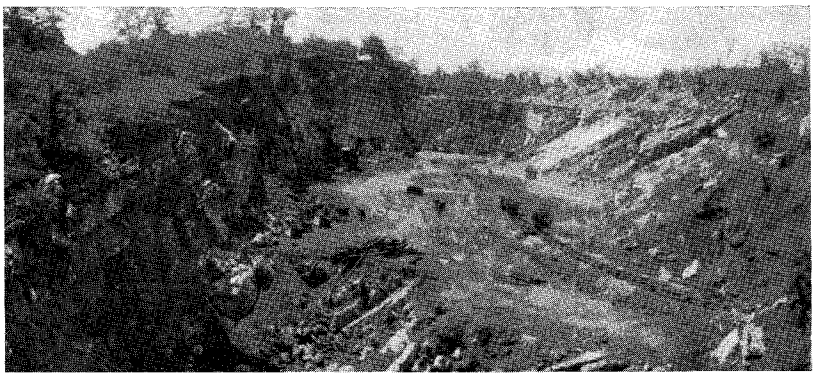
At locality 43 about 1¼ miles southwest of Tumbling Run, approximately 60 feet of Mosheim contains 98.35 per cent calcium carbonate and 0.73 per cent magnesium carbonate, a total of 99.08 per cent carbonates. Although the base of the Mosheim is covered at this locality, the position of the exposed underlying beds of dolomite limits the possible maximum thickness of the high-calcium rock to about 70 feet. Farther southwest, near U. S. Highway 11, the geologic sequence and character of the rocks (Pl. 8, loc. 44) are as follows:

Geologic Section 21.—About 1 mile northeast of Toms Brook, Shenandoah County, Virginia

	Thickness Feet
Lenoir limestone	
2. Limestone, dark-gray, granular, sparsely cherty; SiO_2, 3.77; Fe_2O_3, 0.26; Al_2O_3, 0.43; $CaCO_3$, 95.28; $MgCO_3$, 1.65; total, 101.39	100
Mosheim limestone: strike N. 31° E.; dip 26° SE.	
1. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.34; Fe_2O_3, 0.08; Al_2O_3, 0.84; $CaCO_3$, 96.94; $MgCO_3$, 1.33; total, 99.53	80
Beekmantown formation	

Since the analysis of unit 1 includes the full thickness of the Mosheim, it is reasonable to assume that a higher percentage of calcium carbonate could be obtained from a sample of the upper 60 to 70 feet of beds above the slightly impure zone at the base of the formation.

The Toms Brook Lime and Stone Company quarry (Pl. 8, loc. 45) is on the eastern side of the village of Toms Brook, near U. S. Highway 11 and the Southern Railway. It is about 600 feet long, 200 feet wide, and 100 feet deep (Pl. 10B). Due to the similarity of these



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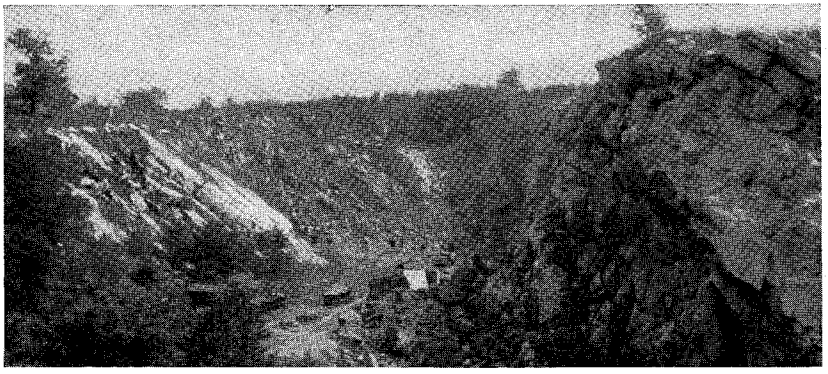

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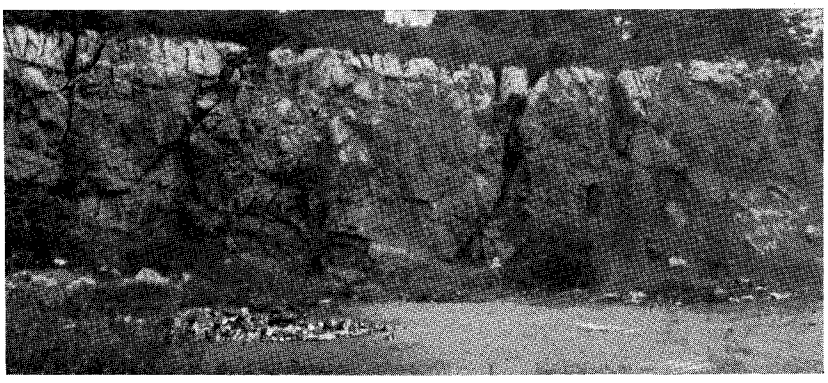
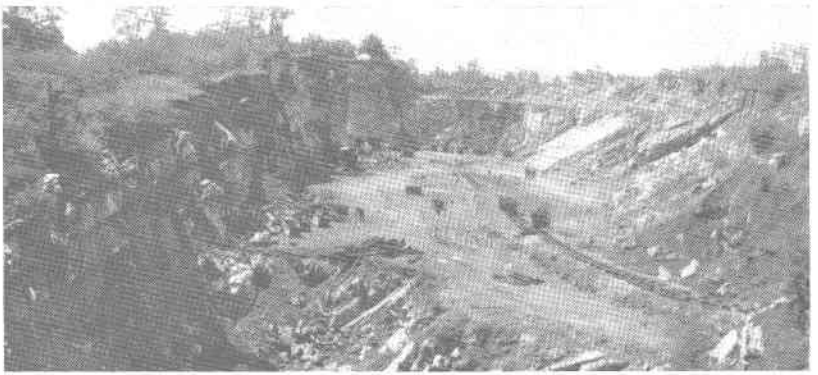


C.

A, Strasburg Lime Company quarry one mile west of Strasburg, Va. Looking southwest. B, Toms Brook Lime and Stone Company quarry at Toms Brook, Shenandoah County, Va. Looking northeast. C, Abandoned quarry near Melrose Caverns, Rockingham County, Va., showing thin soil mantle.



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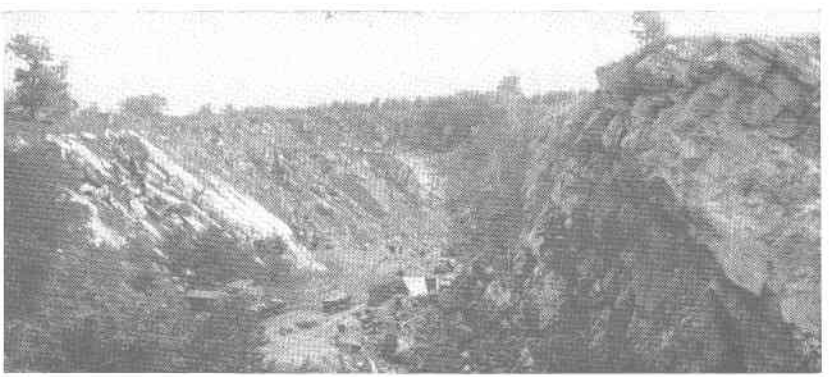

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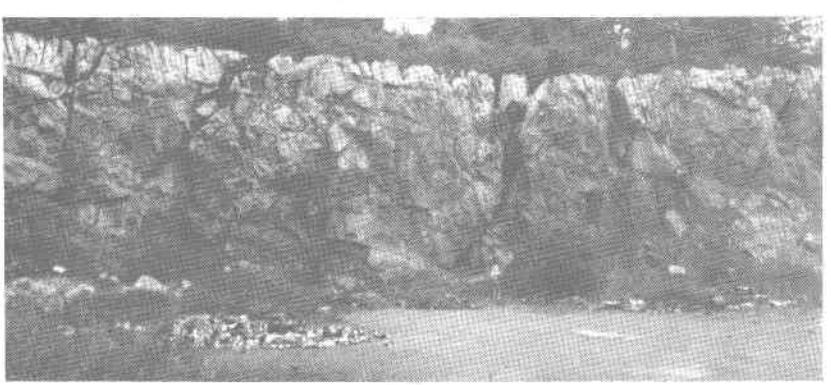
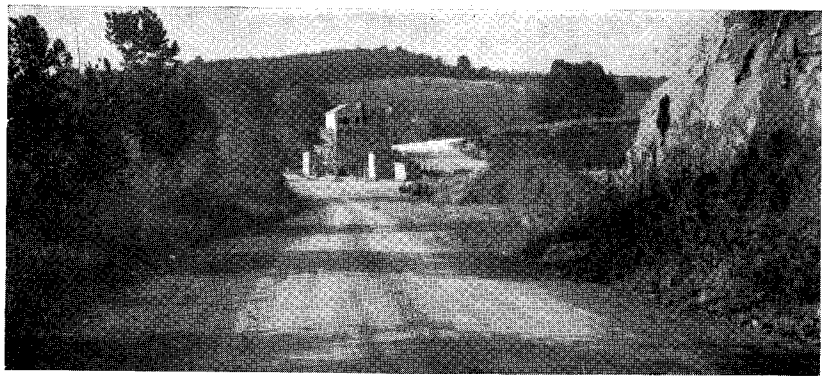


C.

A, Strasburg Lime Company quarry one mile west of Strasburg, Va. Looking southwest. B, Toms Brook Lime and Stone Company quarry at Toms Brook, Shenandoah County, Va. Looking northeast. C, Abandoned quarry near Melrose Caverns, Rockingham County, Va., showing thin soil mantle.



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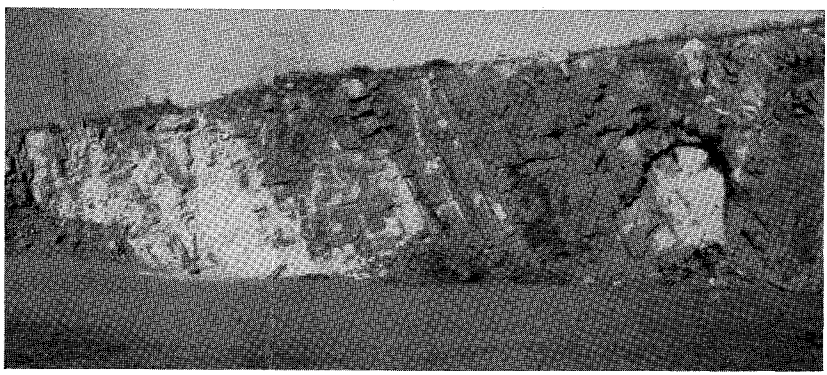

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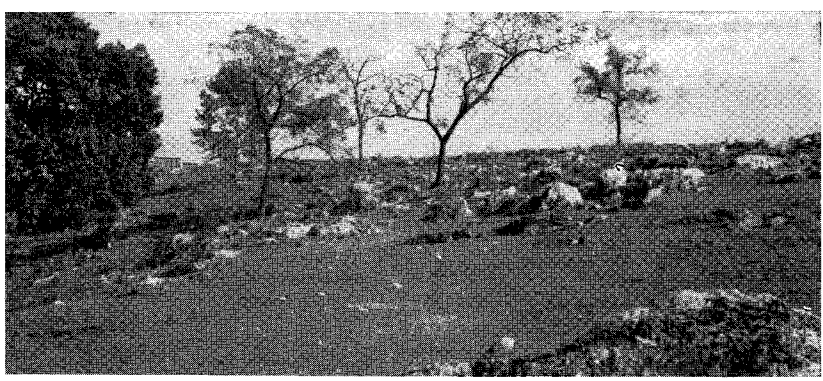
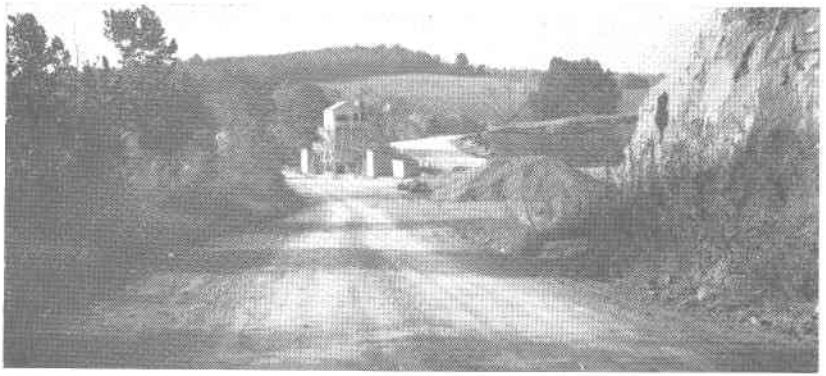
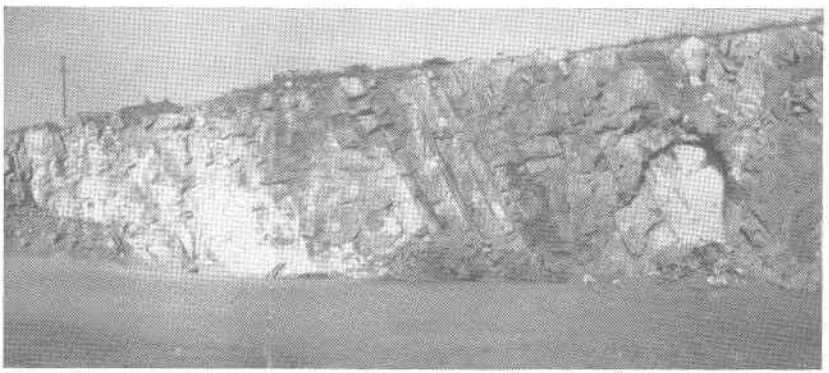


C.

A, Crusher at the Bowling quarry half a mile northeast of Verona, Augusta County, Va. B, Looking northeast along strike of Beekmantown dolomite in the Bowling quarry. C, Coarsely granular Lenoir limestone 3 miles northwest of Stuarts Draft, Augusta County, Va.



A.



B.

C.

A, Crusher at the Bowling quarry half a mile northeast of Verona, Augusta County, Va. B, Looking northeast along strike of Beekmantown dolomite in the Bowling quarry. C, Coarsely granular Lenoir limestone 3 miles northwest of Stuarts Draft, Augusta County, Va.

rocks to those described at localities 43 and 44, no samples for analysis were taken here. The thickness of the Mosheim at the western end of the quarry is about 97 feet, the lower 20 to 25 feet probably being slightly impure. The basal part of the overlying Lenoir near the northeastern end of the quarry is chert free, whereas towards the southwestern end black chert nodules closely overlie the Mosheim. It is important to recognize that cherty horizons in the Lenoir are not necessarily persistent within the formation, and thus within a few hundred feet along the strike the rock may vary from high-calcium limestone to impure limestone.

The belt of high-calcium limestone closely parallels U. S. Highway 11 between Toms Brook and Pughs Run, a distance of 4 miles. No satisfactory sections for accurate determination of thickness were observed along this belt, although the width of outcrop and structure suggest that the high-calcium limestones thin southwest of Toms Brook. This suggestion is corroborated by the following section along Pughs Run (Pl. 8, loc. 46), about 200 yards east of U. S. Highway 11.

Geologic Section 22.—Along Pughs Run, 2 miles northeast of Woodstock, Shenandoah County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, medium grained, cherty	170
Mosheim limestone (66 feet): strike N. 47° E.; dip 36° SE.	
2. Limestone, dove-gray, compact, thick bedded	22
1. Limestone, dove-gray, compact, thin bedded; a few impure beds	44
Beekmantown formation	

In the small abandoned quarry along Road 663, about 100 yards southwest of locality 46, the upper 32 feet of the Mosheim contains 98.26 per cent calcium carbonate and 1.59 per cent magnesium carbonate, a total of 99.85 per cent carbonates (Table 8). The thickness of the Mosheim in the general vicinity of Woodstock probably averages about 40 feet, although no fully exposed sections were found. The character of the rocks between Woodstock and Edinburg (Pl. 8, loc. 48) is given in the following section.

Geologic Section 23.—Along North Fork of Shenandoah River at dam, 1 mile northeast of Edinburg, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone: strike N. 35° E.; dip 47° SE.	
3. Limestone, dove-gray, compact; some layers slightly impure; lower boundary uncertain; SiO_2, 1.57; Fe_2O_3, 0.39; Al_2O_3, 0.81; $CaCO_3$, 96.60; $MgCO_3$, 1.24; total, 100.61	40
Beekmantown formation (upper part, 60 feet)	
2. Limestone, bluish-gray, fine grained to compact; a few thin layers of dolomite	20
1. Dolomite, bluish-gray, fine grained	40

The thickness of the Mosheim along Road 675 and North Fork of Shenandoah River (Pl. 8, loc. 49), about half a mile east of Edinburg, is 62 feet. The lower 37 feet is mostly medium thin-bedded, slightly impure limestone. The belt of limestone between Edinburg and the general latitude of Shenandoah Caverns is largely covered, thus the geologic mapping in this area is generalized. The first completely exposed section (Pl. 8, loc. 51) of high-calcium limestone southwest of Shenandoah Caverns is shown in the geologic section given below.

Geologic Section 24.—About three-tenths of a mile west of U. S. Highway 11 and 1½ miles east of Quicksburg, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (103 feet): strike N. 40° E.; dip 50° SE.	
2. Limestone, dove-gray, compact, thick bedded	76
1. Limestone, dove-gray, compact, thin bedded, slightly impure	27
Beekmantown formation	

The southwestern end of the Strasburg-New Market limestone belt is almost fully exposed between State Highway 262 and the Rockingham County line near New Market. Four sections were measured at intervals of approximately one-fourth of a mile along this belt. The

geologic sequence and character of the rocks beginning with locality 52 near the northeastern end of the belt are as follows:

Geologic Section 25.—About 100 yards east of North Fork of Shenandoah River and 1½ miles north of New Market, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (113 feet): strike N. 30° E.; dip 32° SE.	
2. Limestone, dove-gray, compact, thick bedded	91
1. Limestone, dove-gray, compact, thin bedded, slightly impure	22
Beekmantown formation	

About 100 yards southwest of the above location, along the strike (Pl. 8, loc. 53), the Mosheim is 111 feet thick and fully exposed in a vertical cliff along North Fork of Shenandoah River. Here the thin characteristic clayey streaks were observed in the lower part of the formation. At locality 54, the Mosheim is about 100 feet thick, the upper 76 feet being thick-bedded, high-calcium limestone. The character and thickness of the Mosheim (Pl. 8, loc. 55) about three-fourths of a mile northeast of Road 728 and about half a mile north of New Market are as follows:

Geologic Section 26.—About half a mile north of New Market, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (112 feet): strike N. 20° E.; dip 40° SE.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.22; Fe_2O_3, 0.12; Al_2O_3, 0.42; $CaCO_3$, 97.34; $MgCO_3$, 1.13; total, 99.23	79
1. Limestone, dove-gray, compact, thin bedded, slightly impure	33
Beekmantown formation	

A similar section was measured at locality 56, about 800 feet northeast of Road 728 and one-fourth of a mile northwest of New Market. In summary, localities 52 to 56 contain from 75 to 90 feet of high-grade limestone. It is also thought that additional

quantities of lower grade stone, averaging about 96 per cent calcium carbonate could be obtained from approximately the lower 25 feet of the formation. A detailed description of the Mosheim limestone, fully exposed in the Madden quarry at the western end of the Strasburg-New Market belt (Pl. 8, loc. 57), is given in the following section:

Geologic Section 27.—Madden quarry, half a mile southwest of New Market, Shenandoah County, Virginia

	Thickness Ft.	Thickness In.
Mosheim limestone (89+ feet): strike N. 25° E.; dip 38° SE.		
18. Limestone, dove-gray	9	0
17. Limestone, mottled light- and dark-gray, compact	3	
16. Limestone, dove-gray, compact; a few dark-gray beds	15	
15. Limestone, dark-gray, fine grained; irregular fracture	11	
Analysis of units 15 to 18, sampled thickness 38 feet: SiO_2, 0.26; Fe_2O_3, 0.08; Al_2O_3, 0.24; $CaCO_3$, 98.15; $MgCO_3$, 1.03; total, 99.76.		
14. Limestone, dove-gray, compact; a few clayey streaks	1	6
13. Limestone, dark-gray, compact; white calcite veins	6	
12. Limestone, dark-gray, compact		3
11. Limestone, dove-gray, compact; white calcite veins	7	
10. Limestone, clastic; fragments of compact limestone		10
9. Limestone, dove-gray, compact	1	
8. Limestone, clastic; fragments of compact limestone		9
7. Limestone, dove-gray, fine grained		6
6. Limestone, dove-gray, clastic; fragments of compact limestone	7	

	Thickness Ft.	In.
5. Limestone, drab-gray, fine grained, impure	1	6
4. Limestone, dove-gray, compact; calcite veins	2	6
3. Limestone, impure, thin bedded		5
2. Limestone, dove-gray, compact; contains yellowish streaks	5	
Analysis of units 2 to 14, sampled thickness 34+ feet: SiO_2, 1.24; Fe_2O_3, 0.08; Al_2O_3, 0.72; $CaCO_3$, 96.95; $MgCO_3$, 1.17; total, 100.16.		
1. Limestone, dove-gray to yellowish-gray, compact; a few clastic beds; slightly impure	17	

Beekmantown formation

Lantz Mills-Forestville belts.—The rocks described under the Lantz Mills-Forestville belts include several narrow bands of high-calcium Mosheim limestone exposed on the flanks of minor folds between the Mount Jackson anticline on the east and the Saumsville fault on the west. The structure of the limestone belts in the vicinity of Hamburg is shown on Plate 8. Some of the largest deposits of high-calcium limestone in Shenandoah County occur near the northeastern end of these belts west of Lantz Mills.

The Mosheim at locality 61 crops out around the end of a small anticline pitching northeastward (Fig. 2). Here a tributary to

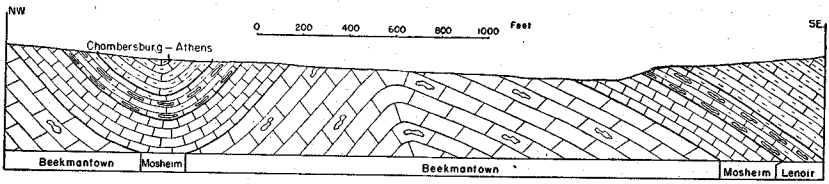


FIGURE 2.—Cross section of the Lantz Mills-Forestville high-calcium limestone belts along a tributary to Stony Creek, 1 mile southwest of Lantz Mills, Shenandoah County, Va.

Stony Creek flows in a narrow valley across the structure, thus affording excellent exposures for measurement and sampling along the steep-sided valley walls.

Geologic Section 28.—About four-tenths of a mile north of Road 693 and three-fourths of a mile southwest of Lantz Mills, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (175 feet): strike north; dip 26° E.	
7. Limestone, dove-gray, compact	5
6. Limestone, nodular, impure	1
5. Limestone, dove-gray, compact	8
4. Limestone, dark-gray, medium grained	6
Analysis of beds 4 to 7, sampled thickness 20 feet: SiO_2, 0.98; Fe_2O_3, 0.04; Al_2O_3, 1.24; $CaCO_3$, 95.89; $MgCO_3$, 1.77; total, 99.92.	
3. Limestone, dove-gray, compact; SiO_2, 0.16; Fe_2O_3, 0.04; Al_2O_3, 0.58; $CaCO_3$, 98.02; $MgCO_3$, 0.89; total, 99.69	60
2. Limestone, dove-gray, compact; a few impure beds; SiO_2, 0.92; Fe_2O_3, 0.04; Al_2O_3, 1.24; $CaCO_3$, 95.28; $MgCO_3$, 2.14; total, 99.62	65
1. Limestone, dove-gray, compact; some thin-bedded impure layers; SiO_2, 0.94; Fe_2O_3, 0.04; Al_2O_3, 1.08; $CaCO_3$, 96.30; $MgCO_3$, 1.18; total, 99.54	30
Beekmantown formation	

The analyses given in Geologic Section 28 show that the full thickness of the Mosheim at this locality averages about 96.5 per cent calcium carbonate. Another complete exposure (Pl. 8, loc. 62), about 1000 feet northwest of locality 61, is given in the following section.

Geologic Section 29.—Along tributary to Stony Creek, four-fifths of a mile southwest of Lantz Mills, Shenandoah County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, granular, cherty	100

	Thickness Feet
Mosheim limestone (141 feet): strike N. 60° E.; dip 50° NW.	
2. Limestone, dove-gray, compact; SiO_2, 1.25; Fe_2O_3, 0.21; Al_2O_3, 0.15; $CaCO_3$, 97.31; $MgCO_3$, 1.36; total, 100.28	76
1. Limestone, dove-gray, in part laminated; a few impure beds; SiO_2, 2.99; Fe_2O_3, 0.12; Al_2O_3, 0.28; $CaCO_3$, 95.98; $MgCO_3$, 2.38; total, 101.75	65
Beekmantown formation	

The high-calcium Mosheim limestone is overlain by impure limestones and shales in a shallow syncline (Fig. 2) west of locality 62. The thickness of the Mosheim along the west limb of this syncline, including a few impure beds in the lower part, is about 180 feet (Pl. 8, loc. 63). Due to the similarity of these rocks to those given in Geologic Sections 28 and 29, no samples for analysis were taken here.

The high-calcium limestones between Lantz Mills and State Highway 263 are poorly exposed. A small abandoned roadside quarry about one mile west of Mount Jackson is approximately 350 feet long, 150 feet wide, and 25 feet deep along the northern side. High-calcium limestones exposed in the quarry (Pl. 8, loc. 64) occupy the trough of a local syncline that pitches gently northeastward. The thickness of the Mosheim limestone in this area is estimated to be about 100 feet. Farther west in the vicinity of Rinkerton (Pl. 8, loc. 65) the geologic sequence and character of the rocks are as follows:

Geologic Section 30.—Along Crooked Run about 1½ miles northwest of Mount Jackson, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (111 feet): strike N. 35° E.; dip 43° SE.	
9. Limestone, dove-gray, compact, thick bedded; SiO_2, 1.76; Fe_2O_3, 0.08; Al_2O_3, 0.62; $CaCO_3$, 94.72; $MgCO_3$, 2.53; total, 99.71	93
8. Limestone, dove-gray; a few impure beds	18

	Thickness Feet
Beekmantown formation (upper part, 339 feet)	
7. Dolomite, gray, fine grained	15
6. Limestone, dove-gray, compact	29
5. Dolomite, gray	2
4. Limestone, dove-gray; sheared	35
3. Dolomite, gray, fine grained	20
2. Dolomite, medium-gray	38
1. Partly covered; exposed beds are dolomite	200

The Mosheim limestone east of the Saumsville fault along State Highway 263 (Pl. 8, loc. 66) occupies the trough of a narrow syncline. South of a point between locality 67 and Forestville, the western limb of the syncline is concealed by faulting. One of the thickest bodies of high-calcium limestone noted along the eastern limb of this syncline (Pl. 8, loc. 68) is in the vicinity of Forestville.

Geologic Section 31.—About 100 yards north of State Highway 262 and three-tenths of a mile southeast of Forestville, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (185 feet): strike N. 38° E.; dip vertical	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.28; Fe_2O_3, 0.12; Al_2O_3, 0.56; $CaCO_3$, 98.15; $MgCO_3$, 1.00; total, 100.11	130
1. Limestone, dove- to yellowish-gray, banded, impure	55
Beekmantown formation	

The thickness of the Mosheim at locality 69, about 3 miles west of Quicksburg, is about 187 feet, the upper 150 feet being thick-bedded, dove-gray, high-calcium limestone. A zinc prospect, containing beautiful specimens of sphalerite, occurs in the upper part of the underlying Beekmantown dolomite at this locality. Field studies indicate that this mineralization is restricted to a narrow zone and probably does not affect the purity of the overlying high-calcium limestone.

Saint Luke-Mount Clifton belt.—The Saint Luke-Mount Clifton belt of high-calcium limestone extends from the vicinity of Saint Luke southwestward into Rockingham County, passing east of Columbia Furnace and Mount Clifton. A smaller band of high-calcium Mosheim limestone cropping out east of Saint Luke and north of State Highway 261 is included in this belt. The thickness and composition of the Mosheim about 1 mile northeast of Saint Luke (Pl. 8, loc. 58) are given in the following section.

Geologic Section 32.—About 500 feet northwest of Road 623 and 1 mile northeast of Saint Luke, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (184 feet): strike N. 47° E.; dip, overturned, 73° SE.	
2. Limestone, dove-gray, compact	112
1. Limestone, dove-gray, compact, thin bedded, impure	72
Analysis of units 1 and 2, sampled thickness 184 feet: SiO_2, 0.72; Fe_2O_3, 0.08; Al_2O_3, 1.00; $CaCO_3$, 95.73; $MgCO_3$, 1.67; total, 99.20.	
Beekmantown formation	

It should be noted that the analysis given in the above section represents a composite sample of the full thickness of the Mosheim, and that probably the upper part of the formation (bed 2) contains a higher percentage of calcium carbonate.

The upper part of the Chambersburg formation which crops out 500 feet northwest of the Mosheim at locality 58, is composed of about 85 feet of light-gray, fine-grained limestone containing 97.56 per cent calcium carbonate and 1.10 per cent magnesium carbonate (Table 8). Limestone of similar composition occurs in the upper part of the Chambersburg at locality 73 about 2 miles southwest of Hamburg (Pl. 8). These occurences of high-calcium limestone appear to be limited to the northern part of the Saint Luke-Mount Clifton belt in Shenandoah County. A description of the rocks from the Beekmantown dolomite to the Martinsburg shale, east of Saint Luke (Pl. 8, loc. 59), is given in the following section.

Geologic Section 33.—About 800 feet north of Road 605 and half a mile east of Saint Luke, Shenandoah County, Virginia

	Thickness Feet
Chambersburg limestone (590± feet): strike N. 25° E.; dip 75° NW.	
4. Limestone, gray, compact to fine grained; SiO_2, 2.13; Fe_2O_3, 0.24; Al_2O_3, 0.40; $CaCO_3$, 96.87; $MgCO_3$, 1.72; total, 101.36	75–90
3. Limestone, dark-gray, fine grained; in part nodular and shaly; may include a thin occurrence of the Athens in the lower part	400–500
Lenoir limestone	
2. Limestone, dark-gray, granular, cherty	100
Mosheim limestone	
1. Limestone, dove-gray, compact; thickness estimated	100
Beekmantown formation	

The limestones in this belt extend southwest along the eastern limb of a syncline to locality 60, then swing abruptly around the end of a pitching anticline and continue eastward to the Saumsville fault. The belt is largely covered east of locality 60. The limestones cropping out along the western limb of the syncline extend from the general vicinity of Saint Luke southwestward across Shenandoah County. Due to limited time available no detailed measurements were made of exposures in the northern part of the belt. The following section (Pl. 8, loc. 71) is almost fully exposed along Swover Creek in western Shenandoah County.

Geologic Section 34.—Along Swover Creek about 2½ miles west of Lantz Mills, Shenandoah County, Virginia

	Thickness Feet
Chambersburg limestone (415 feet)	
11. Limestone, buff, clayey, cobbly weathering	12
10. Limestone, dark-gray, fine grained	10
9. Limestone, gray, fine to coarse grained	47

Analysis of units 9 and 10, sampled thickness 57 feet: SiO_2, 0.90; Fe_2O_3, 0.16; Al_2O_3, 1.10; $CaCO_3$, 96.34; $MgCO_3$, 1.11; total, 99.61.

	Thickness Feet
8. Limestone, bluish-gray, fine grained, medium bedded	9
7. Limestone, nodular, cobbly weathering	65
6. Limestone, dark-gray, nodular	131
5. Covered interval	63
4. Limestone, dense, black; some nodular beds	78
Lenoir limestone	
3. Limestone, dark-gray, medium grained, cherty; weathers cobbly	136
Mosheim limestone (218 feet): strike N. 30° E.; dip 20° SE.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.14; Fe_2O_3, 0.04; Al_2O_3, 0.52; $CaCO_3$, 98.56; $MgCO_3$, 0.82; total, 100.08	116
1. Limestone, dove-gray, compact; clayey partings; SiO_2, 1.20; Fe_2O_3, 0.08; Al_2O_3, 0.78; $CaCO_3$, 95.22; $MgCO_3$, 2.65; total, 99.93	102
Beekmantown formation	

An analysis of a separate sample of unit 2 in the above section shows 0.01 per cent phosphorus pentoxide (P_2O_5). The thickness of the Mosheim limestone given in the above section may not be accurate, since the exposed bedding surfaces are very irregular. The average of several determinations indicates that the dip of the beds is about 20° SE. The thickness and character of the Mosheim at locality 72, about 800 feet southwest of Swover Creek, are given in the following section.

Geologic Section 35.—About 800 feet southwest of Swover Creek and 2½ miles west of Lantz Mills, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (195 feet): strike N. 30° E.; dip 20° SE.	
2. Limestone, dove-gray, compact; SiO_2, 0.40; Fe_2O_3, 0.08; Al_2O_3, 0.78; $CaCO_3$, 96.60; $MgCO_3$, 1.35; total, 99.21	135
1. Limestone, dove-gray; some thin-bedded, impure layers; partly covered	60
Beekmantown formation	

Along the strike to the southwest the thickness of the high-calcium limestones ranges from about 90 feet at locality 74 to 125 feet near the Shenandoah-Rockingham County line. It is thought that the following section (Pl. 8, loc. 75) represents the general character of the rocks in the southwestern part of the Saint Luke-Mount Clifton belt.

Geologic Section 36.—Along Road 614 about 1¼ miles southwest of Forestville, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (125 feet): strike N. 50° E.; dip 18° SE.	
2. Limestone, dove-gray, compact; SiO_2, 0.20; Fe_2O_3, 0.04; Al_2O_3, 0.36; $CaCO_3$, 98.05; $MgCO_3$, 0.85; total, 99.50	85
1. Limestone, dove-gray, banded; a few impure beds	40
Beekmantown formation	

In summary, large deposits of high-calcium limestone occur along the Saint Luke-Mount Clifton belt, but since the area is remote from railroads no large-scale commercial development appears likely in the near future.

Saumsville-Fairview belt.—The Saumsville-Fairview high-calcium limestone belt extends from Saumsville southwestward for about 5 miles. It probably represents a faulted slice along the North Mountain overthrust. Southwest of Fairview, near the middle of the belt, the general southwestward trend of the rocks is modified by two small folds. The thickness and composition of the Mosheim limestone which is fully exposed southwest of Fairview (Pl. 8, loc. 70) are given in the following section.

Geologic Section 37.—About 1 mile southwest of Fairview and 1½ miles northeast of Saint Luke, Shenandoah County, Virginia

	Thickness Feet
Mosheim limestone (241 feet): strike N. 45° E.; dip 55° SE.	
4. Limestone, dove-gray, compact, thick bedded	94
3. Limestone, dark-gray, knotty	10
2. Limestone, dove-gray, compact	83

Analysis of units 2 to 4, sampled thickness 187 feet: SiO_2, 0.18; Fe_2O_3, 0.08; Al_2O_3, 0.60; $CaCO_3$, 97.76; $MgCO_3$, 0.56; total, 99.18.

	Thickness Feet
1. Limestone, dove-gray; few impure beds; SiO_2, 0.42; Fe_2O_3, 0.12; Al_2O_3, 1.76; $CaCO_3$, 94.82; $MgCO_3$, 2.56; total, 99.68	54

Beekmantown formation

Approximately 158 feet of high-calcium Mosheim limestone was measured about 500 feet east of locality 70, thus it is assumed that at least 150 feet of limestone, containing about 97.5 per cent calcium carbonate, occurs locally in the Saumsville-Fairview belt.

IMPURE LIMESTONE

Formations composed largely of impure limestones in Shenandoah County include the Chepultepec, Lenoir, Athens, and Chambersburg. Exceptions are occurrences of high-calcium limestone in the lower part of the Lenoir limestone at a few localities, where it is free of chert, and in the upper 60 to 90 feet of the Chambersburg limestone in the northwestern part of the county.

The Chepultepec limestone crops out in a narrow band on the east and west limbs of the Mount Jackson anticline, as a faulted slice extending for about 3 miles southwest of Saumsville, and near the western edge of Shenandoah Valley from a point about 1½ miles west of Saint Luke southwestward across the county (Pl. 8). The general character of the Chepultepec which crops out along the eastern limb of the Mount Jackson anticline in the vicinity of Quicksburg (Pl. 8, loc. 78) is as follows:

Geologic Section 38.—Along bluff above North Fork of Shenandoah River about half a mile south of Quicksburg, Shenandoah County, Virginia

	Thickness Feet
Chepultepec limestone: strike N. 40° E.; dip 35° SE.	
1. Limestone, dark-gray to black, fine grained; a few layers mottled pink; SiO_2, 8.87; Fe_2O_3, 0.76; Al_2O_3, 0.15; $CaCO_3$, 87.02; $MgCO_3$, 2.30; total, 99.10	370±

Conococheague formation

The belt of Chepultepec which extends along the west limb of the Mount Jackson anticline in the southern part of the county is concealed by older limestones and dolomites along the Saumsville fault northeast of the latitude of Woodstock. The western belt is partly exposed in the Hanner quarry, one mile southwest of Columbia Furnace, and along State Highways 260 and 263 northwest of Mount Clifton and Forestville. An analysis of a composite sample collected from stock-piles at this quarry (Pl. 8, loc. 76) shows 86.26 per cent calcium carbonate and 7.30 per cent magnesium carbonate, a total of 93.56 per cent carbonates. Additional chemical constituents of the rock from this quarry are given in Table 8.

The Lenoir is composed chiefly of dark-gray, granular limestone containing zones of black nodular chert. Samples from the lower part of the formation showing an analysis from 95 to 97 per cent calcium carbonate are not uncommon at localities where chert is absent or only sparsely developed. Examples of this purity may be observed in a few quarries near Strasburg and Toms Brook. Generally, the Lenoir is impure and at no place in the county could the full thickness be quarried for high-calcium limestone. The principal character of the formation is well displayed along Tumbling Run (Pl. 8, loc. 42). Another complete exposure of the Lenoir along the Strasburg-New Market belt (Pl. 8, loc. 48) is shown in the following section.

Geologic Section 39.—Along North Fork of Shenandoah River, 1 mile northeast of Edinburg, Shenandoah County, Virginia

	Thickness Feet
Lenoir limestone (167 feet)	
4. Limestone, dark-gray, medium grained, cobbly weathering; partly covered	77
3. Limestone, dark-gray, medium grained; sparsely cherty	46
2. Limestone, dark-gray; irregular bands of black chert	20
1. Limestone, dark-gray, fine grained, cobbly weathering	24
Mosheim limestone	

The thickness of the Lenoir along the Strasburg-New Market belt of high-calcium limestone ranges from 75 to 175 feet and averages

about 135 feet. At many localities the cherty beds are responsible for a low ridge adjacent to the high-calcium limestone belt. The same general character of the Lenoir persists in all of the northwestern belts, but the thickness is perhaps greater. At least 200 feet were measured west of Lantz Mills.

The rocks between the Lenoir and the Martinsburg, along the western edge of the Massanutten Mountain syncline, recently have been mapped by Butts[9] as Chambersburg limestone northeast of Mount Jackson, and as Athens and Chambersburg limestones between Mount Jackson and Rockingham County on the southwest. Other belts composed largely of argillaceous, in part cobbly weathering, limestone, probably Chambersburg, occur in the western part of the county southwest of Fairview. In the most westerly belt, beds of high-calcium limestone occur locally near the top of the formation.

The general character of the Chambersburg along Tumbling Run (Pl. 8, loc. 42) is given in the following section.

Geologic Section 40.—Along Road 601 and Tumbling Run, 1½ miles southwest of Strasburg, Shenandoah County, Virginia

	Thickness Feet
Chambersburg limestone (580± feet)	
11. Limestone, shale, and siltstone	50
10. Limestone, buff-gray, crumbly, cobbly weathering	40
9. Limestone, dark-gray, dense, slabby to cobbly	200±
8. Limestone, black, dense; in part shaly and cobbly weathering	259±
7. Limestone, granular, thick bedded	9
6. Limestone, buff-gray, cobbly weathering	3
5. Siltstone, brownish-buff	3
4. Metabentonite	1
3. Limestone, cobbly weathering; thin partings of metabentonite	7
2. Limestone, medium to coarse grained; 8-inch layer of metabentonite at base	8
Lenoir limestone	
1. Limestone, dark-gray, granular, cherty; upper boundary uncertain	132
Mosheim limestone	

The same belt of limestone is well displayed along Road 638 in the western environs of Strasburg. The upper half of the section at this locality (Pl. 8, loc. 39), representing about 250 feet of rock, contains 92.41 per cent calcium carbonate, whereas the more impure lower part contains only 83.49 per cent. The lower 100 feet of the Chambersburg at locality 44 contains 90.29 per cent calcium carbonate and 3.37 per cent magnesium carbonate, a total of 93.66 per cent carbonates. From the vicinity of Tumbling Run southwestward across Shenandoah County the exposures contain more and more dense black limestone with clayey partings. Cobbly weathering is also less pronounced than in the northeastern part of the belt. A description of a part of the impure limestones which crop out near the southwestern end of the Strasburg-New Market belt (Pl. 8, loc. 50) is given in the following section.

Geologic Section 41.—Between U. S. Highway 11 and abandoned quarry, 4 miles northeast of New Market, Shenandoah County, Virginia

	Thickness Feet
Chambersburg limestone (500± feet)	
8. Limestone, dark-gray to black, fine grained; bedding surfaces irregular; exposed in abandoned quarry	40
7. Limestone, black, compact; breaks with conchoidal fracture	34
6. Limestone, black; shale partings	32
5. Limestone, black, fine grained	45
4. Limestone, gray, fine grained; few clayey layers	28
3. Limestone, clayey, cobbly weathering	36
2. Limestone, dark-gray, fine grained, banded	135
1. Surface covered with fragments of black limestone and shaly limestone; may include upper part of Athens	150±

The impure limestones in the western part of Shenandoah County show considerable variations in lithology and composition. One of the best exposures is along Swover Creek about 2½ miles west of Lantz Mills (Geologic Section 34). Here the thickness of the Chambersburg formation is approximately 400 feet, with the upper part containing about 60 feet of high-calcium limestone.

HIGH-MAGNESIUM DOLOMITE

High-magnesium dolomite occurs in a small area, near the trace of the North Mountain fault, in southwestern Shenandoah County. The best exposure noted in this area is in the Kipps quarry (Pl. 8, loc. 77), along Road 726 about 3½ miles southwest of Mount Clifton. Rocks exposed along the northeastern side of the quarry include 75 to 100 feet of intensely brecciated, mealy weathering, light- to dark-gray Elbrook dolomite. Slightly brecciated lower grade dolomite, striking N. 22° E. and dipping 27° SE., is partially exposed east of the quarry for a distance of approximately 1000 feet.

A composite sample of the mealy weathering dolomite in the quarry (Table 8) contained 43.77 per cent magnesium carbonate, 54.56 per cent calcium carbonate, and 1.60 per cent silica. Analyses of samples collected at several localities southwestward along the strike in adjoining Rockingham County show similar composition. Sampled dolomite zones in the Elbrook formation, except where intensely brecciated, are generally low grade and do not meet the specifications for high-magnesium dolomite as defined in this report. The higher magnesium content of the brecciated dolomite may be due, in part, to secondary deposition of the mineral dolomite in fractures in the breccia. Brecciated high-magnesium dolomite was not observed north of the Kipps quarry.

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

In Shenandoah County the Beekmantown and Conococheague formations, and the Elbrook except for thin local occurrences of high-magnesium dolomite, are composed largely of interbedded limestone, magnesian limestone, and dolomite. On the geologic map (Pl. 8) the Beekmantown formation is separated from the older formations by a thin band of Chepultepec limestone. Although the rocks comprising the Conococheague and most of the Elbrook were not studied in detail in Shenandoah County, it is thought that the descriptions of these formations in adjoining Frederick County are applicable in this county. Generally the Elbrook and Conococheague formations in Shenandoah Valley contain relatively large quantities of clayey and siliceous materials.

The Beekmantown in Shenandoah County, with a thickness of about 2500 feet, is composed chiefly of dolomite, although there are a few conspicuous beds of intercalated limestone. Several partial ex-

posures indicate that the limestone beds are thicker and more abundant in the lower part of the formation. The general character of the Beekmantown may be seen along Pughs Run (Pl. 8, loc. 47).

Geologic Section 42.—Along Pughs Run about 2 miles northeast of Woodstock, Shenandoah County, Virginia

	Thickness Feet
Beekmantown formation (2127± feet)	
24. Dolomite, dark-gray, fine grained	53
23. Dolomite, medium grained, laminated	32
22. Limestone, bluish-gray, laminated	11
21. Dolomite, medium-gray, fine grained	73
20. Limestone with thin beds of dolomite	10
19. Dolomite, medium-gray, fine grained	61
18. Dolomite, light-gray, fine grained	45
17. Dolomite, dark-gray, fine grained	47
16. Mostly covered; a few beds of dolomite	177
15. Dolomite with a few thin beds of mottled light- and dark-gray limestone	56
14. Dolomite; weathers bluish-gray	44
13. Dolomite, gray, cherty	51
12. Dolomite, light-gray, fine grained; partly covered	403
11. Dolomite, medium-gray	77
10. Dolomite, dark-gray	118
9. Limestone and dolomite	7
8. Dolomite, medium-gray, fine grained	198
7. Dolomite, dark-gray	81
6. Dolomite, light- to brownish-gray, coarse grained	42
5. Dolomite, light-gray, fine grained	135
4. Limestone, dark brownish-gray	70
3. Dolomite, light-gray, granular	90
2. Dolomite, gray; partly covered	206
1. Limestone and dolomite	40
Chepultepec limestone	

The composition and character of the upper part of the Beekmantown dolomite along the Strasburg-New Market belt in the northeastern part of the county (Pl. 8, loc. 34) are given in the following section.

Geologic Section 43.—About 200 yards southwest of the Central Chemical Company plant and 2 miles northeast of Strasburg, Shenandoah County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 300 feet)	
3. Dolomite, dark-gray, fine grained; SiO_2, 3.43; Fe_2O_3, 0.46; Al_2O_3, 0.64; $CaCO_3$, 54.79; $MgCO_3$, 41.55; total, 100.87	100
2. Dolomite, gray, fine grained; SiO_2, 4.12; Fe_2O_3, 0.43; Al_2O_3, 0.52; $CaCO_3$, 53.99; $MgCO_3$, 38.20; total, 97.26	100
1. Dolomite, gray, fine grained; SiO_2, 5.91; Fe_2O_3, 0.55; Al_2O_3, 1.07; $CaCO_3$, 56.40; $MgCO_3$, 36.46; total, 100.39	100

The analyses in Geologic Section 43 represent the approximate range in composition for the highest grade dolomites sampled in the Beekmantown formation in Shenandoah County. Except for the relatively high content of noncarbonates, a part of the Beekmantown would be classified in this report as high-magnesium dolomite. Commonly the dolomite beds are not persistent in the upper part of the formation over wide areas. For example the upper 100 feet of the Beekmantown in the vicinity of Strasburg is dolomite (Pl. 8, loc. 34), whereas along the strike to the southwest in the vicinity of Edinburg (Pl. 8, loc. 48) the same interval is composed of interbedded limestone and dolomite. Farther southwest, in the vicinity of Quicksburg (Pl. 8, loc. 78), the lower 100 feet of the Beekmantown is predominantly limestone, containing 89.69 per cent calcium carbonate and 1.76 per cent magnesium carbonate, a total of 91.45 per cent carbonates. The upper part of the Beekmantown along the Saumsville fault (Pl. 8, loc. 67) is composed largely of thick-bedded, light-gray dolomite.

TABLE 8.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Shenandoah County, Virginia (Pl. 8)*

(Froehling & Robertson, Inc., and John H. Yoe, Analysts)

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
33	16	4	Mosheim	160±	98.25	0.80	0.10	0.04	0.42	99.61	Along Road 629 about 2 miles northeast of Strasburg.
34	43	3	Beekmantown	100	54.79	41.55	3.43	0.46	0.64	100.87	About 200 yards southwest of Road 629 and 2 miles northeast of Strasburg.
		2		100	53.99	38.20	4.12	0.43	0.52	97.26	
		1		100	56.40	36.46	5.91	0.55	1.07	100.39	
36			Mosheim	100±	98.15	0.95	0.14	0.08	0.52	99.84	Standard Lime and Stone Company quarry about 1 mile north of Strasburg.
39			Chambersburg	250	92.41	0.59	6.03	1.21	0.58	100.82	Along Road 638, between Strasburg and Strasburg Junction.
				250	83.49	1.48	10.05	0.97	3.13	99.12	
40	18	3	Lenoir	50	96.97	1.21	0.92	0.08	0.56	99.74	Northeastern end of Shenandoah Lime Company quarry at Strasburg Junction.
41	19	2	Mosheim	64	98.45	0.91	0.18	0.08	0.40	100.02	Strasburg Lime Company quarry, half a mile southwest of Strasburg Junction.

43			Mosheim	60	98.35	0.73	0.24	0.04	0.34	99.70	About 800 feet west of U. S. Highway 11 and 1¼ miles southwest of Tumbling Run.
44	21	2	Lenoir	100	95.28	1.65	3.77	0.26	0.43	101.39	About 100 yards east of U. S. Highway 11 and 1 mile northeast of Toms Brook.
		1	Mosheim	80	96.94	1.33	0.34	0.08	0.84	99.53	
			Chambersburg	100	90.29	3.37	6.19	0.55	1.03	101.43	
46			Mosheim	32	98.26	1.59	0.79	0.24	0.09	100.97	Abandoned quarry along Pughs Run, one-fourth of a mile east of U. S. Highway 11.
48	23	3	Mosheim	40	96.60	1.24	1.57	0.39	0.81	100.61	Along North Fork of Shenandoah River about 1 mile northeast of Edinburg.
55	26	2	Mosheim	79	97.34	1.13	0.22	0.12	0.42	99.23	Along bluff of North Fork of Shenandoah River, half a mile north of New Market.
57	27	15–18	Mosheim	38	98.15	1.03	0.26	0.08	0.24	99.76	Madden quarry, half a mile southwest of New Market.
		2–14		34	96.95	1.17	1.24	0.08	0.72	100.16	
58	32	1–2	Mosheim	184	95.73	1.67	0.72	0.08	1.00	99.20	About 500 feet northwest of Road 623 and 1 mile northeast of Saint Luke.
			Chambersburg	85	97.56	1.10	0.82	0.04	0.60	100.12	
59	33	4	Chambersburg	75–90	96.87	1.72	2.13	0.24	0.40	101.36	Along Narrow Passage Creek, half a mile east of Saint Luke.

TABLE 8.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Shenandoah County, Virginia (Pl. 8)—Continued*

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
61	28	4–7	Mosheim	20	95.89	1.77	0.98	0.04	1.24	99.92	About three-fourths of a mile southwest of Lantz Mills.
		3		60	98.02	0.89	0.16	0.04	0.58	99.69	
		2		65	95.28	2.14	0.92	0.04	1.24	99.62	
		1		30	96.30	1.18	0.94	0.04	1.08	99.54	
62	29	2	Mosheim	76	97.31	1.36	1.25	0.21	0.15	100.28	About 1000 feet northwest of locality 61 and four-fifths of a mile southwest of Lantz Mills.
		1		65	95.98	2.38	2.99	0.12	0.28	101.75	
65	30	9	Mosheim	93	94.72	2.53	1.76	0.08	0.62	99.71	Along Crooked Run, 1½ miles northwest of Mount Jackson.
68	31	2	Mosheim	130	98.15	1.00	0.28	0.12	0.56	100.11	About 100 yards north of State Highway 262, three-tenths of a mile southeast of Forestville.
70	37	2–4	Mosheim	187	97.76	0.56	0.18	0.08	0.60	99.18	About 1 mile southwest of Fairview.
		1		54	94.82	2.56	0.42	0.12	1.76	99.68	

71	34	9–10	Chambersburg	57	96.34	1.11	0.90	0.16	1.10	99.61	Along Swover Creek about 2½ miles west of Lantz Mills.
		2	Mosheim	116	98.56	0.82	0.14	0.04	0.52	100.08	
		1		102	95.22	2.65	1.20	0.08	0.78	99.93	
72	35	2	Mosheim	135	96.60	1.35	0.40	0.08	0.78	99.21	Just south of Road 691 about 2½ miles west of Lantz Mills.
73			Chambersburg	50	97.55	1.09	0.58	0.08	0.54	99.84	About 500 feet west of Road 710 and 2 miles southwest of Hamburg.
75	36	2	Mosheim	85	98.05	0.85	0.20	0.04	0.36	99.50	Along Road 614 about 1¼ miles southwest of Forestville.
76			Chepultepec		86.26	7.30	6.97	0.24	0.70	101.47	Hanner quarry, about 1 mile southwest of Columbia Furnace.
77			Elbrook	75–100	54.56	43.77	1.60	0.08	0.48	100.49	Kipps quarry along Road 726 about 3½ miles southwest of Mount Clifton.
78	38	1	Chepultepec	370±	87.02	2.30	8.87	0.76	0.15	99.10	Along North Fork of Shenandoah River, half a mile south of Quicksburg.
			Beekmantown	100	89.69	1.76	5.87	0.46	0.20	97.98	

CENTRAL ROCKINGHAM COUNTY

GENERAL STATEMENT

Rockingham County (Fig. 1) lies between the West Virginia line on the west and the Blue Ridge on the east and is bounded on the northeast by Shenandoah and Page counties and on the southwest by Augusta County. It has an area of 876 square miles. About three-fifths of the county, extending from the Blue Ridge northwest to Little North Mountain, represents the full width of Shenandoah Valley. Massanutten Mountain, which rises as a conspicuous ridge near McGaheysville and extends northeastward to the vicinity of Strasburg in Shenandoah County, divides the valley portion of Rockingham County into two parts. In this report that part of the county between Massanutten and Little North mountains is described as central Rockingham County; that part between Massanutten Mountains and the Blue Ridge is discussed under eastern Rockingham County.

The broad valley surrounding Massanutten Mountain slopes gradually southeastward from an altitude of about 1500 feet along the southeast base of Little North Mountain to approximately 900 feet along South Fork of Shenandoah River. The topography of the western part of the valley in Rockingham County (Pl. 9) is characterized by low ridges trending northeastward, and rounded or conical hills which rise from a few feet to about 200 feet above the surrounding area. The principal streams are North Fork of Shenandoah River, which enters the valley at Brocks Gap and thence extends eastward into Shenandoah County, passing near Broadway and Timberville, and Middle River which flows southeastward across the county to join South Fork of Shenandoah River at Port Republic. Harrisonburg, the county seat, is located near the geographical center of Shenandoah Valley. Central Rockingham County is served by the Chesapeake Western Railway which connects with the Norfolk and Western at Elkton, and by the Southern Railway along the western part of the valley northeast of Harrisonburg. The location of these railroads (Pl. 9) is favorable for the exploitation of many occurrences of the industrial limestones and dolomites.

GEOLOGY

Central Rockingham County is underlain by several narrow belts of high-calcium limestone separated by relatively impure limestone,

dolomite, and shale (Pl. 9). High-calcium limestone is restricted chiefly to the Mosheim formation and locally a part of the overlying Lenoir limestone where it is free of chert. The Elbrook formation which crops out along the western side of Shenandoah Valley in Rockingham County locally contains quarriable zones of high-magnesium dolomite, averaging more than 43 per cent magnesium carbonate and less than 2 per cent silica. A summary of the carbonate formations in central Rockingham County is given in Table 9.

TABLE 9.—*Summary of carbonate rocks in the Shenandoah Valley portion of central Rockingham County, Virginia*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Chambersburg and Athens	Chiefly calcareous black shale and shaly black limestone. Shales predominate along the Massanutten Mountain syncline, whereas limestones are more abundant in the western belts. Upper 75 to 100 feet in vicinity of Harrisonburg contains abundant Chambersburg fossils. Sampled units contain from about 60 to 90 per cent calcium carbonate.	850–1350[a]
Whitesburg	Rusty weathering, impure, dark-gray limestone. Observed locally near Linville and southwest of Harrisonburg.	0–30
Lenoir	Commonly granular, cherty, dark-gray limestone. A part of the formation contains high-calcium limestone at a few localities where free of chert.	40–150
Mosheim	Compact, dove-gray limestone. Commonly divisible into two parts; an upper division, including more than half of the total thickness and containing from 97.0 to 98.5 per cent calcium carbonate, and a lower slightly impure part averaging about 96 per cent. Locally contains less than 95 per cent calcium carbonate in the Honeyville-Dayton belt.	60–240
Beekmantown	Chiefly fine- to medium-grained, light- to dark-gray dolomite, with a few intercalations of light bluish-gray limestone; a few cherty layers. Locally the top 30 feet in the belt west of Broadway contains impure dolomite, straticulate limestone, and shale.	2000±
Chepultepec	Chiefly fine-grained, slightly banded, bluish-gray limestone.	300–500[a]

[a] Estimated.

TABLE 9.—*Summary of carbonate rocks in the Shenandoah Valley portion of central Rockingham County, Virginia—Continued*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Conococheague	Chiefly fine-grained, bluish-gray limestone and minor amounts of gray dolomite. Distinctive features are thin laminae, containing siliceous material, which weather out in relief on the surface of the limestones, and layers of coarse-grained sandstone.	2500[a]
Elbrook	Chiefly shaly weathering dolomite and limestone; locally, near the North Mountain fault, contains quarriable zones of brecciated dolomite averaging about 43.5 per cent magnesium carbonate.	2000[a]

[a] Estimated.

The major structures along a line extending northwestward through Paulington, Linville, and Edom are shown on Plate 9. The largest fold in Rockingham County, which is also one of the major structural units of Shenandoah Valley, is the Massanutten Mountain syncline. The trough of the syncline, exclusive of the area of Massanutten Mountain, is occupied by Martinsburg shale that has been worn down to the general level of the valley. West of the Massanutten Mountain syncline is an anticline, the main area of which is occupied by Cambrian and Ordovician limestones and dolomites. Southwest of Endless Caverns (Pl. 9, loc. 97), the normal geologic sequence of formations which should be repeated on opposite limbs of the fold is disrupted by the Staunton fault, a major overthrust that extends southwestward into Rockbridge County. Along this fault at the Rockingham-Augusta County line, the Elbrook dolomite is thrust upon Beekmantown. An interesting feature[4] associated with this fault southwest of Mount Crawford is a detached area of the overthrust block (klippe) consisting of Beekmantown, Chepultepec, and Conococheague formations resting unconformably upon Athens, Chambersburg, and Martinsburg.

The next major anticline, separated from the previously described fold by a narrow trough filled with impure limestone and shale, extends from the Shenandoah-Rockingham County line southwestward to a locality between Linville and Harrisonburg. Here

the high-calcium limestones and the underlying impure limestones and dolomites pass beneath the surface around the end of the structure which is pitching gently southwestward. The part of the anticline occupied by limestone and dolomite varies in width from 4 miles along the Shenandoah County line to about 1½ miles east of Linville.

A third syncline showing Martinsburg shale along the trough of the fold occurs just west of Timberville and Linville (Pl. 9). Near the southwestern end of this structure, the rocks are disarranged by a series of small gentle folds. In a small area northwest of Harrisonburg, erosion has removed the crest of one of these minor anticlines, exposing an elliptical body of Beekmantown dolomite surrounded by high-calcium limestone.

The area between the Honeyville-Dayton high-calcium limestone belt and the North Mountain fault is underlain in normal geologic sequence, from west to east, by broad belts of the Elbrook, Conococheague, Chepultepec, and Beekmantown formations. The time available for field study did not permit an examination of local occurrences of Ordovician limestones along the overthrust west of Singers Glen and Mount Clinton.

HIGH-CALCIUM LIMESTONE

Honeyville-Dayton belt.—The Honeyville-Dayton belt of high-calcium limestone extends from the Shenandoah County line north of Honeyville southwestward across Rockingham County, passing west of Broadway, Dayton, and Bridgewater. At a locality about 2 miles east of Mount Clinton the belt veers eastward for about one mile and then continues southwestward crossing U. S. Highway 33, about 3 miles west of Harrisonburg. Four geologic sections, spaced at intervals of 3 to 4 miles along the strike of the rocks, were measured northeast of U. S. Highway 33. Southwest of this point the limestone belt is largely covered.

Several measured sections and chemical analyses indicate that this belt of limestone contains more impurities and is lower in total carbonates than any of the other high-calcium limestone belts west of Massanutten Mountain. The character and sequence of the rocks near the northeastern end of the Honeyville-Dayton belt (Pl. 9, loc. 79) are as follows:

Geologic Section 44.—Along Road 793 about 1½ miles northwest of Timberville, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (157 feet): strike N. 40° E.; dip 23° SE.	
10. Limestone, dove- and dark-gray, compact	99
9. Limestone, dove-gray; thin clayey streaks	18
8. Limestone, slightly impure	24
7. Limestone, thin-bedded, slabby weathering, impure	16
Analysis of units 7 to 10, sampled thickness 157 feet: SiO_2, 2.44; Fe_2O_3, 0.24; Al_2O_3, 0.78; $CaCO_3$, 94.00; $MgCO_3$, 2.82; total, 100.28.	
Beekmantown formation (upper part, 146 feet)	
6. Dolomite, gray, fine grained	4
5. Limestone, dove-gray; weathers buff	36
4. Limestone with intercalations of dolomite	66
3. Dolomite, light-gray; weathers cream-colored	19
2. Limestone, light-gray, magnesian, fine grained	11
1. Dolomite, light-gray, fine grained	10

Since the analysis given above represents a composite sample of the full thickness of the Mosheim, it is thought that a higher percentage of calcium carbonate could be obtained from the upper part of the formation (bed 10), which is relatively free of impurities. High-calcium limestones cropping out along State Highway 259 (Pl. 9, loc. 80) are shown in the following section.

Geologic Section 45.—Along State Highway 259 about 1 mile northwest of Broadway, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (157 feet): strike N. 18° E.; dip 30° SE.	
6. Limestone, dove-gray, compact	18
5. Limestone, dark bluish-gray, fine grained	7
4. Limestone, dove-gray, thin bedded; clayey partings	49
3. Covered	20
2. Limestone, dove-gray, compact, banded; clayey partings	63
Beekmantown formation	

No samples were collected for chemical analysis at this locality, since most of the rocks contain abundant clayey partings. The same general lithologic character of the rocks is maintained southwestward to locality 82 where the following section is fully exposed.

Geologic Section 46.—Near intersection of Roads 782 and 617 about 3½ miles northwest of Linville, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (97 feet): strike N. 28° E.; dip 31° SE.	
2. Limestone, dove-gray, compact; thin bedded near base; SiO_2, 1.20; Fe_2O_3, 0.08; Al_2O_3, 0.40; $CaCO_3$, 96.96; $MgCO_3$, 1.21; total, 99.85	36
1. Limestone, dove-gray; medium bedded; clayey partings	61
Beekmantown formation	

It is thought that the following section (Pl. 9, loc. 83) gives a general summary of the rocks comprising the Honeyville-Dayton high-calcium limestone belt between locality 82 and U. S. Highway 33.

Geologic Section 47.—Near intersection of Roads 777 and 761 about 3½ miles west of Linville, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (174 feet): strike N. 45° E.; dip 33° SE.	
3. Limestone, dove-gray, thin bedded, impure	52
2. Limestone, dove-gray, compact	67
1. Limestone, dove-gray, thin bedded; clayey streaks; partly covered	55
Beekmantown formation	

Park View belt.—The Park View belt comprises an elliptical body of limestone, approximately 2 miles long, that begins at a point 2 miles northwest of Harrisonburg and extends southwestward nearly to U. S. Highway 33. Structurally, it is a narrow elongate dome with Beekmantown dolomite occupying the crest of the fold. The

character and sequence of the rocks along the northwestern limb of the structure (Pl. 9, loc. 84) are as follows:

Geologic Section 48.—About 200 yards north of Road 763 and 1½ miles northwest of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (242± feet): strike N. 24° E.; dip 55° NW.	
2. Limestone, dove-gray, compact; SiO_2, 0.32; Fe_2O_3, 0.08; Al_2O_3, 0.46; $CaCO_3$, 97.96; $MgCO_3$, 0.89; total, 99.71	75
1. Limestone, dove-gray, compact, sheared; a few clayey streaks; SiO_2, 0.96; Fe_2O_3, 0.20; Al_2O_3, 1.00; $CaCO_3$, 96.14; $MgCO_3$, 1.20; total, 99.50	167±
Beekmantown formation	

The data summarized in the above section indicate that this belt, although limited in size, should offer several quarry sites for large-scale production of high-calcium limestone. Further studies, including core drilling, are recommended in this area.

Timberville-Linville belt.—The Timberville-Linville limestone belt extends from the Shenandoah County line northeast of Timberville, southwestward to a point about 2 miles south of Linville where it connects with the Tenth Legion-Melrose belt. From Timberville to Linville, a distance of approximately 8 miles, high-calcium limestones are within half a mile of the Valley Division of the Southern Railway. There are excellent exposures of bedrock along the entire belt, commonly along the southeast slope of a low ridge (Fig. 3). Considering location with respect to railroad facilities, thickness, and chemical composition of the limestone, this belt is thought to offer the best potential quarry sites for large-scale

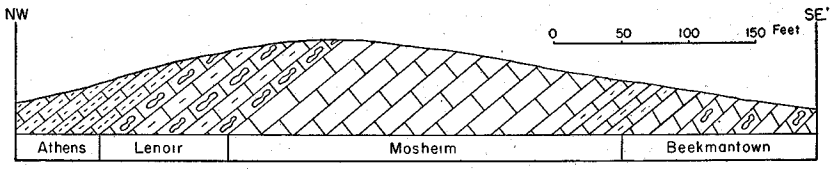


FIGURE 3.—Cross section of the Timberville-Linville high-calcium limestone belt, 1½ miles northeast of Linville, Rockingham County, Va.

production of high-calcium limestone in Rockingham County. The character of the limestone in the northern part of the area (Pl. 9, loc. 85) is as follows:

Geologic Section 49.—Along the Shenandoah-Rockingham County line about 3 miles northeast of Timberville, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (186 feet): strike N. 28° E.; dip 85° NW.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.26; Fe_2O_3, 0.08; Al_2O_3, 0.78; $CaCO_3$, 97.55; $MgCO_3$, 0.83; total, 99.50	108
1. Limestone, dove-gray; a few clayey partings	78
Beekmantown formation	

The Timberville-Linville belt, maintaining approximately the same thickness as shown in Geologic Section 49, extends southwestward along State Highway 260 to the vicinity of Timberville. About half a mile east of Broadway and 1½ miles southwest of Timberville the Beekmantown (Pl. 9, loc. 86) is overlain by 165 feet of Mosheim, the upper 108 feet being compact, thick-bedded, dove-gray limestone. Between Broadway and Linville there are many complete exposures of limestone. The character of the rocks about 3 miles south of Broadway (Pl. 9, loc. 87), and at a locality 2 miles southwest of Daphna (Pl. 9, loc. 88) are summarized in the following sections.

Geologic Section 50.—About 3 miles south of Broadway and half a mile southwest of the intersection of Roads 809 and 803, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (154 feet): strike N. 25° E.; dip 46° NW.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.26; Fe_2O_3, 0.08; Al_2O_3, 0.40; $CaCO_3$, 98.66; $MgCO_3$, 0.97; total, 100.37	117
1. Limestone, dove-gray, compact; a few impure beds	37
Beekmantown formation	

Geologic Section 51.—Between Road 803 and the Southern Railway about 2 miles southwest of Daphna, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (173 feet): strike N. 24° E.; dip 44° NW.	
7. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.18; Fe_2O_3, 0.08; Al_2O_3, 0.50; $CaCO_3$, 98.35; $MgCO_3$, 0.76; total, 99.87	136
6. Limestone, dove-gray, thin bedded; a few clayey partings	37
Beekmantown formation (upper part, 122 feet)	
5. Dolomite, gray, fine grained	16
4. Limestone, light-gray, thick bedded	30
3. Limestone, magnesian, mottled light- and dark-gray	13
2. Limestone and dolomite	13
1. Dolomite, gray, fine grained	50

High-calcium limestone, showing apparently similar chemical properties, gradually increases in thickness from the vicinity of Daphna southwest to Linville. The maximum thickness measured along this belt (Pl. 9, loc. 89) is given in the following section.

Geologic Section 52.—Along Road 803 about 1½ miles northeast of Linville, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (191 feet): strike N. 27° E.; dip 40° NW.	
2. Limestone, dove-gray, compact, thick bedded	160
1. Limestone, dove-gray, compact; a few impure beds	31
Beekmantown formation	

The Southern Lime and Stone Works quarry at Linville (Pl. 9, loc. 90) is in the upper part of the Mosheim. Since these rocks appear similar to those sampled at several localities near Linville, no samples for analyses were collected here. Immediately overlying the Mosheim and cropping out along the northwest wall of the quarry are beds of granular, nodular weathering, gray Lenoir limestone. The

thickness and chemical composition of these beds as determined from incomplete exposures at the entrance to the quarry (Pl. 9, loc. 90) are as follows:

Geologic Section 53.—Southwestern end of quarry of the Southern Lime and Stone Works at Linville, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone (53 feet): strike N. 45° E.; dip 33° NW.	
4. Covered interval	7
3. Limestone, medium-gray, granular; white chalky crusts	6
2. Limestone, medium-gray, nodular weathering; impure beds near base	22
1. Limestone, dark-gray, granular	18
Analysis of units 1 to 3, sampled thickness 46 feet: SiO_2, 0.40; Fe_2O_3, 0.32; Al_2O_3, 0.88; $CaCO_3$, 96.96; $MgCO_3$, 0.89; total, 99.45.	
Mosheim limestone	

The total carbonates in the above analysis may not represent the average composition of the full thickness of the Lenoir, since the complete section was not exposed. The same beds (Pl. 9, loc. 91) are better exposed about half a mile southwest of the Southern Lime and Stone Works quarry where they contain 95.67 per cent total carbonates. High-calcium limestone crops out along the northwest slope of a low ridge extending southwestward from Linville. The following section (Pl. 9, loc. 91), representing one of the best deposits of high-calcium limestone in Rockingham County, is fully exposed about half a mile southwest of Linville.

Geologic Section 54.—About two-tenths of a mile west of Road 753 and half a mile southwest of Linville, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone (37± feet)	
7. Limestone, medium- to light-gray, medium grained; upper boundary uncertain	10
6. Limestone, bluish-gray; sparsely cherty	12

	Thickness Feet
5. Limestone, dark bluish-gray, medium grained	10
4. Limestone, light-gray, coarse grained	2
3. Limestone, dark-gray, fine grained	3
Analysis of units 3 to 7, sampled thickness 37 feet: SiO_2, 2.52; Fe_2O_3, 0.80; Al_2O_3, 0.98; $CaCO_3$, 94.34; $MgCO_3$, 1.33; total, 99.97.	
Mosheim limestone (139 feet): strike N. 41° E.; dip 30-40° NW.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.10; Fe_2O_3, 0.08; Al_2O_3, 0.34; $CaCO_3$, 98.57; $MgCO_3$, 0.62; total, 99.71	91
1. Limestone, dove-gray; a few impure beds; SiO_2, 1.94; Fe_2O_3, 0.12; Al_2O_3, 0.60; $CaCO_3$, 95.83; $MgCO_3$, 0.77; total, 99.26	48
Beekmantown formation	

An analysis of a separate sample of unit 2 in the above section shows 0.021 per cent phosphorus pentoxide (P_2O_5).

Another excellent exposure of the Mosheim, near the southwestern end of the Timberville-Linville belt (Pl. 9, loc. 92), is described in the following section.

Geologic Section 55.—Along and north of Road 765 about 1½ miles southwest of Linville, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (171 feet): strike N. 30° E.; dip 42° NW.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.22; Fe_2O_3, 0.08; Al_2O_3, 0.58; $CaCO_3$, 98.76; $MgCO_3$, 0.74; total, 100.38	115
1. Limestone, dove-gray, compact; a few impure beds; SiO_2, 1.24; Fe_2O_3, 0.04; Al_2O_3, 1.08; $CaCO_3$, 95.73; $MgCO_3$, 1.17; total, 99.26	56
Beekmantown formation	

The Mundy Lime and Stone Company (Pl. 9, loc. 93) operates a quarry in the Mosheim limestone at Zirkle, on the Southern Railway

about 2 miles southwest of Linville. Although the rocks in this immediate area were not sampled, it is reasonable to assume that they are of similar composition to those analyzed at locality 92 half a mile northeast along the strike. The Mundy Lime and Stone Company quarry is located at the southwestern end of the Timberville-Linville belt, where the strike of the limestone changes from a southwesterly to a southeasterly direction connecting with the Tenth Legion-Melrose belt.

Tenth Legion-Melrose belt.—The Tenth Legion-Melrose high-calcium limestone belt enters Rockingham County about half a mile northwest of U. S. Highway 11 and parallels the highway southwestward to a point about 2 miles northeast of Harrisonburg. The high-calcium limestones in this belt commonly crop out near the crest of a low ridge.

The Mosheim limestone in the Madden quarry (Pl. 8, loc. 57), in Shenandoah County about half a mile north of the Rockingham County line, has a thickness of about 88 feet, the upper 70 feet containing about 97.5 per cent calcium carbonate. The limestone thickens to the southwest, but from the Madden quarry to the general vicinity of Tenth Legion there are no full sections exposed, so that the maximum thickness is not known. In the vicinity of Mauzy (Pl. 9, loc. 94) about 2 miles farther southwest, the thickness and character of the rocks in this belt are as follows:

Geologic Section 56.—Along U. S. Highway 11 near Mauzy and about three-fourths of a mile northeast of Lacey Spring, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (157 feet): strike N. 40° E.; dip 28° SE.	
2. Limestone, dove-gray, compact, thick bedded; partly covered	95
1. Limestone, dove-gray, medium thin bedded; a few impure partings	62
Beekmantown formation	

Between Mauzy and Melrose, especially along the northwest slope of a prominent ridge just east of Road 805, the thickness of the Mosheim is estimated to range from 100 to 150 feet. The upper 75 feet of Mosheim at locality 95 contains 95.90 per cent calcium carbonate and 2.76 per cent magnesium carbonate, a total of 98.66 per

cent carbonates (Table 11). Large reserves of high-calcium limestone occur in the vicinity of Melrose, particularly for a distance of one mile northeast of the abandoned quarry (Pl. 10C) along Road 721, near Melrose Caverns (Pl. 9, loc. 96). Southwest of Melrose the width of the limestone belt gradually widens as the axis of the anticline is approached (Pl. 9). No exposures satisfactory for accurate thickness determinations were observed in the southern part of this belt.

Zenda-Rockingham belt.—The Zenda-Rockingham high-calcium limestone belt extends from Endless Caverns southwestward into Augusta County, passing near Rockingham, Harrisonburg, and Zenda. At Endless Caverns it connects with the Paulington-Penn Laird belt. Except for the small area southwest of Rockingham the bedrock exposures are numerous and afford excellent sections for measurement and sampling. The Mosheim, beginning at Cedar Grove Church about 2 miles east of Harrisonburg and extending northeastward for several miles, crops out along the southeast slope of a prominent ridge underlain by cherty Lenoir limestone. The character of the rocks near the northeastern end of the Zenda-Rockingham belt (Pl. 9, loc. 97) is given in the following section.

Geologic Section 57.—Along State Highway 259 about 2½ miles northeast of Lacey Spring, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone (127 feet): strike N. 40° E.; dip 53° NW.	
3. Limestone, medium-gray, granular	25
2. Limestone, light-gray, coarse grained; a few intercalated fine-grained beds	102
Mosheim limestone	
1. Limestone, dove-gray, compact, thick bedded; 3-foot impure bed near middle of formation	93
Analysis of units 1 to 3, sampled thickness 220 feet: SiO_2, 0.20; Fe_2O_3, 0.04; Al_2O_3, 0.56; $CaCO_3$, 97.96; $MgCO_3$, 0.80; total, 99.56.	
Beekmantown dolomite	

Coarsely granular Lenoir limestones, such as shown in the above section (beds 2 and 3), were not observed at any other locality in Rockingham County. However, rocks of similar texture and in approximately the same stratigraphic position are important reserves of high-

calcium limestone in the vicinity of Staunton (Pl. 12, loc. 126) and in a small area (Pl. 13, locs. 145 and 146) southeast of Mint Spring, Augusta County. Near Mint Spring a few feet of cherty limestone separates the compact, dove-gray limestone from the coarsely granular beds. Approximately half a mile northwest of Zenda and 2 miles south of Lacey Spring (Pl. 9, loc. 98), the Beekmantown formation is overlain by 28 feet of impure light-gray limestone, followed by 132 feet of dove-gray compact limestone. This belt of high-calcium limestone continues southwestward to Cedar Grove Church (Pl. 9, loc. 99).

Geologic Section 58.—At Cedar Grove Church about 2 miles east of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone (181 feet): strike N. 30° E.; dip 20° NW.	
4. Limestone, dove-gray, compact, thick bedded; lower part contains calcite veins; SiO_2, 0.40; Fe_2O_3, 0.08; Al_2O_3, 0.34; $CaCO_3$, 98.17; $MgCO_3$, 0.67; total, 99.66	113
3. Limestone, dove-gray, medium to thin bedded	30
2. Covered interval	38
Beekmantown formation (upper part)	
1. Limestone, slightly clayey, laminated	107

An analysis of a separate sample of unit 4 in the above section shows 0.019 per cent phosphorus pentoxide (P_2O_5).

In the vicinity of Cedar Grove Church the upper part of the Beekmantown contains a large proportion of limestone, as contrasted with the western belts of the same formation which are largely dolomite. Butts[7] has pointed out that these occurrences of high-calcium limestone make uncertain the boundary between the Mosheim and Beekmantown. The high-calcium Mosheim limestone northeast of Cedar Grove Church is estimated to have a thickness of about 125 feet. It is also well displayed from Cedar Grove Church southwestward to U. S. Highway 33, where the high-calcium limestone belt is offset about 1½ miles to the northwest by a diagonal fault. The belt, although largely covered, continues southwestward, passing through the eastern environs of Harrisonburg and about one-fourth of a mile west of Rockingham. The only complete exposure of the rocks between the Beekmantown and Athens observed in this area (Pl. 9, loc. 101) is given in the following section.

Geologic Section 59.—About 2 miles southwest of Harrisonburg and just east of the Chesapeake Western Railway, Rockingham County, Virginia

	Thickness Feet
Whitesburg limestone	
4. Limestone, gray, coarse grained; rusty weathering	10
Lenoir limestone (51 feet)	
3. Limestone, black, fine grained	12
2. Limestone, dark-gray, fine grained, cherty; contains irregular pinkish partings	39
Mosheim limestone: strike N. 30° E.; dip 30° NW.	
1. Limestone, dove-gray, compact; thick bedded near base	78
Beekmantown formation	

Paulington-Penn Laird belt.—The Paulington-Penn Laird high-calcium limestone belt extends from Endless Caverns southwestward to North River, passing near Paulington, Massanutten Caverns, Penn Laird, and Cross Keys. Bedrock is largely covered north of U. S. Highway 33 by detrital materials washed down from the steep slopes of Massanutten Mountain. The most northeasterly exposure (Pl. 9, loc. 103) measured along this belt is near the site of a small abandoned quarry and lime kiln, about 4 miles east of Lacey Spring.

Geologic Section 60.—Half a mile east of Road 620 and 4 miles east of Lacey Spring, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, granular, cherty	142
Mosheim limestone (82 feet): strike N. 25° E.; dip 70° SE.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.36; Fe_2O_3, 0.04; Al_2O_3, 0.72; $CaCO_3$, 97.24; $MgCO_3$, 1.05; total, 99.41	72
1. Limestone, dove-gray, compact; a few impure beds	10
Beekmantown dolomite	

Near Paulington (Pl. 9, loc. 104), about 6 miles southwest along the strike from the above locality and 5 miles northeast of Keezletown,

the Mosheim limestone is 80 feet thick. The rocks were not sampled at this locality since the prevalence of clayey partings, particularly toward the base, would probably make them unsuitable for use as high-calcium limestone. About 90 feet of apparently good quality limestone crops out along the northwest slope of a small hill at the entrance of Massanutten Caverns (Pl. 9, loc. 105), three-fourths of a mile east of Keezletown. Measurements at intervals of 3 to 5 miles, along the strike between Massanutten and Endless caverns, indicate that the Mosheim limestone in this part of the belt has an average thickness of about 80 feet. The general character of the Mosheim and Lenoir along U. S. Highway 33, about 2 miles southwest of Massanutten Caverns (Pl. 9, loc. 106), is as follows:

Geologic Section 61.—Along U. S. Highway 33 about 5 miles southeast of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Mosheim and Lenoir limestones (143± feet): strike N. 35° E.; dip 80° SE.	
6. Limestone, dark-gray, granular: pink streaks along irregular bedding surfaces	15
5. Limestone, dove-gray, compact	27
4. Limestone, dark-gray, medium bedded	23
3. Limestone, dove-gray, compact, thick bedded	57
2. Limestone, dark-gray, fine grained; reddish streaks along irregular bedding surfaces; sparsely cherty	7
1. Limestone, dove-gray, compact; lower boundary uncertain	14±
Beekmantown dolomite	

In the above section rocks of Lenoir and Mosheim types appear to be interbedded, hence without more detailed field studies it is impossible to separate the formations. Intercalations of compact, dove-gray limestone in granular dark-gray limestone are not common, but they have been noted at a few other localities in the northern part of Shenandoah Valley.

Southwest of U. S. Highway 33, along Road 620, are several complete exposures of high-calcium limestone. The thickest occurrence of the Mosheim noted along this part of the belt (Pl. 9, loc. 107) is given in the following section.

Geologic Section 62.—Along Road 620 about 1½ miles southwest of U. S. Highway 33, Rockingham County, Virginia

	Thickness Feet
Mosheim limestone: strike N. 50° E.; dip 60° SE.	
2. Limestone, dove-gray, compact, thick bedded; a few intercalated dark-gray beds; partly covered; SiO_2, 0.36; Fe_2O_3, 0.08; Al_2O_3, 0.74; $CaCO_3$, 97.74; $MgCO_3$, 1.23; total, 100.15	175±
Beekmantown dolomite (upper part)	
1. Dolomite, gray, fine grained	50+

About one-fourth of a mile northeast of Cross Keys (Pl. 9, loc. 108), less than 2 miles southwest along the strike, the Mosheim has apparently thinned to about 50 to 60 feet. It should be noted also that a similar thinning occurs along the strike of the same beds in a northeasterly direction (Pl. 9, loc. 106). The character and thickness of the rocks near the southwestern end of the belt (Pl. 9, loc. 109) are as follows:

Geologic Section 63.—Three-tenths of a mile northwest of Road 620 and 3½ miles southwest of Cross Keys, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone	
4. Limestone, dark-gray, granular, cherty	109
Mosheim limestone (82 feet): strike N. 63° E.; dip vertical	
3. Limestone, dove-gray, compact, thick bedded	29
2. Limestone, gray, slightly nodular, thin bedded	6
1. Limestone, dove-gray, compact, medium bedded	47
Beekmantown dolomite	

IMPURE LIMESTONE

Formations composed largely of impure limestones in central Rockingham County include the Lenoir limestone at most localities, the Whitesburg in the western and southwestern parts of the area,

and the full thickness of the Athens and Chambersburg. The Chepultepec is also composed of about 300 to 500 feet of bluish-gray, slightly banded impure limestone in adjoining counties on the northeast and southwest, but in central Rockingham County it was not measured or sampled.

The Lenoir, immediately overlying the Mosheim high-calcium limestone, is commonly a dark-gray, granular, cherty, impure limestone with a thickness from about 40 to 150 feet in central Rockingham County. Exceptions to the general impure character of the formation have been given under the discussion of high-calcium limestone (Pl. 9, locs. 90, 91, and 97). The overlying Whitesburg is present along the Honeyville-Dayton belt, in the vicinity of Linville, and in the general area southwest of Harrisonburg. In these areas it consists of dark-gray, rusty weathering, impure limestone that ranges from about 10 to 30 feet in thickness. The general character of the Lenoir and Whitesburg limestones near the northeastern end of the Honeyville-Dayton belt (Pl. 9, locs. 80 and 82) and in the vicinity of Harrisonburg (Pl. 9, loc. 101) is as follows:

Geologic Section 64.—Along State Highway 259 about 1 mile northwest of Broadway, Rockingham County, Virginia

	Thickness Feet
Whitesburg limestone	
3. Limestone, dark-gray, medium grained, rusty weathering	20
Lenoir limestone (157 feet)	
2. Limestone, dark-gray, granular, cherty	75
1. Covered interval; black chert float	82
Mosheim limestone	

Geologic Section 65.—Three-tenths of a mile northwest of the intersection of Roads 782 and 617 about 3½ miles northwest of Linville, Rockingham County, Virginia

	Thickness Feet
Whitesburg limestone	
3. Limestone, dark-gray, coarse grained, rusty weathering	30

	Thickness Feet
Lenoir limestone (95 feet)	
2. Limestone, dark-gray, medium grained; irregular pinkish partings, cherty	67
1. Limestone, dark-gray, fine grained, even bedded	28
Mosheim limestone	

Geologic Section 66.—About 2 miles southwest of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Whitesburg limestone	
3. Limestone, gray, coarse grained, rusty weathering	10
Lenoir limestone (51 feet)	
2. Limestone, black, fine grained	12
1. Limestone, dark-gray, fine grained, cherty; contains irregular pinkish partings	39
Mosheim limestone	

Several exposures along the Zenda-Rockingham belt north of Harrisonburg and along the Paulington-Penn Laird belt show that the thickness of the cherty Lenoir limestone ranges from about 65 to 140 feet.

The beds between the Whitesburg limestone and Martinsburg shale, or between the Lenoir and Martinsburg in areas where the Whitesburg is absent, are composed chiefly of calcareous black shale and shaly black limestone with thin intercalations of siltstones. Although these rocks are mapped as a single unit in this report, they have been identified and mapped separately by Butts[4] as the Athens formation along the eastern belt southwest of Paulington, and as the Athens overlain by a relatively thin body of Chambersburg in the western belts. Field studies indicate that shale predominates in the belt along the Massanutten Mountain syncline, whereas the western belts are composed chiefly of densely black limestone with minor shale partings. Estimated thicknesses of the Athens-Chambersburg in Rockingham County range from about 850 to 1350 feet. The calcium carbonate content ranges from a low of about 60 per cent for the shaly units to a high of about 90

per cent for the limy units. A representative section showing the general character of the Athens and Chambersburg formations along the Zenda-Rockingham high-calcium limestone belt (Pl. 9, loc. 111) is as follows:

Geologic Section 67.—About 2 miles southwest of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Chambersburg limestone (65+ feet)	
12. Limestone, shaly	25+
11. Limestone, blocky, shaly; contains diagnostic fossils; lower boundary uncertain	40
Athens formation (1281± feet)	
10. Limestone, black, fine grained	150
9. Limestone, black, thin bedded, slabby weathering	324
8. Limestone, black, medium bedded	170
7. Covered interval; along U. S. Highway 11	12
6. Limestone, black; partly covered	300
5. Limestone and shale, black	287
4. Shale, black; weathers pink; contains limonite on weathered surfaces	38
Whitesburg limestone	
3. Limestone, gray, coarse grained, rusty weathering	10±
Lenoir limestone (51 feet)	
2. Limestone, dark-gray, fine grained	12
1. Limestone, dark-gray, fine grained, cherty; contains irregular pinkish partings	39
Mosheim limestone	

The rocks in the above section were not analyzed, but along the strike (Pl. 9, loc. 110) about 2½ miles north of Harrisonburg, 375 feet of dense black Athens type limestone contains 89.96 per cent calcium carbonate and 3.83 per cent magnesium carbonate, a total of 93.79 per cent carbonates. Another complete exposure of the Chambersburg and the upper part of the Athens is in the Burke quarry along State Highway 33 in the western environs of Harrisonburg. This quarry, operated by the State Department of Highways, is a large producer of crushed stone. A description of

the rocks between the Lenoir and the Martinsburg east of Harrisonburg (Pl. 9, loc. 106) is given in the following section.

Geologic Section 68.—Along U. S. Highway 33 about 5 miles southeast of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Athens formation (833+ feet)	
7. Shale and slabby limestone; partly covered; upper boundary uncertain	150+
6. Limestone, black, nodular weathering; partings of black shale	100
5. Siltstone, dark-gray, sandy	4
4. Shale, black; intercalated limy beds	70
3. Mostly covered; exposures of black shale and shaly black limestone	165
2. Limestone, black, medium bedded	134
1. Mostly covered; exposures of shale and shaly limestone	210
Lenoir limestone	

Analyses cited by Bassler,[1] showing the range in chemical composition of certain impure limestones and calcareous shales in the vicinity of Harrisonburg, are given in Table 10.

TABLE 10.—*Analyses of limestone and shale in the vicinity of Harrisonburg, Rockingham County, Virginia*

(J. H. Gibboney, Analyst)

	1	2	3	4	5	6
Insoluble	4.60	8.68	30.72	12.82	23.24	30.56
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	0.56	0.94	3.52	1.84	3.22	3.82
Calcium carbonate ($CaCO_3$)	92.00	90.36	62.78	81.07	71.07	61.07
Magnesium carbonate ($MgCO_3$)	2.79	0.41	0.71	2.52	1.72	3.44
Total	99.95	100.39	97.73	98.25	99.25	98.89

1, 2. Dark-blue, compact limestone, along the railroad track near the Southern Railway station, Harrisonburg.
3, 4. Semicrystalline limestone, western edge of Harrisonburg.
5. Argillaceous limestone, just west of Southern Railway station, Harrisonburg.
6. Calcareous shales, along street west of Southern Railway station, Harrisonburg.

HIGH-MAGNESIUM DOLOMITE

Deposits of intensely brecciated high-magnesium dolomite were noted at several localities, near the trace of the North Mountain fault, along a narrow belt extending at least from a point about 2 miles northeast of Cootes Store southwestward to the general vicinity of Singers Glen, a distance of about 8 miles. Except for a small exposure along Road 731 about 1½ miles northwest of Ottobine, brecciated dolomite was not identified farther southwestward along any of the roads which cross the area. The zones of brecciated, mealy weathering dolomite, 80 feet or more thick, at localities 217 and 218, occur in the upper part of the Elbrook formation and are closely overlain by sandstones in the Conococheague.

The Mundy quarry which produces high-magnesium dolomite for agricultural use is located (Pl. 9, loc. 217) about one-fourth of a mile east of Road 613 and 1½ miles northeast of Cootes Store. It is about 300 feet long, 200 feet wide, and 20 to 30 feet deep at the northeastern end. The rocks exposed in the quarry are light- and dark-gray, mealy weathering, brecciated Elbrook dolomite. Some of this dolomite can be handled with a power shovel without blasting. A composite sample representing about 80 feet of beds exposed in the quarry contains 43.12 per cent magnesium carbonate, 55.36 per cent calcium carbonate, and 1.56 per cent silica. Additional analyses of smaller units exposed in the quarry are given in Table 11.

At locality 218, about 4 miles southwest of the Mundy quarry and one-fourth of a mile west of Road 613, brecciated Elbrook dolomite is well exposed in a small area estimated to be 300 feet long and 200 feet wide. A composite sample of about 80 feet of beds at this locality contains 43.81 per cent magnesium carbonate, 54.56 per cent calcium carbonate, and 1.56 per cent silica. Partial exposures of the same type of brecciated dolomite southwest of locality 218 were noted along Road 776 (Pl. 9, loc. 219) and Road 783 (Pl. 9, loc. 220). Farther southwest about 75 feet of dolomite in the upper third of the Elbrook formation crops out along Road 763 about 2½ miles north of Mount Clinton (Pl. 9, loc. 221). The rocks at this locality, although fractured, are very hard and dense on weathered exposures. One analysis of the full thickness of the rocks exposed at this locality shows 41.66 per cent magnesium carbonate, 53.36 per cent calcium carbonate, and 4.72 per cent silica.

Although the rocks along the western side of the valley in Rockingham County have not been studied in detail, it is thought that zones of brecciated dolomite in the Elbrook formation locally contain commercial deposits of high-magnesium dolomite. Additional field investigation and testing are recommended in this area.

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

Carbonate rocks composed largely of varying proportions of interbedded limestone, magnesian limestone, and dolomite in central Rockingham County include the Conococheague and Beekmantown formations and most of the Elbrook. On the geologic map (Pl. 9) a narrow band of Chepultepec limestone is shown between the Beekmantown and Conococheague. The principal belts of Cambrian and Ordovician limestones and dolomites are along the eastern side of the valley west of Massanutten Mountain, in the middle part of the valley north of Harrisonburg, and west of Broadway and Dayton (Pl. 9). The rocks below the Beekmantown formation, except for local occurrences of high-magnesium dolomite in the Elbrook, were not measured or sampled in this area, since a preliminary field examination of several partial exposures indicates that they are composed largely of impure limestone and dolomite.

The character of the rocks, from the lower part of the Beekmantown upward to the Mosheim, along the west side of the Honeyville-Dayton belt west of Broadway (Pl. 9, loc. 114), is as follows:

Geologic Section 69.—Along State Highway 259 about 1 mile northwest of Broadway, Rockingham County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 1592+ feet)	
20. Impure dolomite with interbedded compact straticulate limestone; a few brecciated beds; shaly at base	32
19. Mostly covered; a few beds of fine-grained, medium-gray dolomite near top	45
18. Covered interval	61
17. Dolomite, medium-gray, fine grained	48
16. Covered interval	156
15. Dolomite, medium-gray, medium grained	11

		Thickness Feet
14.	Dolomite, light-gray, straticulate	8
13.	Dolomite, dark bluish-gray, medium bedded, fine grained	40
12.	Dolomite, light-gray to buff, laminated	15
11.	Dolomite, dark-gray, fine grained; contains carbonate veins	55
10.	Dolomite, medium-gray, medium grained	35
9.	Limestone, dark-gray, magnesian	15
8.	Dolomite, light-gray, fine grained	139
7.	Dolomite, light-gray, medium grained	21
6.	Limestone, dove-gray	17
5.	Dolomite, light-gray, fine grained	12
4.	Covered interval; chert float	399
3.	Dolomite, medium-gray, fine grained, cherty	17
2.	Conglomerate; dolomite and chert pebbles; partly covered	18
1.	Scattered exposures of fine- to medium-grained, light- and dark-gray dolomite; covered at the base	448+

This section is of special interest since it is composed almost entirely of dolomite, whereas in all of the eastern belts the Beekmantown contains conspicuous layers of limestone. Composition intermediate between the eastern and western belts is well shown by the upper part of the Beekmantown southwest of Linville (Pl. 9, loc. 92).

Geologic Section 70.—Along and north of Road 765 about 1½ miles southwest of Linville, Rockingham County, Virginia

		Thickness Feet
Beekmantown formation (upper part, 522 feet)		
13.	Dolomite, gray; contains thin intercalations of light-gray limestone	40
12.	Dolomite, pearl-gray, granular	60
11.	Dolomite, gray	38
10.	Dolomite and mottled light- and dark-gray limestone	26
9.	Dolomite, gray	17
8.	Limestone, light-gray, fine grained	20
7.	Dolomite, gray, fine grained	48

	Thickness Feet
6. Limestone, light-gray, thin bedded	47
5. Dolomite, medium-gray, fine grained	80
4. Limestone and dolomite, mottled light- and dark-gray	16
3. Limestone, gray, compact	4
2. Limestone and dolomite; limestone laminated	36
1. Dolomite, pearl-gray, fine grained; covered at base	90+

In the vicinity of Cedar Grove Church (Pl. 9, loc. 99) where the following section is displayed, the upper part of the Beekmantown is predominantly limestone, some units containing more than 90 per cent calcium carbonate.

Geologic Section 71.—Southeast of Cedar Grove Church about 2 miles east of Harrisonburg, Rockingham County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 372 feet)	
13. Limestone, laminated, slightly impure	107
12. Dolomite and magnesian limestone	7
11. Dolomite, gray, fine grained	1
10. Limestone; thin clayey bands	24
9. Dolomite, gray, fine grained	5
8. Limestone; partly covered	38
7. Dolomite, gray, fine grained	13
6. Limestone, bluish-gray	3
5. Dolomite, medium-gray, fine grained	32
4. Limestone, magnesian, medium-gray	72
3. Limestone, medium bedded	20
2. Limestone, platy	3
1. Limestone, dove-gray, compact; covered at base	47

The upper part of the Beekmantown maintains the same general character as shown in the above section near Cedar Grove Church southwestward to the vicinity of U. S. Highway 33. The Betts quarry (Pl. 9, loc. 100), producing crushed stone and ground limestone for agricultural use, is located along this belt of limestone and dolomite, a short distance north of U. S. Highway 33 and about 1 mile southeast of Harrisonburg.

Dolomite in the lower part of the Beekmantown is well displayed in vertical cliffs above Road 693 and North River about 2 miles southeast of Mount Crawford (Pl. 9, loc. 222). A composite sample of about 230 feet of beds, exclusive of several cherty horizons, at this locality contains 40.16 per cent magnesium carbonate, 52.56 per cent calcium carbonate, and 7.16 per cent silica (Table 11). Approximately 80 feet of Beekmantown dolomite, closely overlying the beds sampled at the above locality, is exposed in the Kaylor quarry (Pl. 9, loc. 223), located along Road 693 about 1½ miles southeast of Mount Crawford. Other small inactive quarries in the Beekmantown are near Rockingham (Pl. 9, loc. 102), Bridgewater (Pl. 9, loc. 112), and about 2 miles west of Dayton (Pl. 9, loc. 113).

The Beekmantown formation is poorly exposed along the Paulington-Penn Laird belt southwest of Endless Caverns.

TABLE 11.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of central Rockingham County, Virginia (Pl. 9)*

(Froehling & Robertson, Inc., Analysts)

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
79	44	7–10	Mosheim	157	94.00	2.82	2.44	0.24	0.78	100.28	Along Road 793 about 1½ miles northwest of Timberville.
82	46	2	Mosheim	36	96.96	1.21	1.20	0.08	0.40	99.85	Near intersection of Roads 782 and 617 about 3½ miles northwest of Linville.
84	48	2	Mosheim	75	97.96	0.89	0.32	0.08	0.46	99.71	About 200 yards north of Road 763 and 1½ miles northwest of Harrisonburg.
		1		167±	96.14	1.20	0.96	0.20	1.00	99.50	
85	49	2	Mosheim	108	97.55	0.83	0.26	0.08	0.78	99.50	Along Shenandoah-Rockingham County line, 3 miles northeast of Timberville.
87	50	2	Mosheim	117	98.66	0.97	0.26	0.08	0.40	100.37	Half a mile southwest of the intersection of Roads 809 and 803 about 3 miles south of Broadway.
88	51	7	Mosheim	136	98.35	0.76	0.18	0.08	0.50	99.87	Between Road 803 and Southern Railway, 2 miles southwest of Daphna.

90	53	1–3	Lenoir	46	96.96	0.89	0.40	0.32	0.88	99.45	Southwestern end of quarry of Southern Lime and Stone Works at Linville.
91	54	3–7	Lenoir	37	94.34	1.33	2.52	0.80	0.98	99.97	About two-tenths of a mile west of Road 753, half a mile southwest of Linville.
		2	Mosheim	91	98.57	0.62	0.10	0.08	0.34	99.71	
		1		48	95.83	0.77	1.94	0.12	0.60	99.26	
92	55	2	Mosheim	115	98.76	0.74	0.22	0.08	0.58	100.38	Along and north of Road 765 about 1½ miles southwest of Linville.
		1		56	95.73	1.17	1.24	0.04	1.08	99.26	
95			Mosheim	75	95.90	2.76	0.24	0.08	0.56	99.54	Along northwest slope of ridge, 1½ miles southwest of Lacey Spring.
97	57	1–3	Mosheim and Lenoir	220	97.96	0.80	0.20	0.04	0.56	99.56	Along State Highway 259 about 2½ miles northeast of Lacey Spring.
99	58	4	Mosheim	113	98.17	0.67	0.40	0.08	0.34	99.66	Just southeast of Cedar Grove Church, 2 miles east of Harrisonburg.
103	60	2	Mosheim	72	97.24	1.05	0.36	0.04	0.72	99.41	Half a mile east of Road 620 about 4 miles east of Lacey Spring.
107	62	2	Mosheim	175±	97.74	1.23	0.36	0.08	0.74	100.15	Along Road 620 about 1½ miles southwest of U. S. Highway 33.

TABLE 11.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of central Rockingham County, Virginia (Pl. 9)—Continued*

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
110			Athens	375	89.96	3.83	5.20	0.16	0.72	99.87	About half a mile west of intersection of Road 767 and State Highway 260 about 2½ miles northwest of Harrisonburg.
217			Elbrook	80±	55.36	43.12	1.56	0.12	0.32	100.48	Mundy quarry about one-fourth of a mile east of Road 613 and 1½ miles northeast of Cootes Store.
				3	55.36	43.88	0.68	0.16	0.48	100.56	
				4	52.96	41.05	5.28	0.44	0.40	100.13	
218			Elbrook	80±	54.56	43.81	1.56	0.08	0.40	100.41	About one-fourth of a mile west of Road 613 and 3 miles southwest of Cootes Store.
221			Elbrook	75±	53.36	41.66	4.72	0.40	0.32	100.46	Along Road 763 about 2½ miles north of Mount Clinton.
222			Beekmantown	230	52.56	40.16	7.16	0.52	0.40	100.80	Along Road 693 about 2 miles southeast of Mount Crawford.

CENTRAL AUGUSTA COUNTY

GENERAL STATEMENT

Augusta County (Fig. 1), with an area of 1006 square miles, is bounded on the northeast by Rockingham County, on the southeast by Nelson and Albemarle counties, on the southwest by Rockbridge County, and on the northwest by Bath and Highland counties and the West Virginia line. That part of the county, extending from the Blue Ridge northwestward to Little North Mountain, represents the full width of Shenandoah Valley. Central Augusta County as herein discussed includes that part of the county lying between the North Mountain fault on the west and the broad belt of Martinsburg shales in the Massanutten Mountain syncline (Pl. 12) on the east. Staunton, the county seat, is located in the east central part of the county near the belt of Martinsburg shale.

Altitudes range from about 1100 feet along North River at the Augusta-Rockingham County line to approximately 2000 feet between Mint Spring and Little North Mountain. The characteristic land forms in the areas underlain by carbonate rocks are short elongate hills and low ridges which trend northeastward, conforming to the strike of the underlying bedrock. Conspicuous rounded hills, rising from 100 to 400 feet above the surrounding valleys, are also prominent in areas of limestone containing abundant chert.

Central Augusta County is crossed from east to west by the main line of the Chesapeake and Ohio Railway and the valley area north of Staunton is served by the Chesapeake Western Railway.

GEOLOGY

The carbonate rocks in the Shenandoah Valley portion of central Augusta County comprise high-calcium limestone; impure limestone; and interbedded limestone, magnesian limestone, and dolomite. The formations and their character are given in Table 12. High-calcium limestones occur in the Mosheim and locally parts of the overlying Lenoir. The formations mapped as impure limestone include the Chepultepec, most of the Lenoir, and the Whitesburg, Athens, and Chambersburg. The other formations shown in Table 12 are composed chiefly of varying proportions of interbedded limestone, magnesian limestone, and dolomite. A few of the sampled dolomite units contain a maximum of about 40 per cent magnesium carbonate.

The major structures along a line extending northwest from Staunton are shown on Plate 12. The largest structure in Augusta

TABLE 12.—*Summary of carbonate rocks in the Shenandoah Valley portion of central Augusta County, Virginia*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Chambersburg, Athens, and Whitesburg	Chambersburg, in western belts, chiefly black, nodular or platy weathering impure limestone; Athens, chiefly limy black shale and impure black limestone with intercalations of pinkish weathering shale. About 15 feet of dark-gray, granular, rusty weathering Whitesburg limestone observed locally northeast of Staunton.	600–1000[a]
Lenoir	Largely granular, cherty, dark-gray limestone with local occurrences of intercalated coarsely granular, light-gray beds. Sampled units of coarsely granular beds contain about 96 to 98 per cent calcium carbonate.	60–200
Mosheim	Compact, dove-gray limestone; commonly slightly impure near base. Sampled units generally contain about 96 to 97.5 per cent calcium carbonate.	0–135
Beekmantown	Largely fine-grained, light-gray dolomite with a few conspicuous layers of bluish-gray limestone, mainly in the lower part. Several horizons yield large masses of spongy-looking gray chert. Sampled units of dolomite contain from about 30 to 40 per cent magnesium carbonate.	1500–2000
Chepultepec	Dark bluish-gray limestone with thin beds of gray dolomite; sparsely cherty. Sampled units contain about 87 per cent calcium carbonate.	400–500
Conococheague	About equal amounts of bluish-gray limestone and dark-gray dolomite; abundant thin wavy siliceous partings and thin sandstone layers.	2000–2500
Elbrook	Chiefly shaly weathering dolomite and limestone; contains zones of dolomite averaging about 40 per cent magnesium carbonate.	2000[a]

[a] Estimated.

County is the Massanutten Mountain syncline, along the sides of which occur large deposits of high-calcium limestone. The southwestern end of the belt of the Martinsburg shale in the syncline terminates about 2 miles northeast of Greenville.

A normal succession of Beekmantown, Chepultepec, Conococheague, and a part of the Elbrook formation lies between the belt of high-calcium limestone along the western edge of the Martinsburg shale in

the Massanutten Mountain syncline and the next major structure on the west, the Staunton fault (Pl. 12). The Staunton fault enters Augusta County about 2 miles west of Spottswood and continues northeastward to the vicinity of Endless Caverns, Rockingham County. West of Verona the trace of the fault swings abruptly southwestward to a point about one mile east of Galena and thence continues northeastward, passing near Long Glade and Burketown. From Verona southwestward to Rockbridge County the Elbrook is thrust upon Beekmantown along the Staunton fault. Northeast of Verona, the Elbrook is in contact with the Athens formation. In a small area northwest of Burketown a detached segment of the overthrust block (klippe), consisting of Beekmantown, Chepultepec, and Conococheague, rests unconformably upon the Athens.

The northeastern end of a small anticline in Elbrook limestone and dolomite is exposed along U. S. Highway 250 between the Staunton fault, in the northwest environs of Staunton, and Galena. The next major structure to the west of the Staunton fault and north of Staunton is the Long Glade syncline. The western limb of this structure contains a belt of high-calcium limestone which extends from the Rockingham County line southwestward about 2 miles beyond Galena. Here the limestones wrap around the end of the fold and continue northeastward for about 5 miles to the Staunton overthrust.

The broad belts of Cambrian and Ordovician limestones and dolomites west of the Long Glade syncline are bounded on the northwest side by the North Mountain fault. Local occurrences of carbonate rocks along this overthrust south of Stribling Springs and Swoope were not included in the study on which this report is based.

HIGH-CALCIUM LIMESTONE

High-calcium limestone in central Augusta County is confined mainly to the Mosheim and locally a part of the Lenoir. These formations crop out in narrow bands on the flanks of the Long Glade syncline and on the western limb of the Massanutten Mountain syncline.

Mount Solon-Churchville belt.—The Mount Solon-Churchville belt of high-calcium limestone extends from Rockingham County southwestward to the general latitude of Staunton, passing about 2 miles east of Mount Solon, Parnassus, and Churchville. The thickness and chemical composition of the Mosheim near the northeastern end of the belt (Pl. 12, loc. 115) are as follows:

Geologic Section 72.—At the intersection of Roads 613 and 754 about 3 miles southeast of Mount Solon, Augusta County, Virginia

	Thickness Feet
Mosheim limestone (137 feet): strike N. 23° E.; dip 30° SE.	
2. Limestone, dove-gray, compact	57
1. Limestone, dove-gray, compact, irregularly bedded; a few thin impure beds	80
Analysis of units 1 and 2, sampled thickness 137 feet: SiO_2, 1.86; Fe_2O_3, 0.08; Al_2O_3, 0.40; $CaCO_3$, 96.96; $MgCO_3$, 0.98; total, 100.28.	
Beekmantown formation	

Although present the thickness of the Lenoir was not determined at the above locality, but along the belt to the southwest (Pl. 12, loc. 116) the formation is estimated to be 100 feet. Between locality 116 and Middle River the Mosheim limestone appears to thin to about 50 feet. The general character of the Mosheim and the upper part of the Beekmantown along the northwest slope of a low ridge in the vicinity of an abandoned quarry along Middle River (Pl. 12, loc. 117) is given in the following section.

Geologic Section 73.—About 500 feet north of Road 728 and 3 miles east of Churchville, Augusta County, Virginia

	Thickness Feet
Mosheim limestone: strike N. 35° E.; dip 20° SE.	
2. Limestone, dove-gray, compact; SiO_2, 1.53; Fe_2O_3, 0.16; Al_2O_3, 0.91; $CaCO_3$, 95.74; $MgCO_3$, 1.14; total, 99.48	50
Beekmantown formation (upper part)	
1. Dolomite, light-gray, fine grained	150

The upper part of the Beekmantown dolomite and the lower beds of the Mosheim are well exposed in an abandoned quarry along Road 728 about 500 feet southwest of the above section. The northwest side of the quarry contains numerous masses of coarsely crystalline white calcite ranging in thickness from a few inches to several feet. Another small abandoned quarry in the Mosheim is located along Middle

River near the intersection of Roads 732 and 728. Here the thickness of the Mosheim is about 50 feet. Deposits of high-calcium limestone in the vicinity of Middle River and near the northeastern end of the belt are remote from rail transportation. South of Middle River the limestone belt is largely covered.

Galena belt.—The Galena high-calcium limestone belt is a part of the eastern limb of the Long Glade syncline. It extends from the Staunton fault, about 4 miles north of Staunton, southwestward across U. S. Highway 250 to a point 1½ miles north of Snyder where it connects with the Mount Solon-Churchville belt. The Galena belt is poorly exposed, except at the junction of U. S. Highway 250 and State Highway 56 (Pl. 12, loc. 118) where the following section was measured.

Geologic Section 74.—Along U. S. Highway 250 about 4 miles northwest of Staunton, Augusta County, Virginia

	Thickness Feet
Mosheim limestone: strike N. 21° E.; dip 60° NW.	
3. Limestone, dove-gray, compact; a few clay partings	44
Beekmantown formation (upper part, 303 feet)	
2. Dolomitic mudrock, reddish; contains dolomite and chert fragments	3
1. Dolomite, light-gray, fine grained; contains spongy chert	300

The thin reddish dolomitic mudrock (unit 2) in the above section is overlain by dove-gray, slightly impure Mosheim limestone, cherty Lenoir limestone, and a thick body of shaly Athens limestone. Coarse-grained high-calcium limestones which are well displayed east and south of Staunton were not observed in the Galena or Mount Solon-Churchville belts.

A small elongate body of Beekmantown dolomite, surrounded by Mosheim and Lenoir limestones, crops out along the crest of a minor anticline about one mile south of Long Glade (Pl. 12, loc. 119). Studies along the eastern side of the structure indicate that the Mosheim is too thin here for any large-scale commercial development.

Verona-Mint Spring belt.—The Verona-Mint Spring limestone belt extends from North River along the Rockingham-Augusta County line southwestward nearly to Greenville, paralleling U. S. Highway 11 and passing near Verona, Staunton, and Mint Spring. This belt of high-

calcium limestone in central Augusta County crops out along the west side of the Athens in the Massanutten Mountain syncline. Of special interest are the elongate hills or ridges, 20 to 100 feet in height, which mark the outcrop of the cherty Lenoir limestone. Measurements at three localities (Pl. 12, locs. 120, 121, and 122) northeast of Verona show from 30 to 40 feet of typical Mosheim and 60 to 100 feet of Lenoir. Detailed descriptions of the limestones which are fully exposed in the vicinity of Verona (Pl. 12, loc. 123) are as follows:

Geologic Section 75.—Bowling quarry along Middle River half a mile northeast of Verona, Augusta County, Virginia

	Thickness Feet
Mosheim limestone: strike N. 38° E.; dip 60° SE.	
3. Limestone, dove-gray, compact; cherty near top; SiO_2, 2.36; Fe_2O_3, 0.50; Al_2O_3, 0.84; $CaCO_3$, 92.61; $MgCO_3$, 3.79; total, 100.10	63
Beekmantown formation (upper part, 196 feet)	
2. Limestone, dark-gray to black, compact; SiO_2, 15.59; Fe_2O_3, 0.92; Al_2O_3, 4.31; $CaCO_3$, 69.51; $MgCO_3$, 9.63; total, 99.96	46
1. Dolomite, gray, fine-grained, cherty; SiO_2, 2.34; Fe_2O_3, 0.26; Al_2O_3, 1.14; $CaCO_3$, 57.80; $MgCO_3$, 38.16; total, 99.70	150

Fine-grained, gray Beekmantown dolomite in the western part of the quarry (Pl. 11B) is overlain by compact, almost black limestone of questionable correlation (unit 2). The general texture suggests Mosheim, but, since the sample shows only 69.51 per cent calcium carbonate, the beds are tentatively correlated as representing a local occurrence of magnesian limestone in the upper part of the Beekmantown. The overlying light-gray compact limestone (Unit 3) is also a deviation from the usual high-calcium content of the Mosheim, but this low analysis may be due to the inclusion of a part of the underlying magnesian limestone in the sample taken here. Less than 4 miles southwest along the strike, Beekmantown dolomite is overlain by about 50 feet of high-calcium Mosheim limestone (Pl. 12, loc. 124).

A complete exposure of the rocks from the top of the Beekmantown into the Athens occurs at locality 125, about one mile northeast of

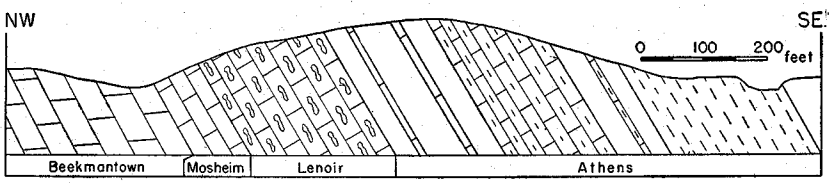


FIGURE 4.—Cross section of the Verona-Mint Spring high-calcium limestone belt, 1 mile northeast of Staunton, Augusta County, Va.

Staunton (Pl. 12). Here the Beekmantown-Mosheim boundary is along the northwest base of a low ridge; cherty Lenoir limestone near the summit; and Athens limestone and shale along the crest and southeast side (Fig. 4). Another thick occurrence of high-calcium limestone was observed in a small area along the Chesapeake Western Railway and its connecting spur to the brick yards in the eastern environs of Staunton (Pl. 12, loc. 126). The succession of beds here and their tentative correlation are as follows:

Geologic Section 76.—Along Chesapeake Western Railway and spur line in the eastern environs of Staunton, Augusta County, Virginia

	Thickness Feet
Lenoir limestone (140 feet)	
4. Limestone, dark-gray, medium grained, cherty	60
3. Limestone, light-gray, coarse grained; SiO_2, 0.28; Fe_2O_3, 0.20; Al_2O_3, 0.61; $CaCO_3$, 98.00; $MgCO_3$, 0.83; total, 99.92	60±
2. Limestone, dark-gray, nodular	20±
Mosheim limestone: strike N. 80° W.; dip 45° SE.	
1. Limestone, dark-gray, compact; SiO_2, 0.71; Fe_2O_3, 0.10; Al_2O_3, 0.86; $CaCO_3$, 96.90; $MgCO_3$, 1.21; total, 99.78	84
Beekmantown formation	

The coarse-grained beds and overlying cherty limestones in the above section are fully exposed in an abandoned quarry and along the spur line to the brick yard, whereas the underlying Mosheim is displayed along the crest of a small anticline extending northeast of the power line and paralleling the Chesapeake Western Railway.

A part of the same limestone belt and the upper 150 feet of the underlying dolomite are exposed in the Belmont Trap Rock Company quarry (Pl. 12, loc. 127).

Geologic Section 77.—Belmont Trap Rock Company quarry half a mile southeast of Staunton, Augusta County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, medium grained, cherty	100
Mosheim limestone: strike N. 76° E.; dip 45° NW.	
2. Limestone, dove-gray, compact, fractured; SiO_2, 0.63; Fe_2O_3, 0.30; Al_2O_3, 0.39; $CaCO_3$, 97.55; $MgCO_3$, 1.05; total, 99.92	40
Beekmantown formation (upper part)	
1. Dolomite, gray, fine grained	150

Coarsely granular high-calcium limestone, so well displayed at locality 126, was not observed in the Belmont quarry. It is also of interest to note that in the quarry the Mosheim is only about 40 feet thick.

The Mosheim limestone and the upper part of the Beekmantown dolomite are exposed in the Whitmore quarry (Pl. 12, loc. 128) half a mile east of the Belmont quarry. Three measurements of the Mosheim in the Whitmore quarry, at intervals of about 200 feet along the strike, show thicknesses that vary from about 20 to 40 feet. The northeast side of the quarry and the adjacent low ridge are underlain by nodular, cherty, dark-gray limestone with a few thin interbedded layers of coarse-grained limestone. The Mosheim in this area and locally throughout Shenandoah Valley is characterized by variations in thickness, thus any generalizations regarding the possible quarriable thickness of this unit over a large area are subject to error.

The Staunton Lime Corporation quarry (Pl. 12, loc. 129) is located about two-fifths of a mile east of locality 128. It consists of a long narrow opening, along the outcrop of high-calcium limestone for about 600 feet, and a smaller opening in dolomite adjoining the limestone belt on the southeast side. Geologic Section 78 is near the middle of the quarry; 79 at the southwestern end.

Geologic Section 78.—Near middle of Staunton Lime Corporation quarry, 1½ miles east of Staunton, Augusta County, Virginia

	Thickness Feet
Mosheim limestone (56 feet): strike E.; dip 28° N.	
4. Limestone, dove-gray, compact	25
3. Limestone, dark-gray, nodular	6
2. Limestone, light-gray, medium grained; clastic texture; SiO_2, 0.44; Fe_2O_3, 0.14; Al_2O_3, 0.36; $CaCO_3$, 98.16; $MgCO_3$, 1.01; total, 100.11	25
Beekmantown formation (upper part)	
1. Dolomite, fine grained, gray; a few limestone beds	150

Bed 2 in the above section is composed of rounded grains of compact gray limestone in a matrix of colorless calcite. These rocks are tentatively correlated as an occurrence of clastic limestone in the lower part of the Mosheim, but it is possible that they may be older since there is a hiatus between the Beekmantown and Mosheim. The sequence and character of the rocks at the southwestern end of the quarry are as follows:

Geologic Section 79.—Near western end of Staunton Lime Corporation quarry, 1½ miles east of Staunton, Augusta County, Virginia

	Thickness Feet
Mosheim limestone: strike E.; dip 30° N.	
2. Limestone, dove-gray, compact; SiO_2, 0.88; Fe_2O_3, 0.30; Al_2O_3, 0.46; $CaCO_3$, 96.60; $MgCO_3$, 1.50; total, 99.74	41
Beekmantown formation (upper part)	
1. Dolomite, gray, fine grained; a few limestone beds	100

A comparison of the above section with Geologic Section 78, less than 300 feet east along the strike, is of special interest. In Geologic Section 79 the dolomite in the upper part of the Beekmantown is succeeded by 41 feet of typical Mosheim, with no intervening granular layers. The Mosheim in both sections is overlain by medium-grained, cherty, dark-gray Lenoir limestone. The total

thickness of high-calcium rock, including compact limestone at the western end and both coarse and compact beds near the middle of the Staunton Lime Corporation quarry, ranges from about 40 to 50 feet.

A large quarry, operated by the State Department of Agriculture for ground limestone, is located about 2 miles east of Staunton (Pl. 12, loc. 130). High-calcium limestone crops out along the northeastern rim of the quarry. The main operation is in the upper 150 feet of the Beekmantown dolomite. Fifty feet of Mosheim limestone could be quarried at the present site. A sample (Table 13) of pulverized Beekmantown dolomite and limestone from the storage bin shows 64.61 per cent calcium carbonate and 30.98 per cent magnesium carbonate, a total of 95.59 per cent carbonates. Limestones fully exposed along the northwest side of a low ridge on the DeJarnette State Sanatorium property (Pl. 12, loc. 131), about one mile southwest of the State Department of Agriculture quarry, are as follows:

Geologic Section 80.—DeJarnette State Sanatorium property about 2 miles southeast of Staunton, Augusta County, Virginia

	Thickness Feet
Lenoir limestone (180 feet): strike N. 30° E.; dip 40° SE.	
6. Limestone, dark-gray, cherty	50
5. Limestone, dark-gray, medium-grained	50
4. Limestone, dark-gray, cherty	25
3. Limestone, bluish-gray, fine grained, cobbly	10
2. Limestone, gray, medium grained; SiO_2, 0.32; Fe_2O_3, 0.46; Al_2O_3, 0.13; $CaCO_3$, 98.16; $MgCO_3$, 0.76; total 99.83	45
Beekmantown formation (upper part)	
1. Dolomite, gray, fine grained, partly covered	400

The granular rock immediately overlying the Beekmantown in the above section (bed 2) is tentatively correlated as the lower part of the Lenoir, since compact limestone of typical Mosheim lithology is not represented. About 40 feet of Mosheim was observed at locality 132, one mile southwest of the DeJarnette State Sanatorium property. One of the best displays of the Mosheim in the Verona-Mint Spring belt is along the northwest slope of a prominent ridge about 4 miles southwest of Staunton (Pl. 12, loc. 133).

Geologic Section 81.—Near intersection of U. S. Highway 11 and Road 654 about 4 miles southwest of Staunton, Augusta County, Virginia

	Thickness Feet
Lenoir limestone	
2. Limestone, dark-gray, cherty	75±
Mosheim limestone	
1. Limestone, dove-gray, compact, sheared; bedding indistinct; SiO_2, 0.61; Fe_2O_3, 0.18; Al_2O_3, 0.57; $CaCO_3$, 97.55; $MgCO_3$, 0.91; total, 99.82	100±
Beekmantown formation	

Although pronounced shearing of the Mosheim has almost destroyed the bedding at the above locality, it is estimated that its thickness, based on the width of outcrop and probable structure of the adjacent beds, is about 100 feet. The belt of high-calcium limestone, between locality 133 and Road 624, swings around the end of a minor northeastward-pitching syncline, and continues in an easterly direction to locality 134 where about 30 feet of Mosheim is exposed in a small abandoned quarry. At this locality the Mosheim is characterized by a 4-foot bed of cherty limestone and irregular masses of pink limestone near the base. Some of the pinkish masses appear to fill cavities along prominent fractures. Overlying the compact limestone is about 25 feet of fine-grained, bluish-gray, cherty limestone; 18 feet of coarse-grained gray and pink limestone; and about 25 feet of finer grained, bluish-gray limestone. The Verona-Mint Spring limestone belt extends southwestward to a point about 3 miles southwest of Mint Spring. This belt was crossed at several places, but the exposures are inadequate for detailed measurements and study.

IMPURE LIMESTONE

Impure limestone, excluding those interbedded with dolomite which are discussed under a separate heading, include the Chepultepec, the Lenoir at most localities, and the full thickness of the Whitesburg, Athens, and Chambersburg formations.

The Chepultepec at the base of the Ordovician system crops out as a narrow band on the flanks of the Massanutten Mountain and the Long Glade synclines. The general character and chemical composition of the formation west of Staunton (Pl. 12, loc. 135) are given in the following section.

Geologic Section 82.—Along State Highway 252 about 1 mile southwest of Staunton, Augusta County, Virginia

	Thickness Feet
Chepultepec limestone (434± feet)	
5. Limestone, dark bluish-gray, fine grained; a few thin beds of gray dolomite	86
4. Dolomite and limestone	34
3. Limestone, bluish-gray, platy, cherty	18
2. Limestone, dark bluish-gray, fine grained, medium bedded; a few thin beds of dolomite	96
Analysis of units 2 to 5, sampled thickness 234 feet: SiO_2, 4.12;; Al_2O_3, 1.01; Fe_2O_3, 0.28; $CaCO_3$, 87.55; $MgCO_3$, 6.85; total, 99.81.	
1. Mostly covered; a few beds of limestone and dolomite; lower boundary uncertain	200±
Conococheague formation	

Lenoir limestone, ranging in thickness from about 60 to 200 feet, was observed along all of the high-calcium limestone belts in central Augusta County. At most localities the formation is impure, but locally along the Massanutten Mountain syncline east (Pl. 12, loc. 126) and south (Pl. 13, loc. 143) of Staunton it is composed largely of light-gray granular limestones which contain about 98 per cent calcium carbonate. Samples showing similar analyses have been obtained from a part of the Lenoir, where it is free of chert, at a few other localities in Shenandoah Valley. The general character of the Lenoir along U. S. Highway 250 west of Staunton (Pl. 12, loc. 118) and in the vicinity of Verona (Pl. 12, loc. 123) is given in the following sections.

Geologic Section 83.—Along U. S. Highway 250 about 4 miles northwest of Staunton, Augusta County, Virginia

	Thickness Feet
Lenoir limestone (187 feet)	
2. Limestone, dark-gray, medium grained, cherty	100
1. Limestone, light-gray, shaly, cherty	87
Mosheim limestone	

Geologic Section 84.—Bowling quarry along Middle River, half a mile northeast of Verona, Augusta County, Virginia

	Thickness Feet
Lenoir limestone (167 feet)	
6. Limestone, dark-gray, cherty	15
5. Covered interval; chert float	29
4. Limestone, dark-gray, cherty	29
3. Limestone, dark-gray, cobbly weathering, clayey	42
2. Limestone, dark-gray, cherty	31
1. Limestone, clayey, cherty	21
Mosheim limestone	

A few feet of granular, dark-gray Whitesburg limestone, occurring between the Athens and Lenoir, was observed locally along the high-calcium limestone belt northeast of Staunton. Since these granular beds contain abundant clayey partings, no samples for chemical analyses were taken. The rocks between the Lenoir, or Whitesburg at certain localities, and the Martinsburg formation are shown on the geologic map of the Appalachian Valley in Virginia as Athens along the Massanutten Mountain syncline in central Augusta County, and as Athens overlain by Chambersburg in the Long Glade syncline (Pl. 12) west of Staunton. The shale facies of the Athens, with a few intercalated limestone layers, is best displayed east of Staunton, whereas the Athens and overlying Chambersburg in the northwestern belts are composed largely of impure black limestone with shale partings. The general character and thickness of the Athens northeast of Staunton (Pl. 12, loc. 125) are given in the following section.

Geologic Section 85.—About 2000 feet south of the junction of U. S. Highway 11 and alternate U. S. 11 and 1 mile northeast of Staunton, Augusta County, Virginia (Fig. 4)

	Thickness Feet
Athens formation (575± feet)	
5. Shale, dark-gray, limy; upper boundary uncertain; SiO_2, 22.02; Fe_2O_3, 3.34; Al_2O_3, 9.15; $CaCO_3$, 61.48; $MgCO_3$, 3.64; total, 99.63	200
4. Covered interval	75

	Thickness Feet
3. Limestone, black, thin bedded, compact; contains black shale partings; SiO_2, 8.45; Fe_2O_3, 0.98; Al_2O_3, 2.07; $CaCO_3$, 85.95; $MgCO_3$, 2.20; total, 99.65	150
2. Mostly covered; few exposures of shaly black limestone; thin Whitesburg limestone at base	150
Lenoir limestone	
1. Limestone, dark-gray, medium-grained, cherty	200
Mosheim limestone	

Since the Chambersburg limestone is not represented along this part of the Massanutten Mountain syncline (Pl. 12, loc. 125), it is impossible, without faunal studies, to locate a definite boundary between the shaly facies of the Athens and the overlying Martinsburg shale. The Athens and Chambersburg formations were not sampled or measured in the Long Glade syncline in Augusta County, but along the same belt northeastward in Rockingham County the combined thickness of the two formations is approximately 1350 feet.

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

The broad belts mapped as Beekmantown and undifferentiated Elbrook and Conococheague formations (Pl. 12) are composed chiefly of limestone, magnesian limestone, and dolomite with variable amounts of noncarbonates.

The Elbrook is not fully exposed in central Augusta County, since it is either bounded on one side by a fault or crops out along the crest of an anticline with no older rocks exposed. A part of the formation is exposed along the Staunton overthrust southwest of Staunton and along the North Mountain fault. The Elbrook consists chiefly of shaly weathering dolomite and limestone, but contains locally thick zones of dolomite averaging about 40 per cent magnesium carbonate. Approximately 80 feet of slightly fractured dolomite near the top of the Elbrook formation, along Jennings Branch about 1¼ miles northwest of Churchville (Pl. 12, loc. 224), contains 40.50 per cent magnesium carbonate, 51.94 per cent calcium carbonate, and 6.96 per cent silica (Table 13). At locality 137, one-fourth of a mile north of State Highway 254 and 6 miles west of Staunton, 300 feet of dolomite shows

40.18 per cent magnesium carbonate. This sampled unit is tentatively identified as occuring in the upper part of the Elbrook. However, it may represent a part of the overlying Conococheague, since dolomite is an important constituent of the Conococheague in the vicinity of Newport and Vesuvius, near the Augusta-Rockbridge County line.

The principal constituents of the Conococheague formation in the Staunton area (Pl. 12, loc. 136) are shown in the following section.

Geologic Section 86.—Extending south from State Highway 252 about 1 mile southwest of Staunton, Augusta County, Virginia

	Thickness Feet
Conococheague formation (upper part, 1305 feet)	
21. Limestone and dolomite, dark-gray, fine grained, laminated	163
20. Sandstone	1
19. Limestone and dolomite, gray, fine grained, laminated	75
18. Sandstone	2
17. Limestone and dolomite, gray, fine grained, laminated	76
16. Limestone and a few thin beds of dolomite; contains black chert	20
15. Limestone and dolomite, gray, fine grained, laminated	100
14. Sandstone and sandy limestone	16
13. Limestone and dolomite, folded, crushed, cherty	78
12. Mostly covered; sandstone float	64
11. Limestone and dolomite, dark-gray	4
10. Sandstone	1
9. Limestone and dolomite; limestone bluish-gray, dolomite dark-gray	23
8. Sandstone	2
7. Dolomite and limestone, bluish-gray, fine grained	102
6. Limestone, bluish-gray; crinkly siliceous partings	81
5. Limestone and dolomite, dark bluish-gray; crinkly siliceous partings that form distinct ribs on the surface of the rock	153
4. Limestone and dolomite, dark-gray, fine grained	168
3. Dolomite, dark-gray; two-foot bed of cherty limestone at base	53
2. Dolomite, dark-gray, medium grained	43
1. Dolomite and limestone; covered interval at base	80

Approximately 1300 feet of rocks, consisting of about an equal amount of interbedded limestone and dolomite, were measured in the above section. Since there is a wide covered interval at the base, it is estimated that the Conococheague has a thickness of 2000 to 2500 feet in this area.

The Beekmantown is composed chiefly of fine-grained, light-gray dolomite with conspicuous bluish-gray layers of limestone, mainly in the lower part. Several horizons within the formation contain large masses of spongy-looking chert. The character of the beds comprising the upper part of the formation north of Verona (Pl. 12, loc. 138), is as follows:

Geologic Section 87.—Beginning at west end of Bowling quarry along Middle River about 1 mile north of Verona, Augusta County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 765 feet)	
30. Dolomite, cherty	150
29. Chert; irregular, jagged surfaces	1
28. Dolomite, light-gray; weathers yellowish	20
27. Chert; spongy texture	2
26. Dolomite, light-gray, fine grained, cherty	59
25. Dolomite; partly covered	56
24. Chert, jagged; dolomite matrix	20
23. Dolomite, gray, fine grained	48
22. Covered interval; chert fragments	37
21. Chert and dolomite, interbedded	37
20. Dolomite, light-gray, cherty	57
19. Limestone, bluish-gray; shaly partings	8
18. Dolomite, light-gray, fine grained	4
17. Limestone, bluish-gray, fine grained	1
16. Dolomite; weathers brownish	11
15. Limestone with thin layers of dolomite	5
14. Covered interval	46
13. Limestone, bluish-gray; clayey laminations	11
12. Dolomite, gray, banded	9
11. Limestone, bluish-gray, banded	5
10. Dolomite, light-gray	2
9. Limestone, bluish-gray, banded	12
8. Dolomite, light-gray, fine grained	5

	Thickness Feet
7. Limestone and dolomite	18
6. Dolomite, light-gray	35
5. Limestone, bluish-gray	2
4. Dolomite, light-gray	15
3. Limestone, bluish-gray, irregularly banded; thin beds of edgewise conglomerate	11
2. Dolomite, light-gray; partly covered	16
1. Limestone and dolomite	62

Butts[6] measured the Beekmantown along Middle River, reporting 1140 feet exposed, and estimated an additional thickness of 500 to 1000 feet in the underlying covered interval strewn with typical Beekmantown chert. Another fine display of a part of the Beekmantown dolomite (Pl. 12, loc. 139) is shown in the following section.

Geologic Section 88.—Along Chesapeake and Ohio Railway near depot at Staunton, Augusta County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 505 feet)	
4. Dolomite medium-gray, fine grained	146
3. Dolomite, medium-gray, sparsely cherty	83
2. Dolomite, gray, fine to medium grained	245
1. Dolomite, gray; a few laminated beds	31

A composite sample (Table 13) of these beds contains 37.17 per cent magnesium carbonate and 52.37 per cent calcium carbonate. Farther southwest, in the Staunton municipal quarry (Pl. 12, loc. 140), the following section is fully exposed.

Geologic Section 89.—Staunton municipal quarry along State Highway 252 in southwestern environs of Staunton, Augusta County, Virginia

	Thickness Feet
Beekmantown dolomite (in lower part, 195 feet)	
7. Dolomite, bluish-gray, fine grained, cherty	47
6. Dolomite, gray, fine grained, sandy	23
5. Dolomite, light-gray, medium grained	59

		Thickness Feet
4.	Dolomite, light-gray, sandy	21
3.	Dolomite, medium-gray, cherty	27
2.	Dolomite, bluish-gray	6
1.	Dolomite, gray, medium grained, cherty	12

Analysis of units 1 to 7, sampled thickness 195 feet: SiO_2, 5.27; Fe_2O_3, 0.82; Al_2O_3, 1.48; $CaCO_3$, 52.20; $MgCO_3$, 40.54; total, 100.31.

The analyses of the Beekmantown show that it has a variable composition, and at no place in this area do the dolomites fulfill the requirements for high-magnesium dolomite as defined in this report. Certain parts of the formation, ranging in thickness from 200 to 500 feet, contain from 30.98 to 40.54 per cent magnesium carbonate. However, the analysis showing the highest per cent of total carbonates contains more than 5 per cent silica. The best estimates of thickness of the Beekmantown range from 1500 to 2000 feet.

TABLE 13.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of central Augusta County, Virginia (Pl. 12)*

(Froehling & Robertson, Inc., Analysts)

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
115	72	1–2	Mosheim	137	96.96	0.98	1.86	0.08	0.40	100.28	At intersection of Roads 613 and 754 about 3 miles southeast of Mount Solon.
117	73	2	Mosheim	50	95.74	1.14	1.53	0.16	0.91	99.48	About 500 feet north of Road 728 and 3 miles east of Churchville.
123	75	3	Mosheim	63	92.61	3.79	2.36	0.50	0.84	100.10	Bowling quarry along Middle River, half a mile northeast of Verona.
		2	Beekmantown	46	69.51	9.63	15.59	0.92	4.31	99.96	
		1		150	57.80	38.16	2.34	0.26	1.14	99.70	
125	85	5	Athens	200	61.48	3.64	22.02	3.34	9.15	99.63	Two-fifths of a mile south of the junction of U. S. Highway 11 and alternate U. S. 11 and 1 mile northeast of Staunton.
		3		150	85.95	2.20	8.45	0.98	2.07	99.65	
			Mosheim	75	97.70	0.64	0.99	0.26	0.35	99.94	

TABLE 13.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of central Augusta County, Virginia (Pl. 12)—Continued*

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
126	76	3	Lenoir	60±	98.00	0.83	0.28	0.20	0.61	99.92	Along Chesapeake Western Railway and spur line to abandoned brick yard in the eastern environs of Staunton.
		1	Mosheim	84	96.90	1.21	0.71	0.10	0.86	99.78	
127	77	2	Mosheim	40	97.55	1.05	0.63	0.30	0.39	99.92	Belmont Trap Rock Company quarry, half a mile southeast of Staunton.
129	78	2	Mosheim	25	98.16	1.01	0.44	0.14	0.36	100.11	Staunton Lime Corporation quarry, 1½ miles east of Staunton.
	79	2		41	96.60	1.50	0.88	0.30	0.46	99.74	
130			Beekmantown		64.61	30.98	2.31	0.50	1.25	99.65	State Department of Agriculture quarry, 2 miles east of Staunton.
131	80	2	Lenoir	45	98.16	0.76	0.32	0.46	0.13	99.83	DeJarnette State Sanatorium property, 2 miles southeast of Staunton.
133	81	1	Mosheim	100±	97.55	0.91	0.61	0.18	0.57	99.82	Near intersection U. S. Highway 11 and Road 654 about 4 miles southwest of Staunton.
135	82	2–5	Chepultepec	234	87.55	6.85	4.12	0.28	1.01	99.81	Along State Highway 252 about 1 mile southwest of Staunton.

137			Elbrook (?)	300	51.75	40.18	4.72	0.82	2.23	99.70	One-fourth of a mile north of State Highway 254 and 6 miles west of Staunton.
139	88	1–4	Beekmantown	505	52.37	37.17	7.66	0.72	2.22	100.14	Along Chesapeake and Ohio Railway near depot in Staunton.
140	89	1–7	Beekmantown	195	52.20	40.54	5.27	0.82	1.48	100.31	Municipal quarry in southwestern environs of Staunton.
224			Elbrook	80	51.94	40.50	6.96	0.32	0.56	100.28	Along Jennings Branch one-fourth of a mile northeast of U. S. Highway 250 and 1¼ miles northwest of Churchville.

EASTERN AUGUSTA COUNTY

GENERAL STATEMENT

That part of Augusta County (Fig. 1) between the Massanutten Mountain syncline on the west and the Blue Ridge on the east and north of Greenville is here termed eastern Augusta County. Carbonate rocks extend from the eastern limit of the broad belt of Martinsburg shales and fine-grained sandstones in the Massanutten Mountain syncline eastward to the clastic rocks along the northwest foothills of the Blue Ridge. Altitudes in the valley range from about 1100 feet at the junction of North and Middle rivers near the Rockingham-Augusta County line to an average of 1400 feet in the southwestern part of the area. A few discontinuous ridges and rounded hills underlain by cherty limestone and sandstone rise from 100 to 300 feet above the valley floor. Eastern Augusta County is drained northeastward by South and Middle rivers. The area is served by the Chesapeake and Ohio Railway east and west through Waynesboro, the second largest town in Augusta County, and by the Norfolk and Western Railway along the west side of the Blue Ridge.

GEOLOGY

The carbonate rocks which have been mapped[4] in eastern Augusta County include the Tomstown, Waynesboro, Elbrook, Conococheague, Chepultepec, Beekmantown, Mosheim, Lenoir, and Athens formations. Scattered outcrops indicate that the formations occur in generally parallel belts, with the oldest rocks on the east side, along the northwestern foothills of the Blue Ridge.

Since the impure limestones along the eastern boundary of the Martinsburg shales and the interbedded limestones and dolomites in the eastern part of the county are so poorly exposed, this description is restricted mainly to the high-calcium limestones.

HIGH-CALCIUM LIMESTONE

In eastern Augusta County high-calcium limestone occurs in one belt along the eastern side of the broad expanse of Martinsburg shale in the Massanutten Mountain syncline. The Mosheim and Lenoir formations, locally containing high-calcium limestone, extend from the vicinity of Greenville northeastward into Rockingham County, passing near Fishersville and New Hope (Pl. 13). The largest deposits of high-calcium limestone occur in a rather limited

area northwest of Stuarts Draft. Northeastward along the strike the high-calcium limestones are thin, locally absent, and poorly exposed. The character and thickness of the Mosheim and Lenoir limestones near the southwestern end of the Massanutten Mountain syncline (Pl. 13, loc. 147) are as follows:

Geologic Section 90.—About 1000 feet west of Road 655 and 4 miles northeast of Greenville, Augusta County, Virginia

	Thickness Feet
Lenoir limestone (180+ feet)	
5. Limestone, dark-gray, cherty; covered at top	10+
4. Limestone, dark-gray, medium grained	60
3. Limestone, dark-gray, medium grained, cherty; few compact, light-gray beds	110
Mosheim limestone	
2. Limestone, dove- to dark-gray, compact	60
Beekmantown formation (upper part)	
1. Dolomite and bluish-gray limestone	75+

Another exposure less than 2 miles northeast along the strike, is composed largely of high-calcium limestone. The commercial development possibilities at this locality (Pl. 13, loc. 146) are indicated in the following section.

Geologic Section 91.—About one-fourth of a mile west of the intersection of Roads 652 and 654 and 3 miles northwest of Stuarts Draft, Augusta County, Virginia

	Thickness Feet
Lenoir limestone (219+ feet)	
5. Limestone, gray, coarse grained; covered at top; SiO_2, 0.81; Fe_2O_3, 0.26; Al_2O_3, 0.59; $CaCO_3$, 96.71; $MgCO_3$, 1.08; total, 99.45	150+
4. Limestone, dark-gray, nodular	69
Mosheim limestone (210 feet): strike N. 45° E.; dip 75-90° NW.	
3. Limestone, dove-gray, compact; SiO_2, 0.85; Fe_2O_3, 0.20; Al_2O_3, 0.62; $CaCO_3$, 96.85; $MgCO_3$, 1.62; total, 100.14	65

	Thickness Feet
2. Limestone, dove-gray, compact; SiO_2, 0.98; Fe_2O_3, 0.26; Al_2O_3, 0.80; $CaCO_3$, 96.50; $MgCO_3$, 1.39; total, 99.93	65
1. Limestone, light-gray, compact to fine grained; SiO_2, 0.04; Fe_2O_3, 0.22; Al_2O_3, 0.25; $CaCO_3$, 98.66; $MgCO_3$, 0.71; total, 99.88	80

Beekmantown formation

If units 1 to 3 in the above section are properly identified, this locality represents the thickest body of the Mosheim limestone observed in Augusta County. Unit 5, tentatively correlated as Lenoir, is best described as a lens of high-calcium, marble-like limestone with poorly defined bedding. Another exposure of the high-calcium limestones in this belt, about half a mile northeast of locality 146, is described in the following section (Pl. 3, loc. 145).

Geologic Section 92.—One-fourth of a mile southwest of the intersection of Roads 651 and 652 about 3 miles northwest of Stuarts Draft, Augusta County, Virginia

	Thickness Feet
Lenoir limestone (244± feet)	
7. Limestone, dark-gray, nodular, sparsely cherty	35±
6. Limestone, light-gray, coarse grained; a few compact beds; SiO_2, 0.41; Fe_2O_3, 0.14; Al_2O_3, 0.43; $CaCO_3$, 96.40; $MgCO_3$, 2.21; total, 99.59	112
5. Limestone, gray, medium grained; SiO_2, 0.47; Fe_2O_3, 0.26; Al_2O_3, 0.64; $CaCO_3$, 98.26; $MgCO_3$, 0.51; total, 100.14	41
4. Limestone, dark-gray, nodular, sparsely cherty	56
Mosheim limestone (126 feet): strike N. 70° E.; dip 58° NW.	
3. Limestone, dove-gray, compact	51
2. Limestone, dark-gray, compact	5
1. Limestone, dove-gray, compact	70

Analysis of units 1 to 3, sampled thickness 126 feet: SiO_2, 0.72; Fe_2O_3, 0.30; Al_2O_3, 0.38; $CaCO_3$, 96.60; $MgCO_3$, 1.40; total, 99.40.

Beekmantown formation

The surface along the traverse of the above section slopes gently northwestward from Road 652 to Christian Creek, along the limestone-shale boundary. Although this relatively flat area (Pl. 11C) is not ideal for quarrying operations, it contains a thickness of approximately 279 feet of high-calcium limestone. Field studies indicate that the thick body of high-calcium limestone extends at least from locality 146 northeast to Road 651, a distance of approximately one mile. Since the bedrock is largely covered, the exact limits of this belt along the strike to the northeast and southwest can be determined only by drilling. A decided change in rock character and thickness was observed at locality 144, about 2½ miles north of Stuarts Draft, where the Mosheim is only about 60 feet thick. Furthermore, the Lenoir at this locality is largely cherty, nodular weathering limestone, with a few thin intercalations of coarse-grained high-calcium limestone (Fig. 5).

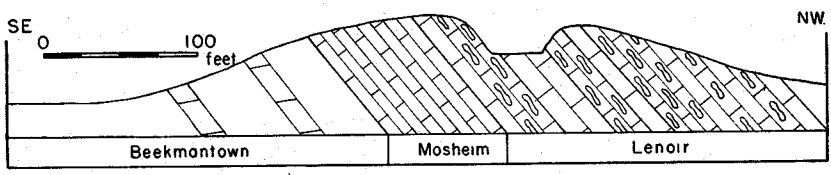


FIGURE 5.—Cross section of high-calcium limestone belt at abandoned quarry, 3 miles southwest of Tinkling Spring Church, Augusta County, Va.

Between localities 142 and 144 the Mosheim and Lenoir are generally thin and locally the overlying shales are in contact with the Beekmantown dolomite. Faulting along this belt is evident in the vicinity of Fishersville and may be present at other localities, but insufficient time for a thorough field study made it necessary to generalize the geologic mapping in this area.

At locality 142, about 2 miles northeast of Fishersville, the Beekmantown is overlain by 10 feet of fine-grained, bluish-gray limestone and by about 60 feet of coarse clastic light-gray limestone. The limestone is closely overlain by shale. The rounded grains which are responsible for the coarse texture are composed of compact limestone, ranging from about one millimeter to more than

an inch in diameter. The cementing matrix is colorless calcite. These beds appear similar to those observed in the eastern environs of Staunton (Pl. 16, loc. 122). One analysis, representing the full thickness of the coarsely granular rocks at this locality, shows 98.26 per cent calcium carbonate and 0.85 per cent magnesium carbonate, a total of 99.11 per cent carbonates.

Exposures of limestone adequate for detailed study were not observed along the Massanutten Mountain syncline between locality 142 and Rockingham County (Pl. 13). A few incomplete exposures of the Mosheim and Lenoir along this belt indicate that there are no large deposits of high-calcium limestone. Near the Rockingham County line (Pl. 13, loc. 141) the geologic sequence is Beekmantown dolomite, cherty Lenoir limestone, and Athens shale.

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

Due to poor and limited exposures, the Tomstown and Waynesboro formations in eastern Augusta County were not examined. Scattered exposures of the overlying Elbrook, Conococheague, Chepultepec, and Beekmantown in this area appear to be similar in character to exposures of these formations previously described in central Augusta County.

One sample representing about 300 feet in the lower part of the Conococheague along Road 796 about 1½ miles northwest of Waynesboro (Pl. 13, loc. 148) contains 35.49 per cent magnesium carbonate, 49.12 per cent calcium carbonate, and 9.26 per cent silica. The Beekmantown along the belt of high-calcium limestone southwest of Fishersville is composed chiefly of dark-gray dolomite with minor amounts of limestone. The upper 238 feet, which was sampled about half a mile east of the intersection of Roads 649 and 652 (Pl. 13, loc. 143), contained 65.19 per cent calcium carbonate, 31.16 per cent magnesium carbonate, and 2.68 per cent silica. These sampled units show that the Cambrian and Lower Ordovician rocks in eastern Augusta County commonly are impure, but are suitable for general construction uses.

TABLE 14.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of eastern Augusta County, Virginia (Pl. 13)*

(Froehling & Robertson, Inc., Analysts)

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
142			Mosheim	60	98.26	0.85	0.29	0.52	0.25	100.17	Along Road 795 about 2 miles northeast of Fishersville.
143			Beekmantown	238	65.19	31.16	2.68	0.38	0.93	100.34	Half a mile southeast of the intersection of Roads 635 and 652 about 4 miles southwest of Fishersville.
145	92	6	Lenoir	112	96.40	2.21	0.41	0.14	0.43	99.59	One-fourth of a mile southwest of the intersection of Roads 651 and 652 about 3 miles northwest of Stuarts Draft.
		5		41	98.26	0.51	0.47	0.26	0.64	100.14	
		1–3	Mosheim	126	96.60	1.40	0.72	0.30	0.38	99.40	
146	91	5	Lenoir	150+	96.71	1.08	0.81	0.26	0.59	99.45	One-fourth of a mile west of the intersection of Roads 652 and 654 about 3 miles northwest of Stuarts Draft.
		3	Mosheim	65	96.85	1.62	0.85	0.20	0.62	100.14	
		2		65	96.50	1.39	0.98	0.26	0.80	99.93	
		1		80	98.66	0.71	0.04	0.22	0.25	99.88	
148			Conococheague	300	49.12	35.49	9.26	1.24	4.70	99.81	Along Road 796 about 1½ miles northwest of Waynesboro.

EASTERN ROCKINGHAM COUNTY

GENERAL STATEMENT

That part of Rockingham County (Fig. 1) east of Massanutten Mountain, comprising Page Valley, is here called eastern Rockingham County. Carbonate rocks (Pl. 14) crop out across Page Valley between Massanutten Mountain and the Blue Ridge. Altitudes vary from about 900 feet along South Fork of Shenandoah River, in the eastern part of the county, to about 1200 feet along the eastern foothills of Massanutten Mountain. The area is served by the Chesapeake Western Railway between Elkton and Harrisonburg and by the Norfolk and Western Railway along the eastern side of Page Valley.

GEOLOGY

In eastern Rockingham County a complete geologic sequence of the formations from the Cambrian clastic rocks along the Blue Ridge to the Martinsburg shales in the Massanutten Mountain syncline, includes the Tomstown, Waynesboro, Elbrook, Conococheague, Chepultepec, Beekmantown, Mosheim, Lenoir, and Athens formations. Although generally poorly exposed the above formations, with the exception of the Mosheim, Lenoir, and Athens, extend southwestward across the eastern part of the county in relatively broad belts. The Tomstown, Waynesboro, Elbrook, and Conococheague are mapped together in one broad belt and the Beekmantown and Chepultepec together in another belt.

High-calcium limestone occurs locally in the Mosheim overlying the Beekmantown formation. The Mosheim in eastern Rockingham County is generally thin, poorly exposed, and apparently absent at a few localities. Because time was not available for detailed study, it is mapped (Pl. 14) with the overlying impure Lenoir limestone.

HIGH-CALCIUM LIMESTONE

The belt containing high-calcium limestone extends from South Fork of Shenandoah River along the Page-Rockingham County line, in the vicinity of Shenandoah, southwestward into Augusta County, passing near Greenwood, McGaheysville, Montevideo, and Port Republic. Exposures along this belt indicate that the thickness and quality of the limestones are inadequate for commercial development of high-calcium limestone. North of the latitude of Elkton the rocks between the Beekmantown and the Athens are commonly

thin and largely covered. At a few localities the Mosheim is missing, whereas at other places along the belt it is present but commonly shows considerable variations in thickness within short distances along the strike. Whether these variations are the result of minor thrust faulting or variations in sedimentation can not be determined without more detailed field study.

A small syncline east of the main belt and about 3 miles west of Elkton shows, from east to west, a sequence of Beekmantown conglomeratic limestone and dolomite, cherty Lenoir limestone, and Athens shaly limestone (Pl. 14). No rock of Mosheim type was observed here. The main belt of limestone along Road 602, about 2 miles southwest of Millbank, contains a thin bed of Mosheim which is repeated locally by folding or faulting. The character and sequence of the rocks which overlie the Beekmantown in the vicinity of Montevideo are given in the following sections (Pl. 14, locs. 150 and 151).

Geologic Section 93.—Along U. S. Highway 33 about half a mile northeast of Montevideo, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone	
2. Limestone, dark-gray, granular, sparsely cherty	75
Mosheim limestone: strike N. 60° E.; dip 60° NW.	
1. Limestone, dove-gray, compact; covered at base	25+

Geologic Section 94.—Along State Highway 12 about two-tenths of a mile southeast of Montevideo, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone	
5. Limestone, dark bluish-gray, fine grained, cherty	69
Mosheim limestone (70 feet): strike N. 57° E.; dip 47° NW.	
4. Limestone, dove-gray, compact; two-foot clayey bed at base	14
3. Limestone, gray, granular, thin bedded	42
2. Limestone, dove-gray to drab, compact	6
1. Limestone, medium-gray, coarse grained; thin compact limestone at base	8
Beekmantown formation	

Another complete exposure of the upper part of the Beekmantown and the overlying Mosheim and Lenoir limestones (Pl. 14, loc. 152) is described in the following section.

Geologic Section 95.—About two-tenths of a mile northwest of State Highway 12 and 1 mile southwest of Montevideo, Rockingham County, Virginia

	Thickness Feet
Lenoir limestone (48 feet)	
16. Limestone, dark-gray, nodular; streaked red	17
15. Limestone, dark-gray, fine grained, cherty	20
14. Limestone, gray, granular	11
Mosheim limestone (35 feet)	
13. Limestone, dove-gray, compact	15
12. Limestone, dove-gray; clayey partings	7
11. Limestone, dark-gray, fine grained	5
10. Limestone, gray, compact, impure	8
Beekmantown formation (upper part, 275 feet)	
9. Dolomite, gray, fine grained	16
8. Limestone, dove-gray, fine grained	20
7. Dolomite with thin beds of limestone	32
6. Limestone, light-gray	4
5. Mostly covered; a few thin layers of dolomite	109
4. Limestone, dove-gray	31
3. Mostly covered; a few layers of limestone and dolomite	25
2. Limestone, dove-gray	16
1. Dolomite, gray, fine grained	22

Mosheim limestone was not observed in three sections studied between Goods Mill and the Augusta County line, but it is possible that a thin body of Mosheim may be included in the covered interval between the Beekmantown dolomite and the overlying cherty Lenoir limestone.

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

Although this heading includes all of the formations between the Tomstown dolomite and the Mosheim limestone, the older formations generally are poorly exposed in the eastern part of Page

Valley. No natural outcrops of the Tomstown dolomite were observed in the area, but King[12] reports that unweathered Tomstown dolomite was encountered in test holes drilled by the U. S. Bureau of Mines northeast and southwest of Elkton. Clays residual from the Tomstown were observed in several abandoned manganese pits. The overlying Waynesboro, Elbrook, Conococheague, Chepultepec, and Beekmantown formations, although commonly deeply weathered and partly covered by detrital materials, are composed chiefly of interbedded impure limestone and dolomite. Shale and fine-grained sandstone occur in the Waynesboro and Elbrook formations, and coarse-grained beds of sandstone in the Conococheague.

The character of the rocks comprising approximately the upper half of the Beekmantown, in the Elkton Lime and Stone Company quarry (Pl. 14, loc. 149) and extending southeastward across Road 602, is as follows:

Geologic Section 96.—Vicinity of Elkton Lime and Stone Company quarry, 3 miles northwest of Elkton, Rockingham County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 1202 feet)	
88. Limestone, dark-gray, magnesian, fine grained	5
87. Limestone, bluish-gray, fine grained	3
86. Limestone, mottled light- and dark-gray, magnesian	18
85. Limestone, bluish-gray, compact	3
84. Dolomite, gray, fine grained	1
83. Limestone, mottled light- and dark-gray, magnesian	3
82. Limestone, bluish-gray, compact	2
81. Dolomite, gray, fine grained	2
80. Limestone, bluish-gray, compact	3
79. Dolomite, light-gray	1
78. Limestone, mottled light- and dark-gray, magnesian	3
77. Limestone, bluish-gray, compact	1
76. Dolomite, gray	5
75. Limestone, dark-gray, magnesian	1
74. Dolomite, dark-gray, fine grained	2

		Thickness Feet
73.	Limestone, bluish-gray, compact; 6-inch clay zone at base	3
72.	Limestone, mottled light- and dark-gray, magnesian	15
71.	Limestone and dolomite, banded; light bands dolomite; dark bands limestone	7
70.	Dolomite, gray, fine grained	1
69.	Dolomite, fine grained; weathers drab-gray; 2-inch shale bed at top	13
68.	Limestone, dark-gray, fine grained	5
67.	Dolomite, greenish-gray, fine grained	2
66.	Limestone, bluish-gray, compact	1
65.	Limestone, mottled light- and dark-gray, magnesian	3
64.	Dolomite, gray, fine grained	3
63.	Limestone, mottled light- and dark-gray, magnesian	5
62.	Dolomite, dark-gray	8
61.	Limestone, dark-gray, compact; a few layers of mottled magnesian limestone	12
60.	Limestone, magnesian, banded	5
59.	Limestone, mottled light- and dark-gray, magnesian	26
58.	Limestone, magnesian	6
57.	Limestone, mottled light- and dark-gray, magnesian	30
56.	Dolomite, dark-gray	5
55.	Limestone, magnesian, banded	2
54.	Limestone, mottled light- and dark-gray, magnesian	18
53.	Limestone, magnesian	2
52.	Dolomite, light-gray, fine grained	19
51.	Dolomite, fine grained; light and dark bands	43
50.	Limestone, dark-gray, magnesian	3
49.	Dolomite, gray, fine grained	8
48.	Dolomite, medium-gray	6
47.	Dolomite, medium-gray; vugs of carbonate minerals; 2-inch shale bed at top	7
46.	Limestone, dark-gray, magnesian	1

		Thickness Feet
45.	Dolomite, light-gray, fine grained; weathers drab-gray	23
44.	Limestone, gray, compact	4
43.	Limestone, mottled light- and dark-gray, magnesian	2
42.	Dolomite, gray, fine grained	5
41.	Limestone, mottled light- and dark-gray, magnesian	14
40.	Limestone, bluish-gray, compact	5
39.	Dolomite, dark-gray	9
38.	Limestone, mottled light- and dark-gray, magnesian	14
37.	Dolomite, gray, fine grained	25
36.	Dolomite, light- and dark-gray, banded	34
35.	Mostly covered; a few beds of light-gray dolomite	23
34.	Covered interval	37
33.	Dolomite, gray, fine grained	4
32.	Limestone, bluish-gray, compact	11
31.	Limestone, mottled light- and dark-gray, magnesian	8
30.	Dolomite, light-gray, fine grained	3
29.	Limestone, mottled light- and dark-gray, magnesian	13
28.	Dolomite, gray, fine grained	3
27.	Limestone, bluish-gray, compact	7
26.	Limestone, magnesian	5
25.	Dolomite, gray, fine grained	5
24.	Limestone, bluish-gray	5
23.	Dolomite, light-gray	13
22.	Limestone, mottled light- and dark-gray, magnesian	4
21.	Dolomite, dark-gray, fine grained	22
20.	Limestone, bluish-gray, compact	4
19.	Limestone, mottled light- and dark-gray, magnesian	10
18.	Dolomite, gray, fine grained	22
17.	Dolomite and banded blue limestone	14
16.	Covered interval	37
15.	Limestone, bluish-gray, compact	8

	Thickness Feet
14. Dolomite, light-gray, fine grained	8
13. Limestone, mottled light- and dark-gray, magnesian	23
12. Dolomite, gray, fine grained	13
11. Limestone and dolomite	45
10. Mostly covered; a few beds of gray dolomite	54
9. Dolomite, gray, fine grained	40
8. Limestone, mottled light- and dark-gray, magnesian	5
7. Limestone and dolomite	70
6. Limestone, mottled light- and dark-gray, magnesian	32
5. Dolomite, gray, fine grained	46
4. Limestone and dolomite	98
3. Limestone, bluish-gray	56
2. Dolomite, medium-gray, fine grained	7
Igneous intrusion	
1. Diabase (?), fine grained; weathers dark-brown	29

A composite sample of approximately 78 feet of Beekmantown dolomite from the middle of the Elkton Lime and Stone Company quarry (Pl. 15A) contains 57.28 per cent calcium carbonate, 37.01 per cent magnesium carbonate, and 3.52 per cent silica.

PAGE COUNTY

GENERAL STATEMENT

Page County (Fig. 1) is bounded on the northeast by Warren, on the northwest by Shenandoah, on the southwest by Rockingham and on the southeast by Rappahannock, Madison, and Greene counties. Prominent features of the landscape, which serve as natural boundaries of the county, are Massanutten Mountain along the northwest side and the Blue Ridge on the southeast. The part of Shenandoah Valley between these mountains, locally known as Page Valley, is approximately 27 miles long and varies in width from 4 to 7 miles. Altitudes range from about 600 feet along South Fork of Shenandoah River at the Page-Warren County line to an average of about 900 feet throughout most of the valley. The county is drained northeastward by South Fork of Shenandoah River and its tributaries. This river, characterized by a series of closely spaced meanders (Pl. 17), joins North Fork at Riverton, Warren County, to form Shenandoah River which flows northeastward to the Potomac at Harpers Ferry.

Luray, the county seat and largest town, is located at the intersection of U. S. Highway 211 and State Highway 12 near the geographical center of the county. The full length of Page Valley is served by the Norfolk and Western Railway.

GEOLOGY

That part of Page County between the Massanutten Mountain syncline and the clastic rocks along the western foothills of the Blue Ridge is underlain chiefly by carbonate rocks, ranging from the Tomstown dolomite to the Chambersburg limestone, inclusive. These rocks are described briefly in Table 15.

TABLE 15.—*Summary of carbonate rocks in the Shenandoah Valley portion of Page County, Virginia*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Chambersburg and Athens	Chiefly black, fine-grained limestone, shaly limestone, and shale. Sampled units of limestone in the lower part of the Athens, contain from 71 to 86 per cent calcium carbonate.	400–600[a]

[a] Estimated.

TABLE 15.—*Summary of carbonate rocks in the Shenandoah Valley portion of Page County, Virginia—Continued*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Lenoir	Granular, cherty, dark-gray limestone. Sampled units, which are sparsely cherty, contain a maximum of about 92 per cent calcium carbonate.	40–135
Mosheim	Compact, dove-gray limestone with occasional dark-gray beds and small amounts of clayey impurities. Sampled units contain from 93.4 to 97.3 per cent calcium carbonate.	0–55
Beekmantown	Interbedded limestone, magnesian limestone, and dolomite. Ratio of limestone to dolomite is about 1 to 2. Sampled units of limestone, exclusive of thin high-calcium beds near top of formation, generally contain from about 80 to 90 per cent calcium carbonate; dolomite units, from about 35 to 38 per cent magnesium carbonate.	3000±
Chepultepec	Slightly laminated, bluish-gray limestone. Sampled units contain from 84 to 93 per cent calcium carbonate.	300+
Conococheague	Interbedded limestone and dolomite with siliceous bands and intercalated layers of sandstone. Sampled units of limestone contain approximately 85 per cent calcium carbonate; dolomite units, approximately 38 per cent magnesium carbonate.	2500[a]
Elbrook and Waynesboro	Partly covered; Waynesboro composed of red and green shale, fine-grained sandstone, and interbedded impure limestone and dolomite; Elbrook, chiefly shaly weathering dolomite and limestone.	4000[a]
Tomstown	No natural bedrock exposures observed in Page County.	

[a] Estimated.

The rocks cropping out in Page Valley range in age from early Cambrian along the northwest foothills of the Blue Ridge to Silurian along the steep slopes and crest of Massanutten Mountain. A normal geologic sequence is maintained across the valley in the vicinity of Luray. The prevailing southeast dip of the strata suggests that the rocks probably are crumpled in a series of small parallel folds overturned toward the northwest. Close folding of this type is well displayed in

the quarry of the Woodward Stone Company (Pl. 17, loc. 161), 4 miles southwest of Luray. Minor faulting (Pl. 17) was also observed locally in the Martinsburg shale and in the underlying limestone belts west of Luray, Compton, and Overall. Faulting on a larger scale occurs in the general vicinity of Stanley and along the eastern side of Page Valley north of Vaughn (Pl. 17).

HIGH-CALCIUM LIMESTONE

In Page County high-calcium limestone includes local occurrences of the Mosheim and an occasional thin layer in the upper part of the Beekmantown. The Mosheim limestone generally is thin and apparently absent at a few localities. Because of this and the lack of time for detailed field study, the Mosheim is mapped (Pl. 17) with the overlying impure Lenoir. Locally, in adjoining counties, the Lenoir is of good quality, but none of the units sampled in Page County meet the requirements for high-calcium limestone as defined in this report.

The belt containing high-calcium limestone enters Page County about half a mile northwest of Overall and continues southwestward across the county, passing near Rileyville, Leaksville, Alma, and Shenandoah. Some of the best exposures of the Mosheim and Lenoir are in bluffs along South Fork of Shenandoah River.

About one-fourth of a mile north of the Page-Warren County line the Beekmantown is overlain directly by about 100 feet of Lenoir, with no rock of Mosheim character represented. Between this locality and the Page County line occurs a 15-foot bed of compact light-gray limestone intercalated in the upper 100 feet of the Beekmantown dolomite. This layer, although too thin for quarrying, contains approximately 99 per cent calcium carbonate and less than one per cent insoluble matter. Chemically it is similar to other layers, commonly only a few feet thick, which locally characterize the upper part of the Beekmantown formation.

The structure of the high-calcium limestone belt between Overall and a locality about one mile west of Compton is generalized on the geologic map, but the disordered distribution of the rocks probably is due to local cross faulting. The character of the rocks and their faulted relationship about one mile northwest of Compton (Pl. 17, loc. 153) are as follows:

Geologic Section 97.—In northeast bluff along South Fork of Shenandoah River about 1 mile northwest of Compton, Page County, Virginia

	Thickness Feet
Mosheim limestone (32 feet): strike N. 50°, E.; dip, overturned, 70° SE.	
11. Limestone, dove-gray, compact	30
10. Limestone, mottled light- and dark-gray, fine grained	2
Beekmantown formation (upper part, 242 feet)	
9. Covered interval	35
8. Dolomite, gray, fine grained	90
7. Covered interval	27
6. Dolomite, gray, fine grained	90
Fault; precise location uncertain	
Athens formation (lower part, 157 feet)	
5. Covered interval; abundant dark, shaly limestone float	60
4. Limestone and shale, black, fine grained	97
Lenoir limestone (104 feet)	
3. Limestone, dark-gray, granular, cherty	94
2. Limestone, gray, medium grained, thick bedded	10
Mosheim limestone	
1. Limestone, dove-gray, compact, sheared; SiO_2, 0.26; Fe_2O_3, 0.08; Al_2O_3, 0.62; $CaCO_3$, 97.36; $MgCO_3$, 1.44; total, 99.76	42
Beekmantown formation	

Thin layers of limestone are also offset by a minor fault along South Fork of Shenandoah River about one mile due west of Compton (Pl. 17, loc. 154). The geologic sequence, from east to west, about 100 yards northeast of Road 663, includes typical Beekmantown dolomite with 15 to 20 feet of finely granular, dark limestone containing angular fragments of dolomite at the top, 20 feet of high-calcium Mosheim, and 40 to 50 feet of cherty Lenoir. Just south of the road these rocks have been terminated by faulting and the outcrop belt shifted northward a few hundred feet. Although the bedrock is partly covered, it is thought that the limestone belt continues southwestward for a distance of about 8 miles. Complete exposures of the Mosheim

and Lenoir along the west slope of a low ridge underlain by Beekmantown limestone and dolomite (Pl. 15B), about half a mile west of Rileyville (Pl. 17, loc. 155), are as follows:

Geologic Section 98.—Along Road 662 about half a mile west of Rileyville, Page County, Virginia

	Thickness Feet
Lenoir limestone	
7. Limestone, dark-gray, granular, cherty	62
Mosheim limestone: strike N. 35° E.; dip, overturned, 80° SE.	
6. Limestone, light-gray, compact; lower boundary irregular; SiO_2, 0.98; Fe_2O_3, 0.20; Al_2O_3, 0.38; $CaCO_3$, 93.43; $MgCO_3$, 4.27; total, 99.26	24–32
Beekmantown formation (upper part, 502 feet)	
5. Dolomite, gray, fine grained	198
4. Limestone with a few thin beds of dolomite	216
3. Dolomite, gray, fine grained	38
2. Limestone, bluish-gray, fine grained	20
1. Dolomite, gray, fine grained	30

Since the percentage of magnesium carbonate given in the above analysis (Unit 6) is higher than that determined for the Mosheim at other localities in Shenandoah Valley, it is thought that some magnesium layers in the upper part of the Beekmantown may have been included in the sample analyzed. Natural exposures of the upper part of the Beekmantown, the Lenoir, and the lower part of the Athens occur in a bluff along South Fork of Shenandoah River about 500 feet east of Bixler Bridge and 3 miles northwest of Luray (Pl. 17, loc. 156). No Mosheim was observed in this exposure. South and east of Bixler Bridge post-Beekmantown limestone and shale occur in a small syncline which is faulted on the northwest side and detached from the main belt. Near the northeastern end of this syncline Beekmantown is overlain by Lenoir whereas at locality 157, about 2½ miles west of Luray, the Mosheim in its normal position has a thickness of from 15 to 30 feet.

Thin occurrences of high-calcium limestone were observed in the upper part of the Beekmantown at the western end of the power dam (Pl. 1C), 2 miles northwest of Luray, and in the Page County Cooperative Lime Association quarry (Pl. 17, loc. 159) along South Fork

of Shenandoah River about 3 miles west of Luray. These beds, from 2 to 5 feet thick, are intercalated in fine-grained dolomite. One analysis of a hand specimen of limestone from the above quarry shows 99.45 per cent calcium carbonate and 0.40 per cent magnesium carbonate, a total of 99.85 per cent carbonates. A composite sample of about 45 feet of interbedded Beekmantown limestone and dolomite in the same quarry (Pl. 15C) contains 85.28 per cent calcium carbonate and 11.78 per cent magnesium carbonate (Table 17). The Mosheim, normally occurring between the Beekmantown and Lenoir, is absent at this locality. Along the same belt, one-fourth of a mile north of the quarry (Pl. 17, loc. 158), the Mosheim with a pebble conglomerate of dolomite at the base is about 5 feet thick. One of the best exposures of the Mosheim and Lenoir in Page County is along Mill Creek (Pl. 17, loc. 160) about half a mile northwest of Hamburg and 3 miles southwest of Luray.

Geologic Section 99.—Along Mill Creek half a mile northwest of Hamburg, Page County, Virginia

	Thickness Feet
Lenoir limestone (73 feet)	
3. Limestone, dark-gray, medium grained, nodular	28
2. Limestone, dark-gray, medium grained; contains black chert	45
Analysis of units 2 and 3, thickness sampled 73 feet: SiO_2, 7.89; Fe_2O_3, 0.83; Al_2O_3, 1.12; $CaCO_3$, 90.82; $MgCO_3$, 0.67; total, 101.33.	
Mosheim limestone: strike N. 35° E.; dip 50° NW.	
1. Limestone, dove-gray, compact; a few impure beds near base; SiO_2, 2.74; Fe_2O_3, 0.12; Al_2O_3, 0.20; $CaCO_3$, 94.83; $MgCO_3$, 1.53; total, 99.42	55
Beekmantown formation	

The upper 37 feet of the Mosheim at the above locality contains 97.30 per cent calcium carbonate and less than one per cent silica. It is not likely that there are large reserves of high-calcium limestones in this area, since the Mosheim is absent in the Page Cooperative Lime quarry, about half a mile to the northeast, and only a few feet of it are exposed along U. S. Highway 211, about one mile to the southwest.

A complete exposure of the Mosheim in the vicinity of Leaksville (Pl. 17, loc. 163) is as follows:

Geologic Section 100.—About one-fourth of a mile northwest of Leaksville and 5 miles southwest of Luray, Page County, Virginia

	Thickness Feet
Mosheim limestone (49 feet): strike N. 40° E.; dip 50° NW.	
5. Limestone, dove-gray, compact	10
4. Limestone, dark-gray, medium grained; surfaces blotched red	4
3. Limestone, dove-gray, compact	10
2. Limestone, light-gray, compact, impure, striped	21
1. Limestone, dove-gray, compact	4
Beekmantown formation	

Although the total thickness of the beds tentatively assigned to the Mosheim in the above section is about 50 feet, it is reasonably certain that only units 1, 3, and 5 would meet the requirements for high-calcium limestone. The underlying 150 feet of the Beekmantown at the above locality is characterized by beds containing pebble-like masses of limestone in granular dolomite (Pl. 4A).

The beds between the Beekmantown and Athens are largely covered southwest of Leaksville for a distance of approximately 3 miles. Beginning just south of State Highway 12, about one mile west of Alma, and extending southwestward around the end of a broad pitching anticline, are good exposures of Lenoir close to the Beekmantown, thus the Mosheim is either very thin or absent in the covered interval here. At locality 164, where the rocks are fully exposed in a bluff along South Fork of Shenandoah River, the Beekmantown is directly overlain by 75 feet of Lenoir. Another exposure, 1½ miles southwest of locality 164, shows the same geologic sequence.

The same belt is largely covered north and south of Cub Run for a distance of about 2 miles, but it is evident from a few scattered exposures that this area does not contain commercial deposits of high-calcium limestone. In a complete exposure about 1½ miles north of Shenandoah (Pl. 17, loc. 166) and one-fourth of a mile west of State Highway 12, there is about 2 feet of compact, dove-gray limestone, perhaps Mosheim, between Beekmantown dolomite and 90 feet of cherty Lenoir. The Mosheim thickens to about 50 feet in the northern en-

virons of Shenandoah, where exposures along the Norfolk and Western Railway (Pl. 17, loc. 167) and in an abandoned roadside quarry (Pl. 17, loc. 168) are fully displayed.

Geologic Section 101.—Between South Fork of Shenandoah River and the Norfolk and Western Railway in the northern environs of Shenandoah, Page County, Virginia

	Thickness Feet
Mosheim limestone (55 feet)	
2. Limestone, dove-gray, compact; a few impure layers; SiO_2, 0.92; Fe_2O_3, 0.08; Al_2O_3, 1.04; $CaCO_3$, 95.05; $MgCO_3$, 2.38; total, 99.47	50
1. Limestone, light-gray, striped; base covered	5
Beekmantown formation	

Geologic Section 102.—In a small abandoned roadside quarry in the northern environs of Shenandoah, Page County, Virginia

	Thickness Feet
Mosheim limestone (50± feet)	
4. Limestone, dove-gray, compact	10
3. Limestone, light-gray, striped; a few thin magnesian limestone beds	15
2. Limestone, dove-gray, compact	15
1. Limestone, light-gray, compact, striped; lower boundary uncertain	5–10
Beekmantown formation	

IMPURE LIMESTONE

Formations described as impure limestone in Page County include the Chepultepec, Lenoir, Athens, and Chambersburg. Many of the relatively thin units in the Beekmantown and older formations could be similarily classified, but since these layers are intercalated with dolomites they are described under "Limestone, magnesian limestone, and dolomite".

Rocks described as Chepultepec limestone crop out in a narrow belt which extends southwestward through the middle of Page Valley, passing through or near Compton, Rileyville, Luray, and Verbena.

The composition and character of the Chepultepec in the northeastern part of the county (Pl. 17, loc. 171) are given in the following section.

Geologic Section 103.—About three-tenths of a mile east of Rileyville, Page County, Virginia

	Thickness Feet
Beekmantown formation (lower part, 88 feet)	
11. Dolomite, fine to medium grained	27
10. Limestone, bluish-gray, thick bedded	6
9. Limestone, bluish-gray, laminated	9
8. Dolomite, gray; a few granular beds	30
7. Limestone, bluish-gray	15
6. Dolomite, gray, fine grained	1
Chepultepec limestone (321± feet)	
5. Limestone, bluish-gray; a few layers clayey	20
4. Limestone, bluish-gray; occasional thin beds of dolomite; SiO_2, 7.71; Fe_2O_3, 0.70; Al_2O_3, trace; $CaCO_3$, 84.10; $MgCO_3$, 3.91; total, 96.42	81
3. Limestone, bluish-gray; crinkly siliceous laminations; SiO_2, 7.50; Fe_2O_3, 0.30; Al_2O_3, 0.31; $CaCO_3$, 87.64; $MgCO_3$, 4.23; total, 99.98	45
2. Limestone, bluish-gray; crinkly siliceous laminations; a few layers contain black chert nodules; SiO_2, 7.04; Fe_2O_3, 0.29; Al_2O_3, 0.57; $CaCO_3$, 89.28; $MgCO_3$, 2.09; total, 99.27	75
1. Largely covered; lower boundary uncertain	100±
Conococheague formation	

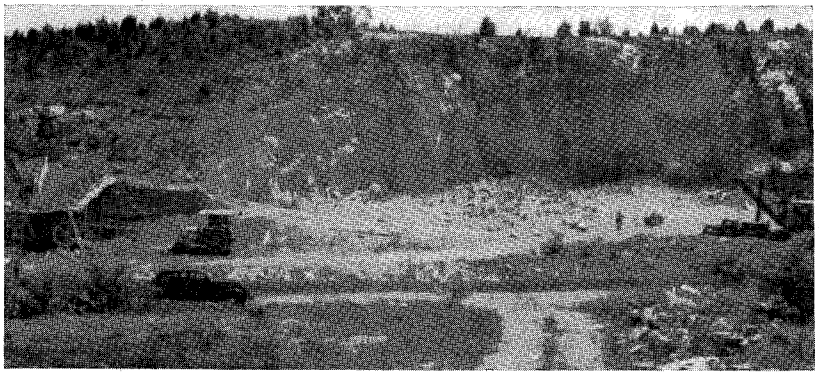
The Chepultepec, except for a few exposures along Road 615 near the underpass of the Norfolk and Western Railway, was not observed between Rileyville and Dry Run, one mile northeast of Luray. The occurrence of diagnostic Chepultepec fossils 300 feet below the base of the Beekmantown dolomite along Dry Run (Pl. 17, loc. 173) indicates a similar minimum thickness for the formation. An analysis representing 100 feet of limestone from this locality shows 93.03 per cent calcium carbonate, 2.74 per cent magnesium carbonate, and about 5 per cent of noncarbonates (Table 17). Other partial exposures of bluish-gray limestone of Chepultepec type occur near the southern corporate limits of Luray (Pl.

17, loc. 174); crossing Road 633 about 1½ miles east of Leaksville; along State Highway 258 about 3 miles northeast of Shenandoah (Pl. 17, loc. 175); and in an abandoned quarry along State Highway 12 about 1½ miles north of Verbena. Because of the similarity of these rocks to those at locality 171, no samples for chemical analyses were taken at these four localities.

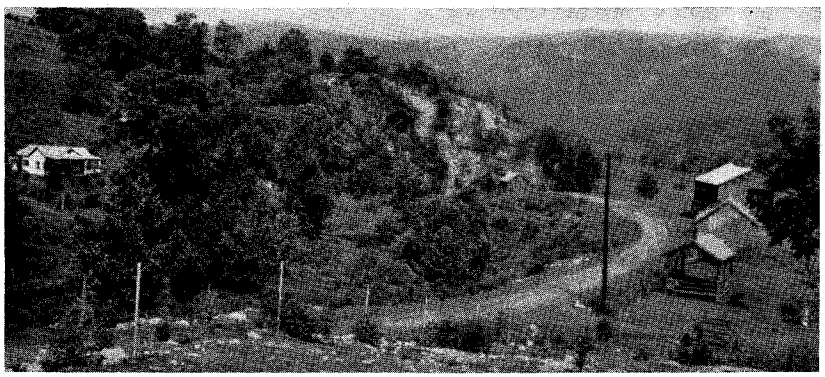
In a normal geologic sequence the Lenoir overlies the Mosheim, but at many localities in Page County the Mosheim is absent and the Lenoir directly overlies the Beekmantown. Field studies indicate that the Lenoir is persistent throughout the county, ranging in thickness from 40 to 135 feet with an average of about 75 feet. The few analyses of the Lenoir from Page County show that the formation is impure, whereas, locally in adjoining Warren County, the full thickness, or a part of the formation, is of sufficient purity to be described as high-calcium limestone. At locality 153, about one mile northwest of Compton, the full thickness of the Lenoir includes 10 feet of medium-grained, thick bedded, gray limestone overlain by 94 feet of granular, cherty, dark-gray limestone. One mile southwest along the strike (Pl. 17, loc. 154) the exposed thickness of cherty limestone is about 50 feet. A complete exposure west of Rileyville (Pl. 17, loc. 155) contains 62 feet of cherty, dark-gray limestone. The thickness and character of the Lenoir in the general vicinity of Bixler Bridge (Pl. 17, loc. 156) are as follows:

Geologic Section 104.—About 500 feet east of Bixler Bridge and 3 miles northwest of Luray, Page County, Virginia

	Thickness Feet
Lenoir limestone (134 feet): strike N. 44° E.; dip, overturned, 35° SE.	
3. Limestone, dark-gray, nodular, cherty; contains reddish films on weathered surfaces	31
2. Limestone, dark-gray, cherty	45
Analysis of units 2 and 3, thickness sampled 76 feet: SiO_2, 3.17; Fe_2O_3, 0.23; Al_2O_3, 0.58; $CaCO_3$, 92.76; $MgCO_3$, 3.37; total, 100.11.	
1. Limestone, dark-gray, fine grained; cherty at top and base; SiO_2, 7.94; Fe_2O_3, 0.61; Al_2O_3, 0.66; $CaCO_3$, 76.93; $MgCO_3$, 12.77; total, 98.91	58
Beekmantown formation	



A.



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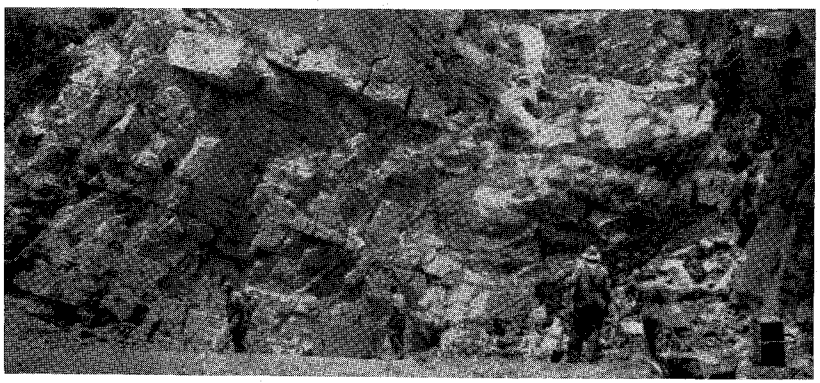
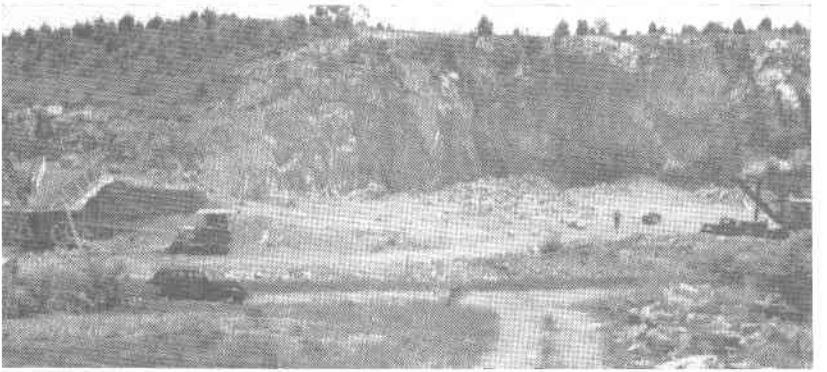


C.

A, Elkton Lime and Stone Company quarry 3 miles northwest of Elkton, Va. B, Bluff of Beekmantown limestone and dolomite half a mile west of Rileyville, Page County, Va. C, Page County Cooperative Lime Association quarry 3 miles west of Luray, Va.



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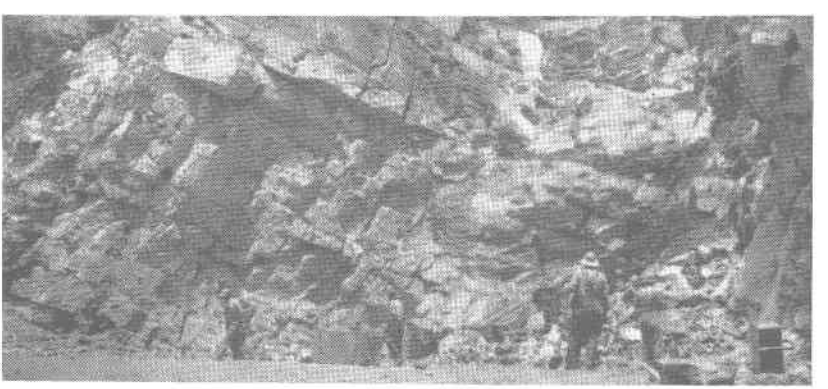
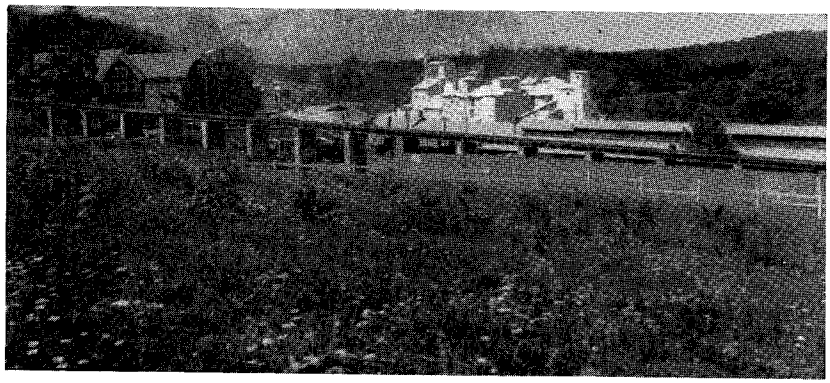


C.

A, Elkton Lime and Stone Company quarry 3 miles northwest of Elkton, Va. B, Bluff of Beekmantown limestone and dolomite half a mile west of Rileyville, Page County, Va. C, Page County Cooperative Lime Association quarry 3 miles west of Luray, Va.



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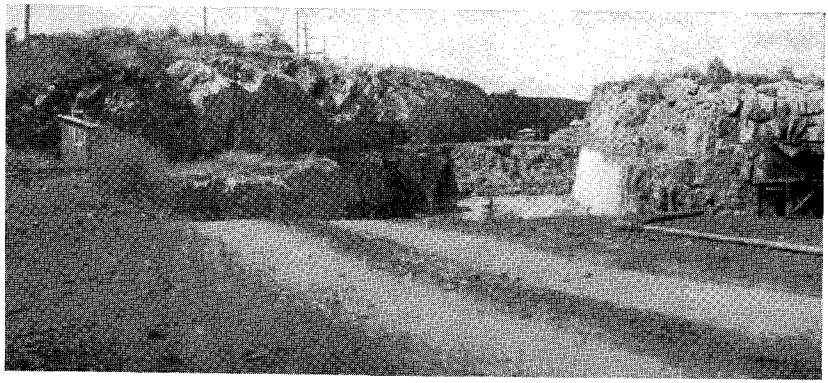

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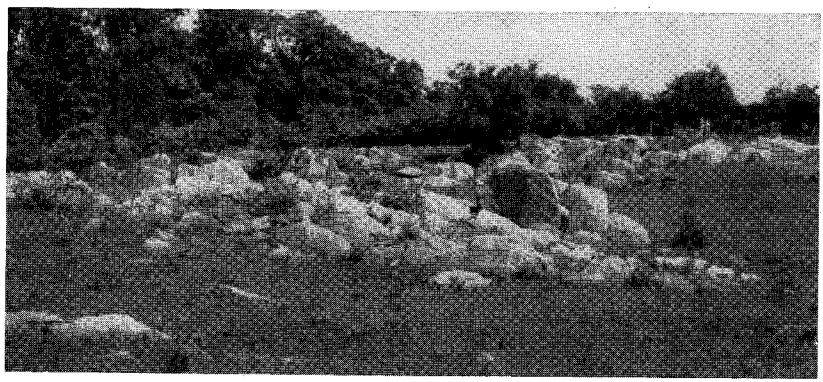
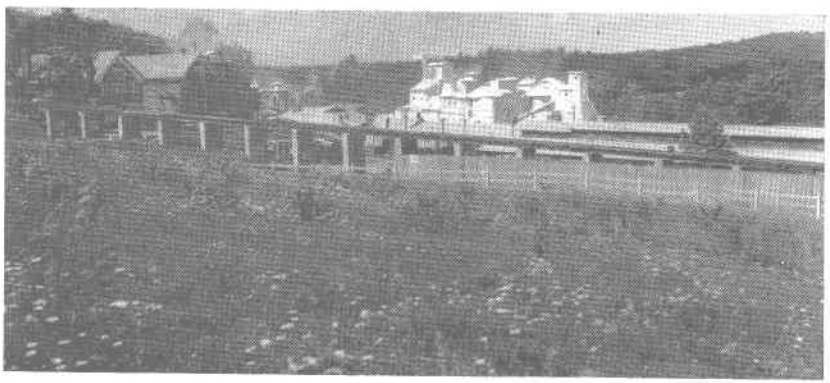


C.

A, Plant of Riverton Lime and Stone Company near Riverton, Warren County, Va. B, "Ash quarry" of Riverton Lime and Stone Company. Looking northeast. C, Typical exposure of Beekmantown limestone 1½ miles southeast of Glendale School, Clarke County, Va.



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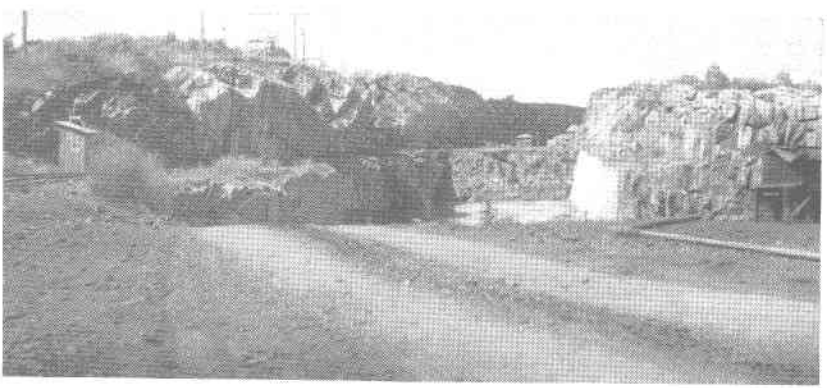

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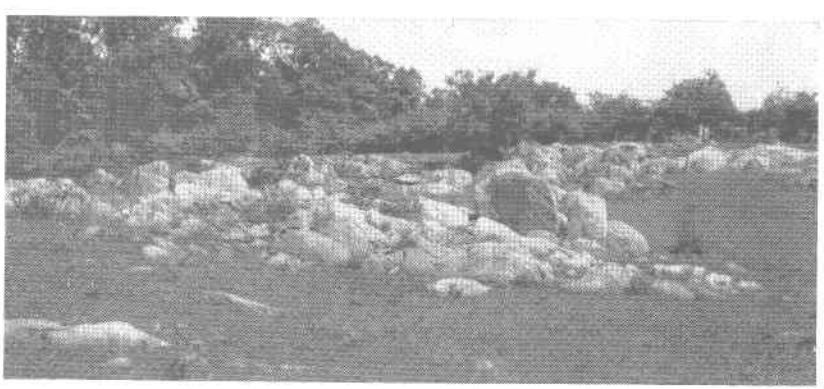

C.

A, Plant of Riverton Lime and Stone Company near Riverton, Warren County, Va. B, "Ash quarry" of Riverton Lime and Stone Company. Looking northeast. C, Typical exposure of Beekmantown limestone 1½ miles southeast of Glendale School, Clarke County, Va.

The Lenoir along Mill Creek, about 100 yards east of its junction with South Fork of Shenandoah River, has a thickness of 73 feet. A composite sample, representing the full thickness of the formation at this locality (Pl. 17, loc. 160), contains 90.82 per cent calcium carbonate and 0.67 per cent magnesium carbonate. Impurities include 7.89 per cent silica, 1.12 per cent alumina, and 0.83 per cent iron oxide (Fe_2O_3). Southwest of Luray, along South Fork of Shenandoah River 2 miles southwest of Alma, the Lenoir is about 75 feet thick. At a locality about 1000 feet west of State Highway 12 and one mile northeast of Shenandoah it is 90 feet thick. The Lenoir along this belt is a granular, dark-gray limestone containing variable quantities of black chert.

The rocks between the Lenoir limestone and the Martinsburg shale are chiefly shaly black limestone and black shale. These rocks have been divided[4] into a lower division, the Athens formation which extends throughout Page County, and an upper thinner unit, the Chambersburg formation, which extends from the Page-Warren County line southwestward to the general vicinity of Newport. These formations are shown as a single belt, about 1000 feet wide, on the geologic map (Pl. 17). Since these rocks are poorly exposed and locally complicated by structure, no specific data on their character and thickness are given. A reasonable estimate of the thickness for both formations in Page County is 400 to 600 feet. The lower 200 feet of the Athens, which crops out along South Fork of Shenandoah River at several localities about 3 miles west and northwest of Luray, is composed of impure black limestone and shaly limestone. Minor folding and fracture cleavage (Pl. 3A) are well shown in the lower part of the Athens east of Bixler Bridge (Pl. 17, loc. 156). About 50 feet of shaly limestone from this locality contains 71.34 per cent calcium carbonate and 3.66 per cent magnesium carbonate, a total of 75 per cent carbonates. Impurities include 22.93 per cent silica, 2.02 per cent alumina, and one per cent iron oxide (Fe_2O_3).

One of the best exposures of the lower part of the Athens limestone is in the Woodward quarry (Pl. 17, loc. 161), along Road 646 about one-fourth of a mile south of U. S. Highway 211 and 4 miles southwest of Luray. This quarry, which produces crushed stone, is in the northwest side of a low ridge bordering South Fork of Shenandoah River. Along the eastern quarry face there are small recumbent folds (Pl. 3B) and abundant veins of white calcite with minor amounts of fluorite. A sample representing the full thick-

ness of about 60 feet of limestone displayed in the quarry contains 86.56 per cent calcium carbonate, 4.35 per cent magnesium carbonate, and 8.86 per cent noncarbonates (Table 17).

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

Formations composed chiefly of limestone and dolomite, with variable amounts of siliceous and clayey impurities, include the Waynesboro, Elbrook, Conococheague, and Beekmantown. The Tomstown dolomite at the base of this thick succession of carbonate rocks was not observed in natural outcrop in Page County. A few scattered exposures of the Waynesboro, the Elbrook, and the Conococheague, were observed in Page County, but none were of sufficient extent to warrant detailed description.

Red and green shales and impure limestone and dolomite, all diagnostic of the Waynesboro formation, occur along Road 602 about 2 miles east of Shenandoah, along the Norfolk and Western Railway 3 miles south of Alma, in the general vicinity of Stanley, and near Kimball. Shaly weathering dolomite in the normal position of the Elbrook formation was observed at a big bend in South Fork of Shenandoah River about 3 miles northeast of Shenandoah, and along State Highway 259 about 4 miles south of Alma. The Elbrook was not observed farther northeast, although the belt probably continues beneath a covering of surface wash to the general vicinity of Vaughns (Pl. 17) where it is terminated by faulting.

The Conococheague is better displayed in Page County than are the Waynesboro and Elbrook formations. A partial exposure of the Conococheague occurs along Road 611 and Dry Run (Pl. 17, loc. 170). One of the thickest units of dolomite, estimated at 100 feet, associated with impure limestone at this locality, contains 53.72 per cent calcium carbonate, 38.06 per cent magnesium carbonate, and 6.94 per cent silica. The upper part of the Conococheague at locality 171, about half a mile east of Rileyville, is composed chiefly of banded impure limestone. Here the calcium carbonate content is about 85 per cent and the silica 7 per cent. A few thick-bedded layers of coarse-grained sandstone, which characterize the Conococheague formation throughout Shenandoah Valley, are fully displayed along State Highway 12 about three-fourths of a mile southeast of Luray (Pl. 1B). Other partial exposures of sandstone and impure limestone and dolomite in the Conococheague

were observed along the Norfolk and Western Railway in the southern environs of Shenandoah, and along Naked Creek near Verbena.

The Beekmantown formation, consisting of limestone, magnesian limestone, and dolomite, is largely exposed in a bluff along South Fork of Shenandoah River, from a point about one-fourth of a mile southwest of Overall westward for approximately half a mile. A thickness of about 50 feet of magnesian limestone, with intercalated layers of high-calcium limestone in the upper part of the formation at locality 169, contains 80.32 per cent calcium carbonate, 19.21 per cent magnesium carbonate, and 1.57 per cent silica. Approximately 3 miles southwest along the strike (Pl. 17, loc. 172) the general character of the Beekmantown is as follows:

Geologic Section 105.—East and west of State Highway 12 at Rileyville, Page County, Virginia

	Thickness Feet
Beekmantown formation (3360± feet)	
25. Dolomite, gray, fine grained	198
24. Limestone with a few thin beds of dolomite	216
23. Dolomite, gray, fine grained	38
22. Limestone, bluish-gray, fine grained	20
21. Dolomite, gray	30
20. Largely covered; a few thin beds of dolomite	77
19. Limestone, mottled light and dark bluish-gray	11
18. Dolomite, gray, fine grained	17
17. Limestone, mottled light and dark bluish-gray	10
16. Dolomite, gray, fine grained	58
15. Limestone, bluish-gray	32
14. Dolomite, gray, fine grained	13
13. Limestone, bluish-gray	9
12. Limestone and dolomite	12
11. Dolomite, dark-gray, medium grained	138
10. Dolomite with abundant chert	45
9. Limestone and dolomite	311
8. Dolomite, medium-gray, fine grained	180
7. Partly covered; a few beds of limestone and dolomite	613
6. Limestone with a few thin beds of dolomite	157

	Thickness Feet
5. Limestone with a few thin beds of magnesian limestone; SiO_2, 5.03; R_2O_3, 0.85; $CaCO_3$, 90.90; $MgCO_3$, 3.79; total, 100.57	110
4. Dolomite with a few thin beds of banded limestone	142
3. Dolomite and limestone	105
2. Limestone with a few thin beds of dolomite	75
1. Largely covered; a few beds of limestone and dolomite	743±

Chepultepec limestone

Since there are variations in the structure and several covered intervals, the thickness of about 3300 feet for the Beekmantown at the above locality should be considered only as an estimate. The upper 45 feet of the Beekmantown, which is quarried by the Page County Cooperative Lime Association (Pl. 17, loc. 159), one mile northwest of Hamburg, consists of magnesian limestone with intercalated thin beds of high-calcium limestone. One composite sample from the quarry (Pl. 15C) contains 85.28 per cent calcium carbonate and 11.78 per cent magnesium carbonate. The upper 600 feet of the Beekmantown is fully exposed along Mill Creek about 400 feet east of its junction with South Fork of Shenandoah River (Pl. 17, loc. 160). On the basis of detailed field study the ratio of limestone to dolomite in this exposure is about 1 to 2. In an abandoned quarry near Road 646, about 4½ miles southwest of Luray, there is a good exposure of 175 feet of interbedded limestone and dolomite in the upper part of the Beekmantown (Pl. 17, loc. 162). Beds which are duplicated several times in this quarry include finely granular, light-gray dolomite; compact, dove-colored limestone; and a mixture of limestone and finely granular dolomite. The chemical composition of a typical limestone and dolomite bed in the quarry is given in Table 16.

The thickest body of dolomite in the Beekmantown formation observed in this area is exposed at locality 163, one-fourth of a mile north of Leaksville. Here 270 feet of dolomite in the upper third of the formation contains 59.30 per cent calcium carbonate, 37.05 per cent magnesium carbonate, and 2.20 per cent silica (Table 17). Other good exposures of a part of the Beekmantown occur along Cub Run (Pl. 17, loc. 165) about 3 miles southeast of Alma; and in a steep bluff along South Fork of Shenandoah River about 1¼ miles northeast of Shen-

TABLE 16.—*Analyses of Beekmantown limestone and dolomite in abandoned quarry, 4½ miles southwest of Luray, Page County, Virginia.*

(Froehling & Robertson, Inc., Analysts)

	1	2
SiO_2	0.42	0.28
Fe_2O_3	0.08	0.04
Al_2O_3	0.94	0.38
$CaCO_3$	62.64	97.92
$MgCO_3$	35.97	0.86
Total	100.05	99.48

1. Twelve-foot bed of fine-grained, light-gray dolomite.
2. Four-foot bed of compact, dove-gray limestone.

andoah. The character of the rocks northeast of Shenandoah (Pl. 17, loc. 166) are as follows:

Geologic Section 106.—Bluff along South Fork of Shenandoah River about 1¼ miles northeast of Shenandoah, Page County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 1033 feet)	
30. Dolomite, gray, fine grained	54
29. Limestone, light-gray, compact	12
28. Dolomite with thin layers of bluish-gray limestone	21
27. Limestone, bluish-gray, impure, slightly banded; a few thin layers of dolomite	75
26. Dolomite, gray, fine grained	9
25. Limestone, bluish-gray	9
24. Largely covered; a few thin beds of limestone and dolomite	63
23. Limestone, light-gray, compact	10
22. Dolomite and impure banded limestone	120
21. Limestone, light bluish-gray	12
20. Dolomite, gray, fine grained	30
19. Limestone, banded, impure	18
18. Dolomite and impure banded limestone	51
17. Dolomite, gray, fine grained	21
16. Limestone, light bluish-gray	6
15. Dolomite, light-gray, fine grained	180
14. Dolomite, gray, medium grained	12

		Thickness Feet
13.	Dolomite, light-gray, fine grained	120
12.	Limestone, mottled light- and dark-gray	3
11.	Dolomite, gray, fine grained	12
10.	Limestone, bluish-gray	3
9.	Dolomite, fine grained; a few thin beds of limestone	90
8.	Limestone, mottled light- and dark bluish-gray	6
7.	Dolomite, gray, fine grained	2
6.	Limestone, mottled light- and dark-gray	6
5.	Dolomite, gray, fine grained	3
4.	Limestone, bluish-gray	5
3.	Dolomite, gray, fine grained	20
2.	Limestone, bluish-gray, impure	10
1.	Dolomite, gray, fine grained; along State Highway 12	50

In summary, 35 to 38 per cent magnesium carbonate is about the average for the Beekmantown dolomite units sampled throughout Page County. Although a few thin layers of high-calcium limestone occur, the greater part of the limestones contain generally less than 90 per cent calcium carbonate.

TABLE 17.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Page County, Virginia (Pl. 17)*

(Froehling & Robertson, Inc., and John H. Yoe, Analysts)

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
153	97	1	Mosheim	42	97.36	1.44	0.26	0.08	0.62	99.76	Northeast bluff on South Fork of Shenandoah River, 1 mile northwest of Compton.
155	98	6	Mosheim	32±	93.43	4.27	0.98	0.20	0.38	99.26	Along Road 622, half a mile west of Rileyville.
156	104		Athens	50	71.34	3.66	22.93	1.00	2.02	100.95	About 500 feet east of Bixler Bridge and 3 miles northwest of Luray.
		2–3	Lenoir	76	92.76	3.37	3.17	0.23	0.58	100.11	
		1		58	76.93	12.77	7.94	0.61	0.66	98.91	
159			Beekmantown	45	85.28	11.78	1.52	0.16	0.58	99.32	Page County Cooperative Lime Association quarry, 3 miles west of Luray.
160	99	2–3	Lenoir	73	90.82	0.67	7.89	0.83	1.12	101.33	Along Mill Creek, half a mile northwest of Hamburg.
		1	Mosheim	55	94.83	1.53	2.74	0.12	0.20	99.42	
				37	97.30	1.36	0.80	0.30	0.30	100.06	
161		60	Athens	60	86.56	4.35	7.27	0.54	1.05	99.77	Woodward quarry, 4 miles southwest of Luray.

TABLE 17.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Page County, Virginia (Pl. 17)—Continued*

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
162			Beekmantown	12	62.64	35.97	0.42	0.08	0.94	100.05	Abandoned quarry, 4½ miles southwest of Luray.
				4	97.92	0.86	0.28	0.04	0.38	99.48	
163			Beekmantown	270	59.30	37.05	2.20	0.32	0.94	99.81	About one-fourth of a mile north of Leaksville.
167	101	2	Mosheim	50	95.05	2.38	0.92	0.08	1.04	99.47	Northern environs of Shenandoah.
169			Beekmantown	50	80.32	19.21	1.57	0.27	0.16	101.53	About 1 mile southwest of Overall.
170			Conococheague	100	53.72	38.06	6.94	1.26	0.11	100.09	About half a mile southeast of Compton.
171	103	4	Chepultepec	81	84.10	3.91	7.71	0.70	trace	96.42	About three-tenths of a mile east of Rileyville.
		3		45	87.64	4.23	7.50	0.30	0.31	99.98	
		2		75	89.28	2.09	7.04	0.29	0.57	99.27	
172	105	5	Beekmantown	110	90.90	3.79	5.03	0.85[a]		100.57	About one-fourth of a mile west of Rileyville.
173			Chepultepec	100	93.03	2.74	4.12	0.77[a]		100.66	Along Dry Run, 1 mile northeast of Luray.

[a] Reported as R_2O_3.

WARREN COUNTY

GENERAL STATEMENT

Warren County, with an area of 219 square miles, is bounded on the north by Frederick and Clarke counties; on the southeast by Fauquier and Rappahannock counties; on the southwest by Page County; and on the northwest by Shenandoah County (Fig. 1). The southeastern part of the county, embracing approximately half of the total area, is within the Blue Ridge province. The belt of country between Massanutten Mountain on the northwest and the Blue Ridge lies in Shenandoah Valley, locally known as Page Valley southwest of Front Royal (Pl. 18). Altitudes range from about 420 feet along Shenandoah River at the Warren-Clarke County line to a general average of 600 to 700 feet throughout most of the valley portion. The northwestern and southwestern parts of the county are drained by North Fork and South Fork of Shenandoah River, respectively. These two forks unite at Riverton and flow thence northeastward, as Shenandoah River, to the Potomac at Harpers Ferry.

Front Royal, the county seat, is located near the geographical center of the county, about one mile east of South Fork of Shenandoah River and about 6 miles southeast of the northern end of Massanutten Mountain. The county is served by the Norfolk and Western Railway and a branch line of the Southern which connects with the main line at Manassas, Prince William County.

GEOLOGY

The valley portion of Warren County is underlain chiefly by carbonate rocks ranging from the Tomstown dolomite, on the east, to the Athens formation, on the west, inclusive. A brief description of these rocks is given in Table 18.

Pre-Cambrian crystalline rocks of the Blue Ridge in northern Warren County are separated from the carbonate rocks of Shenandoah Valley by a thick succession of Lower Cambrian quartzites, sandstones, and shales. Southwest of Front Royal (Pl. 18) the clastic rocks are concealed by faulting and the pre-Cambrian crystalline rocks, locally granitic rocks, are thrust westward upon limestones and dolomites of Ordovician age. The outstanding structure in the western part of the county is the Massanutten Mountain syncline. A belt of Martinsburg shale, occupying the trough of the fold, is approximately 8 miles wide between Riverton and Strasburg

TABLE 18.—*Summary of carbonate rocks in the Shenandoah Valley portion of Warren County, Virginia*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Athens	Black limestone, shaly limestone, and shale. Sampled units contain from 62 to 87 per cent calcium carbonate.	400±
Lenoir	Chiefly medium-grained, cherty, dark-gray limestone; locally where free of chert, high-calcium limestone. Sampled units contain from 86 to 97.7 per cent calcium carbonate.	20–100
Mosheim	Compact, dove-gray limestone; commonly slightly impure in lower part. Sampled units contain from about 95 to 99 per cent calcium carbonate, averaging about 96 per cent.	0–100
Beekmantown	Chiefly bluish-gray limestone with small amounts of gray dolomite. Sampled units of limestone, except for a few thin high-calcium beds, generally contain less than 90 per cent calcium carbonate; and the associated dolomite units, less than 38 per cent magnesium carbonate.	3000±
Chepultepec	Slightly banded, light bluish-gray limestone. Sampled units contain from about 78 to 82 per cent calcium carbonate, and generally 5 to 8 per cent magnesium carbonate.	300–500
Conococheague	Chiefly siliceous banded, bluish-gray limestone with intercalated thin beds of dolomite and sandstone.	2000–3000
Elbrook and Waynesboro	Partly covered; Elbrook, chiefly a heterogeneous mixture of impure limestone and dolomite; Waynesboro also contains red and green shales and fine-grained sandstone.	4000±
Tomstown	Largely covered; a few exposures of fine-grained, light-gray dolomite near the Warren-Clarke County line.	

in Shenandoah County (Fig. 1). South and southeast of Strasburg, along the Warren-Shenandoah County line, the Martinsburg is overlain by thick resistant Silurian sandstones which form the conspicuous ridges of Massanutten Mountain. The geologic sequence across the county in a northwesterly direction includes rocks ranging from the Tomstown dolomite along the Blue Ridge to Silurian sandstones in Massanutten Mountain. Minor folding and thrust faulting of the strata immediately underlying the Martins-

burg shale were noted in the vicinity of Nineveh, Cedarville, Front Royal, Limeton, and southwest of Bentonville.

HIGH-CALCIUM LIMESTONE

Formations that contain more than 95 per cent calcium carbonate include the Mosheim limestone at several localities northeast and southwest of Riverton Junction (at the crossing of the Norfolk and Western and Southern railways), and locally a part of the overlying Lenoir where it is free of chert. The Mosheim commonly is thin, poorly exposed, and absent in much of the area southwest of Karo (Pl. 18). Field studies indicate that many of the local variations in thickness of the Mosheim are due to its deposition upon an irregular surface of the underlying Beekmantown formation. Minor thrust faulting is also evident at a few localities where the normal geologic sequence is not displayed.

The best exposures of the Mosheim and Lenoir limestones are along U. S. Highway 522 between the Warren-Clarke County line and the vicinity of Riverton Junction. The character of the Mosheim near the northeastern end of this belt (Pl. 18, loc. 176) is as follows:

Geologic Section 107.—About 100 yards east of U. S. Highway 522 and 1½ miles northeast of Nineveh, Warren County, Virginia

	Thickness Feet
Mosheim limestone	
2. Limestone, dove-gray, compact; a few impure beds near base; SiO_2, 0.20; Fe_2O_3, 0.08; Al_2O_3, 0.80; $CaCO_3$, 95.89; $MgCO_3$, 2.97; total, 99.94	55
Beekmantown formation (upper part)	
1. Dolomite, light-gray, fine grained	50+

It should be noted that the full thickness of the Mosheim, including the basal slightly impure part, is represented in the above analysis, thus it is probable that rock of higher quality could be obtained from the upper beds. Generally, where differences in rock character can be observed in the Mosheim, the lower beds contain more insoluble matter and magnesium carbonate.

High-calcium limestones are well displayed along U. S. Highway 522 from locality 176 southwestward to the vicinity of Zion

Church, where the belt wraps around the end of a northeastward pitching syncline and from where it extends westward into Frederick County. The thickest occurrence of Mosheim observed in Warren County (Pl. 18, loc. 177) is near the southwestern end of this syncline.

Geologic Section 108.—About 100 yards east of Zion Church and three-tenths of a mile northeast of Nineveh, Warren County, Virginia

	Thickness Feet
Mosheim limestone: strike east; dip 28° N.	
1. Limestone, dove-gray, compact, sheared; thin light-gray conglomeratic limestone at base; SiO_2, 0.44; Fe_2O_3, 0.04; Al_2O_3, 0.58; $CaCO_3$, 95.76; $MgCO_3$, 2.79; total, 99.61	100±
Beekmantown formation	

Due to faulting, the Mosheim and Lenoir limestones are not exposed at the surface for approximately one-fourth of a mile southwest of the Frederick-Warren County line (Pl. 18). Beginning near Nineveh the normal geologic sequence is represented and good exposures are maintained southwestward along U. S. Highway 522 for a distance of about 4 miles. Along the northern part of this outcrop belt the Mosheim ranges in thickness from about 60 feet at locality 178 to 27 feet in the vicinity of Cedarville (Pl. 18, loc. 179). Farther southwest, about 500 feet east of U. S. Highway 522 and 1½ miles north of Riverton Junction, the Mosheim and Lenoir limestones crop out in a broad belt around the end of an anticline which pitches gently southwestward. Although the exposures are not adequate for precise thickness determination, it is estimated that at least 30 feet of high-calcium limestone is present here. Farther east the Mosheim and Lenoir extend under a shallow syncline of impure shaly Athens limestone and appear again at the surface as the outcrop belt in which are located the quarries of the Riverton Lime and Stone Company. The character of the rocks which crop out along the eastern limb of this syncline, about 800 feet northeast of the "Ash quarry" of the above company (Pl. 18, loc. 180), is summarized in the following section.

Geologic Section 109.—About 1 mile north of Riverton Junction and one-fourth of a mile west of Shenandoah River, Warren County, Virginia

	Thickness Feet
Lenoir limestone	
5. Limestone, dark-gray, medium-grained; SiO_2, 0.69; R_2O_3, 0.34; $CaCO_3$, 97.79; $MgCO_3$, 1.95; total, 100.77	20
Mosheim limestone: strike N. 25° E.; dip 80° NW.	
4. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.61; R_2O_3, 0.37; $CaCO_3$, 99.04; $MgCO_3$, 2.10; total, 102.12	28
Beekmantown formation (upper part, 142 feet)	
3. Limestone, light-gray, striped, impure; this unit may belong to the overlying Mosheim	17
2. Limestone and dolomite	50
Analysis of units 2 and 3, thickness sampled 67 feet: SiO_2, 2.10; Fe_2O_3, 0.45; Al_2O_3, 0.38; $CaCO_3$, 73.98; $MgCO_3$, 25.08; total, 101.99.	
1. Dolomite, light-gray, fine grained; a few thin beds of bluish-gray limestone	75

The Mosheim, the Lenoir, and the lower part of the Athens, along the strike to the southwest (Pl. 18, loc. 181), are fully exposed at the southwestern end of the "Ash quarry" of the Riverton Lime and Stone Company (Pl. 16A and B).

Geologic Section 110.—"Ash quarry" of the Riverton Lime and Stone Company near Riverton; about one mile north of Riverton Junction, Warren County, Virginia

	Thickness Feet
Athens formation (lower part)	
3. Limestone, black, shaly; SiO_2, 21.46; Fe_2O_3, 1.64; Al_2O_3, 5.76; $CaCO_3$, 62.72; $MgCO_3$, 6.01; total, 97.59	80

	Thickness Feet
Lenoir limestone	
2. Limestone, dark-gray, medium grained; SiO_2, 0.58; Fe_2O_3, 0.08; Al_2O_3, 0.40; $CaCO_3$, 97.31; $MgCO_3$, 1.00; total, 99.37	26
Mosheim limestone	
1. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.34; Fe_2O_3, 0.16; Al_2O_3, 0.68; $CaCO_3$, 96.86; $MgCO_3$, 1.62; total, 99.66	33
Beekmantown formation	

In a small abandoned quarry just south of Crooked Run and about 1000 feet southwest of locality 181, the Mosheim is not more than 5 to 10 feet thick. Along the strike of the same belt to the southwest the Mosheim thickens to about 40 feet, in the quarry of the Riverton Lime and Stone Company (Pl. 18, loc. 182) along the road leading from U. S. Highway 522 to the plant.

Geologic Section 111.—Riverton Lime and Stone Company quarry near Riverton; at the southwest base of Guard Hill, half a mile north of Riverton Junction, Warren County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, medium grained	30
Mosheim limestone: strike N. 20° E.; dip 60° NW.	
2. Limestone, dove-gray, compact, thick bedded; SiO_2, 0.56; Fe_2O_3, 0.12; Al_2O_3, 0.30; $CaCO_3$, 97.36; $MgCO_3$, 1.64; total, 99.98	40
Beekmantown formation (upper part)	
1. Limestone, magnesian, light-gray; SiO_2, 1.42; Fe_2O_3, 0.16; Al_2O_3, 0.98; $CaCO_3$, 89.10; $MgCO_3$, 7.69; total, 99.35	25

The geologic map (Pl. 18) in the vicinity of Riverton Junction and Front Royal is generalized, since the bedrock is largely covered. A few scattered exposures of Mosheim and Lenoir limestone, which

crop out in the quarries north of Riverton Junction, extend southwestward across North Fork and South Fork of Shenandoah River to the general vicinity of Randolph-Macon Academy. Near the Academy the limestones wrap around the end of a southwestward pitching anticline and thence continue northeastward to a fault, which apparently terminates the belt about half a mile northeast of Riverton Junction (Pl. 18, loc. 183). The eastern limb of the anticline is largely covered, but exposures of Mosheim and Lenoir may be observed along Happy Creek half a mile west of Front Royal; crossing the Southern Railway about 100 yards east of Riverton Junction; and near the abandoned quarry of the Riverton Lime and Stone Company near Riverton; about half a mile northeast of Riverton Junction.

Southwest of Front Royal the belt of high-calcium limestone is not continuous, due to minor faulting and local irregularities in deposition. Even at localities where a normal geologic sequence is maintained, the thickness of high-calcium limestone is not sufficient for large-scale commercial development. A few feet of Mosheim is displayed along U. S. Highway 522 in the northern environs of Front Royal; along Road 619 about 500 feet east of the Norfolk and Western Railway; and in a small abandoned quarry (Pl. 18, loc. 185) along State Highway 12 about 2 miles southwest of Front Royal. The first exposure of the full thickness of the Mosheim observed along this belt (Pl. 18, loc. 186) is about 2 miles northeast of Karo.

Geologic Section 112.—Between the Norfolk and Western Railway and State Highway 12 about 2 miles northeast of Karo, Warren County, Virginia

	Thickness Feet
Mosheim limestone (85 feet): strike N. 60° E.; dip 70° NW.	
2. Limestone, dove-gray, compact, sheared; SiO_2, 0.26; Fe_2O_3, 0.08; Al_2O_3, 0.74; $CaCO_3$, 96.70; $MgCO_3$, 1.73; total, 99.51	60
1. Limestone, light-gray, striped, impure	25
Beekmantown formation	

The Mosheim, maintaining about the same thickness as given in the above section, extends for at least 400 feet northeast along

the strike, whereas to the southwest the thickness diminishes to about 15 feet in a distance of 200 feet. One of the best exposures of post-Beekmantown limestones in the southwestern part of Warren County occurs about one mile north of the intersection of Road 607 and State Highway 12 (Pl. 18, loc. 187). Here the Mosheim in a distance of 300 feet along the strike ranges in thickness from 5 to 28 feet, showing clearly deposition upon an irregular Beekmantown surface. The overlying rocks include 49 feet of nodular, sparsely cherty Lenoir limestone and about 258 feet of shaly limestone in the lower part of the Athens.

The quarry of the Limeton Lime Company near Karo (Pl. 18, loc. 188) is in the upper part of the Beekmantown formation, which locally contains beds of high-calcium limestone intercalated in dolomite. The company formerly operated a quarry near Limeton (Pl. 18, loc. 190). In 1942 the operations near Karo (Pl. 4B) consisted of an open cut, approximately 400 feet long, 100 feet wide, and 60 to 100 feet deep. In addition, a small mine was being developed in an 18-foot bed of high-calcium limestone along the southeast side of the quarry. The character of the upper Beekmantown, the Mosheim, and the lower part of the Lenoir along the Norfolk and Western Railway in the general vicinity of the Limeton quarry (Pl. 18, loc. 188) is as follows:

Geologic Section 113.—In the Limeton Lime Company quarry and extending northwest along the Norfolk and Western Railway, Warren County, Virginia

	Thickness Feet
Lenoir limestone (lower part)	
17. Limestone, gray, medium grained	7+
Mosheim limestone (24± feet)	
16. Limestone, dove-gray, compact	16±
15. Limestone, dark-gray, fine grained; irregularly bedded; pinkish partings	8±
Beekmantown formation (upper part, 1347 feet)	
14. Dolomite, light-gray, fine grained; a few thin layers of bluish-gray limestone	67
13. Limestone, bluish-gray, banded	18
12. Dolomite, gray, fine grained	29
11. Limestone and dolomite, mottled and banded	394

		Thickness Feet
10.	Dolomite, gray, fine grained; a few layers of limestone near top	186
9.	Mostly covered; a few layers of dolomite	93
8.	Limestone, bluish-gray; partly covered	75
7.	Limestone with a few thin layers of dolomite	50
6.	Dolomite with a few thin layers of limestone	31
5.	Dolomite and limestone; in about equal amounts	246
4.	Limestone, light-gray, fine grained; a few layers of magnesian limestone	100
3.	Limestone, light- to pinkish-gray, compact	15
2.	Limestone, light- and dark-gray, compact; unit exposed in mine; SiO_2, 2.78; Fe_2O_3, 0.16; Al_2O_3, 0.52; $CaCO_3$, 94.95; $MgCO_3$, 0.95; total, 99.36	18±
1.	Limestone and dolomite; limestone, dark-gray; dolomite, light-gray; exposed along eastern wall of quarry above mine entrance	25+

Analysis of hand specimen of light-gray bed; SiO_2, 5.45; Fe_2O_3, 1.46; Al_2O_3, 0.06; $CaCO_3$, 62.12; $MgCO_3$, 30.54; total, 99.63.

Analysis of hand specimen of dark-gray bed; SiO_2, 4.28; Fe_2O_3, 0.84; Al_2O_3, 0.10; $CaCO_3$, 88.16; $MgCO_3$, 7.07; total, 100.45.

The relatively low carbonate content of unit 2 in the above section suggests that a part of the adjacent impure beds may have been included in the sample taken. About 15 feet of a similar appearing, compact limestone in the upper part of the Beekmantown formation along the Page-Warren County line, about 7 miles southwest of Limeton, contains about 99 per cent calcium carbonate.

The structure of the limestone belt between Limeton and Overall, along the Warren-Page County line, has not been fully determined. Minor faulting occurs in the general vicinity of Limeton, where the limestone belt is offset approximately one mile; and between Bentonville and Road 628, where Beekmantown dolomite is thrust upon Martinsburg shale. The Mosheim, except for a possible thin bed along State Highway 12 at Limeton, was not observed in this part of the county. These relationships may be seen north of Limeton (Pl. 18, loc. 189) and near the Page-Warren County line (Pl. 18, loc. 191). The Lenoir,

which directly overlies the Beekmantown near the Page County line, contains 94.95 per cent calcium carbonate, thus it almost meets the requirements for high-calcium limestone.

IMPURE LIMESTONE

Formations mapped as impure limestone in Warren County include the Chepultepec, the Lenoir at most localities, and the Athens (Pl. 18). The Chepultepec at the base of the Ordovician system is composed predominantly of light bluish-gray limestones with thin siliceous laminations. Generally, the upper boundary is fairly well defined by the overlying typical Beekmantown dolomite (Pl. 18, loc. 193), whereas the beds in the lower part of the formation pass gradually through increasing amounts of siliceous partings into the underlying Conococheague. The Chepultepec, with a thickness estimated at 300 to 500 feet, is restricted to one narrow belt that enters Warren County about 2 miles northeast of Success and extends southwestward to an overthrust fault (Pl. 18, loc. 195) about half a mile southeast of the intersection of the Skyline Drive and State Highway 12. Some of the best exposures of the formation in Warren County are in the bluffs along Shenandoah River about 2 miles southeast of Cedarville and one mile southeast of the Norfolk and Western Railway. Although shearing of the rocks along this belt has largely obliterated the bedding, it is possible to determine that many of the dark siliceous bands are overturned. A description of the main constituents of the Chepultepec in northern Warren County (Pl. 18, loc. 194) is as follows:

Geologic Section 114.—Along Shenandoah River at Horseshoe Bend, 2 miles southeast of Cedarville, Warren County, Virginia

	Thickness Feet
Chepultepec limestone (480± feet): strike N. 30° E.; dip, overturned, 30°-60° SE.	
5. Limestone, bluish-gray, impure; sheared	100
4. Covered interval	20
3. Limestone, bluish-gray, impure; sheared	60

Analysis of units 3 and 5, thickness sampled 160 feet: SiO_2, 8.53; Fe_2O_3, 1.06; Al_2O_3, 3.07; $CaCO_3$, 78.59; $MgCO_3$, 7.87; total, 99.12.

	Thickness Feet
2. Limestone, bluish-gray; thin siliceous partings; sheared	300±

Average of 5 analyses of unit 2, each representing 60 feet: SiO_2, 11.05; Fe_2O_3, 0.66; Al_2O_3, 0.86; $CaCO_3$, 81.79; $MgCO_3$, 5.57; total, 99.93.

Conococheague limestone (upper part)

1. Limestone, bluish-gray; abundant crinkly siliceous partings; sheared	150

Average of 2 analyses of unit 1, each representing 75 feet: SiO_2, 8.75; Fe_2O_3, 0.86; Al_2O_3, 0.38; $CaCO_3$, 82.59; $MgCO_3$, 7.44; total, 100.02.

Although the analyses of the Chepultepec and Conococheague in the above section are similar, the lithology of the sampled units indicates that the Conococheague contains more of the impure crinkly laminations. In adjacent parts of Frederick and Clarke counties the Chepultepec generally contains from 8 to 10 per cent more calcium carbonate.

In normal geologic sequence the Lenoir overlies the Mosheim, but at a few localities in Warren County, where the Mosheim is absent, the Lenoir rests directly upon Beekmantown dolomite. Throughout most of the county it is composed of cherty, medium-grained, dark-gray limestone. Locally, where the formation is practically free of chert, it meets the requirements of high-calcium limestone (Pl. 18, locs. 180 and 181). The Lenoir, ranging from about 20 to 100 feet in thickness, is overlain by about 400 feet of compact, black shaly limestone and limy shale identified as the Athens formation. The lower part of the Athens consists mainly of limestone with thin shale partings, whereas in the upper part the shale bands are thicker with corresponding smaller amounts of limestone. The limestone facies of the Athens is readily distinguished from other limestones in this area by its distinctive alternating light- and dark-gray bands. The general character of the Lenoir and Athens limestones in the northern part of Warren County, at Cedarville (Pl. 18, loc. 179), and north of Riverton Junction (Pl. 18, loc. 180), is as follows:

Geologic Section 115.—About 100 yards west of U. S. Highway 522 at Cedarville, Warren County, Virginia

	Thickness Feet
Athens formation	
4. Limestone, black, fine grained; shaly partings; SiO_2, 16.23; Fe_2O_3, 0.48; Al_2O_3, 1.45; $CaCO_3$, 78.38; $MgCO_3$, 5.13; total, 101.67	385
Lenoir limestone (61 feet)	
3. Limestone, gray, medium grained	30
2. Limestone, dark-gray; a few black chert nodules	3
1. Limestone, gray, medium grained	28
Analysis of units 1 to 3, thickness sampled 61 feet: SiO_2, 0.80; Fe_2O_3, 0.09; Al_2O_3, 0.21; $CaCO_3$, 86.02; $MgCO_3$, 13.37; total, 100.49.	
Mosheim limestone	

Geologic Section 116.—About 1 mile north of Riverton Junction and one-fourth of a mile west of Shenandoah River, Warren County, Virginia

	Thickness Feet
Athens formation (lower part)	
2. Limestone, densely black; shaly partings; SiO_2, 8.09; Fe_2O_3, 0.57; Al_2O_3, 1.27; $CaCO_3$, 87.84; $MgCO_3$, 1.95; total, 99.72	60
Lenoir limestone	
1. Limestone, dark-gray, medium grained; SiO_2, 0.69; R_2O_3, 0.34; $CaCO_3$, 97.79; $MgCO_3$, 1.95; total, 100.77	20
Mosheim limestone	

The best exposures of the Athens and Lenoir formations observed in the southwestern part of Warren County are about one mile north of the intersection of Road 607 and State Highway 12 (Pl. 18, loc. 187), and near the Warren-Page County line (Pl. 18, loc. 191).

Geologic Section 117.—Near South Fork of Shenandoah River, 1 mile north of the intersection of Road 607 and State Highway 12, Warren County, Virginia

	Thickness Feet
Athens formation (lower part, 258 feet)	
8. Shale with thin intercalations of limestone	118
7. Limestone and shale, black	70
6. Limestone, black, compact; thin shale partings	47
5. Limestone and shale, black	9
4. Shale, black; thin intercalations of limestone	14
Lenoir limestone (49 feet)	
3. Limestone, dark-gray, fine grained, nodular	14
2. Limestone, fine grained, nodular, cherty	27
1. Limestone, gray, medium grained, nodular	8
Mosheim limestone	

Geologic Section 118.—About 1000 feet west of State Highway 12 and one-fourth of a mile north of Overall, Warren County, Virginia

	Thickness Feet
Athens formation (lower part)	
2. Limestone, black, dense; shaly partings; SiO_2, 7.66; Fe_2O_3, 0.48; Al_2O_3, 1.92; $CaCO_3$, 87.14; $MgCO_3$, 2.24; total, 99.44	118
Lenoir limestone	
1. Limestone, dark-gray, fine to medium grained, sparsely cherty; SiO_2, 1.72; Fe_2O_3, 0.08; Al_2O_3, 0.36; $CaCO_3$, 94.95; $MgCO_3$, 1.95; total, 99.06	98
Beekmantown formation	

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

Formations composed chiefly of interbedded limestones and dolomites, with variable amounts of siliceous and clayey impurities, include

the Tomstown, Waynesboro, Elbrook, Conococheague, and Beekmantown. North of Front Royal a narrow band of impure Chepultepec limestone, at the base of the Ordovician system, separates the Beekmantown on the northwest from the older carbonate formations on the southeast (Pl. 18). Tomstown dolomite which is well displayed at several localities in adjoining Clarke County to the northeast was not mapped separately in this area, since natural outcrops, representing but a part of this formation, were observed at only one locality (Pl. 18, loc. 192). Clay residual from the Tomstown was noted in several of the abandoned manganese operations in the vicinity of Happy Creek Station, thus it is probable that a part of the formation persists beneath the soil mantle in the northeastern part of the county. Southwest of Front Royal the Beekmantown is bounded on the east by a prominent fault.

Scattered exposures along Milldale Run, near the northern boundary of the county, indicate that the Waynesboro here is a heterogeneous formation, composed of distinctive red and green shales, brownish fine-grained sandstone, and impure dolomite and limestone. The dolomites commonly weather to a yellowish ocherous rock. Although the thickness of the Waynesboro can not be accurately measured, the width of the outcrop and dip of the strata indicate a probable thickness of 2000 feet. The Waynesboro is overlain by the Elbrook formation, consisting of about 2000 feet of thin-bedded, light-gray dolomite and dark-gray limestone with interbedded shaly partings.

Several partial exposures of the Conococheague formation, which overlies the Elbrook, show that it is composed mainly of banded, medium-bedded, bluish-gray limestone with a few intercalated beds of dolomite. The banded structure is caused by thin wavy partings of siliceous materials which commonly stand out in relief on weathered surfaces. In addition, intercalated beds of coarse-grained sandstone are distinctive characteristics of the formation. The thickness of the Conococheague is estimated to be between 2000 and 3000 feet.

The Chepultepec limestone above the Conococheague is overlain by about 3000 feet of Beekmantown limestone and dolomite. The following geologic sections describe units which were measured and sampled at different horizons in the Beekmantown. The character of the upper part of the formation near the Warren-Page County line (Pl. 18, loc. 191) is as follows:

Geologic Section 119.—About 1000 feet west of State Highway 12 and one-fourth of a mile north of Overall, Warren County, Virginia

	Thickness Feet
Beekmantown formation (upper part, 203 feet)	
3. Dolomite, light-gray, fine grained	156
2. Limestone, light-gray, compact	4
1. Dolomite, light-gray, fine grained	43

Analysis of units 1 to 3, sampled thickness 203 feet: SiO_2, 1.20; Fe_2O_3, 0.24; Al_2O_3, 0.90; $CaCO_3$, 61.82; $MgCO_3$, 34.77; total, 98.93.

Another exposure of the upper part of the Beekmantown, locally containing thin units of high-calcium limestone at the Limeton Lime Company (Pl. 18, loc. 188), has been discussed. At several localities in the southwestern part of the county the upper part of the Beekmantown is predominantly dolomite, whereas in one of the quarries of the Riverton Lime and Stone Company (Pl. 18, loc. 182) the upper 25 feet of the formation contains 89.10 per cent calcium carbonate and only 7.69 per cent magnesium carbonate. Northeast of Riverton Junction the upper part of the Beekmantown is well displayed along and east of U. S. Highway 522, from Nineveh southwestward to a point about one mile beyond Cedarville. The thickness and character of the rocks comprising the upper part of the Beekmantown at Cedarville (Pl. 18, loc. 179) are as follows:

Geologic Section 120.—East and west of U. S. Highway 522 at Cedarville, Warren County, Virginia

	Thickness Feet
Mosheim limestone	
Beekmantown formation (upper part, 729 feet)	
71. Dolomite, fine grained; weathers light-gray	10
70. Limestone, bluish-gray	1
69. Limestone, clayey; contains irregular fragments of limestone	3
68. Limestone, mottled light and dark bluish-gray	6
67. Dolomite, gray, fine grained	6
66. Limestone, bluish-gray	1
65. Limestone, bluish-gray, magnesian	18

		Thickness Feet
64.	Limestone, bluish-gray	3
	Analysis of units 64 to 71, sampled thickness 48 feet: SiO_2, 1.73; Fe_2O_3, 0.28; Al_2O_3, 0.23; $CaCO_3$, 73.92; $MgCO_3$, 21.90; total, 98.06.	
63.	Dolomite, gray	9
62.	Covered interval	12
61.	Dolomite, light-gray, fine grained	6
60.	Limestone, bluish-gray	8
59.	Dolomite, gray, fine grained	5
58.	Limestone, bluish-gray, magnesian	4
57.	Dolomite, light-gray	2
56.	Limestone, bluish-gray; irregular bedded	3
55.	Dolomite, gray, fine grained	14
54.	Limestone, blue, thinly laminated	9
53.	Dolomite, bluish-gray	4
52.	Limestone, blue	3
51.	Dolomite, bluish-gray	4
50.	Limestone, clayey	2
49.	Dolomite, gray, fine grained	1
48.	Dolomite and limestone; crinkly laminations	15
47.	Covered interval	6
46.	Limestone, bluish-gray, magnesian	6
45.	Limestone, bluish-gray, compact	5
44.	Covered interval	12
43.	Dolomite, gray, fine grained	5
42.	Limestone, bluish-gray	8
41.	Dolomite, bluish-gray	5
40.	Limestone, dove-gray, compact	6
39.	Limestone, bluish-gray, fine grained; pitted surface	15
38.	Covered interval	12
37.	Limestone, clayey; irregularly marked surfaces	20
36.	Limestone, blue; clayey partings	30
	Analysis of units 36 and 37, sampled thickness 50 feet: SiO_2, 0.75; Fe_2O_3, 0.12; Al_2O_3, 0.54; $CaCO_3$, 88.95; $MgCO_3$, 10.71; total, 101.07.	
35.	Dolomite, gray, fine grained	3
34.	Covered interval	3

		Thickness Feet
33.	Dolomite, gray	3
32.	Covered interval	4
31.	Limestone, dove-gray, compact	5
30.	Dolomite, gray, fine grained	1
29.	Limestone, bluish-gray	6
28.	Dolomite, gray	3
27.	Limestone, clayey; cobbly weathering	9
26.	Covered interval	3
25.	Dolomite, gray	3
24.	Limestone, bluish-gray; irregular clayey bands	6
23.	Limestone, bluish-gray, magnesian	9
22.	Covered interval	4
21.	Dolomite, fine grained; weathers yellowish	18
20.	Limestone, bluish-gray	3
19.	Covered interval	12
18.	Dolomite, bluish-gray	3
17.	Limestone, bluish-gray	2
16.	Dolomite, bluish-gray	5
15.	Covered interval	50
14.	Dolomite, light-gray	2
13.	Covered interval	40
12.	Dolomite, gray	10
11.	Limestone; partly covered	30
10.	Dolomite, gray	4
9.	Limestone, bluish-gray	3
8.	Dolomite, gray	6
7.	Covered interval	20
6.	Limestone, dove-gray, compact, sheared	15
5.	Dolomite, gray	8
4.	Limestone, bluish-gray	2
3.	Limestone and dolomite; partly covered	80
2.	Limestone, compact and fine grained, thick bedded; SiO_2, 0.47; Fe_2O_3, 0.21; Al_2O_3, 0.33; $CaCO_3$, 94.50; $MgCO_3$, 6.48; total, 101.99	50
1.	Dolomite, gray; along crest of local anticline	25

From 100 to 150 feet of Beekmantown limestone crops out in a bluff near Leach Run, about one-fourth of a mile southeast of Riverton Junction (Pl. 18, loc. 184). Here the limestone is con-

tinuously exposed for about 1000 feet. The average of five analyses, each representing chips collected from 20 to 30 feet of beds, shows 87.10 per cent calcium carbonate and 2.94 per cent magnesium carbonate. The full thickness of the exposure is very uniform in composition, since none of the analyses varied more than 3 per cent in the calcium carbonate content (Table 19). Except for a few thin local occurrences of high-calcium limestone, the main body of Beekmantown limestone in Warren County is not suitable for uses that require more than 95 per cent calcium carbonate and, so far as known, the associated dolomites are thin and generally contain less than 38 per cent magnesium carbonate.

TABLE 19.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Warren County, Virginia (Pl. 18)*

(Froehling & Robertson, Inc., and John H. Yoe, Analysts)

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
176	107	2	Mosheim	55	95.89	2.97	0.20	0.08	0.80	99.94	About 100 yards east of U. S. Highway 522 and 1½ miles northeast of Nineveh.
177	108	1	Mosheim	100±	95.76	2.79	0.44	0.04	0.58	99.61	About 100 yards east of Zion Church and three-tenths of a mile northeast of Nineveh.
178			Athens	100	88.77	1.65	6.51	3.02[a]		99.95	Along U. S. Highway 522 and about 1 mile southwest of Nineveh.
			Lenoir	30	94.20	2.17	2.53	0.41[a]		99.31	
			Mosheim	60	95.04	3.16	1.03	0.29[a]		99.52	
179	115	4	Athens	385	78.38	5.13	16.23	0.48	1.45	101.67	East and west of U. S. Highway 522 at Cedarville.
		1–3	Lenoir	61	86.02	13.37	0.80	0.09	0.21	100.49	
	120	64–71	Beekmantown	48	73.92	21.90	1.73	0.28	0.23	98.06	
		36–37		50	88.95	10.71	0.75	0.12	0.54	101.07	
		2		50	94.50	6.48	0.47	0.21	0.33	101.99	

TABLE 19.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Warren County, Virginia (Pl. 18)—Continued*

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
180	116	2	Athens	60	87.84	1.95	8.09	0.57	1.27	99.72	About 1 mile north of Riverton Junction and one-fourth of a mile west of Shenandoah River.
		1	Lenoir	20	97.79	1.95	0.69	0.34[a]		100.77	
	109	4	Mosheim	28	99.04	2.10	0.61	0.37[a]		102.12	
		2–3	Beekmantown	67	73.98	25.08	2.10	0.45	0.38	101.99	
181	110	3	Athens	80	62.72	6.01	21.46	1.64	5.76	97.59	"Ash quarry" of Riverton Lime and Stone Company, near Riverton, about 1 mile north of Riverton Junction.
		2	Lenoir	26	97.31	1.00	0.58	0.08	0.40	99.37	
		1	Mosheim	33	96.86	1.62	0.34	0.16	0.68	99.66	
182	111	2	Mosheim	40	97.36	1.64	0.56	0.12	0.30	99.98	Riverton Lime and Stone Company quarry, one-fourth of a mile northwest of Riverton Junction.
		1	Beekmantown	25	89.10	7.69	1.42	0.16	0.98	99.35	
184			Beekmantown	25	87.00	0.65	11.26	0.23	trace	99.14	In bluff near Leach Run, one-fourth of a mile southeast of Riverton Junction.
				25	86.68	4.25	9.03	0.31	0.24	100.51	
				25	88.28	1.95	8.00	0.27	0.29	98.79	
				25	85.84	3.62	10.15	0.40	0.55	100.56	
				25	87.70	4.23	6.90	0.71	0.11	99.65	

186	112	2	Mosheim	60	96.70	1.73	0.26	0.08	0.74	99.51	Along northwest slope of low ridge between the Norfolk and Western Railway and State Highway 12 about 2 miles northeast of Karo.
188	113	2	Beekmantown	18±	94.95	0.95	2.78	0.16	0.52	99.36	Limeton Lime Company quarry at Karo.
					62.12	30.54	5.45	1.46	0.06	99.63	
					88.16	7.07	4.28	0.84	0.10	100.45	
191	118	2	Athens	118	98.14	2.24	7.66	0.48	1.92	99.44	About 1000 feet west of State Highway 12 and one-fourth of a mile north of Overall.
		1	Lenoir	98	94.95	1.95	1.72	0.08	0.36	99.06	
	119	1–3	Beekmantown	203	61.82	34.77	1.20	0.24	0.90	98.93	
192			Tomstown (?)	50	78.09	14.62	3.16	0.74	0.01	96.62	Along Shenandoah River, 2 miles east of Milldale.
				50	53.16	37.70	5.70	2.62	0.19	99.37	
194	114	3, 5	Chepultepec	160	78.59	7.87	8.53	1.06	3.07	99.12	In bluff of Shenandoah River, 2 miles southeast of Cedarville.
		2		60	81.77	5.04	10.96	0.44	0.58	98.79	
				60	79.20	8.35	10.83	0.40	0.76	99.54	
				60	85.06	5.33	9.01	0.48	0.78	100.66	
				60	84.07	1.17	11.04	0.65	1.32	98.25	
				60	78.89	7.95	13.44	1.33	trace	101.61	
		1	Conococheague	75	80.07	9.90	8.08	1.16	0.13	99.34	
				75	85.11	4.98	9.43	0.56	0.62	100.70	

[a] Reported as R_2O_3.

CLARKE COUNTY

GENERAL STATEMENT

Clarke County, with an area of 171 square miles, is bounded on the northeast by West Virginia, on the northwest by Frederick County, on the southwest by Warren County, and on the southeast by Loudoun and Fauquier counties (Fig. 1). Approximately two-thirds of the county, or the area between the Blue Ridge on the east and Opequon Creek on the west, lies in Shenandoah Valley. Altitudes in the valley portion range from 375 feet along Shenandoah River at the West Virginia-Virginia boundary to about 700 feet in the southwestern part of the county.

Berryville, the county seat, is located on the Norfolk and Western Railway in the central part of the valley. The northern part of the county is also served by the Baltimore and Ohio Railroad which passes through Wadesville and Swimley.

GEOLOGY

The valley part of the county is underlain chiefly by carbonate rocks, ranging from the Tomstown dolomite, along the west foot of the Blue Ridge, to the Athens and Chambersburg formations along Opequon Creek, on the northwest. A brief description of these rocks is given in Table 20.

The thick carbonate formations in the valley part of Clarke County occur as broad belts trending southwesterly, which are

TABLE 20.—*Summary of carbonate rocks in the Shenandoah Valley portion of Clarke County, Virginia*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Chambersburg and Athens	Chiefly shaly and cobbly weathering black limestone with thin beds of siltstone and shale. Chambersburg, with an estimated thickness of about 75 feet, is probably limited to the northern part of the county.	500±
Lenoir	Fine- to medium-grained, dark-gray limestone; commonly cherty. Locally, where free of chert, contains about 97 per cent calcium carbonate.	40–85
Mosheim	Compact, dove-gray, limestone; commonly impure in lower part. Sampled units contain from about 96 to 98 per cent calcium carbonate.	15–65

TABLE 20.—*Summary of carbonate rocks in the Shenandoah Valley portion of central Clarke County, Virginia—Continued*

FORMATION	CHARACTER	APPROXIMATE THICKNESS (Feet)
Beekmantown	Chiefly light bluish-gray limestone with minor amounts of magnesian limestone and dolomite; a few relatively thin high-calcium beds.	3000[a]
Chepultepec	Fine-grained, bluish-gray limestone. Sampled unit contains about 91 per cent calcium carbonate.	400±
Conococheague	Chiefly siliceous banded, bluish-gray limestone with minor amounts of dolomite and thin sandstone.	2500[a]
Elbrook and Waynesboro	Partly covered; chiefly a heterogeneous mixture of impure limestone and dolomite; Waynesboro also contains red and green shales and fine-grained sandstone.	4500[a]
Tomstown	Partly covered; chiefly fine- to medium-grained, light and dark-gray dolomite, with some limestone, dolomite, and thin silty beds in the lower part. Sampled units of light-gray and dark-gray dolomite contain from about 41 to 43 per cent magnesium carbonate.	1000–1500[a]

[a] Estimated.

locally modified by gently pitching folds producing sinuous boundaries (Pl. 19). The prevailing southeast dip of the beds over much of the area also indicates that there may be a number of minor folds or wrinkles overturned toward the northwest. Relatively thin belts of Ordovician limestone adjacent to the thick body of Martinsburg shale in the Massanutten Mountain syncline, near Opequon Creek, are intensely folded and locally disarranged by faulting (Pl. 19).

HIGH-CALCIUM LIMESTONE

In Clarke County high-calcium limestone occurs in the Mosheim, locally a part of the Lenoir, and in thin layers associated with magnesian limestone and dolomite in the Beekmantown formation. Field studies indicate that most probably there are no occurrences of high-calcium limestone in Clarke County that would warrant large-scale commercial development. One of the best exposures of the Mosheim limestone in northern Clarke County (Pl. 19, loc. 198) is given in the following section.

Geologic Section 121.—About 1000 feet south of State Highway 274 and 1½ miles southwest of Wadesville, Clarke County, Virginia

	Thickness Feet
Mosheim limestone (68 feet): strike N. 24° E.; dip 70° NW.	
2. Limestone, dove-gray, compact; SiO_2, 0.28; Fe_2O_3, 0.08; Al_2O_3, 0.90; $CaCO_3$, 96.78; $MgCO_3$, 1.12; total, 99.16	39
1. Limestone, gray, compact, impure; thin conglomerate at base	29
Beekmantown formation	

Farther northeast the Mosheim and Lenoir limestones are well displayed in a small area about 200 yards north of the crossing of Road 668 and the Baltimore and Ohio Railroad at Wadesville. This locality (Pl. 19, loc. 196) is of special interest, since the full thickness of the Lenoir here is high-calcium limestone, whereas the Mosheim is thin and impure.

Geologic Section 122.—About 200 yards north of Road 668 and 100 yards northwest of the Baltimore and Ohio Railroad at Wadesville, Clarke County, Virginia

	Thickness Feet
Lenoir limestone	
3. Limestone, dark-gray, medium grained; SiO_2, 0.40; Fe_2O_3, 0.08; Al_2O_3, 0.88; $CaCO_3$, 97.01; $MgCO_3$, 1.29; total, 99.66	85
Mosheim limestone (35 feet)	
2. Limestone, dove-gray, compact	20
1. Limestone, light-gray, compact, impure; yellowish weathering	15
Beekmantown formation	

Just south of the railroad and about 150 yards southeast of locality 196 the rocks exposed include about 50 feet of Lenoir limestone and 12 to 15 feet of impure Mosheim limestone. The continuity of the Mosheim-Lenoir belt is broken and the beds offset a

few feet by a small cross fault near locality 196, but details of such minor structures are not shown on the geologic map (Pl. 19). Along this belt about one-fourth of a mile south of the West Virginia line, the thickness of the Mosheim is estimated at 20 to 40 feet. The Mosheim along Road 668 about three-fourths of a mile southeast of Wadesville (Pl. 19, loc. 197) is 65 feet thick, the upper 30 feet apparently being high-calcium limestone.

In an area east of Opequon Creek and extending for about 1½ miles north and south of U. S. Highway 340, the Mosheim and Lenoir limestone belts are complicated by folding and faulting. At locality 199, along Road 660 and about one-fourth of a mile southeast of Glendale School, the thickness of the Mosheim is estimated at 20 feet. Except for a thin covered interval, it is overlain along the northwest side by shaly black Athens limestone. Cherty Lenoir limestone, so well displayed in a broad area (Pl. 19, loc. 200) along Marsh Run about 1½ miles southeast of Glendale School, was not observed at this locality. Similar relationships exist along U. S. Highway 340, about 1½ miles east of Opequon Creek, where about 30 to 40 feet of Mosheim is overlain by the Athens (Pl. 19, loc. 201).

The thickness of the Mosheim at several localities south of U. S. Highway 340 (Pl. 19, loc. 202) and in the general vicinity of the new location of U. S. Highway 50 (Pl. 19, loc. 204) is estimated to be between 15 and 30 feet. Although these exposures are inadequate for precise determination of thickness and for representative sampling, it is thought that there are no large deposits of high-calcium limestone in this area. One of the largest deposits of Mosheim limestone (Pl. 19, loc. 203) observed in Clarke County occurs along the northwest limb of a faulted syncline, east of the main outcrop belt, near Opequon Creek. The rocks exposed here are described in the following section.

Geologic Section 123.—Along Road 657 about 1½ miles east of Opequon Creek, Clarke County, Virginia

	Thickness Feet
Mosheim limestone: strike N. 25° E.; dip 30° SE.	
1. Limestone, dove-gray, compact; SiO_2, 0.16; Fe_2O_3, 0.08; Al_2O_3, 0.78; $CaCO_3$, 98.15; $MgCO_3$, 0.92; total, 100.09	45
Beekmantown formation	

Deposits of calcareous marl occur locally near Shenandoah River. One of these deposits (Pl. 19, loc. 216), at Calmes Neck about 2 miles east of Millwood, is being operated for agricultural lime.

IMPURE LIMESTONE

Impure limestone formations in Clarke County include the Chepultepec, the Lenoir at most localities, and the full thickness of the Athens and Chambersburg. Other relatively impure limestones which are interbedded with dolomites are described under "Limestone, magnesian limestone, and dolomite".

A belt of Chepultepec limestone enters Clarke County about 2 miles southeast of Swimley and extends southwestward across the county, passing about 1½ miles west of Berryville and Old Chapel, through Boyce, and through the southeastern environs of White Post. The width of the outcrop belt averages about 800 feet and the thickness is estimated to be about 400 feet.

The upper half of the Chepultepec, which crops out in a broad area about one mile southwest of Boyce (Pl. 19, loc. 209), contains 91.60 per cent calcium carbonate, 3.25 per cent magnesium carbonate, and 5.80 per cent silica (Table 21). Rock of a similar appearing character, although not sampled, is displayed at locality 208 about half a mile northeast of Boyce, and at locality 210 one mile southwest of White Post.

The Lenoir in Clarke County shows a wide variation in chemical composition, depending upon the amount of chert present. From the vicinity of Wadesville (Pl. 19, loc. 196) southwestward to locality 198, a distance of 1½ miles, the Lenoir apparently is practically free of chert. The full thickness of the formation, estimated at 85 feet at Wadesville, contains 97.01 per cent calcium carbonate (Table 21). All of the other exposures of the Lenoir in Clarke County which were examined contain relatively large quantities of chert. Localities where chert is particularly abundant are along Marsh Run (Pl. 19, loc. 200) about one mile southeast of Glendale School, in the small area north of U. S. Highway 340, and along an intensely folded belt extending about 2 miles southwest of the new location of U. S. Highway 50. The thickness of the Lenoir, except at a few exposures which may be thinned by faulting, appears to range from about 40 to 85 feet.

The rocks between the Lenoir and the Martinsburg consist chiefly of impure black limestones with minor shale partings and a

few interbedded siltstones. These impure rocks have been identified[10] as Athens in the southwestern part of the county and as Athens overlain by a thin occurrence of Chambersburg in the general area northeast of U. S. Highway 340. A description of the rocks which comprise the Athens and Chambersburg formations in the northwestern part of the county (Pl. 19, loc. 198) is given in the following section.

Geologic Section 124.—About 1000 feet south of State Highway 274 and 1½ miles southwest of Wadesville, Clarke County, Virginia

	Thickness Feet
Chambersburg limestone (75± feet)	
9. Limestone, black, nodular weathering	72
8. Siltstone, dark-gray; weathers brown; partly covered; lower boundary uncertain	3
Athens formation (455± feet)	
7. Limestone, shaly, cobbly weathering	16
6. Siltstone and shale	10
5. Limestone, black, irregularly bedded; brown partings	145
4. Limestone, black, buff weathering, cobbly	35
3. Limestone, black; shaly partings; a few feet of shaly siltstone at base	56
2. Limestone, black, cobbly weathering; shaly partings	47
1. Limestone, black, compact, thin bedded	146
Lenoir limestone	

Other fairly complete exposures of the impure Athens formation in Clarke County occur near Opequon Creek south of U. S. Highways 50 and 340.

HIGH-MAGNESIUM DOLOMITE

A part of the Tomstown in Clarke County contains more than 40 per cent magnesium carbonate and less than 4 per cent noncarbonates, thus it is considered a high-magnesium dolomite. The upper part of the Tomstown, in exposures 1½ miles northeast of Castleman Ferry Bridge (Pl. 19, loc. 211), along State Highway 7

about 3½ miles east of Berryville (Pl. 19, loc. 213), and at several places along Shenandoah River, particularly one mile west of Shepherd Ford (Pl. 19, loc. 215), is composed predominantly of fine-grained, light- to dark-gray dolomite. White to cream-colored dolomite, in part saccharoidal, was observed near the West Virginia line and along State Highway 7 about one-fourth of a mile west of Castleman Ferry Bridge. A few exposures of dark bluish-gray limestone, dark-gray dolomite, and thin silty beds, perhaps in the lower part of the Tomstown, were observed west of Parker Island, near the mouth of Shepherd Run, and along Road 605 south of Shepherd Ford.

The formation, although not fully exposed at any place in the county, is estimated to have a thickness of 1000 to 1500 feet. It is mapped (Pl. 19) as closely following Shenandoah River across Clarke County from the West Virginia line southwestward into Warren County. In Clarke County the general southwestward trend of the Tomstown belt locally is modified by minor folding which has produced a sinuous outcrop pattern. Dolomite in the upper part of the Tomstown, which is well displayed in the trough of a minor syncline in the northeastern part of Clarke County (Pl. 19, loc. 211), is described in the following section.

Geologic Section 125.—About one-fourth of a mile northwest of Shenandoah River and 1½ miles northeast of Castleman Ferry Bridge, Clarke County, Virginia

	Thickness Feet
Tomstown dolomite (upper part, 230 feet)	
3. Dolomite, light-gray to white, fine to medium grained; covered at top; SiO_2, 0.64; Fe_2O_3, 0.52; Al_2O_3, 0.28; $CaCO_3$, 54.82; $MgCO_3$, 43.74; total, 100.00	40
2. Dolomite, light- and bluish-gray, fine grained	40
Analysis of units 2 and 3, sampled thickness 80 feet: SiO_2, 1.54; Fe_2O_3, 0.44; Al_2O_3, 0.36; $CaCO_3$, 54.02; $MgCO_3$, 42.51; total, 98.87.	
1. Dolomite, dark-gray, fine grained; in part brecciated and veined with white dolomite; covered at base; SiO_2, 1.58; Fe_2O_3, 0.68; Al_2O_3, 0.64; $CaCO_3$, 54.22; $MgCO_3$, 42.53; total, 99.65	150

An analysis of a separate sample of units 2 and 3 in the above section shows a trace of sodium (Na_2O) and 0.25 per cent potassium (K_2O).

The occurrence of irregularly bedded chert in the upper part of the dolomite at the above locality is of interest. These resistant cherty beds, which resemble dense quartzite, can be traced along the crest of a low ridge for about one-fourth of a mile northeast of locality 211, and across a broad area one-fourth of a mile southwest of Cool Spring. Similar beds have not been observed at other localities in Clarke County. A part of the Tomstown dolomite is exposed near the crest of a broad anticline, pitching gently northward, crossing State Highway 7 about 3½ miles southeast of Berryville (Pl. 19, loc. 213).

Geologic Section 126.—About three-tenths of a mile north of State Highway 7 and 3½ miles southeast of Berryville, Clarke County, Virginia

	Thickness Feet
Tomstown dolomite (in upper part, 368 feet)	
4. Dolomite, bluish-gray, fine grained; partly covered	53
3. Dolomite, bluish-gray; gnarly weathering	34
2. Dolomite, white to light-gray and cream-colored, fine to medium grained; a few saccharoidal beds; SiO_2, 0.12; Fe_2O_3, 0.32; Al_2O_3, 0.08; $CaCO_3$, 57.02; $MgCO_3$, 42.45; total, 99.99	96
1. Dolomite, dark-gray; in part brecciated and veined with white dolomite; base covered	185

Other good exposures of light- to dark-gray dolomite in the upper part of the Tomstown were observed in a small abandoned quarry (Pl. 19, loc. 212) along State Highway 7 about 1½ miles northwest of Castleman Ferry Bridge. Because of the similarity of these rocks to those sampled at locality 213, no samples for analyses were taken here.

The finest continuous exposure of the upper part of the Tomstown dolomite observed in Clarke County is in a steep bluff along Shenandoah River, beginning 1½ miles southwest of Shepherd Ford and extending eastward for about 2200 feet (Pl. 19, loc. 215). Al-

though all of the beds along this traverse dip southeastward, the occurrence of Waynesboro shales and impure limestones and dolomites east and west of the Tomstown indicates a local anticlinal fold overturned in a northwest direction. Since the details of structure at this locality were not determined, the rocks are described in two geologic sections, each representing about half of the total exposure. The geologic sequence and character of the rocks in the western part of the exposure (Pl. 19, loc. 215) are as follows:

Geologic Section 127.—In north bluff of Shenandoah River, 1½ miles southwest of Shepherd Ford, Clarke County, Virginia

	Thickness Feet
Waynesboro formation (lower part, 275 feet)	
8. Dolomite, shaly, thin bedded; contorted	75+
7. Mostly covered; a few exposures of bluish-gray, fine-grained dolomite and magnesian limestone; conspicuous black chert near base	200±
Tomstown dolomite (upper part, 528 feet)	
6. Dolomite, light- and dark-gray, fine grained	94
5. Dolomite, white to light-gray, fine to medium grained; a few saccharoidal beds	148
Analysis of units 5 and 6, sampled thickness 242 feet: SiO_2, 1.50; Fe_2O_3, 0.44; Al_2O_3, 0.60; $CaCO_3$, 54.82; $MgCO_3$, 42.24; total, 99.60.	
4. Dolomite, light-gray, fine grained	28
3. Covered interval	27
2. Dolomite, dark-gray, medium grained	31
1. Partly covered; exposed beds light- and dark-gray dolomite; SiO_2, 0.96; Fe_2O_3, 0.56; Al_2O_3, 0.64; $CaCO_3$, 54.92; $MgCO_3$, 42.44; total, 99.52	200

The character and thickness of the rocks in the eastern part of the exposure, which probably represent a repetition by folding of approximately the same interval described in Geologic Section 127, are summarized below:

Geologic Section 128.—In north bluff of Shenandoah River, 1½ miles southwest of Shepherd Ford, Clarke County, Virginia

	Thickness Feet
Waynesboro formation (lower part)	
4. Dolomite and limestone, dark-gray, laminated; weathers shaly; contains black chert	50+
Tomstown dolomite (upper part, 589 feet)	
3. Dolomite, dark-gray, medium grained; SiO_2, 2.20; Fe_2O_3, 0.44; Al_2O_3, 0.78; $CaCO_3$, 54.63; $MgCO_3$, 41.52; total, 99.57	149
Dolomite, white to light-gray, fine to medium grained; a few saccharoidal beds; about 25 feet of dolomite near middle of unit contains abundant rounded quartz grains; SiO_2, 2.04; Fe_2O_3, 0.36; Al_2O_3, 0.70; $CaCO_3$, 54.72; $MgCO_3$, 42.00; total, 99.82	128
1. Partly covered; exposed beds light- and dark-gray, fine- to medium-grained dolomite; SiO_2, 1.76; Fe_2O_3, 0.36; Al_2O_3, 1.04; $CaCO_3$, 55.62; $MgCO_3$, 40.95; total, 99.73	312

Additional analyses from this exposure, representing units of approximately 200 feet, show from about 40 to 43 per cent magnesium carbonate. Another good display of 300 to 500 feet of light- to dark-gray dolomite in the upper part of the Tomstown occurs along Road 612 and Shenandoah River (Pl. 19, loc. 214), about three-fourths of a mile northwest of Shepherd Ford.

In summary, it is thought that there are large occurrences of dolomite along Shenandoah River in Clarke County which contain about 42 per cent magnesium carbonate.

LIMESTONE, MAGNESIAN LIMESTONE, AND DOLOMITE

The formations in Clarke County (Pl. 19) which are referred to under this heading include the Waynesboro, Elbrook, Conococheague, and Beekmantown. The Waynesboro is a heterogeneous formation, composed of clayey limestone, dolomite, fine-grained sandstone, and shale. The most distinctive criteria for the identification of the formation are red and green shales and shaly mudrock. Much of the lime-

stone and dolomite weathers to a yellowish ocherous rock. A few exposures of parts of the Waynesboro occur in a belt, approximately a mile in width, that extends southwestward through the eastern valley portion of Clarke County. Some of the most extensive exposures of the lower part of the formation occur in bluffs along large meanders of Shenandoah River west of Shepherd Ford and along Milldale Run in adjoining Warren County. Immediately succeeding the Waynesboro, but without sharp contact, is a thickness of about 2500 feet of chiefly impure shaly Elbrook limestone and dolomite. There are also a few thin layers of compact, dove-gray limestone interbedded with the more impure rocks.

The overlying Conococheague is predominantly banded, medium thick-bedded, bluish-gray limestone. Fine-grained dolomite layers occur, but perhaps constitute less than one-fifth of the full thickness. The most distinctive features of the Conococheague are thin bands of siliceous materials which weather out on the surface as crinkly ribs, and beds of coarse-grained friable sandstone distributed throughout the entire thickness estimated at about 2500 feet. The Conococheague, cropping out in a belt about 2 miles wide, extends southwestward through the central part of the valley crossing U. S. Highway 50 between Boyce and Millwood. Although exposures of the Waynesboro, Elbrook, and Conococheague are not adequate for a detailed description, it is thought that these formations in Clarke County do not contain quarriable thicknesses of either high-calcium limestone or high-grade dolomite.

The Beekmantown consists of light-gray limestone (Pl. 16C), with minor amounts of fine-grained, gray dolomite, and a few thin beds of high-calcium limestone. These rocks crop out in one belt in the western part of Clarke County that ranges in width from about 2 to 4 miles (Pl. 19). The thickness of the Beekmantown was determined from incomplete exposures west of White Post as about 4500 feet. Since this thickness is greater than any of the measurements in adjoining counties, it is most likely that a part of the formation is repeated by folding. Perhaps between 2500 and 3500 feet is a more reasonable estimate of the true thickness. Calculations based on several incomplete exposures between Wadesville and White Post indicate that the ratio of limestone to dolomite in the Beekmantown is about 4 to 1. The character and composition of prominent limestone zones in the upper part of the Beekmantown along Road 646 northwest of White Post (Pl. 19, loc. 205), and near the base of the formation along Road 639, about 3 miles north of Berryville (Pl. 19, loc. 207) are given in the following sections.

Geologic Section 129.—Along Road 646 about 1½ miles northwest of White Post, Clarke County, Virginia

	Approximate thickness (Feet)
Beekmantown formation (upper part, 180 feet)	
6. Limestone, light-gray; a few layers of magnesian limestone; SiO_2, 1.49; R_2O_3, 0.57; $CaCO_3$, 90.06; $MgCO_3$, 8.77; total, 100.89	40
5. Limestone, dove-gray, compact; sheared; SiO_2, 0.94; R_2O_3, 0.54; $CaCO_3$, 98.77; $MgCO_3$, 1.04; total, 101.29	20
4. Limestone with a few thin beds of dolomite; SiO_2, 2.31; R_2O_3, 1.00; $CaCO_3$, 80.83; $MgCO_3$, 14.89; total, 99.03	40
3. Dolomite, gray, fine grained; a few layers of limestone; SiO_2, 2.63; R_2O_3, 1.26; $CaCO_3$, 67.28; $MgCO_3$, 29.97; total, 101.14	20
2. Limestone, light-gray; a few thin layers of dolomite; SiO_2, 1.82; R_2O_3, 1.10; $CaCO_3$, 90.67; $MgCO_3$, 7.69; total, 101.28	20
1. Limestone, dove-gray, thin bedded; sheared; SiO_2, 0.94; R_2O_3, 0.51; $CaCO_3$, 97.43; $MgCO_3$, 3.29; total, 102.17	40

Geologic Section 130.—Along Road 639 about 3½ miles north of Berryville, Clarke County, Virginia

	Thickness Feet
Beekmantown formation (lower part, 600 feet)	
3. Limestone, light-gray, compact; a few impure beds; SiO_2, 5.32; Fe_2O_3, 0.32; Al_2O_3, 0.55; $CaCO_3$, 92.10; $MgCO_3$, 3.60; total, 101.89	300
2. Limestone, light-gray; a few impure beds; sheared; SiO_2, 4.37; Fe_2O_3, 0.95; Al_2O_3, 0.87; $CaCO_3$, 90.63; $MgCO_3$, 3.30; total, 100.12	150
1. Limestone with a few thin beds of dolomite; SiO_2, 8.55; Fe_2O_3, 0.56; Al_2O_3, 0.75; $CaCO_3$, 85.09; $MgCO_3$, 4.37; total, 99.32	150

Limestones occurring in the middle part of the Beekmantown are conspicuously displayed about three-fourths of a mile northwest of White Post. One limestone unit about 100 feet thick at this locality (Pl. 19, loc. 206) contains 92.17 per cent calcium carbonate, 2.08 per cent magnesium carbonate, and 4.52 per cent silica. The analyses given in Geologic Section 129 show that a part of the Beekmantown in Clarke County is composed of high-calcium limestone. The high-calcium limestones commonly occur as relatively thin units interbedded with magnesian limestone and dolomite. Sampled units, 50 feet or more thick, generally contain less than 95 per cent calcium carbonate.

TABLE 21.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Clarke County, Virginia (Pl. 19)*

(Froehling & Robertson, Inc., and John H. Yoe, Analysts)

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
196	122	3	Lenoir	85	97.01	1.29	0.40	0.08	0.88	99.66	About 200 yards north of Road 668 and 100 yards northwest of Wadesville.
198	121	2	Mosheim	39	96.78	1.12	0.28	0.08	0.90	99.16	About 1000 feet south of State Highway 274 and 1½ miles southwest of Wadesville.
203	123	1	Mosheim	45	98.15	0.92	0.16	0.08	0.78	100.09	Along Road 657 about 1½ miles east of Opequon Creek.
205	129	6	Beekmantown	40	90.06	8.77	1.49	0.57[a]		100.89	Along Road 646 about 1½ miles northwest of White Post.
		5		20	98.77	1.04	0.94	0.54[a]		101.29	
		4		40	80.83	14.89	2.31	1.00[a]		99.03	
		3		20	67.28	29.97	2.63	1.26[a]		101.14	
		2		20	90.67	7.69	1.82	1.10[a]		101.28	
		1		40	97.43	3.29	0.94	0.51[a]		102.17	
206			Beekmantown	100	92.17	2.08	4.52	0.12	0.86	99.75	About 1000 feet north of State Highway 277, three-fourths of a mile northwest of White Post.

[a] Reported as R_2O_3.

TABLE 21.—*Analyses of limestones and dolomites in the Shenandoah Valley portion of Clarke County, Virginia (Pl. 19)—Continued*

Locality	Geologic Section		Name	Thickness Sampled (Feet)	Chemical Composition						General Location
	No.	Unit			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total	
207	130	3	Beekmantown	300	92.10	3.60	5.32	0.32	0.55	101.89	Along Road 639 about 3½ miles north of Berryville.
		2		150	90.63	3.30	4.37	0.95	0.87	100.12	
		1		150	85.09	4.37	8.55	0.56	0.75	99.32	
209			Chepultepec	125	89.77	3.53	6.67	0.41	0.94	101.32	About 1000 feet south of State Highway 12 and 1 mile southwest of Boyce.
				125	93.43	2.97	4.94	0.54	0.29	102.17	
211	125	3	Tomstown	40	54.82	43.74	0.64	0.52	0.28	100.00	One-fourth of a mile northwest of Shenandoah River, 1½ miles northeast of Castleman Ferry bridge.
		2–3		80	54.02	42.51	1.54	0.44	0.36	98.87	
		1		150	54.22	42.53	1.58	0.68	0.64	99.65	
213	126	2	Tomstown	96	57.02	42.45	0.12	0.32	0.08	99.99	About three-tenths of a mile north of State Highway 7 and 3½ miles southeast of Berryville.
215	127	5–6	Tomstown	242	54.82	42.24	1.50	0.44	0.60	99.60	In north bluff of Shenandoah River about 1½ miles west of Shepherd Ford.
		1		200	54.92	42.44	0.96	0.56	0.64	99.52	
	128	3		149	54.63	41.52	2.20	0.44	0.78	99.57	
		2		128	54.72	42.00	2.04	0.36	0.70	99.82	
		1		312	55.62	40.95	1.87	0.36	1.04	99.73	

BIBLIOGRAPHY

1. Bassler, R. S., The cement resources of Virginia: Virginia Geol. Survey Bull. 2-A, pp. 92-93, 1909.

2. Bowles, Oliver, and Banks, D. M., Limestone: U. S. Bur. Mines Inf. Cir. 6723, pp. 7-11, 1933.

3. ————, and Jensen, M. S., Stone, *in* Minerals Yearbook, 1943, U. S. Bur. Mines, p. 1306, 1945.

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

5. ————, Geology of the Appalachian Valley in Virginia: Virginia Geol. Survey Bull. 52, pt. 1, p. 63, 1940.

6. ————, Idem, pp. 110-111.

7. ————, Idem, p. 114.

8. ————, Idem, pp. 443-445, 451-453.

9. ————, Manuscript geologic map of parts of the Luray and Woodstock quadrangles, in files of Virginia Geological Survey.

10. ————, Unpublished manuscript on Clarke County, Virginia, in files of Virginia Geological Survey.

11. King, Philip B., Manganese deposits of the Elkton area, Virginia: U. S. Geol. Survey Bull. 940-B, pl. 4, 1943.

12. ————, Idem, p. 20.

13. Lamar, J. E., and Willman, H. B., A summary of the uses of limestone and dolomite: Illinois State Geol. Survey Rept. Inv. no 49, 50 pp., 1938.

14. Moyer, Forrest T., and Gradijan, F. D., Lime, *in* Minerals Yearbook, 1943, U. S., Bur. Mines, p. 1359, 1945.

15. Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, fig. 1, 1919.

16. ————, Idem, pl. 3.

17. Stose, G. W., Geography, *in* Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 6-7, 1922.

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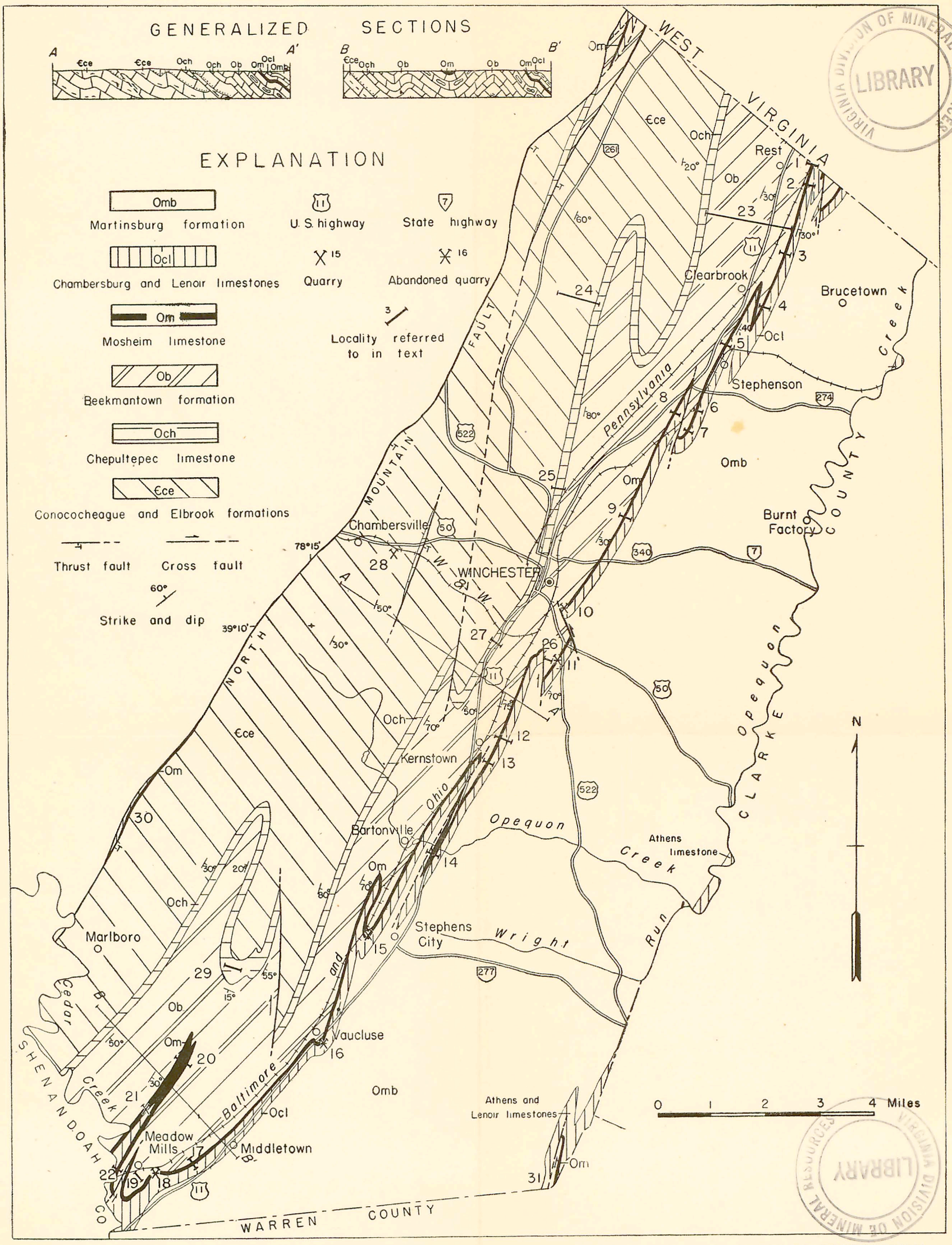
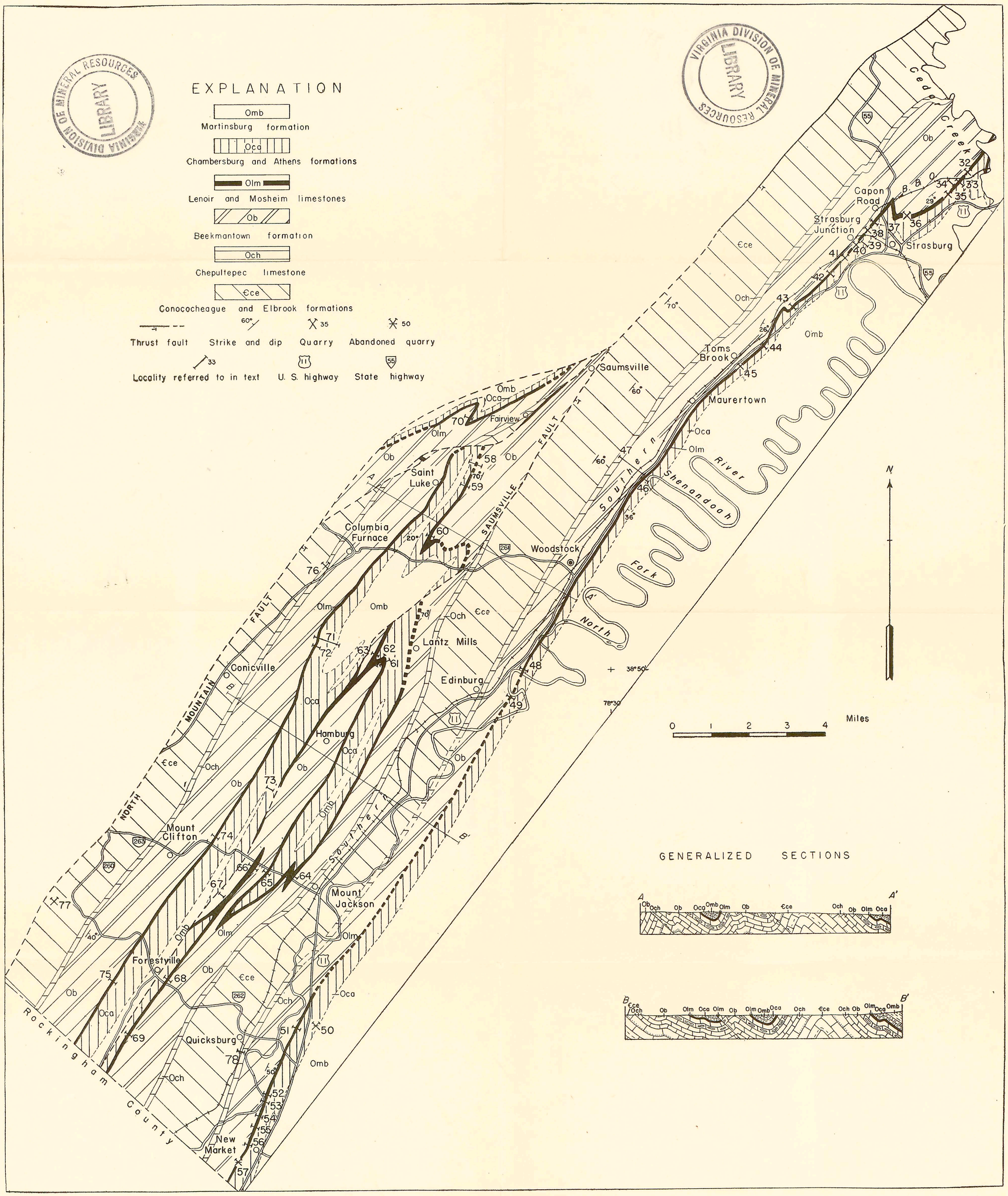


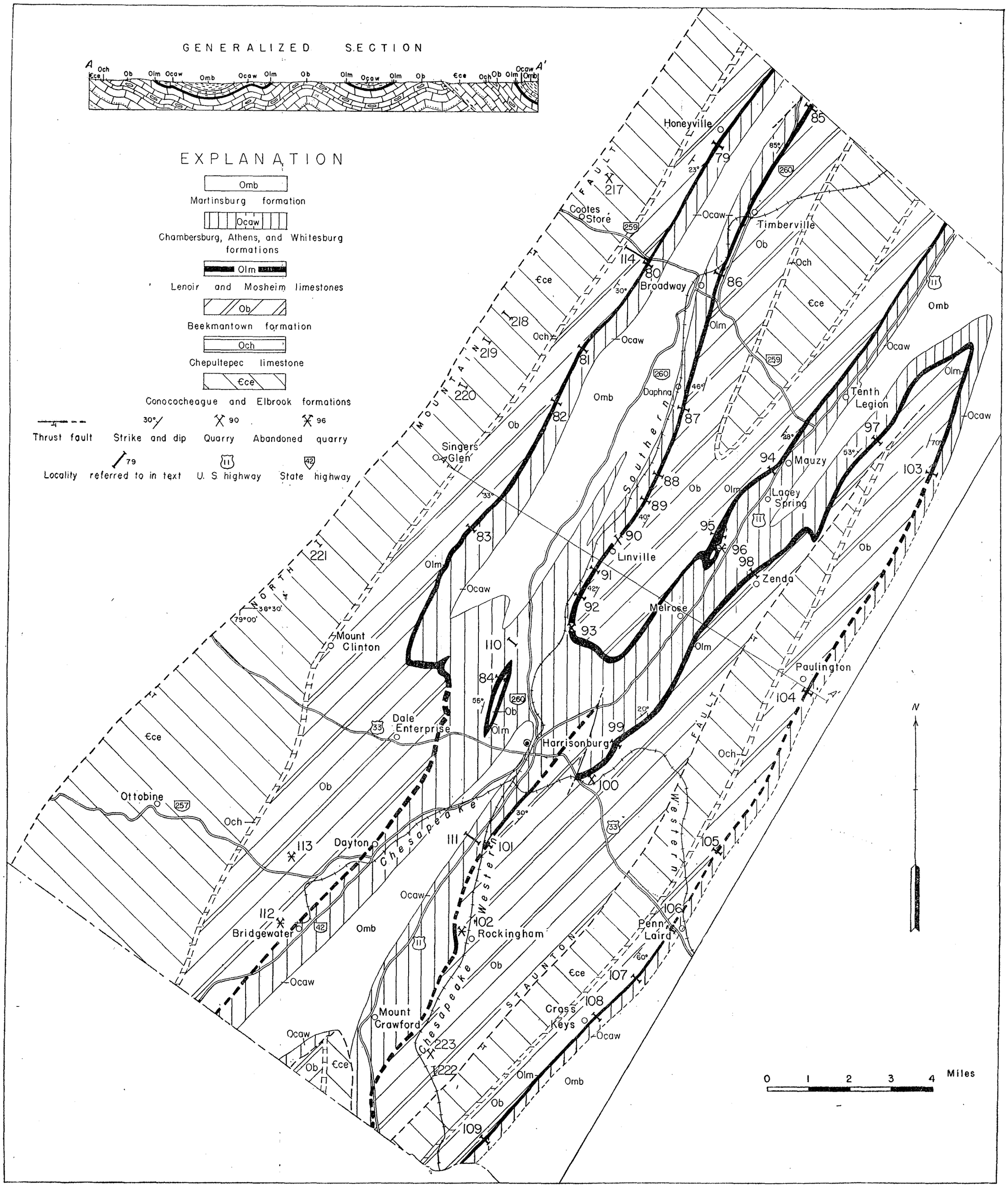
GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF FREDERICK COUNTY, VIRGINIA.

Geology compiled from manuscript geologic maps by Charles Butts and R. S. Edmundson (in files of Virginia Geological Survey). Base from Virginia State Planning Board map of Frederick County, and U. S. Geological Survey topographic maps of the Gerrardstown, Middletown, and Winchester quadrangles.



GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF SHENANDOAH COUNTY, VIRGINIA.

Geology south of Strasburg modified from Geologic map of the Appalachian Valley of Virginia by Charles Butts: Virginia Geol. Survey Bull. 42, 1933. Geology north of Strasburg compiled from manuscript geologic maps by Charles Butts and R. S. Edmundson (in files of Virginia Geological Survey). Base from Virginia State Planning Board map of Shenandoah County, and U. S. Geological Survey topographic maps of the Luray, Middletown, and Woodstock quadrangles.



GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF CENTRAL ROCKINGHAM COUNTY, VIRGINIA

Geology modified from Geologic map of the Appalachian Valley of Virginia by Charles Butts: Virginia Geol. Survey Bull. 42, 1933. Base from Virginia State Planning Board map of Rockingham County, and U. S. Geological Survey topographic maps of the Harrisonburg, Staunton, and Woodstock quadrangles.

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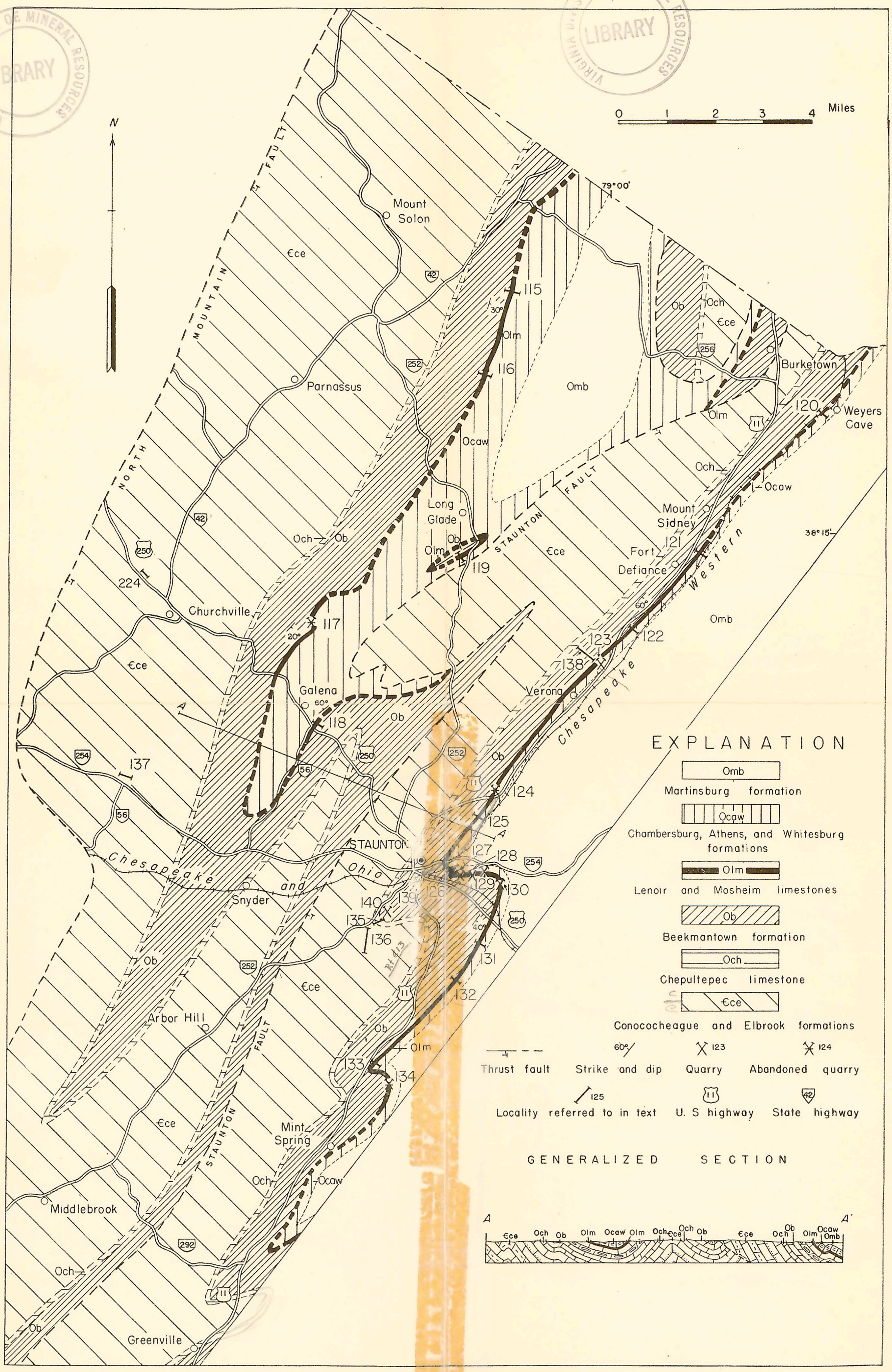

GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF CENTRAL AUGUSTA COUNTY, VIRGINIA.

Geology modified from Geologic map of the Appalachian Valley of Virginia by Charles Butts: Virginia Geol. Survey Bull. 42, 1933. Base from Virginia State Planning Board map of Augusta County, and U. S. Geological Survey topographic maps of the Harrisonburg, Staunton, and Waynesboro quadrangles.

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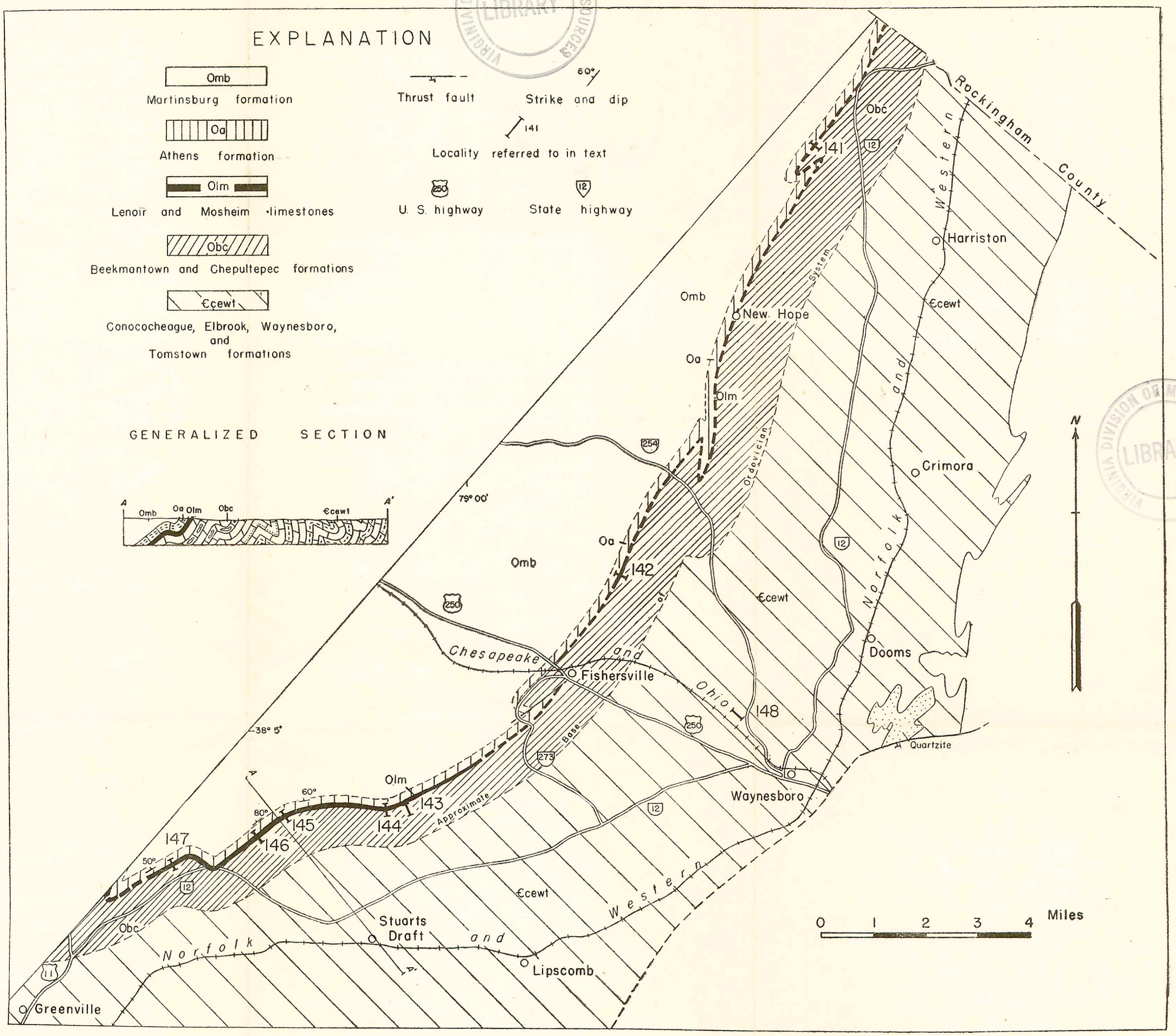
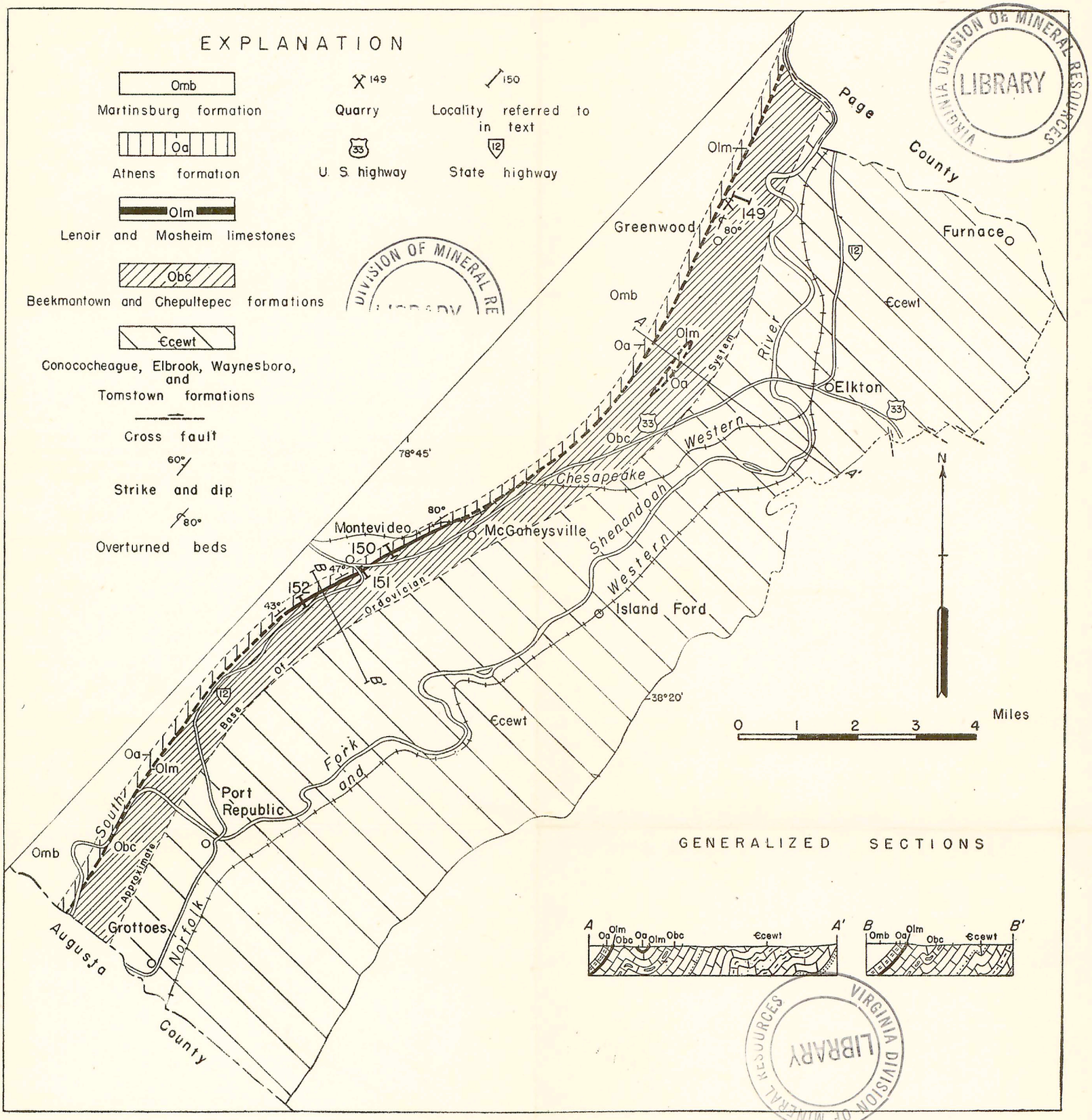


GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF EASTERN AUGUSTA COUNTY, VIRGINIA.

Geology modified chiefly from Geologic map of the Appalachian Valley of Virginia by Charles Butts: Virginia Geol. Survey Bull. 42, 1933. Eastern boundary of carbonate rocks sketched from Geologic map of a portion of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, Pl. 3, 1919. Base from Virginia State Planning Board map of Augusta County, and U. S. Geological Survey topographic maps of the Harrisonburg, Staunton, and Waynesboro quadrangles.



GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF EASTERN ROCKINGHAM COUNTY, VIRGINIA.

Geology modified chiefly from Geologic map of the Appalachian Valley of Virginia by Charles Butts: Virginia Geol. Survey Bull. 42, 1933. Eastern boundary of carbonate rocks north of parallel 38°20′ sketched from Geologic map of the Elkton area, Virginia: U. S. Geol. Survey Bull. 940-B, Pl. 4, 1943; boundary to the southwest sketched from Geologic map of a portion of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, Pl. 3, 1919. Base from Virginia State Planning Board map of Rockingham County, and U. S. Geological Survey topographic maps of the Elkton and Harrisonburg quadrangles.

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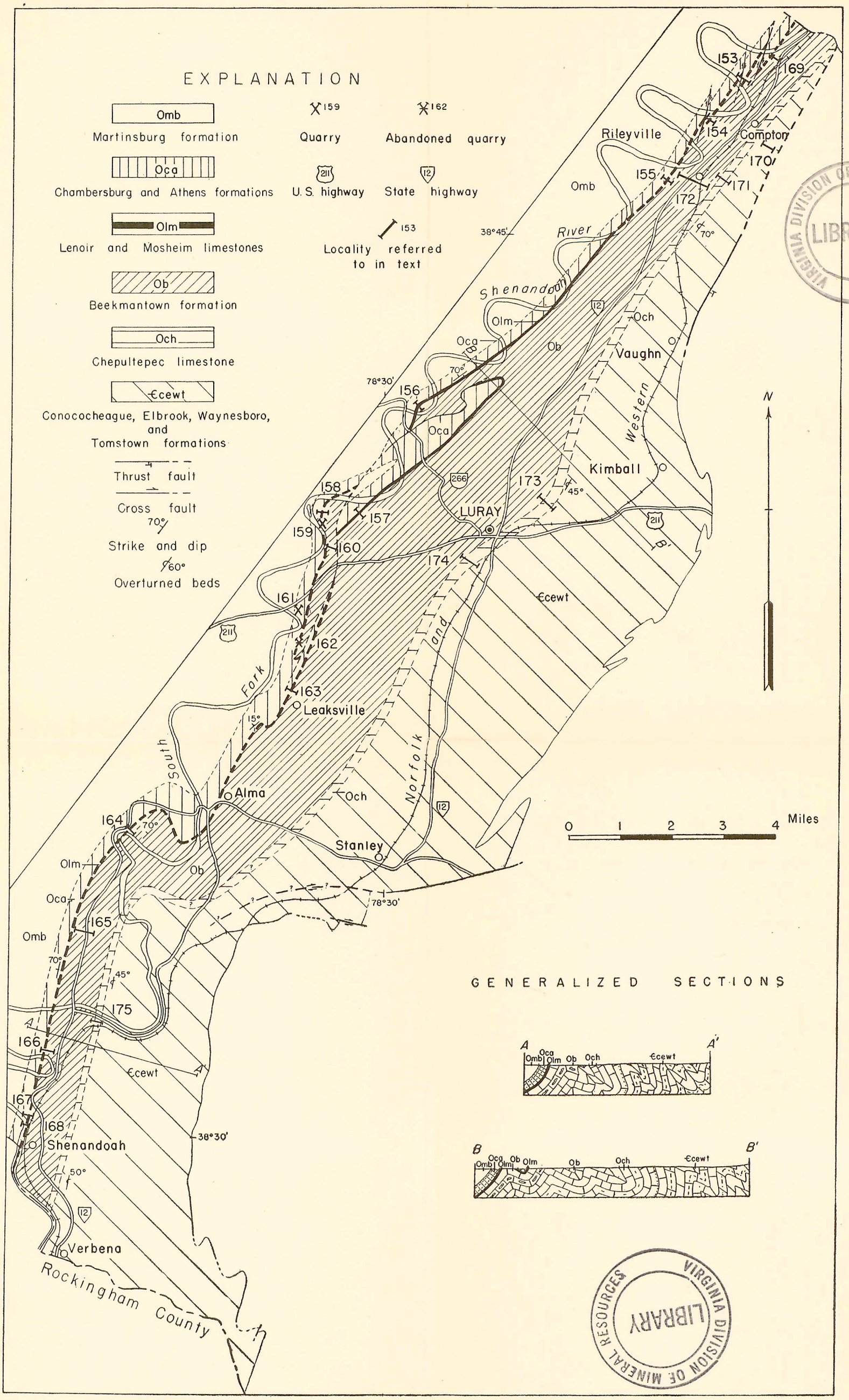
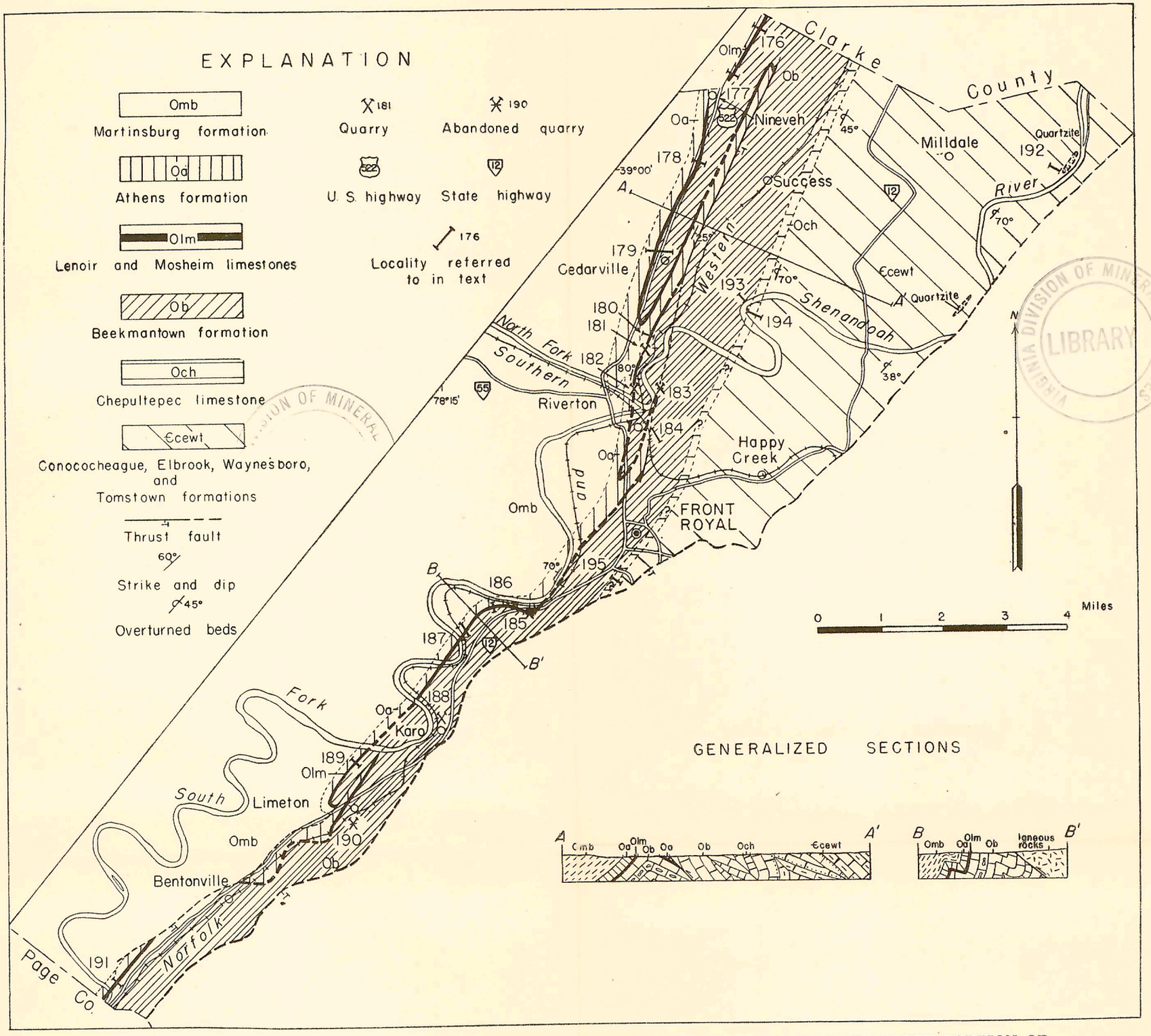


GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF PAGE COUNTY, VIRGINIA.

Geology south of parallel 38°45′ and east of meridian 78°30′ modified from manuscript geologic map of the Stony Man quadrangle by H. P. Woodward (in files of the Virginia Geological Survey). Eastern boundary of carbonate rocks south of Stanley sketched from Geologic map of the Elkton area, Virginia: U. S. Geol. Survey Bull. 940-B, Pl. 4, 1943. Base from Virginia State Planning Board map of Page County, and U. S. Geological Survey topographic maps of the Elkton, Luray, and Woodstock quadrangles.



GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF WARREN COUNTY, VIRGINIA.

Geology south of Milldale modified from Geologic map of the Appalachian Valley of Virginia by Charles Butts: Virginia Geol. Survey Bull. 42, 1933. Geology north of Milldale compiled from manuscript geologic maps by Charles Butts and R. S. Edmundson (in files of the Virginia Geological Survey). Base from Virginia State Planning Board map of Warren County, and U. S. Geological Survey topographic maps of the Front Royal, Luray, and Winchester quadrangles.

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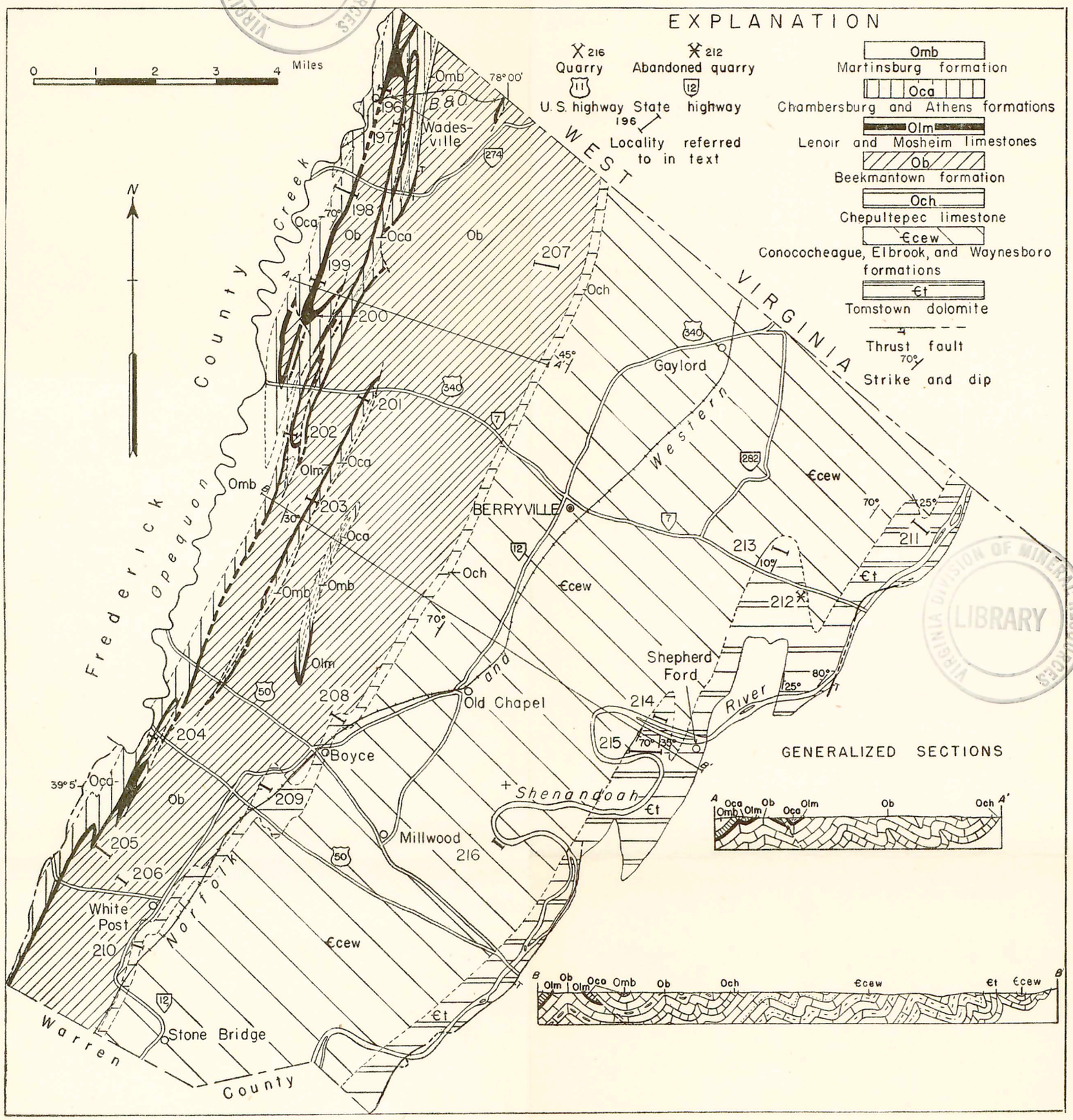

GEOLOGIC MAP SHOWING LIMESTONE AND DOLOMITE RESOURCES IN THE SHENANDOAH VALLEY PORTION OF CLARKE COUNTY, VIRGINIA.

Geology compiled mainly from manuscript geologic maps by Charles Butts and R. S. Edmundson (in files of Virginia Geological Survey). Southeastern boundary of carbonate rocks from manuscript geologic map by G. W. Stose and Anna Jonas Stose (in files of Virginia Geological Survey). Base from Virginia State Planning Board map of Clarke County, and U. S. Geological Survey topographic maps of the Berryville and Winchester quadrangles.