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

Bulletin 62

Industrial Limestones and Dolomites in Virginia: New River-Roanoke River District

By

BYRON N. COOPER

VIRGINIA
DIVISION OF MINERAL RESOURCES
P. O. Box 3667
Charlottesville, Va. 22903

UNIVERSITY, VIRGINIA
1944

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Division of Purchase and Printing
Richmond
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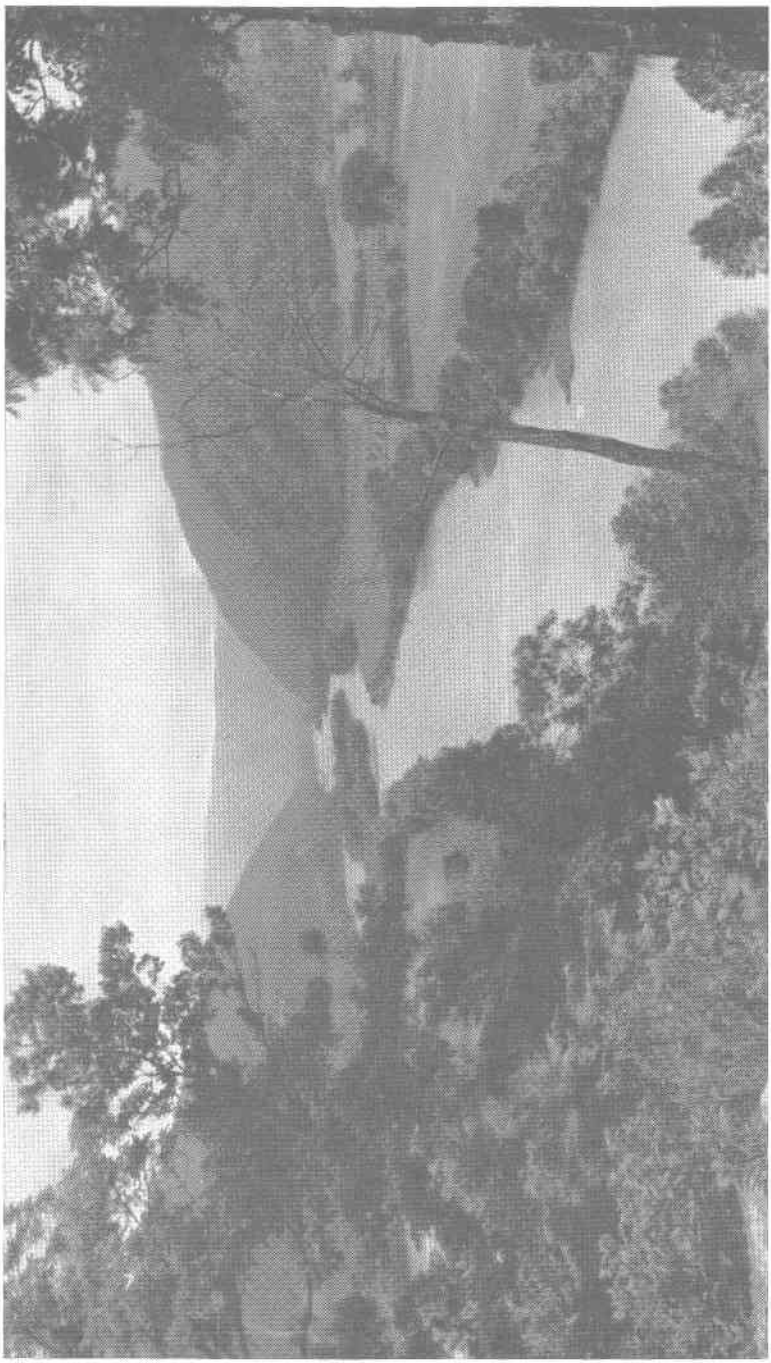
The Narrows of New River, Giles County, Virginia. Photograph by Arthur Bevan.



The Narrows of New River, Giles County, Virginia. Photograph by Arthur Bevan.

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COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., May 1, 1944.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit for publication as Bulletin 62 of the Virginia Geological Survey, the text and illustrations of a report on *Industrial Limestones and Dolomites in Virginia: New River-Roanoke River District,* by Dr. Byron N. Cooper, Associate Geologist of the Virginia Geological Survey.

This report is the first in a series on the limestones and dolomites of present and potential industrial value in the State. As investigations in progress are completed, other reports in the series will be issued until all of the industrial limestones and dolomites in Virginia have been described.

Bulletin 62 contains a discussion of the industrial limestones and dolomites in nine areas in the district embraced in the New River and Roanoke River drainage systems and served mainly by the Norfolk and Western and Virginian railroads. Those areas are in Giles, Montgomery, Roanoke, and Botetourt counties. Geologic data pertinent to the industrial use of these rocks are given, but data chiefly of scientific interest have been excluded. The essence of the report is in the measured geologic sections and the chemical analyses of carefully selected field samples.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, May 9, 1944.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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Industrial Limestones and Dolomites in Virginia: New River-Roanoke River District

By Byron N. Cooper

ABSTRACT

Between the West Virginia line and the west foot of the Blue Ridge, large, undeveloped deposits of high-calcium limestone and high-magnesium dolomite occur along or near the main lines of the Norfolk and Western Railway and the Virginian Railway.

Favorable quarry sites were determined by detailed study of exposed rocks, by chemical analyses of carefully collected samples of rock, and by geologic mapping. The report includes maps showing the distribution of the rocks, active and abandoned quarries, and other localities studied in detail, and numerous geologic sections showing the character and attitude of the beds and the chemical composition of the more important units. Tonnage estimates of the amount of recoverable rock above drainage are given for the most important localities.

The Giles County and Catawba Valley areas contain a number of favorable sites for large-scale quarrying or mining of high-calcium limestone. One large deposit of high-magnesium dolomite and several smaller deposits were found in Giles County. Several excellent quarry sites, where crushed stone and allied products could be produced, were found in Montgomery, Giles, and Botetourt counties.

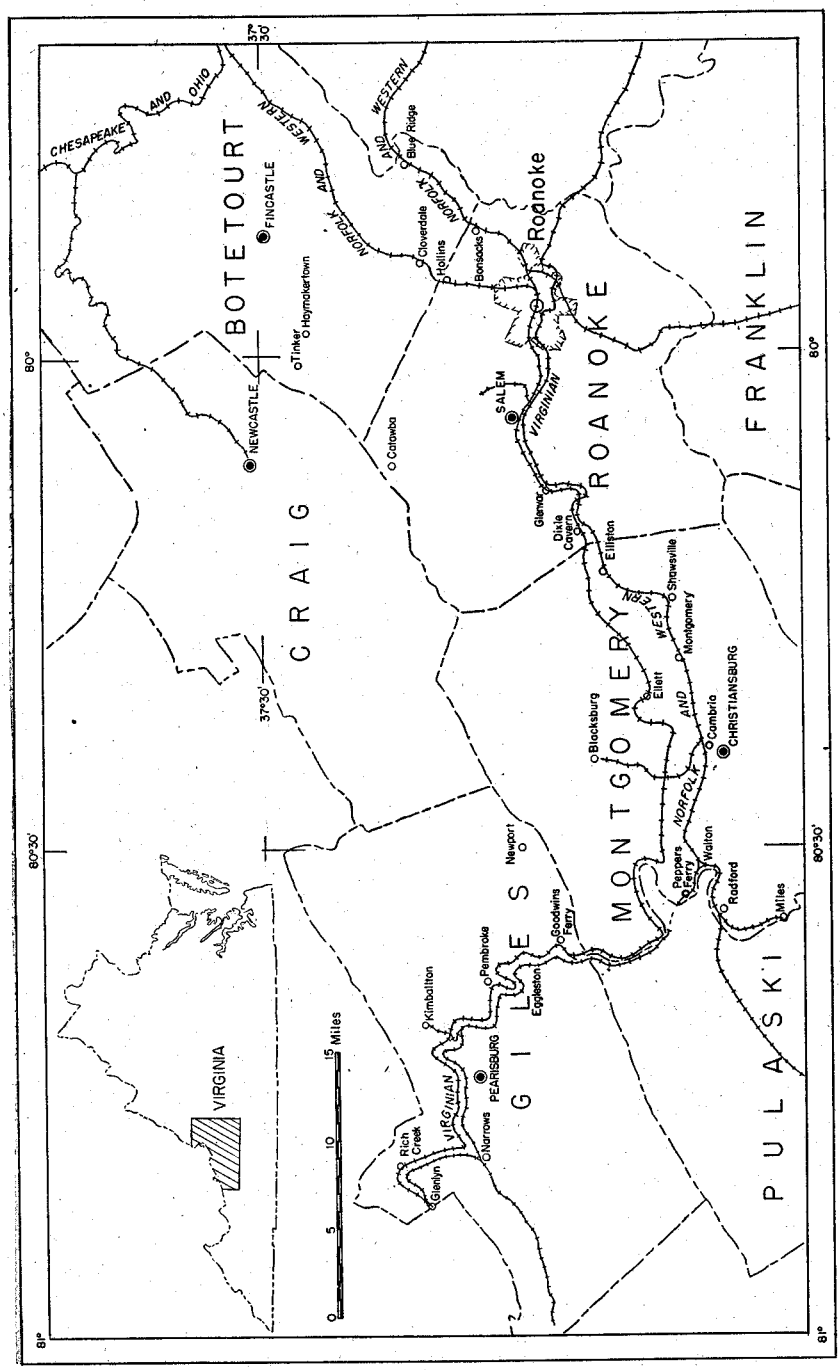


FIGURE 1.—Index map showing location of railroads and the principal towns and cities in the Roanoke River-New River district.

INTRODUCTION

LOCATION OF THE DISTRICT

The district described in this report (Fig. 1) is situated in the Appalachian Valley and Ridge province, mainly in the drainage basins of New and Roanoke rivers. Together, these rivers provide water-level routes for two main-line railroads crossing the Appalachian Valley—the Norfolk and Western from Cincinnati, Ohio, to Norfolk, Virginia, and the Virginian Railway between Deepwater, West Virginia, and Norfolk. Most parts of the district are relatively close to all-weather roads. U. S. Routes 11 and 460 provide ready access to the eastern part of the district, and State Highway 8 between Christiansburg and Narrows serves the area in the New River basin. Two areas in the district are located several miles from the main railroads: one along a spur line of the Norfolk and Western, about five miles south of Radford, Montgomery County; the other in Catawba Valley between Catawba Sanatorium and Haymakertown.

The principal towns and villages along the main lines of the railroads are shown in Figure 1. From this index map, the relative locations of the areas shown on Plates 3, 8, 11 and 12 and Figures 4, 6, 9, 10 and 14 can be determined. The Bristol Branch of the Norfolk and Western Railway, which extends southwest to the Virginia-Tennessee line, joins the main line of the railroad at Walton Junction, Montgomery County. The Shenandoah Valley Division, which joins the main line of the Norfolk and Western Railway in Roanoke, provides rail connections with the northern part of the Appalachian Valley.

PURPOSE OF THE REPORT

This report is intended to furnish accurate information on the location, thickness, character and chemical composition of available deposits of industrial limestone and dolomite. Its main purpose is to facilitate utilization of these rocks, particularly the premium grades of limestone and dolomite, which are sufficiently pure to be used in chemical industries.

In the time available for field work, only the more important areas could be studied in detail, and in these areas only the calcareous rocks in representative localities were studied and sampled.

All statements concerning the availability of estimated quantities of rock for quarrying or mining are based wholly on surface observations. They are necessarily based on the assumption that the structure, thickness, and character of the rocks observed at the surface persist to considerable depth. Only by core drilling can the precise character of the buried rocks be determined. Although specific data are given for representative localities, this report is necessarily general in scope. Property ownership is not discussed, since in most instances the occurrences of workable bodies of limestone and dolomite are not as localized as those of many mineral deposits.

ACKNOWLEDGMENTS

The general distribution of the various rock formations in this part of the State is shown on the Geologic map of the Appalachian Valley of Virginia.[2]* Most of the area east of Christiansburg and Ellett has been mapped by Woodward.[15] Both of these maps were useful in this investigation. The writer has used also a manuscript map by A. A. L. Mathews showing the distribution of the rocks in Giles County, Virginia, which is in the files of the Virginia Geological Survey. The distribution of the dolomite and shale belts and of the Mississippian limestone and the locations of major faults shown on Plate 3, are taken from Mathews' manuscript map, but the Ordovician limestone belts were mapped independently.

The writer appreciates the friendly assistance rendered by various persons, particularly quarry operators who furnished information on the various uses for limestone and dolomite quarried in this district. Special thanks are given to Dr. R. S. Edmundson, also of the Virginia Geological Survey, for numerous helpful suggestions during the preparation of the report.

FIELD WORK

The field work was done jointly with Dr. R. S. Edmundson. The report, including the maps and geologic sections, was prepared by the writer.

Much of this report is based on chemical analyses of the limestones and dolomites. In order to insure that the rock samples for chemical analysis were representative, they were collected with special care. Wherever possible, small fresh chips about 1 inch

*References are listed at the end of the report.

across were obtained at stratigraphic intervals of 1 foot or less. Impure partings between relatively pure beds were included in the samples. The quantity of chips collected varied with the thickness of the sampled beds; the average was about 5 pounds for most of the samples and 5 to 10 pounds for those which were to be analyzed also for soda and potash. All of the samples were analyzed by Froehling and Robertson, Inc., Richmond.

RELIEF AND DRAINAGE

New River, which enters the Appalachian Valley near Austinville, Wythe County, Virginia, flows northwest across many alternate valleys and ridges and leaves the State near Glenlyn, Giles County. This river is entrenched 200 to 400 feet below a broad gently rolling upland which is underlain chiefly by limestone and dolomite. The bluffs along New River (Pls. 4B, 5B) afford some of the finest and most nearly complete exposures of sedimentary rock in the Appalachian region. Exceptionally large amounts of "dry rock" are therefore available for quarrying. Indeed, the gorge of New River affords more large quarry sites than are found in any area of similar extent elsewhere in the State.

Some of the moderately large tributaries of New River, such as Sinking Creek, become "lost streams" before reaching New River, which indicates considerable depth of the water table below the general level of the upland. The topography of the New Valley in Giles County is well shown on the topographic maps of the Narrows and Pearisburg quadrangles, which were used as the base map for Plate 3.

In contrast to the broad upland of the valley of New River, all the drainage area of Roanoke River is deeply and intricately dissected into a maze of hills, particularly between Christiansburg and Salem. Although stream dissection is further advanced than along the valley of New River, there are countless hills suitable for large quarrying operations. Near Roanoke, the Roanoke Valley widens into a broad oval lowland, encompassed by the Blue Ridge, Tinker Mountain, and Short Ridge north of Salem. Because of the low relief in the vicinity of Roanoke, the bedrock is very poorly exposed.

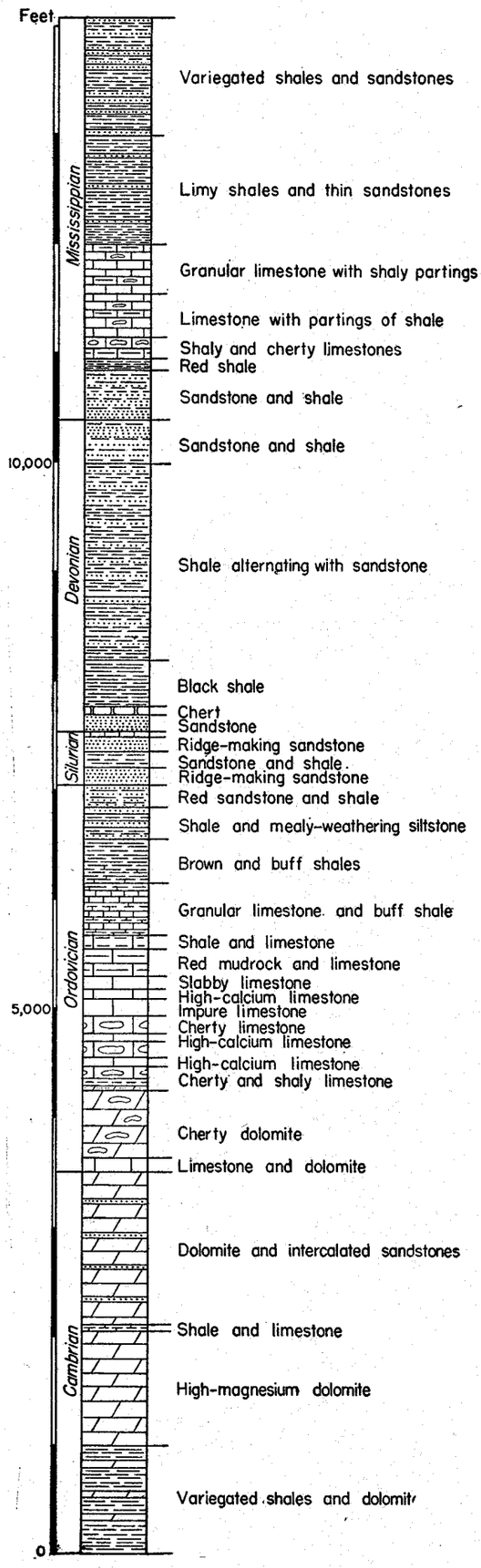
Catawba Valley (Pl. 13), which includes one of the most important areas discussed in this report, is tributary to James River.

GEOLOGY

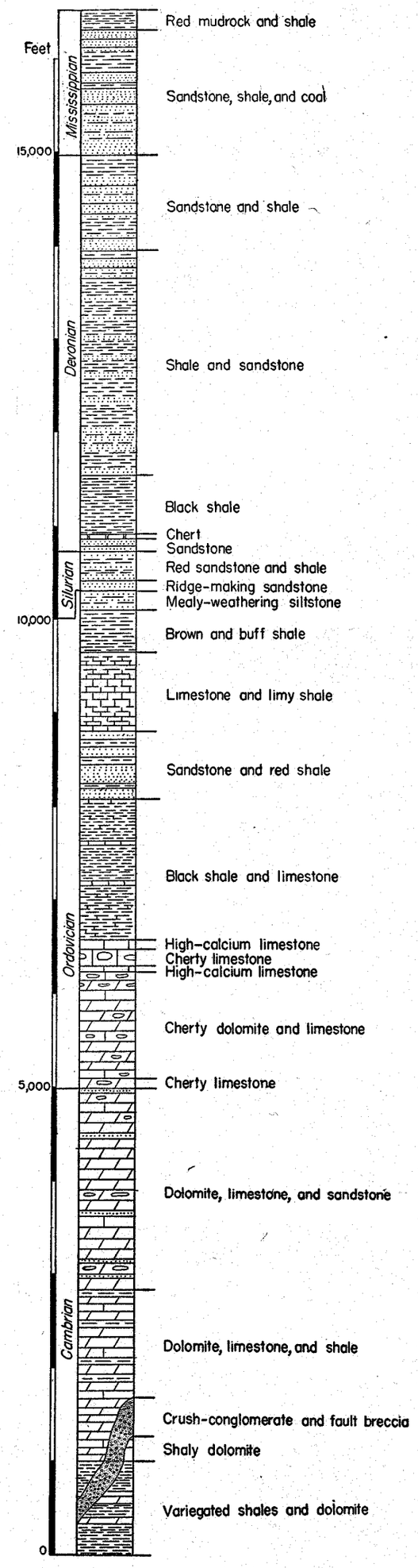
The limestones and dolomites discussed in this report comprise only about one-fourth of the total thickness of exposed rocks, nearly all of which accumulated as sediments in ancient seas covering much of the eastern part of North America during the Paleozoic era. Such an origin is indicated by the abundant and widespread occurrence of such shallow-water depositional features as ripple marks, mud cracks, and cross bedding. Most, if not all, of the sediments were deposited in water considerably less than a few hundred feet deep. The sea bottom must have subsided at about the same rate as the sediment accumulated, because at least 17,000 feet of sedimentary rock was laid down in shallow water by more or less continuous deposition (Pl. 2).

Toward the close of the Paleozoic era, the thick mass of sedimentary rocks which had been deposited in the eastern part of the Paleozoic inland sea was folded during intense crustal movements which elevated the Appalachian region far above sea level and above the surrounding lands. Thereupon, the Appalachian region began to undergo erosion. During the period of deformation, the thick mass of sedimentary rock was broken along several great faults. Enormous slices or blocks of strata, overlapping each other like shingles on a roof, were thrust northwestward, some for many miles. Prior to overthrusting and also during displacement of the fault blocks, the beds were folded, crumpled, jointed, and fractured. The district discussed in this report contains at least five great overthrust blocks, four of which are well exposed along New River. Their bounding faults—from northwest to southeast, the St. Clair, Narrows, Saltville, and Pulaski overthrusts—are better exposed along New River than elsewhere in the Appalachian Valley of Virginia.

Folding has caused the rock formations, originally deposited as horizontal layers of sediment, to dip at various angles and to be repeated in several belts (geologic section 15). The slow but inexorable work of erosion has resulted in the development of an erosion surface which truncates dipping beds of different resistance. Late in the geologic past, New River developed a rather broad rolling plain on the belts of softer rock. Since that time the region has been uplifted so that the river has entrenched its course a few hundred feet below the general level of its old valley floor.



A, Generalized columnar section for Giles County, Va.



B, Generalized columnar section for the eastern part of the district in Montgomery, Roanoke, and Botetourt counties, Virginia.

In most sections of the Appalachian Valley, the folds and faults in the strata can be ascertained only by detailed field study but along New River the structure of the rock is an "open book." The St. Clair fault is exceptionally well exposed along State Highway 8 in The Narrows of New River in Giles County (Pl. 3). Along this fault, Lower Ordovician dolomite has been thrust upward and northwestward onto Upper Devonian shale. The thickness of the beds which normally intervene between the two formations there observed in juxtaposition is about 6,500 feet (Pl. 4A). A natural cross section of one of the major folds of this district is displayed along the river bluffs in the vicinity of Ripplemead. The bottom, or trough, of the synclinal fold is shown in the quarry of the Ripplemead Lime Company.

The gentle inclination of the bedding, shown on the quarry floor, indicates the northeast pitch of the syncline. North of the bridge, both bluffs show a thick succession of limestone and dolomite dipping beneath the quarry beds. The same succession of limestone and dolomite crops out along the river south of the bridge but dips northwest.

In much of the Roanoke Valley and eastward to Blue Ridge Station on U. S. Route 460, the main streams and railroads roughly parallel the strike of the beds, and there are no continuous exposures of a great thickness of rock, such as occur in Giles County. The rocks comprising the Pulaski overthrust block seem to have been subjected to the greatest deformation. Close to this fault, the beds are exceedingly crumpled, sheared and somewhat metamorphosed. Localized zones in these overriding beds have been crushed, dismembered and rolled out along the fault zone to produce a peculiar type of rock composed of angular to rounded masses of shale and dolomite, which are set in a matrix of finely ground rock.

Near Roanoke, the formations underlying the broad valley floor are mostly concealed beneath a thick cover of mantle rock. According to Woodward[16] the rocks upholding the Blue Ridge and forming the southern border of the district are part of an overthrust mass composed of Lower Cambrian and pre-Cambrian rocks. The trace of this overthrust is believed to be along the west base of the Blue Ridge. Local details of the structures southeast of Giles County are described by Butts[6], Campbell and Holden[10], and Woodward[18].

STRATIGRAPHY

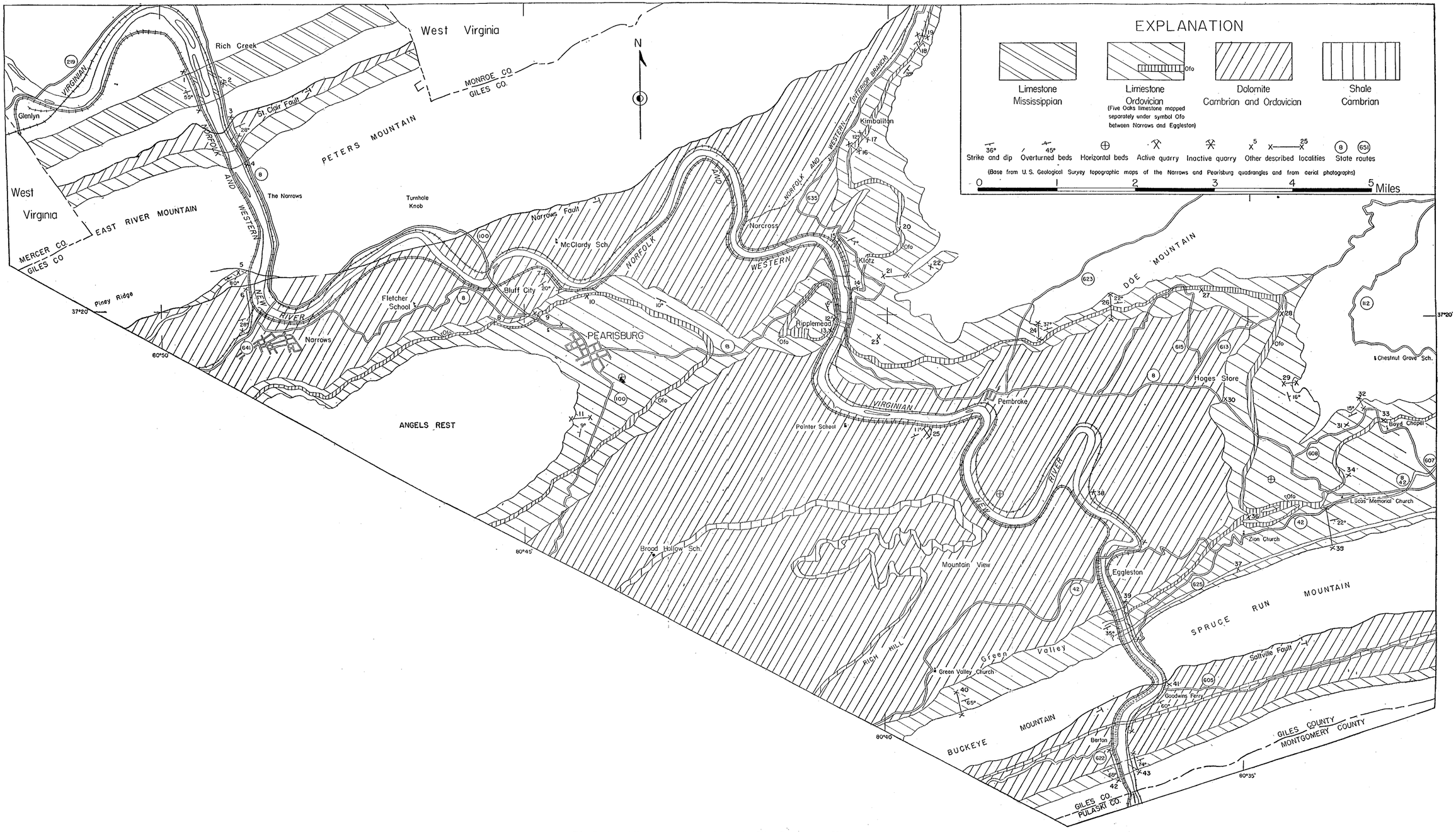
GENERAL FEATURES

The oldest formation, the Rome, is exposed only in the area east of Christiansburg. It is Lower and Middle Cambrian, but is not the oldest sedimentary rock in the Appalachian Valley. In many places along the foot of the Blue Ridge, the Rome formation overlies 1,000 feet or more of pure dolomite, the Shady formation. The Shady is in turn underlain by several thousand feet of sandstone, quartzite, conglomerate, and shale, comprising the initial clastic series of sediments deposited in the Appalachian sea which flooded much of the eastern part of North America at the beginning of the Paleozoic era. In this district the Shady is confined to local areas south of Roanoke but is too poorly exposed to be studied or sampled. The details of its distribution there are unknown.

Above the Rome is a succession of beds with a total thickness of 3,500 to 4,500 feet, composed mainly of dolomite but containing intercalated shale, sandy beds, and limestone. The Middle and Upper Cambrian and Lower Ordovician dolomite is overlain by a number of Middle Ordovician limestone formations, which individually vary in thickness and character within relatively short distances. Although composed mainly of cherty and clayey limestone, the Middle Ordovician contains generally one or two zones of limestone sufficiently pure to be burned for lime and used in chemical industries. Ton for ton, this type of limestone is the most valuable found in the Appalachian Valley. The average thickness of pure limestone found in most sections of the Appalachian Valley comprises less than one per cent of the total thickness of exposed rocks.

The average thickness of the Ordovician limestone is about 800 feet in Giles County, but southeast of the Pulaski fault the thickness averages about 250 feet. The Ordovician limestone is overlain by 5,300 feet of predominantly clastic rocks, mostly shale and sandstone, of Middle and Upper Ordovician, Silurian, Devonian, and Mississippian ages.

About 1,000 feet of Mississippian limestone occurs in one belt in the northwestern salient of Giles County, north of the St. Clair fault. These limestones are very well displayed along the Norfolk and Western Railway southwest of Rich Creek. If the Mississippian limestones were ever deposited in the southeastern part of the district, they have since been buried beneath older, overthrust rocks.



Distribution of limestone and dolomite in the Giles County area, Virginia.
(Based in part on a manuscript map of Giles County, by A. A. L. Mathews.)

For convenience, the 3,500- to 4,500- foot series of predominantly dolomitic rock will be referred to as Cambrian and Ordovician dolomite, the overlying limestone formations as Ordovician limestone, and the limestone belt north of the St. Clair fault will be described as Mississippian limestone.

DEFINITION OF TERMS

In this report, only simple descriptive terms are used. The terms *fine-*, *medium-*, and *coarse-grained* are used to describe textures. *Fine-grained* means that the grains are too small to be distinguished without a magnifier; *coarse-grained* refers to sizes of particles readily distinguished with the naked eye; and *medium-grained* for intermediate or borderline textures. The "knit," or packing, of the particles in a rock is described as compact, mealy, or sugary. *Oolitic* is used to describe rocks which contain small concentrically banded, roundish particles, or oolites, which are about the size of fish roe (Pl. 10A). The color adjectives, unless otherwise designated, refer to the color of freshly broken rock surfaces.

Carbonate, when used alone, refers to both calcium and magnesium carbonates. The silica, alumina, iron oxide, and alkalies are referred to collectively as *noncarbonates.* Limestones containing more than 95 per cent calcium carbonate are called *high-calcium limestones.* Dolomite refers to varieties of carbonate rock containing 20 to 46 per cent magnesium carbonate. *High-magnesium dolomite* contains more than 40 per cent magnesium carbonate. *Magnesian limestone* refers to varieties containing 5 to 20 per cent of magnesium carbonate. *Impure limestone* denotes a carbonate content of less than 95 per cent.

USES OF LIMESTONE AND DOLOMITE

Together, limestone and dolomite have a greater number of important uses than other naturally occurring substances, except coal and petroleum. By far the greater part of the annual tonnage of limestone and dolomite produced in Virginia, particularly in the district covered by this report, is used in the form of crushed stone and allied products such as limestone dust, stone sand, and riprap. For crushed stone the physical properties rather than the chemical composition of the rock are considered most important. With few exceptions, only the pure, premium grades of limestone are suitable for chemical and industrial uses (Table 1).

Because of their greater value and variety of possible uses, high-calcium limestones are among the most important rocks quar-

ried in Virginia. Most of the high-calcium limestone produced in the State is used for fluxing iron ore. Other important uses are as ground limestone for conditioning and neutralizing acid soils; in water purification; in the manufacture of alkalies, calcium carbide, glass, and sugar; and in the tanning industry. High-magnesium dolomite has been used as a fluxing stone and in the manufacture of dead-burned dolomite, magnesia, and finishing limes. High-magnesium dolomite has been used elsewhere during the war for making magnesium metal.

TABLE 1.—*Important chemical uses of limestone and dolomite*[13]

USES	High-calcium limestone	Impure limestone	Magnesian limestone	High-magnesium dolomite
Agricultural limestone or "agstone"	x	x	x	x
Alkalies	x			
Ammonia (cyanamide process)	x			
Calcium carbide	x			
Dolomite refractories			?	x
Fluxing:				
Open-hearth furnace	x			
Blast furnace	x		x	x
Nonferrous metals	x			
Glass manufacture	x			x
Lime:				
High-calcium lime	x			
Low-magnesium lime			x	
High-magnesium lime			?	x
Hydraulic lime		x		
Magnesium metal manufacture				x
Mine dust (bituminous coal mines)	x		x	x
Natural cement		x		
Paper manufacture:				
Sulphite pulp (Tower system)	x			x
Sulphite pulp (milk-of-lime system)				x
Soda pulp and sulphate pulp	x			
Plastics	x			
Portland cement	x	x		
Rock wool	x	x	x	x
Salt manufacture	x			
Sugar refining	x			
Whiting substitute	x		x	x

GILES COUNTY AREA

GENERAL FEATURES

The area shown on Plate 3 comprises the largest and the westernmost limestone-dolomite area discussed in this report. The almost continuous exposure of rocks along the gorge of New River affords a natural cross section of the folded and faulted strata, which is unique in the Appalachian Valley of Virginia. Much of the open, broadly rolling land of Giles County is 200 to 400 feet above New River, but, as shown by numerous deposits of boulders and gravel on the upland, it was once the flood plain of New River. New River gorge has afforded excellent locations for two main-line railroads. The Norfolk and Western Railway, on the west side of the river, is a double-track line which is joined by two branches: one heads in the timbering and mining section of Bland County to the southwest, the other extends across New River to Kimballton. These spur lines are known as the Bastian Branch and the Interior Branch, respectively.

Most sections of the New River gorge are rather accessible to through roads. State Highway 8, which crosses New River at Ripplemead, joins U. S. Route 11 at Christiansburg. State Route 100 connects Pearisburg with Dublin which is also located on U. S. Route 11 (Fig. 1). The southern part of the Giles County area is traversed by State Highway 42, which crosses New River at Eggleston.

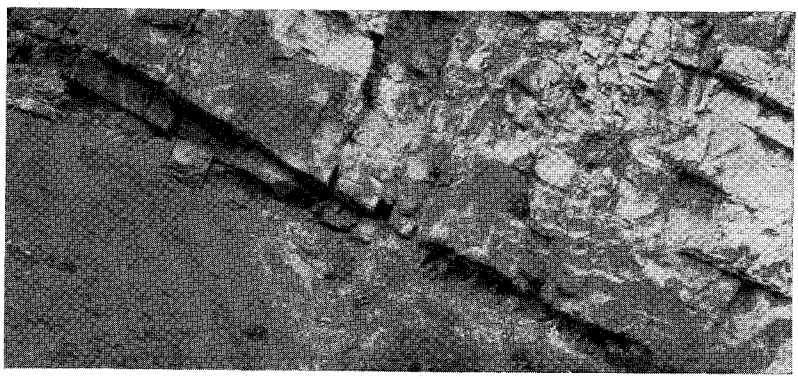
GEOLOGY

As shown on the Geologic map of the Appalachian Valley[2], Giles County is crossed by three overthrust faults. The northwestern salient of the county, along New River, is underlain mainly by Devonian and Mississippian beds. Devonian shales, which lie below the overthrust Ordovician dolomite (Pl. 4A), have been overturned and dip almost parallel to the St. Clair fault. Overturning of the beds persists northwestward to the vicinity of Rich Creek, but between this point and Glenlyn the beds are in normal position and essentially horizontal. The southeastward dipping succession shown in The Narrows of New River between the St. Clair and Narrows overthrusts, is one of the most nearly complete exposures of rock in the entire Appalachian Valley.

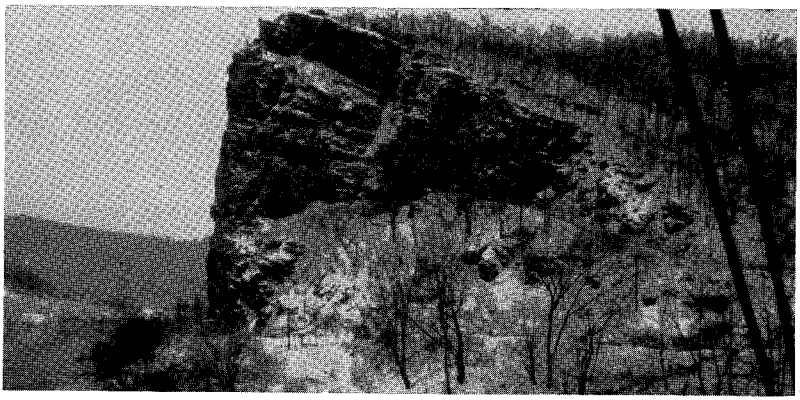
The broad segment between the Narrows and Saltville faults, including the greater part of the Giles County area, shows five major folds in the strata and numerous minor wrinkles. The sector between Eggleston and Goodwins Ferry shows a synclinal fold which is faulted on the southeast by the Saltville overthrust and wrinkled on the northwest flank by minor folds (geologic section 15; Pl. 3). A syncline is present between Hoges Store and the intersection of State Highways 8 and 42. Another syncline, the trough of which crosses New River at Ripplemead (Pl. 5C), extends from Pembroke northwest to the Narrows fault. These three synclines are separated by broad gentle anticlines. The well-exposed succession southeast of the Saltville fault dips steeply to the southeast. About 2 miles southeast of the intersection of the Giles, Pulaski, and Montgomery county lines, this succession is broken by the Pulaski fault.

Columnar section	Name	Character and thickness	Average chemical composition (%)				
			$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	Beekmantown	Light- to dark-gray, fine- to coarse-grained dolomites and intercalated beds of chert; 550 to 1,000 feet thick	54	37 (exclusive of chert beds)	6.0	2.5	0.5
		Light-gray compact limestone and dolomite; 90 feet thick					
	Copper Ridge	Medium-gray, granular, sparsely cherty dolomite with intercalated beds of sandstone; about 1400 feet thick	52	39 (exclusive of sandstone)	6.0	2.0	0.5
	Nolichucky	Shale and intercalated limy layers; about 60 feet thick					
	Honaker	Dark- to light-gray fine-grained dolomite; about 1,000 feet thick; relatively free of sandstone and chert	54	43	2.0	0.6	0.4

FIGURE 2.—Cambrian and Ordovician dolomitic formations in Giles County, Va.



A.



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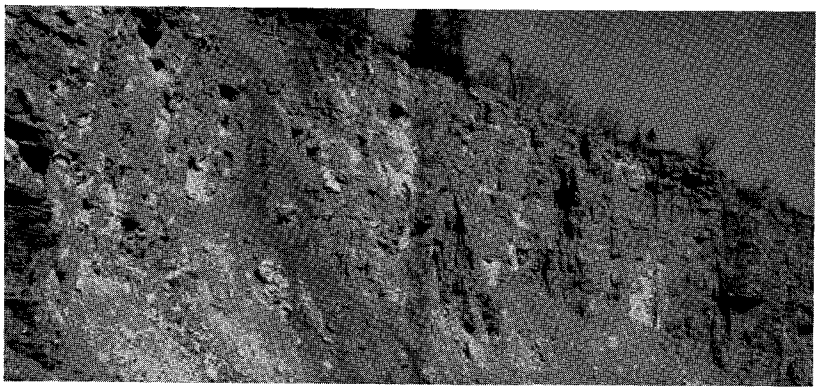
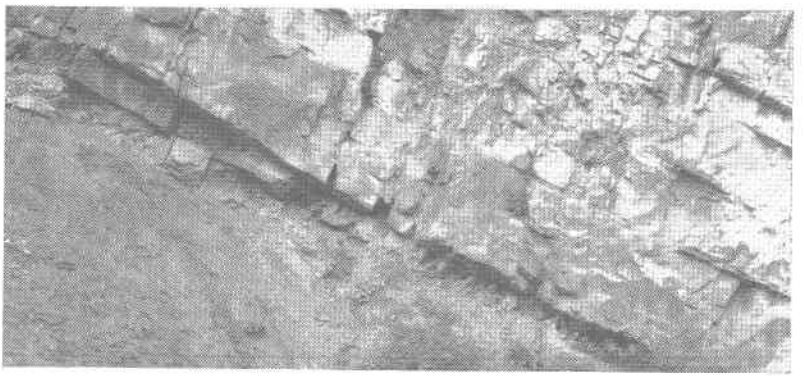
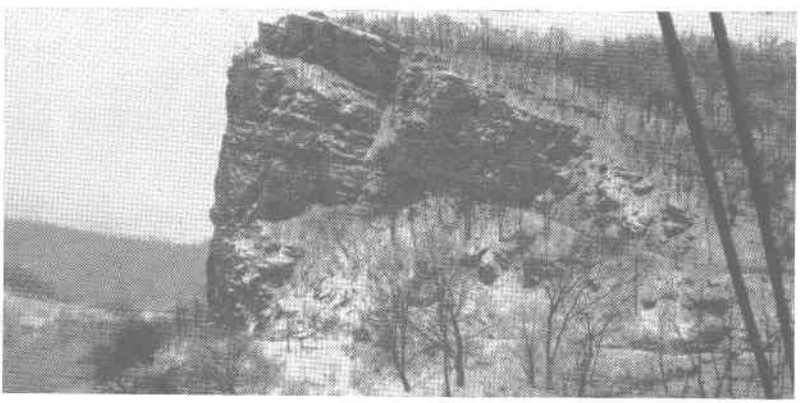


C.

A, Beekmantown dolomite overthrust on Devonian shale along the St. Clair fault, in The Narrows. Photograph by Arthur Bevan. B, Castle Rock along New River, near Pembroke, Va. C, West face of the quarry of the Pembroke Limestone Corp.



A.



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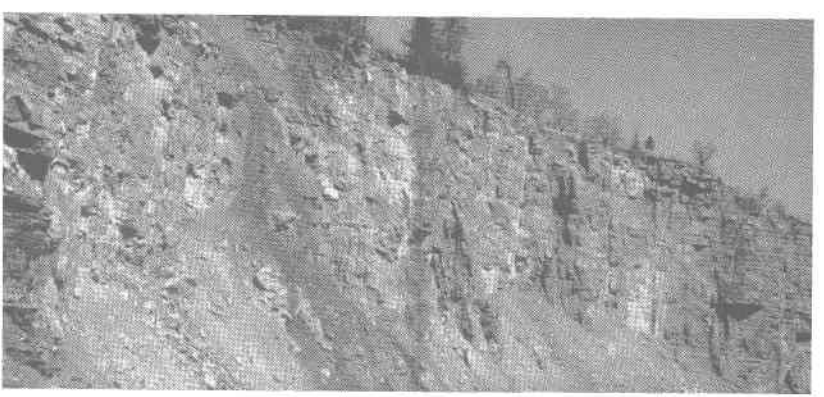
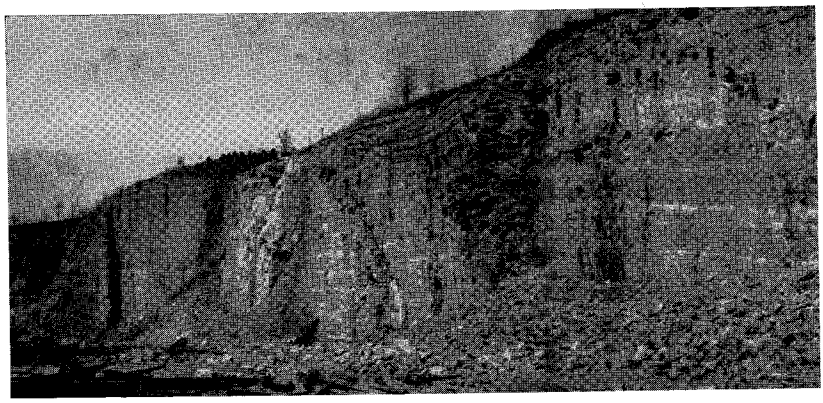


C.

A, Beekmantown dolomite overthrust on Devonian shale along the St. Clair fault, in The Narrows. Photograph by Arthur Bevan. B, Castle Rock along New River, near Pembroke, Va. C, West face of the quarry of the Pembroke Limestone Corp.



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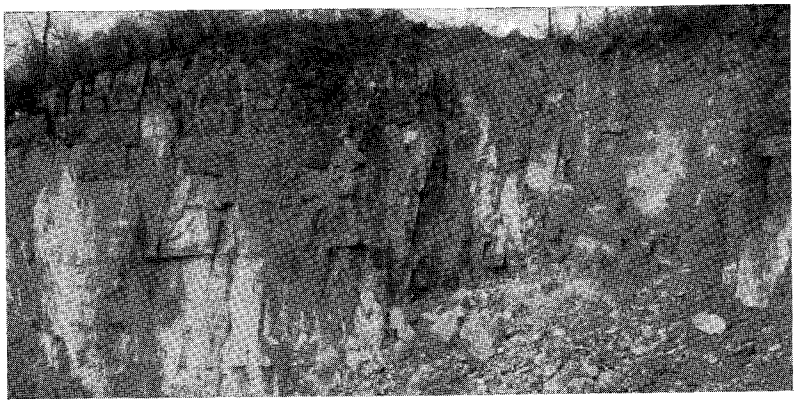
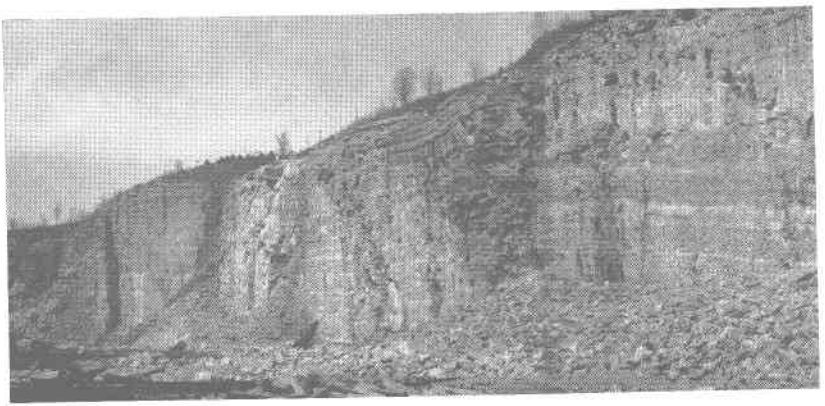


C.

A, Quarry of the Virginian Limestone Corp. B, Pinnacles of Eggleston along New River. C, Quarry of the Ripplemead Lime Co.



A.

B.

C.

A, Quarry of the Virginian Limestone Corp. B, Pinnacles of Eggleston along New River. C, Quarry of the Ripplemead Lime Co.

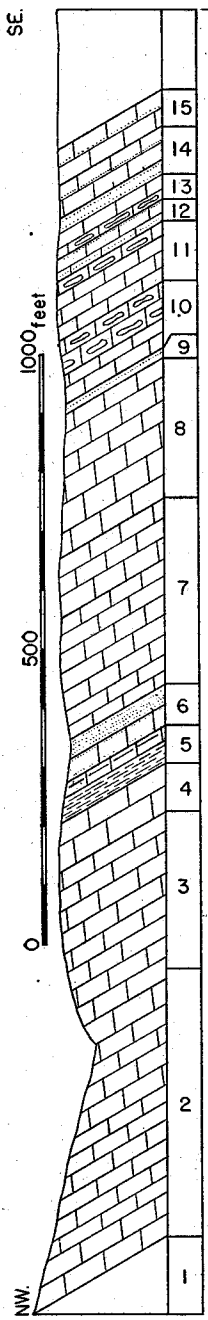
The distribution of the limestone and dolomite belts is shown on Plate 3. Except in the sector west of Eggleston, the principal belt of high-calcium limestone is mapped separately. The Cambrian and Ordovician dolomite belts include the Honaker, Copper Ridge, and Beekmantown formations. A thin, shaly formation, the Nolichucky, separates the Honaker and Copper Ridge formations and is shown separately on Plate 3. The Ordovician limestones, besides the Five Oaks limestone, include four other members of the Cliffield formation, as well as the Benbolt, the Gratton, and the Witten limestones. A distinctive red mudrock directly above the Ordovician limestone formations shown on Plate 3 contains limy beds suitable for interior decorative marble.[14] The belt of Mississippian limestone, exposed along New River north of The Narrows, includes formations identified by Butts[5] as the Warsaw, St. Louis, Ste. Genevieve, and Gasper limestones.

DOLOMITE

HONAKER DOLOMITE

The Honaker dolomite, the oldest carbonate rock exposed in Giles County, crops out in a broad belt from the Saltville fault southward nearly to Berton Station. It is separated from the overlying dolomites by 55 feet of Nolichucky shale (geologic section 1). About 800 feet of the Honaker is well exposed along the Virginian Railway south of Goodwins Ferry. The formation also occurs in an extensive area west of New River (Pl. 1) but was not studied or sampled because of its relative remoteness from railroads.

The Honaker is a medium- to fine-grained, gray, high-magnesium dolomite which is almost devoid of clay, sand, and chert. The absence of clay is reflected by an exceptionally low content of alkalies. Most of the finer grained dolomites are thoroughly fractured and weather to a rubble of angular pieces 2 to 4 inches across. The beds close to the Saltville fault have been brecciated but without disruption of the bedding. Not all of the Honaker is present south of Goodwins Ferry; an unknown thickness at the base has been faulted out.

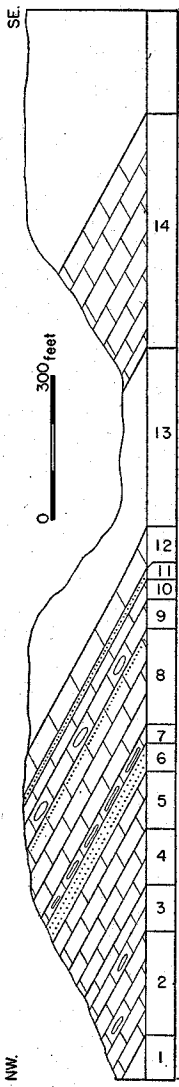


Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
COPPER RIDGE DOLOMITE						
15 Dolomite, light-gray	55					
14 Dolomite, light-gray and dark-gray beds; intercalated sandstones	74					
13 Dolomite and magnesian limestone	33					
12 Sandstone and dolomite, interbedded	31					
11 Dolomite, fine grained, bluish-gray	88					
10 Dolomite, medium grained, cherty	94					
9 Sandstone and sandy dolomite	14					
8 Dolomite, fine grained, gray	209	52.78	42.21	3.60	1.32	0.58
7 Dolomite, coarse to fine grained; very compact	231					
6 Sandstone and sandy dolomite	65					
NOLICHUCKY SHALE						
5 Shale and magnesian limestone	56					
HONAKER DOLOMITE						
4 Dolomite, brownish-gray, granular	81					
3 Dolomite, finely granular, dark-gray, thoroughly fractured	250	53.92	43.06	2.52	0.67	0.34
2 Dolomite, light-gray, fine grained, very compact	380					
1 Dolomite, brecciated, light-gray	115					

GEOLOGIC SECTION 1.—Dolomitic formations along Virginian Railway at locality 41, near Goodwins Ferry, Giles County, Virginia.

COPPER RIDGE DOLOMITE

About 55 feet of Nolichucky shale (geologic section 1) separates the Honaker from the Copper Ridge formation. This shale is shown separately on Plate 3. The Copper Ridge averages 1,400 to 1,650 feet thick in Giles County, being thickest in the belt south of the Saltville fault. Quartz sandstones, with a maximum thickness



	Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
14	Dolomite, medium-gray, granular; very uniform in color and texture; exposed along Bastian Branch of the Norfolk and Western Railway near its junction with the main line	273	52.15	40.00	6.08	2.00	0.48
13	Covered interval	200±					
12	Dolomite, brownish-gray, cherty	34					
11	Sandstone, light-gray	10					
10	Sandstone and sandy dolomite	25					
9	Dolomite, gray, thin bedded, cherty	28					
8	Dolomite, light-gray and dark-gray beds, cherty	85					
7	Dolomite, light-gray, fine grained	18					
6	Sandstone and dolomite	33					
5	Dolomite, gray, fine grained	58					
4	Dolomite, gray, granular	57					
3	Dolomite, light-gray, fine grained	47					
2	Dolomite, light-gray	106					
1	Covered, near branch of Narrows fault						

GEOLOGIC SECTION 2.—Part of Copper Ridge dolomite, along the Norfolk and Western Railway at locality 6, northwest of Narrows, Giles County, Virginia.

of 70 feet, occur at several horizons in the formation and are so rare in other dolomite formations of the area as to be a reliable criterion for identification of the Copper Ridge. Along New River a thickness of 250 to 450 feet of Copper Ridge dolomite is relatively free of sandstone (geologic sections 1 and 3). The prevailing color of the Copper Ridge is medium-gray, but some variation in color from bed to bed is evident wherever a considerable thickness is exposed. Many beds have characteristic crinkled laminae of silty material, which weather in strong relief against the purer dolomitic layers. The texture of the Copper Ridge is somewhat coarser than the Honaker formation.

Chert commonly occurs in thin beds and on weathering breaks into small rectangular pieces. As shown in the section along the Norfolk and Western Railway just northwest of Narrows, many of the cherty beds show concentric banding of algal origin. Many chert bands are oolitic and some are sandy.

Probably the most nearly complete exposure of the formation occurs south of the Nolichucky shale belt which crosses New River. The most spectacular display, however, is in the picturesque Pinnacles of Eggleston along New River (Pl. 5B). Color banding is prominent at this locality.

Geologic section 3 (locality 38).—Part of the Copper Ridge dolomite along the Virginian Railway, north of Eggleston, Giles County, Virginia

	Thickness Feet
Copper Ridge dolomite	
19. Covered interval at top; section begins at first exposures north of crossing of State Highway 42	
18. Dolomite, dark-gray, medium grained, very thin bedded	31
17. Dolomite, alternate light-gray and dark-gray beds, medium grained; darker beds generally thicker than lighter ones	204
16. Dolomite, fine grained, mottled light-gray and salmon-pink, laminated	84
15. Dolomite, dark-gray, medium grained, partly covered	80

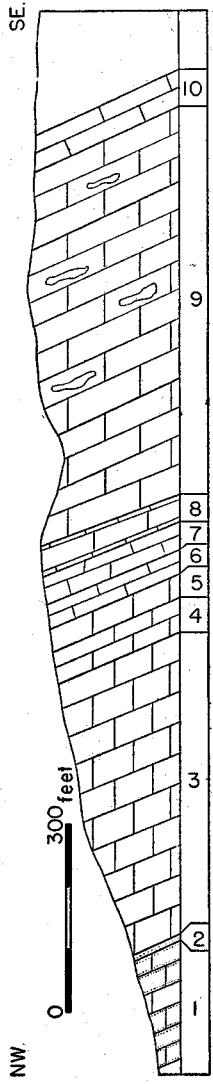
		Thickness Feet
14.	Dolomite, light-gray to creamy-white, medium-grained	52
13.	Dolomite, light-gray, fine grained	45
12.	Dolomite, medium grained, light-gray	32
11.	Dolomite, medium-gray, fine grained; contains beds of chert 2 to 6 inches thick and sandstone beds up to 2 feet thick	20
10.	Sandstone, coarse grained, dolomitic	8½
9.	Dolomite, fine grained, dense	5
8.	Sandstone, sugary, dolomitic	1
7.	Dolomite, fine grained, cherty	5
6.	Dolomite, fine grained, medium-gray	7
5.	Sandstone, wavy bedded	¼
4.	Dolomite	5
3.	Sandstone; ripples in New River	1½
2.	Dolomite, medium grained, light-gray	35
1.	Dolomite, medium grained, dark-gray; beds below are largely concealed	50

The analysis of a composite sample collected from units 11 to 18 is given in Table 2. As shown in Figure 2 and in geologic sections 2 and 4, the magnesium carbonate content of the purer parts of the Copper Ridge averages 39 to 42 per cent, but the non-carbonates average 6 to 7 per cent.

BEEKMANTOWN DOLOMITE

Although predominantly a dolomite, the Beekmantown contains beds of fine-grained, very compact, light-gray limestone. A characteristic feature of these limestones is their invariable association with, or gradation into, beds of coarse-grained dolomite. The only limestone in the Beekmantown known to be persistent in thickness is the one at the base of the formation, which is well exposed along the Norfolk and Western Railway south of Berton (geologic section 4).

The main body of the Beekmantown is a rather fine-grained, pearl-gray, very compact dolomite. Chert, in the form of large "cauliflower" masses and distinct beds, is a common impurity in the Beekmantown. Chert beds are especially abundant in the belt



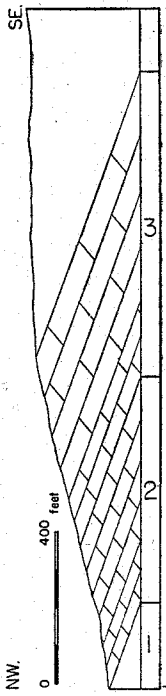
Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
CLIFFIELD FORMATION						
Limestone, coarse grained, gray	55	97.52	0.76	0 49	0.56	0.24
BEEKMANTOWN DOLOMITE						
Dolomite, pearl-gray, medium bedded	557	51.67	37.50	6.84	3.27	0.80
Dolomite, limy at base and top	36					
Limestone, fine to coarse grained	46					
COPPER RIDGE DOLOMITE						
Dolomite with inclusions of limestone	38					
Dolomite, coarse grained, light-gray	34					
Dolomite, medium grained, gray	52					
		53.16	39.68	4.55	2.01	0 64
Dolomite, granular, light-gray	450					
Sandstone	10					
Dolomite, sandy; base opposite Berton Station	110					

GEOLOGIC SECTION 4.—Dolomitic formations along the Norfolk and Western Railway at locality 42, Berton Station, Giles County, Virginia.

immediately south of the St. Clair fault. In the 600 feet of dolomite exposed in the section along State Highway 8 in The Narrows, the thickest interval of chert-free dolomite is less than 35 feet.

Medium- to coarse-grained dolomite is prominent in the lower part of the Beekmantown on the Narrows fault block. The coarse-

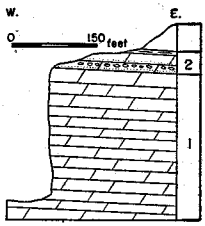
grained beds are well exposed at the south end of the west side of the Pembroke Limestone Corporation quarry, near Pembroke, but it is better exposed along the Norfolk and Western Railway east of Bluff City (locality 7). As shown in geologic section 7, the 165 feet of high-magnesium dolomite in the Pembroke quarry is the purest Beekmantown dolomite found anywhere in the Giles County area.



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
Dolomite, medium to fine grained, dark-gray	265	56.75	38.17	2.84	0.84	0.74
Dolomite, coarse grained, light-gray	200	53.51	41.42	4.71	0.93	0.54
Covered interval						

GEOLOGIC SECTION 5.—Beekmantown dolomite along the Norfolk and Western Railway at locality 7, near Bluff City, Giles County, Virginia.

Color banding is a notable feature of the Beekmantown beds exposed in the quarries near Pembroke and Klotz (Pls. 4C, 5A). The analyses in geologic section 6 would seem to imply that the composition of the light- and dark-colored beds is about the same. As shown in geologic sections 4 to 7 and in Figure 2, most of the formation is too impure for chemical use. Although chemically inferior to the Honaker dolomite and to parts of the Copper Ridge, the Beekmantown, as a whole, is a superior rock for crushed stone and stone sand (Fig. 2).



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
Dolomite, very cherty; weathers readily (basal Blackford)	15	49.51	36.61	8.92	3.80	0.92
Dolomite, alternating dark- and light-colored; light-gray zones average 12 feet thick; darker beds average 8 feet thick	225	56.68 (light-gray beds)	40.53	1.56	0.58	0.32
		57.18 (dark-gray beds)	38.52	3.32	0.88	0.40

GEOLOGIC SECTION 6.—Beekmantown dolomite and lower part of Blackford member of Cliffield formation in the Virginian Limestone Corp. quarry, at locality 15, near Klotz, Giles County, Virginia.

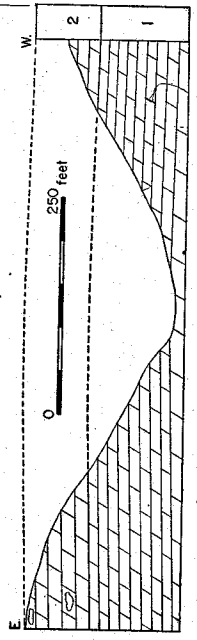
At the top of the succession of Cambrian and Ordovician dolomites is a thin, but persistent and characteristic, zone composed of very impure dolomite (geologic section 6) of angular pieces of chert and rounded fragments of dolomite, both of which are set in a matrix of fine-grained, silty dolomite. Because it weathers so readily and contains so much chert, this dolomite is carefully avoided in quarrying. A fine exposure of this very cherty dolomite is at the south end of the quarry of the Virginian Limestone Corporation at Klotz.

The Beekmantown is also well exposed along New River between Pembroke and Ripplemead, just south of Pembroke at Castle Rock (Pl. 4B), and along the Virginian Railway south of Eggleston.

QUARRIES

Two of the largest stone quarries in the State are located in Giles County (Pls. 4C, 5A). The quarry of the Virginian Limestone Corporation at Klotz, is in the upper 225 feet of the Beekmantown (geologic section 6). A more or less rhythmic color banding characterizes the quarry face, which is about 1,500 feet long. The dark-colored beds average about 8 feet thick, and the light-gray beds 12 feet. About 20 repetitions of the color bands occur in the quarry face. Crushed stone and stone sand are the main products.

The Pembroke Limestone Corporation operates a large quarry (Pl. 4C) along the south side of New River, about a mile west of Pembroke. Quarry operations were started in a relatively narrow valley or ravine, and quarry faces were developed on both sides of the stream. Coarse-grained beds at the south end of the west face of the quarry are the highest in magnesium carbonate (geologic section 7). Only the east face was being quarried in May, 1943.



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
2	Dolomite, light-gray to dark-gray, fine grained, cherty	75	53.26	40.44	4.48	1.76	0.48
1	Dolomite, coarse grained, gray	90	52.86	42.55	3.58	1.17	0.43

GEOLOGIC SECTION 7.—Beekmantown dolomite in quarry of Pembroke Limestone Corp., at locality 25, near Pembroke, Giles County, Virginia.

An analysis of limestone dust taken from the crusher is shown in Table 2.

QUARRY SITES

Enormous quantities of dolomite, readily available for quarrying and suitable for use as crushed rock, stone sand, and riprap, occur at so many places along New River that no special description of localities is necessary. Quarriable thicknesses of high-magnesium dolomite are, however, more restricted.

The only deposits of relatively pure high-magnesium dolomite occur in the Honaker formation south of Goodwins Ferry. Inexhaustible quantities could be obtained from the upland east of the river along the Virginian Railway. Very large tonnages of similar high-grade dolomite could also be quarried on the west side of the river, but the overburden is probably much thicker. The Honaker appears to be the only dolomite in the Giles County area, which is low in alkalies.

Another large body of high-magnesium dolomite occurs in the Copper Ridge, between the Nolichucky shale belt and Berton, but it contains more than 5 per cent of non-carbonates (geologic section 4).

Large quantities of dolomite containing 40 to 42.5 per cent magnesium carbonate occur in the lower part of the Beekmantown from Castle Rock west along New River for 1¾ miles. This sector includes the quarry of the Pembroke Limestone Corporation. The same beds are repeated along New River at locality 7, south of McClardy School, where 275 feet of coarse-grained high-magnesium

dolomite forms part of a large hill and bluff rising 350 feet above New River. The noncarbonates in this dolomite total more than 5 per cent (geologic section 5).

About 275 feet of dolomite containing 40 per cent magnesium carbonate is exposed along the Bastian Branch of the Norfolk and Western Railway just west of the town of Narrows (geologic section 3). This dolomite underlies the hills rising 350 to 400 feet above the railroad and could be quarried on a large scale. The color, texture, and compactness of this body of dolomite are more nearly uniform than in any of the other dolomites sampled. However, the rock contains considerably more noncarbonate than some of the other high-magnesium dolomites.

In summary, inexhaustible quantities of dolomite occur along New River in Giles County, a considerable part of which contains more than 40 per cent magnesium carbonate. Large deposits of high-magnesium dolomite, containing less than 5 per cent noncarbonates and very little alkalies, occur only in the Honaker belt exposed along New River south of Goodwins Ferry.

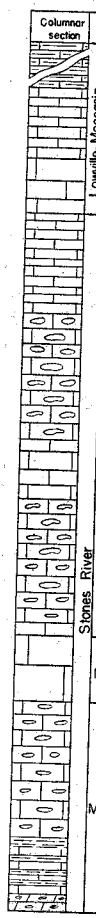
ORDOVICIAN LIMESTONES

GENERAL STATEMENT

The thickness and character of the Ordovician limestone formations vary somewhat from one fault block to another. The most noticeable differences are between the succession on the Saltville fault block and that on the fault blocks to the northwest. Butts[3] has described the Ordovician limestones of this general part of the Appalachian Valley under different formation names than are used in this report. Relations of the two sets of names are given in Figure 3, which shows the general character and composition of various divisions of the limestone succession.

CLIFFIELD FORMATION

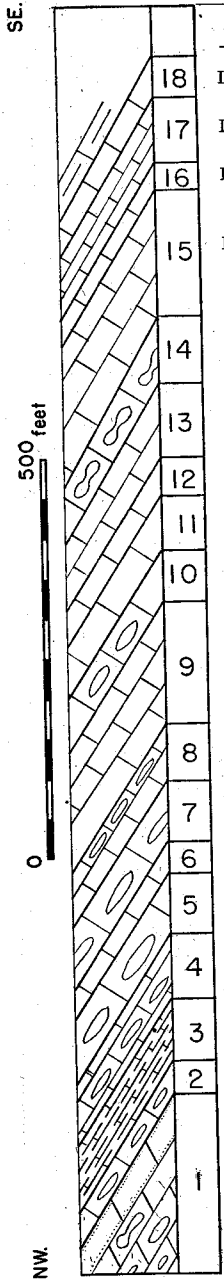
The Cliffield formation includes the thick succession of predominantly cherty limestones above the Beekmantown dolomite. The members shown in Figure 3 are persistent in all of the belts northwest of the Saltville fault and most of them can be recognized locally on the Saltville fault block.



Columnar section	Names used by Butts	Names used in this report		Character and thickness	Average chemical composition (%) $CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	Lowville-Moccasin	Moccasin		Red limestone and mudrock; thickness 200 feet	88	00.5	1.0	1.0	1.0
	Lowville-Moccasin	Lowville: Witten		Interbedded coarse- and fine-grained, slabby limestones; 50 to 250 feet thick	93	2.0	2.5	1.2	0.35
	Lowville-Moccasin	Lowville: Gratton		Thick-bedded, fine-grained limestone; topmost 15 feet commonly impure; thickness 60 feet	96.5	1.5	1.0	.75	0.40
	Stones River	Lenoir	Cliffield formation	Benbolt: Dark-gray impure nodular limestone; 60 to 100 feet thick	88	5.0	5.0	1.50	0.50
	Stones River	Lenoir	Cliffield formation	Upper cherty limestone member: Dark-gray medium-grained limestone, 125 feet thick	86	4.0	8.0	1.20	0.50
	Stones River	Lenoir	Cliffield formation	Coarse-grained limestone member: Medium-gray coarse-grained limestone; 40 to 60 feet thick	97	1.5	1.0	0.5	0.50
	Stones River	Lenoir	Cliffield formation	Lincolnshire member: Dark-gray cherty limestone; 100 feet thick	85	5.0	8.0	1.5	0.50
	Stones River	Mosheim	Cliffield formation	Five Oaks member: Dove-gray fine-grained limestone; 40-100 feet thick	97.5	1.0	1.0	0.5	0.10
	Stones River	Murfreesboro	Cliffield formation	Blackford member: Cherty fine-grained limestone; 125 feet thick	80±		15±		
	Stones River	Murfreesboro	Cliffield formation	Blackford member: Light-gray shaly limestone and limy shale; 50 feet thick	75±		20±		
	Stones River	Murfreesboro	Cliffield formation	Blackford member: Cherty buff-gray dolomite, 15 to 25 feet thick	50	36.0	9.0	4.0	1.00

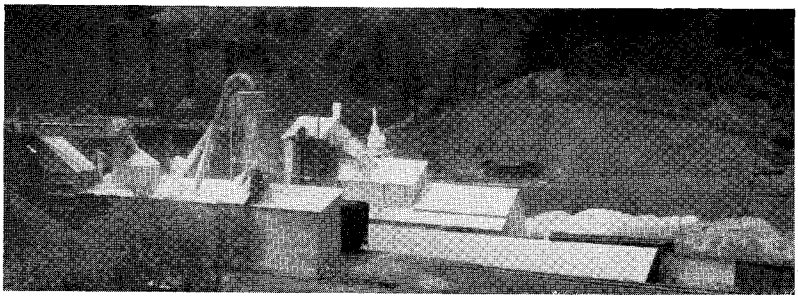
FIGURE 3.—Ordovician limestones in Giles County, Virginia.

Blackford member.—Although the Blackford member is composed of a variety of rock types, almost all the beds are cherty. The thickness increases from about 100 feet on the St. Clair fault block to 350 feet in the belt exposed along the Virginian Railway south of Eggleston (geologic section 8), which is the best exposure of the member in Giles County. At this locality, the lower 115 feet is a clastic dolomitic rock composed of pebbles of dolomite and angular pieces of detrital chert, both of which are set in a matrix of silty, mealy dolomite. Several layers of reddish-brown to olive-drab mudrock, such as are typical of the Blackford in southwestern Vir-



	Character	Thickness Feet
	WITTEN LIMESTONE	
18	Limestone, red to drab-gray, fine grained, slabby	20
17	Limestone, fine grained, thin bedded, slabby; few coarse-grained beds	38
16	Limestone, fine grained, clayey, laminated	21
	GRATTON LIMESTONE	
15	Limestone, dark bluish-gray, fine grained, compact; only about half the beds are well exposed	85
	BENBOLT LIMESTONE	
14	Limestone, medium-gray, faintly cross-laminated, cherty	41
13	Limestone, medium grained; clayey streaks	45
12	Limestone, clayey streaks, coarse grained	25
11	Limestone, clayey, dark bluish-gray	35
	CLIFFIELD FORMATION	
10	Limestone, fine grained, smoky-gray, cherty	37
9	Covered interval, few showings of dark-gray limestone	82
8	Limestone, fine grained, dark-gray	41
7	Limestone, dark bluish-gray, cherty	44
6	Limestone, fine grained, compact	18
5	Limestone, medium grained, dark-gray, cherty	43
4	Limestone, fine grained, cherty	44
3	Limestone, very shaly, light-gray	65
2	Limestone, magnesian, cherty	20
1	Dolomite, containing angular pieces of detrital chert	90

GEOLOGIC SECTION 8.—Ordovician limestone along Virginian Railway in The Narrows of New River, at locality 4, Giles County, Virginia.



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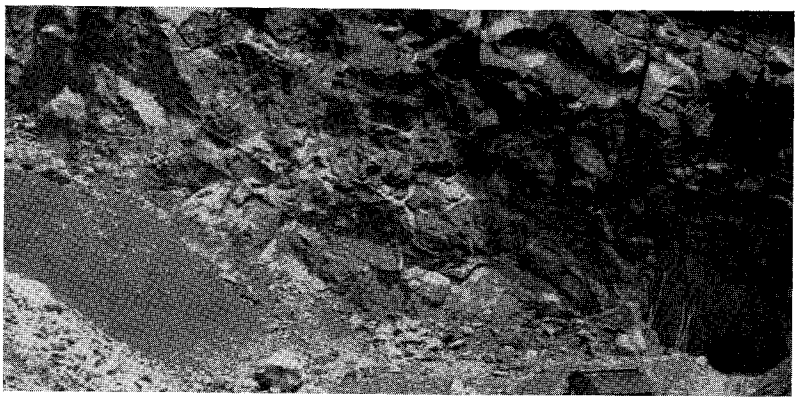

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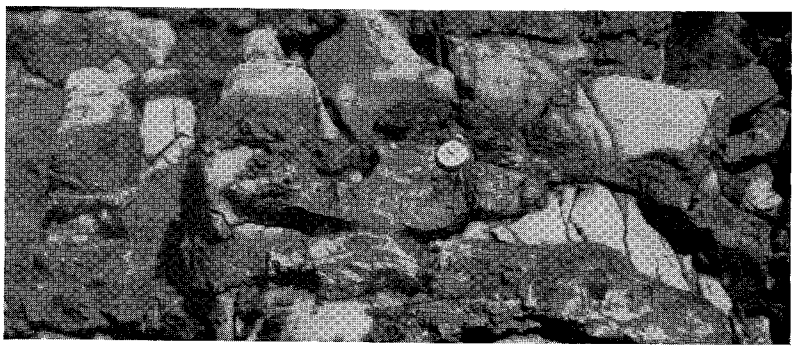
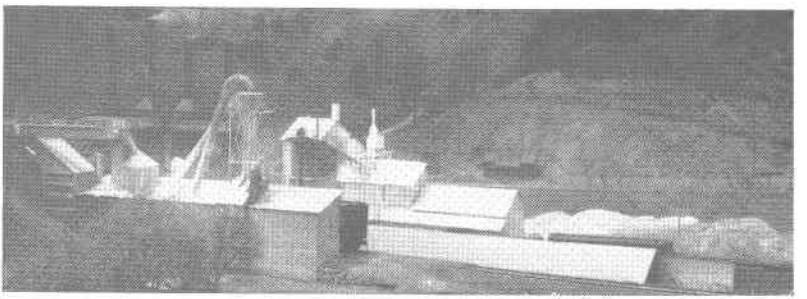


C.

A, Plant of the Kimballton Lime Co. B, Quarry and mine entrance of the Kimballton Lime Co. C, Cherty limestone in the upper part of the Blackford member at locality 14, near Klotz, Va.



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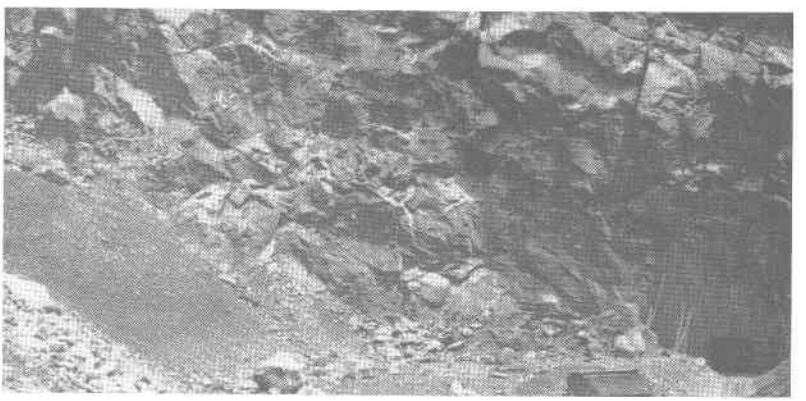

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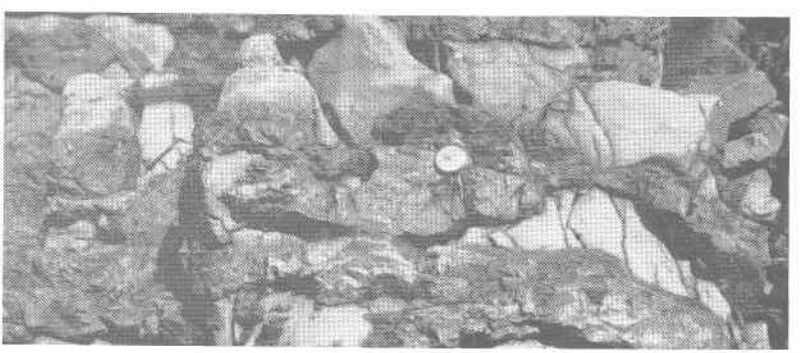
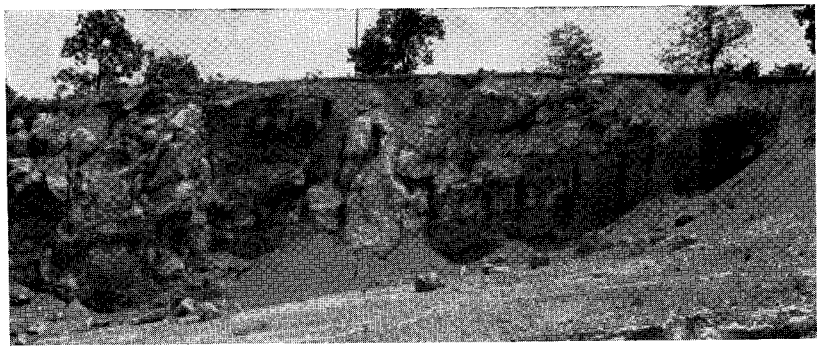


C.

A, Plant of the Kimballton Lime Co. B, Quarry and mine entrance of the Kimballton Lime Co. C, Cherty limestone in the upper part of the Blackford member at locality 14, near Klotz, Va.



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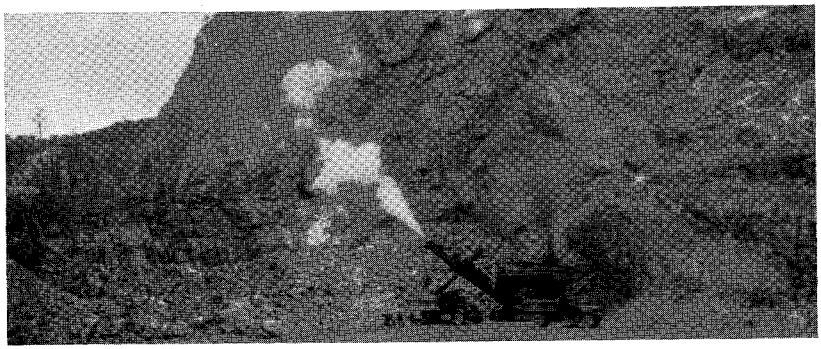

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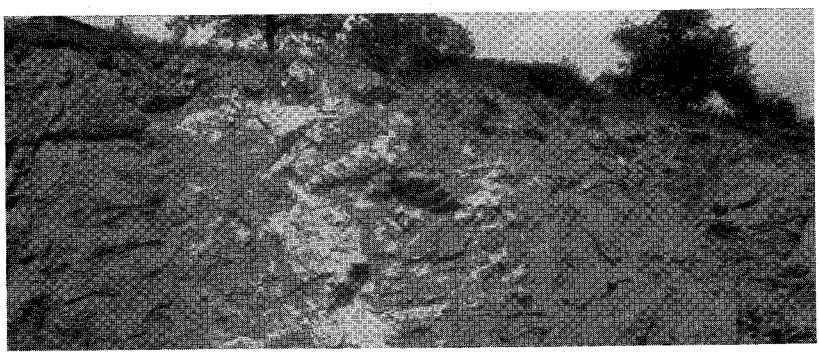
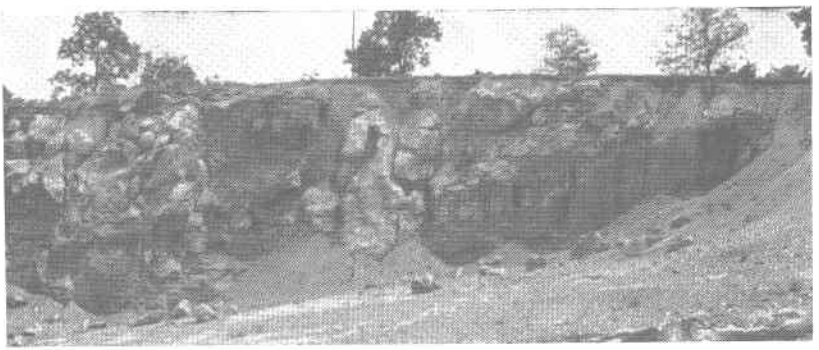


C.

A, Quarry in the Chepultepec formation near Blacksburg, Va. B, Quarry of the Radford Limestone Co. C, Roadside quarry in the Copper Ridge dolomite along Road 603 at locality 63, near Ellett, Va.



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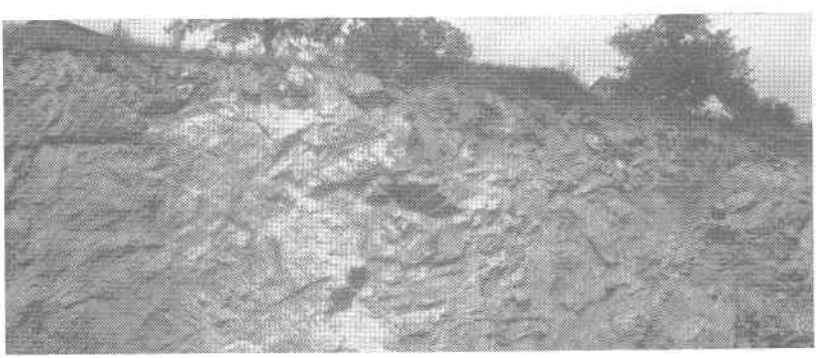


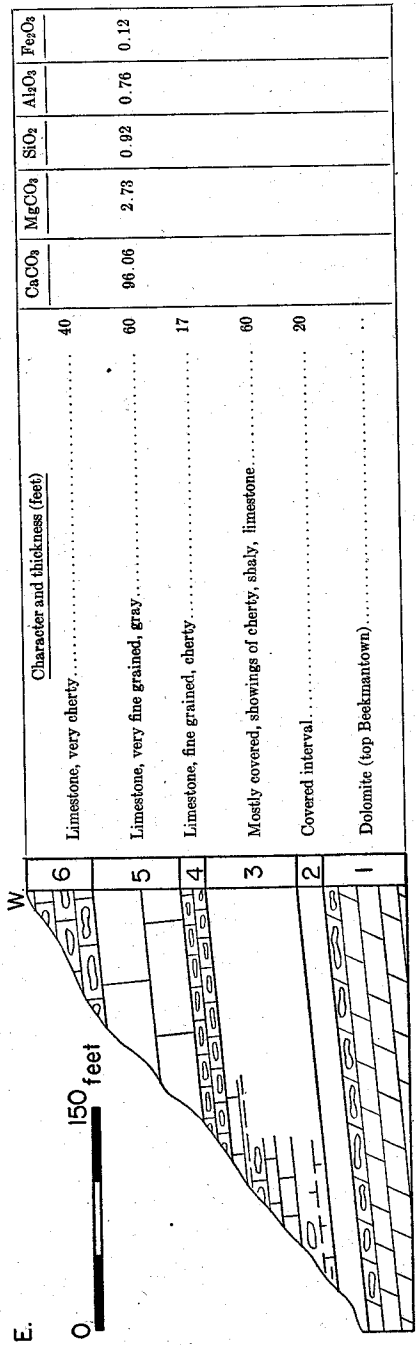
C.

A, Quarry in the Chepultepec formation near Blacksburg, Va. B, Quarry of the Radford Limestone Co. C, Roadside quarry in the Copper Ridge dolomite along Road 603 at locality 63, near Ellett, Va.

ginia[4], are also present. The middle part, also about 100 feet thick, is composed of light-gray, mealy shales and shaly limestones, and bedded chert which weathers in rectangular blocks. The upper third is composed of very cherty limestone, most of which is light-gray and fine grained. The same three-fold development is found elsewhere, although the total thickness is considerably less. A fine section of the Blackford is exposed along the east bluff of Stony Creek (geologic section 10) about one-fourth of a mile northeast of the entrance to the limestone mine at Kimballton. The same beds occur also along New River north of Ripplemead. Light-gray cherty limestone in the upper third of the Blackford is prominently displayed in the creek bed near locality 14 (Plate 6C). Shaly beds in the middle and lower parts of the Blackford are better exposed on the opposite side of New River. The best exposure of the chert breccia and conglomerate beds at the base is along the Virginian Railway in The Narrows (locality 4).

Locally, the upper part of the Blackford member is composed mainly of very fine-grained compact limestone which is relatively free of chert. One-fourth of a mile south of Ripplemead (locality 12), 60 feet of sparsely cherty fine-grained limestone, overlain by 20 feet of very cherty limestone, occurs in the upper part of the Blackford member (geologic section 9). One and one-half miles northeast of Hoges Store (locality 28), 50 to 60 feet of very fine-grained compact limestone, containing no chert, occurs about 60 feet below the top of the Blackford member. This zone averages more than 97 per cent calcium carbonate, which is somewhat greater than the calcium carbonate content of the overlying Five Oaks limestone (Table 2). A similar, sparsely cherty limestone in the Blackford is exposed in the bed of an intermittent stream about a mile southwest of Boyd Chapel.

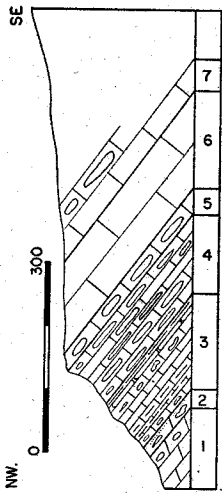
Five Oaks limestone member.—The Five Oaks limestone is a uniformly compact, very fine-grained, dark-gray, high-calcium limestone. It is poorly displayed on the Saltville and St. Clair fault blocks and was not separately mapped. Northwest of Pearisburg (geologic section 11) the Five Oaks is only 25 feet thick. In the undercut bluff rising above the cut-off meander of New River west of Pearisburg (locality 8) the Five Oaks is probably less than 30 feet thick. In a section along the northwest slope of Wolf Creek Mountain, 7 miles southwest of Narrows and 2 miles due east of Boxley bridge (Narrows quadrangle) the Five Oaks is only 25 feet thick.



	Character and thickness (feet)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
6	Limestone, very cherty	40				
5	Limestone, very fine grained, gray	60	96.06	2.73	0.92	0.76	0.12
4	Limestone, fine grained, cherty	17				
3	Mostly covered, showings of cherty, shaly, limestone	60				
2	Covered interval	20				
1	Dolomite (top Beekmantown)	..				

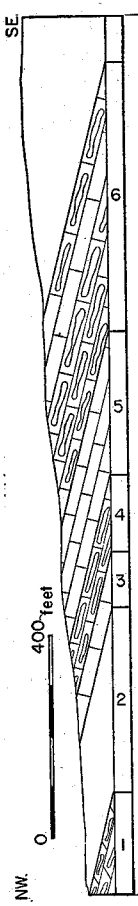
GEOLOGIC SECTION 9.—Lower part of Cliffield formation, at locality 13, about one-fourth of a mile south of Ripplemead, Giles County, Virginia.

The Kimballton Lime Company operates a limestone mine in the upper 65 feet of the Five Oaks limestone, which has a total thickness of 90 to 130 feet between localities 16 and 19, along the east bluff of Stony Creek. At locality 16, where the Five Oaks limestone has its maximum thickness, a 30-foot lens of dark-gray cherty limestone occurs 20 to 50 feet below the top of the member. The chert disappears within one-third of the distance between localities 16 and 17 and does not reappear in any of the sections east of Kimballton, along the east valley wall of Stony Creek. Along the west bluff of New River, near Ripplemead, the Five Oaks is 60 feet thick (geologic section 9; Pl. 5C), but on the opposite side of the river, at locality 14, the total thickness is only 35 to 40 feet. Between Ripplemead and Pembroke, the Five Oaks is poorly exposed, but seems to be less than 40 feet thick. However, at locality 26, northeast of Pembroke, the Five Oaks is 75 feet thick, and it is at least 60 feet thick 1¼ miles to the northeast at locality 27. At locality 28, 1½ miles northeast of Hoges Store, the Five Oaks member is 52 feet thick and occurs 60 feet above a similar but somewhat purer limestone in the upper part of the Blackford member (Table 2). South and east of Hoges Store, the Five Oaks thins to 40 feet at locality 36 along Sinking Creek and to 30 feet south of Eggleston (geologic section 13). Along the Virginian Railway south of Goodwins Ferry (locality 43), the Five Oaks is 35 feet thick but is absent on the opposite side of the river.



	Character	Thickness Feet
7	Limestone, dark-gray, medium grained, compact, cherty	40+
6	Limestone, very pure, dove-gray, compact, fine grained (see Table 2)	90
5	Limestone, brownish-gray, fine grained, cherty	26
4	Limestone, very thin bedded, cherty and shaly	97
3	Shale, light-gray, with intercalated cherty limestone	63
2	Dolomite and dolomitic mudrock, contains chert pebbles	18
1	Dolomite, cherty (top of the Beekmantown formation)	..

GEOLOGIC SECTION 10.—Lower part of Cliffield formation along east bluff of Stony Creek, at locality 19, near Kimballton, Giles County, Virginia.

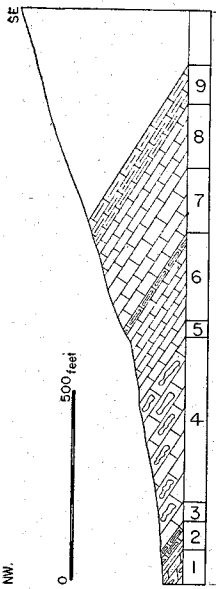


Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
CLIFFIELD FORMATION						
6 Limestone, dark-gray, cherty	130	90.65	2.24	6.20	0.90	0.22
5 Limestone, coarse grained, gray	58	96.45	1.47	1.26	0.34	0.28
4 Limestone, medium grained, cherty	68					
3 Limestone, fine grained, dove-gray (Five Oaks)	25					
2 Covered interval	90–100					
BEEKMANTOWN DOLOMITE						
1 Dolomite, pinkish-gray						

GEOLOGIC SECTION 11.—Cliffield formation along State Highways 8 and 100, at locality 9, 1¼ miles northwest of Pearisburg, Giles County, Virginia.

Lincolnshire limestone member.—The Lincolnshire limestone member is composed mainly of dark-gray granular limestone containing nodules of black chert. A few feet at the base is generally somewhat coarser grained than the rest of the member and locally is free of chert. All except the basal part of the Lincolnshire occurring northwest of the Saltville fault is too impure for any known use, but locally, south of Berton, the basal 35 to 55 feet is a coarse-grained high-calcium limestone (geologic section 14), which directly overlies the Beekmantown dolomite. Across the river, 35 feet of coarse-grained limestone directly succeeds 35 feet of the Five Oaks limestone (locality 43).

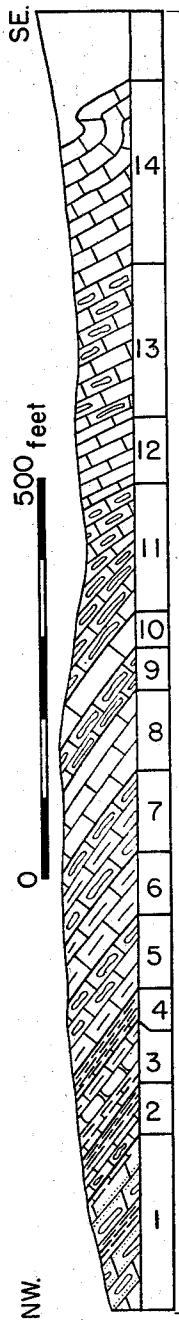
Just southeast of the St. Clair fault, the Lincolnshire contains two intercalations of fine-grained limestone like that in the Five Oaks member (geologic section 8), but such beds were not seen elsewhere in the Giles County area. The best exposures of the Lincolnshire limestone are: (1) at the east end of the Ripplemead bridge across New River; (2) along the Virginian Railway south of Eggleston (geologic section 15); (3) along the Norfolk and Western Railway south of Berton Station; and (4) in the quarries at Ripplemead and at Kimballton (Pls. 5C and 6B). The thickness ranges from 50 to 150 feet, being greatest in the southeastern part of the county. Locally, the lowest beds are as pure as the underlying Five Oaks.



	Character	Thickness feet
9	MOCCASIN FORMATION (lower part)	
	Limestone and mudrock, red and green, mottled	55
8	WITTEN LIMESTONE	
	Limestone, medium-gray, fine grained, slabby	78
7	GRATTON LIMESTONE	
	Limestone, dove-gray, fine grained, compact, thick bedded	72
6	BENBOLT LIMESTONE	
	Limestone, nodular, clayey in the lower part; granular and cross laminated in the upper part; cherty at the very top	120
5	Limestone, dark-gray, coarse grained	24
4	CLIFFIELD FORMATION	
	Limestone, fine grained, dark-gray, cherty	270
3	Limestone, fine grained, compact, dove-gray	25
2	Shale and limestone, cherty	20
1	Dolomite and mudrock, reddish-gray to dark-brown	..

GEOLOGIC SECTION 12.—Ordovician limestone along the northwest slope of Wolf Creek Mountain, 7 miles southwest of Narrows and 2 miles due east of Boxley Bridge across Wolf Creek, Giles County, Virginia.

Coarse-grained limestone member.—North of the Saltville fault in Giles County a coarse-grained gray limestone overlies the Lincolnshire limestone member. It is fully exposed in The Narrows (geologic section 8), along State Highways 8 and 100 about 1½ miles northwest of Pearisburg (locality 9), along the base of Spruce Run Mountain near State Highway 42, and along the Virginian Railway south of Berton. The average thickness is about 50 feet near



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
BENBOLT LIMESTONE						
14 Limestone, nodular, clayey	150±					
CLIFFIELD FORMATION						
13 Limestone, dark-gray, cherty	165					
12 Limestone, dark-gray, lower half rather coarse grained	72					
11 Limestone, dark-gray, cherty	125					
10 Limestone, fine grained, dove-gray; 2½ feet of chert in middle	30	94.11	1.27	3.69	0.59	0.20
		(exclusive of chert bed)				
9 Limestone, impure, light-gray	30					
8 Limestone, medium grained, cherty	50					
7 Limestone, light-gray, shaly and cherty	57					
6 Shale and limestone, mealy	45					
5 Shale and chert	57					
4 Shale, limy, poorly exposed	18					
3 Shale and shaly limestone, cherty	35					
2 Limestone and shale, light-gray	37					
1 Dolomite and chert-pebble conglomerate, few red beds	115					

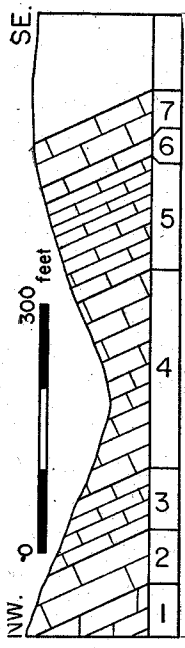
GEOLOGIC SECTION 13.—Lower part of Ordovician limestone, at locality 39, about a mile south of Eggleston, Giles County, Virginia.

Pearisburg, but farther southeast it is thinner (geologic section 16). Whether the coarse-grained member is continuous could not be determined because of poor exposures.

Upper cherty limestone member.—Dark-gray cherty limestone, much the same as the Lincolnshire, forms the upper 100 to 150 feet of the Cliffield formation. It contains too much chert to be used. The best sections of the cherty limestone are along State Highways 8 and 100 about 1¼ miles northwest of Pearisburg (locality 9) and along the base of Spruce Run Mountain (geologic section 16).

BENBOLT LIMESTONE

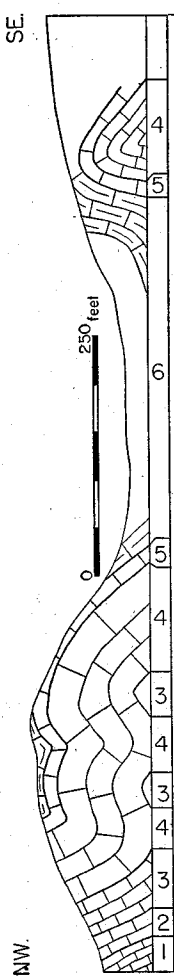
Soft, crumbly, nodular-weathering limestones comprise the greater part of the Benbolt formation, but the basal 20 to 30 feet are generally granular and somewhat less clayey than the rest of the formation. In most sections, the nodular beds are 30 to 50 feet thick, but along the Virginian Railway south of Eggleston (geologic section 13), the nodular beds are more than 150 feet thick. East of



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
WITTEN LIMESTONE						
Limestone, flaggy, golden-gray, fine grained	54					
Limestone, coarse grained, pinkish	22	95.48	2.35	0.86	0.37	0.32
BENBOLT LIMESTONE						
Limestone, clayey, weathers nodular	127					
CLIFFIELD FORMATION						
Limestone, cherty, dark-gray	216					
Limestone, medium-gray, granular, no chert	70					
Limestone, coarse grained, gray	55	97.52	0.76	0.49	0.56	0.24
BEEKMANTOWN DOLOMITE						
Dolomite, mostly fine grained	..					

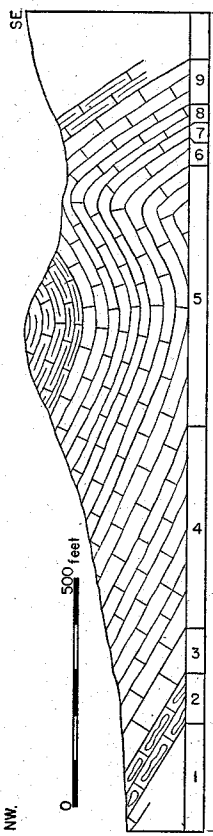
GEOLOGIC SECTION 14.—Ordovician limestone along the Norfolk and Western Railway, at locality 42, near Berton Station, Giles County, Virginia.

Klotz (locality 21) the upper 30 feet of the Benbolt is medium-bedded, dark-gray cherty limestone. North of Pembroke (locality 24), 45 feet of the formation is black fine-grained compact limestone. West of Boyd Chapel (locality 32), 75 feet of coarse-grained, light-gray high-calcium limestone occurs at the top of the Benbolt, and near Green Valley Church (locality 40), 67 feet of the same type of beds occurs just below the top. Similar but somewhat finer grained beds comprise a 70-foot thickness of high-calcium limestone



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
WITTEN LIMESTONE						
Limestone, fine grained, clayey	..					
Limestone, dove-gray, fine grained	..					
MOCCASIN FORMATION						
Mudrock and limestone, exposed in shallow syncline; beds are dark-red to brown	..					
WITTEN LIMESTONE						
Limestone, fine grained, dove-gray	20					
Limestone, contains clayey stringers	70	90.52	2.57	4.52	1.58	0.48
GRATTON LIMESTONE						
Limestone, fine grained, thin bedded	..					
WITTEN LIMESTONE						
Limestone, contains clayey stringers	..					
GRATTON LIMESTONE						
Limestone, fine grained, dove-gray	..					
WITTEN LIMESTONE						
Limestone, fine grained, clayey	..					
GRATTON LIMESTONE						
Limestone, dove-gray, fine grained	42	93.33	2.42	1.89	1.40	0.42
Limestone, dove-gray, fine grained, medium to thick bedded	37	96.80	1.26	0.58	0.56	0.18
BENBOLT LIMESTONE						
Limestone, steel-gray, nodular	30	81.89	7.83	6.69	2.09	0.72

GEOLOGIC SECTION 15.—Ordovician limestone along Virginian Railway, at locality 39, about a mile south of Eggleston, Giles County, Virginia.



	Character	Thickness Feet
	WITTEN LIMESTONE	
9	Limestone, nodular, clayey stringers, slabby; few coarse layers near the base.	64
	GRATTON LIMESTONE	
8	Limestone, fine grained, dove-gray, medium bedded	38
	BENBOLT LIMESTONE	
7	Limestone, coarse grained, light-gray	16
6	Limestone, gray, clayey, weathers nodular	55
5	Limestone, fine grained, dark-gray; few intercalations of granular limestone toward the base	102
	CLIFFIELD FORMATION	
4	Limestone, dark-gray, granular; contains nodules of black chert	178
3	Limestone, coarse grained	47
2	Limestone, very cherty, dark-gray	58
1	Limestone, fine grained; only upper beds exposed	..

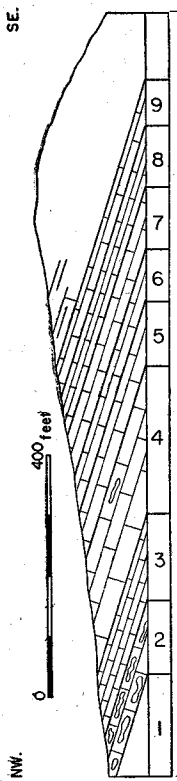
GEOLOGIC SECTION 16.—Ordovician limestone along the northwest base of Spruce Run Mountain, at locality 35, Giles County, Virginia.

northwest of Narrows (locality 5; geologic section 19), and at the top of the Benbolt north of Pembroke (geologic section 18). Except at these three localities, the Benbolt contains little or no high-calcium limestone. The general composition of the formation is shown in Figure 3.

GRATTON LIMESTONE

The Gratton is mainly a fine-grained compact limestone 20 to 80 feet thick. Although much like the Five Oaks in color and texture, its calcium carbonate content is almost invariably 1 to 3 per cent lower than that of the Five Oaks, and only locally can the formation be classified as high-calcium limestone (Fig. 3). In most

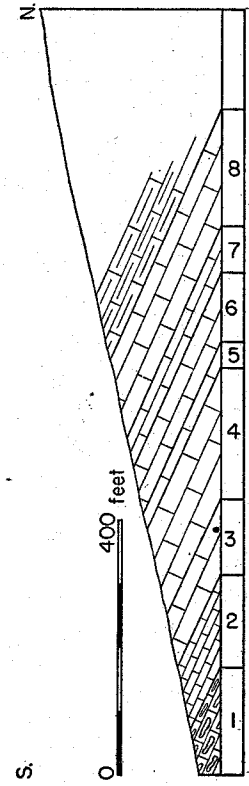
sections, the Gratton contains 5 to 20 feet of impure, laminated, nodular-weathering limestone at the base and in some sections a bed of brown-weathering siltstone (geologic sections 20 and 21). Another nodular limestone, 10 to 20 feet thick, generally occurs at the top.



	Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	WITTEN LIMESTONE						
9	Limestone, nodular, clayey	26+					
8	Limestone, granular, cross bedded, conglomeratic	24					
	GRATTON LIMESTONE						
7	Limestone, nodular, clayey	24					
6	Limestone, dove-gray, fine grained	31	94.59	1.95	2.26	1.08	0.32
	BENBOLT LIMESTONE						
5	Limestone, medium bedded, gray	35	89.40	6.23	2.50	1.12	0.40
4	Limestone, nodular, clayey	75	87.19	2.51	6.10	2.66	0.68
3	Limestone, nodular, granular	40					
	CLIFFIELD FORMATION						
2	Limestone, cherty, dark-gray	40					
1	Covered	..					

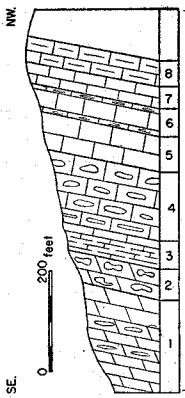
GEOLOGIC SECTION 17.—Ordovician limestone at locality 21, about one mile northeast of Ripplemead, Giles County, Virginia.

The Gratton is apparently absent southeast of the Saltville fault but is persistent in the rest of the Giles County area. It is fully exposed at the following places: (1) along the base of Salt Pond Mountain (locality 29); (2) near Boyd Chapel (locality 32), on the opposite limb of a syncline (Pl. 3); (3) along the Virginian Railway, south of Eggleston (locality 39); (4) near Green Valley Church (locality 40); (5) at the east foot of Angels Rest (locality



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
WITTEN LIMESTONE						
Limestone, fine grained, slabby	74					
GRATTON LIMESTONE						
Limestone, gray, nodular, clayey	30					
Limestone, fine grained, dove-gray	45	92.72	2.77	2.20	1.24	0.32
Limestone, laminated, impure	22					
BENBOLT LIMESTONE						
Limestone, coarse grained, gray	88	95.05	2.88	0.88	0.56	0.28
Limestone, dense, fine grained, black, impure	45	92.72	3.52	2.48	0.74	0.40
Limestone, nodular, clayey	50					
CLIFFIELD FORMATION						
Limestone, fine grained, dark-gray, very cherty	75+					

GEOLOGIC SECTION 18. Ordovician limestone along east bluff of Little Stony Creek, one mile north of Pembroke, at locality 24, Giles County, Virginia.



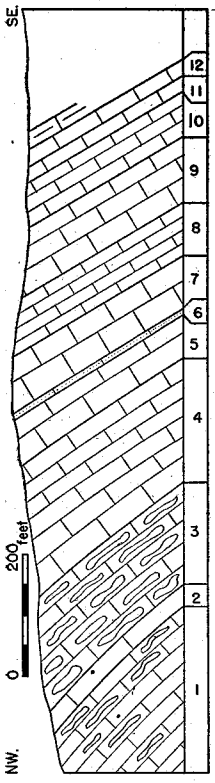
Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
MOCCASIN FORMATION						
Limestone, dark-red, clayey	50					
WITTEN LIMESTONE						
Limestone, slabby, gray, coarse grained	40					
GRATTON LIMESTONE						
Limestone, fine grained, dove-gray, cherty	52	93.46	1.94	3.68	1.24	0.28
BENBOLT LIMESTONE						
Limestone, granular, dark-gray	70	95.36	1.64	2.24	0.68	0.24
CLIFFIELD FORMATION						
Limestone, granular, dark-gray, cherty	140					
Shale and limestone, light-gray, few dense limy layers at top	54					
Chert breccia and clastic dolomite	60					
BEEKMANTOWN FORMATION						
Dolomite, gray, poorly exposed	..					

GEOLOGIC SECTION 19.—Ordovician limestone at locality 5, northwest of Narrows, Giles County, Virginia.

11); and (6) along the northwest slope of Wolf Creek Mountain, 7 miles southwest of Narrows and 2 miles due east of Boxley bridge (geologic section 12). The maximum thickness of 72 feet of relatively pure limestone in the Gratton was measured in that locality. The general composition of the Gratton is shown in Figure 3.

WITTEN LIMESTONE

The topmost formation of Ordovician limestone, which directly underlies the dark-red Moccasin formation, is composed of coarse- and fine-grained limestones about 100 feet thick. The lowermost beds are typically laminated and contain a few beds of limestone conglomerate. The laminated beds are generally overlain by a few feet of fine-grained compact limestone, similar to the Gratton, and



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
WITTEN LIMESTONE						
Limestone, fine grained, dense	24	93.94	1.62	2.38	1.05	0.36
Limestone, clayey, nodular	20					
Limestone, light-gray, fine grained	66	96.45	1.47	0.78	0.50	0.34
Limestone, nodular, mostly fine grained, but coarse intercalations near base	91	91.77	3.24	3.02	1.16	0.38
Limestone, fine grained, slabby	78	92.20	2.15	3.43	1.49	0.38
GRATTON LIMESTONE						
Limestone, mostly fine grained, dove-gray, thick bedded	78	96.39	1.24	0.93	0.72	0.30
Limestone, very silty, weathers dark-brown	6					
BENBOLT LIMESTONE						
Limestone, coarse grained, light-gray, composed largely of shells	67	95.43	2.30	0.78	0.75	0.28
Limestone, nodular, clayey	180					
CLIFFIELD LIMESTONE						
Limestone, dark-gray, cherty	135					
Limestone, dark-gray, coarse grained	30					
Limestone, dark-gray, cherty	150					

GEOLOGIC SECTION 20.—Ordovician limestone at locality 40, about 3½ miles southwest of Eggleston, Giles County, Virginia.

this in turn by 5 to 10 feet of coarse-grained limestone. Most of the upper half of the formation is fine-grained, dove-gray limestone containing buff clayey stringers which weather more rapidly than the enclosing limestone and thereby produce a "worm-eaten" appearance. At the top, 10 to 20 feet of fine-grained compact limestone is generally present. Although well exposed in The Narrows (geologic section 8), the most spectacular display of the Witten is in the bluff overlooking New River, south of Eggleston, where the beds are repeated by minor folding (geologic section 15). None of the Witten is high-calcium limestone, except at locality 40 (geologic section 20) where, possibly, close folding has repeated some of the beds.

Geologic section 20a (locality 11).—Ordovician limestone along east base of Angels Rest, near Pearisburg, Giles County, Virginia

	Thickness Feet
Moccasin formation	
Witten limestone (55 feet)	
12. Limestone, fine grained, gray, slabby	15
11. Limestone, dove-gray, fine grained	1
10. Limestone, "worm-eaten" appearance; contains clayey stringers; weathers slabby	13
9. Limestone, cross-bedded, conglomeratic, impure	22
8. Limestone, fine grained, laminated	4
Gratton limestone (27 feet)	
7. Limestone, fine-grained, dove-gray	20
6. Limestone, fine-grained, laminated; very silty; weathers dark-brown	7
Benbolt limestone (83 feet)	
5. Limestone, coarse grained, cross laminated, light-gray	16
4. Limestone, granular, dark-gray, cherty	15
3. Limestone, dark-gray, clayey, nodular	33
2. Limestone, nodular, clayey, very impure; contains few thin beds of coarse-grained limestone	32
Cliffield formation	
1. Limestone, cherty, dark-gray, medium bedded	45

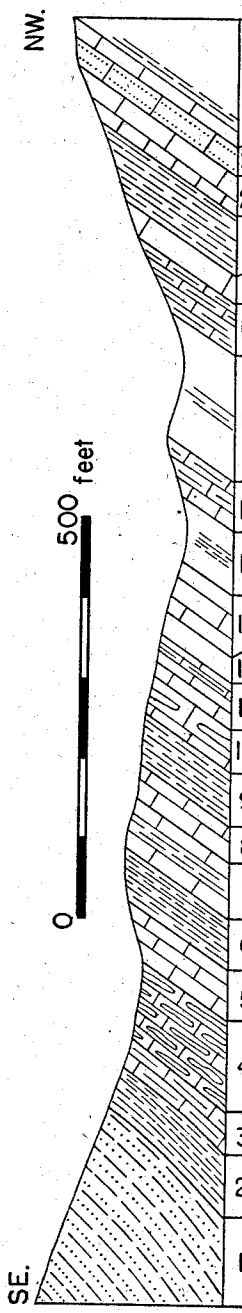
MISSISSIPPIAN LIMESTONES

As shown in geologic section 21, the Mississippian limestones are overturned, so that younger beds on the northwest dip eastward beneath older beds. Shale and shaly limestone are so abundant throughout the entire 1,000-foot succession that none of the rock would be suitable for crushed stone or for chemical purposes. In the detailed study of this section, units 8 and 11 of geologic section 21 were selected as the limestones containing the least impurities. As shown by their analyses, none of the three sampled limestones is high-calcium limestone. A roadside quarry in the upper part of the Mississippian limestone (locality 2) shows fine-grained and coarse-grained oolitic layers and numerous partings of calcareous shale. The succession in geologic section 21 contains representatives of Butts' Warsaw (unit 2), St. Louis (unit 3), Ste. Genevieve, and Gasper limestones.

QUARRIES

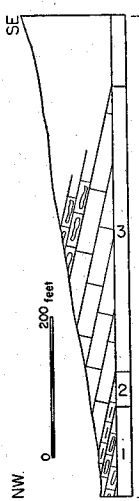
Two limestone quarries have been operated in Giles County, one at Ripplemead and the other at Kimballton. (Pls. 5C, 6A-B.) The Kimballton operation has recently undertaken limestone mining, and has worked underground for more than 700 feet northeastward along the strike of the Five Oaks limestone. The hanging wall of the mine is the bottom of the Lincolnshire limestone. It makes an excellent roof rock, being relatively free of open joints. The roof is supported by pillars about 30 feet in diameter. The rock is broken and sized before leaving the mine. Underground operations of this type have the advantage of excellent working conditions throughout the entire year. The Five Oaks limestone member, which dips about 35° in the Kimballton mine, gradually flattens to the northeast as the beds pass beneath Butt Mountain. Provided that the thickness and quality of the beds now being mined persist down the dip for a considerable distance, millions of tons of very high-grade limestone could be extracted without changing the present method of mining. It is considered unlikely that ground water will become troublesome as the deposit is worked down dip.

The Ripplemead Lime Company operates a small quarry at the west end of the highway bridge across New River (Pl. 5C). The quarry beds, pitching gently to the northeast, consist of about 50 feet of Five Oaks limestone and the lower part of the Lincolnshire.



	Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
21	Siltstone, limy, weathers brown, mealy.	15					
20	Limestone coarse grained, thick bedded.	35					
19	Limestone, very shaly	76					
18	Limestone, oolitic, sandy	28					
17	Limestone, shaly	50					
16	Covered interval, few showings of shale.	145					
15	Limestone, shaly, magnesian, oolitic	35					
14	Covered interval; probably all shaly limestone	67					
13	Limestone, coarse grained, oolitic	46					
12	Covered interval	27					
11	Limestone, coarse grained, gray	43	88.95	3.03	5.24	1.74	0.66
10	Limestone, coarse grained at base, cherty toward top	44					
9	Shale, limy, weathers buff	60					
8	Limestone {coarse grained, oolitic	12	94.66	1.54	2.12	0.98	0.62
	{fine grained, dove-gray	27	94.06	1.91	2.98	1.12	0.52
7	Limestone, shaly, medium gray	50					
6	Shale, limy, weathers buff	45					
5	Limestone, coarse grained, slabby	45					
4	Limestone, black, cherty	87					
3	Limestone, greenish-gray, shaly	35					
2	Shale, mudrock, and limy layers; red	60					
1	Sandstone and shale, thickness not determined	..					

GEOLOGIC SECTION 21.—Mississippian limestone along Norfolk and Western Railway, at locality 1, southeast of Rich Creek, Giles County, Virginia.



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
FIVE OAKS LIMESTONE MEMBER						
Limestone, very fine grained, uniform texture; slightly more magnesian and thin bedded toward base.....	96	97.13	1.50	0.28	0.58	0.08
Limestone, shaly, fine grained.....	20					
BLACKFORD MEMBER						
Limestone, cherty, poorly exposed.....	20					

GEOLOGIC SECTION 22.—Lower part of Cliffield formation along Stony Creek, at locality 17, near Kimballton, Giles County, Virginia.

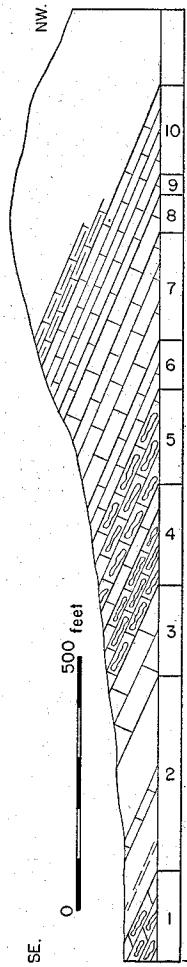
Only fine-grained limestone is burned for lime, but the Lincolnshire and Five Oaks are mixed together and sold as ground limestone and limestone dust. An analysis of the ground limestone is given in Table 2.

QUARRY SITES

High-calcium limestone in thicknesses of 50 feet or more is favorably situated for quarrying or mining at a number of localities in Giles County. It is doubtful whether thinner zones of high-grade limestone could be developed profitably.

Just west of New River, near Narrows (locality 5), 70 feet of dark-gray high-calcium limestone (geologic section 19) occurs in the upper part of the Benbolt formation. Assuming that this limestone is sufficiently persistent to be quarried for a distance of 500 feet along the strike and down to the level of the railroad, about half a million tons would be available for open quarrying. Since the rock is close to the lower limit of high-calcium limestone, additional samples should be collected to determine whether the rock could be used for chemical purposes.

Along the west side of New River at Ripplemead, 60 feet of high-calcium limestone occurs for a distance of at least 1,000 feet south of the present quarry (geologic section 9). Because of the

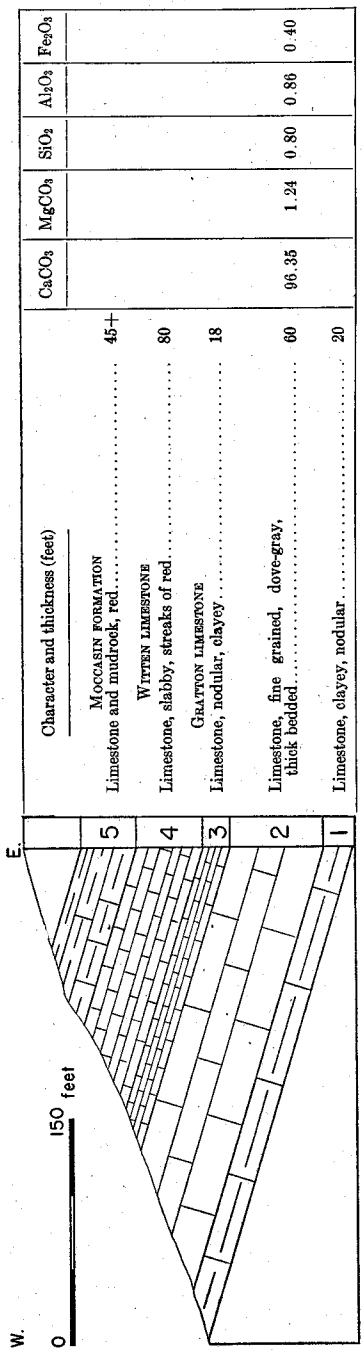


Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
WITTEN LIMESTONE						
10 Limestone, thin bedded, light-gray, weathers slabby	65					
GRATTON LIMESTONE						
9 Limestone, nodular, clayey	20					
8 Limestone, fine grained, dove-gray	30					
BENBOLT LIMESTONE						
7 Limestone, black, fine grained	80					
6 Limestone, nodular, clayey	40					
CLIFFIELD FORMATION						
5 Limestone, cherty, dark-gray	75					
4 Limestone, cherty in lower 60 feet; coarser grained in upper 20 feet	80					
3 Limestone, very fine grained, dove-gray (Five Oaks member)	70	95.55	2.61	0.86	0.90	0.12
2 Covered interval, showings of cherty limestone and shale	150					
1 Beekmantown dolomite	..					

GEOLOGIC SECTION 23.—Ordovician limestone along southeast base of Doe Mountain, at locality 26, near Hoges Store, Giles County, Virginia.

low dip of these beds, mining may be feasible. The occurrence of numerous sinks on the upland to the west may indicate caverns west of the river bluff, and before mining is undertaken, the area west of the quarry should be drilled.

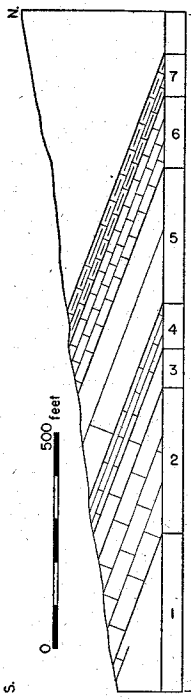
The greatest thickness of high-calcium limestone in the Giles County area was measured at locality 17 along Stony Creek (geologic section 22). Because of the low dip and uncommonly great thickness of the Five Oaks limestone, conditions seem to be ideal



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
MOCCASIN FORMATION						
Limestone and mudrock, red	45+					
WITTEN LIMESTONE						
Limestone, slabby, streaks of red	80					
GRATTON LIMESTONE						
Limestone, nodular, clayey	18					
Limestone, fine grained, dove-gray, thick bedded	60	96.35	1.24	0.80	0.86	0.40
Limestone, clayey, nodular	20					

GEOLOGIC SECTION 24.—Ordovician limestone at locality 29, about 1¼ miles east of Hoges Store, Giles County, Virginia.

for mining. A thickness of approximately 90 to 95 feet, as measured at locality 16, extends southward along the valley wall for at least 1,200 feet. The same thickness probably persists from locality 17 along the valley wall to a point one-fourth of a mile north of the Kimballton limestone mine (locality 19). Half a mile east of locality 17, the upper part of the Ordovician limestone succession and the overlying red Moccasin formation are crumpled and sheared, but no crumpling was noted in any of the beds within 1,000 feet of the outcrop of the Five Oaks limestone at locality 17. Along Little Stony Creek, north of Pembroke, the Five Oaks is no more than 50 feet thick; hence, the member must become thinner down the dip from the exposures near Kimballton (localities 16 and 17). If half the rock could be removed from an underground area extending 1,000 feet down the dip between localities 16 and 17, more than 5,000,000 tons of high-calcium limestone could be extracted. This estimate is based upon the assumption that the thickness averages 70 feet. Between localities 17 and 19, the Five Oaks limestone is largely covered by alluvium. If the thickness and quality of the limestone are essentially the same between these localities, as it is reasonable to suppose, and if the Five Oaks member can be mined



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
MOCCASIN FORMATION						
Mudrock and limestone, mainly red	20+					
WITTEN LIMESTONE						
Limestone, light-gray, fine grained, weathers slabby	35					
GRATTON LIMESTONE						
Limestone, dove-gray, fine grained thick bedded	55					
Limestone, clayey, nodular	15–20					
Limestone, fine grained, gray	15					
BENBOLT LIMESTONE		96.05	2.17	0.48	0.28	0.36
Limestone, coarse grained, gray	70					
Limestone, nodular, clayey	..					

GEOLOGIC SECTION 25.—Ordovician limestone at locality 32, near Boyd Chapel, Giles County, Virginia.

down the dip for at least 1,000 feet, more than 30 million tons of very high-grade limestone could be mined. The valley floor of Stony Creek offers many favorable plant sites, and the spur line of the Norfolk and Western Railway offers direct railroad connections. Considering all these factors, the Five Oaks limestone member along the east wall of Stony Creek Valley, in the general vicinity of Kimballton, offers better possibilities for the extraction of enormous tonnages of superior quality limestone than any other sectors of the New River-Roanoke River district.

Another large body of high-calcium limestone is indicated by the thickness measurements and analyses of the Five Oaks at localities 26 and 27, along the base of Doe Mountain northeast of Pembroke. The dips in this vicinity, which average 20° to 25° NW., would seem to favor mining rather than open quarrying. A thickness of 65 to 75 feet of Five Oaks limestone could be worked there (geologic section 23). The dip probably increases somewhat below

the surface. Fifty to sixty feet of fine-grained compact limestone, averaging more than 97 per cent calcium carbonate (Table 2), occurs in the upper part of the Blackford member about 1½ miles northeast of Hoges Store (locality 28). A similar limestone containing about 96 per cent calcium carbonate is present about 60 feet higher in the same section (Table 2). The beds in this immediate vicinity are near the crest of a major anticline and dip somewhat less than 10° NE. Probably a large tonnage of high-calcium limestone could be quarried or mined in this locality, but the nearest railroad is 4 miles away. Utilizing the 600-foot difference in elevation, stone could be transported to the railroads by way of a gravity bucket line.

The area in the vicinity of localities 29 and 32, northeast of Hoges Store, is believed to be one of the most suitable areas for future development. The structure between these two localities is a shallow syncline, with dips of less than 20° prevailing on either limb. As shown in geologic sections 24 and 25, there are workable thicknesses of high-grade limestone, one in the Gratton and the other in the upper part of the Benbolt. The intervening impure layers may be thin enough to permit extraction of both zones of high-calcium limestone. A minimum thickness of 55 to 60 feet of fine-grained compact, high-calcium limestone between these two localities seems assured. The thickness of the high-calcium limestone in the Benbolt could not be determined at locality 29 because of poor exposures. Conditions seem to be ideal for the mining of rock in this area, and millions of tons of high-calcium limestone could be extracted. Although this locality is more than 3 miles from railroads (Pl. 3), it is sufficiently above New River for the construction of a gravity bucket line. Smaller quantities of high-calcium limestone could be obtained from other localities in this general area. The Gratton seems to be at least 50 feet thick at locality 31, which is located on an outlier of Gratton and Witten limestones.

Along the Virginian Railway about 1 mile south of Eggleston (locality 39), 37 feet of high-calcium limestone occurs at the base of the Gratton (geologic section 15). The overlying 42 feet of fine-grained limestone contains slightly less than 95 per cent calcium carbonate. That the lower half of the 42-foot zone is possibly purer than the upper half is suggested by the relatively thicker bedding in the lower 20 feet of the zone. It seems to be invariably true that

in fine-grained compact limestones, such as occur in the Five Oaks and Gratton, the amount of impurities is directly proportional to the thinness of the bedding. Practically all of the insoluble material in rocks of this type is concentrated as thin films along the bedding. Although a thickness of at least 50 feet of high-calcium limestone probably occurs at this locality, the extent of possible development is strictly limited by crumpling of the beds (geologic section 15). Exposures on the opposite side of the river are too poor to permit accurate thickness measurements and sampling of the fine-grained beds.

The limestones exposed along the southeast side of Green Valley (locality 40), about 3 miles southwest of Eggleston, comprise an unusually thick development of the Benbolt, Gratton, and Witten formations. This section is also unique among those studied in Giles County in containing three thick belts of high-calcium limestone above the Five Oaks member (geologic section 20). The steep dip in this area would facilitate selective quarrying or stope mining of the three high-calcium limestones. Since Green Valley is 350 to 400 feet above New River, quarrying could probably be carried to a depth of at least 200 feet without encountering the water-saturated zone. Assuming that the sampled beds persist for at least 1,000 feet along the strike, several million tons of limestone, having a calcium carbonate content of 96 per cent and a total carbonate content of 98 per cent, could be quarried. A tramroad, with a grade of 100 feet per mile, could be extended southwest from Eggleston, or a gravity bucket line could be constructed from the property eastward to any one of several plant sites along New River near Eggleston.

Coarse-grained limestones at the base of the Lincolnshire member, which directly overlie the Beekmantown dolomite, south of Berton (locality 42), are among the purest found in the Giles County area. Assuming that the rock could be quarried from railroad level to the upland, 250 feet or more above New River, and that the exposed thickness persists southwestward for 1,000 feet, approximately 850,000 tons of high-calcium limestone, containing less than 1 per cent magnesium carbonate and less than 1½ per cent noncarbonates, are available for quarrying (geologic section 14). Quarrying operations would be hampered somewhat by the steep dip of the beds, but stope mining might be feasible.

Besides these relatively large deposits of high-calcium limestone, smaller quantities of high-grade limestone could be produced for local consumption. In such operations, the location, rather than the quality and thickness of the rock, is the prime consideration. The distribution of the Five Oaks limestone, shown on Plate 3, should be helpful in locating smaller quarries.

RADFORD-PEPPERS FERRY AREA

LOCATION

The Radford-Peppers Ferry area is the first limestone-dolomite area southeast of Giles County. It is located along the Norfolk and Western Railway and New River. U. S. Route 11 and State Highway 114 provide access to the almost continuous exposures of rock along the east bluff of New River (Fig. 4).

GEOLOGY

The Cambrian beds in the Radford-Peppers Ferry area are shales, dolomites, and limestones, all or nearly all of which belong to the Elbrook formation (Fig. 5). Their complicated structure[7] is the result of overthrusting along the Pulaski fault. The northwestern edge of the Pulaski fault block is about 3 miles north of the Norfolk and Western Railway bridge across New River (Fig. 4), but the fault is repeated twice between Peppers Ferry and Walton. The Devonian shale which crops out between these two localities is a window. This feature, and others like it in near-by sections of Montgomery, Pulaski, and Wythe counties[8, 11], indicates that the Pulaski overthrust has been folded as though it were a bedding surface.

The great thickness of Elbrook exposed along the bluff of New River north of Peppers Ferry contains very little dolomite or limestone sufficiently free of shale to be suitable for crushed stone and none pure enough to be used in chemical industries. Analyses of various parts of the succession are given in Table 2. Another body of Elbrook was sampled south of Walton, near U. S. Route 11. Great masses of fault breccia and crush conglomerate, similar to those occurring in Pulaski and Wythe counties[12], are prominently displayed in several places, particularly near Peppers Ferry and along U. S. Route 11 at locality 50. Campbell[9] believed this material to be a surficial deposit made by streams emptying into New

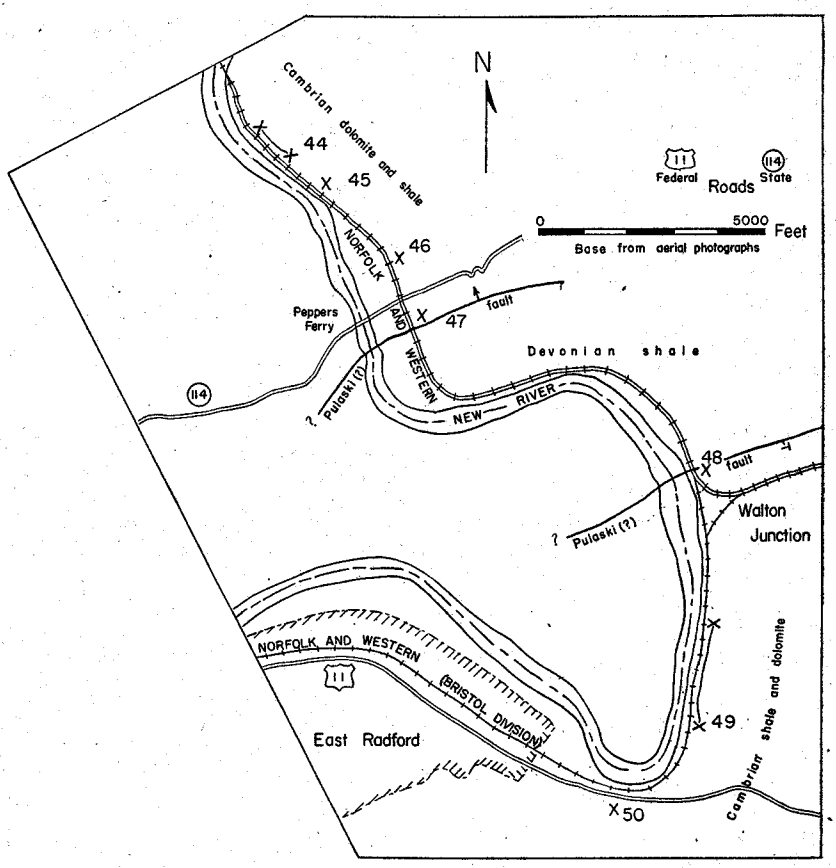
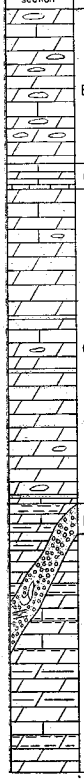


FIGURE 4.—Limestone and dolomite in the Radford-Peppers Ferry area, Va.

River. Butts[7] regards the rock as a cave filling. Its general occurrence and distribution near or along overthrust faults indicate that the material is of tectonic origin.[12] The breccia is composed chiefly of masses of Rome shale and of Elbrook shale and dolomite.

DEVELOPMENT POSSIBILITIES

Although the bluff along New River between Radford and the Norfolk and Western Railway bridge across New River, affords many favorable locations for quarries, the rocks are too impure to be of much value. The crush conglomerate and fault breccia, in some places several hundred feet thick, are rather high in silica



Columnar section	Name	Character and thickness	Average chemical composition (%)				
			$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	Beekmantown	Fine-to coarse-grained gray cherty dolomite and intercalated beds of light-gray limestone; 1,000 feet thick	52	36 (exclusive	9.0 of chert	1.5 beds)	1.5
	Chepultepec	Fine-grained limestone and sugary dolomite; 150 feet thick					
	Copper Ridge	Medium-gray granular sparsely cherty dolomite with intercalated beds of sandstone; 2,100 feet thick	53	40 (exclusive	5.0 of sandstone)	1.0	1.0
	Max Meadows	Poorly indurated crush-conglomerate composed of rounded fragments of dolomite and shale; 10 to 500 feet thick	43	33	16.5	6.0	1.5
	Elbrook	Intercalated zones of shaly magnesian limestone, shaly dolomite, and dolomitic shale and phyllite; at least 2,000 feet thick; complexly folded and faulted — shaly magnesian limestone	77	13	6.5	2.5	0.5
		shaly dolomite	40	35	17.5	5.5	2.0
		dolomitic shale	37	39	16.5	6.0	1.5
		phyllite	35	22	28.0	10.5	3.0

FIGURE 5.—Dolomitic formations in the Radford-Peppers Ferry, Miles, and Ellett areas, Virginia.

(Fig. 5). They might be suitable for use in the manufacture of rock wool, if mixed with small amounts of shale, such as occurs in the window between Peppers Ferry and Walton.

MILES AREA

LOCATION

The Miles area (Fig. 6) is a small tract about 5 miles south of Radford, which is located at the junction of Little and New rivers. A spur line of the Norfolk and Western Railway extends south from Radford to the quarry of the Radford Limestone Company, which is located on the neck of land between the two rivers. A hard surfaced road (605) connects Miles with Radford.

GEOLOGY

According to Butts[2], the beds in this area are part of the overturned, southeast limb of a syncline in the Pulaski overthrust block. They constitute the most southeastern belt of Cambrian-Ordovician rocks in the Appalachian Valley of southwestern Virginia. The youngest beds in this syncline are Ordovician limestones which are thin and poorly exposed along the Norfolk and Western Railway a mile or so west of Cambria (Pl. 8). Southwestward, along the strike, the northwest flank of the syncline terminates against a

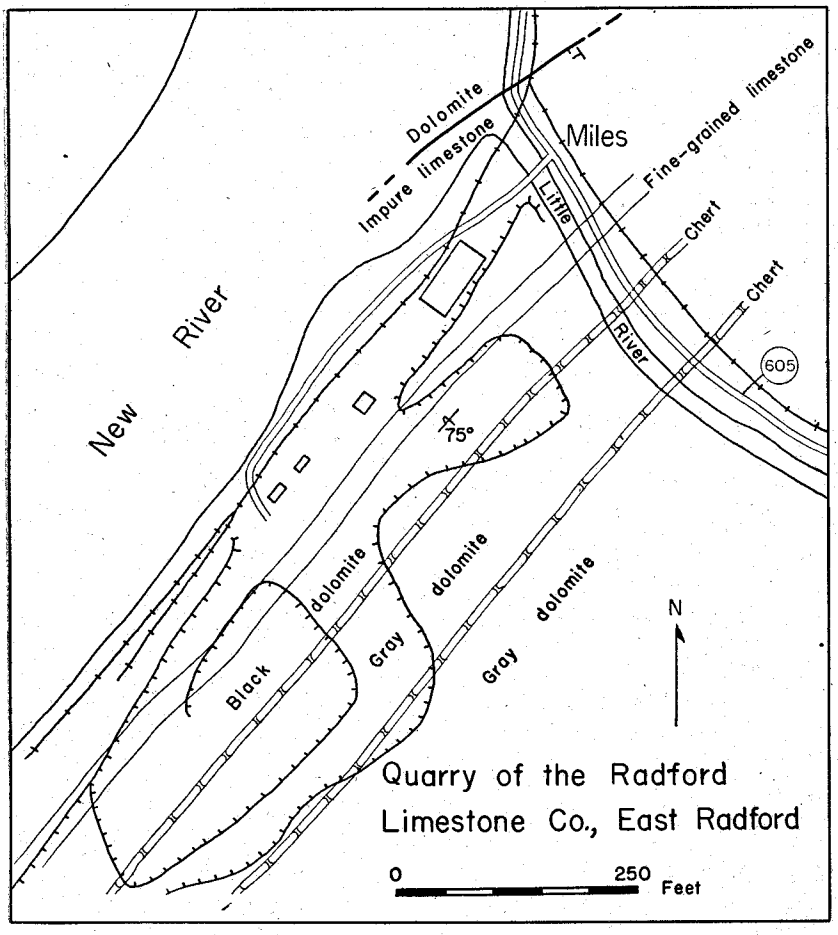
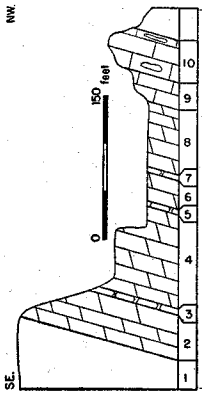


FIGURE 6.—Limestone and dolomite in the vicinity of Miles, Va.

thrust fault, but in the immediate vicinity of Miles, and for a disance of 2 to 3 miles northeast of New River, the Beekmantown dolomite and a thin development of Ordovician limestone occur south of this fault. The character and composition of the beds are fully shown in the quarry of the Radford Limestone Company (Pl. 7B, geologic section 26) and also along the railroad siding just east of the quarry office.



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
"LENOIR" LIMESTONE						
Limestone, dark-gray, nodular	50+	84.20	7.85	4.99	1.66	0.82
"MOSHEIM" LIMESTONE						
Limestone, dove-gray, weathers mealy	27	84.30	8.99	3.39	1.98	0.74
BEEKMANTOWN DOLOMITE						
Dolomite, black, fine grained	59	50.65	37.80	7.30	2.62	1.40
Chert, laminated	6					
Dolomite, gray	30					
Chert, laminated	2-3					
Dolomite, medium- to dark-gray	95	52.55 (exclusive of chert beds)	38.12	7.13	1.78	0.84
Chert	4-6					
Dolomite, medium-gray	45					
Covered, east of quarry rim	..					

GEOLOGIC SECTION 26.—Dolomite and limestone in the Miles area, at locality 52, along New River, Montgomery County, Virginia.

DOLOMITE

Most of the dolomite exposed in the quarry is light- to medium-gray and fine grained, but the 60-foot zone at the top is black. Chert occurs sparsely in the form of disseminated nodules, but there are three distinct beds of chert 3 to 6 feet thick. The silica content of the dolomite is rather high and the magnesium carbonate somewhat less than 40 per cent. Because of its compactness and rather uniform grain, the rock is well suited for crushed rock and stone sand. The Radford Limestone Company furnished the aggregate and stone sand used in construction of Claytor Dam[1] on New River just south of the quarry. The beds in the Miles area are overturned, so that the younger limestones on the west side of the quarry dip beneath the Beekmantown.

LIMESTONE

Two belts of Ordovician limestone crop out near the western rim of the quarry (Fig. 6). Although these limestones have been identified by Butts[2] as Mosheim and Lenoir, the character of the beds is different from that of his Lenoir and Mosheim in other belts of the Appalachian Valley. In the Miles area, Butts' "Mosheim," which directly succeeds the Beekmantown, is a granular, mealy textured, dark-gray limestone about 27 feet thick. This limestone is flanked on the west by a dark-colored granular limestone with clayey streaks and partings. Although very different in general appearance, the "Mosheim" and "Lenoir" have almost the same composition (geologic section 26). In the vicinity of the Radford Limestone Company's quarry, both limestones are too impure for chemical uses.

DEVELOPMENT POSSIBILITIES

Since the rocks exposed in the quarry persist northeastward toward Christiansburg, there are large supplies of dolomite in the upland northeast of Little River. After all the available rock has been extracted from the present quarry location, a new quarry can be opened along the railroad siding just east of Little River.

ELLETT AREA

LOCATION

The Ellett area, a narrow tract about 6 miles long and 2 miles wide, is located in the valley of the North Fork of Roanoke River, about 3 miles east of Blacksburg. Ellett is centrally located along the Virginian Railway which crosses the southern half of the area. State Highway 114 connects Lusters Gate with Blacksburg, and Road 615, which provides direct access to all parts of the area, connects the area with U. S. Route 11 and the Norfolk and Western Railway (Pl. 8).

GEOLOGY

Formations studied in the Ellett area include 3,250 feet of dolomite and intercalated limestone of Cambrian and Ordovician

age and 60 to 250 feet of Ordovician limestone. The rocks mapped on Plate 8 dip 70° E. near the Salem fault but progressively less toward Lusters Gate, where dips of 15° to 20° E. prevail. The Salem fault and the overthrust rocks to the south of it are very poorly exposed and were not studied. The position of the Salem fault is indicated locally along Road 615 by crush conglomerate.

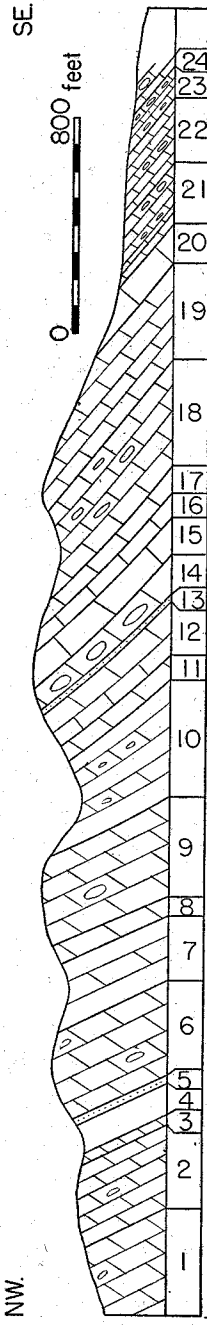
The general character and thickness of the various formations in the area are shown in Figures 5 and 7. The belt mapped as "Dolomite and Limestone (Cambrian and Ordovician)" includes the Beekmantown, Chepultepec, and the greater part of the Copper Ridge formation. The Five Oaks limestone, directly overlying the Beekmantown, is mapped separately; the Lincolnshire and Whitesburg are shown as a single unit on Plate 8. The Whitesburg is flanked on the east by a relatively broad belt of black shale and intercalated limy beds, identified by Butts[2] as Athens shale.

DOLOMITE

COPPER RIDGE DOLOMITE

The Copper Ridge in the Ellett area is very similar in character to that in Giles County but is notably thicker. A little more than 2,000 feet of the formation was measured along the Virginian Railway southeast of Yellow Sulphur Station (locality 66). This does not represent all of the formation, for an undetermined thickness at the base has been cut out by a fault which crosses the railroad about 1,000 feet east of Yellow Sulphur Station. Much of the formation is exposed in cuts along the railroad, and parts of it crop out along Road 603 west of Ellett. The general character of the dolomite is well shown in a roadside quarry, formerly operated by the State Department of Highways, at locality 63 along Road 603 (Pl. 7C).

As shown in geologic section 27, relatively few sandstones occur in the Copper Ridge along the Virginian Railway. Two zones, one about 275 feet thick (geologic section 27, unit 2) and the other over 400 feet thick (units 4-6) contain little sand and chert and average more than 40 per cent dolomite. The 275-foot zone of high-magnesium dolomite is low in noncarbonates and alkalies and may be suitable for chemical purposes. The other zone is too high in noncarbonates for chemical uses.



	Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
24	Limestone, fine grained, gray (Five Oaks)	25					
	BEEKMANTOWN FORMATION						
23	Dolomite, medium grained; few limy layers	75					
22	Dolomite, medium grained, gray	135					
21	Dolomite, medium grained; about 20 feet of fine grained limestone near the base	157					
20	Limestone, fine grained, pearl-gray; contains coarse-grained dolomitic layers	92					
19	Dolomite, partly covered	215					
18	Dolomite, very cherty, medium to coarse grained	275					
17	Dolomite, coarse grained, gray	80					
	CHEPULTEPEC FORMATION						
16	Limestone and dolomite, partly covered	53					
15	Limestone and dolomite, interbedded	93					
	COPPER RIDGE DOLOMITE						
14	Dolomite, medium-gray, fine grained	86					
13	Sandstone, and sandy dolomite	20					
12	Limestone and dolomite, interbedded	65					
11	Dolomite, medium gray	60					
10	Covered interval	284					
9	Dolomite, thoroughly fractured, gray	305					
8	Dolomite, light-gray, fine grained	80					
7	Covered	220					
6	Dolomite, medium-gray, dense	330	50.24	40.26	6.18	2.22	1.26
5	Sandstone, rusty brown	26					
4	Covered	110					
3	Dolomite, dark-gray, laminated, silty	37					
2	Dolomite, light-gray, fine grained	225	54.66	42.00	3.06	0.31	0.34
1	Dolomite, thoroughly fractured	250					

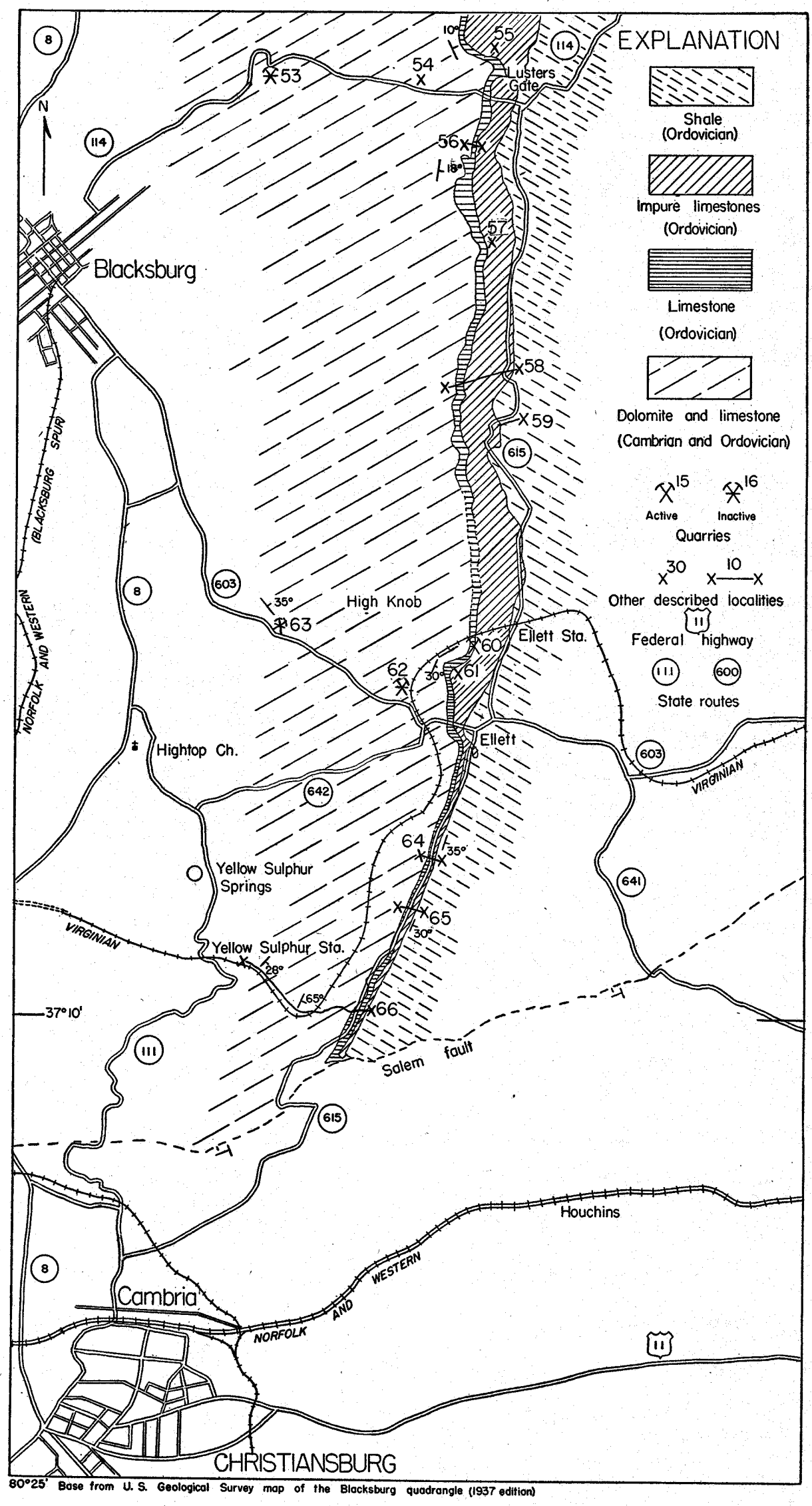
GEOLOGIC SECTION 27.—Dolomite along Virginian Railway at locality 66, southeast of Yellow Sulphur Station, Montgomery County, Virginia.

CHEPULTEPEC FORMATION

The Copper Ridge is directly overlain by 100 to 150 feet of fine-grained compact limestone and intercalated layers of dolomite and of a peculiarly mottled rock made up of interwoven stringers and masses of dolomite and calcite. The dolomitic parts of this rock weather dark-gray; the limestone stringers light bluish-gray. Some of the limestone layers seem to be conglomeratic, and a few are oolitic. Floating sand occurs in the dolomitic layers. The several varieties of limestone and dolomite found in the Chepultepec are well displayed in an abandoned quarry east of Blacksburg (locality 53). Dimension stone of excellent quality taken from this quarry (Pl. 7A) has been used in numerous stone buildings of the Virginia Polytechnic Institute at Blacksburg. The 30 to 45 feet of beds exposed in this quarry is near the base of the Chepultepec, as sandstones of the Copper Ridge formation occur not more than 50 feet below the quarry floor. The Chepultepec identified along the Virginian Railway is about 150 feet thick (geologic section 27). None of the formation is suitable for chemical uses.

BEEKMANTOWN FORMATION

About 1,000 feet of fine- to coarse-grained dolomite and intercalated beds of fine-grained compact limestone comprise the Beekmantown in the Ellett area. Much of the Beekmantown is so cherty as to be of little value. In the cuts along the railroad north and west of Ellett, the greatest thickness of chert-free dolomite is considerably less than 75 feet. The limestone beds are uniformly fine grained and dove-gray but do not occur in thicknesses greater than 90 feet. An attempt was made to quarry a thickness of Beekmantown limestone west of Ellett. As shown in the quarry, the limestone layers are not persistent but grade into or are replaced by masses of chert or beds of coarse-grained dolomite. The upper 300 feet of the Beekmantown along State Highway 114 at locality 54, west of Lusters Gate, contains considerably more limestone than was seen along the railroad west of Ellett, but intercalations of dolomite are so common as to make the rock worthless as a source of chemical limestone. The general character of the Beekmantown is shown in Figure 5.



Limestone and dolomite in the Ellett area, Virginia.

QUARRY SITES

Large quantities of relatively pure high-magnesium dolomite could be obtained by quarrying unit 2 of geologic section 27 northeastward along the strike toward Road 603. A quarry face at least 300 feet high and 400 to 500 feet wide could be developed in this unit. The upland to the north of the exposures along the railroad could furnish enormous quantities of dolomite suitable for crushed stone and stone sand from either of the sampled units shown in geologic section 27.

ORDOVICIAN LIMESTONES

FIVE OAKS LIMESTONE

In the Ellett area, the Five Oaks limestone immediately succeeds the Beekmantown formation. The contact is well defined in most places, but just north of the quarry of the Montgomery Lime Company (locality 60) and also midway between Lusters Gate and Ellett (locality 58) the uppermost beds of the Bekmantown are also

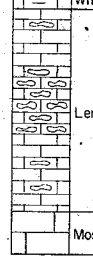
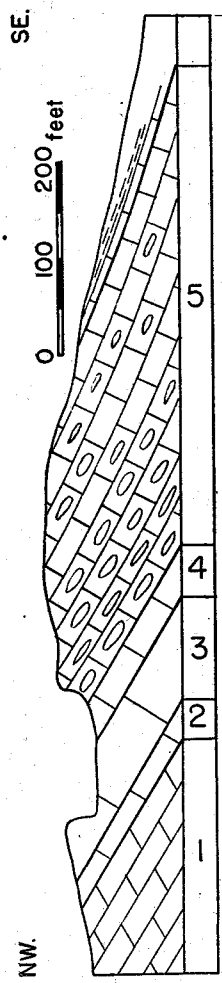
Columnar section	Names used by Butts	Names used in this report	Character and thickness	Average chemical composition(%)				
				$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	Whitesburg	Whitesburg	Coarse-grained impure limestone; 20 feet thick	80±		15±		
	Lenoir	Lincolnshire	Dark-gray granular cherty limestone; 20 to 200 feet	87	4.5	7.0	1.0	0.40
	Mosheim	Five Oaks	Dove-gray fine-grained limestone 40 feet thick	95	2.0	1.5	1.0	.40

FIGURE 7.—Ordovician limestone in the Ellett area, Virginia.

fine-grained limestone. The latter, however, is somewhat shaly and weathers light-buff, whereas the Five Oaks weathers smoky-gray. The general character of the limestone is the same as it is in Giles County.

Close study of the Beekmantown-Five Oaks contact indicates that the Five Oaks was deposited on an erosional surface having irregularities of the magnitude of 50 to 75 feet. Along Road 615 at locality 64, the irregularity at the base of the Five Oaks is



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
LINCOLNSHIRE LIMESTONE						
Limestone, medium grained, dark-gray, cherty	195	87.64	4.62	5.28	1.65	0.46
Limestone, medium grained, dark-gray.	27	90.12	4.02	4.73	0.90	0.28
FIVE OAKS LIMESTONE						
Limestone, dove-gray, fine grained	52	95.22	1.91	1.13	0.90	0.28
BEEKMANTOWN DOLOMITE						
Limestone, buff-gray, impure	20					
Dolomite, cherty, poorly exposed	..					

GEOLOGIC SECTION 28.—Ordovician limestone in the vicinity of the Montgomery Lime Co. quarry, at locality 60, Montgomery County, Virginia.

shown by local variations in thickness of the limestone from 15 to 40 feet. Less than half a mile south along the same road, at locality 65, the Five Oaks locally thickens to 110 feet and appears to occupy an erosional trough in the Beekmantown. Several less notable irregularities are found between these two localities. A variation in thickness of about 25 feet occurs just west of Lusters Gate, at locality 55.

The thickness of the Five Oaks limestone averages about 40

feet. The upper 35 feet is exposed in the northwest end of the quarry of the Montgomery Lime Company, near Ellett. Along Indian Run Creek (locality 55), the Five Oaks is nearly horizontal and 30 feet thick.

The calcium carbonate content of the Five Oaks ranges from 93 to slightly more than 95 per cent (geologic sections 28-30, Table 2).

Geologic section 29 (locality 64).—Ordovician limestone along Road 605, about a mile south of Ellett, Montgomery County, Virginia

	Thickness Feet
Whitesburg limestone	
4. Limestone, coarse grained, light-gray, impure	1½
Lincolnshire limestone	
3. Limestone, granular, dark-gray, cherty	102½
Five Oaks limestone	
2. Limestone, fine grained, dove-gray, compact	14
1. Limestone, mostly fine grained, compact; contains a few impure, conglomeratic layers near the base; thins to about 15 feet in a distance of less than 50 feet along the strike	23
Beekmantown dolomite	

Geologic section 30 (locality 58).—Ordovician limestone midway between Lusters Gate and Ellett, Montgomery County, Virginia

	Thickness Feet
Whitesburg limestone	
4. Limestone, coarse grained, light-gray, impure	20
Lincolnshire limestone	
3. Limestone, cherty, rather fine grained in upper part; cherty except for basal 30 feet, which is coarser grained and almost black	238
Five Oaks limestone	
2. Limestone, dove-gray, fine grained, very compact	37
Beds of uncertain age	
1. Limestone, containing intercalated dolomitic layers; banded; Beekmantown or Blackford	140

Although the total carbonate content is well above 96 per cent, the rock is probably not suitable for chemical uses.

WHITESBURG AND LINCOLNSHIRE LIMESTONES

The Whitesburg and Lincolnshire, mapped together on Plate 8, comprise most of the thickness of Ordovician limestone in the Ellett area. Except for the lowermost beds of the Lincolnshire, which are relatively free of chert, none of the succession is sufficiently pure for industrial uses.

South of Ellett, the Lincolnshire is 35 to 100 feet thick, but between the Montgomery Lime Company's quarry (geologic section 28) and locality 58 it is about 200 feet thick. The lower 27 feet of the Lincolnshire at the Montgomery Lime Company's quarry is relatively free of chert and was formerly burned for agricultural lime, but the purer Five Oaks limestone is now being used.

The Whitesburg is composed of cobbly-weathering, impure, granular limestone 20 to 50 feet thick. Most of the beds contain smooth black fragments of trilobites. A few of the Whitesburg beds are relatively dark-colored, like the Lincolnshire, but the typical color is medium- to light-gray. None of the Whitesburg or Lincolnshire is pure enough for chemical uses. The character and composition of these limestones are shown in Figure 6.

QUARRIES

The Montgomery Lime Company operates a quarry and lime-burning plant near Ellett (locality 61). Although located along the Virginian Railway, all the lime is either sold locally or shipped by truck. Except for the locally thickened development of the Five Oaks at locality 65, the thickness and carbonate content of the Five Oaks at the Montgomery Lime Company's quarry are greater than at any of the other localities examined.

Limestone layers in the Beekmantown formation were formerly quarried and burned for lime at locality 62, but the operation was abandoned many years ago. The great amount of chert and dolomite, associated with the limy layers, made quarrying unprofitable.

QUARRY SITES

The calcium carbonate content of the Five Oaks limestone in the Montgomery Lime Company's quarry barely exceeds 95 per

cent, and the Five Oaks is somewhat purer there than elsewhere in the Ellett area. For this reason, it is considered unlikely that additional commercial deposits of high-calcium limestone exist. However, rock suitable for agricultural lime or agstone could be obtained at a number of places from the Five Oaks. The topography is particularly favorable for quarrying at the following localities: (1) along Indian Run Creek just north of Lusters Gate (locality 55); (2) half a mile south of the church along State Highway 114 near Lusters Gate (locality 56); (3) about 1 mile south of Lusters Gate (locality 57); and (4) half a mile west of Road 615 (locality 58). At these localities, the Five Oaks limestone is 35 to 40 feet thick and contains 95 to 97 per cent total carbonates (Table 2). At locality 61, just southwest of the Montgomery Lime Company's quarry, at least 50 feet of high-calcium limestone is believed to be present though in less quantity than at locality 61. Between Ellett and locality 66, the Five Oaks crops out along Road 615 not far above stream level. The uncommon thickness of the Five Oaks at locality 65 is of little value because much of the rock is clayey.

MONTGOMERY AREA

A small tract in the vicinity of Montgomery Station (Figs. 1 and 8) was studied in some detail because the quarrying possibilities seem to be better there than at any other locality between Christiansburg and Roanoke. The area is crossed by U. S. Route 11. The old location of the highway, now an alternate route, connects with the new highway at the top and base of a steep grade near the headwaters of Roanoke River.

GEOLOGY

Greenish and reddish shales of the Rome formation were noted along Road 641 northwest of Montgomery Station. The Rome-Elbrook contact crosses this road a short distance north of the railroad crossing near Montgomery Station. Along the railroad shaly, crumpled Elbrook beds are exposed in several places, but east of the railroad crossing only crush conglomerate and fault breccia are exposed. All these rocks are mapped together in Figure 8. The belt to the south is composed mainly of medium- to dark-gray gran-

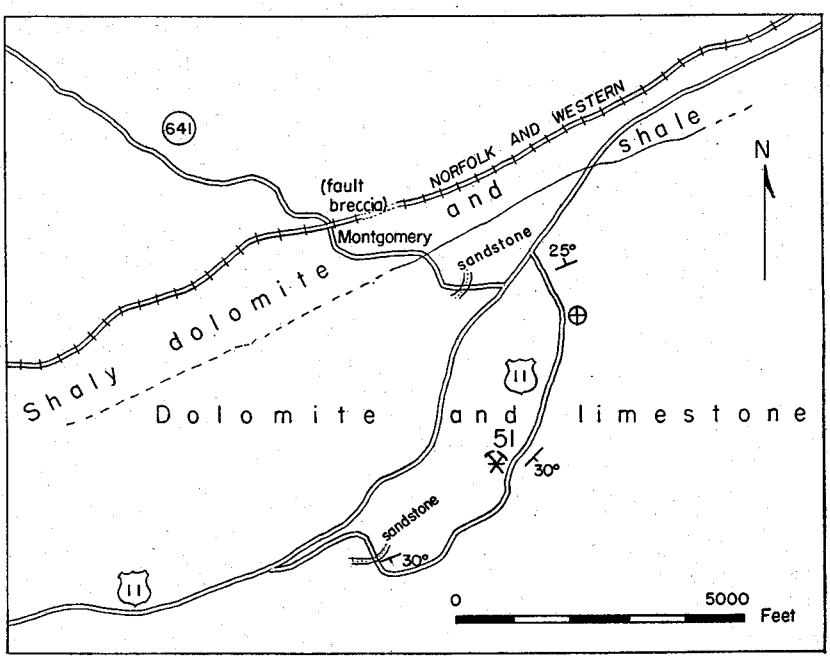


FIGURE 8.—Limestone and dolomite in the vicinity of Montgomery Station, Va.

ular dolomite, with intercalated beds of quartz sandstone and magnesian limestone. Minor flexures in the dolomite are exposed along the lower end of alternate U. S. Route 11. The general dip is about 30° S. The character and composition of the rocks is shown in Figure 5.

QUARRY SITES

About 80 feet of light- to dark-gray medium-grained dolomite is exposed in a roadside quarry (locality 52), along alternate U. S. Route 11. This rock (Table 2) averages about 50 per cent calcium carbonate, 43 per cent magnesium carbonate, and slightly less than 5 per cent silica. An adjoining 75-foot thickness on the south, exposed along the highway, contains only about 30 per cent magnesium carbonate. Neither of these units is sufficiently pure for chemical use, but these and other beds exposed north of the quarry could be quarried on a large scale for crushed stone.

SALEM-ELLISTON AREA

The Salem-Elliston area comprises the sector along the railroads and U. S. Route 11 between the west environs of Roanoke and the Montgomery area (Figs. 1, 9 and 10).

Between Montgomery Station and Roanoke, the Rome shale and Elbrook formation are almost continuously exposed in cuts along the highway or railroads. Crush conglomerate and fault breccia are also prominent in the sector between the Montgomery area and Shawsville. East of this point, the most abundant rock is a sheared, macerated, phyllitic rock resulting from the dynamic metamorphism of dolomitic shale in the Elbrook. A thickness of 200 to 300 feet of this rock was sampled along the Norfolk and

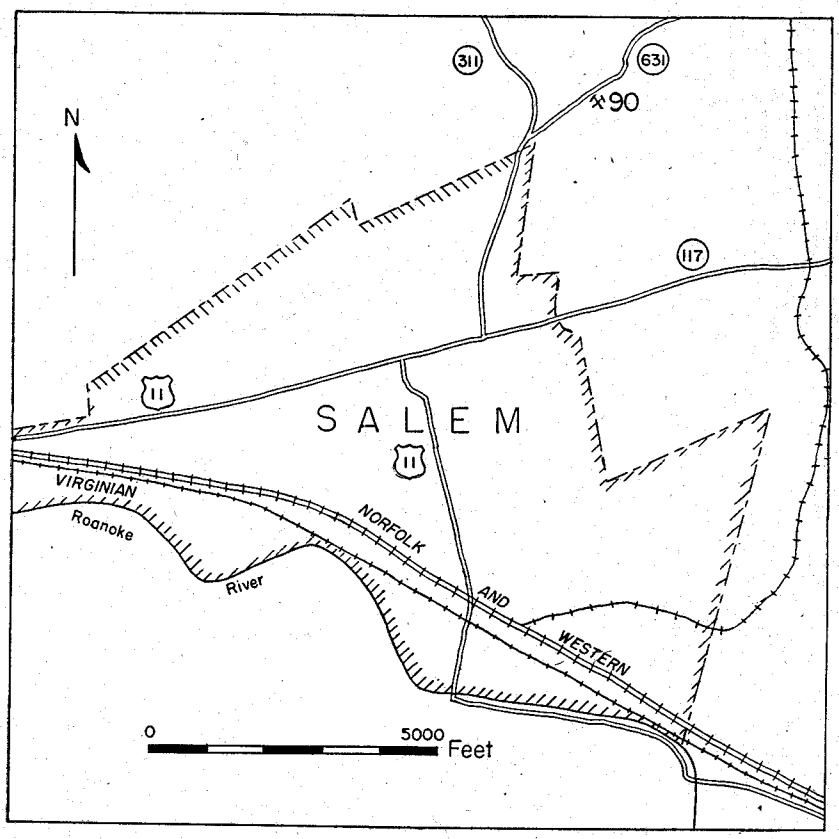


FIGURE 9.—Index map of Salem, Va., and vicinity.

Western Railway about 1 mile west of Elliston (Figs. 1 and 10; Table 2). Crush conglomerate in Elbrook dolomite is well exposed in the Salem municipal quarry (Fig. 9, locality 90). This locality is close to the Salem fault which crosses Road 631 about 750 feet northeast of the quarry. The overridden rock is Athens shale. A thickness of about 200 feet of Elbrook is fully exposed along U. S. Route 11 just southwest of the entrance to Dixie Cavern. The beds dip 60° SE. and are overturned. The same beds are prominent in the undercut bank of Roanoke River about a fourth of a mile due east of the entrance to Dixie Cavern. Although these exposures show a greater proportion of dolomite to shaly rock than was observed in any other localities between Montgomery and Roanoke,

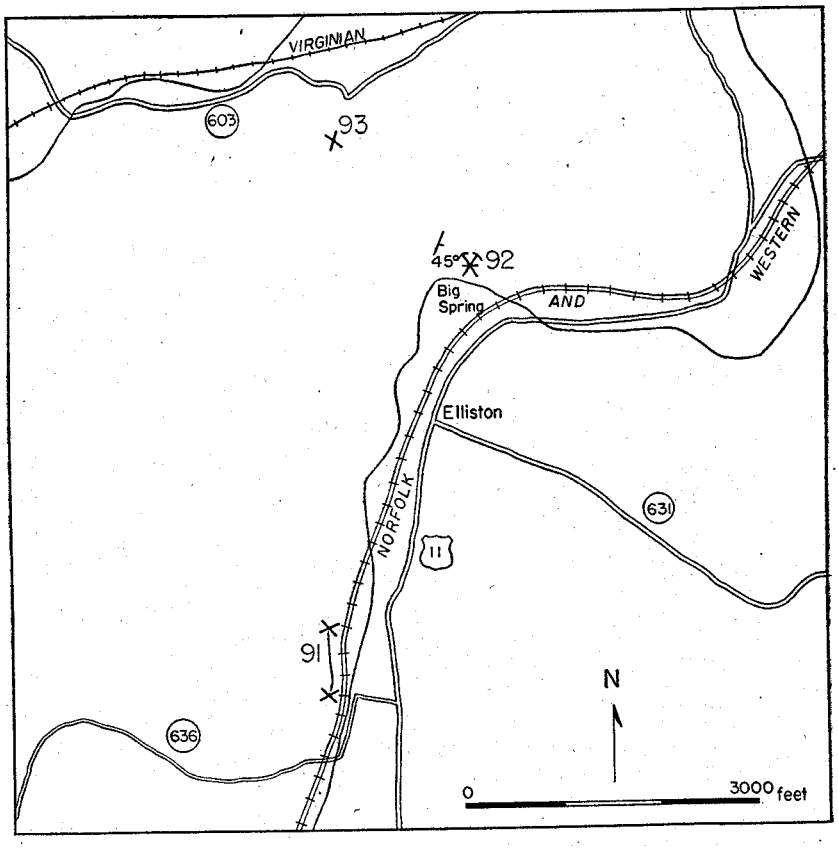


FIGURE 10.—Index map of Elliston, Va., and vicinity.

the rock is believed to be too impure for use as crushed stone or for agricultural purposes. A 40-foot ledge of Elbrook dolomite, overlain and underlain by shaly rock, is exposed in an old quarry along the undercut bluff of the South Fork of Roanoke River and about one-fourth of a mile northwest of Big Spring (Fig. 10). About 100 feet of black brecciated dolomite crops out in the bluff along the North Fork of Roanoke River, about 1 mile north of Elliston (Fig. 10). The general character and prevailingly complicated structure of the Elbrook are well shown along Road 627 (Montgomery County), about 1¼ miles west of the junction of the forks of Roanoke River and about a mile north of U. S. Route 11.

Because of the generally shaly and impure character of the rocks exposed in the sector between Montgomery Station and Roanoke, no deposits of industrial limestone or dolomite are believed to occur. Possibly the most siliceous phases of the Elbrook, exposed along the Norfolk and Western Railway west of Elliston (Fig. 10), could be used in the manufacture of rock wool, if mixed with small amounts of shale. The character and composition of the Elbrook beds of this area have been discussed by Woodward.[17]

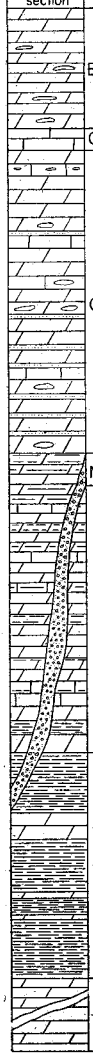
ROANOKE-BLUE RIDGE AREA

LOCATION

The Roanoke-Blue Ridge area is a narrow tract located along the Norfolk and Western Railway and U. S. Route 460 and extending northeast to the Botetourt-Bedford county line (Pl. 11). State Highway 114, leading north from Bonsacks, connects U. S. Route 460 with Cloverdale which is located along the Shenandoah Valley Division of the Norfolk and Western Railway and U. S. Route 11.

GEOLOGY

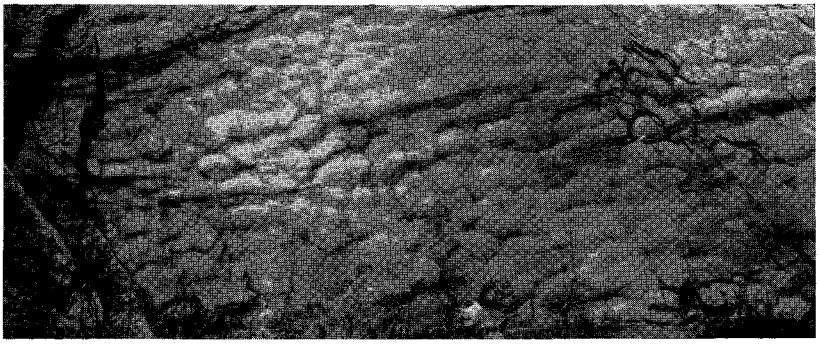
The Rome and Elbrook, the only formations occurring along the railroad and U. S. Route 11, are complexly folded and fractured. They pass beneath the older, overthrust rocks composing the Blue Ridge a mile or so northeast of the Bedford-Botetourt county line. In the vicinity of Blue Ridge Station, the Rome and Elbrook dip about 30° W., but the dips are steeper in the Blue Ridge quarry (Fig. 12). Southwestward toward Webster, the strike changes to northeast and the beds become overturned. Southwest of Coyner,



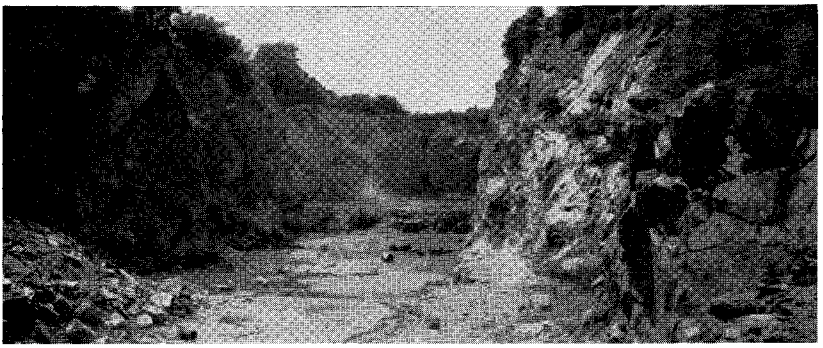
Columnar section	Name	Character and thickness	Average chemical composition (%)				
			$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	Beekmantown	Medium-gray granular dolomite and intercalated fine-grained limestone; very cherty; 800 feet thick	65	30 (exclusive	3.5 of chert	1.0 beds)	0.5
	Chepultepec	Fine-grained light-gray limestone; 150 feet thick	92	3.5	2.0	1.0	0.5
	Copper Ridge	Mainly gray granular dolomite; with intercalated beds of limestone and calcareous sandstone; limestones more abundant near Roanoke; about 2,000 feet thick	63	28 (exclusive	5.5 of	2.5 sandstone)	1.0
	Max Meadows	Crush conglomerate; up to several hundred feet thick	60	30	6.0	2.5	0.5
	Elbrook	Intercalated dolomites, magnesian limestones, dolomitic shales, and phyllites, complexly folded and faulted, at least 2,000 feet thick — shaly dolomite	62	22	9.0	4.0	1.0
		dolomitic shale	48	28	15	7.0	1.0
	Rome	Varied succession of shales, siltstones, limy beds, and zones of phyllite, severely folded and faulted, thickness indeterminate; 150-foot zone of fine-grained dolomite near Roanoke — 150-foot zone dolomite	53	41	2.5	1.5	1.0
	Shady	Dolomite, reported south of Roanoke; unexposed					

FIGURE 11.—Dolomitic formations in the Montgomery, Elliston, Salem, Roanoke, and Cloverdale areas, Virginia.

along U. S. Route 460, many minor folds in the Rome are exposed. Between localities 79 and 81, along Tinker Creek, the same belt of dolomite in the Rome is repeated several times. Anticlines are well exposed in the quarries at localities 79, 80 and 84.



A.



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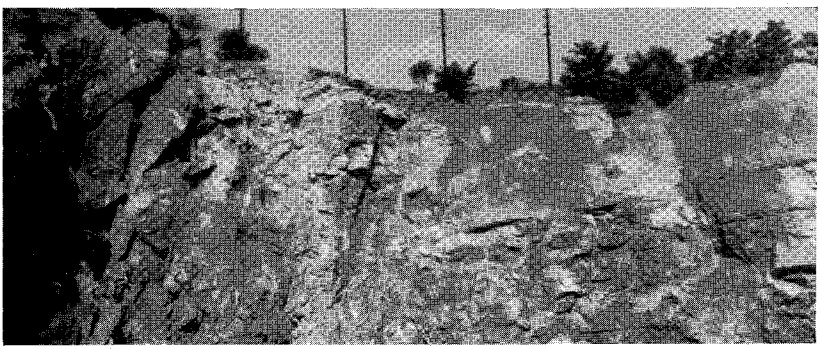
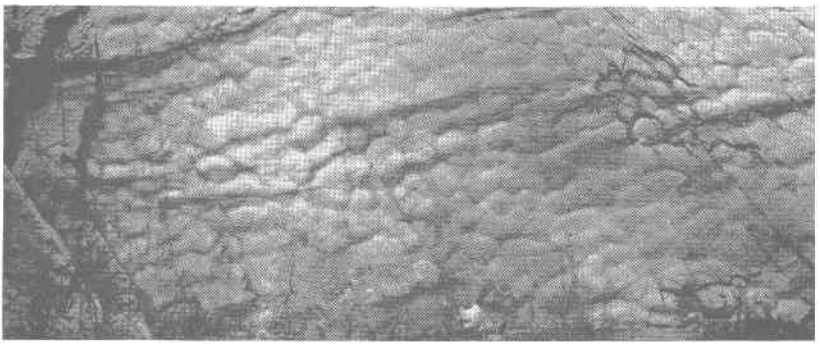
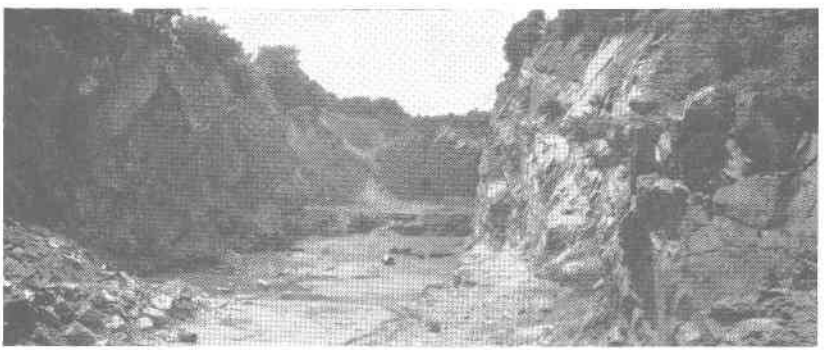


C.

A, Mud cracks in the Rome formation in the Roanoke municipal quarry. B, Roanoke municipal quarry in the dolomite member of the Rome formation. C, Quarry of the Rockydale Quarries Corporation near Roanoke, Va.



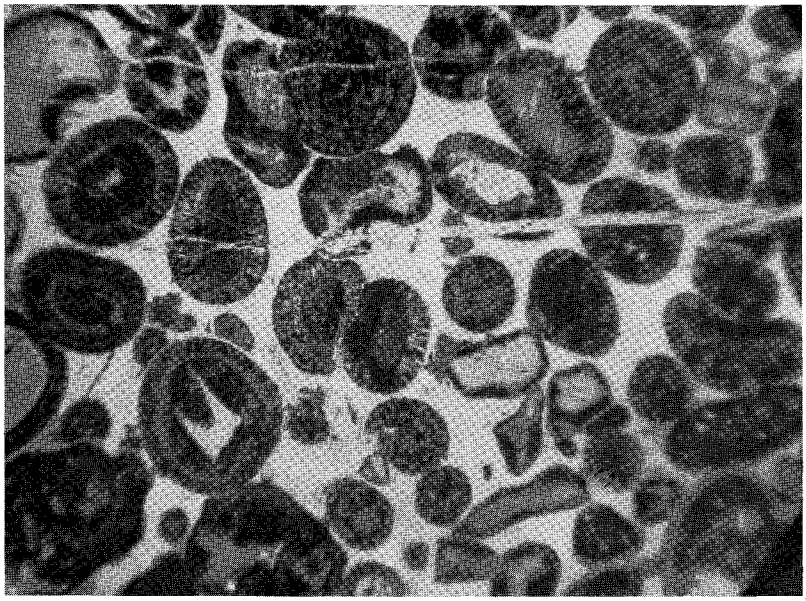
A.



B.

C.

A, Mud cracks in the Rome formation in the Roanoke municipal quarry. B, Roanoke municipal quarry in the dolomite member of the Rome formation. C, Quarry of the Rockydale Quarries Corporation near Roanoke, Va.



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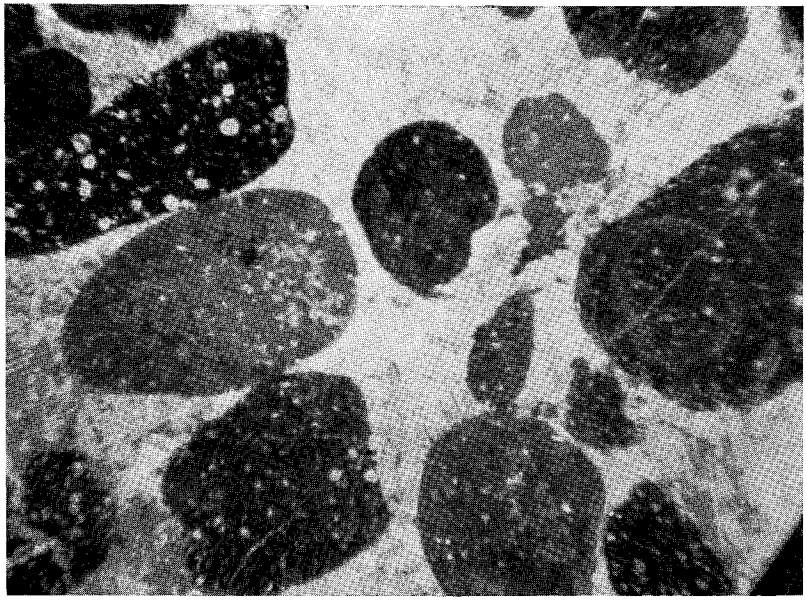
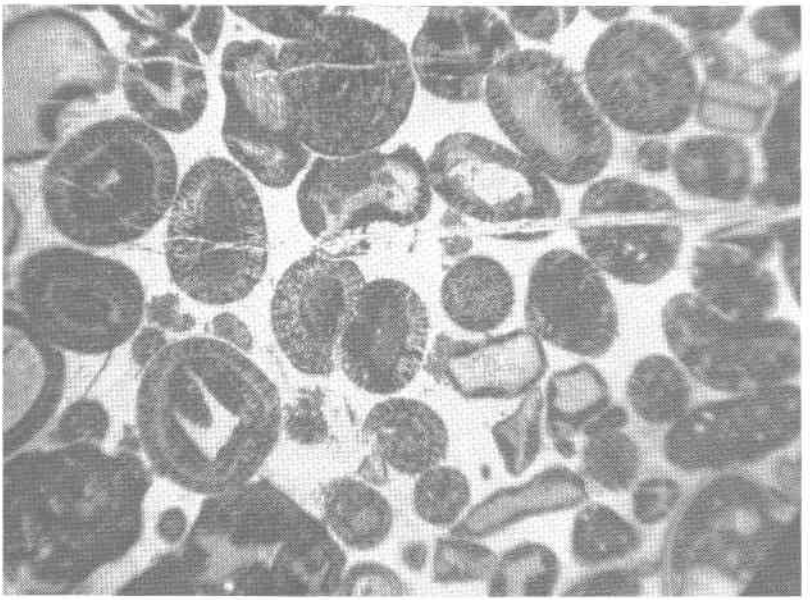


B.

A, Photomicrograph of oolitic limestone from the Mississippian beds southeast of Rich Creek, Va. B, Photomicrograph of clastic limestone in the Five Oaks limestone at locality 73 near East View School. Crossed nicols; X 25.



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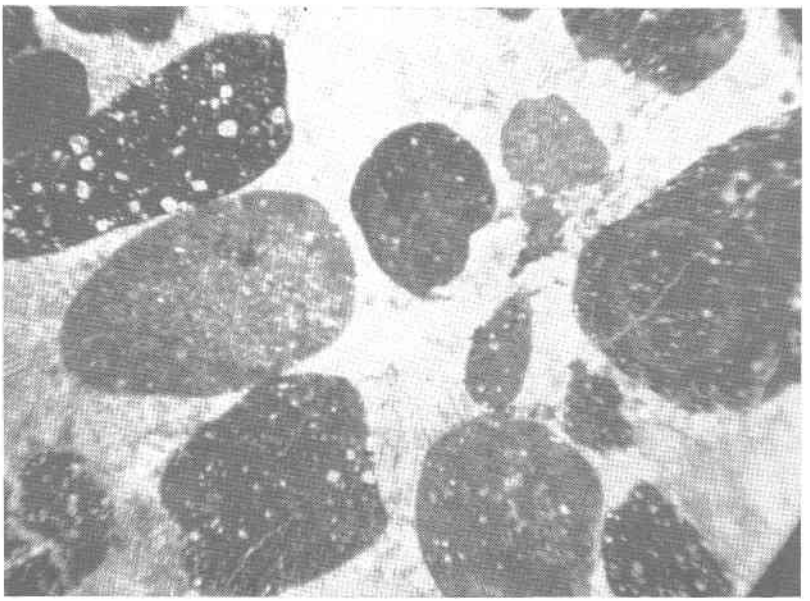


B.

A, Photomicrograph of oolitic limestone from the Mississippian beds southeast of Rich Creek, Va. B, Photomicrograph of clastic limestone in the Five Oaks limestone at locality 73 near East View School. Crossed nicols; X 25.

DOLOMITE MEMBER OF THE ROME FORMATION

Although most of the Rome is shale, it contains several bodies of dolomite, one of which is especially prominent in this area. The principal belt of this dolomite has been traced from the Roanoke municipal quarry (Fig. 13, locality 89) to a point about half a mile east of Tinker Creek and in another segment for a distance of 4 to 5 miles northeast of Bonsacks. The dolomite in the Roanoke quarry (Pl. 9B) is medium bedded, fine grained, and dark-gray. It is the purest dolomite sampled in the Roanoke area. From this quarry, the dolomite extends eastward in a broad arc, following U. S. Route 460 to Tinker Creek, thence through the quarry of the Rockydale Quarries Corporation. The thickness at the Roanoke quarry is 135 feet; at the Rockydale quarry approximately 155 feet. The Rome dolomite between Webster and Bonsacks is well exposed in an abandoned quarry at locality 82.

ELBROOK FORMATION

The Blue Ridge Stone Corporation's quarry, near the Bedford-Botetourt county line, affords the only extensive exposure of the Elbrook dolomite in the vicinity of Roanoke. The rock is mainly a dark-gray, very fine-grained, compact dolomite similar to the dolomite member of the Rome formation. Several light-gray and buff beds are shown in the northern end of the quarry. The beds examined along line B-B′ in Figure 12 contain considerable fluorite in the form of thin intersecting veinlets. Analyses of the quarry beds indicate that the rock is much less dolomitic and markedly higher in silica than the dolomite member of the Rome. The same beds crop out along the low ridge south of U. S. Route 460, in the vicinity of Blue Ridge Station.

QUARRIES

A quarry, formerly operated by Mundy Brothers at locality 79, is situated on an anticline in the dolomite member of the Rome formation. The floor and much of the working faces are now under water and the plant has been dismantled. Another quarry was formerly operated at locality 81, along the Norfolk and Western Railway. The quarry beds may be the same as those quarried at locality 80 near U. S. Route 460, but the beds in the quarry near

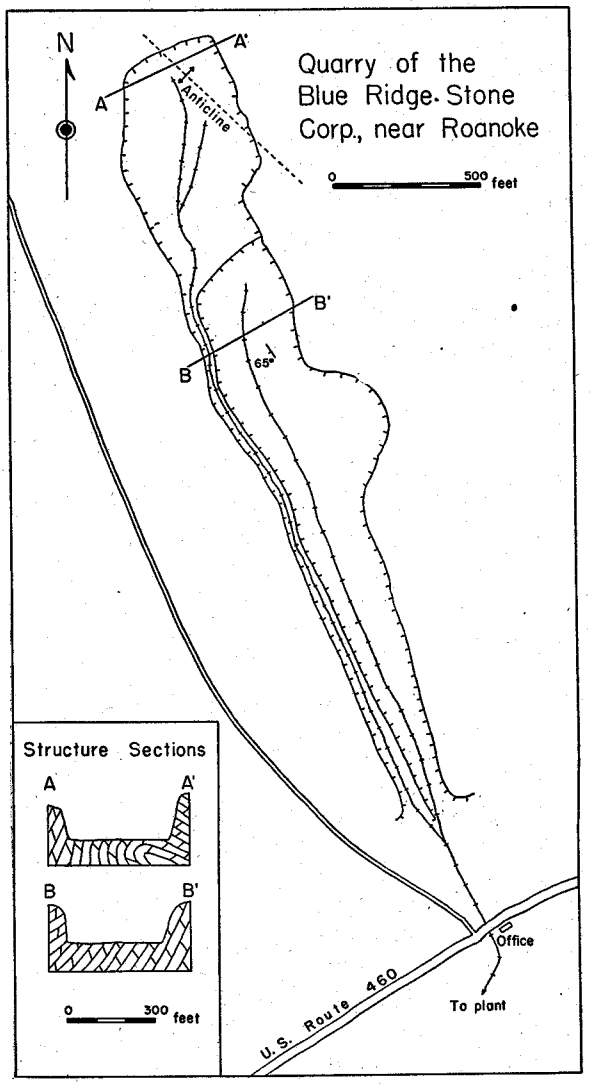


FIGURE 12.—Sketch map of the quarry of the Blue Ridge Stone Corp., near Roanoke, Va.

the railroad are notably thinner and more shaly. The only active quarry in this vicinity is that operated by the Rockydale Quarries Corporation (locality 80). This quarry is also located on an anticline in the dolomite member of the Rome which contains somewhat more impurities than the beds in the Roanoke municipal quarry.

The largest quarry in the district covered by this report is located near Blue Ridge Station, at locality 84. It is operated by the Blue Ridge Stone Corporation. The thickness of beds exposed is about 450 feet and the rock is uniformly fine grained and compact. The northern end of the quarry is in a local, overturned anticline (Fig. 12). Analyses of a composite sample of the quarry beds, collected along line B-B′ (Fig. 12), and of a sample of crushed stone taken from the loading bin are shown in Table 2.

The Roanoke municipal quarry (Fig. 12, locality 89) is situated about a mile northwest of the intersection of U. S. Routes 460 and 11 in the city of Roanoke. The quarry beds, which are the dolomite member of the Rome formation, are vertical or slightly overturned to the southeast (Pl. 9B). The quarry is about 800 feet long and 150 feet wide. Red shale crops out on either side of the quarry. The rock obtained from this quarry is used in surfacing streets and in construction in the city of Roanoke.

DEVELOPMENT POSSIBILITIES

Near the Blue Ridge, the mantle rock increases in thickness and obscures the position of the Blue Ridge fault. In the absence of good exposures, the breadth of the outcrop and northern limits of the beds quarried at locality 84 can be ascertained only by core drilling. A large body of dolomite probably identical in character to that now being quarried occurs in the low ridge between U. S. Route 460 and the railroad in the vicinity of Blue Ridge Station.

The dolomite member of the Rome formation, northeast of Bonsacks and Coyner (Pl. 11), could be quarried on a fairly large scale, particularly in the vicinity of locality 82. The thickness of the dolomite in this belt is about 150 feet and its composition probably is similar to that at locality 80.

ROANOKE-HOLLINS-CLOVERDALE AREA

LOCATION

The Roanoke-Hollins-Cloverdale area consists of a narrow strip along the Shenandoah Valley Division of the Norfolk and Western Railway between Roanoke and Cloverdale, Botetourt County. U. S. Route 11 and State Highway 115 are the principal roads. Tinker and Carvin creeks, which join in the central part of

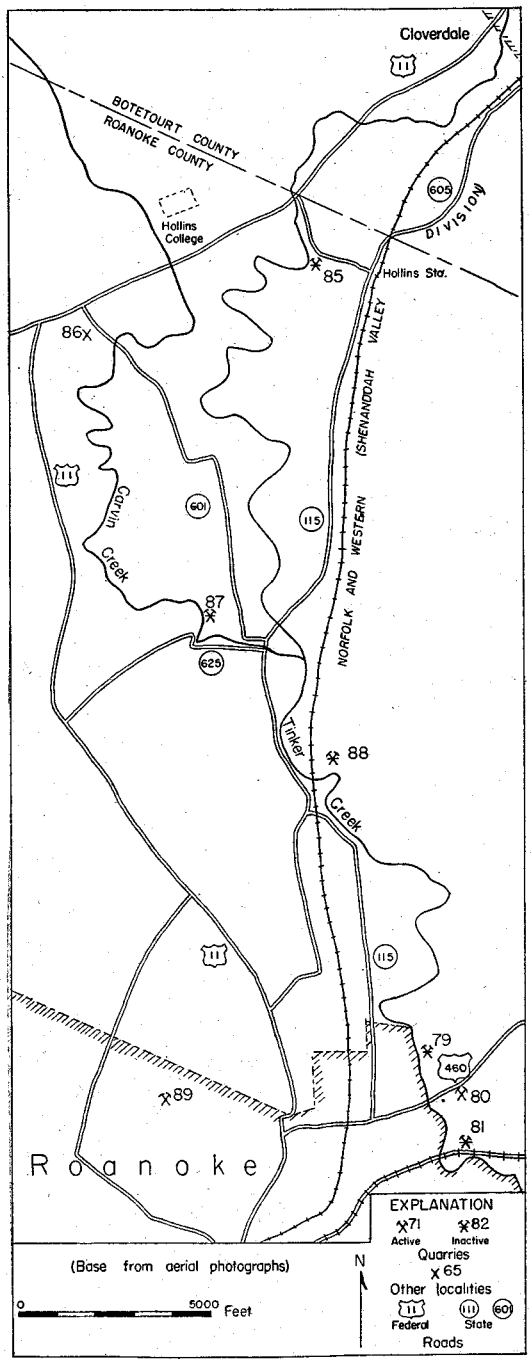
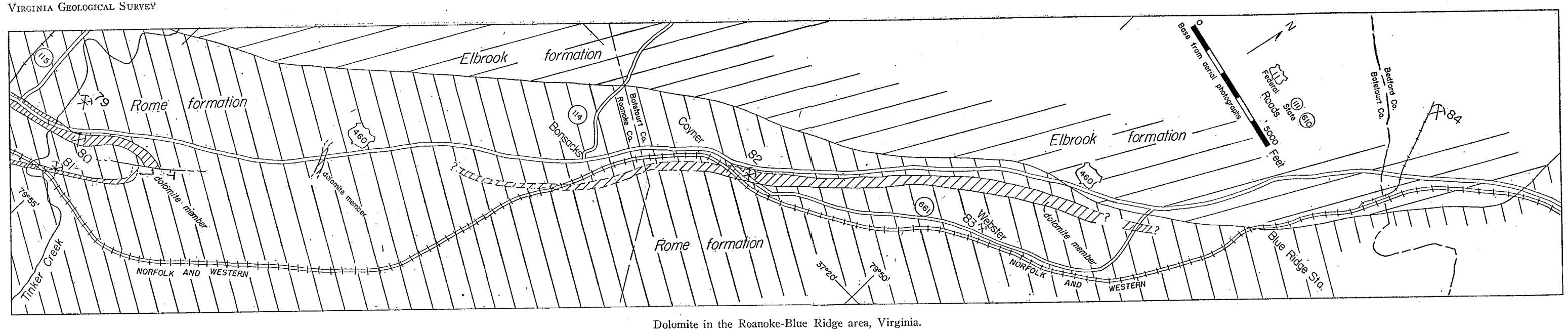


FIGURE 13.—Limestone and dolomite localities in the Roanoke-Hollins-Cloverdale area, Virginia.



Dolomite in the Roanoke-Blue Ridge area, Virginia.

the area, have very narrow valleys 50 to 100 feet below the lowland surface. Nearly all of the good exposures of rock are along these streams, the rest of the area being covered by a thick soil which is extensively cultivated for truck gardens.

GEOLOGY

According to Woodward[16] the Elbrook and Rome formations, which underlie most of the area south of the confluence of Carvin and Tinker creeks, have been thrust upon complexly folded dolomite and limestone of Upper Cambrian and Ordovician ages. Both the position of this fault and the areal distribution of the formations between Hollins and Roanoke are largely obscured by the thick alluvium and other mantle rock.

ELBROOK FORMATION

Dolomites of the Elbrook formation are exposed in a few places along State Highway 115 and along the railroad. All the beds seem to be very shaly. Possibly the quarry at locality 88 is in the Elbrook but more probably in the Copper Ridge formation.

COPPER RIDGE DOLOMITE

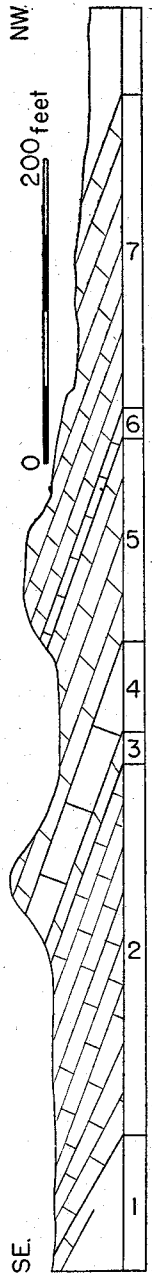
A few exposures of dolomite were seen along the railroad within the area mapped by Woodward[16] as Conococheague, northeast of the junction of Carvin and Tinker creeks. No sandstone was seen and the identification of the beds is uncertain.

CHEPULTEPEC LIMESTONE

The Chepultepec limestone is almost fully exposed in an abandoned quarry along Carvin Creek (geologic section 31), and about half of the formation crops out along adjacent Road 625 west of the quarry. Although the Chepultepec is too impure to be used for chemical purposes, it could be used for agricultural limestone as well as crushed stone.

BEEKMANTOWN DOLOMITE

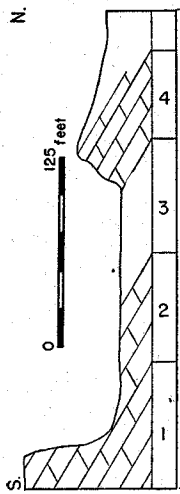
Parts of the Beekmantown dolomite are well exposed in four places in the area: (1) at the north end of the quarry along Carvin



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
BEEKMANTOWN DOLOMITE						
Dolomite, medium-gray, medium grained	72	56.46	35.14	5.82	2.16	0.84
Limestone, fine grained, pearl-gray	6					
Dolomite, fine grained, medium-gray	45					
CHEPULTEPEC LIMESTONE						
Limestone, magnesian, mottled brown and gray	20					
Dolomite, light-gray	8					
Limestone, bluish-gray, fine grained	110	92.63	3.59	2.19	0.85	0.24
Dolomite, mostly covered	..					

GEOLOGIC SECTION 31.—Ordovician dolomite and limestone at locality 87, near junction of Carvin and Tinker creeks, Roanoke County, Virginia.

Creek (locality 87); (2) in bluffs along the same creek between localities 86 and 87; (3) in an abandoned quarry along Tinker Creek (locality 85); and (4) along the railroad about 1¾ miles north of Cloverdale Station (Fig. 13, locality 94). The beds at



	Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
4	Dolomite, dark-gray, fine grained.....	28					
3	Covered interval, below water.....	35	63.29	28.01	5.63	2.52	1.04
2	Dolomite, medium-gray, granular.....	30					
1	Dolomite, concealed.....						

GEOLOGIC SECTION 32.—Part of Beekmantown dolomite, along Tinker Creek at locality 85, near the Roanoke-Botetourt county line, Virginia.

localities 85 and 94 are much the same in character and composition, although those at locality 94 are lower in the section than those in the quarry along Tinker Creek (geologic section 32).

ORDOVICIAN LIMESTONE

The limestones between the Beekmantown and Athens are thin and very poorly exposed. Their general distribution is given by Woodward[16]. The most accessible good exposure is near the junction of State Highway 115 with U. S. Route 11 (locality 86). At this locality, the succession consists of a few feet of fine-grained compact limestone (Woodward's Mosheim), overlain by 20 feet of dark-gray cherty limestone, and this by 15 feet of light-gray, very coarse-grained limestone (Woodward's Lenoir and Holston, respectively). At a locality along Deer Branch, half a mile northwest of Hollins School, the entire succession between the Beekmantown and Athens consists of 8 to 12 feet of coarse-grained limestone, probably all referable to Woodward's Holston limestone.

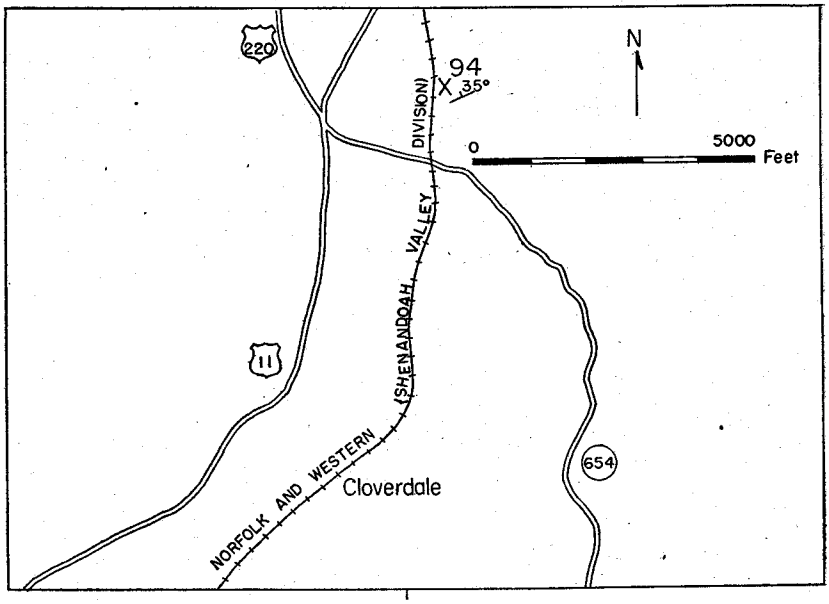


FIGURE 14.—Index map of Cloverdale, Va., and vicinity.

DEVELOPMENT POSSIBILITIES

Operations are not likely to be resumed at any of the abandoned quarries in this area, except possibly the one along Carvin Creek (locality 87), which could produce a good grade of agricultural limestone or crushed stone. Only one additional site is considered to be a favorable quarry location, namely, along the railroad north of Cloverdale at locality 94 (Fig. 14). The extent of this thickness of rock away from the railroad could not be ascertained because of poor exposures, but probably this site could be developed on a fairly large scale. The analysis of the rock is given in Table 2.

CATAWBA VALLEY AREA

LOCATION

The Catawba Valley area (Pl. 12) comprises a narrow belt along State Highway 114 between Catawba Sanatorium, Roanoke County, and Mt. Union and Haymakertown, in Botetourt County. This road connects the eastern part of the area with U. S. Route 11 and the Shenandoah Valley Division of the Norfolk and Western Railway in the vicinity of Cloverdale, 8 miles southeast of Mount Union. State Highway 331, which joins State Highway 114 in Catawba Valley, crosses Catawba Mountain and joins U. S. Route 11 in Salem, 11 miles south of Catawba Sanatorium. A spur line of the Norfolk and Western Railway formerly extended to the base of Catawba Mountain, but service on this line was discontinued and the tracks removed north of Hanging Rock, 5 miles north of Salem.

GEOLOGY

The rocks in the Catawba Valley area are on the northwest flank of a major syncline in the Pulaski overthrust block[19, 20]. The abrupt change in strike of the beds near Tinker parallels the bend in Tinker Mountain. Between Mt. Union and Tinker, the beds dip 20° to 50° SW., and along the foot of Catawba Mountain 30° to 50° SE. Between the Pulaski fault, which extends along the base of North Mountain, and State Highway 114, Cambrian and Ordovician dolomites occur, but the beds are too far from railroads to be developed commercially.

LIMESTONE

Outcrops of the Ordovician limestone are immediately adjacent to the highway throughout nearly all of the Catawba Valley area, and exposures are numerous. If the same general thickness and character of the Ordovician limestone noted in the Ellett area prevailed in Catawba Valley, the area would not be worth consideration as a source of commercial limestone. However, greater thicknesses of high-calcium limestone are present in the Catawba Valley area than in any other section of the district discussed in this report.

The general character and thickness of the limestones are shown in Figure 15. This succession was mapped by Woodward[16]

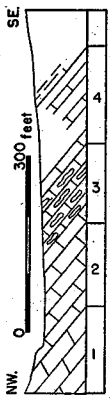
Columnar section	Names used by Butts	Names used in this report	Character and thickness	Average chemical composition (%)				
				$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	Whitesburg	Whitesburg	Coarse-grained impure limestone; 25 feet thick	80±		15±		
	Holston	Effna	Coarse-grained light-gray limestone; about 50 feet thick in most places, but locally 500 feet	98	0.8	0.4	0.5	0.25
	Lenoir	Lincolnshire	Dark-gray nodular impure limestone; 70 feet thick	80±		15±		
	Mosheim	Five Oaks	Dove-gray fine-grained limestone; 100 feet thick	96	2.0	1.0	0.7	0.30

FIGURE 15.—Limestone formations in the Catawba Valley area, Va.

as "Stones River," and divided by him and later by Butts[2] into the Mosheim, Lenoir, Holston, and Whitesburg limestones.

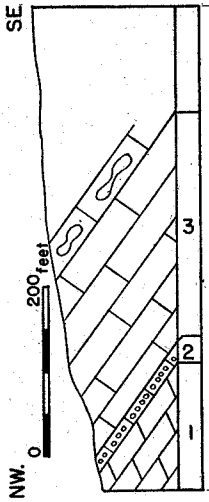
FIVE OAKS LIMESTONE

The Five Oaks limestone, which immediately succeeds the Beekmantown, consists chiefly of very fine-grained dove-gray to black limestone. The first thick section of the Five Oaks, east of Catawba Sanatorium, is at locality 67 (geologic section 33). At locality 68, along the Roanoke-Botetourt county line, the Five Oaks contains about 150 feet of high-calcium limestone (geologic section 34). The lowest beds, best exposed along Catawba Creek 1¼ miles northeast of the Botetourt-Roanoke county line (locality 71), consist of fine-grained, clayey limestone containing angular frag-



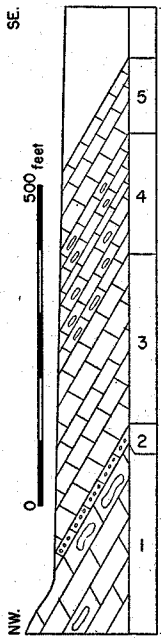
Character	Thickness feet
EFFNA LIMESTONE	
Limestone, coarse grained, light-gray	105
LINCOLNSHIRE LIMESTONE	
Limestone, dark-gray, granular, cherty	83
FIVE OAKS LIMESTONE	
Limestone, fine grained, dove-gray, compact	91
BEEKMANTOWN DOLOMITE	
Dolomite, cherty, mostly covered	..

GEOLOGIC SECTION 33.—Ordovician limestone along Catawba Creek and State Highway 114, at locality 67, Roanoke County, Virginia.



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
FIVE OAKS LIMESTONE						
Limestone, fine grained, dove-gray, compact	154	95.45	2.36	1.03	0.67	0.34
Limestone, conglomeratic	10					
BEEKMANTOWN DOLOMITE						
Dolomite, cherty, poorly exposed	..					

GEOLOGIC SECTION 34.—Ordovician limestone at locality 68, along State Highway 114, at the Roanoke-Botetourt county line, Virginia.

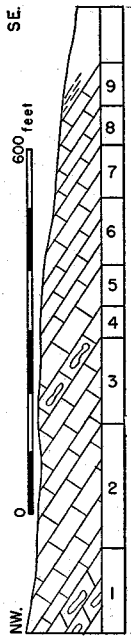


Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
EFFNA LIMESTONE						
Limestone, very coarse grained, light-gray	60	98.06	0.79	0.31	0.29	0.28
LINCOLNSHIRE LIMESTONE						
Limestone, fine grained, dark-gray, cherty, nodular	95					
FIVE OAKS LIMESTONE						
Limestone, fine grained, dove-gray, compact	135	96.02	1.94	0.51	0.72	0.30
Limestone, light-gray, contains pieces of chert and dolomite up to 15 inches in diameter	13					
BEEKMANTOWN DOLOMITE						
Dolomite, mostly covered	..					

GEOLOGIC SECTION 35.—Ordovician limestone along Catawba Creek, at locality 71, near State Highway 114, Botetourt County, Virginia.

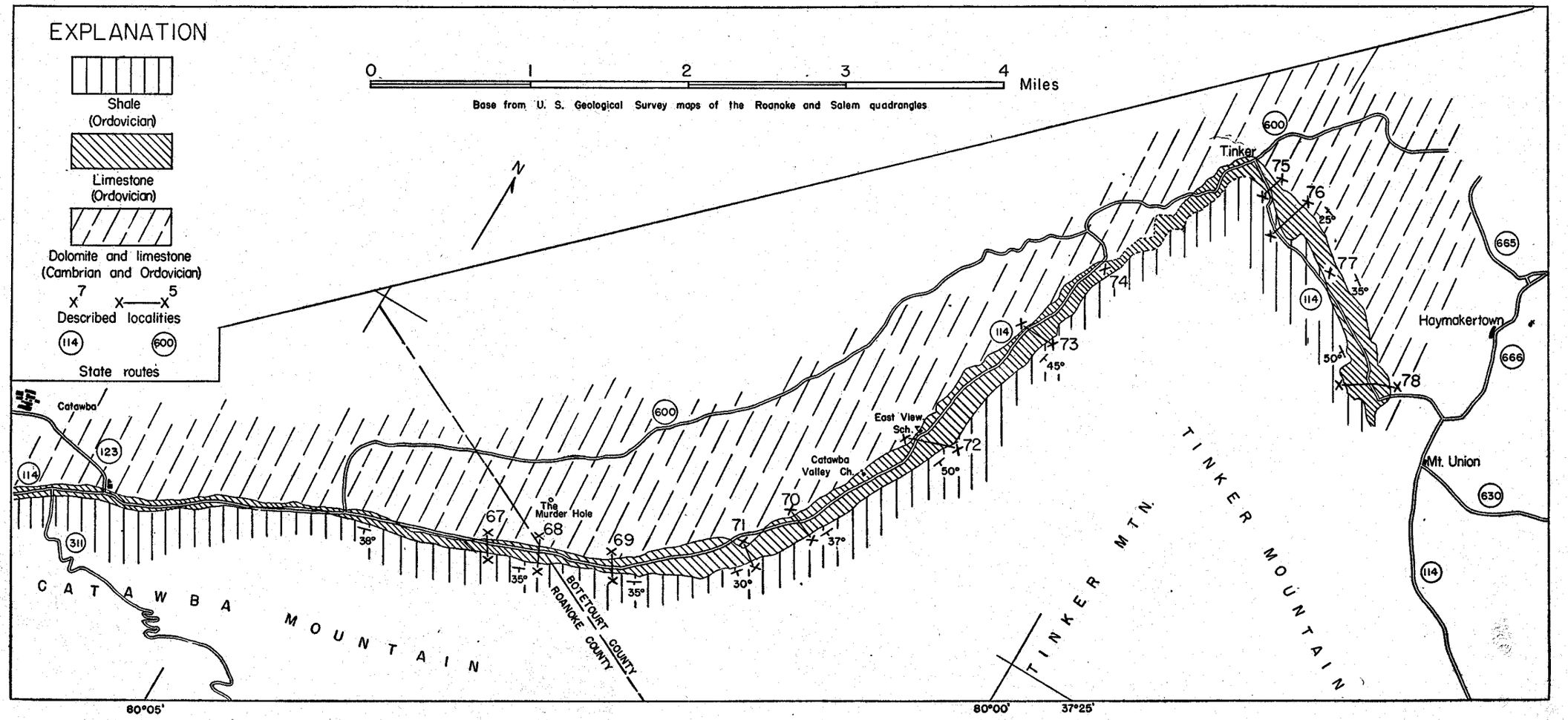
ments of dolomite and chert up to 15 inches across (geologic section 35). The main body of the Five Oaks is fine-grained limestone which averages about 96 per cent calcium carbonate and a little more than 100 feet thick. In the immediate vicinity of East View School (geologic section 36), the Five Oaks is somewhat lower in calcium carbonate but is nearly 200 feet thick. Less than one-fourth of a mile northeast of East View School it is 125 feet thick and averages more than 96 per cent calcium carbonate. At locality 73, all of the formation is high-calcium limestone (geologic section 37). Half a mile farther northeast, the Five Oaks is less than 100 feet thick, and it becomes progressively thinner toward Tinker. Between Tinker and Mount Union, 31 feet is present at locality 75, 15 feet at locality 76, but in the immediate vicinity of locality 78, the Five Oaks is about 120 feet thick. The same belt extends southeast toward Cloverdale, but the entire section of Ordovician limestone is thin.

Although most of the Five Oaks is extremely fine grained and very compact, in a few places the upper 20 to 30 feet of the unit is



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
EFFNA LIMESTONE						
Limestone, coarse grained, light-gray...	42					
Limestone, nodular, clayey.....	38					
Limestone, coarse grained, light-gray...	46					
Limestone, medium- to light-gray, medium grained.....	68					
LINCOLNSHIRE LIMESTONE						
Limestone, medium-gray, medium grained, no chert.....	36					
Limestone, dark-gray, cherty.....	26					
FIVE OAKS LIMESTONE						
Limestone, fine grained, dove-gray.....	80	94.33	2.52	1.59	0.92	0.24
Limestone, fine grained, dove-gray, slightly clayey.....	110	91.03	4.63	2.16	1.37	0.48
BEEKMANTOWN DOLOMITE						
Dolomite, cherty, poorly exposed.....	..					

GEOLOGIC SECTION 36.—Ordovician limestone at locality 72, near East View School, Botetourt County, Virginia.



Limestone and dolomite in the Catawba Valley area, Virginia.

clastic limestone, composed of water-worn pebbles and grains of fine-grained limestone cemented in a matrix of slightly coarser grained limestone. This rock, prominently exposed along Catawba Creek at locality 73, is chemically the same as the rest of the formation.

LINCOLNSHIRE LIMESTONE

The Lincolnshire limestone is a prevailingly dark-gray, medium-grained, nodular cherty limestone with an average thickness of 60 to 80 feet. Black chert nodules, although characteristic of the formation as a whole, do not occur in all the beds, but the chert-free limestone contains so much clay as to be of no value for chemical use. The formation is important only because it occurs between two rather thick formations of chemical limestone. The position, character, and thickness of the Lincolnshire are well shown at localities 68, 70, 72, 73, and 78.

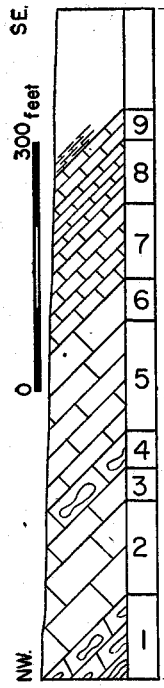
EFFNA LIMESTONE

Above the Lincolnshire is a succession of coarse-grained, generally light-gray and pinkish limestones containing 97 to 98 per cent calcium carbonate and generally less than one per cent of noncarbonates. West of the Roanoke-Botetourt county line, the Effna limestone is less than 50 feet thick and is so poorly exposed as to be easily overlooked. Northeastward toward Tinker, the thickness increases progressively to nearly 100 feet. Along the east base of Tinker Mountain, between Tinker and Mt. Union, the thickness ranges upward to more than 500 feet in the well-exposed section at locality 78. This sector of the Catawba Valley area contains the thickest body of coarse-grained high-calcium limestone reported in the Appalachian Valley of Virginia (geologic section 38).

Along Catawba Creek at locality 73, impure limestones are intercalated at three horizons in the formation, but between Tinker and Mt. Union, impure partings are thin or absent (geologic sections 38 and 39).

WHITESBURG LIMESTONE

The Whitesburg limestone forms the top of the succession of Ordovician limestone in the Catawba Valley area (Fig. 15). Al-



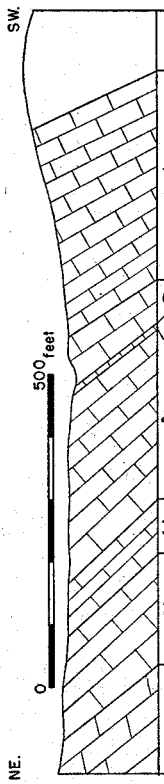
Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
WHITESBURG LIMESTONE						
Limestone, light-gray, impure	28					
EFFNA LIMESTONE						
Limestone, light-gray, coarse grained, thick bedded	55	97.91	0.70	0.40	0.40	0.36
Limestone, impure, nodular	64					
Limestone, coarse grained, gray	35	98.21	0.50	0.20	0.43	0.16
LINCOLNSHIRE LIMESTONE						
Limestone, medium grained, dark-gray	94					
Limestone, gray, granular, cherty	35					
FIVE OAKS LIMESTONE						
Limestone, clastic texture	30	96.15	1.83	0.78	0.53	0.24
Limestone, fine grained, dove-gray	80					
BEEKMANTOWN DOLOMITE						
Dolomite, cherty, fine grained	..					

GEOLOGIC SECTION 37.—Ordovician limestone at locality 73, about a mile northeast of East View School, Botetourt County, Virginia.

though coarse grained like the Effna, the Whitesburg contains no chemical limestone. As in the Ellett area, the Whitesburg contains abundant fragments of trilobites.

QUARRY SITES

As shown in geologic sections 35, 36, and 37, the Five Oaks limestone, between the Roanoke-Botetourt county line and a point one mile southwest of Tinker, averages well over 100 feet thick and, except in one place (locality 72), is high-calcium limestone. Between the county line and locality 71—a distance of 6,000 feet—approximately 10 million tons of fine-grained, high-calcium limestone could be quarried from the Five Oaks without excavating below the level of Catawba Creek. This body of rock would probably contain about 98 per cent carbonates. Between locality 71 and Catawba Valley Church, about 6 million tons of the Five Oaks



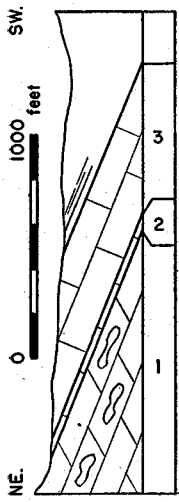
	Character and thickness (feet)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
	EFFNA LIMESTONE					
7	Limestone, light-gray, coarse grained... 320	97.30	0.91	0.58	0.75	0.32
6	Limestone, medium grained, gray..... 60					
5	Limestone, nodular, clayey..... 15	97.65	0.77	0.65	0.68	0.30
4	Limestone, coarse grained, light-gray... 110					
	LINCOLNSHIRE LIMESTONE					
3	Limestone, granular, gray; weathers cobbly; very impure..... 62					
	FIVE OAKS LIMESTONE					
2	Limestone, fine grained, light-gray..... 120	95.69	1.79	1.02	0.82	0.30
	BEEKMANTOWN DOLOMITE					
1	Dolomite, mostly covered..... ..					

GEOLOGIC SECTION 38.—Ordovician limestone at locality 78, near Mt. Union, Botetourt County, Virginia.

could be quarried above drainage. Another 6 million tons of high-calcium limestone could be quarried between locality 74 and a point about two-thirds of a mile southwest of locality 73. The calcium carbonate content of this deposit would probably be the same as that at locality 71.

Between Tinker and the Roanoke-Botetourt county line, relatively small quantities of very high-grade chemical limestone could be quarried from the Effna limestone, particularly in the immediate vicinity of localities 71 and 73 (geologic sections 35 and 37).

Between locality 75, near Tinker, and locality 78, the Effna limestone averages about 97½ per cent calcium carbonate and only about one per cent of noncarbonates. Eight to ten million tons of coarse-grained limestone could be quarried in the general vicinity of localities 75 and 76, and a similar quantity in the vicinity of local-



Character and thickness (feet)		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
EFFNA LIMESTONE						
Limestone, very coarse grained, light-gray	275	97.91	0.80	0.59	0.57	0.32
FIVE OAKS LIMESTONE						
Limestone, fine grained, gray, contains chert	20					
BEEKMANTOWN DOLOMITE						
Dolomite, gray, cherty	..					

GEOLOGIC SECTION 39.—Ordovician limestone at locality 76, half a mile southeast of Tinker, Botetourt County, Virginia.

ity 77 (geologic section 38). At locality 78, where the Effna limestone seems to be more than 500 feet thick, at least 2 million tons of very high-grade coarse-grained limestone could be quarried. The Five Oaks, which is 125 feet thick and contains more than 95 per cent calcium carbonate, could be quarried on a smaller scale.

In summary, the Five Oaks and Effna limestones are of sufficient thickness and purity to furnish 40 to 50 million tons of high-calcium limestone. In each of five possible quarry locations—three southwest of Tinker and two between Tinker and Mt. Union—the estimated tonnage of high-calcium limestone, which could be obtained by shallow quarrying, is at least 6 million tons. In spite of the rather remote location, the Catawba Valley area is considered very favorable for extensive quarrying of high-calcium limestone.

TABLE 2.—*Analyses of limestones and*

Locality	Geologic Section No.	Unit	Location	Formation and Rock Character
1	21	11	Giles County; along Norfolk and Western Railway southeast of Rich Creek	Mississippian limestone; coarse grained, gray
1	21	8		Mississippian limestone; coarse grained, oolitic
1	21	8		Mississippian limestone; fine grained, compact
5	19	6	Giles County; one mile northeast of Narrows	Gratton limestone; fine grained
5	19	5		Benbolt limestone; dark-gray, granular
6	2	14	Giles County; near Narrows	Copper Ridge dolomite; gray
7	5	3	Giles County; east of Bluff City	Beekmantown dolomite; dark-gray
7	5	2		Beekmantown dolomite; coarse grained
9	11	6	Giles County; 1¼ miles west of Pearisburg, along State Highways 8 and 100	Upper cherty limestone member of the Cliffield formation
9	11	5		Coarse-grained limestone member of the Cliffield formation
12			Giles County; Ripplemead Lime Co.	Rock dust (Five Oaks and lower part of Lincolnshire limestones)
13	9	5	Giles County; about ¼ mile South of Ripplemead	Five Oaks limestone; fine grained, compact, dove-gray
15	6	2	Giles County; quarry of the Virginian Limestone Corp., Klotz	Blackford member; basal cherty dolomite beds
15	6	1		Beekmantown dolomite; dark-gray beds averaging about 8 feet thick
15	6	1		Beekmantown dolomite; light-gray beds averaging about 12 feet thick
17	22	3	Giles County; near Kimballton	Five Oaks limestone
19	10	6	Giles County; near Kimballton	Five Oaks limestone; very fine grained and compact

dolomites in central-western Virginia

THICKNESS	CHEMICAL COMPOSITION							
Feet	$CaCo_3$	$MgCo_3$	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	Total
43	88.95	3.03	5.24	1.74	0.66			99.62
12	94.66	1.54	2.12	0.98	0.62			99.92
27	94.96	1.91	2.98	1.12	0.52			101.49
52	93.46	1.94	3.68	1.24	0.28			100.60
70	95.36	1.64	2.24	0.68	0.24			100.16
273	52.15	40.00	6.08	2.00	0.48			100.71
265	56.75	38.17	2.84	0.84	0.74			99.34
200	53.51	41.42	4.71	0.93	0.54	0.04	0.39	101.54
130	90.65	2.24	6.20	0.90	0.22			100.21
58	96.45	1.47	1.26	0.34	0.28			99.80
	95.56	2.30	1.72	0.56	0.16			100.30
60	96.06	2.73	0.92	0.76	0.12			100.59
15	49.51	36.61	8.92	3.80	0.92			99.76
225	56.68	40.53	1.56	0.58	0.32	0.04	0.16	99.87
	57.18	38.52	3.32	0.88	0.40	0.04	0.17	100.51
96	97.13	1.50	0.28	0.58	0.08			99.57
90	98.37	0.85	0.24	0.48	0.08			100.02

TABLE 2.—*Analyses of limestones and dolomites*

Locality	Geologic Section No.	Geologic Section Unit	Location	Formation and Rock Character
21	17	6	Giles County; one mile northwest of Ripplemead	Gratton limestone; dove-gray
21	17	5		Benbolt limestone; even bedded
21	17	4		Benbolt, limestone; nodular, clayey
24	18	6	Giles County; east bluff of Little Stony Creek about a mile north of Pembroke	Gratton limestone; dove-gray
24	18	4		Benbolt limestone; coarse grained
24	18	3		Benbolt limestone; black, impure
25	7	1	Giles County; quarry of Pembroke Limestone Corp., along Norfolk and Western Railway	Beekmantown dolomite; coarse grained
25	7	2		Beekmantown dolomite; fine grained
26	23	3	Giles County; southeast base Doe Mountain	Five Oaks limestone; dove-gray
28	24	5	Giles County; 1½ miles northeast of Hoges Store	Five Oaks limestone; dove-gray
28	24	2		Blackford; dove-gray limestone
29	24	2	Giles County; near Hoges Store	Gratton limestone; dove-gray
32	25	2–3	Giles County; near Boyd Chapel	Gratton limestone; lower 15 feet; Benbolt limestone; upper 70 feet
38	3	11–18	Giles County; along Norfolk and Western, near Eggleston	Copper Ridge dolomite; light- to dark-gray, banded
39	15	4	Giles County; along Virginian Railway, south of Eggleston	Witten limestone; thin bedded toward top; clayey stringers
39	15	3		Gratton limestone; fine grained, upper 42 feet
39	15	2		Gratton limestone; fine grained, lower 37 feet
39	15	1	Giles County; along Virginian Railway, south of Eggleston	Benbolt limestone; impure, nodular
39	13	10		Five Oaks limestone; except chert

in central-western Virginia—Continued

THICKNESS	CHEMICAL COMPOSITION							
Feet	$CaCo_3$	$MgCo_3$	SiO_2	Al_2O_3	Fe_3O_3	Na_2O	K_2O	Total
31	94.59	1.95	2.26	1.08	0.32			100.20
35	89.90	6.23	2.50	1.12	0.40			100.15
75	87.19	2.51	6.10	2.66	0.68			99.14
45	92.72	2.77	2.20	1.24	0.32			99.25
88	95.05	2.68	0.88	0.56	0.28			99.45
45	92.72	3.52	2.48	0.74	0.40			99.86
90	53.26	40.44	4.48	1.76	0.48	0.03	0.30	100.75
75	52.86	42.55	3.58	1.17	0.43	0.36	0.22	101.17
75	95.55	2.61	0.86	0.90	0.12			100.04
52	95.50	1.61	1.18	0.64	0.08			99.01
50–60	97.54	1.26	0.46	0.76	0.12			100.14
60	96.35	1.24	0.80	0.86	0.40			99.65
85	96.05	2.17	0.48	0.28	0.36			99.34
548	53.10	39.77	4.66	2.08	0.60			100.21
70	90.52	2.57	4.52	1.58	0.48			99.67
42	93.33	2.42	1.89	1.40	0.42			99.46
37	96.80	1.26	0.58	0.56	0.18			99.38
30	81.89	7.83	6.69	2.09	0.72			99.22
30	94.11	1.27	3.69	0.59	0.20			99.86

TABLE 2.—*Analyses of limestones and dolomites*

Locality	Geologic Section No.	Geologic Section Unit	Location	Formation and Rock Character
40	20	12	Giles County; along southeast side of Green Valley, 3½ miles southwest of Eggleston	Witten limestone; clayey stringers
40	20	10		Witten limestone; light-gray
40	20	9		Witten limestone; nodular, impure
40	20	8		Witten limestone; fine grained
40	20	7		Gratton limestone; dove-gray
40	20	5		Benbolt limestone; coarse grained
41	1	7–8	Giles County; along Virginian Railway, near Goodwins Ferry	Copper Ridge dolomite; medium grained; little sand or chert
41	1	1–4		Honaker dolomite; very pure, dark-gray, medium to fine grained
42	4	9	Giles County; along Norfolk and Western Railway south of Berton Station	Beekmantown dolomite; fine grained, pearl-gray
42	4	3–5		Copper Ridge dolomite; light-gray
42	14	6		Witten limestone; coarse-grained zone at the base
42	14	2		Lincolnshire limestone; coarse grained limestone at base
44			Montgomery County; along Norfolk and Western Railway north of Peppers Ferry	Elbrook dolomite; thin bedded
44				Elbrook dolomite; very shaly
45				Elbrook dolomite; shaly
46				Elbrook magnesian limestone
49			Montgomery County; along Norfolk and Western Railway between Walton and U. S. 11	Elbrook dolomite; very shaly
49				Elbrook formation; phyllite breccia
51			Montgomery County; near Montgomery Station, along old location of U. S. Route 11	Copper Ridge dolomite; dark-gray
51				Copper Ridge dolomite; light-gray

in central-western Virginia—Continued

THICKNESS	CHEMICAL COMPOSITION							
Feet	$CaCo_3$	$MgCo_3$	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	Total
24	93.94	1.62	2.38	1.05	0.36			99.35
66	96.45	1.47	0.78	0.50	0.34			99.54
91	91.77	3.24	3.02	1.16	0.38			99.57
78	92.20	2.15	3.43	1.49	0.38			99.65
78	96.39	1.24	0.93	0.72	0.30			99.58
67	95.43	2.30	0.78	0.75	0.28			99.54
440	52.78	42.21	3.60	1.32	0.58			100.49
825	53.92	43.06	2.52	0.67	0.34	trace	0.11	100.62
557	51.67	37.50	6.84	3.27	0.80			100.08
536	53.16	39.68	4.55	2.01	0.64	trace	0.56	100.60
22	95.48	2.35	0.86	0.37	0.32			99.38
55	97.52	0.76	0.49	0.56	0.24			99.57
100	54.89	24.23	13.45	5.80	1.74			100.11
350	36.80	39.14	16.61	6.06	1.52			100.13
100	40.54	34.50	17.77	5.46	2.30			100.57
50	77.17	12.69	6.66	2.33	0.70			99.55
150	42.67	33.52	16.78	5.29	1.54			99.80
100	35.32	22.57	28.14	10.48	3.16			99.67
80	49.83	43.03	4.61	1.22	1.06			99.75
75	64.31	29.00	3.81	2.07	0.62			99.81

TABLE 2.—*Analyses of limestones and dolomites*

Locality	Geologic Section No.	Unit	Location	Formation and Rock Character
52	26	10	Montgomery-Pulaski counties; quarry of the Radford Limestone Co., near Miles; along New River	"Lenoir" limestone; nodular
52	26	9		"Mosheim" limestone; impure
52	26	8		Beekmantown dolomite; black beds at top
52	26	2–7		Beekmantown dolomite; composite
56			Montgomery County; half a mile south of Lusters Gate	Five Oaks limestone; fine grained and compact
60	28	5	Montgomery County; in and near quarry of Montgomery Lime Co., near Ellett Station	Lincolnshire limestone; cherty
60	28	4		Lincolnshire limestone; no chert
60	28	3		Five Oaks limestone; dove-gray
66	27	6	Montgomery County; southeast of Yellow Sulphur Station on the Virginian Railway	Copper Ridge dolomite
66	27	2		Copper Ridge dolomite
68	34	3	Roanoke-Botetourt county line in Catawba Valley	Five Oaks limestone; dove-gray
71	35	5	Botetourt County; 1½ miles northeast of Roanoke-Botetourt county line	Effna limestone; coarse grained
71	35	3		Five Oaks limestone; dove-gray
72	36	3	Botetourt County; near East View School	Five Oaks limestone; dove-gray
72	36	2		Five Oaks limestone; lower beds
73	37	8	Botetourt County; about a mile northeast of East View School along State Highway 114	Effna limestone; coarse grained
73	37	6		Effna limestone; coarse grained
73	37	2–3		Five Oaks limestone
76	39	3	Botetourt County; near Tinker	Effna limestone; coarse grained
78	38	6–7	Botetourt County; near Mt. Union, along State Highway 114	Effna limestone; coarse grained
78	38	4–5		Effna limestone; coarse grained
78	38	2		Five Oaks limestone; fine grained
80			Roanoke County; quarry of the Rockydale Quarries Corp., near U. S. Route 460	Rome dolomite; fine grained
80				Agstone from crusher bin

in central-western Virginia—Continued

THICKNESS	CHEMICAL COMPOSITION							
Feet	$CaCo_3$	$MgCo_3$	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	Total
50±	84.82	7.85	4.99	1.66	0.82			100.14
27	84.30	8.99	3.39	1.98	0.74			99.40
59	50.65	37.80	7.30	2.62	1.40			99.77
170	52.55	38.12	7.13	1.78	0.84			100.42
40	93.64	2.56	1.85	1.04	0.42			99.51
195	87.64	4.62	5.28	1.65	0.46			99.65
27	90.12	4.02	4.73	0.90	0.28			100.05
52	95.22	1.91	1.13	0.90	0.28			99.44
330	50.24	40.26	6.18	2.22	1.26	0.13	0.78	101.07
225	54.66	42.00	3.06	0.31	0.34	0.06	0.09	100.52
154	95.45	2.36	1.03	0.67	0.34			99.85
60	98.06	0.79	0.31	0.29	0.28			99.73
135	96.02	1.94	0.51	0.72	0.30			99.49
80	94.33	2.52	1.59	0.92	0.24			99.60
110	91.03	4.63	2.16	1.37	0.48			99.67
55	97.91	0.70	0.40	0.40	0.36			99.77
35	98.21	0.50	0.43	0.20	0.16			99.50
110	96.15	1.83	0.78	0.53	0.24			99.53
275	97.91	0.80	0.59	0.57	0.32			100.19
380	97.30	0.91	0.58	0.75	0.32			99.86
125	97.65	0.77	0.65	0.68	0.30			100.05
120	95.69	1.79	1.02	0.82	0.30			99.62
165	52.80	40.85	3.42	1.54	1.92	0.15	0.40	101.08
	54.30	42.00	1.68	1.56	1.04			100.58

TABLE 2.—*Analyses of limestones and dolomites*

Locality	Geologic Section No.	Geologic Section Unit	Location	Formation and Rock Character
84			Bedford County; quarry of Blue Ridge Stone Corp., along U. S. Route 460	Elbrook dolomite; fine grained
84				Agstone from crusher bin
85	32	2–4	Roanoke County; along Tinker Creek near Hollins Sta.	Beekmantown dolomite; medium grained
87	31	7	Roanoke County; abandoned quarry near junction of Carvin and Tinker creeks	Beekmantown dolomite; pearl-gray
87	31	2		Chepultepec limestone; bluish-gray
89			Roanoke; municipal quarry	Rome dolomite; fine grained
90			Salem; municipal quarry	Elbrook dolomite and Max Meadows fault breccia
91			Montgomery County; 1 mile south of Elliston	Elbrook formation; dolomitic phyllite
94			Botetourt County; 1¾ miles north of Cloverdale	Beekmantown dolomite; medium grained, gray

in central-western Virginia—Continued

THICKNESS	CHEMICAL COMPOSITION							
Feet	$CaCo_3$	$MgCo_3$	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	Total
450±	58.57	26.46	9.16	4.27	1.16	0.21	0.73	100.56
	66.60	18.96	9.13	3.98	1.28			99.95
94	63.29	28.01	5.63	2.52	1.04			100.49
72	56.46	35.14	5.82	2.16	0.84			100.42
110	92.63	3.59	2.19	0.85	0.24			99.50
135	57.89	40.50	0.50	0.43	0.78			100.10
150	59.53	30.79	6.39	2.46	0.86			100.03
200	48.46	28.75	15.14	6.87	1.08			100.30
275	63.49	31.05	3.82	1.40	0.76			100.52

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