COMMONWEALTH OF VIRGINIA
STATE COMMISSION ON CONSERVATION AND DEVELOPMENT
VIRGINIA GEOLOGICAL SURVEY
ARTHUR BEVAN, *State Geologist*

Bulletin 40

Marble Prospects in Giles County, Virginia

BY

A. A. L. MATHEWS

WITH A SECTION ON

Petrography of the Marbles

BY

ARTHUR A. PEGAU

UNIVERSITY, VIRGINIA
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RICHMOND:
DIVISION OF PURCHASE AND PRINTING
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A

B

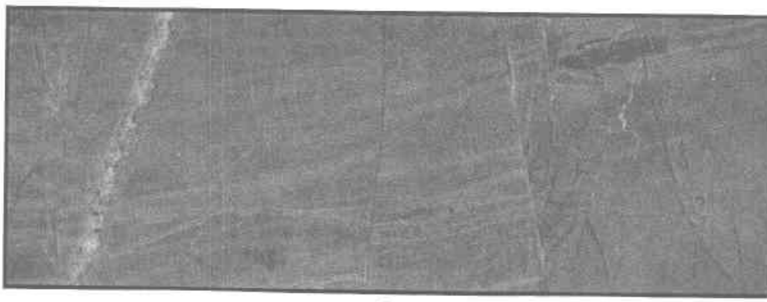
C

D

MARBLE FROM GILES COUNTY, VIRGINIA

A—Carnelian moire
B—Sunset-red
C—Light-mahogany
D—Newport brown

A



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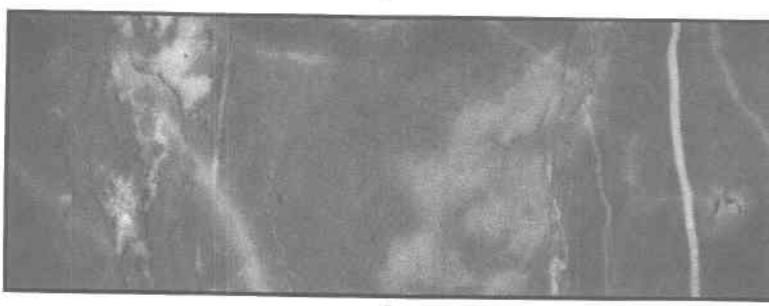

C

D

MARBLE FROM GILES COUNTY, VIRGINIA

A—Carnelian moire
B—Sunset-red
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D—Newport brown

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., December 1, 1932.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 40 of the Virginia Geological Survey series of reports the manuscript and illustrations of a report on *Marble Prospects in Giles County, Virginia,* by A. A. L. Mathews, with a section on Petrography of the Marbles, by Arthur A. Pegau, Survey Mineralogist.

This report treats of one of the undeveloped mineral resources of Giles County which has promise of commercial importance. It discusses the distribution, properties, geologic relations, and types of marble found in the county and describes briefly uses, quarry sites, and methods, and other features connected with development of the deposits. Twelve varieties of marble are described, some of which are illustrated by plates in colors.

The data upon which this report is based have been gathered by Mr. Mathews during a comprehensive survey of the geology and mineral resources of Giles County under the direction of the Virginia Geological Survey. The author has been assisted in some phases of the larger field project by a grant from the National Research Council. Assistance has been given toward the publication of the color plates by the Board of Supervisors of Giles County and Southwestern Virginia, Inc.

The report should be of value not only to the residents of Giles County but to all who are interested in the natural resources of Virginia, and should thus aid in their development and increased utilization.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
State Commission on Conservation and Development,
Richmond, Virginia, December 15, 1932.
RICHARD A. GILLIAM, *Executive Secretary and Treasurer.*

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ILLUSTRATIONS

TABLES

ABSTRACT

The marble deposits described in this report are found in Giles County, Virginia. The same marble zones extend into Bland and Craig counties in Virginia and into Mercer and Monroe counties in West Virginia.

Marble occurs at four distinct horizons. The lowest stratigraphically is found in the Ozarkian system, and the next higher, near the base of the Lower Ordovician in the Murfreesboro limestone. The main deposit is the lower Moccasin marble member of Lowville age. The upper zone is found in the Middle Devonian in the Romney formation. Each of these formations is described.

The structure of Giles County in relation to the occurrence of the marble is briefly discussed as consisting of three shingle blocks, namely, the southern or Walker Mountain shingle block, the central or Angels Rest shingle block, and the northern or East River Mountain shingle block. These shingle blocks are bounded by the four major thrust faults of the area, namely, the Pulaski fault, the Bland or Saltville fault, the Narrows split fault, and the St. Clair fault.

The marbles comprise five groups: Moire, tan-gray, variegated, sunset-red and jet-black. The first group consists of carnelian moire and gray moire; the second group of Virginia gray, opalescent gray, imperial champagne-tan, and golden-gray; and the third group of light-mahogany, Newport brown, amethyst, and palette. These marbles are described and petrographic and chemical analyses are given.

Possible quarry sites, quantitative estimates, transportation facilities, leases, and markets are briefly discussed.

Marble Prospects in Giles County, Virginia

By A. A. L. Mathews

INTRODUCTION

LOCATION AND EXTENT OF AREA

Giles County is situated in northwest Virginia on both sides of New River. (See Fig. 1.) The county is about 35 miles long from northeast to southwest and 17 miles wide. It consists of 221,626 acres or slightly more than 346 square miles. Most of the northwest and southeast boundaries follow the crests of mountain ranges. The other boundaries are straight lines perpendicular to these. The area is broken by long mountain ranges extending northeast and southwest, with numerous spurs and cross ranges. New River and its tributaries constitute the main drainage system. There are no large cities in the area.

When white men first came into this country, they cleared the timber, built log cabins and tilled the soil. Lumbering became an important industry and the mountains as well as the valleys were cleared, but today this industry has passed its zenith and agriculture has nearly reached its peak. Giles County is well situated for the development of its mineral resources. It is well supplied with minerals and is served by two trunk railway lines, two hard-surfaced highways and one interstate electric company.

PURPOSE OF REPORT

This report discusses the marble deposits of the county in respect to their geology, the location of suitable quarry sites, and processes for their development, and calls attention to these marbles as a possible source of decorative and building material.

PREVIOUS WORK

Little was known of these marble deposits until recently. Many of the early settlers used marble to build fireplaces and chimneys, and, because of the resistance of marble to heat, many solitary chimneys stand throughout the area as evidence of this early use. Close examination shows that the stone has been only slightly altered by heat. In 1881 a Norfolk and Western Railway pier was built of marble. (See Pl. 6B.) As early as 1884, W. B. Rogers[1] referred to a "red limestone or marble" near the base of

[1] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, p. 213, New York, D. Appleton and Co., 1884.

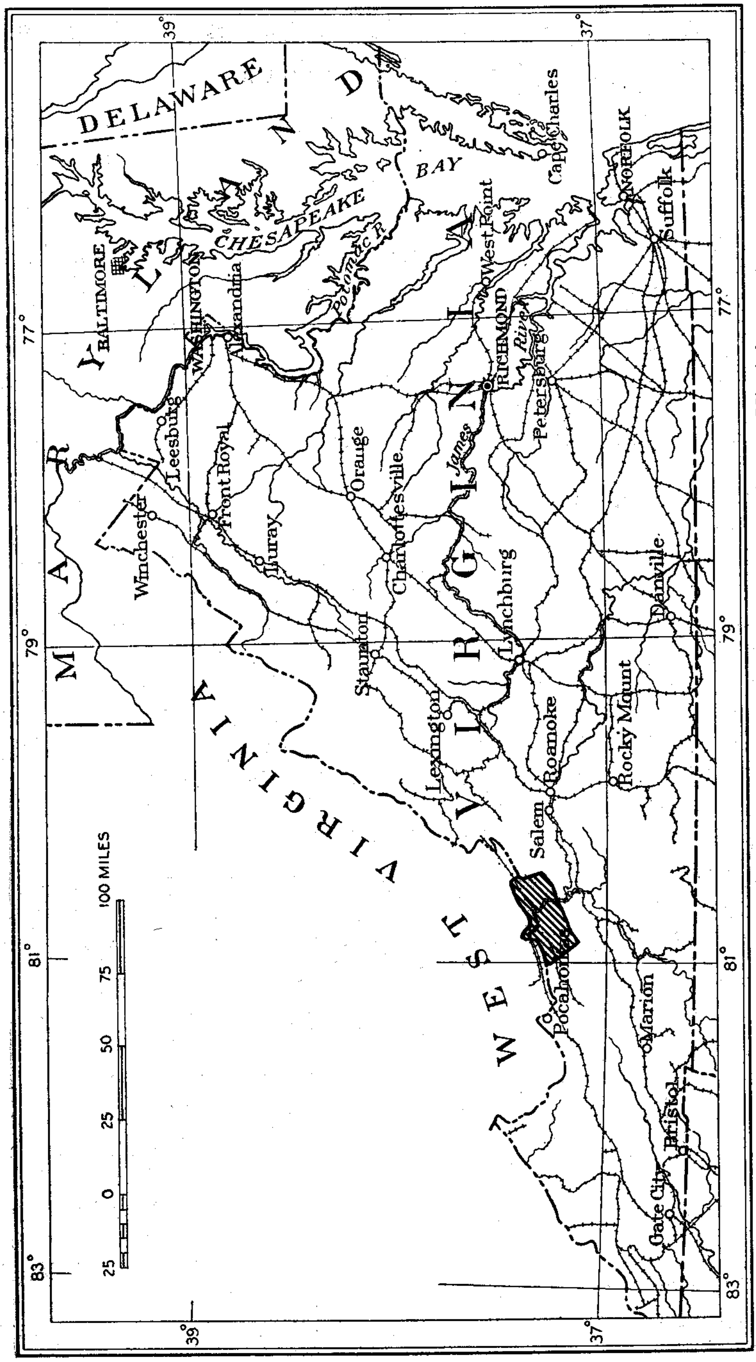

Figure 1.—Index map showing the location of Giles County, Virginia.

Angels Rest and a "more compact and massive rock of the same hue in the neighborhood of Chapman's ferry" (now Pembroke). Watson[2] mentioned the same deposits in 1907.

Hubbard and Croneis[3] considered the deposits a lithographic limestone and it has been tested for that use with apparently unsatisfactory results. Although several publications describe the Moccasin limestone, no further mention of marble is made in the literature referring to this area.

ACKNOWLEDGMENTS

The author is indebted to Dr. Arthur Bevan, State Geologist, for supervision in the field work and for criticism of the manuscript, and to Dr. Charles Butts of the United States Geological Survey for his guidance in studying the stratigraphy of the area. He is further indebted to the National Research Council for the Grant-in-Aid to carry on research on the stratigraphy of Giles County. He appreciates the friendly criticism of Dr. Roy J. Holden of Virginia Polytechnic Institute. He desires to express his thanks for the aid given him by several marble companies and by Southwestern Virginia, Incorporated. He appreciates the cooperation of the members of the Giles County Board of Supervisors who made it possible for property owners to secure aid in prospecting at minimum expense. The contributions of the Board of Supervisors of Giles County and of Southwestern Virginia, Inc., towards the cost of the color plates are also much appreciated. Mr. H. B. White assisted the author in making the photomicrographs. Many residents of the county also gave considerable aid in the field investigations.

[2] Watson, T. L., Mineral resources of Virginia, p. 82, Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., 1907.

[3] Hubbard, G. D., and Croneis, C. G., Notes on the geology of Giles County, Virginia: Denison Univ. Bull., Jour. Sci. Lab., vol. 20, p. 336, 1924.

MARBLE

INTRODUCTORY STATEMENT

Marble is used for building purposes. In spite of its beauty and delicacy, marble is extremely durable, impervious to stains and easy to keep clean. The use of marble for floors, wainscot and wall bases is economical in the long run, because such surfaces are quickly cleaned and seldom need repair.

In the building trades, any calcareous stone that takes a good polish is called marble. Technically, marble is metamorphic limestone or dolomite. It is distinguished from the parent rocks by its greater compactness, purer colors, and crystallization. On the basis of chemical composition marbles may be classed as high-calcium marble consisting essentially of calcite ($CaCO_3$), and dolomitic marble consisting largely or entirely of dolomite ($CaCO_3.MgCO_3$). This distinction can seldom be made commercially; thus the term marble is used in this report without reference to the content of magnesia.

ORIGIN

Calcium carbonate occurs as calcareous marl, travertine, limestone and marble. Marble, in the geologic sense, is metamorphosed limestone, the change being produced chiefly by heat and pressure.

METAMORPHOSED LIMESTONE

According to Pirsson and Knopf,[4] some marble is "produced from limestone by the contact action of intruded igneous rocks." Marble derived from this type of metamorphism is limited to regions where the molten rock invaded a pure limestone, as the impure cherty limestones and dolomites give very different products, such as wollastonite, tremolite and garnet. Under the most favorable conditions the marble is limited to a zone surrounding the intrusion, which is rarely as much as 1 mile wide.

Most marbles have been produced by pressure due to regional metamorphism in regions where the rocks have been highly folded and faulted and thus were subjected to heavy pressures and fairly high temperatures at great depths. Marbles thus produced have the same chemical composition as the limestones from which they were derived. The nature of the physical change is problematical. Most marble is massive and does not show cleavage. This may be due to a rolling of the grains among themselves, or more probably

[4] Pirsson, L. V., and Knopf, Adolph, Rocks and rock minerals, 2d ed., p. 400, New York, John Wiley and Sons, 1926.

to the curious property of calcite which permits movement among the molecules, producing new crystal forms without the destruction of its substance. The result is a complicated microscopic twinning. Thus the stresses are absorbed molecularly and do not change the outward structure as in most rocks.

OTHER LIMESTONE

Commercial marbles also include some onyx marble, a variety of limestone which has the texture and color and will take a sufficiently good polish to satisfy the demand of certain trades, and serpentine. As serpentine takes a good polish it is considered as marble by the trade, although it is not a calcareous rock. Some limestones are recrystallized with little evidence of regional metamorphism. Some marbles contain undistorted fossils.

OCCURRENCE

Some high-grade marbles are found in limestone regions which have been subjected to igneous intrusions. Such deposits are limited in extent and variable in quality. Most of the marble throughout the world has been derived from limestones which have been folded and faulted into mountain ranges. Marble deposits due to regional metamorphism are extensive, varied in composition, color and texture, and are well distributed over the earth. Special marbles with specific color and grain are frequently limited to a very small area. What is known commercially as cave onyx, or Mexican onyx, occurs in limited amounts either in caverns or on surfaces where carbonate waters run over cliffs. The calcareous tufa deposit of thermal springs is not a marble.

PHYSICAL PROPERTIES

Different grades of marble have different physical properties. In general, marble must be sufficiently hard to resist reasonable impact and abrasion, and maintain its character through usage. Hence its texture must be impervious, compact and uniform. Some highly decorative marbles are lacking in resistance to weathering agents, thus rendering the stone suitable for interior uses only. Commercial marbles have a crushing strength sufficiently high for all practical purposes, especially in the construction of modern buildings with reinforced concrete, and where the stone is used merely for facing, interior decoration and flooring.

A fundamental property which determines the value of a building stone is its color. In marble, color is frequently considered second only to the ability of the stone to take a polish. The color in any stone must be durable. Marble has many different colors including white, red, green, yellow, blue, and black. Many shades and combinations of color occur, but the color association must be pleasing to the eye, the pure tints and shades must be constant, and the patterns must be attractive. It is said that "marble has an inherent and mysterious beauty possessed by no other stone. It has delicate markings and shades of color which enkindle the highest artistic feelings in the breast of man."

Bowles[5] states that the black and gray shades of marble are usually due to the presence of carbon; red and brown shades, to manganese oxide or hematite; cream and yellow, to fine particles of hydrous iron oxide; green, to sericite, chlorite or epidote. Many shades have an obscure origin.

CHEMICAL PROPERTIES

Marble must retard the oxidizing effects of the atmosphere and must not contain compounds which will disintegrate and stain the stone. Pyrite may stain by subsequent oxidation, but this reaction does not always occur and does not injure the stone for interior use.

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[5] **Bowles, Oliver, The technology of marble quarrying: U. S. Bur. Mines Bull. 106, pp. 11-13, 1916; Marble quarrying industry in Tennessee, *in* Marble deposits of east Tennessee: Tennessee Div. Geol. Bull. 28, pp. 171-172, 1924.**

GEOLOGY OF THE MARBLE DEPOSITS

INTRODUCTORY STATEMENT

Marble is found in four zones in Giles County: (1) Near the top of the Copper Ridge dolomite and near the base of the overlying Nittany dolomite, (2) just above the base of the Murfreesboro limestone, (3) in the basal member of the Moccasin limestone, and (4) in the Romney shale. A geologic map of Giles County showing the distribution of the bedrock formations is being prepared by the writer for publication in a comprehensive report on the geology and mineral resources of the county. The distribution of the marble-bearing formations, prospects, and possible quarry sites are shown on Plate 2.

STRATIGRAPHY

GENERAL FEATURES

All of the bedrock of Giles County is of Paleozoic age, consisting of many formations which range from Cambrian to Mississippian, inclusive. The sequence of formations containing marble is shown in Table 1, in which those having marble zones are italicized.

TABLE 1.—*Stratigraphic distribution of marble zones in Giles County, Virginia*

Paleozoic rocks
- Devonian system
  - Chemung formation
  - Brallier shale
  - *Romney shale*
  - Onondaga chert
  - Oriskany sandstone
  - Becraft sandstone
- Silurian system
  - Clinton formation
  - Clinch sandstone
  - Juniata formation
- Ordovician system (restricted)
  - Fairview limestone
  - Eden shale (undivided)
  - Trenton limestone (undivided)
  - Eggleston limestone
  - Moccasin limestone
    - Red Moccasin limestone member
    - *Lower Moccasin marble member*

Ordovician system—Continued.
- Lenoir limestone
- Mosheim limestone
- *Murfreesboro limestone*

Canadian system[a]
- Bellefonte dolomite
- *Nittany dolomite*
- Stonehenge limestone

Ozarkian system[b]
- *Copper Ridge dolomite*

Cambrian system (restricted)
- Nolichucky shale
- Honaker limestone
- Rome formation

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[a] The Canadian system as here used corresponds to the lowermost part of the Ordovician system of some geologists.
[b] The Ozarkian system as here used corresponds to the uppermost part of the Cambrian system of some geologists.

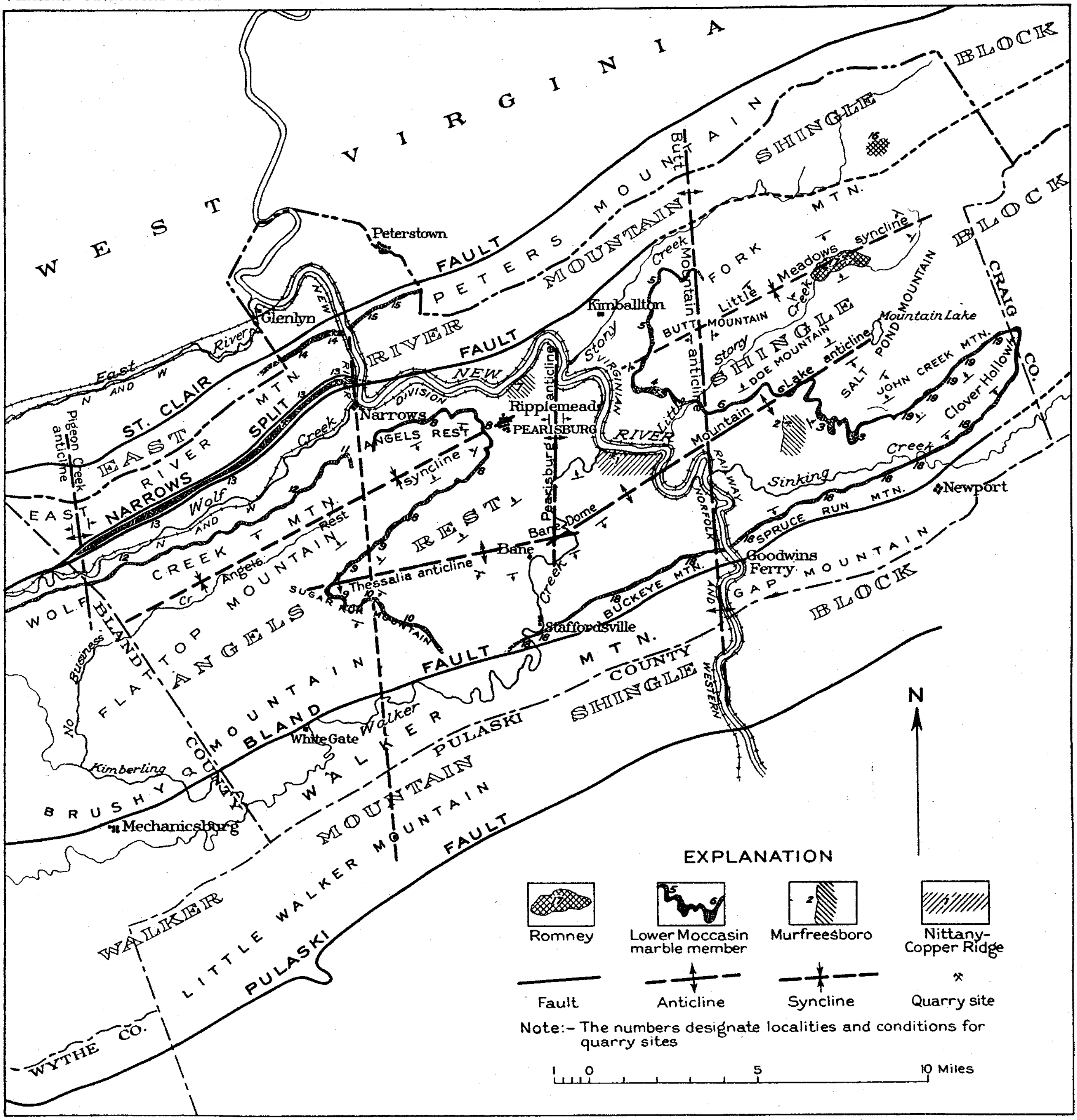
All of these rocks are of sedimentary origin. The oldest exposed formation is the Rome (Lower or Middle Cambrian), which is a fine-grained clastic sediment deposited presumably under marine conditions. A great calcareous division includes the greater part of the exposed Cambrian, and the Ozarkian, Canadian and Ordovician rocks, which were deposited in seas of varying depths. Next is a thick division of coarse- and fine-grained clastic sediments with some intercalated limestone and calcareous shale of Silurian and Devonian age, mostly deposited under marine conditions. The Mississippian system consists of limestones and shales.

All these rocks have undergone great structural changes due to the application of enormous stresses. Some of the limestones have been altered to marble, others have been fractured so as to appear schistose, and others have been broken and cemented by calcite. Most of these formations are fossiliferous and many beds are filled with shells.

MARBLE ZONES

COPPER RIDGE DOLOMITE

General features.—The lowest commercial marble zone in the area occurs near the top of the Copper Ridge dolomite. The best outcrop of the Copper Ridge dolomite is along the railway just west of Narrows, Va. It extends along Wolf Creek into Bland County, occurs around the Bane dome, in part of the valley of Spruce Run and follows in general the north edge of the Walker Mountain shingle block. (See pp. 15-17.) A good exposure is near the mouth of Walker Creek.



Sketch map showing distribution of marble and the major structural features in Giles County, Virginia.

The Copper Ridge dolomite consists of thick beds of different kinds of dolomite with some thinner bedded limestone members, all of which may contain nodular chert. It contains several calcareous sandstones which generally become friable on weathering. Most of the dolomite beds contain fine laminae of very fine sand, which are more resistant to weathering, thus producing an irregular surface. The sandstone and lentil members are diagnostic as they do not occur in the overlying Stonehenge and Nittany formations. Many of the dolomite beds contain an abundance of radial oolites, which are silicified where the rock has been replaced by chert. The chert ranges from white to dark bluish-gray, and occurs in large masses. The formation contains considerable disseminated iron and weathers to a reddish soil in many places. The characteristic fossils are cryptozoans which are found at a number of horizons.

The thickness of the Copper Ridge dolomite along Wolf Creek and New River just northwest of Narrows, is more than 1,500 feet. The estimated thickness throughout the area ranges from 1,500 to 2,000 feet.

Marble.—The beds at or near the top of the Copper Ridge dolomite have been changed into marble in at least one place in the area. Some of the marble beds in this zone may belong to the overlying Nittany dolomite.[6]

The marble zone, more than 100 feet thick, is composed of several members of different colors ranging from an opalescent gray to a dark gray and amethyst. (See Pls. 5 and 6B.) Surface indications of the thickness, uniformity of the stone, and compactness indicate that the marble can be quarried in dimension blocks of considerable size. The rich gray marble of the area occurs at this horizon.

The marble in the Copper Ridge formation has been derived from a dolomite which was apparently precipitated chemically in a shallow sea. (See Table 2.) The conditions necessary for a pure deposit were limited to local areas, not exceeding a few square miles. The characteristic shallow-water bedding does not show through the marble zone; consequently the beds are thick with uniformly thin laminations. The rock makes a thick, compact bed of high-grade stone. Although this zone is limited to a very small area, there is sufficient rock in one hill to furnish marble of this type for many years.

[6] Later study shows that only the lowermost bed of marble occurs in the Copper Ridge dolomite. The upper marble beds are in the overlying Nittany dolomite.

MURFREESBORO LIMESTONE

General features.—A zone at the base of the Murfreesboro limestone carries some beds of marble. Its commercial possibilities are uncertain. Several samples from this horizon have been polished with interesting results.[7]

The Murfreesboro limestone is the lowest formation of the Ordovician system. It is distinctly separated from the underlying Bellefonte dolomite by a well-defined chert breccia, which varies in composition and thickness from place to place. In some places this basal zone is 70 feet thick and in such localities the marble occurs near the contact. Many of the beds of marble contain scattered small chert fragments which do not, however, appear to interfere with the working of the stone or its polish.

The Murfreesboro limestone is well distributed through the county, occurring wherever the older Ordovician rocks crop out. It is the great valley-forming limestone of the county. It is distinguished by its dark-bluish color with still darker fine irregular marks and generally knotty appearance. It is thin to thick bedded and varies so much laterally and vertically from place to place that no two detailed sections are alike. Chert occurs in beds or nodules throughout the formation. The most characteristic feature of the formation is that the limestone dissolves readily and thus makes a conspicuous sink-hole topography. This is the principal limestone which forms the good agricultural lands.

Marble.—Some beds in the basal member of the Murfreesboro limestone have been changed to a stone which takes a polish and could therefore be placed on the market as marble. Some of these beds are 15 feet thick. On fresh fracture the rock is light buff or yellowish-gray, but when polished it becomes a beautiful palette with a taupe groundmass and with small irregular red, dark-pink, gray, and cream-colored specks, thus yielding a very pleasing color. This bed is extremely fossiliferous and contains an abundance of ramose bryozoans and some small brachiopod and trilobite shells. The sections of these shells add to the pleasing appearance of the polished stone. Masses of pyrite are scattered throughout the rock.

MOCCASIN LIMESTONE

General features.—The Moccasin limestone is well exposed throughout the central and northern part of the county. It is absent along Gap Mountain and a part of Walker Mountain, reappearing only

[7] In 1903, Mr. Sam Hoge made an opening 20 feet deep on his farm east of Hoges Store, from which several blocks of marble were obtained and polished for exhibit. These specimens were displayed at the St. Louis Exposition and later at the Jamestown Exposition. Some of them are now in the State Museum in Richmond.

southwest of Walker Mountain gap. With the overlying upper member of the Black River group, referred to here as the Eggleston limestone,[8] it makes a row of sharp hills or distinct shoulders bordering the uniformly continuous slopes of the mountain ranges where younger formations occupy the crest.

The Moccasin limestone is distinctive, containing the one dominantly red limestone in the region. The formation is composed of two distinct units, termed here the upper red Moccasin member and the lower Moccasin marble member. The upper member is a dark-red, argillaceous and arenaceous thick- to thin-bedded limestone, which due to intense deformation has developed pronounced fracture cleavage. (See Pl. 3A.) This cleavage is everywhere a dominant characteristic of the upper Moccasin member. Deformation has been sufficiently intense to develop distinct cleavage in the lower Moccasin marble member only in the Sinking Creek isoclinal fold bordering Spruce Run Mountain. (See Pl. 3B.)

The lower Moccasin marble member is well defined, continuous and resistant. It forms the third ridge in magnitude throughout the area, weathers slowly, and caps some of the outlying hills. The upper part is thin bedded, compact and a very dark reddish-brown. The uppermost part of the member is commonly very thin bedded, but the beds are thoroughly cemented. At a distance the surface looks like one massive bed ranging from 4 to 15 feet in thickness. The lower beds are much thicker, more compact, and variable in color, ranging from a variegated carnelian and light Nile-green to a beautiful gray with golden bands. On the weathered blocks, some beds are separated by very thin layers of argillaceous limestone, which extend only a short distance from the surface. (See Pl. 4A.) The thickness of the marble member ranges from 60 to 121 feet.

Origin.—The limestone which has been altered to marble was deposited in a shallow embayment of the Black River sea, a considerable distance from a low-lying land. The marble is a remarkably pure calcium carbonate, considering the type of deposi-

[8] The Eggleston limestone includes the beds of upper Black River age which are younger than the upper red Moccasin member (Lowville) and older than the Trenton limestone. Although a good section of the formation occurs 1.1 miles south of Eggleston, Va., the best section is along State Highway 8, one mile north of Narrows, Va. This will be considered the type locality and will be described in detail in the comprehensive report on Giles County now in preparation. As the name Narrows has been preoccupied and as there are no suitable local names for the formation, the name Eggleston limestone has been selected and approved.

In general the Eggleston is thin- to thick-bedded, fine-grained, argillaceous, dark-buff to light-brown limestone which upon fracturing forms cuneiform blocks with the jointing perpendicular to the bedding. It contains many thin beds and a few thicker beds of bentonite, and its peculiarities may be due to this material. The formation is widely distributed in the Valley and Ridge province. In the type locality it is more than 150 feet thick. The fossils are of the upper Black River type.

tion. The surfaces of some of the beds show mud cracks characteristic of a mud flat. (See Pl. 4B.) The color is primary and should remain uniform throughout the mass for any given section or bed. The color varies vertically from bed to bed, as conditions affecting deposition changed from time to time.

Marble.—Lower Moccasin marble of commercial grade is well distributed throughout the northern and central parts of the county. (See Pl. 2.) Favorable localities for prospecting are discussed on page 31-32. The following detailed section shows the characteristics of the marble zone in one locality.

Section of the lower Moccasin marble member on a hill on Wm. M. Johnston's farm 1 mile north of Pembroke, Virginia

	Thickness Ft.	In.
(Red Moccasin member 10 to 20 feet thick)		
Lower Moccasin marble member:		
18. Light-gray, vitreous, argillaceous marble which cracks into small fragments	3	
17. Vitreous, dense, peach-colored marble		10
16. Poor grade of coarse-grained soluble marble	1	3
15. Thinly and uniformly bedded, dense, vitreous, hard, reddish-brown marble; in beds 1 inch thick	2	
14. Thick-bedded, slightly variegated, reddish and light-green marble, streaked with white calcite veins; weathered surface uniform	8	
13. Thick-bedded, variegated red and light-green marble, with white calcite veins. One member 18 inches thick is very dark reddish brown	4	
12. Thinly laminated, wavy, carnelian moire marble	1	3
11. Thick beds of variegated carnelian and greenish-gray marble; compact and vitreous with large white calcite veins	15	
10. Imperial champagne-tan and light dove-gray, thin-bedded marble	1	6
9. Thick bed of imperial champagne-tan marble; resistant and blocky; very good quality	2	
8. Vitreous gray marble with golden seams	6	
7. Thick bed of dove-gray vitreous marble, with some dark-red banded beds and white calcite veins	3	
6. Dove-gray marble which weathers readily	12	

Lower Moccasin marble member—Continued.		
5. Dove-gray or imperial champagne-tan marble with broad calcite veins; upper part slightly limy	4	
4. Covered; gray marble float	6	
3. Beautiful dove-gray marble with numerous calcite veins and many irregular golden patterns, imperial champagne-tan on polished surface; a very good stone	8	
2. Dove-gray marble streaked with golden laminations; soluble	20	
1. Covered; not determined, but base of formation not far below		
Total thickness	97	10
(Lenoir limestone; not measured)		

A section is exposed on the other side of the same hill. Measurements were made only for the exposed surface. This section is taken from the zone adjacent to a fault of minor displacement.

Section of lower Moccasin marble member 1 mile north of Pembroke, Virginia

	Thickness Feet
(Red Moccasin member 5 to 15 feet thick)	
Lower Moccasin marble member:	
5. Light-gray argillaceous marble which weathers readily	12
4. Thin-bedded, gray and reddish-brown, irregularly bedded marble, with some argillaceous seams	2
3. Carnelian moire marble; thin and thick beds and waves of amplitudes from 2 inches to 3 feet; very compact	8
2. Imperial champagne-tan marble, partly moire; some beds are more gray than tan; cut with large and small white calcite veins	12
1. Dove-gray marble	40
Total thickness	74
(Beds cut off by a fault)	

ROMNEY SHALE

General features.—The Romney shale is the uppermost formation containing limestone which may be polished and used as marble. It occurs mainly in the synclinal troughs and basins of the higher mountain ranges. The formation consists of dark-gray to black, glazed, splintery, highly fractured, finely laminated, carbonaceous and manganiferous shales, which weather to dull gray and oily brown. The upper part is somewhat lighter colored than the lower part. The formation is more calcareous near the base, where it includes one or more beds, or lenses, of pure black limestone varying from 2 to 7 feet in thickness. In regions which have been subjected to great stresses, these beds and lenses have been changed to marble. The formation grades into the overlying Brallier shale. It lies unconformably upon the Onondaga chert.

The best exposures of the Romney shale are: (1) Just east of the crest of Butt Mountain, (2) between Interior and Kire and (3) along No Business and Dismal creeks, several miles southwest of Pearisburg. The shale occurs in patches in the trough of the recumbent fold adjacent to the Narrows fault which flanks East River and Peters mountains. Patches of the shale also occur north of Bluff City and in the overturned fold along the St. Clair fault.

Marble.—Marble has been found in one locality east of Butt Mountain, where it occurs along the course of Little Stony Creek below the mouth of Pond Drain. (See Pl. 2.) The outcrops and information obtained by shallow diamond core drilling indicate that at least a part of the marble occurs as blocks imbedded in the shale. Known blocks vary in size from a few feet to at least 20 feet across, and it is reasonable to postulate a much greater dimension. Some are as much as 7 feet thick. Whether a marble bed extends continuously under the basin has not been determined, and will not be determined until deep drilling has been done. The outcrops are found near the axis of a spoon-shaped structural basin. The area is known locally as Little Meadows. It is about 2 miles northwest of Mountain Lake and east of the crest of Butt Mountain. The basin is from 5 to 10 miles from a railroad and at a high elevation.

OTHER LIMESTONES

As Giles County is situated in a region which has been subjected to intense deformation, many limestone formations have been sufficiently altered that the stone when cut will take a good polish. These include certain beds or lenses in the Mosheim, Lenoir, Trenton, and Fairview limestones. In each instance the formation is thin bedded and either contains an abundance of chert nodules, has numerous clay and shale partings between the beds, or is a dull uninteresting color. Since the probability of securing a location suitable for quarrying commercial marble from these formations is extremely remote, no further mention is made of them.

STRUCTURE

General Features

Most of the problems connected with the development of the marble deposits of Giles County are related to regional structure and subsequent erosion. The formation of the marble by regional metamorphism is related to the structure of the region and the marble beds have been exposed by erosion.

Giles County has been subjected to tremendous stresses, sufficient in every instance to explain the conversion of limestone to marble. This is indicated by a calcareous schist zone and the large shingle blocks described below. The calcareous schist zone occurs along the north flank of Spruce Run and Buckeye mountains and extends from Clover Hollow west to and beyond Sugar Run Mountain. (See Pl. 2.) It is associated with the Sinking Creek isoclinal fold and parallels the Bland (Saltville) fault. In this zone the limestone and marble have been so completely altered that the bedding has been obliterated. (See Pl. 3B.) A concise discussion of the shingle blocks, necessary to give a clear explanation of the occurrence and attitude of the marble zones and an explanation of the regional structure of the area, are outlined in the following paragraphs.

Structurally, Giles County is included in the Valley and Ridge province, a region which has been subjected to intense earth movements, resulting in the formation here of three major shingle blocks. (See Pl. 2.) The general trend of this primary structure is about N. 60° E. Crossing the major structure are four distinct anticlinal folds and two overlap fault zones, the axes of which cut the primary axes at angles of about 68°, thus forming a grid pattern of all the structures.[9] This great structural region has been carved out by the differential erosion of New River and its tributaries from the extensive peneplain (Cretaceous?) which is indicated by the even crests of the main mountain ranges.

In a shingle block, therefore, the older and lower rocks have been thrust upward and over the younger and higher rocks and

[9] Mathews, A. A. L., New lights on Giles County structure (abstract): Virginia Acad. Sci. Proc., 1931-32, p. 61, 1932.

thus overlap the latter like shingles on a roof, only in reverse order, with the lap turned up. Campbell and Holden[10] have, in reality, defined a "shingle block" as consisting of a segment of the earth's crust which is bounded on both sides by a thrust fault. The structure of Giles County consists of three shingle blocks bounded by four major thrust faults. These are, beginning at the south, the Walker Mountain shingle block, the Angels Rest shingle block and the East River Mountain shingle block.

WALKER MOUNTAIN SHINGLE BLOCK

The Walker Mountain shingle block is bounded on the south by the Pulaski fault and on the north by the Bland (Saltville) fault. This block was shoved northwesterly over the southern flank of the next shingle block so that the Honaker limestone rests upon the Fairview limestone and the Juniata sandstone. It extends from Craig County 80 to 90 miles to the southwest. This block pitches steeply towards the southeast and some of the formations have a dip of 78° SE.

No commercial marbles have been observed on the Walker Mountain shingle block.

ANGELS REST SHINGLE BLOCK

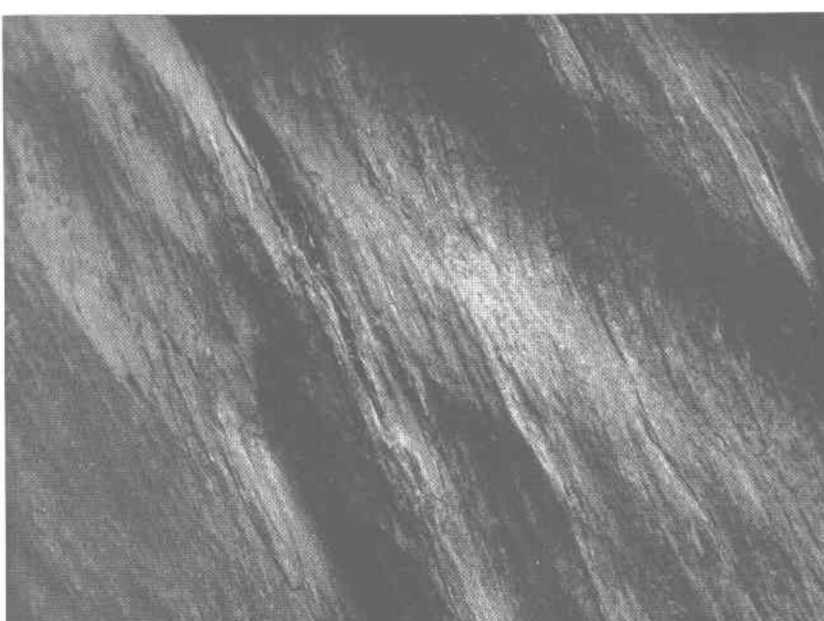
The Angels Rest shingle block, which includes Butt Mountain, is bounded on the south by the Bland (Saltville) fault and on the north by the Narrows fault. In general it pitches gently towards the southeast and is composed of very different structural elements than either the Walker Mountain or East River Mountain shingle blocks. It forms the great central mass of the county and consists of ten open folds and one closed fold, as follows: The Bane dome which is a slightly elongated quaquaversal fold with the long axis northeast-southwest. It is bordered on the south by the Sinking Creek isoclinal fold and on the north by the Pearisburg anticline. Radiating from this dome are the Clover Hollow, Thessalia and Mountain Lake anticlines, and the Johns Creek syncline. The axes of these structures pitch away from the dome. The axes of the Laurel Creek anticline, and the Butt Mountain and Angels Rest synclines parallel the Narrows fault, while that of the Dismal syncline pitches towards the west. The Butt Mountain syncline includes the Little Meadows basin which is almost a perfect spoon-shaped structure with the rim rock dipping towards the axis of the basin. Along the southern margin of the block is an open syn-

[10] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, pp. 38-43, 1925.

A. Fracture cleavage in upper Moccasin limestone, south of Eggleston.

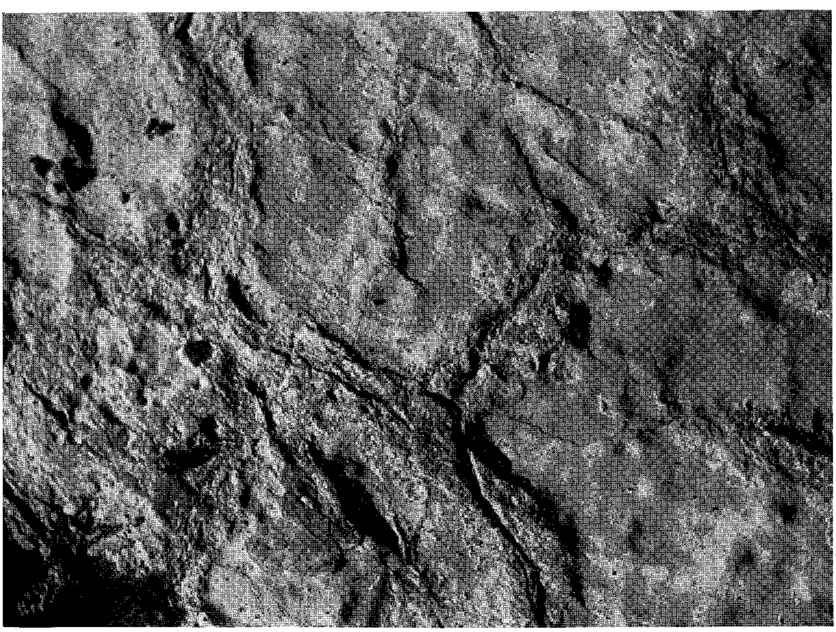
B. Schistose lower Moccasin marble member, south of Eggleston.

A. Fracture cleavage in upper Moccasin limestone, south of Eggleston.

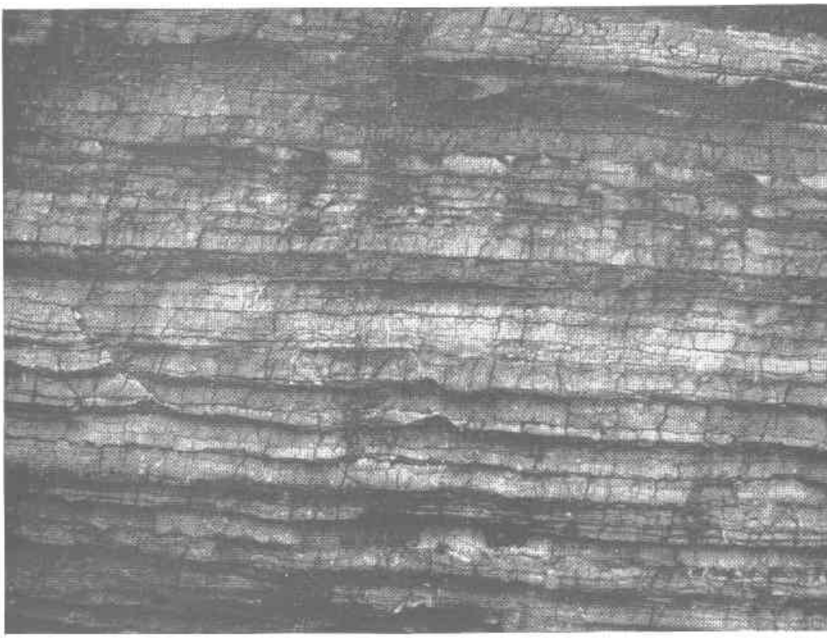


B. Schistose lower Moccasin marble member, south of Eggleston.

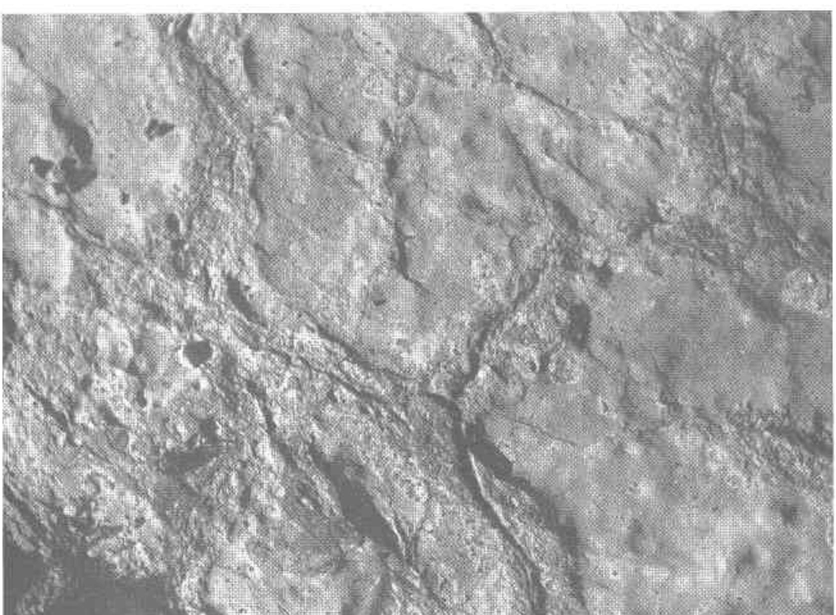
A. Upper part of the marble in the lower Moccasin marble member.



B. Mud cracks on the weathered surface of a bed in the lower Moccasin member.



A. Upper part of the marble in the lower Moccasin marble member.



B. Mud cracks on the weathered surface of a bed in the lower Moccasin member.

clinal fold with the axial plane pitching towards the southeast and parallel to the strike of the Bland fault. The northwest limb of this syncline is formed by the isometric folds in the Moccasin limestone. This entire structure is designated the Sinking Creek isoclinal fold. This structure opens towards the northeast and is well defined in Clover Hollow. The northern edge of the shingle block is thrust over the southern flank of the East River Mountain shingle block, so that the Honaker limestone and the Copper Ridge and Nittany dolomites rest upon or against younger formations.

The best marble sites are located on the Angels Rest shingle block. The best grades of marble are situated in the least disturbed parts of the structure where locally the formations have been subjected to more intense pressures. The areas around Pembroke, near Pearisburg, Sugar Run, the north side of Clover Hollow, and Wolf Creek are especially favorable for prospecting. Black marble is found in Little Meadows.

EAST RIVER MOUNTAIN SHINGLE BLOCK

The East River Mountain shingle block, which includes Peters Mountain and the Narrows split fault zone, is bounded on the south by the Narrows fault and on the north by the St. Clair fault. This block pitches steeply towards the southeast. The fault system along the southern flank of the shingle block is very complicated. Our interest centers only in that part bounded by the split fault section of the Narrows fault. This occurs along the north side of Wolf Creek Valley, where the Honaker and Copper Ridge formations are resting against or upon Lenoir and Moccasin limestones. Here the beds have been overturned from 2° to 15°. (See Pl. 7B.) This segment in turn has been thrust over the Becraft sandstone at New River and over the Juniata and Clinch formations farther southwest. Along the north edge of the East River Mountain shingle block, the Nittany dolomite is thrust over the Chemung and Romney formations which are the lower members of the Rich Creek overturned fold.

Although the marble member of the Moccasin limestone occurs in the northwest part of the East River Mountain shingle block, the best deposits occur in the Narrows split fault zone west of Narrows. Here the marble attains a maximum thickness of 121 feet, and occurs in quantities and of a quality and a variety of colors sufficient to justify thorough exploration.

METAMORPHISM

As a result of the localization of the extreme compressional forces during the period or periods of deformation, many limestone beds of different age have been changed to high-grade marble. This is especially true of the Angels Rest shingle block and the segment caused by the Narrows split fault, in which the best grade of marble is found. In areas where more intense forces accumulated, such as the Sinking Creek isoclinal fold, the limestones have been changed to a calcareous schist or are so broken by fracture cleavage as to render the stone useless for commercial purposes.

ECONOMIC GEOLOGY

INTRODUCTORY STATEMENT

There are no marble quarries in Giles County, and but little prospecting has been attempted. Messrs. Clarence Reynolds, John B. Laing and John Hoge have prospected in Little Meadows with a core drill. Mr. William Johnston has opened up a site near Pembroke and drilled a few feet from the surface. Samples of several varieties of marble, all taken from near the surface, have been cut and polished. Consequently, the discussion of the marble zones and the economic possibilities is based on surface indications, petrographic examination of selected samples, and geologic relations. Tests which have been made of the various kinds of marble have all been favorable. Marble from each zone takes a good polish, is hard, compact, composed of very fine crystals, and has good clear colors.

The suitability of the marble for quarrying, handling, working and finishing gives each type of marble a definite classification, and thus essential characteristics are defined by grading. The essential characters used for determining the quality of marble are stated by Dale.[11] Uniformity of texture is extremely important, as variations in texture detract from the appearance and, upon weathering, stone of variable texture becomes pitted. Fine-grained marbles are in general more durable than coarse grained. Dale[12] states that acid water travels more rapidly between coarse than fine grains. Fine-grained rather than coarse-grained marbles should be used for exterior purposes. Fine-grained marbles take a better polish, are adapted to intricate carving, and are low in porosity. In such marbles there are a minimum number of cracks, joints, fissures and other lines of weakness which may require sticking, waxing and filling. The classification indicated below, with the descriptions of the different marbles, refers to the groups

[11] Dale, T. N., Constitution and adaptation of the Holston marble, *in* Marble deposits of east Tennessee: Tennessee Div. Geol. Bull. 28, pp. 172-173, 1924.

[12] Dale, T. N., Commercial marbles in western Vermont: U. S. Geol. Survey Bull. 521, p. 37, 1912.

arranged by the National Association of Marble Dealers, as given on page 42.

According to the opinions expressed by many marble dealers and architects, the marbles found in this area are as hard, fine grained, dense, low in porosity and have as strong and bright colors as the domestic marbles now on the market. The fact that they take a high polish makes them desirable for decorative uses. The marbles are equal or superior in these same physical properties to imported marbles, with the added advantage of being very tough and strong, thus eliminating waxing and sticking, which is necessary in the preparation of many foreign marbles.

CLASSIFICATION OF LOCAL MARBLES

The commercial marbles of Giles County fall into four groups: Moire, tan-gray, variegated, and a miscellaneous group. They are described from hand and polished specimens, thin sections, chemical analyses, and field relations. Suitable locations for quarrying are indicated and possible uses are suggested. (See Table 3.) The thin sections have been studied by Arthur A. Pegau who gives the results of his microscopic examinations in the section "Petrography of the marbles." (See pp. 36-41.) Chemical analyses of the various marbles are given in Table 2.

MOIRE MARBLES

This group is based entirely on the unusual character of the rock which can be cut in such a manner as to form a moire pattern. The basis is entirely textural and the group may include any color. Two colors, carnelian and gray, represent this group in Giles County.

Carnelian moire marble.—This is the most distinctive and most decorative marble in the area. The color is a deep carnelian, lightened by pale Nile-green variegations. This rock takes a high polish. As the irregular light-golden variations and dull, henna-colored portions do not take a high polish, the combination produces a most exquisite moire pattern. Some irregular masses of white calcite add to the beauty of the marble. When viewed from a distance, the polished marble has a deep rich velvety appearance resembling tapestry. When cut properly, the stone yields patterns of rare beauty for panels. The coloring matter in the groundmass can not be determined from a hand specimen. The golden-colored bands are due to an iron compound. (See Pl. 1.)

Megascopic examination shows that the groundmass is composed of extremely fine crystals. The calcite masses are coarsely crystalline. The head grain of the marble is undulating, forming small folds that are 3 inches to 3 feet from crest to crest. (See Pl. 6A.) It is due to this character that the moire pattern is formed when the cut is parallel with the grain. Fracture due to impact is irregular and seldom follows the grain. The stone is hard, tough, has a low clear resonant tone, and takes a velvety polish. It is resistant to weathering, but the exposed face is somewhat irregular. The seams, bedding and grain are welded. The suggested classification for this marble is group D.[13]

The carnelian moire marble is highly decorative and its use should be restricted to the finest designs and to the best and most permanent buildings. It will make beautiful panels, table tops and novelties.

This marble occurs at the top of the lower Moccasin marble member and is limited to two localities, namely, near Pembroke and in the Narrows split fault zone. It occurs only in an area where compressional forces have been sufficiently strong to produce a fault, thus leaving the adjacent rock in a folded and crumpled condition. (See Pl. 6A.) It is in the adjacent zone that this marble is found. The bed ranges from 2 to 8 feet in thickness, is persistent through the hills where it occurs, and can be quarried in reasonably large blocks. The quantity is limited, the estimated reserve being less than 400,000 cubic feet. This marble is associated with the gray moire variety and has only a slight overburden; hence the stone should be recovered at a profit.

Gray moire marble.—A flushed gray moire marble is found just below the carnelian moire. It is so near the imperial champagne-tan that it might be classified as a tan. It contains many small veins of white calcite. The bedding of the stone is undulatory. When the stone is cut parallel to the grain a very desirable moire pattern is produced.

The groundmass is composed of very fine crystals. The calcite veins are coarsely crystalline. Fracture due to impact is irregular and seldom follows the grain. The stone is hard, tough, and takes a good polish. It is resistant to weathering, but the exposed surface is somewhat irregular. The seams and bedding are closely welded. The suggested classification is group C.

This marble occurs just below the carnelian moire and the two stones can be quarried from the same pit. The estimated reserve is about 200,000 cubic feet. This marble could be used for panels, table tops, base boards, pilasters, and other decorative purposes.

TAN-GRAY MARBLES

Some very excellent tan and gray marbles are found in Giles County. As the distinction between some of the tan and the gray mar-

[13] The group indicated conforms to the classification of the National Association of Marble Dealers.

bles is slight, they are considered together. The colors in this group are Virginia gray, opalescent gray, imperial champagne-tan, and golden-gray.

Virginia gray marble.—This marble is somewhat darker than a rich pearl-gray and lighter than daimler drab. It is streaked with many fine dark-gray and black stylolite bands, which are massed closely throughout the stone, in a very pleasing composition. It contains a few very small white calcite spots. (See Pls. 5 and 9B.)

Examination of a hand specimen shows the groundmass to be composed of microscopic crystals. The crystals in the stylolite bands appear to be slightly coarser, and the calcite crystals in the white spots are relatively large. The stylolite bands are broad, welded and irregular. Break fracture from impact always crosses the stylolite bands. The marble is slightly translucent, emitting a very dim cloudy light. It has a clear low resonant tone and takes a very high polish. The stone is very resistant to weathering. Where exposed to weathering agents for a long time, it forms an even clean face without solution cavities. On extremely weathered surfaces, the thin laminations are indicated by the deposition of fine calcite crystals on the surface. The durability of the stone is indicated by the permanency of the central pier of the Norfolk and Western Railway bridge across Walker Creek. This pier was built more than 50 years ago, but the marble shows little evidence of decomposition or weathering, although the bridge has been continually used for heavy traffic. (See Pl. 6B.) The stone weathers to a very light gray surface. The suggested classification is grade A.

This marble occurs in the Nittany dolomite close to the junction of Walker Creek and New River along the Norfolk and Western Railway. The rock forms a hill, the beds dip about 16° towards the railroad, and the overburden is composed of other commercial marble. This locality offers an excellent site for a quarry. One solid bed without seams is more than 8 feet thick. It is uniform in texture and apparently will furnish marble in large dimension blocks.

This marble is probably best adapted for flooring, steps, base boards, trimmings and pilasters. It is suitable for modernistic and futuristic designs and will serve for fountains, table tops and other fixtures. It might be used also for copings and monuments.

Opalescent gray marble.—The opalescent gray marble is the lightest colored marble in the region. It has an opal-gray groundmass with lighter portions resembling cut Amazon stone which shades irregularly and rapidly into a rosy tan with wavy, irregular, darker rose-colored stylolite bands. This gives a very pleasing color combination. The color appears to be occluded pigment or coatings on the crystals. Along the stylolite bands the relation of the color to the crystals is quite distinct. A few dark-colored dendrite masses, apparently of a manganiferous mineral, are scattered through the lighter groundmass.

The groundmass is composed of very fine calcite rhombs. The crystals in the stylolite bands are much coarser. The stylolite bands are tight and welded. Fracture from impact always crosses the stylolite bands. The marble is slightly translucent emitting a faint white light. The stone is resistant to weathering since it forms a ledge without solution cavities. It weathers to a light cream-colored surface. The stone takes a very fine polish. The suggested classification is grade A.

This marble is in the Copper Ridge dolomite near the junction of Walker Creek and New River. The rock crops out on the flank of an outlying hill with the beds dipping towards the depression. This locality is a quarter of a mile from the Norfolk and Western Railway.

This marble is probably best adapted for light decorations and trimming, wainscot, floorings, steps, novelties, crafts and other ornamental purposes.

Imperial champagne-tan marble.—This is a nickel-gray marble grading into a rich beige and dominantly streaked by distinct silver-gray calcite seams of varying width. The deeper tan with a reddish flush gives the stone a warm color and the silver-gray color gives it life. It is spotted and streaked with very thin dark-gray to black lines, which are the sections of fossil shells, and contains some irregular and scattered stylolite bands. The whole forms a very pleasing tan-gray combination. The silver-gray and white calcite occurs in veins composed of large crystals and in small dots of tiny crystals. Light-colored dots of microscopic size are scattered through the groundmass. The large colored masses are hematite and limonite, which have apparently replaced the groundmass as well as the calcite in the seams. (See Pl. 5.)

The groundmass is composed of microscopic crystals. (See Pl. 8A.) The calcite crystals in the veins are large. The stylolite bands are very thin, welded and widely spaced. Fracture from impact rarely follows the seams and stylolite bands. This marble has been greatly fractured and recemented with pure calcite. It is nearly opaque, has a clear resonant tone and takes a uniformly high polish. It is resistant to weathering, but due to differential erosion the calcite seams stand out in relief. This rock contains many fossil fragments, the sections of which give an unusual variation to the color of the polished surface. The suggested classification is grade B.

This marble occurs near the top of the lower Moccasin marble member, and is found in any area which has been subjected to faulting. It is always below the upper red horizon and is usually associated with the carnelian moire marble.

This stone is probably best adapted for flooring, steps, base boards, pilasters, trimmings, fountains, table tops and other fixtures. It is highly suitable for modernistic designs.

Golden-gray marble.—Wherever the lower Moccasin marble member is present, the greater part of it is of a dark golden-gray color. Some of the beds have a very pleasing association of gray tinged with gold and white. This stone is fine grained, has a clear resonant tone, and takes a good polish. The groundmass is extremely fine and composed of crystals of calcite associated with a pigment which gives the color. (See Pl. 8B.) The stone occurs in large quantities below the imperial champagne-tan marble and is well distributed through the county. The suggested classification is group A.

The more attractive beds would be very desirable for flooring, base boards, and pilasters.

VARIEGATED MARBLES

The variegated marbles of Giles County are decidedly variable in color and design. In certain marbles some colors grade into each other. In other marbles the colors are distinct. The variegated marbles are artistic and pleasing, due primarily to their extremely fine groundmass, a characteristic of all the commercial marbles of the area. The marbles in this group are the variegated light-mahogany, the Newport brown, the amethyst, and the palette. (See Pl. 5.)

Light-mahogany marble.—This marble has a light mahogany-colored groundmass with irregular blotches and streaks of light Nile-green. It contains many seams and irregular masses of white calcite. The color combination is not only pleasing but makes the stone appear massive, and the wide calcite veins make it very attractive. (See Pl. 1.)

The groundmass is composed of very fine crystals. The calcite seams are coarsely crystalline. Fracture due to impact may follow lines of weakness but generally cuts irregularly across the seams. The marble is opaque, very hard, somewhat brittle, has a clear resonant tone and takes an excellent polish. It is very resistant to weathering and forms a shoulder along mountains wherever the Moccasin formation crops out. The weathered face is smooth, forms ledges and is a pleasing reddish-gray. (See Pl. 4A.) Apparently the rock responded slowly to deformational stresses, which resulted in relatively large fractures. They have been welded by calcite. The suggested classification is grade B.

This marble occurs in the lower Moccasin marble member and is well distributed through the county. The beds range in thickness from 4 to 15 feet. The upper part is usually composed of lentils or beds about 1 inch thick, but it grades rapidly into a solid mass below. (See Pl. 4A.) As this stone forms the shoulders surrounding the higher elevations, the outcrops are as a rule some distance from main lines of transportation, but excellent quarry sites may be secured within

2 miles of a railroad shipping point. The estimated reserve is very large.

This marble is probably most suitable for columns, capitals, base blocks, balustrades, plaques, flooring, copings, building block facing and many other uses, such as crafts, fixtures, and novelties. It may be used also for terrazzo. Some blocks may be suitable for monuments.

Newport brown marble.—This is an unusual stone. It is difficult to describe all the colors. In general the groundmass is a Newport brown or nearly a dark brown which makes it very dark colored. It contains spots, irregular ribbons and blotches of old rose and gold. The groundmass is cut by fine irregular, branching and braided white calcite seams. These warm colors produce a very pleasing composition. The color of the irregular blotches is due to the crystals being coated with an iron compound. (See Pls. 1 and 9A.)

Megascopic examination of the marble does not reveal the crystalline character of the groundmass. The rose and gold masses are distinctly crystalline, but the crystals are not as large as those of the white calcite seams. The groundmass is primary. After consolidation the rock was fractured and recemented by white calcite; then, both the groundmass and the white calcite were replaced by rose- and golden-colored spots, giving a mottled appearance. Fracture due to impact is irregular and conchoidal. The stone is opaque, hard, has a clear resonant tone and takes an excellent polish. A few bryozoa are embedded in the matrix. The stone is very resistant to weathering, but contains some small solution cavities. It weathers to a dull gray. The suggested classification is grade C.

This marble occurs in the lower Moccasin marble member and has been found only in the Narrows split fault segment, where the beds are overturned about 15°. (See Pl. 7B.) The main bed is about 5 feet thick, but is associated with other commercial marbles in a zone 120 feet thick. The estimated reserve is limited. One of the best locations for a quarry is near the Norfolk and Western Railway, along New River, just below Narrows, and near Shumate, Va.

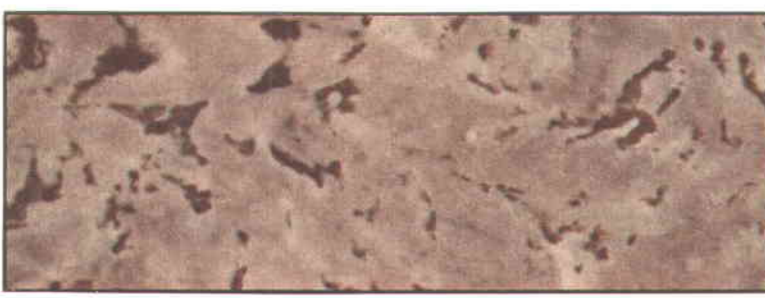
Its use will probably be limited to interior decorations and modernistic designs.

Amethyst marble.—In one locality a dark moonbeige or amethyst marble occurs just above the Virginia gray bed. This stone is somewhat variegated due to irregular patches of different shades of amethyst and tan. It is streaked with white seams. The color pigment is intimately associated with the crystals. (See Pl. 5.)

The groundmass is composed of uniform crystals of dolomite. The seams contain much larger crystals of calcite. The marble is slightly translucent emitting a very dim light. Fracture due to impact is irregular. The stone is hard, has a clear resonant tone, and takes a

A

B

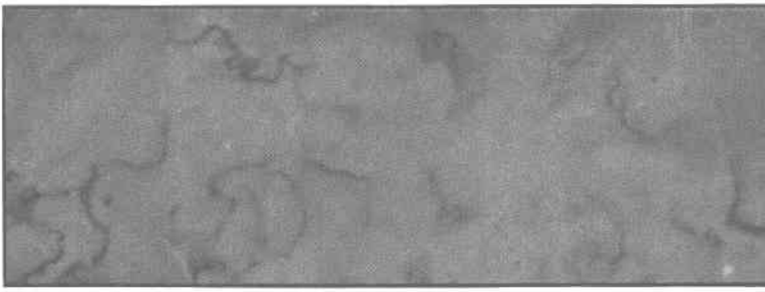


C

D

MARBLE FROM GILES COUNTY, VIRGINIA

A—Virginia gray
B—Imperial champagne-tan
C—Amethyst
D—Palette



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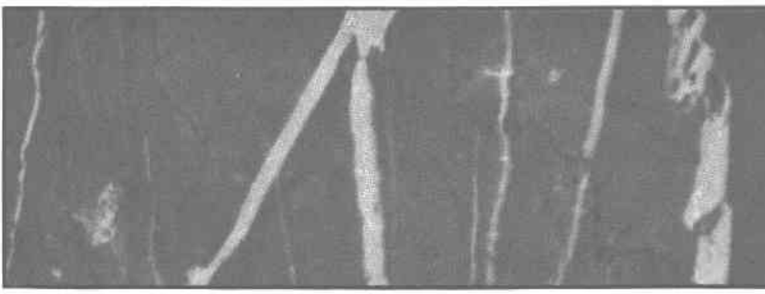

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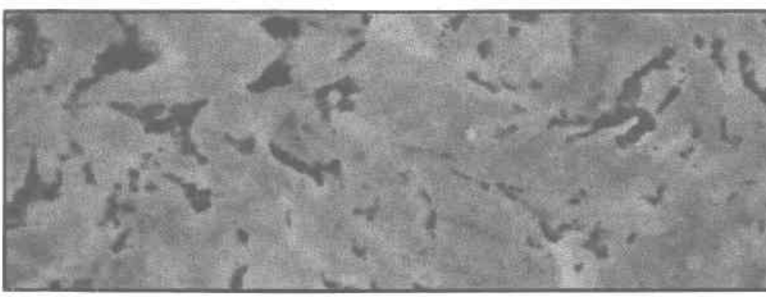
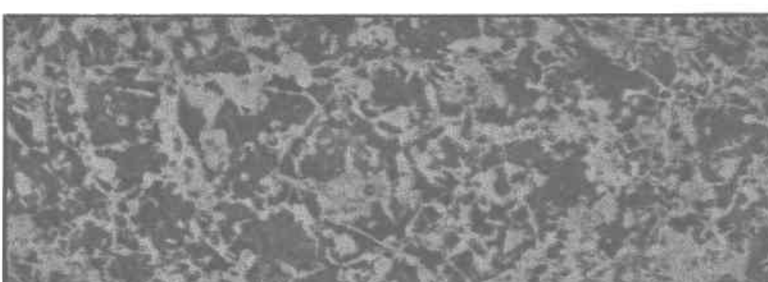


C



D

MARBLE FROM GILES COUNTY, VIRGINIA

A—Virginia gray
B—Imperial champagne-tan
C—Amethyst
D—Palette

good polish. It is resistant to weathering and becomes a light gray on exposed surfaces. Rock from this bed and that of the Virginia gray were used in the construction of the central pier of the railroad bridge crossing Walker Creek. (See Pl. 6B.) The stone shows little alteration or disintegration. The suggested classification is group B.

This marble occurs in the Nittany dolomite and forms a bed 12 feet thick, about 3½ feet above the Virginia gray marble zone. The overburden consists of 15 to 30 feet of gray marble with some thin dolomite beds.

This marble is probably best adapted for pilasters, copings, floorings, plaques and monuments. The darker portions may be used for modernistic and futuristic designs.

Palette marble.—The groundmass of this rather unusual stone is a taupe, slightly darker than an antelope-tan. It is abundantly speckled with irregular red and light silver-gray blotches of variable sizes up to one-half inch in length and one-fourth inch wide, which are uniformly distributed throughout the mass. There are some small flecks of dark blue in the groundmass. The color pigment seems to be a part of the mass. (See Pl. 5.)

The groundmass appears to be made up of very fine fragments of shells mixed with an indistinct non-crystalline mass. Pyrite is abundantly scattered through the stone but does not oxidize readily. The rock is opaque, has a dull resonant tone, but takes a good polish with a very slight relief. It is reasonably resistant to weathering and becomes a light tan on exposed surface. Break fracture due to impact is irregular. Some beds contain fine chert fragments. The suggested classification is grade C.

This stone occurs in the basal member of the Murfreesboro limestone. It appears to be in lenses of considerable size, sufficient to justify exploration. The zone is about 30 feet thick, but the beds range from 3 to 15 feet thick. The stone can be obtained near main railroad lines. The best outcrop observed is just east of Hoges Store.

The stone is probably best adapted for interior decoration, but may be used for fixtures, crafts and novelties.

OTHER VARIETIES OF MARBLE

Many other limestone formations in Giles County contain marble members. The beds vary in color, structure and composition. Little use can be made of the thin-bedded deposits. There are two marbles which can be obtained for commercial purposes, namely, the sunset-red and the jet-black. (See Pl. 1.)

Sunset-red marble.—A highly decorative stone with many small interesting patterns occurs in the marble zone along the Narrows split fault. This stone has the red and gold colors of the deep afterglow of sunset. The mixture of color is variable and intricate, but, in general, the main hues are cardinal, henna and gold. The mass is crossed by many white seams of calcite. In a hand specimen the color appears to be due to the coating of the grains by different iron compounds and to pin-point spots scattered in somewhat rhythmic bands throughout the groundmass. The polished stone offers a very interesting composition. (See Pl. 1.)

The rock is composed of fine crystals and the calcite seams are coarsely crystalline. Fracture due to impact may follow lines of weakness but is generally irregular. The stone is opaque, hard, has a dull resonant tone and takes a good polish. It is resistant to weathering but becomes a dull gray upon long exposure. The stone has been highly fractured and many small faults are present, but all breaks have been tightly welded. The suggested classification is grade C.

This stone occurs in the lower Moccasin marble member and has been found only in the Narrows split fault zone. It is closely associated with the Newport brown marble and can be obtained from the same opening. The bed is 4 feet thick and associated with other commercial marbles in the 120-foot zone. The estimated reserve is limited, but of sufficient quantity for moderate use.

The stone is probably best adapted for interior decorations, novelties, crafts, fixtures and other ornamental purposes.

Jet-black marble.—A jet-black marble which occurs along Little Stony Creek in Little Meadows is a very attractive stone. The color is apparently due to carbonaceous matter and some manganese. This marble is composed of very fine crystals of uniform size. The head grain shows 38 to 62 laminations to the inch, with practically no change in color. The bedding is smooth; however, a few bedding planes are rough suggesting stylolites of very small amplitude. Fractures are either conchoidal and irregular or regular, following laminae. The marble is opaque, hard, somewhat brittle, has a clear resonant tone and takes an excellent polish. The rock is resistant to weathering, but the weathered surface contains solution pits. It is highly calcareous, as shown by the chemical analyses given below. Some blocks have wide calcite seams which yield a beautiful composition of jet-black and sparkling white stone. The suggested classification is grade C.

Analyses of jet-black marble from Little Meadows, Giles County, Virginia

(R. J. Holden, Analyst)

	I	II
Insoluble	6.32	6.84
Ferric oxide and alumina	0.86	0.84
Calcium oxide	50.96	50.42
Magnesium oxide	0.60	0.72
Loss on ignition	40.73	40.67
	99.47	99.49
Computed to:		
Insoluble	6.32	6.84
Ferric oxide and alumina	0.86	0.84
Calcium carbonate	90.86	90.00
Magnesium carbonate	1.25	1.50
Undetermined and loss less carbon dioxide	0.71	0.82
	100.00	100.00

I. From property of John Hoge and Clarence Reynolds.
II. From property of J. B. Laing.

This marble occurs in the lower part of the Romney shale. Outcrops and information obtained by diamond core drilling indicate that the marble occurs in the shale as blocks ranging from a few feet to 20 feet across. Some blocks are about 7 feet and others are only 2 feet thick. The outcrops are found near the axis of a spoon-shaped structural basin, known locally as Little Meadows, which is about 2 miles northwest of Mountain Lake and east of Butt Mountain. The area is 6 to 12 miles from a railroad and at a high elevation. There is no way of estimating the potential reserve in the basin. A count made along Little Stony Creek showed that at one place 6 blocks were present in 100 square feet, or a surface ratio of marble to shale of 1:6. In another section the number of blocks per 100 square feet was 4, but the surface ratio between marble and shale was 1:3. At present the data are insufficient to make a comparison of the relative volumes. Preliminary diamond drilling has been completed, but considerable exploration by technical methods will be necessary before estimates of the quantity of material can be approximately ascertained.

Chemical analysis shows clearly that the stone is dominantly calcium carbonate. The hardness of the stone and its property of taking a very high polish either on the head or bed, practically fulfill the requirements for the technical definition of marble.

TABLE 2.—*Analyses of marbles from Giles County, Virginia*

(John H. Yoe, Analyst)

	1	2	3	4	5	6
R_2O_3	....	1.15	3.15	3.84	1.08	1.18
Al_2O_3	0.46	....	....	....	....	....
Fe_2O_3	1.28	....	....	....	....	....
$CaCO_3$	83.05	83.54	48.30	46.71	82.01	94.14
$MgCO_3$	None	5.03	45.65	41.71	None	2.13
Insoluble	14.52	10.94	5.44	9.33	17.69	2.68
	99.31	100.66	102.54	101.59	99.78	100.13

1. Light-mahogany, near Pembroke, Va.
2. Carnelian moire, Clover Hollow, Va.
3. Virginia gray, south of Ripplemead, Va.
4. Virginia gray, near Walker Creek.
5. Opalescent gray, near Walker Creek.
6. Golden-gray, near Narrows, Va.

	7	8	9	10	11
R_2O_3	3.02	4.20	6.95	1.65	2.50
Al_2O_3	....	....	....	....	....
Fe_2O_3	....	....	....	....	....
$CaCO_3$	90.25	84.07	50.27	51.26	89.30
$MgCO_3$	1.22	2.99	40.07	45.89	1.92
Insoluble	5.82	7.10	4.01	3.02	6.50
	100.31	98.36	101.30	101.82	100.22

7. Light-mahogany, near Pembroke, Va.
8. Newport brown, near Narrows, Va.
9. Amethyst, near Walker Creek.
10. Amethyst, south of Ripplemead, Va.
11. Sunset-red, near Narrows, Va.

TYPES OF QUARRY SITES

There are four structural and topographic conditions under which marble occurs in this area. The main types of quarry sites are: (1) Outlying hills containing horizontal or gently dipping beds of marble capped by a moderate overburden; (2) hills formed by approximately vertical marble beds; (3) marble beds dipping at gentle to steep angles into the flanks and ends of mountain ridges; and (4) structural basins underlain by nearly horizontal beds containing disturbed blocks of marble.

Outlying hills capped by marble.—This type of deposit offers a good quarry site to recover marble, especially if the marble zone has an overburden sufficiently deep to protect it from weathering agents. (See Pl. 7A, and Fig. 2.) Hills of this type occur near Ripplemead, Pem-

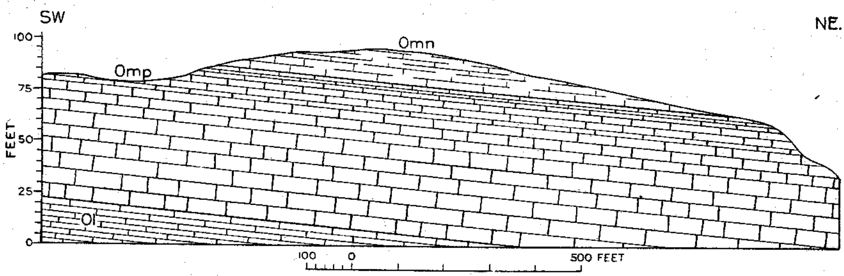


Figure 2.—Diagrammatic section of an outlying hill capped by marble, illustrating Type 1 quarry site. Ol, Lenoir limestone; Omp, lower Moccasin marble member; Omn, red Moccasin member. Dip of marble beds is 9° NE.

broke, east and southeast of Hoges Store and near Thessalia. (See Pl. 2.) There are many advantages in quarrying from this type of deposit. The marble zone is commonly above drainage so that difficulties with water are reduced to a minimum. Roads and loading platforms can be constructed at the base of the quarry, thus reducing the lift to a minimum by the use of gravity. The overburden is generally sufficient but is of minimum extent. There is room for the strippings to be piled without lifting the load higher than the quarry floor. A large area can be stripped without the interference of slumping and machinery can be used to better advantage. The grade of the marble is generally more uniform through this type of hill because of the absence of differential leaching which affects some other types of site. Where the outlying hills do not have sufficient overburden, the upper part of the marble is of an inferior grade.

Hills of this type are limited almost entirely to the Pembroke, Angels Rest and Sugar Run marble belts.

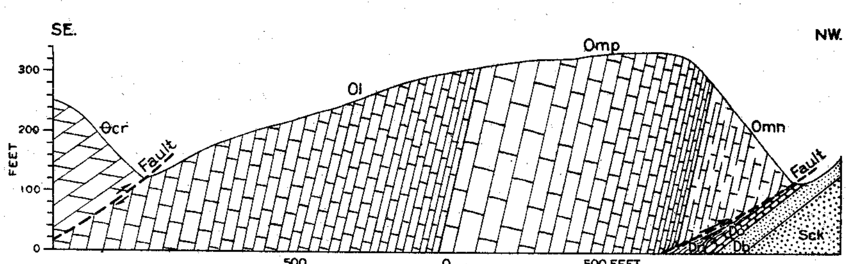


Figure 3.—Diagrammatic section of a hill northwest of Narrows, composed of vertical beds, illustrating Type 2 quarry site. Ꝋcr, Copper Ridge dolomite; Ol, Lenoir limestone; Omp, lower Moccasin marble member; Omn, red Moccasin member; Sck, Keefer sandstone member of the Clinton formation; Db, Becraft sandstone; Do, Onondaga formation; Dr, Romney shale. Dip of marble beds 87° (overturned) to SE.

Hills formed by vertical beds.—Hills of this type occur only in the split fault area west of Narrows (Pl. 2), where the marble zone has been slightly overturned. (See Pl. 7B and Fig. 3.) This type of deposit offers many advantages over the preceding, but it has many disadvantages. The advantages are as follows: (1) Accessibility of the different kinds of marble without disturbing other beds; (2) little or no overburden to be moved; (3) development of the quarry from the side of the hill and along the strike of the beds; (4) disposition of waste material from the base of the quarry; (5) ease of building roadways on grade into the quarry; and (6) aid of gravity in operation of the quarry. The disadvantages are: (1) Irregular and deep weathering from the top downward; (2) changes in the quality of the stone below the surface due to leaching; and (3) need of lateral-cutting instead of vertical-cutting mechanical devices.

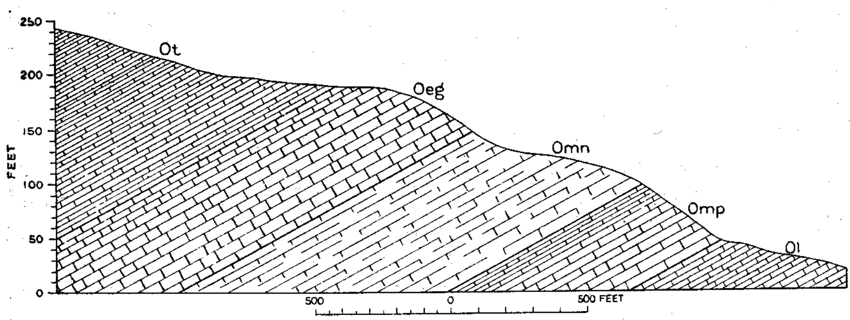
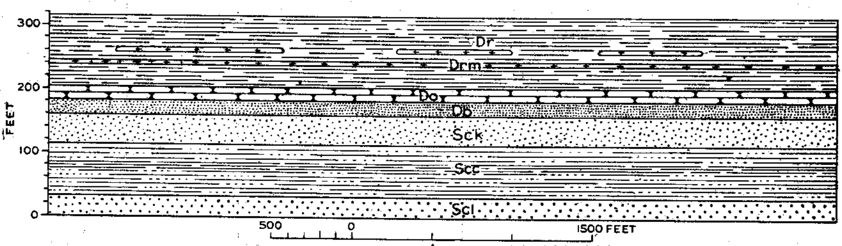


Figure 4.—Diagrammatic section of beds dipping into a ridge, illustrating Type 3 quarry site. Ol, Lenoir limestone; Omp, lower Moccasin marble member; Omn, red Moccasin member; Oeg, Eggleston limestone; Ot, Trenton limestone. Dip of marble beds is 28°.

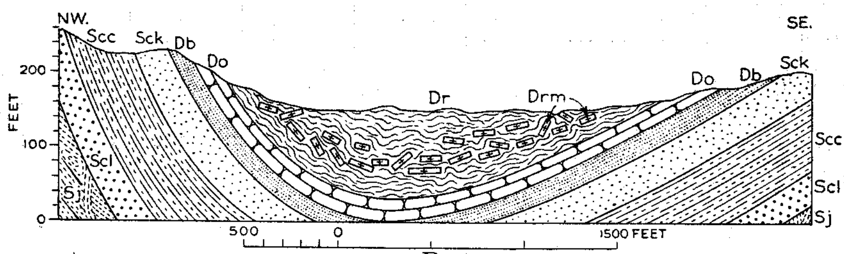
Beds dipping into ridges.—Although this type of quarry site is the most extensive in the area, it offers fewer desirable features for recovery of marble than any other type of deposit. (See Fig. 4.) There is no other type of quarry site where the marble is of more uniform grade and color, where there is less alteration of the product, and where the quality of the stone is better. The cost of quarrying is, however, almost prohibitive unless tunnels are used and the stone is cut underground and recovered by the room and pillar method. Quarrying would follow the strike of the beds. By tunneling, the advantage would be the recovery of the higher-grade stone, a continuous working period throughout the year, and freedom from the removal of waste material and overburden. Disadvantages which would have to be considered are the danger of roof falls, the expense of artificial light and ventilation, and the handling of additional material.

This type of quarry site is found along Clover Hollow, Salt Pond, Butt, Wolf Creek, Angels Rest, Pearis, Sugar Run, and Peters mountains and the northwest flank of East River Mountain. (See Pl. 2.)

Beds in a structural basin.—Little Meadows, about 2 miles northwest of Mountain Lake, is a structural basin. The rocks forming the rim of the basin dip toward the center and it is assumed that they become approximately horizontal in the bottom of the basin. (See Fig. 5.) Quarries located in such a basin would have many disadvantages. Conditions would not warrant development unless the product obtained were of a special variety, limited in quantity elsewhere, and of a grade such as to command a high price.



A



B

Figure 5.—Diagrammatic section of Little Meadows Basin, showing the occurrence of marble in Romney shale and illustrating Type 4 quarry site.
A, Formations before deformation.
B, Present position of formations. Sj, Juniata formation; Scl, Clinch sandstone; Scc, Cacapon sandstone and shale member of the Clinton formation; Sck, Keefer sandstone member of the Clinton formation; Db, Becraft sandstone; Do, Onondaga formation; Drm, marble bed and lenses; Dr, Romney shale. Dip of marble beds, on northwest side, 67° SE.; on southeast side, 78° NW.

SELECTED AREAS FOR PROSPECTING

Certain areas for prospecting have been selected. (See Table 3.) Other areas may prove to be of greater value than those selected, a possibility which should not be overlooked when a more thorough investigation is made.

TABLE 3.—*Selected areas in Giles County, Virginia, showing the type and conditions of occurrence of marble*

No.[a]	Locality	Kinds of Marble	Condition of Marble	Type of Quarry Site	Distance from Railroad (Miles)
1	New River-Walker Creek[b]	C, D, I	Excellent	1	0
2	Hoges Store[c]	J	Good	1	2
	West end of Johns Creek Mountain	E, F, G	Excellent	1	3
4	East of Ripplemead[c]	A, B, E, F, G	Excellent	1	2
5	West end of Butt Mountain	E, F, G	Excellent	3	3
6	Doe Mountain	F, G	Good	3	2
7	Near Curve[b]	J	Good	1	0
8	Angels Rest	E, F, G	Good	1, 3	2–5
9	Sugar Run	F, G	Fair	3	6–10
10	Sugar Run Mountain	E, F, G	Excellent	1	10
11	South of Narrows	F, G	Good	1, 3	2
12	Wolf Creek Mountain	E, F, G	Good	3	2–12
13	Narrows split fault	A, B, E, G, H, K	Excellent	2	0–12
14	East River Mountain	E, F, G, J	Good	3	0–4
15	Peters Mountain	F, G	Good	3	0–2
16	Near Kire	L	Poor	4	0
17	Little Meadows[d]	L	Good	4	7
18	Sinking Creek isoclinal fold	E, F, G	Poor	1, 3	0–12
19	Clover Hollow	E, F, G	Good	3	6–12

Kinds of marble: A, carnelian moire; B, gray moire; C, Virginia gray; D, opalescent gray; E, imperial champagne-tan; F, golden-gray; G, light-mahogany; H, Newport brown; I, amethyst; J, palette; K, sunset-red; and L, jet-black.

Types of quarry sites: (1) Outlying hills capped by marble; (2) hills formed by vertical beds; (3) beds dipping into ridges; and (4) beds in a structural basin.

a Numbers shown on Plate 2.
b Old quarry.
c Prospect.
d Core drilled.

USES

The uses of marble are varied and extensive. The principal uses are for building stones, crafts, monuments and statuary.

Building stone.—For exterior facing purposes, marble must have the qualities to withstand weathering agents and to maintain an attractive appearance. Marble for building purposes should be close grained, uniform, strong, non-abrasive, reasonably non-absorptive, and free from chemical compounds which oxidize readily and stain the stone. It is not necessary for the color to be entirely uniform, because in modern buildings facing blocks are mixed, thus blending colors. For interior decoration, appearance is the first consideration. Marbles suitable for polished copings are desirable. For interior purposes marbles are widely used for floors, steps,

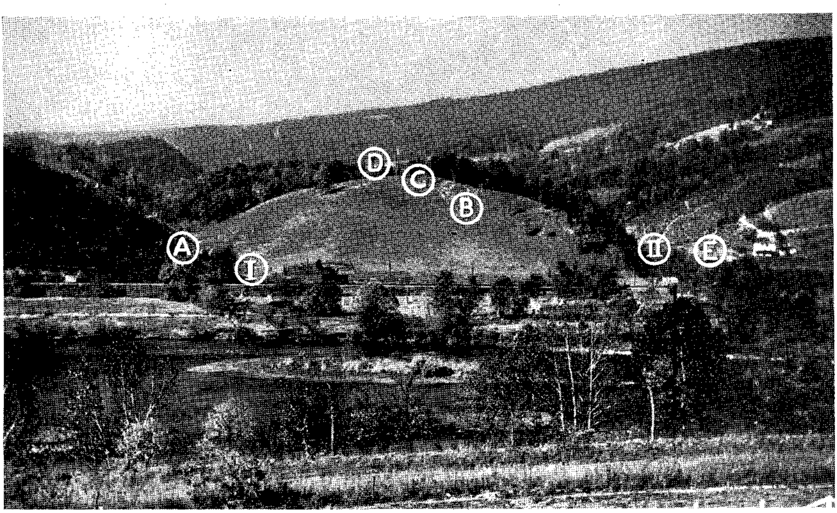
A. Beds of carnelian moire marble near Pembroke.

B. Marble pier in Norfolk and Western Railway bridge over Walker Creek.

A. Beds of carnelian moire marble near Pembroke.

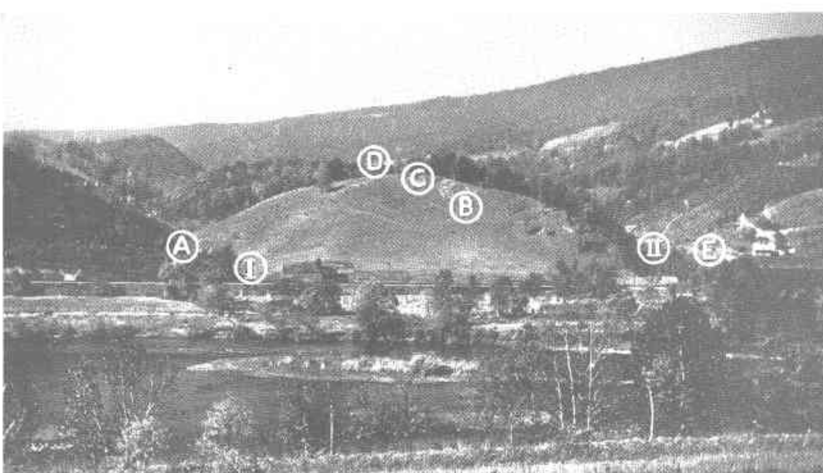
B. Marble pier in Norfolk and Western Railway bridge over Walker Creek.

A. Outlying hill near Pembroke, capped by upper red Moccasin limestone.



B. Hill of marble near Narrows, bounded by the Narrows split fault (I, II). A, Copper Ridge dolomite; B, Lenoir limestone; C, lower Moccasin marble member; D, upper red Moccasin member; E, Becraft sandstone.

A. Outlying hill near Pembroke, capped by upper red Moccasin limestone.



B. Hill of marble near Narrows, bounded by the Narrows split fault (I, II). A, Copper Ridge dolomite; B, Lenoir limestone; C, lower Moccasin marble member; D, upper red Moccasin member; E, Becraft sandstone.

baseboards, columns, balusters, wall panels, wainscoting, and pilasters. Other interior uses are lavatory fittings and sanitary work in general.

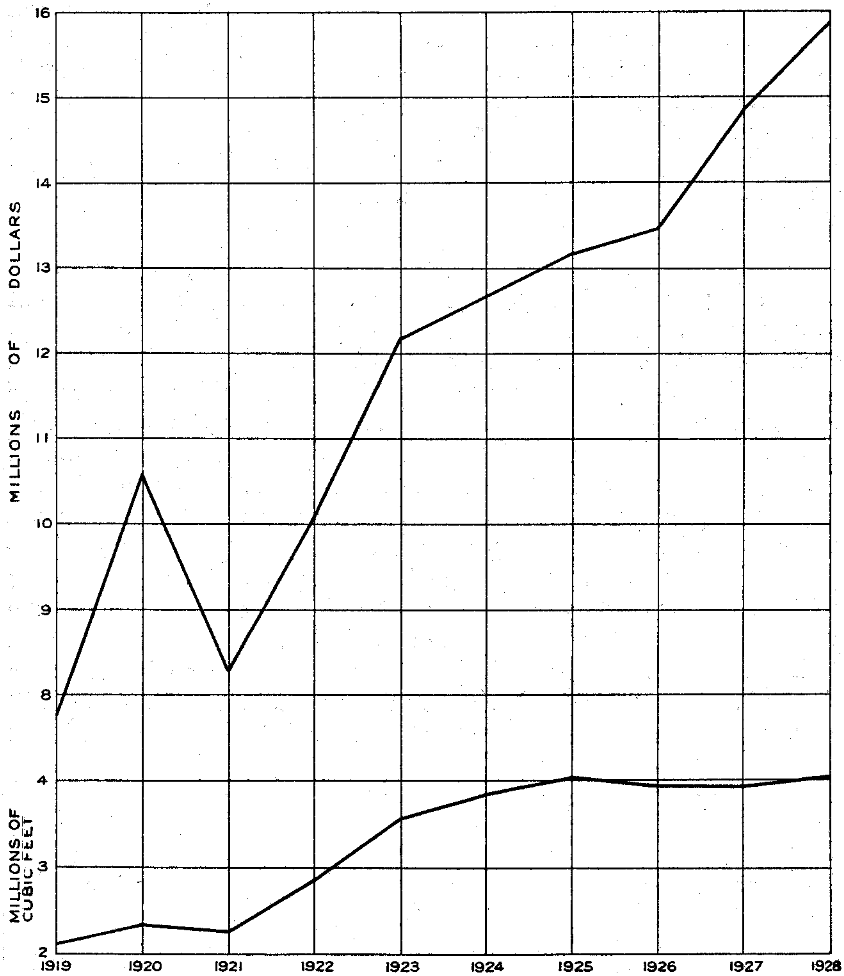


Figure 6.—Graph showing quantity and value of marble produced in the United States during the period from 1919 to 1928. (Data from Bowles and Banks, U. S. Bur. Mines Inf. Circular 6313, 1930.)

Monuments.—For monumental uses marble must not only be uniform and attractive in appearance, but must also take a good polish, withstand all of the weathering agents and not stain.

Statuary.—Marble suitable for statuary is probably the most valuable. The present requirements are that the stone be pure white, uniformly fine grained, workable, and somewhat translucent.

Crafts.—Many of the highly decorative marbles are suitable for table tops, lamp shades and bases, ink-wells, gear-shift balls, and other novelties.

Other uses.—Broken or waste marble is used for terrazzo, stucco, riprap, lime manufacture, flux, marble dust, roofing granules, and in the chemical industry. Desirable marble cubes are used for mosaic. One of the chief difficulties in the minor uses is to find a ready market. The development of by-product industries should broaden the operations and provide a demand for the waste material which usually accumulates in a quarry.

TRANSPORTATION

Transportation is a great economic factor in the development of any natural resource and is especially important in the development of marble. Giles County has two main interstate railways, the Norfolk and Western and the Virginian, which connect the seaboard with the north-central states. The county is traversed by two main hard-surfaced highways. It has also one short branch railway line and several well-developed roads. No place in the county is more than 20 miles from a railway and few places are more than 5 miles from a good road.

The development and value of marble properties in the county will be determined to a great extent by the accessibility of the property to good transportation facilities, especially railways. With modern trucking facilities, this will not be so important a factor in the future as it has been in the past. A road can be built at a comparatively small cost from a quarry to a hard-surfaced

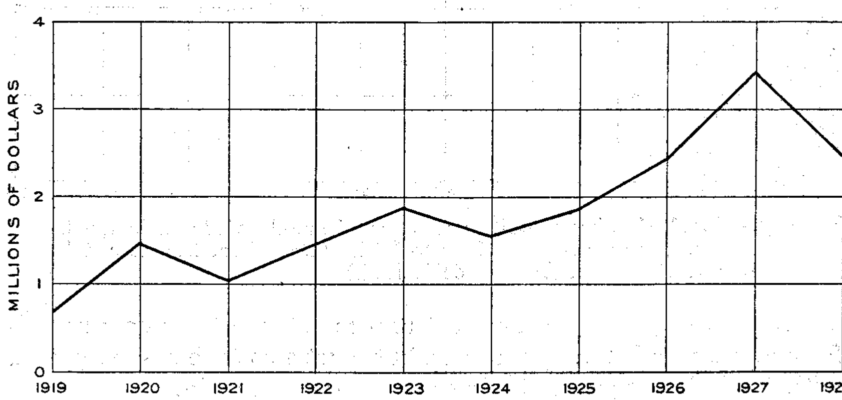


Figure 7.—Graph showing value of marble imported into the United States during the period from 1919 to 1928. (Data from Bowles and Banks, U. S. Bur. Mines Inf. Circular 6313, 1930.)

highway one or more miles distant. The stone can then be trucked to an accessible railroad siding or a mill. The cost of trucking block marble for great distances is prohibitive at the present time. Therefore, quarrying operations can best be developed along the main railroad lines.

MARKETS

Statistics for the period from 1919 to 1930, show that there has been an increase in both volume and total value of marble sold by producers in the United States during that time. The value of imported marble declined slightly in 1928. The value of the marble exported from the United States in the same interval has not declined. (See Figs. 6 and 7.)

PETROGRAPHY OF THE MARBLES

BY ARTHUR A. PEGAU

CARNELIAN MOIRE MARBLE

Megascopic character.—The hand specimen is a reddish-brown to salmon-colored rock. It has a fine-grained, dense texture, and is cut by veinlets of a relatively coarse-grained white calcite, which range in width from 0.1 to 1 centimeter. (See Pl. 1.)

Microscopic character.—The rock has an even-granular, fine-grained texture in which the average grain size is about 0.01 millimeter. It is composed predominantly of an extremely fine-grained calcite that has a smudgy appearance. Veinlets of recrystallized calcite 0.05 to 0.1 millimeter wide cut the fine-grained matrix. Quartz and feldspar, in amounts of less than 5 per cent, occur as tiny anhedral grains. Limonite and magnetite occur sparingly. Rhombs surrounded by limonite are probably of a calcium-iron or calcium-magnesium-iron carbonate.

Metamorphism is evidenced by a compacting of the grains and by a small amount of recrystallization.

GRAY MOIRE MARBLE

Megascopic character.—The hand specimen has a fine-grained, even-grained, banded texture. The banding is caused by the intercalation of reddish-brown layers with greenish-gray layers ranging from a few millimeters to a centimeter thick. The materials of both layers effervesce freely with acid.

Microscopic character.—The rock has a fine-grained, even-granular texture in which the individual grains do not average more than 0.01 millimeter in diameter. It is made up almost entirely of calcite. Small irregular grains of limonite are scattered rather uniformly through the mass and give the rock its reddish to brownish tone. Rhombs of an iron-stained carbonate, about 0.025 millimeter in diameter, occur rather sparingly. High magnifications show quartz and feldspar to be present as small irregular grains in the matrix. A number of veinlets 0.025 to 0.1 millimeter wide, which cut across the matrix, are filled with recrystallized calcite.

This rock has a texture and composition similar to the carnelian moire marble described above. The reddish tone most probably is caused by limonite stains.

VIRGINIA GRAY MARBLE

Megascopic character.—This hand specimen is a gray, fine-grained rock that contains criss-cross fractures filled with white crystalline calcite. The veinlets are especially prominent on the weathered surface, as they seem to resist decomposition more than the other material. (See Pl. 5.)

Microscopic character.—The fine-grained texture and the mineral content, chiefly calcite and dolomite, are similar to those in the two varieties of marble described above. The fine-grained mass is considerably fractured and the crevices are filled with crystallized white calcite which shows twinning. These veinlets range from 0.1 millimeter to 3 millimeters in width, a few being only 0.025 millimeter wide. The veinlets cross each other. There are present spear-shaped and hook-shaped bodies filled with calcite, which are strongly suggestive of fossil remains of sponges. The fine-grained, massive, compact calcite has a smudgy appearance due to very fine-grained inclusions of a black material, which makes the rock gray to dark gray. The rock contains also from 5 to 10 per cent quartz and feldspar. Some of the quartz grains show distinct double terminations and the feldspar grains show polysynthetic twinning. (See Pl. 9B.)

OPALESCENT GRAY MARBLE

Megascopic character.—This rock is fine grained and is cut by veinlets filled with white crystalline calcite. It resembles the Virginia gray marble in color, grain, and texture.

Microscopic character.—This rock is made up chiefly of a very fine-grained calcite that has a smudgy appearance. It contains a small amount of quartz and feldspar, with limonite and magnetite occurring sparingly. The fine-grained mass is cut by veinlets from 0.1 to 1 millimeter wide, which contain a mid-band of an iron-stained sericite. On either side of this band calcite is developed with the cleavage planes at right angles to the walls of the vein. The micaceous material is commonly in the middle of the vein but is sometimes nearer the sides. It appears to be earlier than the calcite. Some of the veins are straight and others have a crenulate form. Areas of recrystallized calcite, as much as 1 millimeter in diameter, are scattered through the fine-grained mass. Calcitized spicules of sponges are occasionally observed, as well as small ovals of fine-grained calcite probably resulting from algae.

IMPERIAL CHAMPAGNE-TAN MARBLE

Megascopic character.—The hand specimen is a dense fine-grained, light-gray rock that has irregular dark-gray crinkly lines through it. It also contains inclusions of white recrystallized calcite 1 centimeter in diameter. (See Pl. 5.)

Microscopic character.—The rock has an even-granular, fine-grained texture. The grains average 0.1 millimeter in diameter, which is distinctly larger than those in the marbles described above. The predominant mineral is calcite. The rock contains some areas about 0.5 millimeter in diameter, in which quartz and feldspar in amounts up to 10 per cent are mixed with calcite. The feldspar shows polysynthetic twinning. Anhedral crystals of quartz, 0.1 millimeter in diameter, occur scattered irregularly through the rock. Very little limonite was observed. (See Pl. 8A.)

Metamorphism is evidenced only by a compacting of the mass.

GOLDEN-GRAY MARBLE

Megascopic character.—This rock is fine grained, massive, and of variable color. A brownish-red color predominates.

Microscopic character.—The rock has a texture and grain size similar to that of the imperial champagne-tan marble. A rather reddish limonite or hematite is distributed irregularly through the rock as films around the calcite grains and as bands 0.1 millimeter wide. An occasional grain of quartz and feldspar also is present. (See Pl. 8B.)

LIGHT-MAHOGANY MARBLE

Megascopic character.—This is a dense, fine-grained rock. It contains pink, irregularly elongated areas about 0.5 centimeter wide and 1 centimeter long, in a gray matrix. (See Pl. 1.)

Microscopic character.—The matrix, as seen under the microscope, is made up of a very fine-grained calcite that has an average grain size of 0.01 millimeter. Included in this matrix is a lenticular body 1.5 by 4 millimeters, composed chiefly of calcite grains 0.1 millimeter in diameter. These grains are enclosed by a film of limonite 0.05 millimeter wide. The rock contains a small amount of quartz and feldspar. The pink color of the lenticles is due to the limonite film on the calcite grains. Grains of recrystallized calcite, 0.05 by 0.1 millimeter, occur sparingly in both the lenticles and in the matrix. They usually show twinning. Narrow fractures cut both the matrix and the lenticles.

Metamorphism is evidenced by a compacting of the material and a small amount of recrystallization.

NEWPORT BROWN MARBLE

Megascopic character.—This is a fine-grained, dense, pink rock. It is cut by numerous branching fissures 0.5 millimeter to 5 millimeters in width that are filled with a reddish-brown iron oxide (limonite or hematite). Some of the larger fractures are filled with gray calcite. (See Pl. 1.)

Microscopic character.—The predominant mineral, as seen under the microscope, is calcite. Quartz and feldspar together make up not more than 5 per cent of the mass. One thin section shows an area 3 by 5 millimeters, in which are present numerous iron-stained rhombs that make up about one-third of the mass. They measure 0.05 to 0.1 millimeter in diameter and have indices higher than those of calcite. These rhombs appear to be of an iron carbonate rather than a manganese carbonate, as suggested by the alteration product.

Numerous cracks not more than 0.1 millimeter wide are commonly filled with a red ferruginous material. Wider veinlets, which cut across the smaller ones, are filled with crystallized calcite. Some of the earlier veinlets are offset by the later ones. (See Pl. 9A.)

The amount of recrystallization is very slight and the general appearance of the rock is that of a compacted calcareous sediment.

AMETHYST MARBLE

Megascopic character.—This is a fine-grained, dense, dark-gray to black rock cut by veinlets of white recrystallized calcite. (See Pl. 5.)

Microscopic character.—The rock has a fine-grained texture, the average grain size being 0.01 millimeter. The chief minerals are calcite and dolomite which occur as unoriented anhedral grains, although many of them form nearly circular bodies from 0.1 to 0.2 millimeter in diameter. This texture may have resulted from algal remains. All of the grains, but less so in the round bodies, are stained by a brown to black material which appears to be a hydrous manganese or manganese-iron oxide. This material also occurs in the interstices between the calcite grains and is no doubt responsible for the dark color of the rock. Quartz and feldspar occur only sparingly. A few veinlets, 0.1 millimeter in width and filled with crystalline calcite, cut the mass.

PALETTE MARBLE

Microscopic character.—The texture is very fine grained, the average grain size being about 0.01 millimeter. The chief mineral is calcite. In the dense matrix occur occasional recrystallized grains of calcite 0.5 by 1 millimeter and fossil fragments. There occur also branching veinlets filled with a fine-grained, iron-stained material that was not positively identified.

The fossil fragments are of several kinds of bryozoans and molluscs. One bryozoan, replaced by calcite, occupies an area 3 by 5 millimeters and is composed of plates or cells. Smaller fragments and hook-shaped masses also occur. There occur also branching veinlets filled with a fine-grained, iron-stained material that was not positively identified. (See Pl. 5.)

SUNSET-RED MARBLE

Microscopic character.—This rock, as seen in thin section, shows two distinct textures: One results from a grain size ranging from 0.01 to 0.05 millimeter in diameter; the other results from a grain size ranging from 0.1 millimeter to 2 millimeters in diameter, with an average of 1 millimeter. (See Pl. 1.)

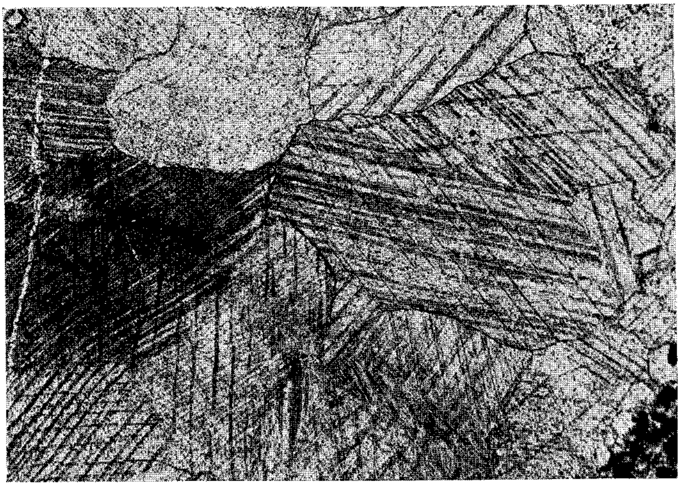
The finer material occupies about one-half of the section and is made up chiefly of calcite, with a small amount of quartz and feldspar and an occasional grain of epidote, titanite, and sericite. Irregular veinlets of limonite cut the mass.

The coarser grained material is made up chiefly of a recrystallized calcite that shows frequent twinning and some distortion. This portion of the section contains irregular thin bands and bodies, 2 millimeters wide, filled with a mixture of quartz and feldspar. This material appears to be later than the calcite.

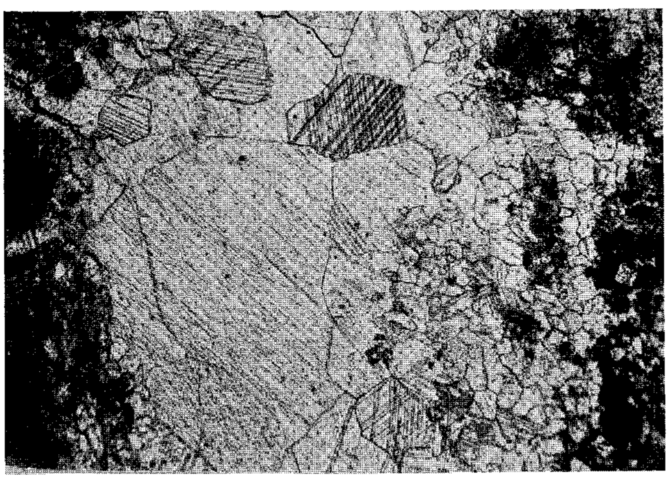
SUMMARY

The rocks examined are dense, fine grained, and of variable color. They are pink, reddish-brown, salmon-colored, gray, and black. Many of the specimens are fractured, the crevices generally being filled with white recrystallized calcite. Some contain a red to brownish-red ferruginous oxide. A few contain reddish lenticles that give the rock a mottled apearance. Some of them show a slight banding due to layers of differently colored calcite. The usual texture of the thin sections is fine grained, in which the average grain size is about 0.01 millimeter. The average grain size in the imperial champagne-tan and the golden-gray marbles is 0.1 millimeter. The grain size of a portion of the sunset-red marble ranges from 0.1 millimeter to 2 millimeters. Recrystallized grains of calcite are common but never make up a considerable part of the mass, except in the sunset-red marble. Most of these grains are twinned.

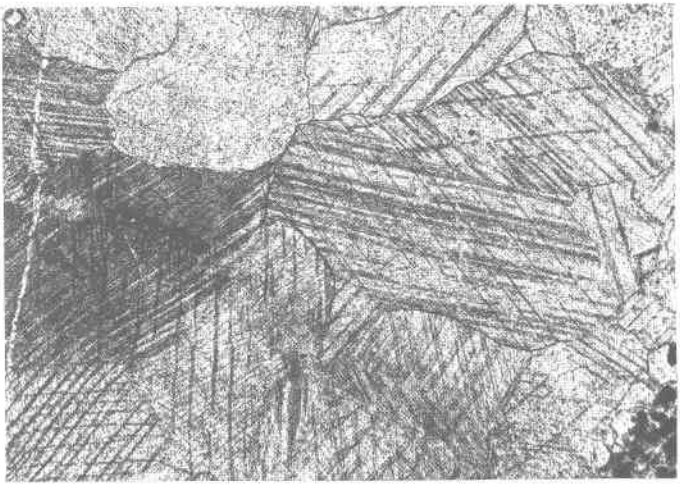
The predominant mineral is calcite. Most of the specimens



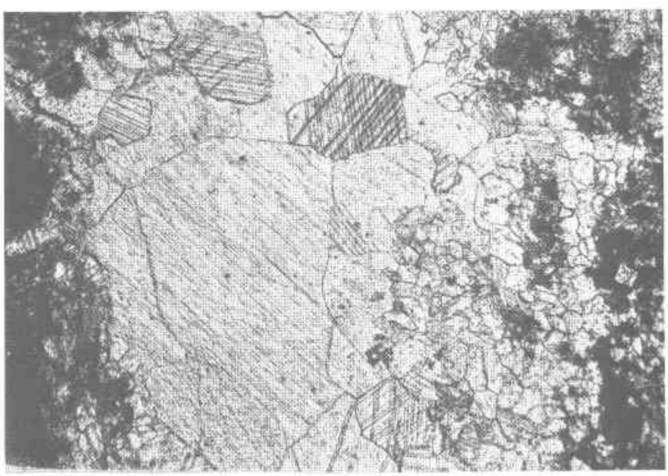
A. Photomicrograph of imperial champagne-tan marble from the lower Moccasin marble member near Pembroke. Shows calcite grains with cleavage and twinning and alteration from a fine groundmass. X 50.



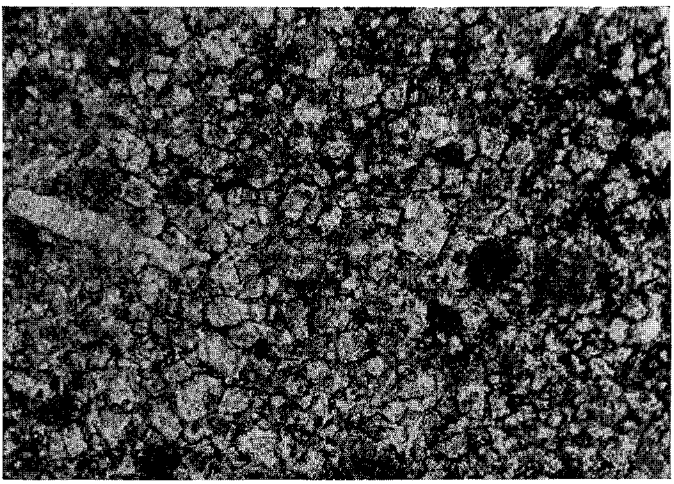
B. Photomicrograph of golden-gray marble from the lower Moccasin marble member near Pearisburg. Shows calcite grains with cleavage and twinning. Pyrite shown by opaque spots. X 50.



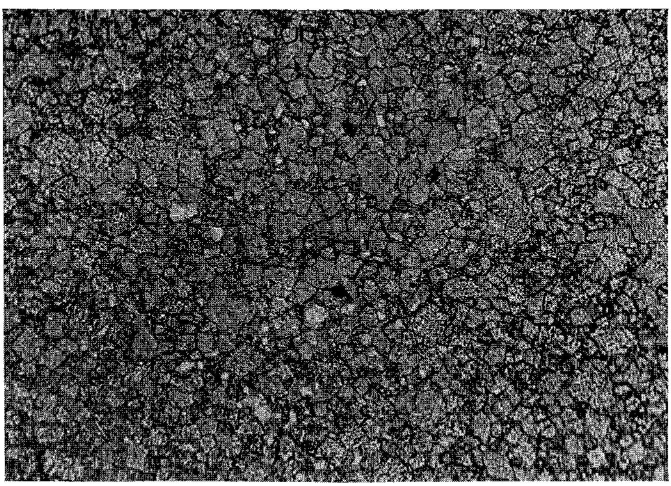
A. Photomicrograph of imperial champagne-tan marble from the lower Moccasin marble member near Pembroke. Shows calcite grains with cleavage and twinning and alteration from a fine groundmass. X 50.



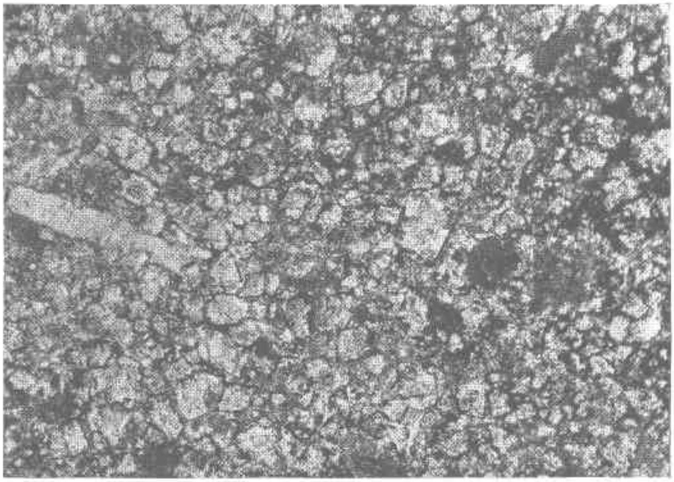
B. Photomicrograph of golden-gray marble from the lower Moccasin marble member near Pearisburg. Shows calcite grains with cleavage and twinning. Pyrite shown by opaque spots. X 50.



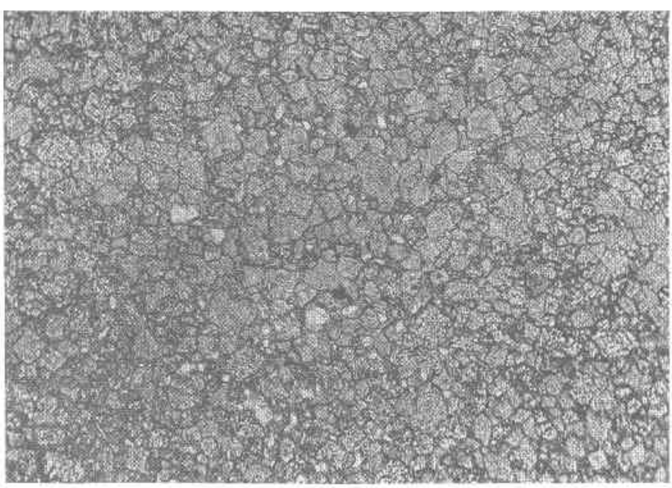
A. Photomicrograph of Newport brown marble from the lower Moccasin marble member near Narrows. The fine-grained groundmass contains some calcite grains with cleavage and twinning. Opaque specks are carbon and iron. X 50.



B. Photomicrograph of Virginia gray marble from the Nittany dolomite near Ripplemead. Shows fine, even grains of calcite and black carbon specks between the grains. X 50.



A. Photomicrograph of Newport brown marble from the lower Moccasin marble member near Narrows. The fine-grained groundmass contains some calcite grains with cleavage and twinning. Opaque specks are carbon and iron. X 50.



B. Photomicrograph of Virginia gray marble from the Nittany dolomite near Ripplemead. Shows fine, even grains of calcite and black carbon specks between the grains. X 50.

contain a small amount of feldspar (usually polysynthetically twinned and where determinable is almost andesine) and quartz, together not more than 5 per cent of the total mass. Limonite, or hematite, is present in many of the slides and gives the marble the reddish and brownish tones. The amethyst marble is colored by a fine-grained black to brownish material that appears to be manganese. Some of the marbles contain rhombs of a carbonate that are almost invariably iron-stained and have higher indices of refraction than calcite and are most probably of a ferruginous carbonate. Small amounts of other minerals are occasionally present, such as magnetite, sericite, and epidote.

Veinlets, generally filled with crystalline calcite, are present in most of these marbles. They range in width from less than 0.01 millimeter to several millimeters. The calcite veins in the opalescent gray marble contain a mid-band of a micaceous material. Some of the smaller veinlets are filled with a red ferruginous material.

Metamorphism is evidenced chiefly by compaction of the material and the development of numerous fractures and some recrystallization.

TECHNOLOGY

TRADE CLASSIFICATION

The National Association of Marble Dealers has standardized the classification of different kinds of marble according to trade usage and demand. The following is an outline of the classification by groups.

Group A.—Sound marbles and stones which require no "sticking," "waxing," or "filling" and which possess characteristically uniform and favorable working qualities.

Group B.—Marbles and stones similar in character to the preceding group, but having somewhat less favorable working qualities; occasional natural faults; limited amount of "waxing" and "sticking" necessary.

Group C.—Marbles of uncertain variations in working qualities; geological flaws, voids, veins and lines of separation common, standard shop practice to repair by "sticking," "waxing" and "filling"; "liners" and other forms of reinforcement freely employed when necessary.

Group D.—Marbles and stones similar to the preceding group and subject to the same methods of finishing and manufacture, but embracing those materials which contain a large proportion of natural faults, and maximum variations in working qualities. This group comprises many of the highly colored marbles prized for their decorative qualities.

It should be carefully noted that these four groups have no reference to comparative merit or value. With proper methods of manufacture, all materials, irrespective of their classification, are regarded as of substantially equal permanence, durability, or utility, with respect to the particular purpose for which they are used. The classification merely defines what shall be proper and acceptable in each instance, as based on trade usage.

PROSPECTING

Thorough prospecting should always precede development. Development should not be attempted unless a careful or detailed exploration has proved that there is sufficient sound marble of suitable color and quality available to warrant the large expenditure of money necessary for opening a commercial quarry and purchasing machinery for working it. Even though the outcrops show the geologic relations, the property should be core drilled in order to ascertain the conditions below the weathered surface and the quality of the stone under an overburden. The facts to be determined by core drilling are: Extent of workable deposit; thickness of desirable beds; soundness, color, range, uniformity, texture, and general appearance of the stone; and depth and nature of the overburden. The more information a property owner can obtain about the rocks and conditions below the surface, the better can he enter into a satisfactory contract for the development of his deposit. As most marble deposits can be worked profitably on a large scale only, it is highly desirable to obtain the information necessary for development before attempts are made to place the stone on the market.

It is thought that those who contemplate the exploration of marble properties for the purpose of commercial development will find it helpful to read the articles listed in the Bibliography under "Technology of Marble Quarrying."

Leases.—The greatest profit accruing from any quarry operation is where the property owner can open, develop, and operate his own quarry. This can rarely be done because of the overhead cost of exploration, development and operating. The operators are usually companies organized with an adequate capital and the property is leased from the owner.

There are many kinds of leases. Any agreement between the owner and operator, giving the operator the exclusive right to quarry and remove the product from the land, constitutes a lease, providing the operator pays a royalty for the product. In other words, the privilege of the lease is given in exchange for the royalty. There are certain fundamental privileges and considerations which should be embodied in any lease.[14]

QUARRY OPERATIONS

The two general types of quarries are open-pit and underground. In the open-pit quarry the overburden is stripped from the marble. If the area is large and the surficial overburden is thick, or if the overburden is a friable stone, power shovels may be used to advantage. If the overburden is thin and the rock surface is nearly level, stripping may be done by scrapers. The stripped surface of a quarry site should be much larger than the pit, so as to prevent undesirable slumping into the pit. Hydraulic stripping may be employed successfully in some areas, but an adequate water supply and good drainage are necessary for its use. In the underground method of quarrying, by use of tunnels, it is essential to have a stable roof. The tunnels are usually driven along the

[14] Information on leases, royalties and contract forms may be obtained from several standard publications or from the Virginia Geological Survey.

strike of the beds. An opening is made the full width of the marble beds and of sufficient height to operate the necessary machinery for cutting and removing the marble blocks.[15]

With either type of quarry, a quarry plan is essential for profitable operation. The chief factors to be considered in developing a quarry plan are the dip of the beds and uniformity of the product in the beds. Bowles[16] states that "if the desirable beds are thin and dip at steep angles, shallow quarries must be worked along the outcrop, or underground mining must be employed. However, thick beds dipping at steep angles may be worked in deep, open pits, as at Knoxville, Tenn. If the strata are flat and the desirable bed is near the surface, a wide shallow quarry results."

MARKETING

There are five groups of agencies for handling or marketing marble. Some quarry, others manufacture, others sell, and still others quarry, process and sell marble. They are: (1) The wholesale dealer, who buys and sells marble blocks and sawed slabs to the trade; (2) the manufacturer, who owns no quarry but who buys, finishes and sells rough blocks of marble or sawed stock, and who usually sets the stone in place in interior work; (3) the marble dealer, who has neither mill nor quarry but who buys finished marble and sells it to customers; (4) the producer, who has quarries only and sells blocks directly to the wholesaler or manufacturer; and (5) the manufacturing producer, who owns his own quarries and plants and who engages in any and all the activities of the trade.

Due to lower freight rates and reduced price of handling, marble is generally shipped in blocks and finished or milled near the point of destination. Thus, large manufacturing plants have been established in many places.

Marble in blocks and in sawed slabs more than 2 inches thick is sold on the market by the cubic foot. If less than 2 inches thick the stone is sold by the square foot. A commercial block must be at least 5 or 6 feet long, 3 feet wide, and 2 feet thick. A standard block is 7 x 5 x 4 feet. Measurements should be taken on the inner rim of the drill hole, and the block should be trimmed before shipping.

Marble should be classified before selling. Stone that is rare and beautiful commands a high price but has a limited market.

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[15] Bowles, Oliver, The technology of marble quarrying: U. S. Bur. Mines Bull. 106, pp. 39-94, 1916; Marble quarrying industry in Tennessee, *in* Marble deposits of east Tennessee: Tennessee Div. Geol. Bull. 28, pp. 163-264, 1924.

[16] Bowles, Oliver, and Banks, D. M., Marble: U. S. Bureau Mines Inf. Circ. 6313, p. 9, July, 1930.

Marbles which can be obtained in quantity and have good tone, texture, and finish bring a fair price but have a wide market. Prices range from $1.50 to $7.00 or more a cubic foot. American marbles for exterior building purposes average about $2.00 a cubic foot.

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