North Carolina
Department of Conservation and Development
William P. Saunders, *Director*

Division of Mineral Resources
Jasper L. Stuckey, *State Geologist*

Bulletin Number 74

CRYSTALLINE LIMESTONES OF THE PIEDMONT AND MOUNTAIN REGIONS OF NORTH CAROLINA

By

Stephen G. Conrad

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Letter of Transmittal

Raleigh, North Carolina
March 2, 1960

To His Excellency, HONORABLE LUTHER H. HODGES
Governor of North Carolina

SIR:

I have the honor to submit herewith manuscript for publication as Bulletin 74, "Crystalline Limestones of the Piedmont and Mountain Regions of North Carolina", by Stephen G. Conrad.

Limestone is the most widely used of all industrial rocks and it is essential in more industries than any other metallic or nonmetallic mineral substance. It is believed that this report will be of value to those interested in the limestone deposits of the Piedmont and Mountain Regions of North Carolina.

Respectfully submitted,

WILLIAM P. SAUNDERS,
Director

Contents

Illustrations

CRYSTALLINE LIMESTONES OF THE PIEDMONT AND MOUNTAIN REGIONS OF NORTH CAROLINA

By

STEPHEN G. CONRAD

ABSTRACT

Crystalline limestones, or marbles, are found in 18 counties in the Central and Western Piedmont and Mountain Regions of North Carolina. They occur as far east as Stokes and Forsyth Counties, and as far west and south as Cherokee County. The bodies of marble in part form elongated areas of considerable size and in part linear groups and isolated lenses of comparatively small size. These areas include several different geologic formations which range in age from Precambrian, the oldest recognized age in the earth's history, to Lower Paleozoic (?).

The most extensive marble formation is the Murphy marble. It occurs in a narrow belt of metamorphosed sedimentary rocks that begins just southwest of the Little Tennessee River in the southwest corner of the State and continues southwest across parts of Swain, Graham, Macon, Clay and Cherokee Counties. The thickness of the marble formation varies considerably along strike, but its maximum thickness is estimated to be about 500 feet. Both dolomitic and calcitic marble are present and the only producer of dimension marble in the State operates a quarry in the Murphy marble in Cherokee County.

In Madison County four types of lime-bearing rocks are present. These are: (1) small lenses of coarse crystalline marble associated with Precambrian (?) gneisses and schists, (2) lenticular limestone beds in the Sandsuck formation, (3) the Shady dolomite, and (4) the Honaker limestone. The Shady dolomite was extensively quarried northwest of Hot Springs, but the quarries have been inactive since about 1930.

Small, apparently isolated lenses of white, coarse-grained marble, associated with Precambrian (?) gneisses and schists occur in Macon, Jackson, Ashe, Mitchell and Cleveland Counties.

The Brevard belt is a narrow belt of metamorphosed sedimentary rocks which enters North Carolina in Transylvania County and passes northeastward through Henderson and Buncombe Counties. White to bluish gray, dolomitic and calcitic marble is known to occur in this belt from southwest of Rosman, in Transylvania County, to northeast of Fletcher in Buncombe County.

Two types of lime-bearing rocks are present in McDowell County. The first, and only one that has been of commercial value, is an elongate area of Shady dolomite which occurs along the North Fork of the Catawba River in the northern part of the county. The other is a series of disconnected outcrops of siliceous marble that occurs along the Catawba River between Greenlee and the west end of Lake James.

The Kings Mountain belt, like the Murphy and Brevard belts, is composed of a narrow zone of steeply dipping metamorphosed sedimentary rocks. It extends from just south of Gaffney, South Carolina, northeastward almost to the Catawba River in North Carolina. The Gaffney marble occurs as discontinuous beds, or lenses, for the entire length of the belt. It ranges in thickness from less than 50 feet to about 800 feet and is predominently a fine grained, dark bluish gray to white, schistose marble. The Superior Stone Company operates the largest crushed limestone quarry in the State at Kings Mountain.

In Stokes, Yadkin and Forsyth Counties two types of marble are present. One is a white to dark blue, fine grained, high calcium to dolomitic marble that is very similar to that in the Kings Mountain and Brevard belts. It occurs in a series of outcrops that begin south of Enon in Yadkin County and continues across Forsyth County through Vienna almost to the Stokes County line near Germanton. The other is predominently a whitish, coarsely crystalline marble that occurs interbedded with mica schist and quartzite. The outcrops of this marble are found in Yadkin and Stokes Counties, but do not form a conspicuous pattern as does the other type.

INTRODUCTION

The limestone resources of North Carolina can be classified into two broad groups. These are: (1) the

limestones and marls of the Coastal Plain, and (2) the crystalline limestones, or marbles, of the Piedmont and Mountain Regions.

The limestones and marls of the Coastal Plain have been described in previous publications by Emmons (1852), Watson and Laney (1906), Clark, et. al. (1912), Loughlin, Berry and Cushman (1921) and Berry (1947). All of these publications, except Berry (1947), have been out of print and unavailable for distribution for a newmber of years. In view of the information contained in the report by Berry (1947), the Coastal Plain was not included in the present study.

The limestone resources of the Piedmont and Mountain Regions were also described in the publications by Watson and Laney (1906) and Loughlin, Berry and Cushman (1921). As these reports have been out of print for a number of years, and as there has been continued interest shown in the limestone resources of the Piedmont and Mountain Regions of the State, this report has been prepared to meet this interest.

Methods of Investigation

The fieldwork for this report was carried out during the summer and fall of 1958, and intermittently during the fall and winter of 1959. An important phase of the field work was to accurately locate and describe every known occurrence of limestone in the Piedmont and Mountain Regions of the State. Many of these deposits were discovered by the early settlers of North Carolina and used by them to provide lime for local use. Most of the deposits were worked from prior to the War Between the States to as late as 1900. Many openings were small and during the years of inactivity they have filled up and are grown over by trees and undergrowth. Consequently, in most cases there is very little physical evidence of their ever having existed.

The examination of these old quarries consisted of a study of the general characteristics of the limestone and associated rocks and, where possible, representative rock specimens were collected. Strike and dip measurements were made along with observations of any other structural features present. The size and shape of the excavations were noted and information collected from local residents on the history and production of each quarry visited.

The examination of the active quarries consisted of the collection of essentially the same information that was noted at the abandoned quarries. In addition, information was secured on the methods and equipment used in quarrying, transportation facilities and equipment and methods used in crushing or cutting and finishing the stone. Information was also collected on the production, uses, and the principle market for limestone from each quarry.

Acknowledgments

This report was authorized by and conducted under the direction of Dr. J. L. Stuckey, State Geologist, who also furnished much background material and examined a number of properties with the writer.

Grateful acknowledgment is also due the owners and quarry operators who were very generous with their time and knowledge. To the owners of the land on which the abandoned quarries and kilns are located, thanks are extended for their permission to examine the properties. Local residents of the various areas visited were most helpful in directing the writer to the abandoned, and in some instances, almost forgotten quarries. On several occasions certain individuals guided the writer to remote or difficult to find localities and their assistance is much appreciated.

Mr. P. N. Sales, Chemist, North Carolina State College Minerals Research Laboratory, did the analyses on 14 selected samples. Mr. Earl C. Van Horn, Consulting Geologist, furnished valuable information in the form of chemical analyses and drill hole logs on the marbles in McDowell, Yadkin, Stokes and Forsyth Counties. Mr. W. F. Wilson of the staff of the Division of Mineral Resources, drafted most of the illustrations. The writer gratefully acknowledges their cooperation.

In order to bring all the available information together and make this report as complete as possible, free use, with proper acknowledgment has been made of a number of previous publications. Particularly helpful were those by Watson and Laney (1906), and Loughlin, Berry and Cushman (1921).

LIMESTONE

Definition

Limestone is a loosely used term that has been applied to a wide range of rocks that yield lime (CaO) when burned. However, the suitability of the rock for the manufacture of lime is not an essential characteristic. Calcium carbonate ($CaCO_3$) is the predominating componant of limestone, but magnesium carbonate ($MgCO_3$) may be present in varying amounts.

Origin

Limestone is a sedimentary rock that originated chiefly from the accumulation of calcareous shells, or

fragments of shells, or other limy remains of organisms that inhabit oceans and lakes. These deposits, supplemented by chemically precipitated calcium carbonate, accumulate for long periods of time and may eventually become quite thick. They may consist almost entirely of carbonates and in time become pure, high-grade limestones. On the other hand, during deposition they may be mixed or interbedded with varying amounts of sand, clay, iron oxide, or other detrital material and become on consolidation sandy limestone, clayey limestone, or calcareous sandstone and calcareous shale, depending upon the ratio of impurities to carbonates.

Although most limestones are formed in the above manner, important deposits have also been formed by the direct precipitation of calcium carbonate in water. Two examples of this process are lithographic limestone which is an extremely fine-grained or dense variety, and oolitic limestone which is composed of very small, rounded grains of calcium carbonate, resembling fish roe.

Physical Properties

Limestones have a hardness of less than 4 (Mohs' hardness scale) and can be easily scratched or cut by a knife. The specific gravity ranges from less than 2.0 to 2.7, and the weight varies from 110 to 170 pounds per cubic foot, depending on the porosity and the amount of impurities present. In texture they range from amorphous to coarsely crystalline. The color is determined largely by the impurities present and may range from pure white to black. When touched with a drop of dilute hydrochloric acid limestone will react with a very brisk foaming or effervescent action. This is due to the escape of carbon dioxide gas (CO_2). A less noticeable reaction can be obtained with vinegar or lemon juice.

Limestones are very soluble in the presence of slightly acid water; consequently, they tend to weather much faster than associated rocks and valleys or depressions often develop along a body of limestone. This is particularly true where the limestone is tilted and dips at a steep angle. During the processes of weathering calcium carbonate is carried away in solution and the insoluble impurities are left behind. These impurities, plus the insoluble remains of rocks that formerly overlay the limestone become concentrated and form residual soils. These soils are usually deep red or yellow clays and loams and are so colored by the oxidation of the iron minerals originally present.

Varieties

There are many varieties of limestone and they have been classified a number of ways. However, the most commonly used and widely accepted classification is based on origin and impurities that give the rock a distinctive character. Listed below are most of the commonly recognized varieties:

Siliceous or **cherty limestone.**—A limestone intimately mixed with silica, usually in the form of chert nodules or layers.

Arenaceous limestone. — Limestone containing considerable amounts of quartz sand.

Argillaceous limestone. — Limestone containing considerable amounts of clay.

Carbonaceous or **bituminous limestone.**—Limestone containing considerable organic matter.

Common compact limestone. — A fine-grained, dense, homogeneous limestone varying from light gray to almost black.

Lithographic limestone. — An exceedingly fine-grained, homogeneous, crystalline limestone. Its surface can be etched with weak acid and it was once used extensively in lithographic printing.

Oolitic limestone. — A limestone composed of small, rounded grains of calcium carbonate with a concentrically laminated structure which resembles fish roe. The name oolite was derived from a Greek word meaning "eggstone". The individual oolites often contain some object, such as a sand grain or shell fragment, that served as a nucleus around which the laminae of carbonate were deposited.

Fossiliferous limestone.—A limestone containing abundant fossil shells or other animal remains such as bones and shark teeth. In some cases the rock is composed almost entirely of the shells or hard parts of one particular kind of organism. In such cases, the limestone is named for the predominating fossils; for instance, crinoid, coral or coquina limestone.

Chalk.—A white to light gray, fine-grained, very porous limestone composed mostly of minute shells of foraminifera and plates and discs of planktonic calcareous algae in a matrix of finely crystalline calcite.

Marl.—A loose earthy material composed chiefly of calcium carbonate intermixed with varying amounts of clay and other impurities. There

are several varieties of marl and they are named according to the special substance which they contain, for instance, sandy marl. Shell marl is a whitish, earthy material composed of fragments of shells intermixed with varying amounts of clay.

Travertine.—A limestone formed by the deposition of calcium carbonate from solution at the orifices of springs. It is usually light colored, concretionary and compact. Varieties that take a good polish are called onyx marble, or Mexican onyx, and used as ornamental stone. Porous or cellular varieties are called calcareous tufa, calcareous sinter, or spring deposits. Stalactites, stalagmites and dripstone, which are deposited in limestone caves, are also forms of travertine.

Uses

Limestone is the most widely used of all industrial rocks and it is essential in more industries than any other metallic or nonmetallic mineral substance (Bowles, 1939, p. 377). This wide range of application is due to the fact that limestone has the necessary physical properties that make it suitable for practically all the uses for which any form of crushed stone may be employed. It has certain chemical properties that make it not only useful, but essential to a great many industrial processes. In addition, it is one of the most important building, or dimension stones.

Listed below are some of the main uses of limestone, based on these three major classes:

Uses as dimension stone:

- Cut stone, including ashler
- Rough building stone
- Rubble
- Flagstone

Uses based on physical properties:

- Concrete aggregate
- Road stone
- Railroad ballast
- Riprap
- Dusting coal mines
- Chalk, whiting and whiting substitutes
- Sewage filter beds
- Stucco and terrazzo
- Poultry grit
- Asphalt filler

Uses based on chemical properties:

- Cement
- Lime
- Furnace flux
- Agricultural limestone
- Alkali
- Calcium carbide
- Sugar beet refining
- Glass making
- Rubber making
- Paper making
- Fertilizer filler
- Carbon dioxide
- Mineral wool

DOLOMITE

Definition

Dolomite is a mineral composed of calcium and magnesium carbonates and expressed by the formula $CaMg(CO_3)_2$. Dolomite also refers to a carbonate rock, which in its pure state is composed of 54.3 percent calcium carbonate ($CaCO_3$) and 45.7 percent magnesium carbonate ($MgCO_3$). This can also be expressed as 30.4 percent lime (CaO), 21.9 percent magnesia (MgO) and 47.7 percent carbon dioxide (CO_2). It is possible for some of the magnesium to be replaced by manganese, ferrous iron and rarely a few other elements without modification of the crystallographic structure.

Origin

The problem of the origin of dolomite (the carbonate rock) has been one of much interest and discussion by geologists for many years. A number of theories of origin have been proposed, but it is now well established that most dolomites were formed by the replacement of limestones. When this replacement took place is still uncertain. It can take place before the sediments are buried by succeeding strata, after burial but before uplift, or after burial and uplift. It is also possible that replacement, or dolomitization, takes place at more than one stage.

For those interested in a more detailed discussion on the origin of dolomite, "Sedimentary Rocks", by F. J. Pettijohn and "Principles of Sedimentation", by W. H. Twenhofel, are recommended.

Physical Properties

Dolomite is very similar to limestone and the description of the color, texture and other physical properties given above for limestone applies equally well to dolomite. Except for the fact that dolomite is slightly harder and heavier than limestone, the two are so similar that it is almost impossible to distinguish them by visual inspection in hand specimens. However, where limestone effervesces freely in cold dilute hydrochloric acid, dolomite will effervesce only slightly or not at all. The acid has to be heated or the dolomite powdered before a strong reaction takes place.

Varieties

In the strict sense of the word only those carbonate rocks in which the ratio of calcium carbonate to magnesium carbonate is 54.3 to 45.7 should be called dolomite. Rocks in which this theoretical ratio is

present are relatively rare. However, limestones that contain varying amounts of magnesia (MgO) are not uncommon. There are all gradation between completely calcitic and completely dolomitic limestones, but rocks that contain appreciable amounts of both calcite and dolomite are less abundant than those in which either calcite or dolomite predominates.

As magnesian limestones may be considered physical mixtures of the minerals calcite and dolomite, it is possible to subdivide the various gradations from high-calcium limestone to high-magnesian limestone to dolomite by determining the ratio of calcite to dolomite present. Several such classifications have been proposed by different workers, but the one which is perhaps most widely recognized is that by Pettijohn (1949, p. 313). Briefly, his classification is as follows:

Limestone.—Contains more than 95% calcite and less than 5% dolomite.

Magnesian limestone. — Contains from 90% to 95% calcite and from 5% to 10% dolomite.

Dolomitic limestone. — Contains from 50% to 90% calcite and from 10% to 50% dolomite.

Calcitic Dolomite.—Contains from 10% to 50% calcite and from 50% to 90% dolomite.

Dolomite.—Contains less than 10% calcite and more than 90% dolomite.

Uses

In crushed and broken form dolomite and calcitic dolomite are used for practically the same purposes as limestone. These uses are based mainly on physical properties and the more important ones include concrete aggregate, road metal, riprap, railroad ballast and as a fertilizer and soil conditioner. The use of dolomite or calcitic dolomite instead of limestone for these purposes, except as a fertilizer and soil conditioner in North Carolina, is mostly a question of economics rather than one type of rock being more desirable than the other.

Although limestone and dolomite are interchangeable for a number of uses, there are some processes and products in which dolomite or calcitic dolomite is essential. The most important of which are:

High magnesium lime
Refractories (dead-burned dolomite)
Technical carbonate (basic magnesium carbonate)
Furnace flux
Glass manufacture
Source of magnesium metal

MARBLE-CRYSTALLINE LIMESTONE

Definition and Origin

Marble is a metamorphic rock that was formed by the recrystallization under heat and pressure of limestone or dolomite. It has essentially the same chemical composition as limestone or dolomite and is composed mostly of grains of calcite, dolomite or a mixture of the two. Crystalline limestone refers to a limestone that has been metamorphosed, or recrystallized, and the term is in most cases synonomous with marble.

In the building industry the term marble has a much wider application. As the facility to take a polish is the chief commercial asset, it includes all calcaceous rocks, and certan serpentine rocks which are adapted to ornamental building or monumental work. Most of the limestones and dolomites in the western half of North Carolina, in the geological sense, should be called marbles. However, owing to excessive fracturing or unattractive color, they have no commercial value as marble, but have been exploited for various uses as limestone or dolomite. Consequently, most of these deposits have been referred to by the producers as limestone. Although this is a misnomer, the term limestone is well established and will probably continue in use as a trade or commercial name, and perhaps as a field term.

Physical Properties

The hardness of pure marble is the same as calcite (3), and can be easily scratched by a knife. However, the presence of impurities such as silica or silicate minerals may increase the hardness. The normal color of pure calcite or dolomite marbles is white. Variations from the whiteness of pure marble are due to pigmentary impurities, mainly carbonaceous matter and iron oxides. These impurities produce such colors as gray, black, yellow or red. The coloration may be uniform, but it is usually present as bands or streaks.

The specific gravity of calcite is 2.7, whereas that of dolomite is 2.9. Therefore, dolomitic marbles are silghtly heavier than calcite marbles. Their weight ranges from about 165 to 180 pounds per cubic foot, depending on the porosity and composition. Unlike most metamorphic rocks, marble unless it contains a relatively high percentage of impurities, is generally massive and nonfoliated but is often badly fractured by joints. The grain size ranges from very fine (less than 0.5 mm) to very coarse (up to 0.5 inch).

Varieties

As previously stated most marbles have been formed by the recrystallization of limestone or dolomite. Based on mineral composition the resulting rock may be a calcite marble or a dolomite marble. A calcite marble may contain from 95 to almost 100 percent calcium carbonate, and a pure dolomite marble approaches the theoretical composition of dolomite, which is 54 percent calcium carbonate and 46 percent magnesium carbonate (Bowles, 1958, p. 1). It is also possible for the resulting rock to have a composition anywhere between the two extremes.

Very few marbles are either pure calcite or pure dolomite, but contain varying amounts of impurities. The impurities occur as minerals, the most common ones being quartz or some other form of free silica, hematite, limonite, graphite, mica, chlorite, tremolite, wallastonite, diopside, hornblende, tourmaline, pyrite, garnet, feldspar, epidote, serpentine and talc.

Fossiliferous marbles have been effected not at all, or only slightly in some cases, by metamorphism and recrystallization and are therefore not marble in the strict sense of the word. They are limestones that have a close enough texture to take a good polish and the fossils add to their decorative qualities. The widely used Holston marble of East Tennessee is an outstanding example.

Onyx marbles, or Mexican onyx, are chemical deposits that are formed by the precipitation of calcium carbonate from cold water solution. These deposits build-up around springs, in rifts and cracks or cavities in the rocks through which the solution flows. Pigmentary impurities such as iron and manganese oxide are often present during deposition and successive layers may have different colors. This causes a banding effect which makes a very attractive decorative stone.

Verde antique is a dark-green rock composed mostly of serpentine, a hydrous magnesium silicate. It is usually streaked or crisscrossed with white and red veinlets of calcium and magnesium carbonates. Verde antique is not related to marble in either composition or origin but is classed commercially as a marble because it takes a good polish and is a highly decorative stone.

Uses

Marble is used primarily as a building stone, both interior and exterior, monuments, statuary and novelties. For exterior use in building the endurance qualities of the marble are important, whereas, for interior use appearance and color are primary considerations. Products included in interior uses are floors, steps, baseboards, wainscotings, wall panels, balusters, columns and arches.

Because of its pure white color and uniform grain size statuary marble is the most valuable variety for monuments, as appearance and color are the primary requirements. A wide variety of marble is used for memorial stone. Onyx marble, verde antique and other ornamental types are used mainly for interior decoration as well as for novelties such as inkwells, lamp bases, ashtrays, book ends, etc.

In even the most efficient marble quarries recovery of usuable stone is usually less than 50 percent of the gross quarry output (Bowles, 1958, p. 27). This plus the further waste resulting from sawing, planning, cutting and carving in the finishing mill, creates a serious problem of waste disposal to most marble producers.

As most marble has the same chemical composition as limestone, waste marble can be used for many of the same chemical and industrial processes as limestone. In crushed and broken form, waste marble is used for terrazzo flooring, agricultural lime, concrete aggregate and roadstone. Waste blocks are cut to convenient thicknesses and used for the same purposes as bricks or other building stone veneers in house construction. Marble used in this manner makes a very attractive wall or fireplace and is being used in increasing quantities.

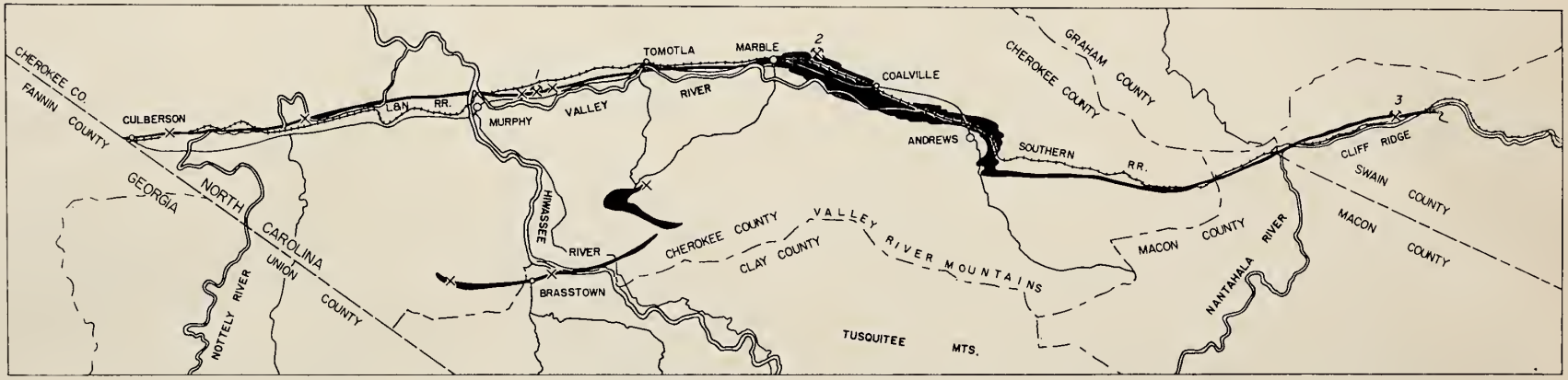
GEOGRAPHIC DISTRIBUTION OF CRYSTALLINE LIMESTONE

Crystalline limestones, or marbles, are found in 18 counties in the Central and Western Piedmont and Mountain Regions of North Carolina. They occur as far east as Stokes and Forsyth Counties, and as far west and south as Cherokee County. The bodies of marble in part form elongated areas of considerable size and in part linear groups and isolated lenses of comparatively small size.

These areas include several different geologic formations which range in age from Precambrian, the oldest recognized age in the earth's history, to Lower Paleozoic (?) (Geologic Map of North Carolina, 1958). In some regions of the country certain limestone formations can be correlated for many miles by fossil and physical evidence. Unfortunately, this is not the case in North Carolina and although some of the formations have been tentatively correlated with others, the age and history of most of the crystalline limestones and dolomites in North Carolina is unknown and not thoroughly understood at the present time. Therefore, each area and potential quarry site must be considered individually and

FIGURE 1.

GEOGRAPHIC DISTRIBUTION OF MARBLE AND DOLOMITE IN NORTH CAROLINA



1 ⚒ REGAL QUARRY - COLUMBIA MARBLE CO.
2 ⚒ MARBLE QUARRY - COLUMBIA MARBLE CO.
3 ⚒ NANTAHALA TALC & LIMESTONE CO. QUARRY
× INACTIVE QUARRIES

SCALE
0 1 2 3 4 5 MILES

FIGURE 2.

MAP SHOWING
OUTCROP AREA OF MURPHY MARBLE IN
CHEROKEE, CLAY, MACON AND SWAIN COUNTIES,
NORTH CAROLINA

for this reason the crystalline limestones and dolomites will be discussed in geographic rather than geologic order.

DESCRIPTION BY AREAS

Murphy Belt

General Statement

The Murphy belt begins just south of the Little Tennessee River in the southwest corner of North Carolina and continues southwest across parts of Swain, Graham, Macon, Clay and Cherokee Counties (Geologic Map of North Carolina, 1958). It continues into Georgia and is known to occur as far southwest as Cartersville. The belt is composed of a sequence of metasedimentary rocks which Keith (1907) mapped and named in ascending order: Tusquitee quartzite, Brasstown schist, Valleytown formation, Murphy marble, Andrews schist and Nottely quartzite. According to Keith's interpretation, the rocks in the Murphy belt represent a syncline, the central axis of which is marked by the Murphy marble and Nottely quartzite. Besides Keith, other geologists who have studied the Murphy belt in more or less detail in North Carolina and Georgia, include Watson and Laney (1906), La Forge and Phalen (1913), Loughlin, Berry and Cushman (1921), Stuckey and Fontaine (1933), Bayley (1925), Van Horn (1948) and Hurst (1955). These previous publications were freely drawn upon in the following discussion of the Murphy marble.

Murphy Marble

Distribution.—The main belt of the Murphy marble begins about 2 miles southwest of Wesser, Swain County. It is exposed in the gorge of the Nantahala River, and its tributaries, to Red Marble Gap and Topton. Southwest from Topton to Valleytown the marble occurs as a narrow sinuous band along the headwaters of the Valley River. From Valleytown through Andrews to Marble the Valley River forms a broad valley. Along this interval the dip of the marble beds flatten considerably and the marble spreads out and underlies most of the floor of the valley. From Marble southwest through Murphy and on into Georgia the marble stands nearly on edge and forms a narrow almost straight band along the Valley and Nottely rivers.

A second, but much smaller belt of the Murphy marble, extends from Peachtree down Calhoun Branch, across the Hiwassee River, and up Little Brasstown Creek to the vicinity of Martin Creek School. As stated by Van Horn (1948, p. 8) owing to recent stream deposits, upper terrace gravels and deep overburden, outcrops of the marble in this belt are limited and previous mapping appears to have been based mostly on indirect evidence.

Character.—The formation is a true marble in the geologic sense. Dolomitic marble and calcitic marble are present, but the dolomitic variety predominates. Grain size ranges from fine to coarse and the predominant colors are white and gray. However, dark gray or blue and mottled blue and white beds form a large portion of the marble. Between Red Marble Gap and Nantahala a limited amount of mottled light flesh pink to rose marble is exposed in the steep slopes above Rowlin Creek.

The Murphy marble is overlain by the Andrews schist and underlain by the Valleytown formation (Keith, 1907). Outcrops of the contacts are rare but from exposures in Nantahala River, Hiwassee River, Marble Creek and several of the quarries it can be seen that the marble passes into the overlying and underlying rocks by gradation. Upward it grades into the Andrews schist through a zone of alternating beds of marble and ottrelite schist. Van Horn (1948, p. 13) states that the gradation is broad and that nearly half of the overlying formation is calcareous. Downward it grades into the Valleytown formation through several feet of interbedding with mica schist (Keith, 1907, p. 5). Near the contacts with the overlying and underlying rocks the marble contains more of the secondary minerals and there is considerable development of micaceous minerals. The most common secondary minerals present in the marble are muscovite, biotite, talc, tremolite, actinolite, ottrelite, garnet, pyrite and quartz. Also present are lesser amounts of graphite, phlogopite, chlorite and scapolite.

The thickness of the marble is variable. At the North Carolina-Georgia state line it is less than 200 feet thick. At Kinsey it is estimated by Van Horn (1948, p. 12) to be 350 feet thick. From Marble to just northeast of Andrews the area underlain by the marble reaches its maximum width (about ½ mile). This is due in part to folding but the formation also probably reaches its maximum thickness, which is estimated by Keith (1907, p. 5) to be about 500 feet. Northeast of Andrews the marble thins rapidly and is absent in places along strike. It begins to thicken again northeast of Red Marble Gap and attains a thickness of up to 350 feet between Nantahala and Talc Mountain (Van Horn, 1948, p. 11). Beyond this point the marble again thins rapidly and disappears entirely in the vicinity of Busnell 8. Except for local variations the marble has an average strike

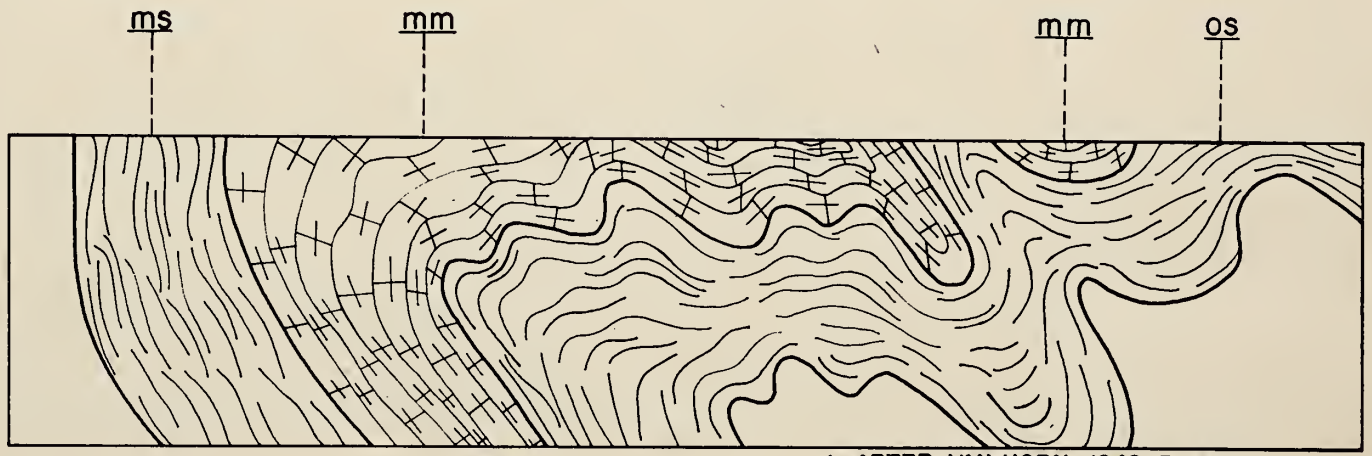


FIGURE 3. GENERALIZED GEOLOGIC SECTION OF THE MURPHY MARBLE BELT IN THE VICINITY OF MARBLE, N.C.

of N 45° E and usually dips about 50° SE. A prominent feature of the marble is the abundance of fractures or joints. Two systems of joints that strike N 20°—35° E and N 30°—70° W, prevail throughout the formation and in most places a third and sometimes a fourth system of subordinate joints are present (Watson and Laney, 1906, p. 193). The joints are spaced from an inch up to sixteen feet apart. This abundance of closely spaced joints greatly reduces the amount of marble suitable for dimension stone. However, large amounts of good material can be found in some areas.

As stated previously, the Murphy marble is composed of both dolomitic marble and calcitic marble. Enough detailed sampling has not been done to determine the ratio of dolomite to calcite throughout the formation but Keith (1907, p. 5) states that dolomitic marble occurs more frequently in the lower portion of the formation. From various analyses of the marble its composition varies from 58 to 93 percent $CaCO_3$ and from 3 to 36 percent $MgCO_3$.

Zoning in the Murphy marble.—Previous to 1948, most of the geologic studies of the Murphy marble were limited to the relatively few natural outcrops, quarries, talc mines and some exploratory core drilling done in the search for suitable quarry sites for dimension stone. Consequently, very little detail was known about the stratigraphy of the formation. As a result of a detail study by Van Horn (1948) on the talc deposits which occur in the Murphy marble a definite zoning or stratigraphic sequence has been established. This sequence was worked out from the study of some 75 drill hole cores which were drilled intermittently from the vicinity of Hewitts southwest to Kinsey. An average sequence as worked out by Van Horn (1948, p. 12) from top to bottom of the local attitude is as follows:

	feet
Fine to medium-grained white and light-gray marble containing ottrelite and phlogoplite, and having interbedded calcareous schist in the upper portion. (Transition zone)	25
White, medium to coarse-grained marble having tremolite and pyrite. (Coarse white zone)	25
Gray, coarse to medium-grained marble having tremolite and pyrite (Coarse gray zone)	30
Blue-black to bluish-gray, coarse-grained, graphitic marble, occasionally styolitic, with short (2 mm) tremolite needles and rarely grains or clusters of pyrite. (Blue zone)	40
Medium to light gray, medium-grained marble, sometimes styolitic at top, with tremolite needles up to 10 mm long. (Gray zone)	20
Light bluish-gray, fine-grained, lusterless marble, with or without tremolite, which is given a distinctive mottled appearance because of a myriad of small internal fractures. (Mottled zone)	15
White, medium to fine-grained dolomitic marble. This is the zone which is often partly silicified and which contains commercial talc deposits. (Talc or white zone)	45
Mixed, sometimes banded, gray and white, medium to coarse-grained marble which contains thin beds of pink marble and accessory pyrite, phlogopite, actinolite, quartz, tremolite, muscovite, chlorite and scapolite. (Mixed zone)	25
Light and dark gray, banded, argillaceous marble, often jointed and brecciated, with accessory biotite, chlorite and muscovite and small specks of talc. (Slaty zone)	25
Medium to fine-grained marble, having intermittent zones of white, pink and gray color, nearly all of which is characterized by the presence of actinolite clusters and pyrite, and which has considerable phlogopite in the lower portions. Sand grains, secondary quartz and small scales of talc occur at random. (Actinolite zone)	85
Dark micaceous marble and thin slate and schist laminae, having pyrite, chlorite, biotite and muscovite. (Transition zone)	20

As stated above, this is an average section where the formation exceeds 150 feet in thickness. In areas where the formation thins the sequence is disrupted. It was also found that where the formation retains a more or less constant thickness along strike the individual zones thicken and thin at the expense of each other.

According to Van Horn (1948, p. 19) the southeast dipping beds of the formations included in the Murphy belt are overturned, except in minor folds. He interprets these overturned beds to be part of the northwest limb of an overturned anticline. This interpretation is in contrast to Keith's theory that the rocks in the Murphy belt are part of a broad syncline in which the marble is prevented from reappearing southeast of the fold axis by faulting. Regardless of which interpretation of the structure is correct, the zoning in the Murphy marble established by Van Horn would be unaffected for all practical purposes and should prove to be a useful geologic tool in any future development in both the talc and marble industry.

Accessibility.—The Southern Railway and U. S. Highway 19-129, follow closely the main belt of the Murphy marble from the northeast terminus of the marble to Murphy. From Murphy southwest to Culberson and on into Georgia the Louisville and Nash-

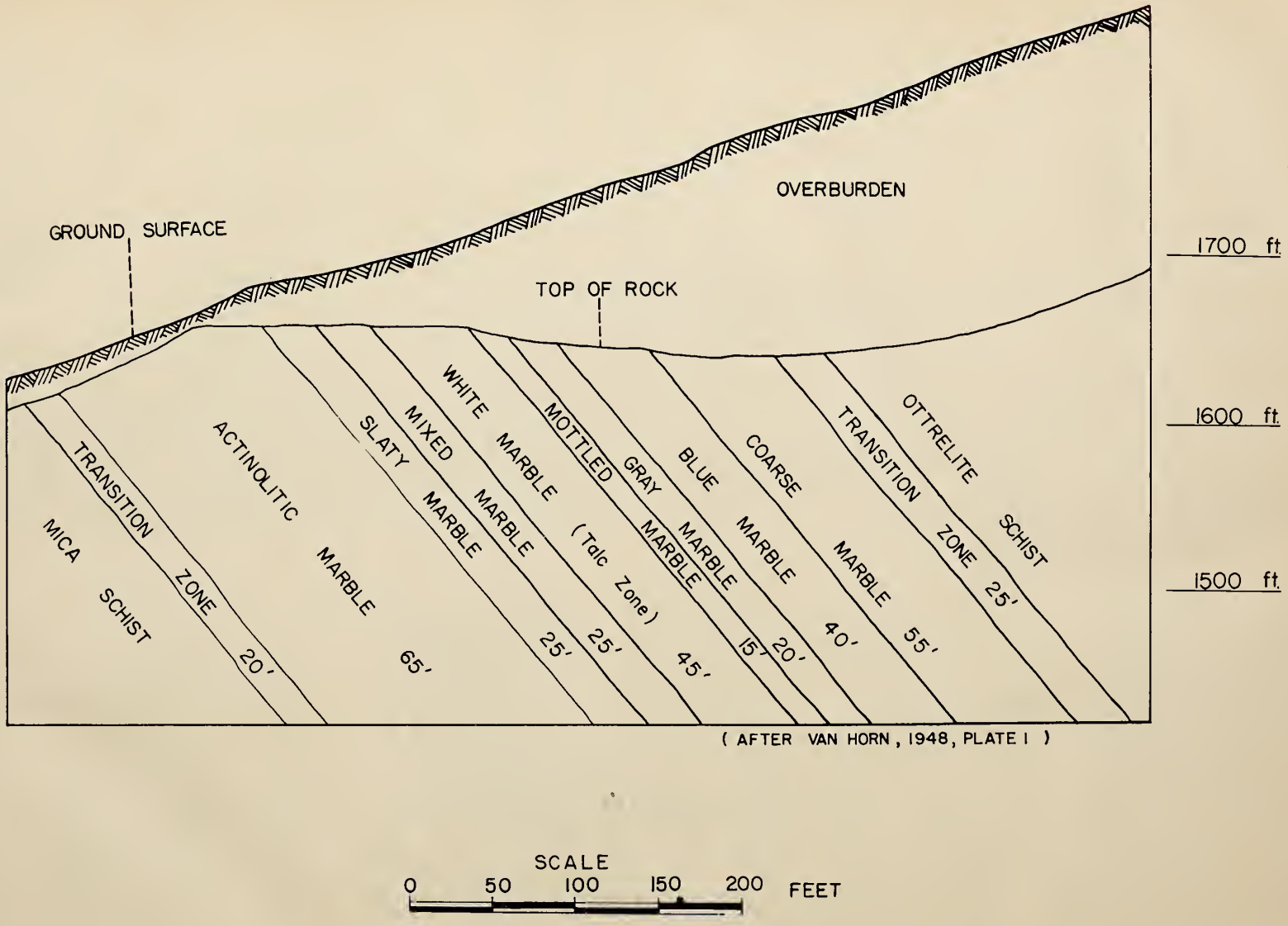


FIGURE 4.

GEOLOGIC SECTION SHOWING STRATIGRAPHIC SEQUENCE IN MURPHY MARBLE

ville Railroad, U. S. Highways 19, 64 and 129 and N. C. Highway 60 serve as access to the marble.

The Murphy belt is covered by up to date 7½ min. topographic maps (scale 1:24,000) published by the Tennessee Valley Authority. The maps which cover the area are: Culberson (TVA 1941), Persimmon Creek (TVA 1957), Murphy (TVA 1957), Peachtree (TVA 1937), McDaniel Bald (TVA 1957), Marble (TVA 1938), Andrews (TVA 1938), Wayah Bald (TVA 1957), Hewitt (TVA 1940) and Wesser (TVA 1940). These maps can be purchased from the Tennessee Valley Authority, Knoxville, Tennessee, or the United States Geological Survey, Washington 25, D. C.

History of Production

Marble beds in Cherokee and a part of Macon County along the course of the Valley River, were noted by Kerr as early as 1875. However, the first recorded attempt to quarry the marble was not until the late 1880's when the marble in the Nantahala River gorge was quarried to a very limited extent. The first attempt to quarry the marble on a systematic basis was in 1891-92 when the Culberson and Kinsey quarries were opened. The Culberson quarry was not successful and operated for only a few years. The Kinsey quarry, operated by the Notla Consolidated Marble and Talc Company was somewhat more successful and was worked intermittently until about 1912. Some dimension stone was produced for the first few years but later production was mostly for flux used in copper smelting.

During the early 1900's, the Murphy marble attracted considerable attention as a potential building and monumental stone and several companies were engaged in exploration and development work. The Hewitt quarry near Hewitt Station was opened about 1901 and the famous Regal quarry was opened about 1902 by the National Marble Company. The stone produced at the Regal quarry was a very attractive mottled blue and white marble and it became widely known as "Regal Blue Marble". The Cherokee County courthouse in Murphy was built with stone from this quarry and about 35,000 cubic feet of cut stone were used. Ownership of the Regal quarry changed hands several times during its history and it was finally closed and the quarry flooded in 1926. After the Regal quarry was closed the Regal Blue Marble Company, which was the last company to operate the quarry was reorganized under the name Carolina Marble Quarries, Inc., and work was started on a new plant and quarry at Marble. No production was ever reported from this company and in 1931 the Columbia Marble Company acquired the property. During 1932 considerable development work was done and an all steel finishing plant was built. Since 1932 the Columbia Marble Company has been in continuous operation and is the only producer of dimension marble in North Carolina.

About 1908 the North Carolina Mining and Talc Company began developing the Hewitt quarry for crushed stone and burned lime. The quarry has changed hands several times since 1908 but it has been in almost continuous production. Today, it is operated by the Nantahala Talc and Limestone Company, and is a large producer of crushed stone.

Description of Workings

Columbia Marble Company.—This company's main quarry and plant are located on the north side of U. S. Highway 19-129 and the Southern Railway, 1.5 miles northeast of Marble, North Carolina. Since operations were started in 1931 some 10 quarries have been opened between Murphy and Coalville. Most of the quarries are located on the north side of U. S. Highway 19-129 between Marble and the present quarry. Two are on the southeast side of the Southern Railway about 3 miles northeast of Murphy. All of the quarries are from 100 to 200 feet in length and range from 40 to 90 feet in depth. In the summer of 1958, all but two of the quarries were inactive and filled with water. The main producing quarry is located on the west side of Welch Mill Creek, 2700 feet northeast of the finishing plant. Approximately 80 percent of the company's production is furnished from this quarry. It was opened in 1947 and since has been in continuous operation. The quarry is about 120 feet long, 60 feet wide and 90 feet deep, the long dimension being almost due east-west. The marble is overlain by about 10 feet of flood plain deposits and the upper few feet of bed rock are highly pitted by solution cavities.

The marble is predominently a mottled or streaked light gray medium grained variety. The upper 8 to 10 feet contain numerous bands of light pink and dark-gray marble. Mica is the predominent accessory mineral, particularly in the dark gray bands, but tremolite and pyrite are present in minor amounts. Joints that strike N 70° W and N 25° E are present, but are so spaced that they do not effect the strength of the marble or cause excessive waste.

The other producing quarry is located on the southeast side of an unpaved county road approximately ¾ mile southwest of Regal Station and 3 miles northeast of Murphy. Development work was started in 1957 and in the summer of 1958 some of the first

sound blocks were being removed from the third level. Owing to large solution cavities, some up to 10 feet high and 6 to 8 feet across the base, and jointing much of the first two levels (upper 9 feet) was waste.

The quarry opening is approximately 60 feet wide and 120 feet long, the long dimension being northeast-southwest. The opening is situated at the base of a rather steep hill and overburden is in excess of 20 feet in places. The marble is predominantly medium-grained, light to dark blue and mottled or streaked with thin bands of white marble.

Located 0.2 mile southwest along the strike of the marble on the southeast side of the same road as the above quarry, is another Columbia Marble Company quarry that was closed in 1957. Development work was started at this site in 1949 and it was worked intermittently for about 8 years. It is now filled with water and is in the process of being backfilled with the overburden stripped from the new quarry. Because of water and thick overburden the marble cannot be seen in the quarry walls, but there is a large dump on the southeast side. Most of that in the dump is the blue mottled variety which is now being quarried 0.2 mile northeast and which was quarried at the original Regal quarry.

About 800 feet southwest of the quarry a rotary drilling rig was drilling exploratory holes for talc on the property of Mr. A. G. Thompson. At the time (June 1958) five holes had been drilled and each hole was about 200 feet deep. The marble was present in each hole under 35 to 80 feet of overburden and consisted of white, blue and gray varieties.

The Columbia Marble Company uses quarry methods and equipment in both of its operations that are more or less standard throughout the industry. The marble is laid out in blocks about 17 feet long and 4 feet wide. A line of vertical holes 3 to 4 inches apart are drilled along the outside dimensions by wagon drills mounted on horizontal bars. An undercut drill then drills a line of horizontal holes along the base of the block. After the drilling is completed, the blocks are wedged loose from the surrounding marble and broken into two smaller blocks about 8½ x 5 x 4 feet. The blocks are lifted from the quarry by a double drum hoist and carried to the finishing plant by truck.

At the finishing plant, the blocks are loaded onto track mounted gang-cars and moved under the gang-saws. These saws are made up of a series of iron blades set parallel in a frame that moves backward and forward. Quartz sand and water are fed to the top of the blocks and as the blades drag the sand across it cuts the marble by abrasion. The thickness of the slabs cut is governed by the spacing of the blades, the minimum thickness being 1 inch. The saws cut at the rate of about 2 inches per hour and are run 24 hours per day. After the blocks are slabbed, part of the slabs go to a guillotine rock breaker where they are broken into sections 4 inches wide. The length and thickness of the sections vary, but do not exceed about 3 feet and 6 to 8 inches respectively. These sections are used as a decorative veneer in the building trade and a 4 inch width is used so that they can be worked in with bricks. This veneer has been marketed for about 4 years and has become an important product. Some of the veneer is sold in North Carolina, but a large percentage of it is shipped to out of state markets.

The slabs not used for veneer go to the mill where they are shaped into products that require cutting and polishing. The slabs are first sawed to predetermined size by a circular diamond saw. The saw is mounted on a rack and pinion gear and the slabs rest on a mobile, hydrologically operated table. This permits the operator to change the position of the slab without disturbing it. After the slabs are cut to proper size they are placed on a large horizontal polishing wheel where they receive a rough polish. Carborundum wheels are then used to cut the slabs into the various desired shapes. Final polishing is done by polishing wheels and buffers.

A majority of the marble finished in the mill is for monumental work but mantles, tabletops, flooring, and several other special products are made. Specialty work includes hand carved figures, mostly lambs and birds, and sand blasted inscriptions and decorative trim on headstones. When in demand, waste marble is crushed to size for terrazzo chips and poultry grit.

Nantahala Talc and Limestone Company. — The plant and quarry are located on the northwest side of the Nantahala River at Hewitt, Swain County. Systematic quarrying was started here as early as 1908 by the North Carolina Mining and Talc Company and except for a short period during World War I, the quarry has been in continuous operation. Early quarrying was done at three places along the west slope of Nantahala gorge some 300 to 400 feet above the railroad (Loughlin, et al. 1921, p. 44). The three openings were connected with a lime kiln and crusher by a tramway. Production was mainly for crushed stone and burned lime, but in the late 1920's enough white and light-gray mottled marble was quarried to use as interior finish in the lobby of the Asheville

Hotel in Asheville (Stuckey and Fontaine, 1933, p. 11).

The marble occurs as a continuous outcrop along the steep west slopes above Nantahala River and according to Van Horn (1948, p. 11) is up to 350 feet thick in the vicinity of Hewitt. At the quarry the formation strikes N 20° E and dips about 45°SE. It is quite variable in color, the beds exposed in the quarry face ranging from light gray to black and from dull white to grayish pink and pink. Most of the marble is very schistose, badly fractured and breaks into thin plates and narrow blocks. The planes of schistosity are frequently coated with a thin layer of serpentine. Besides serpentine other excessory minerals include talc, tremolite, pyrite and quartz. Talc occurs locally as thin stringers and lenses, some of which are quite large. Until a few years ago ground talc and talc crayons were a by-product of the quarry operation.

The composition of the marble ranges from calcite marble to dolomite marble. In 1947 the Tennessee Valley Authority in cooperation with the North Carolina Division of Mineral Resources conducted a sampling program at the Hewitt quarry and immediate vicinity. The purpose of this investigation was to determine the quantity and occurrence of high calcium marble. Preliminary sampling indicated that marble containing up to 97.17 percent $CaCO_3$ was present. However, the high calcium marble was interbedded with the dolomite marble in such a manner that the cost of separating the two would be prohibitive.

Large scale development of the present quarry site was started in 1938-39. The quarry has been advanced into the mountain side and consequently the working face is practically a vertical wall with steep sloping sides. The face is approximately 200 feet high at the apex and 300 to 350 feet wide at the base. As the quarry is situated above the water table drainage is not a problem.

The rock is blasted from the face and trucked to the primary jaw crusher, which is located on the east side of the quarry floor. Final crushing and sizing are done by cone crushers and screens. Conveyor belts move the crushed stone downhill to stockpiles which are located near the railroad. During the summer of 1958 the quarry was operated 2 shifts a day, five days a week. Production ranged from 500 to 750 tons per eight hour shift.

Crushed stone is the principle product of this quarry and most of it is used by the State Highway Commission for highway construction and maintenance. Agricultural lime and terrazzo chips are also produced, terrazzo chips being the more important of the two. Within the past few years a secondary quarry has been opened just northeast of the main quarry in which selected beds with attractive colors are quarried exclusively for terrazzo chips. As mentioned previously talc lenses exposed by the quarry operation were used for ground talc and sawed into crayons but none has been produced within the last few years.

Reserves of marble suitable for the same type of products now marketed by the Nantahala Talc and Limestone Company appear to be unlimited.

Culberson quarry.—This quarry is located 50 feet northwest of Trestle No. 15 on the northwest side of the Louisville and Nashville Railroad, 4500 feet northeast of the community of Culberson and 9 miles southwest of Murphy. This quarry was opened in 1891-92 and was one of the first attempts to quarry the marble for dimension stone. Owing to excessive water and the badly fractured nature of the marble, the operation was unsuccessful and the quarry was abandoned after a few years (Watson and Laney, 1906, p. 194).

The only evidence of the quarry that remains today is a small pond approximately 100 feet in diameter and several large blocks of marble. Some of the blocks of marble project above the water in the middle of the pond and some are scattered along the edge of the pond next to the railroad. All of the visible blocks are very similar and consist of uniform medium grained, dark to medium bluish gray marble. Thin bands of graphite, up to .25 inch thick gives the marble a distinct layered appearance. The marble does not crop out anywhere near the quarry, but according to Watson and Laney (1906, p. 194) it is overlain by from 4 to 7 feet of overburden.

Kinsey quarry. — This quarry is located on the northwest side of the Louisville and Nashville Railroad about 0.3 mile southwest of Comes Trestle (Trestle No. 20) and 5 miles southwest of Murphy. The quarry was named after the small community of Kinsey which was located a few hundred feet southwest of the quarry. Kinsey has long been abandoned and the few houses and buildings which stood there have been torn down.

The quarry was opened about 1891-92 and operated until shortly after 1900 (Pratt, 1900, p. 22). As was the case at Culberson, the marble was too badly fractured by joints to be suitable for dimension stone, but was well adopted for crushed stone and flux. Mr. J. M. Ledford (personal communication) reports

that most of the quarry production was shipped to Ducktown, Tennessee, and used by the Tennessee Copper Company for flux.

By 1906 the quarry had been abandoned for several years and Watson and Laney (1906, p. 194) described the excavation as being about 100 feet long, 80 feet wide, 50 feet deep and extending almost to the railroad. Piles of discarded marble were scattered around the opening and consisted mostly of a coarsely crystalline, dark blue gray, mottled marble. Also noted were lesser amounts of light-gray marble and some blocks of light gray interbedded with pink.

Today the opening is badly slumped and overgrown with a dense cover of vegetation and is barely recognizable. The only rock that can be seen in place is a ledge about 4 feet thick of white, silicified marble that occurs near the top of the southeast wall. Several large blocks of light to medium gray marble are scattered around on the quarry floor.

Southwest from the quarry for a distance of about 1000 feet, between 25 and 30 exploratory drill holes were drilled for talc by Mr. J. M. Ledford about 1954. Although no talc was found, considerable marble was cut in each hole and the cores from a number of the holes were scattered around through the woods. Most of the cores examined consisted of light to medium-gray marble, but white and blue mottled marble was also present. Tremolite crystals, some up to ½ inch long, were quite common, particularly in the light-gray marble. The majority of the holes were drilled on the southeast side of the railroad, which is at a higher elevation than the quarry and the marble was overlain by as much as 60 feet of overburden. The deepest hole drilled was 280 feet and the marble was not drilled through at that depth.

Regal quarry.—This quarry is located on the southeast side of the Southern Railroad at Regal Station, about 3 miles northeast of Murphy. It was opened in 1902 by the National Marble Company and a small production was reported for 1903 and 1904. No production was reported again until 1907 when it was taken over by the Casparis Marble Company. This company produced steadily until 1913 when it was succeeded by the Regal Blue Marble Company. From 1913 to 1926 the quarry was operated continuously and the marble produced gained a wide reputation as "Regal Blue Marble". It was shipped as far as California and used extensively as a building and monumental stone. The Cherokee County Courthouse in Murphy, North Carolina, was constructed from marble from this quarry. After 1926 the quarry was abandoned, allowed to fill up with water and has remained inactive since that time.

All that remains of the quarry today is a pond about 250 feet long and 50 to 60 feet wide. It is reported to be about 175 feet deep. A heavy growth of underbrush and trees have grown up around the edges of the pond and access is limited. Large blocks of marble are piled up around the edges, particularly on the southeast side, and appear to be identical with the marble which is presently being quarried ¾ mile southwest. At the northeast end a large wall, the width of the quarry, was built out of waste blocks. This was done evidently to prevent a nearby stream from overflowing into the quarry.

According to Watson and Laney (1906, pp. 195-197) and Loughlin. et. al. (1921, pp. 37-40) the marble quarried was mainly of two kinds, predominently a dark bluish gray mottled variety and a light gray to white variety. Both varieties were medium grained and had a slight schistose structure. Tremolite, pyrite and graphite were the chief accessory minerals. The beds had a strike of about N 45° E and dipped about 50° SE. In the opening studied by Laney, there were three distinct sets of joints, the more prominent trending N 40° W and N 20° E. The joints ranged from a few inches to a few feet apart and caused considerable waste in the upper part of the quarry. As the quarry was deepened the joints became less prominent and caused less waste. Solution channels and small caves also caused waste in the upper 20 feet.

The property on which the quarry is located is presently controlled by Mr. H. W. Alexander of the Appalachian Veneer Company, Regal, North Carolina.

Red Marble Gap.—Northeast of Red Marble Gap the Murphy marble crops out along the steep slopes of the gorge some 300 feet above Rowlin Creek. One of the better outcrops in the area is located on the northwest side of the railroad tracks approximately 2 miles northeast of Red Marble Gap. The area is rather inaccessible, but can be reached by traveling northeast from Red Marble Gap for 1.9 miles on U. S. Highway 19. At this point the highway crosses Rowlin Creek just a few hundred yards beyond Rowlin Creek Baptist Church. A roadside pull-off is on the northwest side of the road and an old trail that leads up the mountain side to the railroad tracks starts at this point. The marble crops out about 50 feet above the railroad at the place the trail crosses the railroad tracks and beneath the Nantahala Power and Light Company transmission lines.

The side of the mountain is covered with a heavy growth of vegetation, but the marble can be seen intermittently for 300 to 400 feet along strike. The strike is about N 25° E and the dip about 70° SE. The marble is mostly medium grained and varies from light gray to light pink. It has a distinct schistose structure and bands of serpentine, which lie parallel to the schistosity, are distributed irregularly. This combination of colors results in an unusual and very attractive rock.

A small amount of marble was quarried here many years ago as indicated by a small opening toward the northeast end of the outcrop. The old working face is about 15 feet high, slopes off gently on each side and is about 30 feet wide at the base. The floor of the opening is covered with slabs of waste marble.

Another outcrop of marble very similar to the above occurs on the northwest side of U. S. Highway 19, 1.0 mile northeast of Red Marble Gap. The outcrop is on a steep hill directly behind the Gibbons house.

Peachtree-Brasstown area.—A second but much smaller belt of the Murphy marble occurs 5 to 6 miles east and southeast of the main belt. It begins in the vicinity of Peachtree and extends in a southwestward direction down Calhoun Branch, across the Hiwassee River and up Little Brasstown Creek to the vicinity of Martins Creek School (Keith, 1907).

Outcrops of the marble are rare and except for the geologic mapping by Keith (1907), very little detail work has been done on this belt. The few outcrops that can be seen are predominantly fine grained, light bluish gray to dark gray banded marble. The thickness is unknown, but two water wells drilled near Brasstown cut about 67 and 50 feet of marble. Both wells were about 100 feet deep and were still in marble when drilling was stopped (Mr. F. O. Scrogges, personal communication).

Owing mainly to the fact that the belt is not serviced by rail transportation, no recorded attempts have been made to quarry the marble on a commercial basis. However, there are several places where small amounts of marble were quarried and burned, or crushed, for agricultural lime for local consumption. Four such places are: (1) behind Martins Creek School on the west side of the creek, (2) from a bluff near the headwaters of Little Brasstown Creek (Whitmire Hertford Farm), (3) from a farm 1.3 miles northeast of Brasstown near the Hiwassee River and (4) near Peachtree School on Peachtree Creek. According to Mr. F. O. Scrogges (personal communication) these localities were last worked about 1935. The work was done by local residents in an attempt to produce agricultural lime for local farms.

Most of these old workings have been back-filled and could not be examined. However, the outcrop on the Whitmire Hertford farm (Locality 2) occurs in a bluff above the creek and is one of the few reasonably good exposures in the area. The outcrop, which is about 10 feet high and 15 feet long, stands about 15 feet above creek level and is overlain by 10 feet of red clay. The marble is fine grained and light bluish gray to gray. It strikes N 40° E and dips 50° SE. Several sets of joints are present, the most prominent strikes N 40° W.

This is the site of a small quarry and lime kiln which was worked intermittently from about 1890 to 1935 (Mr. E. L. Arrant, personal communication). As most of the quarrying was done by hand methods it appears that only a few tons of rock have been removed from the outcrop. Directly below the quarry are the remains of the last lime kiln that was used on the property.

Macon County

Northeast of the Murphy belt in the northeast corner of Macon County are the only other known deposits of marble in this section of the State. The deposits were briefly described by Watson and Laney (1906, p. 208-209) as follows: "In Macon County, near the headwaters of Ellijay Creek, near Cullowhee Gap, limestone has been burned to lime for building and fertilizing purposes on the property of John Bryson. About one-half mile west of the gap is the Hashett lime quarry that was worked quite extensively some years ago".

During the present investigation two marble deposits were located in this area, but their locations do not conform too closely with the above description. According to local residents the Hashett lime quarry is located about a mile south of Cullowhee Gap on Bryson Branch, a tributary to Ellijay Creek. This deposit was not seen, but it is reported to be next to the creek and about 100 feet upstream from an abandoned pegmatite mine. The other deposit is located 2.0 miles southwest of Cullowhee Gap. It is referred to by local residents as the Dill lime kiln and is on the property of Mr. Lee Dill.

Dill lime kiln.—The Dill deposit can be easily reached from either Franklin or Cullowhee. It is on the northwest side of an unpaved county road, 0.25 mile west of the Ellijay Creek road. The county road intersects the Ellijay Creek road 8.4 miles northeast of U. S. Highway 64 and 9.0 miles southwest of Cul-

lowhee. A few disconnected lenses and pods of marble are exposed in the roadcut, but the main outcrops are located at the old quarry site on the nose of the hill about 50 feet above the road. The largest outcrop stands about 10 feet high and 5 feet wide. It strikes N 30° E, dips about 70° NW and consists mostly of white, coarsely crystalline marble. Grain size ranges from 0.5 to 3 mm. with a few calcite crystals up to 5 mm. Excessory minerals disseminated through the marble include biotite, garnet, quartz, amphibole (tremolite ?), epidote and graphite. The graphite occurs as small foliated masses and as tabular hexangonal crystals. The latter form is very rare, this being the only place where it has been reported in North Carolina. Two other outcrops are present nearby. One is about 15 feet across strike to the east and the other is about 30 feet to the southwest. Both of these outcrops are smaller than the one just described, but for all practical purposes are identical in character.

The marble is composed predominantly of coarse crystals of calcite with very little cementing material. Consequently, the calcite crystals weather out before they are dissolved by chemical action. This produces a rough, granular surface on the outcrop. The outer few inches of the marble are so deeply weathered and badly stained by iron oxide that it is difficult to obtain a representative sample with only a hammer and chisel.

As revealed in the roadcut exposures, the marble is intimately associated with gneissic rocks that have been injected with granitic solutions and badly folded and possibly faulted. On the Geologic Map of North Carolina (1958), the area in which these rocks occur falls into the Precambrian (?) gneiss unit which would in this case correspond to the "Carolina gneiss", as defined by Keith (1903, p. 2).

Owing to the deep soil cover and heavy growth of timber which covers the hillside, the marble could not be traced for any distance along strike. Consequently, no estimate could be made as to the quantity of marble present in this deposit. However, from the surface exposures it is doubtful if a tonnage of any significance is present.

Jackson County

Caney Fork deposit.—An impure crystalline limestone, or marble is reported to occur at Caney Fork, Jackson County (Loughlin, et. al., 1921, p. 71), but it was not visited during the present investigation.

On the 1957 edition of the State Highway Commission's map of Jackson County, there is no place specifically referred to as Caney Fork. However, Caney Fork Creek is a major stream that heads-up in eastern Jackson County, flows west and joins the Tuckaseigee River southeast of Cullowhee at East Laport. It is assumed that the marble deposit is located along this creek or one of its tributaries.

A partial chemical analysis of the marble (Loughlin, et. al., 1921, p. 151) shows 16.45 percent SiO_2, 9.86 percent Al_2O_3 and Fe_2O_3, 71.27 percent $CaCO_3$ and 0.52 percent $MgCO_3$. This deposit has not been previously described and its size and geologic relationships are unknown, but it is probably very similar to the deposit on Ellijay Creek in Macon County.

Hot Springs Area—Madison County

General Statement

The Hot Springs area lies in the rugged mountainous terrain of western Madison County near the North Carolina-Tennessee border. Hot Springs, the only town in the area west of Marshall, is situated on the French Broad River and lies about 40 miles northwest of Asheville.

The French Broad River traverses the area in a northwesterly direction. The Southern Railway and U. S. Highway 70-25 closely follows the river. Numerous paved and unpaved state maintained roads make most of the area reasonably accessible. The following topographic maps on a scale of 1:24,000 cover the area:

Paint Rock (TVA 1940), Hot Springs (TVA 1940), White Rock (TVA 1939), Marshall (TVA 1945), Lemon Gap (TVA 1940) and Spring Creek (TVA 1946). These maps can be purchased from the Tennessee Valley Authority, Knoxville, Tennessee, or the United States Geological Survey, Washington 25, D. C.

Lime Bearing Rocks of the Area

Four types of lime bearing rocks occur within the area. These are: (1) marble lenses in Precambrian gneisses and schists, (2) lenticular limestone beds in the Sandsuck formation, (3) the Shady dolomite, and (4) the Honaker limestone.

Marble lenses in Precambrian gneisses and schists.—The area around Marshall is underlain by a series of gneisses and schists which Keith (1904) mapped as Carolina gneiss. The unit consists mostly of light and dark gray mica gneisses and mica schists with varying amounts of hornblende schist. The enclosed lenses of marble which occur in the vicinity of Marshall were described by Keith (1907) as follows:

"Associated with the gneiss, but forming an unusual exception to it in character, is a group of marble beds. Two of these are found in Marshall and five are two miles west and northwest of Marshall, four of these lying in a nearly straight line southward from French Broad River. Outcrops of the marble are found only in or near the streams, on account of the soluble nature of the rock. At first they seem to be different outcrops of a continuous bed, but it is doubtful if this is the case because at a few intervening points the marble is plainly absent. It is probable, therefore, that the marble deposits are of lenticular shape. Considerable differences in thickness can be observed, even in the small exposures near the streams, but these may be due to the extreme folding that all of the rocks of the region have undergone. The maximum thickness observed was on Walnut Creek northwest of Marshall, where the outcropping beds are 60 feet thick, with a possibility of as much more concealed. About 200 feet farther north the entire section was occupied by gneisses. South of French Broad River, the thickness observed ranged from 10 to 35 feet. The thickness shown in Marshall have about the same variations.

The marble is fine grained and is usually white. It contains 84 percent of carbonate of calcium, 2 percent of carbonate of magnesium, and 13 percent of silica. Many portions have a somewhat greenish color, due to tremolite, which forms many small prisms and stubby crystals. Other variations of color are due to small knots of epidote, tremolite and calcite and to lenses of fine quartz and hornblende. These seem to be in the nature of secondary segregations and are of frequent occurrence throughout all the marble beds. The most important variation in the marble is seen in the series of thin lenses and sheets of silica that it contains. These are seldom over 2 inches in thickness and are composed of extremely fine-grained quartz. They appear to represent original sedimentary bands, replaced by silica and have been extremely contorted and folded like the adjoining gneisses. The value of the marble for building stone is much injured by these various impurities. A few seams of mica-schist found in the marble contain the same minerals and are metamorphosed to the same degree as the adjoining Carolina gneiss. There is, therefore, little doubt that the marbles are of substantially the same age as the gneiss. The gneiss is cut by Cranberry granite at many points within a few feet of the marble, but the granite does not touch the marble at any point".

An attempt was made to locate the marble lenses described by Keith as occurring about two miles west and northwest of Marshall. Those reported to lie southward from the French Broad River could not be found but the one on Walnut Creek 2 miles northwest of Marshall was found. This deposit lies on the south side of Walnut Creek about 100 feet east of where Sweet Water road crosses Walnut Creek and 0.3 mile west of Dry Branch Church. The marble is massive fine grained and varies from white to light green. Mr. Hubert Dill reports that about five years ago a private company attempted to quarry the marble for crushed stone but only about 100 tons of rock was crushed. When the operation was started the marble stood as loose blocks in the face of a cliff about 60 feet high on the south side of the creek. After the blocks were blasted down there was no more marble present in the cliff and the operation was abandoned. A number of loose blocks are now scattered along the creek for about 100 feet.

Lenticular limestone beds in the Sandsuck formation.—The Sandsuck formation is the upper member of the Ocoee Series of Upper Precambrian age. It is of limited extent in North Carolina, most of that present occupying an irregular area northeast of Hot Springs along the northwest edge of the county (Geologic Map of North Carolina, 1958). Keith (1904) originally mapped these rocks as Hiwassee slate, but subsequent work by Ferguson and Jewell (1951) and Oriel (1950) has shown that Keith used the name Hiwassee slate for approximately the same rocks he had mapped in Tennessee as Sandsuck shale. Since the name Sandsuck shale has priority over Hiwassee slate, the latter term has not been used by recent workers.

According to Oriel (1950, p. 24) in the Hot Springs area the formation is about 700 feet thick. It is composed mostly of dark green to black, silty and argillaceous shale and slate. Coarse conglomerate lentils are interbedded with the shale near the top of the formation and light gray to blue gray calcareous sandstones, sandy limestone, and thin-bedded quartzite occur in the lower half of the formation.

The calcareous sandstones and sandy limestones occur as lenticular layers interbedded with the slates. The limestone varies considerably in short distances, but the most common variety is a blue or dove-colored limestone containing abundant grains of quartz sand. In some places the siliceous material increases to the point where the rock becomes a calcareous conglomerate containing pebbles of quartz and feldspar.

There are a number of outcrops of the limestone in the area, but the most accessible are located along Franklin Mountain Road, an unpaved county road

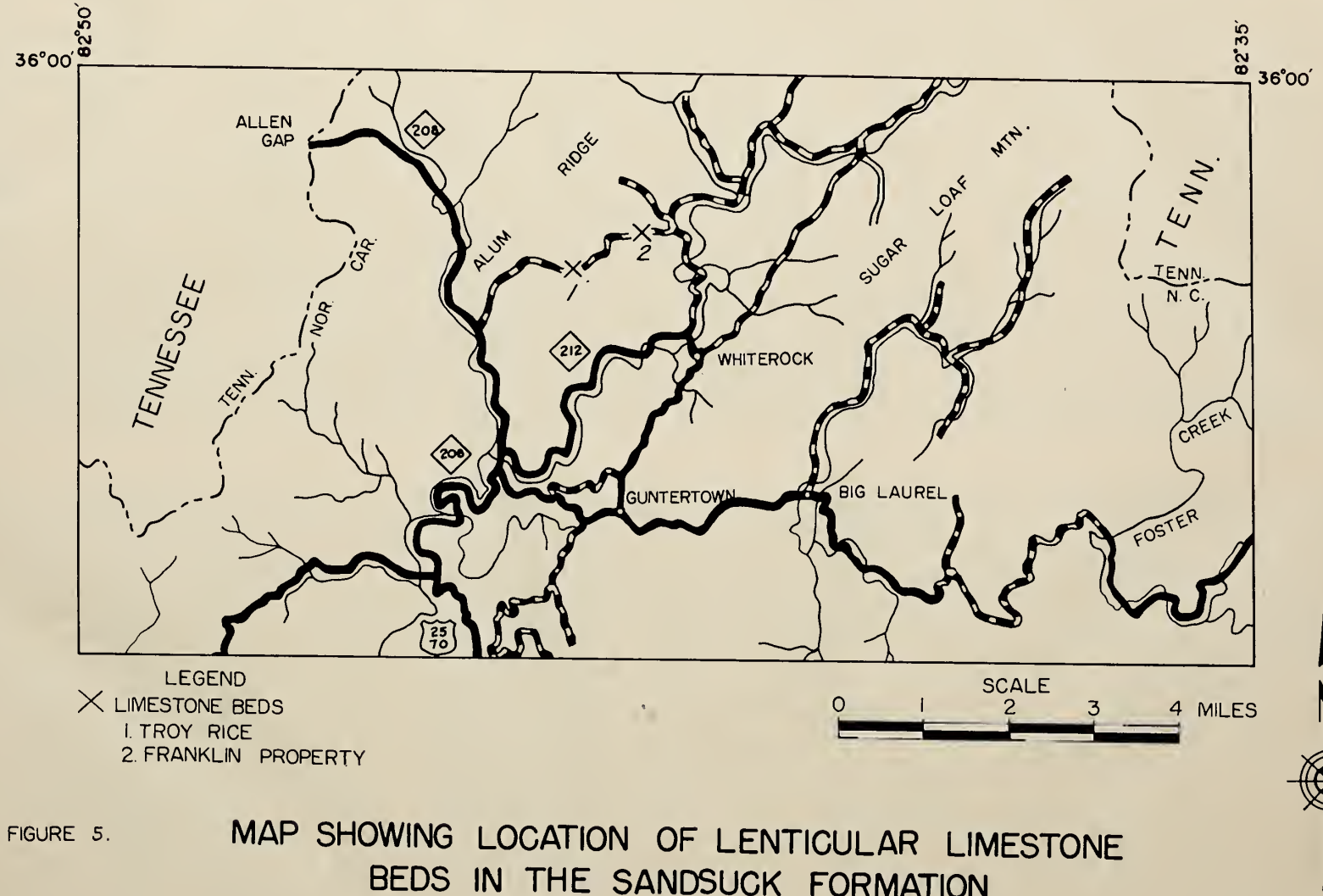


FIGURE 5. MAP SHOWING LOCATION OF LENTICULAR LIMESTONE BEDS IN THE SANDSUCK FORMATION

that connects State Highway 208 with State Highway 212. One outcrop occurs on the north side of Franklin Mountain road, 1.5 miles west of State Highway 212 on the property of Mr. Troy Rice. Here the limestone strikes N 35° E, dips 50° SE and is about 85 feet thick. It is mostly light blue gray to dark blue gray, medium bedded and fine grained. It contains thin stringers of calcite, small cubes of pyrite and a few scattered quartz grains. Another outcrop is present 0.3 mile northeast of the Rice house on the east side of the road. This limestone is in general quite similar to the above but contains argillaceous and sandy beds.

The most extensive outcrop of the limestone seen in the area occurs on the property of a Mr. Franklin, whose house is located on the north side of Franklin Mountain road 0.45 mile west of its intersection with State Highway 212. The limestone is present in the face of a steep hill about 200 yards behind Mr. Franklin's house. Here the limestone strikes N 15° E, dips about 60° SE and is well over 100 feet thick. It is for the most part light to medium blue gray and contains abundant pebbles and cobbles of shale and sandstone along bedding planes. Agillaceous beds and beds containing abundant quartz sand grains, many over 1 mm in diameter, are quite common. It is reported by Mr. Franklin that an attempt was made several years ago to crush the limestone but the operation was abandoned because of the hardness of the limestone.

There is evidently a large tonnage of limestone available which is well situated for quarrying. However, its high silica content and poor location in regard to transportation and markets eliminates it from any foreseeable development.

Shady dolomite.—The Shady dolomite is the oldest (Lower Cambrian) of the thick carbonate deposits of the Paleozoic section in the Appalachians. It is widely distributed in northeastern Tennessee, but is of very limited extent in North Carolina. In the Hot Springs area it, along with other Cambrian rocks, rocks of the Ocoee series and Precambrian crystalline rocks are involved in one of the most complicated and unusual structural units found in the Southern Appalachians, the Hot Springs window.

Within the Hot Springs window the Shady dolomite forms an elongate belt about 6 miles long and from 1500 to 4000 feet wide, the long dimension being east-west. The eastern edge of the belt begins a short distance on the east side of the French Broad River at Hot Springs. It extends almost due west to just beyond the North Carolina-Tennessee border. The belt is terminated at each end by the Mine Ridge thrust fault (Oriel, 1950, Plate 1).

The formation consists predominantly of blue gray, light gray, and white dolomite with a minor amount of interbedded limestone. In northeastern Tennessee in the area of the type section King, et. al. (1944, p. 16-27) made a detail study of the Shady dolomite and divided the formation into several distinct members. Within the Hot Springs window, Oriel (1950, p. 9-10) was able to recognize essentially these same rock types and his generalized section of the Shady dolomite is as follows:

"Maroon shales of the Rome formation above.

Shady Dolomite:

(6) **Upper blue member:** Blue-gray to black, medium to thick-bedded and massive dolomite; interbedded light gray dolomite common; includes some silty and shady beds near the middle. Some irregular blebs and nodules of light-to medium-gray chert are present. Very well displayed in the two quarries along the railroad track on west bank of French Broad River and on the undercut bank opposite the town of Hot Springs.
Approximately ---------- 650

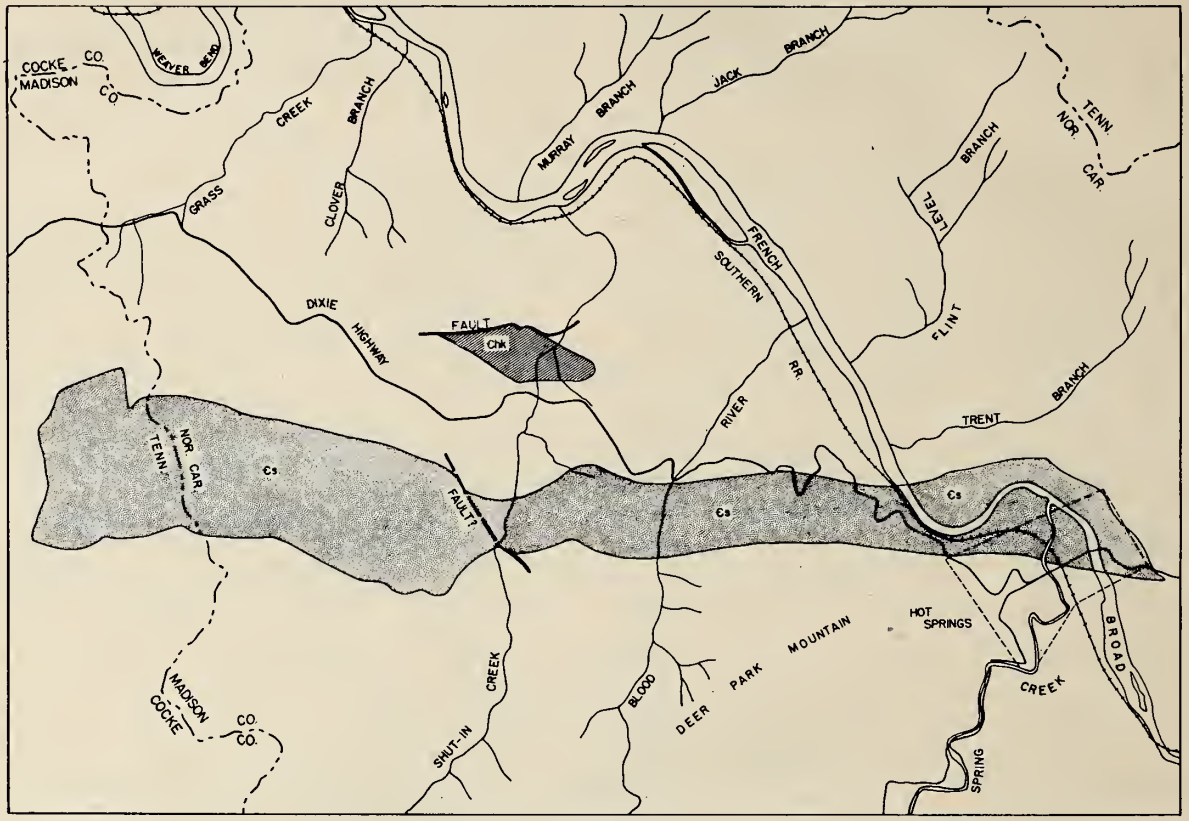
(5) **Upper white member:** Bluff-colored to white to light gray dolomite. Very finely crystalline near base and near top, but middle part is quite saccharoidol. Well exposed in Spring Creek near hotel and south of quarries on railroad track on west bank of French Broad.
Approximately ---------- 600

(4) **Middle blue member:** Blue-gray to black, medium to thick-bedded somewhat silty dolomite. Includes some beds of white to buff-colored coarsely crystalline dolomite. Very well exposed at the old quarry on the east bank of the French Broad just north of Highway 25-70.
Approximately ---------- 250

(3) **Ribboned member:** Medium to coarsely crystalline light gray to buff-colored dolomite in thick layers interbedded with fine-grained blue-gray to black dolomite. Some ribboned limestone is present in this member. Best exposed along lower Spring Creek and in south quarry on east side of river.
Approximately ---------- 300

(2) **Lower blue member:** Light to dark blue-gray, black, generally thick-bedded to massive dolomite; includes some light gray and blue-gray dolomite near base. Best exposed in road cuts on U. S. Highway 25-70 on east side of French Broad River bridge and along Spring Creek.
Approximately ---------- 150

(1) **Basal ribboned member:** Thinly interbedded white and light gray, very fine-grained dolomite. Poor exposures make determination of thickness diffi-



MAP SHOWING

FIGURE 6. OUTCROP AREA OF SHADY DOLOMITE AND HONAKER LIMESTONE IN MADISON COUNTY, NORTH CAROLINA

cult. Outcrops on north side of Camp Grounds road, 700 feet east of French Broad River. Approximately ---------- 25 (?)

Helenmode member of Erwin formation below

Total thickness of Shady dolomite
Approximately ---------- 1975"

This section was not measured directly, but was calculated from a series of discontinuous outcrops. The total thickness of 1975 feet is therefore probably somewhat greater than the true thickness.

Owing to the soluble nature of the dolomite, outcrops of fresh rock are relatively rare. The best exposures occur along the northeast and southwest river bluffs in the vicinity of Hot Springs where the French Broad River has cut across the strike of the formation.

Honaker limestone.—The Honaker limestone occurs as a single, elongated patch about 4000 feet long and 1500 feet wide. It is located 3 miles northwest of Hot Springs between U. S. Highway 25-70 and the French Broad River. This formation was originally mapped by Keith (1904) as part of the Shady dolomite, but Oriel (1950, p. 8) correlated it with the Honaker limestone (Middle Cambrian) of northeastern Tennessee and western Virginia.

The overburden is thin and there are many good exposures along both sides of Mine Hollow, an east flowing tributary to Shut-in Creek; however, the best exposures are in and along the south slope of Mine Hollow. The limestone has a gentle dip and a section about 100 feet thick is exposed. It is predominantly a dense, very fine-grained, dark bluish-gray limestone. Individual beds vary from 1 to 3 feet thick, but faint laminae are present on some weathered surfaces.

About 200 yards up Mine Hollow from its confluence with Shut-in Creek, on the south side of the creek, are the remains of an old lime kiln and a large dump of limestone blocks. When this kiln was active is unknown, but it was probably worked prior to 1900 for local use.

Only limited chemical analyses are available but indications are that the limestone contains upwards of 80 percent $CaCO_3$ and about 10 to 12 percent $MgCO_3$. Whether or not these percentages of $CaCO_3$ and $MgCO_3$ are representative of the entire section can be determined only by more extensive sampling.

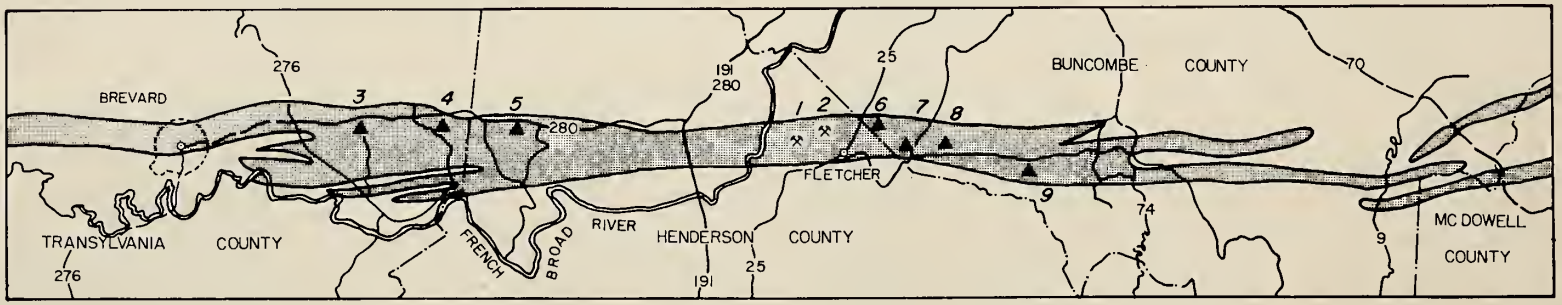
The south slope of Mine Hollow is one of the best undeveloped limestone quarry sites in the State. The limestone is about 100 feet thick and stands well above the creek valley. The gentle dip of the beds would make for easy development of benches and transportation facilities are close by. The Southern Railway is one mile north by an unpaved county road and U. S. Highway 25-70 is only 0.3 mile south. The most serious drawback for the development of a quarry at this site is its poor location with regard to markets. It is in a remote section of the State and unless a demand for a product for which this limestone is suited should develop close by, it will probably remain unexploited.

Description of Workings

G. C. Buquo Lime Company.—Of the four types of lime bearing rocks in the Hot Springs area, the only one that has been of more than local interest is the Shady dolomite. From 1912 to the early 1930's the G. C. Buquo Lime Company operated two quarries about ¾ mile northwest of Hot Springs on the southwest side of the French Broad River adjacent to the Southern Railway. At this point the dolomite is prominently exposed in bluffs more than 75 feet high for about 1200 feet along the river.

The rock exposed in the now abandoned quarries is chiefly the upper blue member of the Shady dolomite (Oriel, 1950, p. 53). It is fine grained and varies from light gray to dark bluish gray, but the dark bluish gray variety predominates. Beds strike east-west, dip about 75° north and range from a few inches to about 3 feet in thickness. Some of the beds are separated by a thin layer of reddish shale. Jointing is conspicuous in places, but the lack of consistant horizontal fractures is said to have made it difficult to maintain benches during the time the quarry was in operation (Loughlin, et. al. 1921, p. 52). The composition of the dolomite is fairly uniform and averages about 54 percent $CaCO_3$ and 41 percent $MgCO_3$. SiO_2 (mainly quartz) averages about 4 percent and the remaining plus or minus one percent consist mostly of small grains of feldspar, sericite, tremolite, pyrite and apatite.

Most of the rock quarried was finely ground and used for agricultural lime; however, some was used for road metal. The grinding plant was located just north of the quarry and the rock was transported to the plant over a short inclined track on cars operated by cable. The plant had a capacity of 20 tons per hour and it was estimated that at that capacity the company had sufficient reserves to last for about 200 years (Loughlin, et. al. 1921, p. 52). This would amount to over 10 million tons, much of which is still in place. After the quarry was closed the plant was torn down and all that remains today is part of the foundation.



SCALE
0 1 2 3 4 MILES

LEGEND

BREVARD BELT

⚒—ACTIVE QUARRIES
1. COGDILL LIMESTONE CO.
2. FLETCHER LIMESTONE CO.

▲—ABANDONED QUARRIES
3. CURITAN QUARRY
4. BARNARD QUARRY
5. WOODFIN, ALLISON, EZELL QUARRIES
6. PINNER CREEK
7. ROBINSON CREEK
8. GROVES LAKE
9. GRAVEL CREEK

FIGURE 7.

MAP SHOWING OUTCROP AREA OF BREVARD BELT

As stated above, there is a large tonnage of dolomite still available at this site. Should the need arise the quarry could be reopened very easily, but ordinary bench type development would be restricted because of the proximity of U. S. Highway 25-70.

Other properties.—The Shady dolomite is well exposed in bluffs for about 2000 feet along the east side of the French Broad River beginning just north of the highway bridge at Hot Springs. The dolomite here is fine-grained, predominantly medium to dark blue gray and is part of the middle blue member of the Shady dolomite (Oriel, 1950, p. 53).

About 0.10 mile north on U. S. Highway 25-70 a small quarry was opened in these exposures on the east side of the river. The quarry has been abandoned for sometime and there are no records available that indicate when the quarry was operated and for what purpose.

The dolomite has practically the same chemical composition as that at the Buquo quarries and there are a number of places where large reserves could be easily developed. The chief disadvantage to a quarry on this side of the river is that if the railroad facilities were to be used the stone would have to be hauled for about one half mile.

Brevard Belt

General Statement

The Brevard belt is a narrow belt of metamorphosed sedimentary rocks which enters North Carolina in Transylvania County and passes northeastward through Henderson and Buncombe Counties (Geologic Map of North Carolina, 1958). Keith (1905, 1907) mapped the belt in North Carolina and showed it as fingering out into the "Carolina gneiss" in the vicinity of Graphite; however, it may continue for some distance northeastward (King, 1955, p. 357). To the southwest the belt follows a straight and persistant course through South Carolina, Georgia and into Alabama, where it passes beneath the Coastal Plain sediments.

In North Carolina the rocks of the belt have not been subdivided into formations and it is referred to as the Brevard schist (Keith, 1905, p. 5). As implied by the name the formation is composed mostly of schist. The scist is always dark colored, varying from bluish black and dark gray to black. It is fine grained and composed mostly of muscovite, quartz and iron oxide. Graphite is commonly disseminated through large masses of the schist and in some layers is concentrated to the extent that the rock becomes a graphite schist. Small garnet crystals are also commonly disseminated through the schist (Keith, 1907, p. 4). Thin quartzite beds, phyllites and marble are also present, but form a minor part of the formation.

The Brevard belt is bordered on the northwest and southeast by different rock types. On the northwest side the contact is gradational with the "Carolina gneiss" and no sharp boundary can be drawn. However, on the southeast there is an abrupt contact between the Brevard schist and the Henderson granite gneiss, and for this reason it is possible that the southeast contact is along a fault (Ingle, 1947, p. 1).

Marble in the Brevard Schist

Marble, or recrystallized limestone, is known to occur in the Brevard schist from Buncombe County, North Carolina, through South Carolina and into Georgia. The deposits in North Carolina begin just southwest of Rosman and occur intermittently over a distance of about 30 miles to a few miles northeast of Fletcher. The marble underlies relatively large areas, but because of its soluble nature outcrops are very rare. In most cases it is present in creek valleys and is overlain by 2 to as much as 30 feet of overburden. Keith (1907, p. 4) interpreted the marble as occuring as disconnected lenses interbedded with the schist. However, Ingle (1947, p. 4) mapped the area from Fletcher to Fairview and concluded that the marble is more extensive than previously thought and that it may be a more or less continuous marble horizon rather than lenses. The writer concurs with this idea, but only core drilling along strike will prove this.

Most of the marble is white and finely crystalline, but it contains beds of light and dark blue marble. Zones of quartzite and chlorite-sercite schist, which may contain some serpentine, are present in the quarries southwest of Fletcher, but the marble is for the most part pure and contains few impurities. The composition ranges from almost pure calcium carbonate to nearly theoretical dolomite. The eastern half of the Blue Ridge Lime Company quarry (now the Fletcher Limestone Company) was reported (Loughlin, et. al. 1921, p. 68) to be high calcium marble, whereas the western half was dolomitic. Whether this is a local relationship or is generally true of all the deposits is unknown.

Locally the strike varies considerably, but averages about N 45° E. The dip is to the southeast between 35° and 85°. In the deposits southwest of Fletcher the marble reaches its known maximum thickness of about 250 feet. The quarries at the

head of Boylston Creek showed about 50 feet of marble (Keith, 1907, p. 4). Northeast of Fletcher the marble evidently thins out because the last known occurrence is 5 miles northeast of Fletcher on Gravel Creek, a tributary to Cane Creek. Northeast of this point the last evidence of any carbonate beds in the Brevard schist is a 2 foot bed of calcareous quartzite. The rock is exposed in a road cut on the northwest side of the paved county road between Fletcher and Fairview, 1 mile southwest of Fairview. This outcrop is next to Cane Creek, in strike with the marble to the southwest, and may represent a sandy facies of the marble.

History of Production

Marble beds in the Brevard schist have been utilized for well over 100 years. Prior to 1900 a number of small quarries were opened and worked intermittently over a period of years in Transylvania, Henderson and Buncombe Counties. These early quarries were small scale operations and all of the production was consumed locally. Lime for fertilizer and building purposes was the principle product. The marble, or "limestone", was burned in small beehive type kilns. Although these kilns have not been used for many years the remains of a few of them can still be seen. The lime obtained from these kilns was evidently of excellent quality, because a structure in which it was used as mortar was in almost perfect condition after having stood for over 60 years (Watson and Laney, 1906, p. 208).

In 1904 the first quarry was opened to produce lime on a commercial scale. The Blue Ridge Lime Company began operations on the Westfeldt property west of Fletcher near the old Lance quarry. Initial kiln capacity was 700 bushels per day, but this was doubled during the second year of production (Pratt, 1907, p. 63). This company was in continuous operation from 1904 until about 1936. Lime was the principle product for many years, but crushed stone was also produced during the latter years of operation.

Sometime between 1908 and 1910 the King Lime Fertilizer Company of Brevard was organized to develop several of the deposits in Transylvania and Henderson Counties. The company had an ambitious plan to lay some 3 miles of track which would connect the quarries with a large crushing plant, six coal burning kilns and the railroad (Pratt, 1911, p. 115). For reasons unknown these plans did not materialize and no production was ever reported from this company.

During the period of 1929 to 1936 three companies worked the deposit west and southwest of Fletcher; The B & C Lime and Stone Company, the Blue Ridge Lime and Stone Company and the Fletcher Limestone Company. The B & C Lime and Stone Company was active from 1926 until 1936. Its quarry was located about 1000 feet southwest of the Blue Ridge Lime and Stone Company. The Fletcher Limestone Company took over the property formerly worked by the Blue Ridge Lime and Stone Company about 1936 and it has been in continuous operation since that time.

The Cogdill Limestone Company opened a quarry about 3500 feet southwest of the Fletcher quarry shortly after World War II and it too has been in continuous operation since that time.

Description of Workings

Transylvania County

Bear Wallow Creek.—A siliceous marble occurs on Bear Wallow Creek about six miles southwest of Rosman. This deposit was not visited during the present investigation but was described briefly by Watson and Laney (1906, p. 208) as outcropping prominently in the creek and on both sides in ridges that rise about 150 feet above the creek. The rock forms Limestone Ridge which is about 0.30 mile above the junction of Bear Wallow Creek with Toxaway River.

Prior to 1900 the marble was worked for a number of years and burned to lime for local use as building lime and fertilizer. The deposit is situated in a very inaccessible area and has not been worked for over 50 years.

Two other deposits occur near Rosman. One is located 1.5 miles northwest of Rosman on the North Fork French Broad River near the confluence of Diamond Creek. The other is located about 2.5 miles southwest of Rosman. Neither of these deposits were visited and there is no information available as to their extent or character.

Curitan (Simms) quarry.—These abandoned workings are located on the southeast side of State Highway 280 at Little Mountain Gap, 2.0 miles northeast of the intersection of this highway with U. S. Highway 64-276. An abandoned unpaved road joins the highway at about the crest of the gap and the workings are about 200 yards up this road.

It was reported (Loughlin, et. al., 1921, p. 71) that this deposit was worked in at least four places. However, the quarries have been abandoned for many years and the faces are now completely covered by soil moving down the steep slopes above the quarries. No outcrops of marble can be seen at present. The

openings are located on the northwest slope of a broad northeast trending ridge. The marble dips steeply to the southeast, or into the ridge, and the overburden is quite thick. This deposit was last worked in 1934 by a Mr. Simms and loose material sliding into the quarry from above was a great hindrance to the operation, finally causing its suspension (Ingle, 1947, p. 2).

The marble is dark blue and dolomitic. Much of it is stained yellow and brown along mud seams, joints and small tight fractures (Loughlin, et. al., 1921, p. 71). There is evidently a large tonnage of rock present in this deposit, but the overburden is so thick that open pit quarrying would probably not be practical.

J. W. McQuire property (Barnard quarry).—This quarry is located 0.2 mile southeast of State Highway 280, 4.1 miles northeast of the intersection of this highway with U. S. Highway 64-276, 0.80 mile southwest of the Henderson-Transylvania County line. The quarry site is reached by turning southeast onto a dirt farm road which dead ends at a house. The old workings are located about 100 feet northeast of the house.

This is the site of one of the oldest "limestone" quarries and kilns in the area and is referred to locally as the Barnard quarry. Rock was quarried here and burned into lime prior to the War Between the States and for many years after. However, no work has been done for a long time and the excavation is covered by slump material and a heavy growth of vegetation. Ingle (1947, p. 3) considered this to be one of the best potential quarry sites in the area—citing light over-burden, thick bedding, moderate dip, light blue color and sufficient elevation to avoid water problems as favorable factors. He also reports that the State Highway Commission drilled 16 feet below the quarry floor and found good "limestone" all the way.

Henderson County

Woodfin, Allison and Ezell quarries.—About 1.5 miles northeast of the Henderson-Transylvania County line, on the flood plain of a southeast flowing tributary to Boylston Creek, and on the northwest side of the State Highway 280, is the site of the old Allison quarry and kiln. The quarry has been abandoned for many years and the marble cannot be seen in place because alluvial material covers the whole locality. This quarry and two others which are located nearby were described by Watson and Laney (1906, p. 208) as follows:

"In Henderson County quite a large body of limestone occurs 7 to 10 miles west of Hendersonville, the county-seat, in the vicinity of Boilston. The limestone outcrops at intervals from about 3 to 5 miles northeast of Boilston to some distance above Brevard, the county-seat of Translyvania County. It is capped in many places by a schistose rock and is dipping approximately 45° SE. On the land of Mr. J. F. Woodfin, about ¾ of a mile a little east of south of the Boilston gold mine, limestone has been worked for a little over 200 feet along the strike. The limestone apparently contains very little grit and is of a bluish tinge known locally as "blue limestone". Considerable of this limestone has been burned to lime, some of which has been used for fertilizing purposes On the W. B. Allison farm, three-eights of a mile due west of the Woodfin quarry the limestone is whiter in color and is known locally as "white limestone", to distinguish it from the "blue limestone" of the Woodfin quarry. A similar quarry has been opened on Bryson Ezell's farm 3 miles northeast of Allison's. Considerable of the lime burned from this limestone has been used for building purposes."

In connection with these quarries it is significant to note the following observations: (1) they are all located on the flood plain of either Boylston Creek or one of its tributaries, (2) Boylston Creek flows from southwest to northeast, which is also the direction of the strike of the marble, and (3) the dip of the marble apparently changes from steep at the Curitan property to moderate at the Barnard quarry. In view of what is known about the geologic conditions in the Murphy belt, these factors strongly suggest that the flood plain of Boylston Creek is underlain with marble from just northeast of the Barnard quarry to possibly as far northeast as the old Ezell quarry or beyond.

Owing to the flood plain deposits which completely cover the bed rock, the only way this could be proved or disproved is by drilling. However, if the valley of Boylston Creek is underlain by marble, as believed, then this would represent a body of marble about 4 miles long and up to half a mile wide. The thickness of the marble is unknown in this area, but 100 feet, more or less, would not be unexpected.

Cogdill Limestone Company.—This quarry is located on Kimsey Creek about 2 miles by road southwest of Fletcher (TVA Map 193—NE). This is one of the two active quarries in the Brevard belt and has been in continuous operation since about 1946.

The rock quarried here is predominently a white, fine grained dolomitic marble whch is about 150 feet

thick. The average strike is about N 45° E and the dip about 45° SE. Closely spaced joints that strike N 45° W and N 10° E, badly fracture the rock. The marble is bounded on the northwest and southeast by a chlorite schist.

The quarry is being developed northeastward along the strike of the formation by standard open pit methods. Overburden is stripped off for a considerable distance in advance of the face. A single bench about 25 to 30 feet high is maintained. After the rock is blasted from the face, a ¼ yard power shovel loads two 6-ton dump trucks which haul the rock to the crushing plant. The crushing plant is located just outside the quarry at the southeast end and consists of a 20 by 36 inch jaw crusher, a gyratory secondary crusher and two sets of shaker screens. This set-up is capable of producing about 50 tons per hour of crushed stone that ranges in size from ⅜ inch up to 1½ inches. Most of the stone produced is used for road metal and concrete aggregate. Fines from the crushing plant are further processed and used as agricultural lime, but this amounts to only a small percentage of the total production.

Fletcher Limestone Company. — This quarry is located on Kimsey Creek about 1.3 miles by road west of Fletcher and about 3500 feet northeast of the Cogdill quarry. This is also the site of the old Blue Ridge Lime Company, but their original quarry lies about 200 feet southwest of the present quarry and is now filled with water. Prior to the Blue Ridge Lime Company, the Lance quarry was located in the same area and its production dates back to or early as 1835 (Loughlin, et. al, 1921, p. 68).

The Fletcher quarry is more extensive than the Cogdill quarry and practically the whole thickness of the marble has been exposed. The southeast side of the quarry extends almost to the contact with the adjacent rock. The marble on this side is predominently bluish white and fine grained. The beds range from less than a foot to about 2 feet in thickness and are badly fractured by joints. The middle portion of the quarry is occupied mostly by white, fine grained marble. The northwest side is composed of a bluish white, fine grained marble very similar to that in the southeast side.

All of the quarry is below average ground level and Kimsey Creek has been diverted around the southeast side of the opening. Excessive water is sometimes a problem and three large pumps are used to control it. The quarry has been advanced northeastward along the strike and is about 1500 feet long and averages about 200 feet wide. The depth to which the marble has been quarried varies between 40 and 60 feet.

The walls of the quarry are advanced by bench drilling with wagon drills and shot in small sections. Primary breakage is not too good and a drop-ball is used for secondary breakage. Quarry equipment seen on the ground at the time of inspection included two wagon drills, three jack hammers, two air compressors, six dump trucks, one ¾ yard power shovel, one ⅜ yard power shovel, one ¾ yard drag line, one front end loader and one bulldozer.

The primary crushing and screening plant is located on the floor of the quarry and is modern and efficient in most respects. The quarry rock is dumped on a traveling roll grizzley and minus 4 inch rock drops through to a conveyor belt. Plus 4 inch rock goes to a 24 by 36 inch jaw crusher. Two 24 inch conveyor belts in series discharge to a double-deck shaker screen. Plus 2 inch rock is returned to the jaw crusher by chute. Plus 1¼ inch minus 2 inch rock passes through a 22 x 40 roll crusher. The discharge, together with the minus 1½ inch rock, which bypassed the rolls, is taken by a 24 inch belt conveyor to a 36 inch short-head cone crusher and final screen outside the quarry.

Production from this set-up was reported to be about 125 tons per hour. However, another 22 by 40 roll crusher was being added to the primary crushing plant at the time the quarry was visited. This addition plus several other adjustments was expected to increase the production to 150 tons per hour.

The main product from this quarry is crushed stone, practically all of which is used by the State Highway Commission for road material. Other uses include crushed stone for concrete aggregate, private roads, driveways, etc. Prior to World War II, considerable lime was burned here for agricultural and building purposes. Owing to the war time shortage of fuel and labor the production of lime was discontinued and as yet has not been resumed.

B & C Lime and Stone Company.—This quarry is located along strike and about half way between the Cogdill and Fletcher quarries. This company was in operation from 1926 to about 1936. The quarry has been inactive since that time and is now filled with water. While the quarry was active it produced lime and crushed stone from the same rock that is now being used at the above active quarries.

Buncombe County

Pinner Creek.—On the flood plain of Pinner Creek, 0.5 mile northwest of the Buncombe-Henderson County line between the creek and the Southern

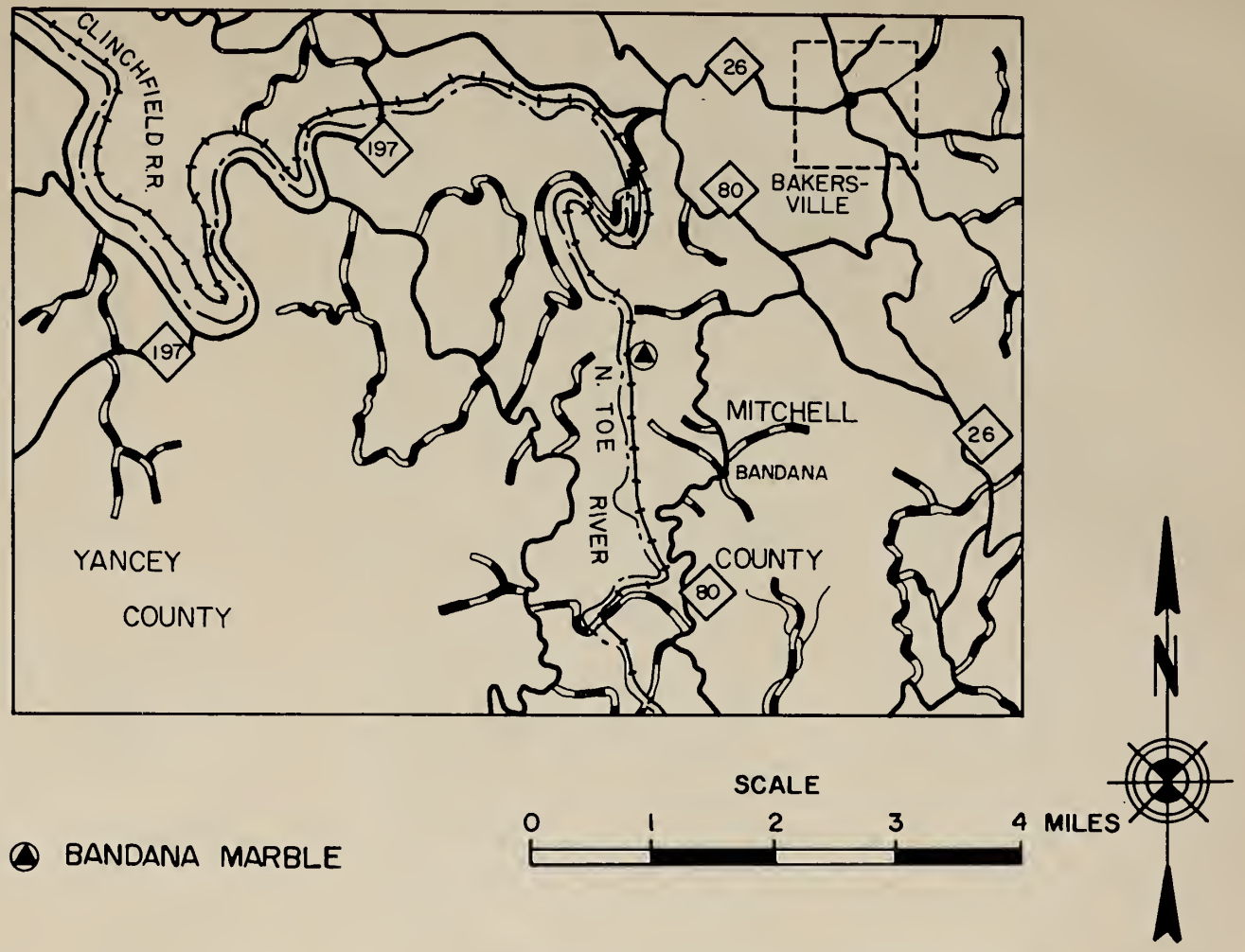


FIGURE 8.

MAP SHOWING
LOCATION OF BANDANA MARBLE

Railway tracks, is the site of a small quarry that was worked many years ago. The excavation has been backfilled and leveled over and all that can be seen now are a few pieces of light colored marble scattered around in the soil. It is possible that a considerable amount of marble underlies the alluvial along the creek.

Robinson Creek.—On the west side of Robinson Creek where the road to Christ School crosses the creek is the site of another small abandoned quarry. The excavation has filled with water, is heavily overgrown with vegetation and no marble can be seen in place. About 600 feet east of the quarry site, on the east side of the paved road to the Asheville-Hendersonville airport, are the remains of a kiln where the marble was burned to lime.

Groves Lake.—This abandoned quarry is located 0.8 mile northeast of the Robinson Creek site on Merrill Cove Creek. The best preserved kiln seen in the area is located at the north end of the lake on the west side. The lake is apparently the site of the old quarry but no rock can be seen in place.

Gravel Creek.—The most northeastern point where the marble in the Brevard belt is known to have been worked is just southeast of where Gravel Creek crosses the road between the Asheville-Hendersonville airport and Fairview. Residents report that "limestone" was quarried here about 50 years ago, but all signs of the old workings are now completely obscured.

Mitchell County

Bandana dolomite marble.—The only known occurrence of carbonate rock in Mitchell County is located on the east side of the North Toe River, 1.3 miles northwest of Bandana. The deposit can be reached by turning northwest onto the first unpaved road northeast of the post office in Bandana and traveling 1.1 miles to the end of this road. From this point follow a small west flowing creek to the Clinchfield Railroad tracks. Walk north along the railroad for about ½ mile, or to the first creek on the east side of the tracks. The marble is exposed in the railroad cut about 200 feet south of the creek.

The deposit is composed of a white, uniformly coarse grained dolomite marble. It is associated with a series of alternating layers of fine to medium grained quartz biotite gneiss and muscovite schist which Keith (1905) mapped as Carolina gneiss. The entire series, including the marble, is cut by an irregular pegmatite dike.

As seen in the railroad cut, there are two distinct layers of marble. The upper layer is about 60 feet thick and is separated by about 15 feet of gneiss from the lower layer of marble, which is about 10 feet thick. All of the contacts between the gneiss, schist, marble and pegmatite are sharp and no transition between the rock types is apparent. The marble, as well as the enclosing gneiss and schist, strikes about N 65° E and dips 50° —55° SE. The marble is massive, free from joints, and the only impurities noted were a few stringers of quartz and some actinolite and serpentine. Chemical analyses show that the marble closely approaches the composition of pure dolomite and that it is also unusually low in acid insolubles.

The marble is not continuously exposed along strike, but has been traced northeast of the roalroad and river by prospect trenches and pits and boulders protruding above ground level for some 2000 feet. It is also exposed in a narrow zone about 18 feet wide on a hill above a small creek about 1800 feet northeast of the railroad. No outcrops of the marble are known to occur on the west side of the river. It has been conservatively estimated (Hunter and Gildersleeve, 1946, p. 28) that the Bandana deposit contains at least 500,000 tons of high-grade dolomite marble. This estimate was based on an average outcrop width of 25 feet and a downward extension of 100 feet below railroad level.

This deposit is favorably situated for quarrying, being well above the river and next to the railroad. Also, it is uniform in color and contains few impurities. The principal disadvantages are the presence of the pegmatite dike, which is reported to extend the whole length of the marble (Watson and Laney, 1906, p. 204), and the distance from a large market.

Ashe County

Horse Creek deposit.—A deposit of moderately coarse grained white marble, containing small grains and lenses of magnetite, is located on Horse Creek near Lansing, in Ashe County. It is situated next to the Norfolk and Western Railroad about 1.2 miles southeast of Lansing.

This locality was not visited during this investigation, but the deposit was worked for iron ore by the Ashe Mining Company in 1920 and was described in detail by Bayley (1923, p. 183-197). The marble is associated with a coarse grained, quartz-feldspar-mica gneiss and mica and hornblende schists. It strikes N 35° E and dips 40° SE.

About 0.3 mile northeast of the railroad station in Lansing and 0.75 mile N 20° E of the deposit on

FIGURE 9

SECTION OF BANDANA DOLOMITE MARBLE
IN MITCHELL COUNTY, NORTH CAROLINA

FIGURE 10.

MAP SHOWING LOCATION OF SHADY DOLOMITE IN McDOWELL COUNTY

Horse Creek, is another old iron ore prospect pit in which marble was found in association with gneisses (Bayley, 1923, p. 194).

McDowell County

General Statement

There are two types of lime bearing rocks in McDowell County. The first, and only one that has been of commercial value, is an elongate area of Shady dolomite which occurs along the North Fork of the Catawba River in the northern part of the county. The other is a series of disconnected outcrops of siliceous marble, or recrystallized limestone, that occur along the Catawba River between Greenlee and Lake James. This siliceous marble was only recently discovered, and although some exploratory drilling has been done its potential as a commercial deposit is still uncertain.

Shady Dolomite

The Shady dolomite occupies three areas in the northern part of the county. The northernmost and largest area extends for about 12 miles from Sevier northward along the North Fork of the Catawba River and U. S. Highway 221 to just south of Linville Falls. The second begins at Woodlawn and underlies part of the flat area of Turkey Cove and the lower part of the ridge on the south side of the cove. It forms an area roughly circular in outline and about one mile in diameter. The third is a small body located 2 miles southeast of Woodlawn where the Clinchfield Railroad crosses the river. This body of dolomite is situated in a very remote and inaccessible part of the county, and as it is practically eliminated from any commercial development it will not be discussed further.

As described and mapped by Keith (1905) and Keith and Sterrett (unpublished) the Shady dolomite in McDowell County consists of white, gray and bluish gray beds of fine to medium grained recrystallized dolomite or marble. The calcium carbonate content ranges from 52 to 62 percent and the magnesium carbonate from 33 to 41 percent (Loughlin, et. al., 1921, p. 56). The layers are thick and massive and badly fractured by closely spaced joints. The beds near the base of the formation contain considerable amounts of silica in the form of detrital quartz grains and chert and some have a high content of iron. Beds in the upper part of the formation are generally less impure than the lower beds, but quartz, pyrite, iron carbonate, feldspar and mica have been noted as excessory minerals (Loughlin, et. al. 1921, p. 57-58).

Considering the total area underlain by the dolomite, outcrops are relatively rare. The base and lower part of the formation are exposed at several places along the North Fork of the Catawba River and U. S. Highway 221 between Ashford and Linville Falls. In places the dolomite is present for at least 200 feet up the west side of the steep slope next to the North Fork, but is almost completely covered by overburden and a thick growth of timber. The best exposure of dolomite along the North Fork is at Linville Caverns on the west side of U. S. Highway 221 about 3 miles south of Linville Falls. Above and behind the caverns the formation has developed a narrow ridge about 2500 feet long and 1250 feet wide. Along the small valley which parallels the western side of the ridge is a completely exposed section of the upper two thirds of the formation (Hunter and Gildersleeve, 1946, p. 27). About 0.75 mile north of the caverns on the southeast end of a northwest trending ridge, is an extremely shattered zone of dolomite about 75 feet wide in which galena occurs in association with several small quartz veins. The dolomite overlying this galena-bearing zone is about 250 feet thick and is much whiter than any other dolomite exposed along the North Fork (Hunter and Gildersleeve, 1946, p. 27).

The Shady dolomite in McDowell County, like the Shady dolomite in the Hot Springs area, is involved in a complicated structural unit that disrupts the normal rock pattern of the Blue Ridge belt in the Grandfather Mountain area. The Shady dolomite, part of the underlying Chillowee group, possibly rocks equivalent to the Ocoee series, and igneous rocks and gneisses of Precambrian (?) age have been folded and faulted into a unique structure known as the Grandfather Mountain window. Although Keith (1903, 1905) and Keith and Sterett (unpublished) were unable to map a fault continuously around the complex southeastern side of the area, the structure has been interpreted by many geologists as a window. Recent mapping in the area by members of the United States Geological Survey (Bryant and Reed, 1959) has confirmed this hypothesis that sedimentary and igneous rocks in the Grandfather Mountain area are exposed in a window beneath an overriding plate of crystalline rocks.

History of Production

Outcrops of "limestone" along the valley of the North Fork of the Catawba River were noted by Kerr in 1875. However, the presence of the dolomite

was undoubtedly known to the local residents long before this. Small amounts of "limestone" were burned in beehive kilns for local use at several places in the area. Kilns are known to have been located along Limekiln Creek, in the Turkey Cove area, and on the North Fork about 1.5 miles north of Linville Caverns. There are no records to indicate when these kilns were active, but some of them were very likely in use prior to the War Between the States.

The first attempt to utilize the dolomite for anything other than burning to lime was made a few years prior to 1890 when the North Carolina Geological Survey conducted an extensive drilling program on the plantation of Col. J. G. Yancey. The purpose of this exploration was to locate a marble deposit suitable for dimension stone. Records made at the time this work was done state that although much of the rock was too badly fractured by joints for use as a dimension stone, portions of it were fairly free from joints and would be well adapted for use as a building and ornamental stone (Lewis, 1893, p. 97-98). Owing to the lack of railroad transportation and other unfavorable economic factors no development work was done on this deposit for dimension stone.

Shortly after the Carolina Clinchfield and Ohio Railroad completed its line from Marion, North Carolina to Johnson City, Tennessee, the first commercial quarry was opened in the Shady dolomite. This was the Clinchfield Lime Company quarry which was opened in 1916, and was located a few tenths of a mile north of Ashford on the west side of North Fork. Production from this quarry consisted of crushed stone and agricultural lime. The quarry was worked by the Clinchfield Lime Company until 1925, after which it was idle until the Campbell Limestone Company took over the property and produced crushed stone for a few years prior to World War II. The quarry has not been worked since about 1940.

In the mid 1930's the State Highway and Public Works Commission obtained an option on the dolomite deposit on the Yancey Estate at Woodlawn. After investigations by the State Geologist and Mr. Frank L. Hess, U. S. Bureau of Mines, the commission purchased the property and opened a quarry to furnish crushed stone for road construction and maintenance and agricultural lime. This quarry has been in continuous operation since 1937 and is still owned and operated by the State Highway Commission.

Description of Workings

Woodlawn quarry (State Highway Commission).— This quarry is located on the south side of Turkey Cove about 0.5 mile south of Woodlawn. It is about 0.25 mile east of U. S. Highway 221 and 7.5 miles north of Marion, North Carolina.

The quarry has been developed southward into the face of a large hill which rises some 600 feet above the level of the cove. It is roughly rectangular in shape with the north end open. The east and west faces are about 360 feet long and the south face about 240 feet wide. Height of the faces vary from 180 feet in the southeast corner to 200 feet on the west side.

Fine grained, bluish-gray dolomite is the predominant rock type, but dark blue, pink and white beds are also present. Thickness of the beds range from a few inches to several feet and all are badly fractured by closely spaced joints. Owing to an undulating effect, the dip varies considerably but averages about 10° to the southeast. This is well displayed in both the east and west faces which have been developed about parallel to the dip.

Quarrying is advanced by drilling a line of 8 inch churn drill holes parallel to and 20 feet back from the south face. The holes are drilled several feet below the level of the quarry floor and the entire face is blasted simultaneously. A very large tonnage of rock is dislodged at one time, reported to be almost enough for one year's production, but primary breakage is poor. Considerable secondary breakage is necessary and this is done with jack hammers and a wagon drill.

A power shovel is used in the quarry to load the rock on two dump trucks which haul it to the crushing plant. The plant is located just outside the quarry at the north end and consists of a 20" x 36" jaw crusher, a 40" roll crusher, triple deck screens (12 feet) a washing system and storage bins. This set-up is reported to be capable of producing up to 100 tons per hour of $\frac{5}{8}$ inch and under crushed stone. All of the stone produced is used by the State Highway Commission for road construction, maintenance and asphalt filler.

When the quarry was first opened it was proposed that the Highway Commission sell agricultural limestone at cost as a by-product from the quarry operation (Bryson, 1937, p. 112). This would have made limestone available to the farmers of North Carolina at a considerable savings. However, since the quarry has been in operation only a comparatively small amount of agricultural limestone has been produced.

Clinchfield Lime Company (inactive).—This quarry is located along the steep bluff on the west side of the North Fork of the Catawba River a few tenths of a mile north of Ashford and 16.5 miles by road north of Marion. The quarry can be reached by turning west off of U. S. Highway 221 onto an abandoned road, which is located 0.4 mile north of where the Clinchfield Railroad crosses over U. S. Highway 221 at Ashford. The road now dead-ends at the creek, but the quarry is only a few hundred yards west of the creek.

When the quarry was opened in 1916 it was equipped with a gyrating crusher with a capacity of 300 tons per day and a rock pulverizer having a capacity of 150 tons per day. Crushed stone was gravity loaded from storage bins into standard gauge cars. The cars were moved by gravity to the main line of the Clinchfield railroad on a spur track 3000 feet long (Loughlin, et. al., 1921, p. 60).

The dolomite dips to the west, or into the bluff, at a low angle. Most of that exposed in the quarry face is a fine grain, dark-blue dolomite, but beds of white and light-gray dolomite are also present. Individual beds range from less than a foot to 3 or 4 feet thick, and are fractured by closely spaced joints. Quartz is the most common impurity, but pyrite and chlorite are also present.

The quarry was developed into the face of the buff and is about 200 feet wide and has a face well over 100 feet high in places. As mentioned above, the dolomite dips into the bluff and as the face was advanced the overburden became greater. This was probably the main reason the quarry was abandoned in 1925. When the quarry was last worked by the Campbell Limestone Company most of the rock quarried was taken from the south end of the face. An opening was started at floor level and advanced into the old quarry face for about 30 feet. On the outside the excavation is about 40 feet high and 40 to 50 feet wide.

There appears to be an unlimited amount of dolomite present at this abandoned quarry, but the increasing amount of overburden prohibits the use of ordinary bench-type quarrying methods. Any future large scale quarrying done at this site will eventually have to use underground methods.

Siliceous Marble Along the Catawba River

General Statement

During the course of field work for this report an interesting occurrence of crystalline limestone, or marble, that had not previously been reported was called to the writer's attention by Mr. Carter Hudgins of Marion, North Carolina. The marble occurs in a series of four outcrops that are in almost perfect alinement. The most southern outcrop is located near Greenlee, 5.1 miles southwest of Marion. The other three lie next to, or very close to, the Catawba River in a N 55° E direction over a distance of about 7 miles to Lake James.

General Geology

The area in which the marble occurs lies mostly within the Mt. Mitchell 30′ quadrangle. As mapped by Keith (1905) and Keith and Sterrett (unpublished) the marble outcrops lie entirely within a large mass of "Carolina gneiss" which begins in the vicinity of Old Fort, strikes northeast across the southeast corner of the Mt. Mitchell quadrangle and continues across the Morganton quadrangle. On the northwest side the "Carolina gneiss" is bounded by a belt about 3 miles wide of Henderson granite gneiss. To the northeast, the Henderson granite gneiss gives way to the Lower Cambrian siliceous and carbonate rocks which form part of the Grandfather Mountain window.

In the Mount Mitchell folio, Keith describes the Carolina gneiss as being, in part, of sedimentary origin and containing small lenses of marble. However, the only marble he specifically mentions is that in the Toe River near Bandana in Mitchell County. Keith evidently did not see the marble outcrops in question; however, this is understandable because it is likely that they were not exposed during the time he was mapping in the area. All of the outcrops except part of one are exposed in roadcuts that have been made since about 1920.

Description of Marble

Although the outcrops are as much as three miles apart, all of the marble is very similar in texture and composition, and there is little doubt that all of the outcrops are closely related and belong to the same "formation".

The marble is fine to medium grained and is either light to medium gray or dark bluish gray in color. On a fresh surface the dark bluish gray variety is streaked with thin stringers and lenses of irregularly spaced white quartz. Upon weathering the difference in the hardness of quartz and marble results in an irregular and rough surface. In addition to the quartz stringers there are also individual grains of quartz scattered through the marble. At two of the outcrops where the top of the marble is exposed, the upper two to three feet contain abundant, irregular

FIGURE 11.

OUTLINE MAP OF MARION AREA
SHOWING MARBLE OUTCROPS

shaped lenses and nodules composed of quartz and/or feldspar. Their size ranges from less than an inch to a foot or more in length or diameter. These nodules and lenses are secondary in origin and were evidently formed at the time of recrystallization.

Muscovite mica is also a conspicuous excessory mineral. It occurs dissminated through the marble and much of it is 1 mm. or more in diameter. In thin section the gray marble contains several percent of irregular shaped and broken feldspar grains, but only a very few grains of feldspar were present in the blue marble examined.

At only one outcrop can the relationship of the marble to the overlying and underlying rocks be seen. This section is located on the northeast side of a paved county road 2 miles northwest of Marion. Here the marble strikes N 35° E and dips 5° to 20° SE. It varies from dark bluish gray to medium bluish gray and is fine grained, micaceous and siliceous. The upper 40 feet of the marble are well exposed but the lower part is covered by a thick mantle of soil.

Immediately overlying the marble is a thin zone of dark reddish brown silty material. It ranges from a few inches to 2 feet in thickness and its thickness changes very abruptly across strike. This material could possibly be a fossil soil preserved on an old erosion surface, but it appears most likely to be a residuum derived from the irregular weathering of the marble.

Overlying the residuum and in places directly in contact with the marble is a thick sequence (in excess of 100 feet) of white to light gray layered rocks that strike N 35° E and dip 5° to 30° SE. The individual layers range from a few inches up to 1.5 feet in thickness. The rock is composed mostly of quartz and feldspar with minor amounts of mica and garnet. It is predominantly fine to medium grained but contains layers up to a foot thick that are composed of coarse grains of feldspar and quartz imbedded in a fine-grained matrix of quartz, feldspar and mica. The coarse grains range from 2 to 30 mm in their longest dimension, which is usually parallel to the layering. Although many of them are augen, or eye-shaped, some are subhedral to anhedral and a few are spherical. These coarse grains are predominantly feldspar.

In thin section the rock has a cataclastic structure and is composed of approximately 68 percent quartz and 29 percent feldspar, which includes orthoclase, microcline, and plagioclase. The remaining 3 percent is about equally distributed between muscovite and garnet. Most of the quartz occurs as a very fine grained matrix of irregular shaped, interlocking grains. The feldspars are present as coarser-grained augen, up to 5 mm. and fine irregular shaped grains scattered through the matrix.

Based on the field relationships and limited thin section study this rock is thought to be a feldspathic quartzite which is genetically related to the marble. However, it has been suggested by other geologists who have examined the outcrops that the rock in question may be highly cataclastic pegmatites rich in potash feldspar. This question of classification can be resolved only by a more detailed petrographic study.

The contact of the marble with the underlying rock cannot be seen because of the weathered condition of the rocks and a thick mantle of soil. There is a covered interval of about 115 feet between the lowest bed of marble and the first exposure of the underlying rock. The upper 12 feet of the underlying rock consists of a series of alternating layers of quartzite and very fine grained quartz gneiss which strikes N 65° E and dips 35° SE. The quartzite layers are 3 to 4 feet thick, white to buff colored and micaceous. The gneiss layers are 2 to 3 feet thick, dull greenish gray colored and are composed mostly of fine-grained quartz with lesser amounts of feldspar, mica and garnet. The lowest layer of gneiss grades downward into a thick section of crenulated garnetiferous-chlorite schist.

Location of Outcrops

For the purpose of describing the location of the outcrops they have been numbered 1, 2, 3 and 4 from northeast to southwest.

Outcrop No. 1.—This outcrop is located on the north side of a paved county road, 2.7 miles north of Marion. It can be reached by traveling northwest from Marion on U. S. Highway 221 for 0.5 mile past the junction of U. S. 70 and 221. Then turn northwest (right) onto a paved county road and travel for 2.1 miles to an unpaved county road and thence southeast (right) on an unpaved road for 0.9 mile. Where the unpaved road interesects the paved county road, turn east (left) onto a paved road. The outcrop is located on the north (left) side of this road, 0.4 mile from the intersection. It consists of a single, large block of gray marble, the base of which is about 12 feet above road level.

Outcrop No. 2.—This outcrop is located on the northeast side of a paved county road, 2 miles northwest of Marion. It can be reached by traveling northwest from Marion on U. S. Highway 70 for 0.8 mile past the junction of U. S. 70 and 221. Just before U. S. 70 crosses the Catawba River turn southeast

(left) onto a paved county road. The outcrop is on the northeast (left) side of this road, 0.4 mile from U. S. 70. This is the best outcrop of the four and is the only one in which both the rocks that overlie and underlie the marble can be seen.

Outcrop No. 3.—This outcrop is located on the south side of an unpaved county road and in the south bank of the Catawba River, 2.9 miles west of Marion. It can be reached by traveling northwest from Marion on U. S. Highway 70 for 1.75 miles past the junction of U. S. 70 and 221. Just before State Highway 80 intersects U. S. 70 turn south (left) onto an unpaved county road and travel 0.4 mile to the Catawba River. Cross the river and turn west (right); the outcrop is 100 feet west of the bridge.

The outstanding feature of this outcrop is the presence of an apparent fault. In the road cut the upper 3 feet of the marble is exposed. This is overlain by a massive layer of feldspathic quartzite. This same sequence is repeated in the river bank. There is a vertical displacement of 25 feet between the top of the marble in the road cut and in the river bank. The angle of the fault plane could not be determined but the fault is apparently normal.

Outcrop No. 4.—This outcrop is located on the northeast side of an unpaved county road, 5.1 miles southwest of Marion. It can be reached by continuing west and southwest on the same road from outcrop No. 3 for 2.3 miles to Greenlee and turning southeast (left) and crossing the Southern Railway tracks. At this point the road forks, take the south (right) fork and continue on this road for 0.9 mile to the outcrop. The exposure is in the drainage ditch and road bank on the northeast (left) side of the road. It consists of a single block of light gray marble about 3 feet high and 5 feet long.

Exploratory Drilling

During the winter of 1958-59 seven exploratory holes were drilled along the strike of the marble. The holes were drilled between outcrops number 4 and 2 and were done under the supervision of Mr. Earl C. VanHorn, Consulting Geologist. Two of the holes were drilled on top of the ridge above outcrop number 4, two were in the first creek valley northeast of outcrop number 4 and two were in the valley of the second creek northeast of outcrop number 4. The last hole was drilled a short distance up the slope above outcrop number 2.

All of the holes encountered the marble at depth, but the only one for which a log is available is the one at outcrop number 2. The log was furnished by Mr. Van Horn and is as follows:

Depth	Interval	Description of core
0.0- 25.0	25	Overburden
25.0- 67.5	42.5	Fine-grained quartzite, nx. core has calcareous quartz - mica gneiss from 57.0 to 58.8 dips 5 to 15 degrees.
67.5-197.0	129.5	Impure marble. Has occassional quartz stringers to 79.0 ft. Dips 5 to 15 degrees.
197.0-213.4	16.4	Calcareous-quartz-mica gneiss. Dips 15 degrees.
216.3-219.6	3.3	Calcareous-chlorite gneiss. Dips 30 degrees.
219.6-223.0	3.4	Quartz-chlorite gneiss.
223.0-227.0	4.0	Calcareous-quartz-mica gneiss. Dips 15 to 30 degrees.
227.0-249.7	22.7	Quartz-chlorite gneiss. Pyritic. Dips 45 degrees.
249.7		Bottom

Chemical analyses from the marble section of this core were made on three foot composite samples. In the 41 samples analyzed the SiO_2 content ranged from 26.76 to 61.08 percent, the R_2O_3 from 11.60 to 24.90 percent, the $CaCO_3$ from 13.18 to 55.39 percent and the $MgCO_3$ from 0.84 to 7.41 percent. The average of the 41 samples gave: 38.36 percent SiO_2, 15.77 percent R_2O_3, 40.73 $CaCO_3$ and 5.14 percent $MgCO_3$. These chemical analyses were also furnished through the courtesy of Mr. Van Horn.

Significance of Alinement of Outcrops

As previously mentioned, the four outcrops are spaced over a distance of 7 miles and form a conspicuous alinement that strikes N 55° E. Enough detail work has not been done in the area to fully explain the reason for this alinement, but one possible explanation is that the outcrops lie along the trace of a major fault. Evidence to support this is; (1) the conspicuous alinement of the outcrops, (2) local faulting at outcrop number 3, (3) the proximity of all the outcrops to the Catawba River, and (4) the absence of any marble northwest of the alinement. Detail geologic mapping now in progress by the United States Geological Survey northeast of and along the strike of the alinement will probably prove whether or not a major fault passes through the area.

Another possible explanation for this alinement is that the outcrop pattern is somewhat coincidental.

Six of the diamond drill holes, located between outcrops number 4 and 3, penetrated the marble at depth. By projecting up dip, the area in which the marble should outcrop was in each case covered by soil or stream alluvium. If the marble was exposed in these areas by natural processes, then the alinement of outcrops now present from road cut exposures would be somewhat altered.

Economic Possibilities of Marble

Although this particular occurrence of marble is highly interesting and significant from a scientific or geological viewpoint, its potential as a commercial rock is limited. As indicated by the drilling already done, if there is a large enough tonnage present to supply a mining operation it would be present at depth and would have to be removed by underground methods. A comprehensive drilling program would first have to be carried out to determine the size, shape and orientation of the marble at depth.

Of equal importance is the chemical composition of the marble. Its high content of SiO_2 and R_2O_3 automatically eliminates it for many uses as an industrial rock. A demand for and a use to which this particular marble is suited would first have to be found before an expensive drilling program could be justified.

Kings Mountain Belt

General Statement

The Kings Mountain belt is comprised of a narrow zone of steeply dipping metamorphosed sedimentary rocks that extends from just south of Gaffney, South Carolina, northeastward almost to the Catawba River in North Carolina, a distance of about 50 miles. It enters North Carolina in Cleveland County just east of Grover, passes northeastward between Kings Mountain and Bessemer City, crosses the northeast corner of Gaston County and continues across the central part of Lincoln County between Lincolnton and Iron Station. It continues into Catawba County for about 8 miles where it terminates just northeast of Bandys Crossroads.

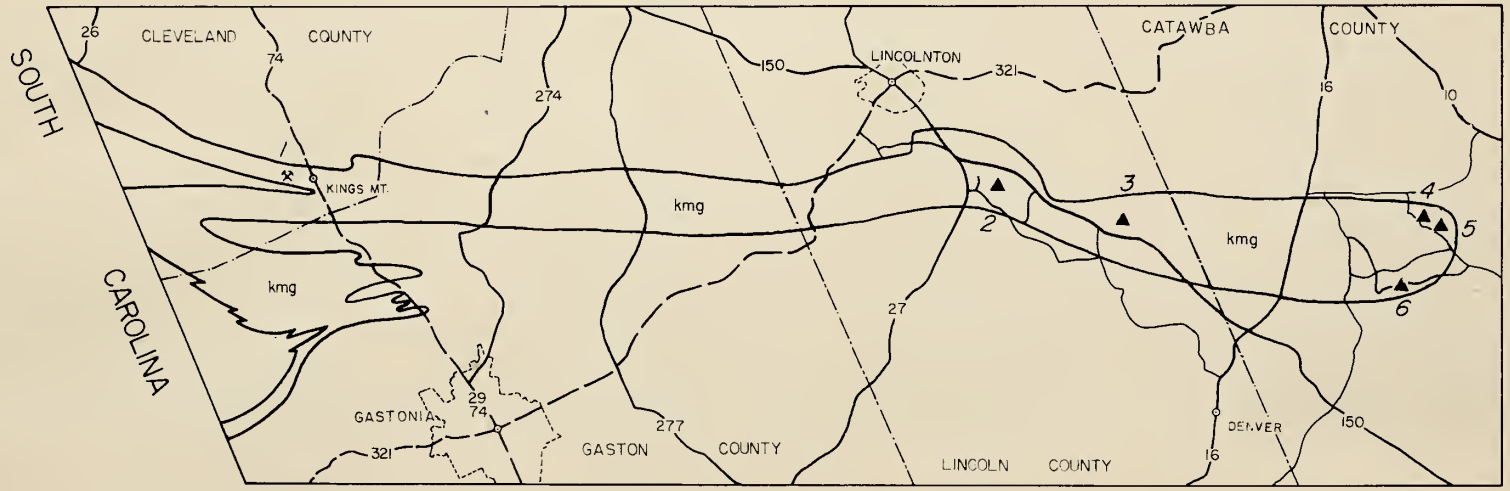
The rocks in the Kings Mountain belt consist of quartzite, schist, volcanics, crystalline limestone and dolomite and calcareous metashales. On the east and west sides, the belt is bordered by more highly metamorphosed gneisses and schists which have been intruded by large, irregular bodies of granitic rocks.

The southwestern one-half of the belt was mapped by Keith and Sterrett (1931) and they considered that the rocks in the belt to be metamorphosed Paleozoic sediments lying unconformably on the adjacent crystalline rocks of Precambrian age. They assigned them to the Cambrian system and named the formations in ascending order; the Kings Mountain quartzite, Blacksburg schist and Gaffney marble. Underlying this sequence of Cambrian rocks is the Battleground schist, which is also composed of metamorphosed sedimentary rocks, but thought to be considerably older (Algonkian—Late Precambrian). Also intimately associated with the metasedimentary rocks are large bodies of hornblende-biotite gneiss and muscovite schist and gneiss which were mapped as Roan gneiss and Carolina gneiss of Archean age (Early Precambrian). The overall structure of the belt was interpreted as synclinal and they mapped numerous longitudinal faults, particularly along the northwest side.

Kesler (1942, 1944, 1955) mapped a part of the belt in the Kings Mountain area in more detail and his interpretation of the structure and correlation of the formations differs considerably from that of Keith and Sterrett. According to Kesler's mapping most of the rocks that Keith included in the Battleground schist and Kings Mountain quartzite were grouped as siliceous metasediments. These siliceous rocks form the higher elevations and prominent ridges that are characteristic of the belt and often called mountains. A younger group of calcareous metasediments consisting largely of crystalline limestone, dolomite and calcareous metashales were grouped to include part of the Battleground schist, Kings Mountain quartzite, Blacksburg schist and Gaffney marble.

Layered gneisses and schists mapped by Keith as Carolina gneiss, Roan gneiss and the finer grained parts of the Bessemer granite were grouped as non-unifrom layered rocks. Kesler (1955, p. 379) believed these rocks were derived from the siliceous and calcareous metasediments but metamorphosed to such a degree that their original sedimentary character is not readily evident. Furthermore, that south of the town of Kings Mountain the calcareous metasediments grade unevenly westward into the series of non-uniform layered gneisses and schists.

Uniform unlayered rocks consisting of feldspathic gneisses with weak foliation and little or no layered structure were mapped by Kesler as the equivalent of the coarser parts of Keith's Bessemer granite. These rocks are enclosed in the non-uniform layered gneisses and schists and may have been derived from the more uniform parts of the original rocks, possibly thick bedded shales or tuffs (Kesler, 1955, p. 379).



LEGEND

- KINGS MOUNTAIN GROUP (kmg)
- ⚒ ACTIVE QUARRY
  - 1. KINGS MOUNTAIN QUARRY
- ▲ ABANDONED QUARRIES
  - 2. FINGER QUARRY
  - 3. KEENER (BEAL) QUARRY
  - 4 SETZER QUARRY
  - 5. OLD LIMESTONE QUARRY OF CATAWBA COUNTY- (POWELL QUARRY)
  - 6. SHUFORD QUARRY

SCALE

0 1 2 3 4 MILES

FIGURE 12.

MAP SHOWING
OUTCROP AREA OF KINGS MOUNTAIN GROUP

Whereas Keith and Sterrett (1931) interpreted the overall structure of the belt as synclinal, Kesler believes the major structure to be a rather tightly compressed anticline whose core includes the siliceous metasediments. The limbs of the anticline would include the non-uniform layered rocks and the uniform unlayered rocks. All of the original sediments were recrystallized to the condition of the rocks in the siliceous and calcareous groups, and parts of them were further metamorphosed to layered and unlayered schists and gneisses in proximity to the regional intrusives (Kesler, 1955, p. 381).

Marble in the Kings Mountain Belt

Two distinct types of marble occur in the Kings Mountain belt. At several places beds of dolomitic marble, 1 to 20 feet thick, are interlayered with mica schists which Keith and Sterrett (1931) mapped as Carolina gneiss. The best example of this is at the old Kings Mountain gold mine, located about 2 miles south of the town of Kings Mountain and 1.5 miles west of the Pinnacle where gold bearing quartz veins are associated with beds or lenses of fine to medium grained white to blue and gray banded dolomitic marble (Keith and Sterrett, 1931, p. 8). Although this deposit was worked intermittently from 1834 to 1913 for gold, no attempt has been made to use the marble.

The other type is the Gaffney marble which was so named by Keith and Sterrett (1931, p. 6) for the exposures in the quarries near Gaffney, South Carolina. It occurs as discontinuous beds, or lenses, for the entire length of the belt. From Gaffney to Grover there are two more or less parallel beds of marble, but from Grover northeastward through the town of Kings Mountain to just southwest of Bessemer City only one bed has been recognized. However, in Lincoln and Catawba Counties two parallel marble bearing zones are again present, as revealed by outcrop pattern and drilling along the strike of the Big Ore Bank.

The Gaffney marble is for the most part very fine to medium grained and varies in color from dark bluish gray to white. It usually has a moderately steep to steep dip to the northwest and much of it is schistose. In composition the marble varies considerably, some beds are high calcium marble, but most of it is dolomitic. Thin beds of mica schist are interbedded with the marble, and are particularly common near the contacts with the adjacent rocks. Close to the contacts, impurities such as quartz, mica, hornblende, epidote, chlorite and pyrite become increasingly abundant and the marble grades into layered schists and gneisses.

The thickness of the marble ranges from less than 50 feet to 800 feet (Kesler, 1955, p. 386). As the marble is more soluble than the rocks with which it is associated, it usually forms low ground and outcrops are rare. Where outcrops are present they are always adjacent to or in creek beds.

History of Production

Included in the Kings Mountain belt are a series of magnetite iron deposits that occur intermittently for the entire length of the belt. These deposits lie east of the marble and are best developed in the southwestern part of Gaston County and in Lincoln and Catawba Counties. At one time these deposits were worked extensively and were the principal source of domestic supplies of iron in North Carolina (Kerr, 1875, p. 251).

One of the most productive areas in this belt was the old magnetite ore bank, which extends from a point about 3 miles northeast of Iron Station in Lincoln County to Anderson's Mountain in Catawba County, a distance of 9 miles. On this ore-belt iron ore was mined and smelted from the time of the Revolutionary War until 1882 (Nitze, 1893, p. 88). The ore was smelted in Catalin forges and small charcoal furnaces, several of which are still standing.

During the time the iron was being mined and smelted, several quarries were opened in the adjacent marble formation and furnished fluxing material for smelting the iron. The best known of these early quarries were the Shuford and Powell quarries in Catawba County and the Keener and Finger quarries in Lincoln County.

After the last iron furnace closed in 1882 the quarries were worked intermittently for several years to furnish lime for local use. The last work done at any of these old quarries was about 1916 when some limestone was burned at the Powell quarry (Loughlin, et. al., 1921, p. 77).

In 1940 the Superior Stone Company began developing a quarry for crushed stone near the town of Kings Mountain. The company has continued operations at this site since that time and now has one of the largest limestone quarries in the southeast.

During 1941 and 1942 the Setzer quarry, located 1 mile northeast of Bandys Crossroads in Catawba County, was operated by the Catawba Limestone Corporation to supply local demands for crushed stone and agricultural limestone. The Burgess Stone and Lime Company succeeded the earlier operator

and worked the quarry for about a year, but the quarry has been abandoned since 1944.

Description of Workings

Cleveland County

Superior Stone Company (Kings Mountain quarry).—This quarry is located about 1 mile south of the town of Kings Mountain on a headwaters tributary to Kings Creek. The quarry can be reached by traveling south on State Highway 216 for 0.8 mile past the intersection of Highway 216 with U. S. Highway 74. A well marked access road to the quarry is on the left (southeast) at this point and the quarry is 0.4 mile from Highway 216.

The rock quarried here is predominently a dark bluish gray, fine grained dolomitic marble. It is referred to as limestone, but is sufficiently recrystallized to be classed as marble. The formation strikes about N 30° E and dips about 40° to the northwest; however, there are local variations in both strike and dip. Individual beds range from a few inches to 5 or 6 feet thick, but average about 1 foot. Numerous calcite veinlets, paper thin to a ¼ inch thick, give the rock a streaked or bedded appearance. Most of the calcite is parallel to the bedding, but also occurs at various angles to it. Considerable calcite is also present as smears on joint faces. The formation is badly fractured by closely spaced vertical and horizontal joints, which intersect at almost right angles. This causes the marble to break into blocks of various dimensions.

On a fresh surface in the extreme northwest corner, the marble contains considerable pyrite, chalcopyrite and thin quartz stringers. Also present are interbeds of mica and chlorite schist and the marble has a definite schistose appearance.

The quarry has been developed along the strike of the formation. As the marble is about 800 feet thick here, the quarry is much longer than it is wide, It covers an area of about 22 acres and has been developed by standard bench type quarrying methods. The benches are about 70 feet high and are advanced perpendicular to the strike. At the time the quarry was visited, two benches were being worked in the northeast end of the quarry and a third was being developed. When production was started in 1940 the plant had a capacity of 150 tons per hour. In 1958 the capacity was 500 tons per hour. This is by far the largest limestone quarry in the state and it uses up to date equipment.

The general quarry operation is outlined as follows: Two rotary drills are used for drilling the holes for blasting the bench faces. It is interesting to note that this was the first company to use rotary drills in a commercial stone operation (Rock Products, 1949, p. 79). Primary breakage is usually very good and the necessary secondary drilling is done with pack hammer drills. At the quarry face, 3 Koering power shovels are used to load 6 Euclid dump trucks (14 tons capacity) that haul to the primary crusher. The primary crusher is located at the southwest end of the quarry at the first bench level.

The stone is first run through a 48 x 60 inch jaw crusher. From the jaw crusher it is carried by a 48 inch conveyor belt to 4 inch screens. All sizes under 4 inches go to a 38 inch conveyor belt. Oversize goes to a Simone cone crusher and then to the 38 inch conveyor belt. This belt carries the stone from the quarry level to ground level where it is then dumped on a set of vibrating screens. All stone under 1¾ inches falls on to another conveyor belt and is carried to loading bins and stockpile (crusher-run). Oversize from the screens is fed to 3 Simone cone crushers. From the cone crusher it is carried to another set of vibrating screens—size 1⅛, ¾, and 9/16 inches. All stone over 1⅛ inches is fed back to the cone crusher. All stone less than 9/16 inch goes to two more screens—sizes ⅜ and ¼ inch. Stone less than ¼ inch goes to a stockpile and is used for asphalt filler. The ¾ inch and 9/16 inch stone goes to loading bins and stockpile.

Most of the production from this quarry is used for crushed stone in highway construction, railroad ballast and aggregate. Owing to the fact that the quarry is located within the town limits of Kings Mountain, its future development is restricted. To the northeast the quarry has been developed almost to its limit. However, to the southwest the company has ample reserves for the near future and development will be in this direction.

Lincoln County

Finger quarry.—This quarry is located about 4.5 miles northeast of Lincolnton on a tributary to Run Creek. It can be reached by traveling northeast on State Highway 150 for 1.9 miles past the intersection of Highway 150 with Highway 27 at Goodsonville. At this point turn southeast onto an unpaved county road and follow this road for 0.4 mile to a narrow farm road. Then turn southwest onto this road and follow it for 0.35 mile to its end. The site of the quarry is located about 300 yards southwest of the farm house near the edge of the woods and next to the creek.

Very little can be said about this quarry because it has been abandoned for many years and is now slumped and covered by a thick growth of underbrush and trees. It is known that while iron ore was being mined in the area the quarry produced some fluxing material (Loughlin, et. al., 1921, p. 79). Also some of the rock was burned to lime because part of a beehive kiln is still standing and is in an excellent state of preservation. No outcrops could be found close by, but a few blocks of white and bluish-gray marble are scattered around the kiln. The property is now owned by Mr. J. F. Burke of Lincolnton.

Keener (Beal) quarry.—This quarry is located about 8 miles northeast of Lincolnton on the north side of a paved county road. The road turns west off of State Highway 150, 0.7 mile northeast of Pumpkin Center and directly across from Macedonia Baptist Church. The old quarry site is 0.4 mile northwest of Highway 150 and about 100 feet north of where the county road crosses a southeast flowing tributary to Lippard Creek. On the south side of the road about 100 yards downstream are the remains of an old lime kiln.

This quarry has been abandoned for many years and there are no visible signs of it today. The excavation has been filled and is now part of a pasture. However, in the bed of the creek which flows through the pasture a good outcrop of marble is present. It strikes N 10° E, dips 20° SE and is exposed for about 25 feet along the creek and occurs as a series of small ledges. The thickness of the marble could not be determined, but it is also exposed in the creek bed for a short distance on the south side of the road.

Three varieties of marble are present in about equal amounts. The first is a fine-grained, sugary textured marble that varies in color from white to bluish white and contains very few impurities. The second variety is a fine-grained, dark bluish gray marble which contains considerable pyrite, chalcopyrite and mica. The third is a fine to medium grained, buff to light brown marble. Considerable amounts of mica and quartz are present and this appears to be the most impure variety.

Contacts with the adjacent rocks are covered by stream alluvium, but a long section of country rock is exposed downstream from the marble on the south side of the road. Hornblende gneiss is the first rock exposed and this is followed by an interval in which hornblende gneiss is interlayered with mica gneiss. Further downstream the hornblende gneiss begins to give way and finally mica gneiss is the predominant rock type. This change takes place over a distance of several hundred yards.

Mr. Mason Beal, whose house is about 150 yards southeast of the quarry site is the present owner of the property.

Catawba County

Setzer quarry.—This quarry is located about 4 miles south of Catawba and one mile northeast of Bandys Crossroads. The quarry is on the property of Mr. Roy Setzer, whose house is on the north side of a paved county road 1.0 mile east of Bandys Crossroads. It can be reached by proceeding north from Mr. Setzers house along a farm road for 0.2 mile. This road leads directly to the quarry which is situated on the flood plain between two small streams.

During 1941 and 1942 the property was worked on a relatively small scale by the Catawba Limestone Corporation and in 1943 by the Burgess Stone and Lime Company. Both companies produced crushed stone and agricultural lime for local consumption. The quarry has been inactive since 1944 and is now filled with water. Depth of the opening could not be determined because of the water, but it probably does not average over 10 feet. Its outside dimensions are about 150 feet long and 100 feet wide. The long dimension is across the strike of the formation, which is N 15° E and the dip is 50° NW.

A dark bluish gray, banded fine-grained marble is the predominating rock type. Small crystals of pyrite and chalcopyrite occur as thin streaks parallel to the bands or bedding planes. A subordinate, but conspicuous type is a white, fine-grained marble that occurs as interbeds with the bluish gray type. Large crystals of calcite, up to ½ inch across, are present in both types. The beds of marble on the northwest side of the quarry appear to contain more impurities, particularly quartz.

Old limestone quarry of Catawba County (Powell quarry).—The site of this abandoned quarry is about 0.5 mile northwest of the Setzer quarry on another tributary creek to the North Fork of Mountain Creek. It can be reached either from the Setzer quarry or by following the creek downstream from where it heads-up near a paved county road.

The old quarry is slumped and covered by a thick growth of trees and underbrush. However, the plant site is marked on the west side of the creek by parts of the former foundation and fallen timbers. A good outcrop of marble is present for about 50 feet along the creek bed. It strikes N 15° E, dips about 30° northwest and is composed of interbeds of dark blue and white fine-grained marble.

Work was carried on here intermittently for about 50 years. It is reported (Loughlin, et. al. 1921, p. 77) that the last work done was about 1916. Some marble was burned to lime in one of three kilns that were standing at the time.

Sometime during the early 1940's a stone company drilled a series of exploratory holes along the creek valley between the Powell quarry and Setzer quarry. Mr. T. R. Lofton, a local resident, worked for the company while they were drilling in the area. He reports that the holes revealed that the marble is continuous between the two quarries and that some of the holes were drilled to a depth of 300 feet and were still in marble. The marble is overlain by 3 to 10 feet of overburden.

Mr. John Carpenter of Maiden is the present owner of the property.

Shuford quarry.—This quarry is located about six miles south of Catawba and 4.5 miles north of Chronicle, a small community at the intersection of State Highways 150 and 16. The quarry area can be reached by traveling south out of Catawba on the paved county road that goes to Sherrills Ford. At 4.75 miles from the town limits of Catawba turn south onto an unpaved county road and follow this road for 1.4 miles to the farm of Mr. Joe Johnson. The house is on the west side of the road and the outcrops can be located from there.

In the only previous description of this property (Loughlin, et. al., 1921, p. 77) the writers referred to only one outcrop of marble, as "best exposed in North Fork about 15 yards above the bridge where it has a thickness of 10 feet or more". During the present investigation three occurrences of marble were located in the area and it is uncertain which of these was the site of the original quarry.

One of the occurrences is about 1000 feet northwest of Mr. John's house on the bank of a southwest flowing tributary to the North Fork of Mountain Creek. It consists of large blocks of white fine-grained marble in two piles. Many of the blocks contain drill holes, which suggests that the marble was quarried elsewhere and dumped here.

About 1000 feet south of the Johnson house and on the opposite side of the road, is the entrance to the old Shuford farm. The farm house has been abandoned but is still standing. In a N 50° E direction at a distance of 700 feet from the front of the house is another large block of white, fine-grained marble. It is on the northwest bank of another tributary to North Fork and also contains several drill holes. This block also appears to have been dumped here. The remains of an old kiln are located on the east side of the creek 450 feet S 45° W of the Shuford house.

The only outcrop of marble found that is definitely in place is located about 2000 feet downstream from the first occurrence described, or about 1500 feet upstream from the confluence of this tributary with the North Fork. It can be reached by turning west onto a farm road 0.3 mile south of the Johnson house. This road deadends 500 feet west of an old house at the creek. The marble is exposed in the creek bed about 600 feet upstream from the road. It strikes N 20° E and dips 55° NW. A section about 10 feet thick is exposed and consists of interbeds of white and dark blue, fine-grained marble. Some beds contain considerable amounts of mica, quartz and pyrite and are quite impure. An amphibole schist is in contact with the marble on the upstream side. The same rock type is also exposed on the downstream side of the marble but there is a covered interval between the two and the contact is concealed.

Although no physical evidence of the original quarry site could be found, this area closely conforms to the previous description and is most likely the locality from which the marble was quarried. The remains of an old kiln are located on the west side of the creek about 300 feet downstream from the outcrop.

Stokes, Yadkin and Forsyth Counties

General Statement

Beginning in south central Yadkin County and continuing in a northeastern direction through southeastern Surry and southwestern and central Stokes County is a narrow belt of metasedimentary rocks that form Sauratown Mountain, Moore Knob, Hanging Rock, Cook Wall and other large and small mountains of the area. The rocks of this belt are predominantly quartzite and quartz-muscovite schist. Because of their general similarity in lithologic character and continuity along strike, these rocks were grouped with the Kings Mountain belt on the Geologic Map of North Carolina (1958) and referred to as the Stokes County belt.

Except for reconnaisance geologic mapping by Mundorff (1948) this belt has received very little attention, and consequently its structural and lithologic relationships are known in only a general way. The moutains are capped by massive quartzite beds with the schist becomig more predominent near the base. In general the strike is northeast and the dip varies considerably, but usually does not exceed 15 or 20 degrees.

The quartzite and schist unit is surrounded by a unit of gneiss that includes several types of interbedded gneisses and schists, most of which appear to be of sedimentary origin (Mundorff, 1948, p. 7). A quartz-micafeldspar gneiss, with the amount of quartz varying considerably from place to place, is the most abundant rock type. The second most important rock type included in this unit is quartz-mica schist. Biotite and muscovite mica usually are present in about equal amounts, but locally one type predominates over the other. Other types of rock included in this unit are hornblende-plagioclase gneiss, hornblende schist and quartzite.

The strike of the gneiss unit is consistently northeast, but the dip varies considerable. Vertical dips are very rare and dips less than 45 degrees are more common than dips greater than 45 degrees. On the southeast side of the quartzite and schist unit the dip is uniformly to the southeast. However, on the northwest side the dip is apparently reversed and is generally to the northwest. The structure of the gneiss unit is therefore apparently a broad anticlinorium whose axis extends from southwestern Stokes County to northeastern Rockingham County (Mundorff, 1948, p. 10).

Marble in the Quartzite and Gneiss Units

Included in the quartzite and gneiss units are interbeds, or lenses, of marble. However, most of the marble is associated with the gneiss unit, but one deposit on the Yadkin River near Silome is apparently in the quartzite unit.

Based on the lithologic character, rock association and area distribution, two distinct types of marble are present. One type is white to dark blue, fine grained, high calcium to dolomitic marble that is very similar to that in the Kings Mountain and Brevard belts. It occurs in a series of outcrops that begin south of Enon in Yadkin County and continues across Forsyth County through Vienna almost to the Stokes County line near Germanton. All of these outcrops lie southeast of a line drawn between the Dan River fault, which borders the Triassic basin on the northwest, and an unnamed fault that separates the quartzite unit from another small occurrence of Triassic rocks in southeastern Yadkin County (see Geologic Map of North Carolina, 1958). Owing to the lack of good exposures it was not possible in every case to establish the rock types with which these deposits are associated. However, in practically every instance where the relationship is visible, quarzite and/or amphibole bearing rocks are present in varying amounts.

The other type of marble is present on the northwest side of the Triassic fault and its extension, and is predominently a whitish, coarsely crystalline marble. From the limited chemical analyses available it appears that high calcium marble is more common than dolomitic marble. The marble occurs interbedded with mica schist and quartzite, the beds ranging from a few inches to several feet in thickness. Large calcite crystals, from 1 to 5 mm. across, are quite common and the most conspicuous excessory mineral is mica. The outcrops of this type of marble are widely separated and do not form a conspicuous pattern as does the other type.

History of Production

Marble deposits in Stokes, Yadkin and Forsyth Counties were known and worked to supply stone for local use and for burning into lime prior to the War Between the States. Emmons (1852, p. 162-63) visited the Bolejack and Martin properties and reported that the thickness at both deposits exceeded 40 feet and both beds made good lime. Included in Emmons report of 1852 is a report in the form of a letter from Dr. S. McClenahan in which he stated: "Lime in great abundance, and of excellent quality, is found stretching across the State, from Danbury, in Stokes County, to Kings Mountain in South Carolina. I saw it at Williams Kiln on the Yadkin, at Poff's, ten miles above Salem, at Hoosertown, at Germanton, and at Martin's near the Virginia line. I procured a piece near Germanton, at Mr. Bolejack's, which is an excellent marble, and receives a fine polish. The quantity of limestone at this point appears to be inexhaustible, and of good quality; in fact, all the lime I saw at all the kilns appeared to be of good quality."

There are no records available that indicate how long these kilns were operated, but it is unlikely that they were worked for many years after the war. By 1900 they had all been inactive for quite sometime.

During 1914, 1915 and 1916, the deposit on the south side of the Yadkin River near Siloam was worked by the Lime Rock Lime Company. The rock was conveyed by cable to a small plant on the north side of the river and pulverized for agricultural limestone. A flood in 1916 destroyed the plant and the quarry remained inactive until 1942 when it was acquired by the State Highway and Public Works Commission. The State operated the quarry for crushed stone until 1943. However, owing to an increasing amount of overburden and a war time shortage of equipment, the quarry was closed and has

FIGURE 13. MAP SHOWING MARBLE IN STOKES, YADKIN AND FORSYTH COUNTIES

remained inactive since that time. The property is still owned by the State Highway Commission.

Considerable interest was shown in the marble deposits in Yadkin and Stokes Counties by several companies during 1959. One company conducted an extensive drilling program on the deposits between Rural Hall and Germanton, and also drilled several exploratory holes at the deposit on the Yadkin River. The logs and cores from these holes were not available for study and consequently the results are unknown at the present time.

Description of Workings

Yadkin County

Lime Rock quarry.—This quarry is located on the south side of the Yadkin River, 6.5 miles northeast of Boonville and 6 miles northwest of East Bend. The quarry can be reached by traveling on State Highway 67 for 4.1 miles west of East Bend. At this point turn north onto a paved county road that goes to the small community of Richmond Hill and follow this road for 1.8 miles to an unpaved county road that turns north, then proceed north on this unpaved county road for 2.1 miles. At this point the abandoned quarry road intersects the county road on the north side. The quarry is located about 0.5 mile north, next to the river.

The quarry is situated at the base of a steep bluff that rises 150-200 feet above the river. The face of the quarry was developed southward into the bluff and an area about 100 feet high and 80 feet wide has been exposed. The marble is present in the face for about 70 feet above the floor of the quarry and is overlain by about 50 feet of an interbedded sequence of mica schist and a highly siliceous gneiss or quartzite. The contact between the marble and the overlying rock is not sharp, but it is evident that the contact steadily becomes lower to the west, and finally plunges beneath the floodplain about 800 feet west of the quarry face. To the east of the quarry the marble is present in the face of the bluff for about 150 feet. The strike and dip of the marble and overlying rock is quite variable, but the above relationship suggest that the overall structure is that of an asymmetrical anticline that plunges to the south or southwest.

In composition the marble ranges from layers that are quite pure to those that contain conspicuous amounts of impurities, mainly in the form of quartz stringers, coarse grains of mica and pyroxenes. The color is predominently a very light greenish white, In the lower part of the quarry face the marble is massive or thick bedded. However, higher up it becomes thinner bedded as the interbeds of mica schist and quartzite increase. Large piles of waste blocks are scattered around the quarry floor and an examination of them reveals the character of the marble and its relationship to the associated rocks.

During 1940 several exploratory holes were drilled by a private company (Murdock, unpublished report). One of these holes was drilled in the floor of the quarry to a depth of 60 feet and was all in marble. Another hole was drilled on top of the ridge about 300 feet south of the quarry. It was 160 feet deep and marble was present in the lower part.

There is evidently a large tonnage of marble present in this deposit, but it could not be recovered by ordinary open pit quarrying methods. There is over 50 feet of overburden on the marble and some type of underground mining methods would have to be used.

Watkins property.—This property is located in the southeast corner of Yadkin County about 1 mile west of the Yadkin River, and 1 mile southeast of the small community of Enon. It can be reached by traveling west on U. S. Highway 421 for 0.5 mile beyond the bridge over the Yadkin River. At this point, an unpaved farm road turns south. Follow this road southwest for 0.4 mile and bear to the right (southwest) at the first fork. About 500 feet beyond the fork the road crosses the head of a draw. The remains of an old kiln are on the side of the draw 50 feet south of the road, and several excavations are on the opposite side of the draw about 100 feet east of the kiln.

About one-half of the kiln which was constructed with hand-made bricks and various size blocks of quartzite and hornblende gneiss is still standing. At the base of the kiln is a rather large pile of marble. As there are no outcrops of marble in place at this locality, it is assumed that the marble found at the kiln is representative of what was quarried and burned. Two distinct types of marble are present; one is a grayish white, fine-grained variety, and the other is bluish gray and fine grained. Both varieties are in elongated slabs and appear to be somewhat schistose. Limited chemical analyses indicate that the marble contains 90 percent plus of total carbonates, and that the $MgCO_3$ is less than 5 percent. Numerous loose slabs and small piles of marble are scattered through the woods between the kiln and quarry excavations.

The sides of the excavation from which the marble was quarried are slumped and grown over with trees and underbrush. There is no marble exposed and

the only rock found in place occurs along the east and southeast side of the excavation. It consists of iron-stained, fine grained, thin to medium bedded quartzite with thin interbeds of mica schist. The strike is to the northwest and the dip is about 65° southwest. The largest excavation is about 100 feet long (northwest), 50 feet wide and as much as 15 feet below ground level.

It appears that the deposit worked here was a small lense that has been worked out to its horizontal boundaries. Whether or not in continues along strike or depth can be proved only by drilling. The property is presently owned by Mr. H. A. Taylor of Enon.

Stokes County

Bolejack quarry.—This quarry is located in south central Stokes County, 4.5 miles northeast of Rural Hall and 2 miles northwest of Germanton. It can best be reached by traveling northwest on State Highway 8 for 2.4 miles past its intersection with State Highway 65, northeast of Germanton. At this point the Bolejack road, an unpaved county road, turn southwest. Follow this road for 2.2 miles to Neatmans Creek. On the southwest side of the creek is the house of Mr. Alfred Smith, and the old quarry site is located across the road from Mr. Smith's house, on the bank of a small tributary to Neatmans Creek.

This is one of the oldest recorded kilns and quarries in the State. but it has been abandoned for many years and very little can be seen today. Along the bluff of the tributary marble 5 to 6 feet thick is exposed. It is mostly a coarsely crystalline, white to bluish white rock. It occurs as thin beds, a few inches to a foot thick, interbedded with biotite mica schist and quartzite. The quartzite is white, fine grained and thin to medium bedded. Above the marble-bearing sequence, quartzite is the predominent rock type.

The marble-schist-quartzite sequence strikes N 80° E and dips about 10° SE. Total thickness of the marble could not be determined because of the flat dip and cover, but Emmons (1852, p. 165), who visited the quarry at the time it was being worked reported a thickness in excess of 40 feet. Mr. Albert Smith, on whose farm the marble is located, is the present owner.

Wall property.—About 1.5 miles southwest of the Bolejack quarry is the site of another kiln and small quarry, referred to locally as the Old Grime farm, which is now owned by Mr. J. E. Wall of Rural Hall. This site has not been mentioned in previous publications and very little is known about its history. However, it was very likely worked about the same time as the Bolejack quarry.

It can be reached by continuing southwest from the Bolejack quarry for 0.5 mile to the intersection with another unpaved county road. The continuation of the Bolejack road is off-set 300 feet to the southeast. Follow this off-set road for about 0.3 mile southwest of where it crosses Town Fork Creek. At this point the road crosses a small draw at the edge of a wooded area. About 200 feet south of the road, in the middle of a fenced pasture, are the remains of an old kiln. The marble outcrop is located south of the kiln along the bluff of the creek.

The description of the interbedded marble-schist-quartzite sequence given for the Bolejack quarry applies equally well to this outcrop, except that this is a much better exposure. The marble is exposed for several hundred feet along the lower part of the bluff and the interval in which the marble occurs is 20 to 40 feet thick. In the lower part of the bluff the marble is thicker bedded, some beds reaching a thickness of 5 feet or more. Whether or not the marble exposed represents the total thickness of the sequence could not be determined because the base of the bluff is covered by soil. However, there is a good possibility that the marble continues below ground level for some depth.

Several hundred feet west of the kiln, on top of the ridge, is a depression 5 or 6 feet deep and about 10 feet in diameter. This is reported by Mr. Wall to be a caved shaft from which the stone burned in the kiln was removed. The original depth of the shaft, and the depth to the marble are unknown.

Most of the recent exploratory drilling previously mentioned was done on this property.

Edwards property.—This property is located 0.5 mile southeast of the Wall property on a north flowing tributary to Town Fork Creek. It can be reached by continuing southwest on the same road from the Wall property for 0.2 mile to the first intersection. Turn left (southeast) here and travel 0.5 mile to Mr. Edward's house, which is situated on a sharp bend in the road.

The marble is exposed for about 30 feet along the bluff above the stream, directly east of Mr. Edward's barn. It is identical in character with the marble-schist-quartzite sequence at the Bolejack and Wall properties. Only about the upper 10 feet of the sequence is exposed and the quartzite grades upward into a fine grained, quartz-mica gneiss. The remains of an old kiln are present at the foot of the bluff next to the creek.

Martins lime kiln.—This property is located on a north flowing tributary to Snow Creek, 4.5 miles northeast of Danbury and 3 miles west of Prestonville. It can best be reached by traveling northeast from Danbury on a paved county road for 2.6 miles to Hartman. At Hartman turn left (northwest) and proceed on a paved county road for 2.4 miles to an intersection with an unpaved county road. Turn right (east) on this unpaved road and travel 0.7 mile to a farm road. Turn left (northeast) onto this farm road and travel 0.6 mile to the house of Mr. John Moorefield. The quarry site is located about 0.25 mile northeast in a steep bluff on the east side of the creek.

The working face of the quarry is completely covered by slump material and underbrush and the marble is not exposed. However, on the west side of the creek, just a few feet north of where an abandoned road crosses the creek, is a large pile of waste material from the quarry. Most of the marble examined is white to light green and coarsely crystalline. It contains calcite crystals up to ¼ inch in diameter as well as conspicuous flakes of biotite. Some of the marble is streaked with thin seams of serpentine, which in places is altered to asbestos. Stringers of quartz and mica are interlayered with some marble which has an overall appearance very similar to that at the Lime Rock quarry in Yadkin County.

The overlying rock at the quarry faces is about 15 feet thick and consists of alternating layers of fine grained quartz-feldspar-biotite gneiss and biotite gneiss. The gneiss strikes N 55° W and dips 15° NE. Downstream from the quarry are several large outcrops of dark green amphibolite gneiss. This is overlain by a quartz biotite gneiss. Further downstream occur large outcrops of coarse grained quartz-feldspar gneiss.

Forsyth County

Hauser property.—This property is located 0.2 mile north of U. S. Highway 421, 2.1 miles west of Pfafftown and 3.3 miles east of the Yadkin River at the small community of Vienna. It can be reached by turning north off of U. S. Highway 421 onto a deadend farm road, 0.2 mile east of Vienne. Proceed north on this road for 0.2 mile to a small southwest flowing creek. The old quarry site is on the south side of the creek 200 feet downstream from where the road crosses the creek.

The quarry was developed in a bluff and is roughly semi-circular in outline. It is about 100 feet long, parallel to the creek, 50 feet wide and 12 to 15 below the top of the bank. A small pit about 4 feet deep is present in the floor of the quarry. This site has not been worked for many years and the sides of the quarry are completely covered by slump and undergrowth. The only marble found in place is a small outcrop in the creek bed opposite the quarry. It is light gray, fine grained and appears to be schistose.

In a plowed field on the north side of the creek, numerous, various size pieces of marble are scattered through the soil. Two varieties are present in about equal amounts. One is very similar to that exposed in the creek and the other is dark bluish gray and fine grained.

It is reported by Mr. P. E. Hauser, owner of the property, that sometime during the early 1940's a private company drilled 3 exploratory holes along the creek valley between the quarry and the road. Each hole cut about 60 feet of marble, which was overlain by 10 feet of overburden.

Jordan (Franklin) property.—This property is located north of U. S. Highway 421, 1.5 miles northeast of the Hauser property on the south side of an east flowing creek. It can be reached by traveling west from Pfafftown on U. S. Highway 421 for 0.8 mile to Mr. P. E. Jordan's house. The house is on the north side of the highway and the old workings are 300-400 feet northwest of the house at the foot of a hill.

An abandoned farm road leads from behind the Jordan house to the creek valley. On the east and west sides of this road, at the point it reaches the floodplain, are the quarry excavations. The excavation on the west side of the road appears to have been the main quarry. It is about 50 feet long, 30 feet wide and up to 15 feet deep. Murdock (unpublished report) states that in the floor of the quarry there was another excavation about 25 feet deep. During the early 1900's considerable stone was supposedly quarried here and some of it was used in construction work at Salem. A heavy rain flooded the quarry and it has been inactive since that time.

The sides and floor of the excavations are completely covered by soil and underbrush and no marble can be seen in place. However, there are numerous slabs and chips of loose marble scattered around the excavations and in a plowed field to the west. It is very similar to that at the Hauser property and both the grayish white and dark bluish gray varieties are present. Several hundred feet west of the farm road, in the bed of a north flowing tributary, is a small outcrop of grayish white, fine grained marble. It appears to be in place and strikes N 40° E and dips about 30° SE.

There is a good possibility that the marble is more or less continuous between the Hauser and Jordan properties, but this could be proved only by drilling along strike.

Bowen property.—This property is located on the east side of a large unnamed creek, 2 miles southeast of Germanton. The creek is a north flowing tributary to Town Fork Creek and is situated between Redbank Creek on the east and Buffalo Creek on the west. It can be reached by traveling east from Germanton on State Highway 65 for 1.3 miles to the Baux Mountain road, an unpaved county road. Turn south onto this road and travel about 1.5 miles to the house on the J. R. Bowen farm. The house is on the west side of the road and was occupied by a Mr. Davis at the time of this investigation.

The old quarry is about 0.25 mile west of the farmhouse and can be reached by following a farm road which begins just north of the house. A small excavation about 15 feet in diameter and the remains of an old kiln are situated next to the creek. The hole is partly filled with water and the sides are badly slumped and covered. However, a fairly good outcrop of marble is exposed on the east side of the hole. It is a dark bluish gray, banded, fine grained marble that strikes N 30° E and dips 25° SE. Numerous small piles and loose blocks of marble are scattered through the woods in the vicinity of the quarry and kiln. Most of it is the blue variety just described, but some of it is a grayish white, fine grained marble.

The rock type with which the marble is associated could not be found in place; however, numerous loose pieces of thin-bedded quartzite are scattered through the woods above the excavation and in a plowed field.

From the size of the excavation it appears that only a small amount of marble was quarried. The quarry has been abandoned for many years and was probably worked prior to 1900.

Pearl property.—This property is located about 0.4 mile upstream (south) from the Bowen property. It can be reached by continuing south on the Baux Mountain road for about 0.5 mile past the Bowen farm to a farm road that leads to the Pearl house. The marble outcrop is located at the foot of a steep hill about 0.5 mile west of the house.

The marble is exposed intermittently for about 200 feet along the foot of the hill and in a small ravine at the north end of the hill. About 6 feet of marble are exposed but it could not be determined if this is the total thickness. The best exposure of marble is in, and on the south side of the ravine and it displays the extremely contorted nature of the bedding, which is unique to this outcrop. This twisting and tight folding of the bedding made it difficult to measure the strike and dip, but as it could best be determined the marble strikes N 10° E and dips about 25° SE.

On a fresh surface the marble is light greenish gray, fine grained and thin bedded. Thin beds of quartzite and amphibole are interbedded with the marble and on a weathered surface these harder beds stand out and accentuate the contorted bedding.

Several hundred feet south of the marble outcrop is a west flowing tributary to the main creek. Exposed in the bed of the tributary creek is a long section of interlayered hornblende gneiss and quartzite. The hornblende gneiss predominates in the lower end of the creek and the quartzite in the upper end. Included with the quartzite and gneiss are several layers of chlorite schist.

A kiln is reported to have been located on the floodplain of the main creek south of the marble outcrop, but its location could not be found.

Other prospects.—Downstream from the Bowen and Pearl properties near the Stokes-Forsyth County line, a local resident reports that white marble was cut in two water wells that were drilled within the past 15 years. Also, an old kiln is supposed to be located on a small tributary in the same general area, but it could not be found.

If marble is present near the Stokes-Forsyth County line, it is concealed by stream alluvium and soil and can be found only by drilling.

Selected List of Chemical Analyses

Murphy Marble

Sample No.	SiO_2	Al_2O_3	CaO	MgO	CO_2	R_2O_3	$CaCO_3$	$MgCO_3$
1.	1.20	0.82	52.90	1.91	43.66		94.46	4.01
2.	2.93		32.05	17.27	44.92	0.56(Fe)		
3.	0.10	0.30	50.32	4.31	44.28			
4.	0.11					1.06	58.47	39.62
5.	8.05					0.75	50.15	40.65
6.	1.52					2.98	65.14	29.03
7.	1.40					0.50	96.90	1.58

1. Culberson quarry, Loughlin, et. al., 1921, p. 149.
2. Kinsey quarry, Hunter and Gildersleeve, 1946, p. 24.
3. Regal quarry, Loughlin, et. al., 1921, p. 149.
4. Nantahala Talc and Limestone Company, white marble from east side of quarry. Sample collected September, 1946, from files of the Division of Mineral Resources.
5. Nantahala Talc and Limestone Company, marble from near quarry. Sample collected in 1920, from files of the Division of Mineral Resources.
6. Nantahala Talc and Limestone Company, black marble from center face of quarry. Sample collected in June, 1947, from files of the Division of Mineral Resources.
7. Talc Mountain Branch, sample collected in June, 1947, from ledge above old talc prospect pit, from files of the Division of Mineral Resources.

Macon County

Sample No.	Acid Ins.	Fe_2O_3	CaO	MgO	Ign. Loss
1.	30.3	0.94	37.5	0.54	29.9

1. Dill lime kiln, white, coarse-grained marble from outcrop on hill, 50 feet north of unpaved county road. Sample collected in September, 1959, analysis by North Carolina State College Minerals Research Laboratory.

Jackson County

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_2
1.	16.45	7.06	2.80	39.91	0.25	31.64

1. Marble from Caney Fork, Loughlin, et. al., 1921, p. 151.

Hot Springs Area—Madison County

Sample No.	SiO_2	Fe_2O_3	R_2O_3	CaO	MgO	Ign. Loss
1.	4.1	(0.27)	1.4	30.0	19.1	45.1
2.	3.0	(0.30)	1.0	30.2	20.1	45.7
3.	2.3	(0.33)	0.9	30.0	20.5	46.5
4.	3.6	(0.20)	0.9	30.1	20.2	45.5
5.	7.4	(0.42)	2.8	27.8	19.5	42.2
6.	2.3	(0.27)	0.8	30.2	20.1	46.5
7.	16.4	0.21		46.4	0.35	36.2
8.	1.6	0.09		54.5	0.42	42.6
9.	9.1	0.35		47.5	2.49	40.0
10.	7.9			42.6*	7.4	41.5

*Includes R_2O_3

1. Buquo quarry—average composition of northern half of beds exposed in northwest quarry.
2. Buquo quarry—average composition of southern half of beds exposed in northwest quarry.

3. Buquo quarry—average composition of northern third of beds exposed in southeast quarry.

4. Buquo quarry—average composition of middle third of beds exposed in southeast quarry.

5. Buquo quarry—average composition of southern third of beds exposed in southeast quarry.

6. Buquo quarry—average composition of beds exposed in quarry on east bank of French Broad River, 1200 feet northeast of Hot Springs station.

7. Coarse grained, crystalline marble from Walnut Creek locality, 2 miles northwest of Marshall.

8. Blue limestone from the Sandsuck formation. Sample collected on the north side of Franklin Mountain road, 1.5 miles west of State Highway 212 on the property of Mr. Troy Rice.

9. Blue limestone from the Sandsuck formation. Sample collected on the north side of Franklin Mountain road, 0.45 mile west of State Highway 212 on the property of Mr. Franklin.

10. Dark-gray limestone from the Honaker formation. Sample collected on Mine Hollow Creek, 3 miles northwest of Hot Springs.

Note: Samples 1-6 were collected by E. C. Van Horn, T.V.A., and analyzed by the North Carolina State College Minerals Research Laboratory, August, 1958. Samples 7-10 were collected by the writer and analyzed by the North Carolina State College Minerals Research Laboratory, January and September, 1959.

Brevard Belt

Sample No.	SiO_2	Fe_2O_3	R_2O_3	CaO	MgO	Ign. Loss
1.	3.0		1.8	31.9	17.5	44.9
2.	9.7	0.43	3.3	25.9	17.9	40.1
3.	24.2	1.3	5.5	21.3	14.1	33.2
4.	4.2	0.57	2.4	28.1	19.2	43.8
5.	3.4	0.64	1.4	28.8	17.7	44.9
6.	2.2		0.2	53.9	0.45	42.89
7.	0.96		0.33	53.2	1.30	43.48
8.	1.1	0.17	0.50	31.5	19.0	46.50
9.	0.8	0.17	0.60	31.8	18.9	46.30
10.	0.2	0.10	0.60	32.8	20.0	46.80

1. Transylvania County, 2 miles north of Ecusta.

2. Translyvania County, 2.75 miles north of Ecusta.

3. Transylvania County, about 3.5 miles southwest of the Transylvania-Henderson County line, near the headwaters of Turkey Creek (Curitan area).

4. Transylvania County, about 1 mile southwest of Transylvania-Henderson County line, 0.25 mile east of State Highway 280 and 300 feet east of Boylston Creek on W. A. Barnard farm.

5. Henderson County, 1.5 miles northeast of the Henderson-Transylvania County line, under the fourth creek bridge abutment northeast of Boylston Creek Church on State Highway 280.

6. Henderson County, blue marble from Fletcher Limestone Company quarry.

7. Henderson County, white marble from Fletcher Limestone Company quarry.

8. Buncombe County, about 0.25 mile north of the Buncombe-Henderson County line, 75 feet west of the Southern Railway tracks on Pinner Creek.

9. Buncombe County, on Robinson Creek about 1 mile north of the Asheville-Hendersonville airport and 0.75 mile southeast of Christ School.

10. Buncombe County, about 1.75 miles northeast of the Asheville-Hendersonville airport on the east side of Groves Lake at an old lime kiln.

Note: Analyses 1, 2, 3, 4, 5, 8, 9 and 10, from Ingle (1947, p. 5). Analyses 6 and 7 from the files of the Division of Mineral Resources.

Mitchell County

Sample No.	Acid Ins.	Fe	Al_2O_3	CaO	MgO	Ign. Loss
1.	0.20	0.07	0.08	31.38	21.46	46.46

1. Bandana dolomite marble, from Hunter and Gildersleeve, 1946, p. 28.

McDowell County

Sample No.	Acid Ins.	Fe	CaO	MgO	Ign. Loss
1.	1.83	0.52	29.92	20.38	46.18
2.	5.3	0.45	28.16	18.6+	44.48
3.	2.63	0.27	29.36	10.43	45.62
4.	2.83	0.57	30.96	20.42	45.41
5.	8.60	0.25	27.36	19.53	41.56
6.	0.74	0.26	29.76	21.39	45.91
7.	3.13	0.30	28.88	20.56	43.61
8.	38.36(SiO_2)	15.77(R_2O_3)	40.74($CacO_3$)	5.14($MgCO_3$)	

1. Outcrop sample, North Fork Catawba River, 3 miles north of Ashford.
2. Dark-colored stone from Clinchfield quarry.
3. Light-colored stone from Clinchfield quarry.
4. Dolomite from inside Linville Caverns.
5. Outcrop sample from exposures in valley along west side of ridge back of Linville Caverns.
6. Outcrop sample from shattered, galena-bearing zone in ridge 0.75 mile north of Linville Caverns.
7. Outcrop sample from dolomite beds above shattered, galena-bearing zone in ridge, 0.75 mile north of Linville Caverns.
8. Average of 41 composite samples from siliceous marble, 2 miles northwest of Marion.

Note: Analyses of samples 1-7 from Hunter and Gildersleeve, 1946, p. 27-28.
Analyses of sample 8 furnished by Mr. E. C. Van Horn, January, 1959.

Kings Mountain Belt

Sample No.	Acid Ins.	Al_2O_3	Fe_2O_3	CaO	MgO	Ign. Loss
1.		2.60	1.54	34.27	20.90	
2.		1.28	3.17	33.18	19.07	
3.		0.45	4.46	35.90	17.63	
4.	29.5			22.50*	14.20	33.4
5.	28.9			34.70*	3.70	30.0

*Includes R_2O_3

1. Dolomite marble from Powell quarry, Loughlin, et. al., 1921, p. 151.
2. Dolomite marble from Shuford quarry, Loughlin, et. al., 1921, p. 151.
3. Dolomite marble from Keener quarry, Loughlin, et. al., 1921, p. 151.
4. Marble from Setzer quarry.
5. Marble from Kings Mountain quarry.

Note: Samples 4 and 5 were collected by the writer and analyzed by the North Carolina State College Minerals Research Laboratory, January, 1959.

Stokes, Yadkin and Forsyth Counties

Sample No.	Acid Ins.	CaO*	MgO	Ign. Loss
1.	9.4	50.2	0.6	39.4
2.	81.4	9.2	0.3	7.7
3.	2.1	53.6	0.8	42.6
4.	10.6	48.2	1.9	39.0
5.	63.4	16.8	1.9	14.0
6.	50.0	25.5	1.2	21.5
7.	46.8	29.2	1.2	21.9
8.	12.8	44.6	3.7	38.4

*Includes R_2O_3

1. Yadkin County, white, coarse-grained marble from Lime Rock quarry.
2. Yadkin County, siliceous interbed from Lime Rock quarry.
3. Yadkin County, white, fine-grained marble from Watkins property.
4. Yadkin County, blue, fine-grained marble from Watkins property.
5. Forsyth County, dark blue, fine-grained marble from J. R. Bowen property.
6. Forsyth County, light gray, fine-grained, contorted marble from Pearl property.
7. Forsyth County, light greenish, fine-grained marble from Pearl property.
8. Stokes County, white, coarse-grained marble from Bolejack quarry.

Note: Samples collected by writer and analyzed by North Carolina State College Minerals Research Laboratory, December, 1958.

References Cited

Bayley, W. S., 1923, Magnetic Iron Ores of East Tennessee and Western North Carolina: North Carolina Geol. and Econ. Survey Bull. 32, 252 p.

----------, 1925, Deposits of Brown Iron Ores (Brown Hematite) in Western North Carolina: North Carolina Geol. and Econ. Survey Bull. 31, 76 p.

Berry, E. Willard, 1947, Marls and Limestones of Eastern North Carolina; North Carolina Dept. Cons. and Devel. Bull. 54, 16 p.

Bowles, Oliver, 1939, The Stone Industries; New York, McGraw-Hill Book Company, 518 p.

----------, 1958, Marble: U. S. Bureau of Mines Inf. Circ. 7829, 31 p.

Bryant, Bruce, and Reed, John C. Jr., 1959, Structural Features of the Grandfather Mountain Area, Northwestern North Carolina (abs.): Geol. Soc. America Bull., vol. 70, no. 12, part 2, p. 1757.

Bryson, Herman J., 1937, The Mining Industry in North Carolina from 1929 to 1936: North Carolina Dept. Cons. and Devel. Econ. Paper No. 64, 137 p.

Clark, W. B., Miller, B. L., Stephenson, L. W., Johnson, B. L., and Parker, H. N., 1912, The Coastal Plain of North Carolina: North Carolina Geol. and Econ. Survey Vol. III, 552 p.

Emmons, Ebenezer, 1852, Report of Prof. Emmons on his Geological Survey of North Carolina: Ex. Doc. No. 13, Raleigh, Seaton Gales, Printer to the Legislature, 181 p.

Ferguson, H. W., and Jewell, W. B., 1951, Geology and Barite Deposits of the Del Rio District, Cocke County, Tennessee: Tennessee Div. of Geol. Bull. 57, 235 p.

Hurst, Vernon J., 1955, Stratigraphy, Structure and Mineral Resources of the Mineral Bluff Quadrangle, Georgia: Georgia Geol. Survey Bull. 63, 137 p.

Hunter, C. E., and Gildersleeve, Benjamin, 1946, Minerals and Structural Materials of Western North Carolina and North Georgia: Tenn. Valley Authority Report C, 94 p.

Ingle, R. S., 1947, Limestone in the Brevard Schist: North Carolina Dept. Cons. and Devel. R. I. 55, 5 p.

Keith, Arthur, 1903, Cranberry folio: U. S. Geol. Survey Geol. Atlas (no. 90), 9 p.

----------, 1904, Asheville folio: U. S. Geol. Survey Geol. Atlas (no. 25), 7 p.

----------, 1905, Mount Mitchell folio: U. S. Geol. Survey Geol. Atlas (no. 124), 10 p.

----------, 1907, Nantahala Folio: U. S. Geol. Survey Geol. Atlas (no. 143), 12 p.

----------, and Sterrett, D. B., 1931, Gaffney-Kings Mountain folio: U. S. Geol. Survey Geol. Atlas (no. 222), 13 p.

----------, and ----------, unpublished, Geologic Map of Morganton quadrangle.

Kerr, W. C., 1875, Report on the Geological Survey of North Carolina: Physical Geography, Resume, Economical Geology: North Carolina Geol. Survey, Vol. I, 120 p.

Kesler, T. L., 1942, The Tin-Spodumene Belt of the Carolinas: U. S. Geol. Survey Bull. 936-J, p. 245-269.

----------, 1944, Correlation of Some Metamorphic Rocks of the Central Carolina Piedmont: Geol. Soc. America Bull., vol. 55, p. 755-782.

----------, 1955, The Kings Mountain Area: Guides to Southeastern Geology, Geol. Soc. America, p. 374-387.

King, P. B., 1955, A Geologic Section Across the Southern Appalachians: An Outline of the Geology in the Segment in Tennessee, North Carolina and South Carolina: Guides to Southeastern Geology, Geol. Soc. America, p. 332-373.

La Forge, L., and Phalen, W. C., 1913, Ellijay folio: U. S. Geol. Survey Geol. Atlas (no. 187), 18 p.

Loughlin, G. F., Berry, E. W., and Cushman, J. A., 1921, Limestones and Marls of North Carolina: North Carolina Geol. and Econ. Survey Bull. 28, 211 p.

Lewis, J. V., 1893, Notes on Building and Ornamental Stone: North Carolina Geol. Survey First Biennial Report of the State Geologist, 1891-92, p. 61-103.

Mundorff, M. J., 1948, Geology and Ground Water in the Greensboro Area, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 50, 44 p.

Murdock, T. G., unpublished, Limestone Deposits of the Yadkinville Area: North Carolina Dept. Cons. and Devel., Open File Report, 20 p.

Nitze, H. B. C., 1893, Iron Ores of North Carolina: North Carolina Geol. Survey First Biennial Report of the State Geologist, 1891-92, p. 29-56.

North Carolina Dept. Cons. and Devel., 1958, Geologic Map of North Carolina: Compiled by the Div. of Mineral Resources, Jasper L. Stuckey, State Geologist.

Oriel, S. S., 1950, Geology and Mineral Resources of the Hot Springs Window, Madison County, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 60, 70 p.

Pratt, Joseph Hyde, 1900, Talc and Pyrophyllite Deposits in North Carolina: North Carolina Geol. Survey Econ. Paper No. 3, 29 p.

----------, 1907, The Mining Industry in North Carolina During 1905: North Carolina Geol. and Econ. Survey Econ. Paper no. 11, 96 p.

----------, 1911, The Mining Industry in North Carolina During 1908, 1909, and 1910: North Carolina Geol. and Econ. Survey Econ. Paper No. 23, 130 p.

Pettijohn, F. J., 1949, Sedimentary Rocks: New York, Harper and Brothers, 507 p.

Rock Products, 1949. First Rotary Drill Operation in Commercial Stone Quarry: Rock Products, vol. 52, no. 11, p. 79-80, 96.

Stuckey, Jasper L., and Fontaine, James, 1933, Occurrence and Physical Properties of North Carolina Marble: State College Record, Engineering Experiment Station Bull. No. 5, vol. 32, no. 5, 24 p.

Van Horn, Earl C., 1948, Talc Deposits of the Murphy Belt: North Carolina Dept. Cons. and Devel. Bull. 56, 54 p.

Watson, Thomas L., and Laney, Francis B., 1906, The Building and Ornamental Stones of North Carolina: North Carolina Geol. Survey Bull. 2, 261 p.