

NORTH CAROLINA  
DEPARTMENT OF CONSERVATION AND DEVELOPMENT  
WADE H. PHILLIPS, *Director*

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BULLETIN NUMBER 37

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# THE PYROPHYLLITE DEPOSITS OF NORTH CAROLINA

WITH

*A MORE DETAILED ACCOUNT OF THE  
GEOLOGY OF THE DEEP RIVER  
REGION*

By

JASPER L. STUCKEY, PH. D.



RALEIGH  
1928

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RALEIGH, N. C., August 1, 1928.

*To His Excellency, HON. A. W. MCLEAN,*  
*Governor of North Carolina.*

SIR:—I herewith submit for publication as Bulletin No. 37 of the publications of the North Carolina Department of Conservation and Development a report on THE PYROPHYLLITE DEPOSITS OF NORTH CAROLINA, which has been prepared by Dr. Jasper L. Stuckey, former State Geologist. This is the first complete report on the pyrophyllite deposits of this State and will, therefore, be of great interest to those who desire information on such material.

Yours respectfully,

WADE H. PHILLIPS, *Director,*  
*North Carolina Department of Conservation and Development.*

## AUTHOR'S FOREWORD

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This report was begun as a special investigation of the geology and pyrophyllite deposits of the Deep River Region, and accordingly a detailed geologic map of that region was prepared. As the work progressed, other pyrophyllite deposits were found outside the area mapped. It was found impracticable to map in detail the whole slate belt or every portion of it where pyrophyllite occurs; hence, in this report, the detailed descriptions of geological formations refer only to the region shown in the map (Fig. 1). However, each deposit of pyrophyllite, whether in the area mapped or not, has been examined and in some instances thin sections were prepared for detailed study and comparison with the deposits in the Deep River Region.

The writer wishes to thank Dr. Joseph Hyde Pratt, State Geologist at the time the field work was started, for the privilege of studying the region. He wishes also to express his thanks to Major Wade H. Phillips, Director of the Department of Conservation and Development for the help extended in getting the report completed.

He also wishes to express his thanks to Professors H. Ries and A. C. Gill for assistance and advice given him in the course of the work. He would not forget the generous cooperation and help of the citizens of the region who so kindly assisted him in every way possible during the course of the field work.

JASPER L. STUCKEY.

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**THE PYROPHYLLITE DEPOSITS OF NORTH CAROLINA**  
WITH  
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By JASPER L. STUCKEY

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CHAPTER I

**GEOGRAPHY AND HISTORY**

**INTRODUCTION**

The pyrophyllite deposits of North Carolina, especially those in the Deep River region, have been known for one hundred years or more and have been successfully worked with few interruptions for the past seventy-five years. Although prior to the work begun by the writer in 1922 no detailed geological work had been done on them, they have become more or less well known, not only because of their unique character but also for the reason that so far as is known they are the only commercial deposits in the United States. The present investigation was begun as a special report on the geology and mineralogy of the deposits in the Deep River region and a detailed geological map (Fig. 1) has been prepared of that region. However, as the work has progressed other deposits have been investigated outside the area covered by the map, some of which have promise of commercial value. The report in its present form covers, in a general way, the geology of the whole area in which pyrophyllite is found and considers in some detail the geology of the Deep River region (Fig. 2).

**DISTRIBUTION AND GEOGRAPHICAL SETTING**

The most important pyrophyllite deposits in the State are those found along Deep River in the north-central part of Moore and the south-central part of Chatham Counties, about 60 miles southwest of Raleigh. This special area is about 25 or 30 miles long and 6 or 8 miles wide. The part of this area mapped in detail is about 5 miles wide and 20 miles long. In addition to the deposits in Moore and Chatham Counties there are pyrophyllite outcrops of interest in Montgomery County near Troy and in Randolph County four miles west of Staley. Outcrops,

which have not been sufficiently prospected to indicate whether they are of commercial value, occur several miles south of Graham in Alamance County, around Hillsboro and in the vicinity of the Southern Power Company's auxiliary plant near University Station in Orange County. Beginning about two miles north of Stem in Granville County and continuing some two miles in a northeast direction are a series of outcrops of interest, one of which has been prospected to a limited extent.

These deposits all lie in the Piedmont Plateau region in the central part of the State. The elevation of the region varies from 300 to 500 feet above sea level. The topography is in the mature stage of dissection and consists of low-lying, well rounded hills and ridges, and gently sloping valleys. The strongest relief is along the streams and is most striking where they have cut across the ridges. The rocks, which are practically all of the crystalline variety, are deeply weathered and exposures are scarce.

The region in which pyrophyllite is found is well drained. Some of the most important rivers in the State have their sources to the west of this region and flow across it in a southeast direction. The southern portion is drained by the Pee Dee River and its tributaries, especially Little River, which drains most of Montgomery and a part of Randolph counties. The central portion, especially the Deep River region, is drained chiefly by the Deep River and in part by Haw River, which unite to form the Cape Fear. The northern part of the region is drained by the Neuse River and its tributaries and in part by Tar River.

All the deposits of pyrophyllite which have been sufficiently prospected to indicate that they have commercial value are located near railroads. The deposits in the Deep River region and near Troy all lie within two or three miles of the Raleigh-Charlotte branch of the Norfolk Southern Railroad. The deposit near Staley in Randolph County is about four miles from the Atlantic and Yadkin Railroad (a branch of the Southern Railway from Greensboro to Sanford), while the deposits north of Stem in Granville County are convenient to a branch of the Southern Railway between Durham and Danville.

#### PREVIOUS GEOLOGIC WORK

No detailed geological work has been done, previous to the present investigation, on any area in which the pyrophyllite deposits described below are found. Both gold and pyrophyllite

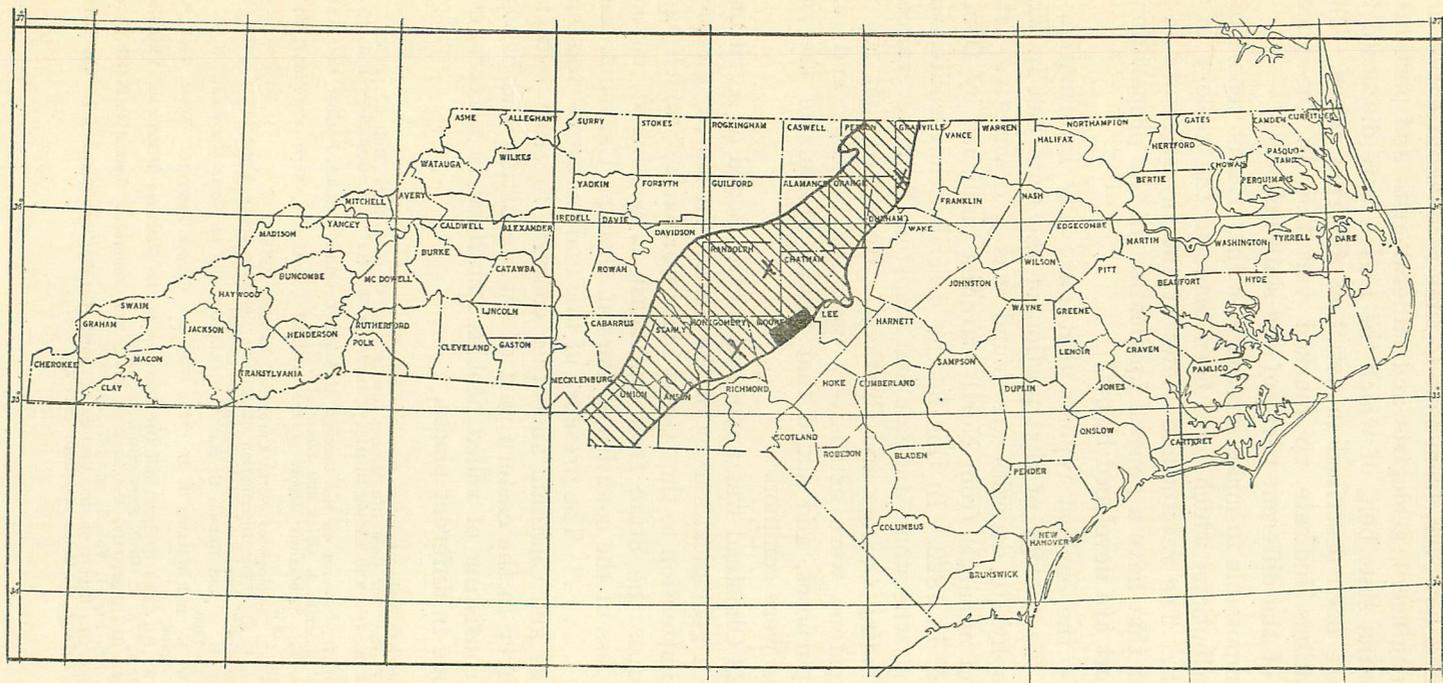


FIGURE 2.—Index map showing the location of the Deep River Pyrophyllite Area (in black) and the "Carolina Slate Belt" (shaded). X indicates pyrophyllite deposits outside the Deep River Area.

mines have, however, from time to time received attention from mining engineers, geologists and mineralogists and portions of the Carolina slate belt, of which the region here discussed is a part, have been described in detail at different times. These investigations indicate no marked variation in the general geology of the different parts of the slate belt.

It is impossible to make reference in the present report to all the contributions which have been made to the geology of the slate belt. The results and views of the investigators in the slate belt that have a general application in the preparation of this report are developed below.<sup>1</sup>

One of the earliest reports that gave any information regarding the geology of that portion of the slate belt in which the pyrophyllite deposits are found was a descriptive list of rocks and minerals from North Carolina published by Denison Olmstead<sup>2</sup> in 1822. In this list he described novaculite, slate, hornstone, whetstone, and talc and soapstone from several counties, including Orange and Chatham. He stated that the talc and soapstone were extensively used for building and ornamental purposes, and added that Indian utensils of the same materials were common.

In 1823 Olmstead was appointed by the Board of Agriculture to make a geological survey of the State. In his early reports<sup>3</sup> he called attention to the "Great Slate Formation" which passes quite across the State from northeast to southwest, covering more or less of the counties of Person, Orange, Chatham, Montgomery . . ." The presence of talc and soapstone was noted in Orange and Chatham and other counties together with beds of porphyry in the eastern part of the formation and bands of breccia consisting of rolled pebbles imbedded in a ferruginous greenstone in different places.

<sup>1</sup> For complete bibliography of the slate belt see:

Laney, F. B., "The Gold Hill Mining District," N. C. Geol. Surv. Bull. 21, 1910.

Pogue, J. E., Jr., "Cid Mining District of Davidson County," N. C. Geol. Surv. Bull. 22, 1910.

See also:

Olmstead, D., "Report on the Geology of North Carolina conducted under the Board of Agriculture," Raleigh, J. Gales and Son, 1825-27.

Emmons, E., "Geological Report of the Midland Counties of North Carolina," Raleigh, pp. 41 et seq., 1856.

Kerr, W. C., "Geology of North Carolina," Raleigh, 1875.

Williams, G. H., "The Distribution of Ancient Volcanic Rocks Along the Eastern Border of North America," Jour. Geol., vol. 2, pp. 1-31, 1894.

Nitze, H. B. C. and Hanna, G. B., "The Gold Deposits of North Carolina," N. C. Geol. Surv. Bull. 3, 1896.

Weed, W. H. and Watson, T. L., "The Virgilina Copper Deposits," Econ. Geol. Vol 1, pp. 309-330, 1906.

Laney, F. B., "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," N. C. Geol. Surv. Bull. 26, 1917.

<sup>2</sup> Olmstead, D., Descriptive Catalogue of Rocks and Minerals Collected in North Carolina, Amer. Jour. Sci. Ser. 1, Vol. 5, pp. 257-264, 1822

<sup>3</sup> Olmstead, D., Report on the Geology of North Carolina conducted under the Board of Agriculture, Raleigh, J. Gales and Son, 1825-27.

In 1856 Ebenezer Emmons<sup>4</sup> published his report on the "Geology of the Midland Counties of North Carolina." He says: "The slates are variable in color and composition. They are mineralogically clay, chlorite and talcose slates, taking silicia into their composition, at times, and even passing into fine grits or hornstones, but still variable in coarseness. In the order in which they lie, the talcose slates and quartzites are the inferior rocks, though quartzite occurs also in the condition of chert, flint or hornstone in all the series."

That the slates are of sedimentary origin is considered proved by the occurrence of "numerous beds containing rounded pebbles." He recognized the volcanic breccia but only as a conglomerate, for he writes:<sup>5</sup> "Brecciated Conglomerate: This is the most remarkable mass of this division of the system. It has an argillaceous or chloritic base. The mass is composed in the main of fragments of other rocks mostly retaining an angular form, but frequently, rounded and worn rocks are inclosed in the mass. The masses are sometimes 18 inches or two feet long . . ."

As to age, he put the whole formation in his "Taconic System." He based his conclusions as to age on lithologic characteristics and on certain nodular masses which he described as sponges and named *Palaeotrochis major*<sup>6</sup> and *Paleotrochis minor*. These have been proved to be spherulites<sup>7</sup> and not fossils.

He described in some detail the pyrophyllite deposits near Glendon, Moore County, then called Hancock's Mill, and classed the talcose slates, or those containing the pyrophyllite, as the basal member or oldest rocks of the system. He further pointed out that pyrophyllite occurs in the same position in Montgomery County.

Up to this time the pyrophyllite had been considered as soapstone, but Emmons tested it before the blowpipe and found it to contain aluminum. He, therefore, called it agalmatolite and suggested that it was the first found in this country. He gave the physical properties of this mineral together with its uses and the methods of mining near Hancock's Mill.

In 1862, Brush<sup>8</sup> analyzed some of the material from Hancock's Mill, Moore County, and showed it to be pyrophyllite.

<sup>4</sup> Emmons, E., "Geological Report of the Midland Counties of North Carolina," Raleigh, pp. 41 et seq. (1856).

<sup>5</sup> Op. Cit. p. 67.

<sup>6</sup> Op. Cit. p. 62.

<sup>7</sup> Diller, J. S., "Origin of Palaeotrochis," *Ellis. Mit. Sci. Soc. Jour.* Vol. 16, pp. 59-67, 1899.

<sup>8</sup> Brush, G. J., *Amer. Jour. Sci.* No. 34, p. 219, 1862.

In his "Geology of North Carolina," including a map of the entire State, issued in 1875, Kerr<sup>9</sup> put the whole slate formation in the Huronian, which in his classification is a division of the Archean, and considered it to be sedimentary. He mentioned talc and soapstone from Orange and Chatham Counties but added nothing to the description already published by Emmons.

In Kerr's and Hanna's<sup>10</sup> "Ores of North Carolina," published in 1893, the authors described some old gold mines in the Deep River region and stated: "It is worth while to add that part of what passes for talc is pyrophyllite and even hydro micaceous."

In 1894, Williams<sup>11</sup> in a very important paper recognized for the first time the occurrence within the slate belt of ancient acid volcanic rocks. He studied a small area in Chatham County and applied for the first time modern petrographic methods to the study of these rocks. Williams writes of this area as follows: "Here are to be seen admirable exposures of volcanic flows and breccias with finer tuff deposits which have been sheared into slates by dynamic agencies." These statements are applicable with little change to all parts of the slate belt.

In 1896 Nitze and Hanna<sup>12</sup> published a report on the "Gold Deposits of North Carolina." In this report they recognized the occurrence of volcanic rocks in the slate belt and suggested that there was more than one volcanic outbreak and during at least one period of inactivity slates were deposited. They did not mention pyrophyllite but described in some detail the Bell, Burns and Cagle gold mines, all of which are in the pyrophyllite area and pointed out that there had been much silicification at all of these and some propylitic alterations at the Bell mine in particular.

Pratt,<sup>13</sup> in a report published in 1900, described the pyrophyllite deposits near Glendon and Carbondon in the northern part of Moore and southern part of Chatham Counties and showed by chemical analyses that the mineral is true pyrophyllite. He described the pyrophyllite deposits as follows: "They are associated with the slates of this region but are not in direct contact with them, being usually separated by bands of siliceous and iron breccia which are probably 100 to 150 feet

<sup>9</sup> Kerr, W. C., "Geology of North Carolina," Raleigh, 1875.

<sup>10</sup> Kerr, W. C., and Hanna, G. B., "The Ores of North Carolina," Chapter 2, Vol. 2 of Kerr's Geology of North Carolina. N. C. Geol. Survey, pp. 242-245, 1893.

<sup>11</sup> Williams, G. H., "The Distribution of Ancient Volcanic Rocks Along the Eastern Border of North America," Jour. Geol. Vol. 2, pp. 1-31, 1894.

<sup>12</sup> Nitze, H. B. C., and Hanna, G. B., "Gold Deposits of North Carolina," N. C. Geol. Survey Bull. No. 3, 1896.

<sup>13</sup> Pratt, J. H., "Talc and Pyrophyllite Deposits of North Carolina," N. C. Geol. Surv. Economic Paper 3, 1900.

thick. These bands contain more or less pyrophyllite and they merge into a stratum of pyrophyllite schist." He offered no suggestion as to the origin of either the slates, breccia or pyrophyllite.

In 1906, Weed<sup>14</sup> and Watson in a paper on the Virgilina copper deposits studied and described a part of the slate belt. They concluded that the rocks of that area were pre-Cambrian volcanics, chiefly an original andesite that had been greatly altered by pressure and chemical metamorphism.

In 1908, Laney<sup>15</sup> prepared a report on the "Gold Hill Mining District" in which he said: "The rocks here included under the general term slates . . . while having many local variations seem clearly to represent a great sedimentary series of shales with which are interbedded volcanic flows, breccias and tuffs . . . In their fresh and massive condition the slates are dense, bluish rocks which show in many places well defined bedding planes and laminations. The volcanic flows, breccias and tuffs which are interbedded with the slates apparently represent two kinds of lava, a rhyolitic and andesytic type."

The next year Pogue<sup>16</sup> prepared a report on the "Cid Mining District of Davidson County" in which the rocks of that area are described as follows: "Wide bands of sedimentary, slate-like rock, composed of varying admixtures of volcanic ash and land waste have the greatest areal extent. Intercalated with these occur strips and lenses of acid and basic volcanic rocks, represented by fine and coarse grained volcanic ejecta and old lava flows."

In 1917 the North Carolina and Virginia Geological Surveys published a joint report on the Virgilina District by Laney.<sup>17</sup> In this the author classes the rocks of that portion of the slate belt included in the report as volcano-sedimentary and said: "Under this group are placed both the acid and basic flows and tuffs and the water laid tuffs and slates."

<sup>14</sup> Weed, W. H., and Watson, T. L., "The Virgilina Copper District," *Econ. Geol.* Vol. 1, pp. 309-330, 1906.

<sup>15</sup> Laney, F. B., "The Gold Hill Mining District," *N. C. Geol. Surv. Bull.* 21, 1910.

<sup>16</sup> Pogue, J. E., Jr., "The Cid Mining District of Davidson County," *N. C. Geol. Surv. Bull.* 22, 1910.

<sup>17</sup> Laney, F. B., "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," *N. C. Geol. Surv. Bull.* 26, 1917.

CHAPTER II  
GEOLOGY OF THE AREA

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GENERAL STATEMENT

The Carolina Slate Belt embraces a belt of country which varies in width from 8 to 50 miles and extends in a general southwesterly direction across the east central part of the State. Its western boundary is marked by a line drawn a few miles east of the towns, Greensboro, Lexington, and Charlotte, and its eastern boundary by a line a few miles west of Durham, Sanford, and Wadesboro. The belt is widest between Sanford and Lexington and becomes narrower to the north and south.

The Deep River portion of this belt (Fig. 1) consists of an area about 20 miles long by 5 miles wide, which lies on its eastern boundary along Deep River in the counties of Chatham and Moore.

The following detailed descriptions of the rocks apply especially to the Deep River region. However, a general reconnaissance survey of the pyrophyllite deposits, all of which as now known occur in the eastern and central parts of the slate belt, indicates that the descriptions given below apply equally well in a general way to the whole slate belt.

THE DEEP RIVER REGION

The rocks of the area, because of the complex character and well defined cleavage, have been called "slates"; but the name is misleading and confusing. They consist of volcanic-sedimentary formations made up of slates and tuffs with which are long interbedded bands and lenses of volcanic breccia, flows and ash. There are two distinct types of tuffs, breccias and flows: one is acid and the other a more basic phase. The acid phase consists of fine and coarse tuffs, and breccias chiefly of a rhyolitic and dacitic character, with flows of rhyolite and dacite. In the basic phase the breccia and flow types are more common than the fine and coarse tuffs, but the latter are usually present in at least small amounts. Diabase dikes doubtless of Triassic Age cut the other formations.

The formations seem to represent a period of continuous deposition during which the series was built up without break

or unconformity. The tuffs are the most abundant rocks of the area and are looked upon as the controlling formation; the other formations, with the exception of the slate, occurring as concordant flows or interbedded with them. The slate is considered as the youngest formation in the series, having been formed at the close of the period of volcanic activity and hence grades directly into the fine tuff.

Bedding planes are seldom found in the coarse tuffs and breccias, but their abundance in the slates bespeak for the latter an aqueous deposition. The chemical composition (page 18) of the slate material indicates, by an excess of soda over potash, that it was transported no great distance. It seems probable that the formations were deposited along shore with increasing estuarine areas into which the finer ash and land waste were washed and settled to form shale.

Metamorphism has been so complete that shales have become slates and the tuffs, flows and breccias have been so sheared that it is difficult to tell in the field which is slate, tuff, or flow. Hence they have all been called "slates." The series has been mashed and bent into folds and the original bedding planes have been largely destroyed by a well defined cleavage which dips from 45 degrees to 85 degrees to the northwest. The strike of the cleavage planes, axes of folding and different formations are all practically parallel and vary from N. 65 degrees E. to N. 30 degrees E.

Enough of the original features of the rocks have been preserved, however, to make possible, after careful field and laboratory study, the identification of the types of sedimentary and volcanic rocks discussed below.

*Slate.* The slate occurs as elongated bands and lenses separated by areas of volcanic rocks. It is important in areal extent, ranking second in amount only to the volcanic tuff. It varies greatly in appearance, but in the fresh state it is dark to black with varying dark green to gray color in the more tuffaceous phases. It has a well defined cleavage and in places still shows bedding, the presence of the latter indicating the position of existing folds. Along its margin the slate grades into a fine tuff. In fact the slate is a mixture of land waste and tuffaceous material, so that with an increase of the latter it grades into normal tuff.

Under the microscope little of its mineralogical character can be determined, but it presents a crystalline mass made up appar-

ently of fine quartz and feldspar with a large amount of dust-like particles of non-polarizing character. Small amounts of secondary chlorite and sericite are often found.

In the following table the first three analyses are from the Carolina Slate Belt while the fourth is a normal slate from Lancaster County, Pennsylvania. The first three analyses show an excess of soda over potash<sup>18</sup> which indicates that the slate of the Carolina Slate Belt did not go through the normal cycle of weathering as the clay slate, number 4.

	1	2	3	4
SiO <sub>2</sub> .....	66.43	61.02	52.62	60.32
Al <sub>2</sub> O <sub>3</sub> .....	16.27	25.54	33.20	23.10
TiO <sub>2</sub> .....	.43	-----	4.04	-----
Fe <sub>2</sub> O <sub>3</sub> .....	4.02	-----	-----	-----
FeO.....	.98	4.46	-----	7.05
MgO.....	.14	.14	.27	.87
CaO.....	1.27	.60	2.52	-----
Na <sub>2</sub> O.....	5.90	2.19	3.80	.49
K <sub>2</sub> O.....	1.76	1.81	.49	3.83
H <sub>2</sub> O.....	2.67	4.20	-----	4.08
P <sub>2</sub> O <sub>5</sub> .....	.07	-----	-----	-----
CO <sub>2</sub> .....	-----	-----	.66	-----
	99.94	99.96	97.60	99.74

1. Typical, banded, dark slate, Wet Creek, Moore County, North Carolina, J. L. Stuckey, analyst.
2. "Slate," from Haile Mine, South Carolina, Charles Baskerville, analyst. Nitze, H. B. C. and Hanna, G. B., "Gold Deposits of North Carolina," N. C. Geol. Surv. Bull. 3, p. 34, 1896.
3. Typical black slate near Gold Hill, R. T. Allen, analyst. Laney, F. B., "Gold Hill Mining District," N. C. Geol. Surv. Bull. 21, p. 28, 1910.
4. "Roofing Slate," Lancaster County, Pa. Merrill, G. P., "Rocks, Rock-Weathering and Soils," p. 119, 1913.

*Tuffs.* The tuffs are the most abundant rocks and make up the only formation that is continuous from one end of the area to the other. All rocks that exhibit a fragmental character in which the fragments are less than one-half inch in diameter are here classed as tuffs. They are considered the controlling formation of the district and exhibit two phases that are sufficiently

<sup>18</sup> Pogue, J. E., Jr., "The Cid Mining District of Davidson County," N. C. Geol. Surv. Bull. 22, pp. 41-42, 1910.

important to warrant description. One of these is a fine, the other a coarse tuff.

*Fine Tuff.* The acid fine tuff occurs interbedded with both the slate and coarse tuff and grades into each of them. It has no wide areal extent, but occurs as narrow lenses and bands which are abundant especially in the coarse tuff. (Fig. 1.)

The rock varies from place to place depending on the schistosity and the amount of silicification it has undergone, and exhibits the following varieties: 1. A highly siliceous rock, gray to nearly black in color, breaking with a conchoidal fracture and sharp edges, the outcrops much jointed, the rock emitting a metallic ring when struck with a hammer, and locally known as "gunflint." This is the most abundant. 2. A less dense, less siliceous rock, light gray or nearly white, ranging in hardness from a soft ash-like material to a solid rock called "whetstone." 3. A bluish gray to green rock resembling a coarse phase of the slate. (Plate 2, Fig. 6.)

When examined microscopically the tuff shows a cryptocrystalline ground mass with fragments of quartz and feldspar (orthoclase, albite, and oligoclase) as well as secondary minerals, epidote, clinozoisite, chlorite and calcite. Iron oxides are common. Some sections show small areas with original flow structure while others exhibit a parallel arrangement of the particles due to metamorphism.

*Coarse Tuff.* The coarse tuff varies from a massive to a highly schistose type of rock, but occasionally the former has been so slightly changed as to show some of its original characters. There is every gradation to a fine tuff on one hand and to an acid volcanic breccia on the other. The freshly broken rock proves to be made up of quartz and feldspar grains and rock fragments of less than one-half inch in diameter set in a dense bluish or greenish gray-ground mass, the whole often resembling an arkose. Portions of the massive phase are dacitic and rhyolitic in character. One small area was found that might be called a true dacite. The mashed and sheared phases have to a great extent had their fragmental nature obliterated.

In thin sections the coarse tuff (Plate 1, Fig. 3) shows fragmental phenocrysts of quartz, orthoclase and acid plagioclase with fragments of different kinds of rocks, some of which show clearly a definite flow structure, all embedded in a fine ground mass. Kaolinite, chlorite, epidote, and calcite form secondary products. Biotite and muscovite are rare. Grains of hematite

and limonite as well as small particles of sphene, titanite and apatite were found in most sections.

*Rhyolite.* Flows of rhyolite occur as narrow bands and lenses in the tuff into which they grade. It is possible that some of the rocks mapped as silicified fine tuff may be a partially desilicified rhyolite. The rhyolite is dense and indistinctly porphyritic, with a dark gray to bluish color, and on fresh fracture shows a greasy lustre. Flow lines have developed in numerous places and are best seen on weathered surfaces, while amygdaloidal structure may be found in a number of outcrops.

In thin sections the rhyolite shows phenocrysts of plagioclase (chiefly oligoclase) orthoclase and quartz, named in the order of relative abundance. Kaolinite, epidote and chlorite have developed in abundance from the weathering of the feldspars, and calcite is plentiful along fractures in the rock.

*Volcanic Breccia.* The identification of this rock is based more upon its general characteristics and field relations than upon microscopic differences. All rocks that exhibit a fragmental character sufficiently well defined to attract attention in the hand specimen, and in which the fragments are over one-half inch in diameter are here classed as volcanic breccia. The size of the fragments observed varies from one-half inch to seven inches in diameter.

This rock is widely scattered through the area, occurring in long bands, lenses, and patches interbedded with the tuffs. Three varieties are recognized: 1. Acid volcanic breccia. 2. Iron volcanic breccia. 3. Basic volcanic breccia.

*Acid Volcanic Breccia.* This rock consists partly of a brecciated tuff and partly of a brecciated rhyolite. When freshly broken the breccia has a greenish or mottled-gray color, produced by various colored fragments in a finer ground mass. In places the breccia has been strongly sheared and it always shows some mashing and schistosity, but on the whole is more massive than the finer tuff rocks.

Thin sections show little difference from the regular coarse tuffs. In fact the fragments are chiefly of tuffaceous or rhyolitic character with occasional slate fragments. Phenocrysts of quartz, orthoclase, and plagioclase (chiefly oligoclase) are abundant. The fragments of the brecciated rhyolite phase show a flow structure. In all phases of the breccia the ground mass is altered and kaolinized. Specks of iron oxides—chiefly hema-

tite—are present, while the secondary minerals, epidote and chlorite and secondary quartz are plentiful.

*Iron Volcanic Breccia.* This rock was first recognized by Ebenezer Emmons<sup>19</sup> in 1856 when he noted it as occurring in connection with the pyrophyllite beds north of Hancocks Mill which was located on Deep River in the area under consideration. It has been called "iron breccia" because it weathers out in round, pitted, iron-colored masses that look more like iron ore (limonite) than a true breccia. The fresh fracture surface is lighter in color and much like an ordinary acid breccia. It contains light and dark colored fragments, the former being largely silicious while the latter contain a great deal of hematite in fine particles.

Thin sections of the freshly broken iron breccia show crystal fragments of quartz and feldspar and areas of almost pure quartz but large areas are rendered almost completely opaque due to the amount of iron present.

The iron breccia is doubtless a variation of the acid breccia in which iron oxides—chiefly hematite—are abundant.

*Basic Volcanic Breccia.* This rock is distinctly more basic than the acid breccia or iron breccia and is thought to be mainly andesitic in character. It consists chiefly of brecciated tuffs and flows but ranges all the way from a fine and highly massed tuff to a massive coarse breccia with fragments up to four inches in diameter. It varies from a dark gray through a chlorite and epidote green in color. The andesitic type of breccia is far more abundant than the iron breccia.

In thin sections this rock appears more uniform than in the hand specimen. Fragmental materials embedded in a feldspathic ground mass make up nearly every section studied. The following minerals are seen, named in order of abundance: orthoclase, plagioclase (oligoclase and andesine), chlorite, epidote, zoisite, clinozoisite, quartz, calcite, iron oxides, kaolinite and sericite.

*Andesite.* Andesite is of limited occurrence within the sector studied, only two small areas having been recognized. It is dark green in color, usually massive or fine grained, but often grades off into a fragmental phase. One of its chief field characteristics is the lack of a well defined cleavage such as is well developed in the other rocks of the area.

<sup>19</sup> Emmons, E., "Geological Report of the Midland Counties of North Carolina," N. C. Geol. Survey, p. 54, Raleigh, 1856.

In thin section it shows two distinct phases, the one amygdaloidal, and the other massive or slightly tuffaceous. Both phases when best developed show a distinct and unmistakable flow structure. The andesite passes by direct gradations into volcanic breccia on one hand and into acid tuff on the other.

The following minerals were found in the sections examined: epidote, plagioclase—mostly oligoclase and andesine—chlorite, quartz, secondary calcite, and iron oxides. Epidote is the most abundant mineral present, having almost completely replaced most of the feldspar crystals and being present through all parts of the ground mass. In the amygdaloidal phase epidote and chlorite nearly always fill the amygdules.

*Diabase.* Dikes of diabase, limited in number and areal extent, cut all the other formations and strike N. E.-S. W. or N. W.-S. E. There are two distinct varieties of diabase: one is a massive fine-grained rock or grayish to black color; the other is a massive rock of medium-grained texture and almost black color.

In thin section the light-colored rock is seen to be made up of the minerals, plagioclase (chiefly labradorite), augite, secondary hornblende, iron oxides, apatite, and chlorite. The dark-colored rock is made up of plagioclase (chiefly labradorite), augite, olivine, iron oxides and chlorite. In both rocks the minerals have typical ophitic structure.

#### STRUCTURE

*Folding and Schistosity.* These two features are so closely related in the area considered here that it seems best to discuss them together. The mashed and schistose character of all the rocks and the well-defined cleavage planes dipping steeply to the northwest are their most outstanding structural features and point conclusively to the great compressive force to which the region has been subjected. The distribution of the different formations in long narrow bands parallel to the direction of the strike of the cleavage planes (N. E.-S. W.), and the poorly preserved bedding planes in the slates—some of which dip southeast and some northwest—seem to indicate definite folding.

There are different possible interpretations of the structure because of the lack of details, but the one which seems most reasonable to the writer is that of a closely compressed synclorium with the axes of the folds parallel to the strike of the formations. From evidence of bedding planes in the slates the

minor folds dip steeply on the northwest side of the troughs and flatten out to the east. The synclinal troughs pitch and flatten out in places as is indicated by the way the slate bands, which are all synclinal in structure, occur in long narrow lenses often pinching out. This pinching and flattening indicates some cross folding. In some instances, especially along Wet Creek, a definite pitch of 10 degrees to the southwest was noted in the syncline.

The slates seem to have consolidated readily and folded like normal sediments while the tuffs and breccias remained in a state of open texture and tended to mash and shear instead of folding. This is indicated by the mashed and sheared condition of practically all the tuffs while in numerous cases poorly preserved bedding planes in the slates indicate a definite synclinal structure. The bands of mashed and sheared tuff between the bands of slate seem to have taken the place of anticlines during compression and to have relieved the pressure largely by mashing and shearing. Some true folding may have developed in them but it was not observed in the field. That the forces producing folding and schistosity did not act equally throughout the area is shown by the fact that some of the folds are more closely compressed and pitch more than others while the dip of the cleavage planes is flatter in some places and steeper and better developed in others.

*Faulting.* In a region that has undergone so much dynamic stress it is natural to look for thrust faulting of some magnitude. There is, however little direct evidence of it. In places a few minor displacements could be seen in old mines but those noted seldom amounted to more than a few inches or, at most, a foot or two. It seems that a lack of faulting may be explained by the fact that the tuffs mashed and sheared readily under compression and shortened enough to relieve the stress before marked faults developed.

#### GENERAL RELATIONS OF THE WHOLE SLATE BELT

A comparison of the rocks of the Deep River region with those of the Cid district<sup>20</sup> of Davidson County, the Gold Hill<sup>21</sup> district, and the Virgilina<sup>22</sup> district shows a marked similarity

<sup>20</sup> Pogue, J. E., Jr., "The Cid Mining District of Davidson County," N. C. Geol. Surv. Bull. 22, 1910.

<sup>21</sup> Laney, F. B., "The Gold Hill Mining District," N. C. Geol. Surv. Bull. 21, 1910.

<sup>22</sup> "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," N. C. Geol. Surv. Bull. 26, 1917.

in the composition and distribution of the formations throughout the four areas. Such striking likeness in the rocks of four areas so widely separated seems to warrant the conclusion that the rocks of the whole slate belt are of the same general types.

Any general statement as to the structure of the slate belt as a whole cannot be so easily made. Laney<sup>23</sup> considered the structure in both the Gold Hill and Virgilina districts as a closely compressed synclinorium and suggested that that structure might apply to the whole slate belt. The writer has applied the same structure to the Deep River region with the added suggestion that the slate areas are true synclines, and feels that a synclinorium or small geo-syncline with the majority of slate areas occupying synclines is the true structure of the whole belt. Visits to a number of localities in the slate belt bear out the conclusion that the slate bands in several places, at least, form true synclines. However, it should not be overlooked that in the southwestern part of the slate belt, especially in Stanly and Union Counties, where the normal tuffs are less abundant or lacking, the slates do develop anticlines. One such anticline is well developed in the town of Monroe, Union County.

It will be necessary to study the slate belt in detail as a unit before any definite conclusions can be stated. Metamorphism has not been uniform throughout its area. In places the rocks are closely compressed and schistose while in others, as near Norwood, Stanly County, and Monroe, Union County, they are hardly disturbed; so little so, in fact, that the Monroe<sup>24</sup> slates were at one time considered younger than those of the rest of the slate belt. Laney,<sup>25</sup> however, found nothing to indicate that the Monroe slates were younger or different geologically from the slates of the other parts of the belt.

It is not only necessary to consider the fact that metamorphism has not been uniform throughout the area, but it is also necessary to consider that the forces probably did not act in the same direction all the time. All that part of the belt to the south of a line drawn approximately between Durham and Greensboro has a well defined cleavage dipping more or less steeply to the northwest. North of this line there is an indefinite

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<sup>23</sup> Laney, F. B., *Op. Cit.*

<sup>24</sup> Nitze, H. B. C., and Hanna, G. B., "Gold Deposits of North Carolina," *N. C. Geol. Surv. Bull.* 3, 1896.

<sup>25</sup> Laney, F. B., "The Gold Hill Mining District of North Carolina," *N. C. Geol. Surv. Bull.* 21, p. 42, 1910.

zone of two or three miles in which the cleavage is almost vertical, and then to the north throughout the remainder of the belt the cleavage dips steeply to the southeast. An explanation of this feature has not yet been attempted.

Nothing was found in the course of the work to definitely indicate the age of the rocks. They have in a majority of cases been classed as pre-Cambrian and are so considered here.

### CHAPTER III

## GEOLOGY OF THE PYROPHYLLITE DEPOSITS

### THE PYROPHYLLITE BODIES

*Introduction.* Just when pyrophyllite was first discovered in North Carolina is not known. Olmstead<sup>26</sup> in 1825 described the slate belt and mentioned talc and soapstone. It is very probable deposits mentioned by him are known today as pyrophyllite but this cannot be proved from the description given. Emmons<sup>27</sup> in his report of 1856 gave a brief geological account of the deposits of the Deep River region and the quarrying methods then used. Pratt<sup>28</sup> in 1900 described the deposits and published further analyses of the pyrophyllite. He pointed out that the deposits had been worked almost continuously since the Civil War. In 1913 Hafer<sup>29</sup> remarked that the pyrophyllite did not differ greatly from the sericite found in the old gold mines of the same belt and may have originated in the same manner. He also called attention to the masses of pyrite-bearing quartz that are often found associated with the pyrophyllite deposits.

*Distribution.* Three mines, of sufficient importance to warrant the building of mills, and numerous prospects locally referred to as mines, represent the present pyrophyllite mining development in the Deep River region. These mines and prospects may be divided into two distinct zones or bands, both of which are found chiefly in the normal acid tuff. The more extensive of these zones begins on Indian Creek in Chatham County and extends southwest along an almost direct line of strike into Moore County about 10 miles, as far as the point where the Norfolk Southern Railroad crosses Buffalo Creek. The most important developments are about one mile north of Glendon.

The second zone lies about two miles southwest of Hemp along Cabin Creek, strikes N. 20 degrees E. and can be traced along the strike from Carter's Mill on the northeast to Wet Creek on the southwest, a distance of about four miles. This zone contains a prominent body or lens of pyrophyllite, on which a mill of modern type is being operated.

<sup>26</sup> Olmstead, D., "Report on the Geology of North Carolina," Raleigh, 1825-27.

<sup>27</sup> Emmons, E., "Geological Report of the Midland Counties of North Carolina," pp. 52-54, Raleigh, 1856.

<sup>28</sup> Pratt, J. H., "Talc. and Pyrophyllite in North Carolina," N. C. Geol. Surv. Econ. Paper 3, 1900.

<sup>29</sup> Hafer, C., "Pyrophyllite in North Carolina," Eng. and Min. Jour., Vol. 96, p. 623, 1913.

Another small body is known about one and one-half miles southwest of Hallison near an old gold mine that lies near the contact between the tuff and slate.

In addition to these deposits, pyrophyllite occurrences are known five miles southeast of Spies on Cabin Creek in Moore County; near Troy and along Little River in Montgomery County; near Staley in Randolph County; around Hillsboro in Orange County; and two miles north of Stem in Granville County. The deposits near Troy, Staley and Stem are of promise.

*Geologic Relations.* All the pyrophyllite bodies found in the district are in acid volcanic rocks, chiefly in the normal coarse-grained tuff, although they occur to a less extent with fine acid tuff and acid volcanic breccia. They were not found at any point in a basic or andesitic type of rock or associated with a typical water-laid slate of the district. Along the main pyrophyllite zone from Indian Creek to Deep River, especially at the important deposits between Rogers Creek and the river, the southeastern or footwall side of the bodies, is an acid or iron volcanic breccia, and at places the pyrophyllite grades into and replaces parts of this rock. Near the point where the pyrophyllite formation is crossed by the Deep River north of Glendon there is locally a partial pyrophyllitization of the rhyolite on the northwest side of the zone. At the river the volcanic breccia on the footwall side disappears and is found only occasionally further to the southwest along the strike, but near Buffalo Creek is found on the hanging-wall side of the pyrophyllite bodies. In every other case the pyrophyllite on the hanging-wall side grades into normal acid tuff. Where the band of volcanic breccia is absent from the footwall side of the deposits the pyrophyllite bodies are much nearer the slate than those at Glendon, but they are never found in the normal slate.

The pyrophyllite area on Cabin Creek occurs in normal to coarse-grained acid tuff or breccia. Along the edges of the pyrophyllite bodies and between them along the strike near the Cagle gold mine there is much silicified fine tuff, but otherwise the country rock is a coarse to fine-grained acid volcanic tuff that is highly sheared and schistose.

The pyrophyllite deposits near Troy, Montgomery County, near Staley, Randolph County and north of Stem in Granville County all occur in a normal medium to coarse-grained acid volcanic tuff. The hanging-wall of the deposit near Staley is a

typical volcanic ash, but there is no indication that this ash has been altered to or replaced by pyrophyllite.

*Form and Structure.* A prominent feature of the pyrophyllite bodies is their irregular, oval, or lens-like form. They lie in a narrow band or zone aligned with the strike. Some of the largest deposits near Glendon are those at the Snow Mine on Rogers Creek, at the old Womble Mine north of Glendon, and at the McConnell Mine. The bodies vary in width from 200 to 500 feet and in length parallel to the strike from 700 to 1,500 feet. Between these bodies there is often no surface indication of pyrophyllite.

The pyrophyllite area southwest of Hemp shows the same features. One important body 150 to 200 feet wide and about 2,000 feet long has been proved by prospecting and mining on Cabin Creek. Along the strike from either end of this body for some distance there is occasional evidence of other, but perhaps smaller, bodies.

The main zone along Deep River has a strike of from N. 40 degrees to 60 degrees E. and a cleavage dip of 30 degrees to 65 degrees to the northwest, while in the area southwest of Hemp the strike varies from N. 20 degrees E. to N. 40 degrees E. and the cleavage dips from 45 degrees to 85 degrees to the northwest.

This general description of the pyrophyllite bodies applies equally well to the deposits outside the Deep River region. The deposit near Staley is 250 to 300 feet wide and 700 to 800 feet long. The strike varies from N. 60 degrees to 70 degrees E. while the cleavage dips steeply to the northwest. North of Stem there are some three bodies which vary in width from 50 to 100 feet and in length up to 500 feet or more. The deposits trend in a northeast direction and have a vertical cleavage dip.

The different pyrophyllite bodies grade in both directions along the strike into acid tuff. Followed vertically downward there has been no change at the depths so far reached. Not only are they lenticular along the strike, but they also have an internal lenticular structure. In quarrying, lenses of pure pyrophyllite are found along with lenses of practically unaltered tuff.

That the pyrophyllite deposits have been intensely squeezed, crumpled and deformed is indicated by the numerous slickensided surfaces and variations in the strike and dip of the cleavage surfaces and planes of parting. Occasionally, as in the

mine of the Standard Mineral Company near Hemp, there is limited faulting.

*Mineralogy of the Deposits.* The minerals observed in the pyrophyllite deposits in the order of their abundance are pyrophyllite, quartz, chloritoid, sericite, pyrite, chlorite, feldspar, iron oxides, epidote, zircon, titanite, rutile, zeolites, and apatite. Of these only the first eight are present in important amounts. The other minerals are noticed in but small quantities, to the extent they might occur as accessory constituents of an igneous rock or as products of regional metamorphism or weathering.

*Pyrophyllite* varies in color from nearly black through yellowish white, green, and apple green to pure white, has a specific gravity of about 2.8 to 2.9 and a hardness less than the finger nail. It occurs in masses, lenses, and pockets associated with chloritoid, sericite, pyrite, and iron oxides, has a greasy feel, pearly luster and generally a foliated, but occasionally a radiated or fibrous structure.

*Quartz* is abundant everywhere except in the very best grade of pyrophyllite. It occurs: (1) as large masses of a cherty or milky appearance; (2) as clear veins and stringers in the deposits and along the walls and; (3) as small masses and nodules in the altered or only partly altered rock.

*Chloritoid* is found in small amounts in all the pyrophyllite deposits, most abundantly in those north of Glendon where they lie in contact with the "iron volcanic breccia." It varies from brown to dark green in color, the latter being far more common. In thin section it is seen to form sheaf-like patches made up of bladed crystals that are often twinned and do not have well developed crystal ends.

*Sericite*\* is present in varying amounts disseminated through the impure pyrophyllite in small scales and flakes. At places it occurs in pockets and lenses near the bottom of the mine as a massive compact material.

*Pyrite* is present in small amounts associated with the silicified tuff along the walls of the pyrophyllite bodies and in the included lenses of silicified country rock.

*Chlorite* occurs commonly in the impure portions of the pyrophyllite bodies and often in otherwise pure pyrophyllite.

*Feldspars*, as orthoclase and albite and in one case andesine,

\* In the material studied for the preparation of this report sericite has been distinguished from pyrophyllite by its smaller optical angle and by the presence of potash in the chemical analyses.

were found in small amounts in the less silicified portions of the wall rock.

*Iron oxides*, chiefly hematite and magnetite are found in small amounts in each pyrophyllite deposit studied but most abundantly in the footwall of the mine near Glendon which is chiefly iron breccia.

*Petrography.* A careful study of about 75 thin sections cut from the various mines and quarries shows that the pyrophyllite deposits have been formed in a normal volcanic tuff and to some extent in a volcanic breccia that varied from dacitic to rhyolitic in composition.

Sections from specimens of tuff collected along the walls and edges of the pyrophyllite bodies usually show as a first change marked silicification accompanied by a marked decrease in the feldspar content. In some places as at the Standard Mineral Company's Mine, near Hemp, and the Snow prospect on Rogers Creek, silicification seems to have been followed immediately by the development of pyrophyllite. In the Womble Mine and the mine of the Southern Talc Company, near Glendon, the silicification seems to have been accompanied by the development of pyrite as this mineral is sometimes found in the silicified wall rock but seldom in the pyrophyllite, while on the foot wall side of the Womble Mine there was a remarkable development of chloritoid along with or more probably immediately after the major silicification.

In passing from the walls of the deposits into the mineral bodies themselves there is a decrease in the amount of quartz, pyrite, and chloritoid. The best mineral bodies consists of practically pure pyrophyllite or pyrophyllite and a small amount of sericite interspersed with lenses of quartz and partly altered country rock.

The chief minerals, pyrophyllite, quartz, chloritoid, sericite, pyrite, feldspar, iron oxides, and chlorite have definite relations to each other.

There is a close relation between the chloritoid and the iron oxides, for the former is far more abundant in the deposits where the latter is present, in fact it shows a marked local concentration in that part of any deposit where iron oxides are most abundant.

The Womble Mine at Glendon has a typical iron breccia for its footwall, in which the iron consists largely of hematite and magnetite. In this mine chloritoid is present in abundance and

it is concentrated largely on the footwall side near the iron breccia. Thin sections from such specimens show that the chloritoid is in direct contact and association with small amounts of magnetite and hematite. The chloritoid was not observed replacing the iron oxides, but the marked increase and close association of chloritoid with the iron oxides at every point where the latter are present suggest a close genetic relation between the two.

The chloritoid was developed along with or soon after the silicification of the tuff and in thin sections it is seen to have partially replaced the quartz. (Plate 1, Fig. 4).

The pyrophyllite appears to have been later than the chloritoid. Some sections showing an abundance of chloritoid contain no pyrophyllite or only tiny flakes of it. This indicates that the chloritoid is earlier than the pyrophyllite in these sections. But in practically every section where chloritoid is abundant pyrophyllite is also abundant. Where pyrophyllite is present in the section with chloritoid it occurs in every crack and opening in the sheaves and bundles of chloritoid, and intergrown into the broken ends of the crystals and even long the cleavage cracks seemingly indicating definite replacement.

The microscope shows the pyrophyllite to be the last mineral formed. In every case silicification had taken place before the development of pyrophyllite. The feldspars disappeared with the silicification so that feldspar and pyrophyllite are seldom found in the same section. Practically every section that contains pyrophyllite contains some quartz, the amount of the latter depending on the purity of the specimen in terms of pyrophyllite. In every one of these sections the pyrophyllite is replacing the quartz (Plate 1a, Fig. 5). This is true of the wall rock, of the masses of cherty or milky quartz in the pyrophyllite, and of the clear quartz seams and veins that cut the pyrophyllite at various angles.

The sericite occurs closely associated with the pyrophyllite. Thin sections cut from partly silicified, partly pyrophyllitized masses along the foot falls and in the deposits show a small amount of sericite occurring with the pyrophyllite and showing about the same relations to the quartz. The cherty or flinty masses of quartz in the pyrophyllite are cracked and shattered and along these cracks pyrophyllite and some sericite are found replacing the quartz.

## PLATE 1

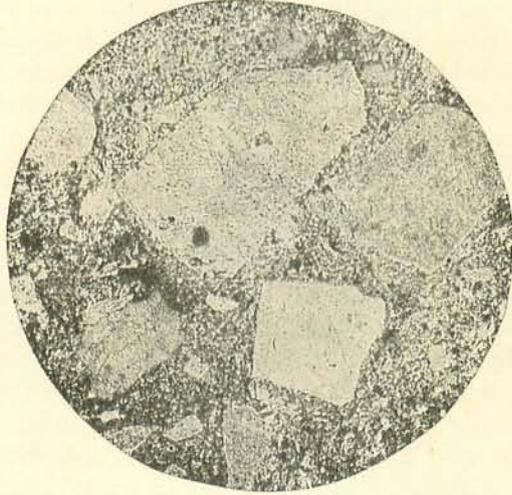


FIG. 3.—Thin section of coarse acid tuff, ordinary light, x40.

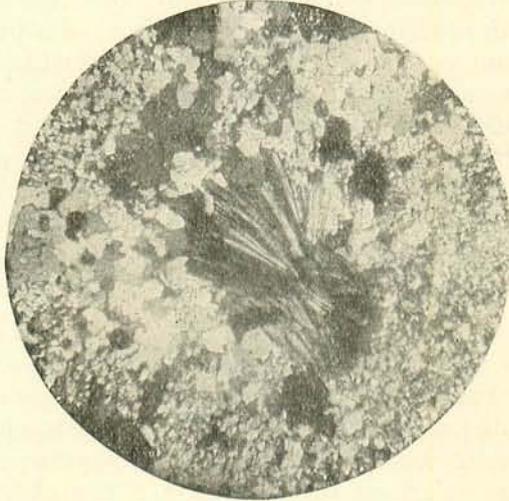


FIG. 4.—Thin section showing chloritoid replacing quartz, crossed nicols, x64.

## PLATE 1a

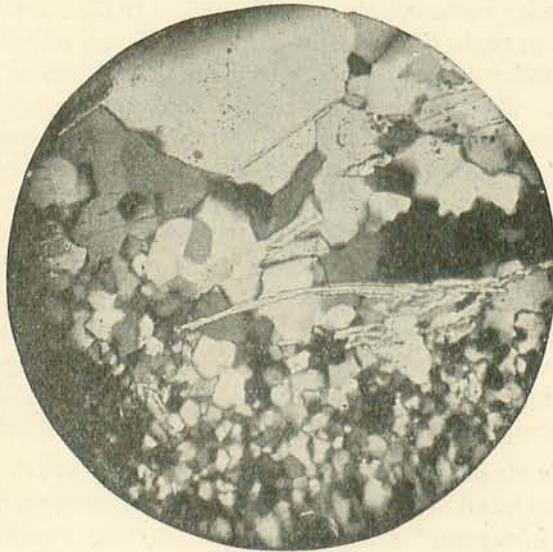


FIG. 5.—Thin section showing pyrophyllite replacing quartz, crossed nicols, x100.

## ORIGIN OF THE PYROPHYLLITE BODIES

In considering the origin of the pyrophyllite bodies, their relation to each other and the enclosing rocks, their shape and distribution, their mineralogical composition and the relation of the constituent minerals to each other, have been taken into account. Future developments of the deposits may bring forth additional facts that may call for other theories and explanations than those here set forth. One great difficulty in formulating a theory of origin is the complex nature and highly metamorphosed state of the rocks of the "slate belt."

*Earlier Theories.* Before discussing the origin of the North Carolina pyrophyllite reference may be made to the views already expressed by other writers on the origin of this mineral and the chloritoid and sericite associated with it.

Emmons<sup>30</sup> (1856) considered pyrophyllite (agalmatolite) as a sedimentary rock near the base of his Tatonic system. Levy<sup>31</sup> and Lacroix (1888) state that pyrophyllite occurs in metamorphic rocks while Dana<sup>32</sup> (1909) classed it as a mineral forming

<sup>30</sup> Emmons, E., "Geological Report of the Midland Counties of North Carolina," Raleigh, 1856.

<sup>31</sup> Levy, M., and Lacroix, A., "Mineraux des Roches," p. 254, 1888.

<sup>32</sup> Dana, E. S., "A System of Mineralogy," p. 691, 1909.

at the base of schists or as a mineral of the crystallizing schists and Paleozoic metamorphics. Clapp<sup>33</sup> (1913) assumed that alunite and pyrophyllite are probably developed only under conditions of moderate temperature and pressure such as exist near the surface. Buddington<sup>34</sup> concluded that the pyrophyllite and pinite of the Avondale volcanics were formed by metasomatic replacement of silicified rhyolites or rhyolitic volcanics by hot waters under conditions of intermediate temperature and pressure. LeChatelier<sup>35</sup> determined the temperature at which pyrophyllite loses its water and found two points of marked loss, one at 700° and the other at 850° C. The present writer<sup>36</sup> made a comparative dehydration test of pyrophyllite and sericite and found that sericite lost its water much faster than pyrophyllite at lower temperatures and at 750° C. was practically dehydrated while the pyrophyllite still held about 1 per cent of water.

Sericite is classed by Rogers<sup>37</sup> as a typically low temperature mineral associated with the last stages of hydrothermal alteration, while Lindgren<sup>38</sup> classes it as a mineral common to hydrothermal alterations at shallow and intermediate depths and points out that in acid rocks of the rhyolitic type silicification and sericitization are common near the surface, but does not agree with Rogers<sup>39</sup> that sericite is a late mineral.

While much has been published regarding the nature of chloritoid there is little definite information on its genesis. Clark<sup>40</sup> states that chloritoid is formed in schists where much iron and water are present, and that it is intermediate between the micas and chlorite and may alter into either. Manasse<sup>41</sup> describes a schist of sericite, quartz, rutile, tourmaline, chlorite, and epidote, from the Alps of Italy, closely associated with and occurring on both sides of a marble, in which chloritoid is abundant.

Niggli<sup>42</sup> in a study of the chloritoid and ottrelite groups of the

<sup>33</sup> Clapp, C. H., "The Geology of the Alunite and Pyrophyllite Rocks of Kyuquot Sound, Vancouver Island," Summary Report of the Geol. Survey, Dept. of Mines for 1913, pp. 109-126, 1914.

<sup>34</sup> Buddington, A. F., "Pyrophyllitization, Pinitization, and Silicification of Rocks Around Conception Bay, Newfoundland," Jour. of Geol., vol. 24, pp. 130-152, 1916.

<sup>35</sup> LeChatelier, M. H., "De l'Action de la Chaleur sur les Argiles," Bull. Soc. Min. France, 10, p. 207, 1887.

<sup>36</sup> Stuckey, J. L., "The Dehydration Temperature of Pyrophyllite and Sericite," Jour. Amer. Ceramic Soc., Vol. 7, pp. 235-237, 1924.

<sup>37</sup> Rogers, A. F., "Sericite as a Low Temperature Hydrothermal Mineral," Econ. Geol., Vol. II, pp. 118-150, 1916.

<sup>38</sup> Lindgren, W., "Mineral Deposits," pp. 478-480 and 549-564, 1919.

<sup>39</sup> Op. cit.

<sup>40</sup> Clark, F. W., "Data of Geochemistry," U. S. G. S. Bull. 695, pp. 615-616, 1920.

<sup>41</sup> Manasse, E., "Cloritoide (Ottrelite) delle Alpi Apuane," Mem. Soc. Tosc., Vol. 26, pp. 121-142, 1910.

<sup>42</sup> Niggli, P., "Die chloritoidschiefer und die sedimentaren Zone am Nordstrande des Gottardmassives," Beitrage zur Geologischen Karte der Schweiz, Vol. 36, 1912.

Swiss Alps decided that the two minerals are identical. He pointed out that the chloritoid is abundantly developed in schists that were originally high in clay content and believes that its formation was directly due to pressure and relatively independent of temperature. He gives a diagram showing that regardless of temperature chloritoid is formed with an increase in pressure and conversely it drops out when the pressure is diminished.

*Analyses of Rocks.* In the table on page 36 there are a number of chemical analyses of rocks and minerals from the Deep River region and for comparison some similar rocks from other regions. Number 1 is a normal dacite tuff from near Montieith Bay on Vancouver Island. Number 2 is the same type of rock a short distance away altered to quartz and sericite. Number 3 is a dacite tuff from near Gold Hill, North Carolina, and Number 4 from nearby is the same kind of rock after silicification.

The material for analyses 3 and 4 came from the same "slate belt" of which the Deep River region is a part. Both these analyses show a decrease in alumina and in alkalies as the silica increases. The same conditions hold in the deposits around Conception Bay described by Buddington. Further replacement by pyrophyllite or sericite is accompanied by an increase in alumina, potash increasing with the sericite content.

While no chemical analyses were made of any tuffs of the Deep River district, a study of thin sections indicated that the same changes occurred there. The normal tuff consists largely of acid feldspars and quartz. The silicified rocks from the mineral bodies show quartz and a very small amount of feldspars as the chief minerals. This seems to indicate a decrease in the alumina and alkalies. Analyses 5, 6, 7 and 8 represent pyrophyllite of different grades of purity, and indicating varying amounts of admixed sericite, while 9 and 10 represent chloritoid and sericite respectively. Analysis 5 is a silicious material that would seem to contain both pyrophyllite and sericite. Number 6 is free from grit or quartz but evidently contains considerable sericite, while numbers 7 and 8 are practically a pure pyrophyllite.

*Origin of North Carolina Pyrophyllite.* The field, microscopic, and chemical evidence suggest that the pyrophyllite bodies have been formed through metasomatic replacement of acid tuffs and breccias of both dacitic and rhyolitic composition. Evidences that the deposits have been formed by replacement are

	1*	2*	3**	4**	5	6	7	8	9	10
SiO <sub>2</sub>	73.22	87.80	56.94	72.16	68.40	57.58	64.68	64.54	29.28	47.07
Al <sub>2</sub> O <sub>3</sub>	13.46	9.08	20.96	9.00	23.80	33.31	28.34	28.88	37.98	36.89
Fe <sub>2</sub> O <sub>3</sub>	2.33	0.40	3.97	2.47	0.38	0.33	0.60	0.45	2.32	0.42
FeO	0.96	nd		3.30	nd	nd	nd	nd	21.97	nd
MgO	0.42		0.41	3.03	0.16	trace	trace	trace	1.28	0.20
CaO	1.50		6.01	0.43	0.51	trace	0.72	0.36	trace	0.55
Na <sub>2</sub> O	5.46	0.62	3.96	3.69	0.07	0.06	0.38	0.12	nd	1.34
K <sub>2</sub> O	1.74	1.70	1.29	0.24	1.48	3.90	0.01	0.18	nd	8.21
H <sub>2</sub> O	0.62	1.04	0.19	4.08	4.96	5.56	5.54	5.40	6.04	5.05
TiO <sub>2</sub>	0.28	nd			nd	nd	nd	nd	0.86	trace
MnO	0.10				nd	nd	trace	nd	0.29	nd
CO <sub>2</sub>			2.52							
S		trace		1.85						
	100.09	100.04	96.25	100.25	99.76	100.74	100.27	99.93	100.02	99.73

1. Dacite tuff, 1 mile southeast of Monteith Bay, N. L. Turner, analyst.
2. Cherty quartz-sericite rock, Quarry of British Columbia Pottery Company, Monteith claim.
3. Typical coarse tuff near Morgan's Mill, Gold Hill, A. S. Wheeler, analyst.
4. Tuff, more or less silicified, Union Mine, A. S. Wheeler, analyst.
5. Silicified tuff, partially pyrophyllized, Standard Mineral Company's Mine, J. L. Stuckey, analyst.
6. Pyrophyllite, Standard Mineral Company's Mine, J. L. Stuckey, analyst.
7. Pyrophyllite, Womble Mine, J. L. Stuckey, analyst.
8. Pyrophyllite, Gerhardt Bros., Staley, N. C., E. E. Randolph, analyst.
9. Chloritoid, Womble Mine, J. L. Stuckey, analyst.
10. Sericite, Standard Mineral Company's Mine, J. L. Stuckey, analyst.

\* Clapp, C. H., "The Geology of the Alunite and Pyrophyllite Rocks of Kyuquot Sound, Vancouver Island," Summary Rept. of the Geol. Surv., Dept. of Mines for 1913, pp. 109-126.

\*\* Laney, F. B., "The Gold Hill Mining District," N. C. Geol. and Econ. Surv., Bull. 21, p. 41, 1910.

as follows: (1) gradational contacts between pure pyrophyllite and the unaltered country rock; (2) the preservation of structures of the primary rocks in the mineralized rocks, such as bedding planes of the finer tuffs, and fragmental outlines of the volcanic breccia, (Plate 2, Fig. 7); (3) the presence of masses and lenses of the country rock practically pure or only partly altered, apparently unattached and completely surrounded in the mineral bodies; (4) introduction of certain elements and the removal of others; (5) the lack of any noticeable change in volume of the original rocks during the process; and (6) the massive and homogeneous structure of the pyrophyllite.

The following sequence of events is deduced:

(1) Metamorphism of the volcanic tuffs and flows in which the mineral bodies were later formed.

(2) The silicification of the tuffs and breccias by metasomatic processes as is indicated by the presence of original structure of the volcanics in the silicified material, and by the presence of entirely surrounded fragments of only partly silicified tuff in the quartz areas.

(3) Accompanying or immediately following the silicification came the development of pyrite in the silicified areas.

(4) Development of chloritoid to some extent in all the mineral bodies and in abundance in parts of those bodies that are near the masses of iron breccia.

(5) Development of pyrophyllite by replacement of the previously silicified and mineralized tuff.

(6) Development of the sericite closely associated with or immediately following the pyrophyllite.

*Source of the Solutions.* That the mineral bodies were formed by heated solutions coming up from below seems established from the foregoing description of the distribution, petrography, and chemical composition of the mineral deposits. However, a source for such solutions has not been established. No igneous rocks were found exposed at the surface, other than the diabase dikes which are later than the mineralization, either in the area mapped or within any reasonable distance of any of the deposits.

There were for a number of years numerous active gold and copper mines throughout the slate belt that were important enough to receive quite a little attention in reports of the State Geological Survey from 1885 to 1898. A number of these mines

PLATE 2

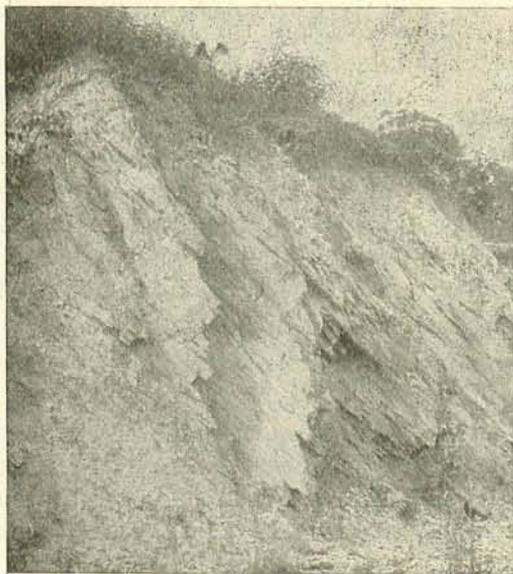


FIG. 6.—Fine acid tuff showing slaty cleavage, near Hemp, Moore County.

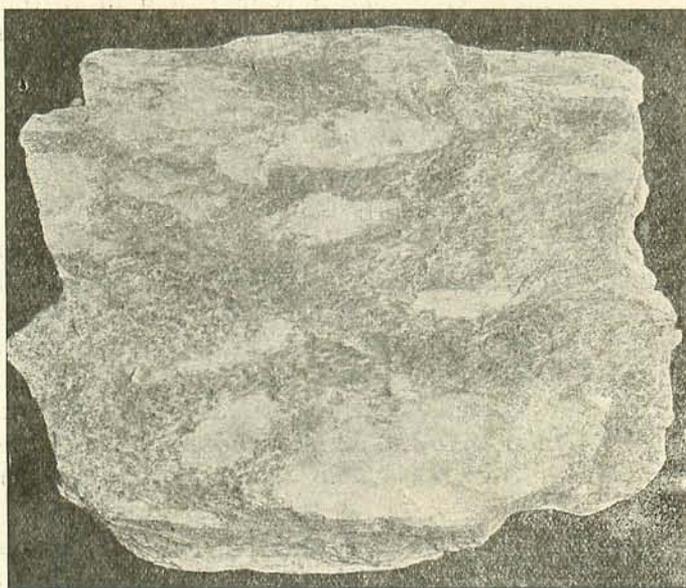


FIG. 7.—Hand specimen of acid volcanic breccia replaced by pyrophyllite.

are found in the district covered in this report. Nitze<sup>43</sup> and Hanna in 1896 pointed out that the gold and copper deposits throughout the entire slate belt are very similar and that much silicification had accompanied the formation of the ores. They attributed the mineralization to hot carbonated, alkaline waters. Laney<sup>44</sup> found much silicification associated with the ore bodies at Gold Hill. He concluded that the mineralization had been produced by hot solutions given off from a granite that had been intruded into the slates in the immediate neighborhood of the ore bodies. Pogue<sup>45</sup> found practically the same conditions in the Cid district of Davidson County except that there were no known intrusive igneous rocks to have furnished the solutions. He concluded, however, that there were large igneous masses intruded into the rocks of the district from below, but that these rocks did not reach the surface.

If Nitze and Hanna are right in their statement that the gold and copper mines of the whole slate belt are in general alike, and if Pogue is right in assuming a large intrusive magma below the Cid district which belonged to a period when large amounts of igneous rocks were intruded into the Piedmont Plateau and brought near the surface, it seems that the same conditions must have existed in the pyrophyllite region and that the gold ores of the various mines were formed by hot solutions from igneous magmas below. There is a close relation between the pyrophyllite bodies and the metalliferous deposits, especially at the mine of the Standard Mineral Company near Hemp where the pyrophyllite schist grades directly into the silicified tuff at the old Cagle Gold Mine. It seems that the same source that furnished the hot solutions to deposit the gold and copper also furnished the hot solutions to produce the pyrophyllite bodies.

*Conditions of Pyrophyllite Formation.* Different investigators have agreed that pyrophyllite may form at conditions varying from high temperature and pressure to low temperature and pressure such as exist near the surface.

The information available as to the formation of chloritoid seems to indicate that it forms at fairly high temperature and according to Niggli is directly dependent on fairly high pressure.

<sup>43</sup> Nitze, H. B. C., and Hanna, G. B., "Gold Deposits of North Carolina," N. C. Geol. Surv. Bull. 3, pp. 44-49, 1896.

<sup>44</sup> Laney, F. B., "The Gold Hill Mining District," N. C. Geol. Surv. Bull. 21, pp. 96-98, 1910.

<sup>45</sup> Pogue, J. E., Jr., "The Cid Mining District of Davidson County," N. C. Geol. Surv. Bull. 22, pp. 124-128, 1910.

Pogue<sup>46</sup> and Laney<sup>47</sup> have both indicated that the gold and copper ores of the district were formed under conditions of temperature and pressure varying from high to intermediate. That the pyrophyllite bodies were formed by hot solutions given off from the same source and acting at about the same time is indicated by the close association of the pyrophyllite bodies with the old gold mines, especially the Cagle gold mine in the Deep River region and at the Brewer<sup>48</sup> gold mine in South Carolina, and Hafer<sup>49</sup> noted the presence of copper bearing pyrite in the mine of the Southern Talc Company at Glendon.

It is possible that in the Deep River region there was a gradual change from high temperature and pressure to the low temperature and pressure of hydro-thermal alteration near the surface during the period of activity of the hot solutions. The writer, however, agrees with Buddington<sup>50</sup> and believes that the pyrophyllite deposits of the Deep River region were formed under conditions of intermediate temperatures and pressure.

While considering the source of the solutions and the conditions under which the pyrophyllite was formed, the problem of a line of entrance for the rising solutions should not be overlooked.

As has been stated, the pyrophyllite deposits occur as elongated bodies or lenses several times as long as they are wide. In at least three localities, along Cabin Creek in Moore County, along Deep River in Moore County, and north of Stem in Granville County, they occur as a long zone of lenses not over 500 to 700 feet wide and from 1,000 feet to 1,800 feet long that can be traced from one to ten miles along the strike. The mineral bodies are all found in the acid tuffaceous rocks and in some cases, particularly in the Deep River region, on the limbs of anticlines as they were worked out and mapped in the field work.

It seems unreasonable for a special type of volcanic tuff to have been formed as long narrow bands so widely separated while at all other points there were such variations in the material.

<sup>46</sup> Op. cit., p. 127.

<sup>47</sup> Laney, F. B., "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," N. C. Geol. Surv. Bull. 26, 1917.

<sup>48</sup> Powers, F. D., "The Pambula Gold Deposits," Quart. Jour. Geol. Soc., Vol. 49, pp. 233-235, 1893. Bauerman, H., statement at end of Power's paper.

<sup>49</sup> Hafer, Claud, "Pyrophyllite in North Carolina," Eng. and Min. Jour., Vol. 96, p. 623, 1913.

<sup>50</sup> Buddington, A. F., "Pyrophyllitization, Pinitization, and Silicification of Rocks Around Conception Bay, Newfoundland," Jour. Geol., Vol. 24, pp. 130-152, 1916.

The conclusion, therefore, is that there was either faulting or some lines of weakness developed, along which the solutions entered to form the mineral deposits.

Since no conclusive proof of pre-pyrophyllitic faulting was found at any point in the area it was necessary to look to other causes for the development of the lines of weakness. The best cause for such lines of weakness seems to be shear zones along the limbs of folds, due either to drag movement in folding or to mashing and shearing in the tuffs instead of normal folding as took place in the slates.

## CHAPTER IV

### DESCRIPTION OF THE MINERAL VEINS AND BODIES

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#### SUPPLY AND USES OF PYROPHYLLITE

*Continuation with Depth.* The pyrophyllite mining so far carried on in the district has been largely by shallow pits and open cuts, the average depth reached being around 50 feet. On the property of the Standard Mineral Company, near Hemp, mining has been almost entirely by shaft, the depth reached being 200 feet. In none of these mines or quarries has there been any change in the pyrophyllite or associated minerals with depth except that in one case small bands of sericite two or three inches thick have been found with the pyrophyllite. The amount of this mineral, however, has not been great enough to justify the conclusion that conditions at this point are different from others where smaller amounts of sericite are found. The volume found has not been great enough to cause any mining or separation difficulties.

Pratt<sup>51</sup> has pointed out that "the pyrophyllite is continuous and of considerable, though unknown, depth": Hafer<sup>52</sup> has suggested that pyrophyllite should be found to the same depths that the gold mines of the area have reached. This statement seems very reasonable when it is realized that there is a close relation in the distribution of the gold and pyrophyllite mines and also a strong possibility that the solutions forming both came from the same source. Gold has been mined to a depth of 800<sup>52</sup> feet in places. Taking into consideration the mineralogy, and origin of the deposits, the source of the solutions and the relation in the distribution of the gold and pyrophyllite deposits it seems reasonable to expect pyrophyllite in commercial amounts to a minimum depth of 500 feet. This statement does not mean that every pyrophyllite prospect can be developed into a mine at that depth. It does mean, however, that all the indications point to a depth of that magnitude for the larger bodies which really show promise at the surface.

*Reserves.* Even though pyrophyllite should not be found in commercial amounts to a depth of over 200 feet, there is enough

<sup>51</sup> Pratt, J. H., "Talc and Pyrophyllite Deposits in North Carolina," N. C. Geol. Surv. Econ. Paper 3, 1900.

<sup>52</sup> Hafer, C., "Pyrophyllite in North Carolina," Eng. and Min. Jour. Vol. 96, p. 623, 1913.

available to that depth, in the really promising deposits of the district, to support an important industry for many years under really efficient milling and concentration practices.

The processes of milling have been such that everything that went into the mill had to be pure enough to make a good finished product. It is only recently that any attempt has been made to use separating and concentrating machinery in the removal of grit and other impurities. This means that a large amount of material which contains from 50 per cent to 75 per cent or more of pyrophyllite has been going on the dumps as waste. If the method of milling could be improved to the point where all material containing as much as 50 per cent pyrophyllite could be utilized, it would practically double the available amount on the basis of the milling practices carried on prior to 1922.

In 1921 the Talc Products Company operating the old Womble mine one mile north of Glendon on Deep River had an estimate<sup>53</sup> made of the material available on the property. According to this estimate, the material available to the present depth of the old pits, which does not, in any case, exceed 75 feet, and on the old dump will amount to 500,000 tons of commercial pyrophyllite. This estimation was based on the proposed installation of modern concentrating machinery in which material containing as low as 50 per cent pyrophyllite could be used.

Ladoo<sup>54</sup> describing the same property states: "Although no considerable tonnage of ore has been actually developed, it seems probable that supplies can stock a moderate size mill for many years."

In 1926 the Talc Products Company was succeeded by the United Talc and Crayon Company. This company does not control the old Womble mine but instead has the old Phillips mine which joins the Womble mine on the southwest.

After having the property investigated and doing some prospecting this company concluded that there is sufficient commercial pyrophyllite on this property to justify the erection of a mill. A modern mill has just been completed at Glendon, one mile from the mine.

On the property of the Standard Mineral Company, near Hemp, now owned by the R. T. Vanderbilt Company, examinations and prospecting have demonstrated the presence of a body of pyrophyllite some 2,000 feet long by 30 feet wide which is

<sup>53</sup> Private communication.

<sup>54</sup> Ladoo, R. B., "Talc and Soapstone: Their Mining, Milling, Products and Uses." Bureau of Mines, Bull. 213, pp. 118-121, 1923.

known from diamond drilling tests to extend to a depth of 300 feet. These tests have demonstrated conclusively that there is ample material in this deposit to supply a mill for many years.

Messrs. Paul and Charlie Gerhardt, who organized and established the Standard Mineral Company, near Hemp, have been engaged for several months in prospecting an interesting pyrophyllite deposit near Staley in Randolph County. While no definite tonnage of material has been actually developed, it seems from general geological examinations and some prospecting that sufficient commercial pyrophyllite is present in this deposit to justify the erection of a modern mill and plans are being worked out to that end.

The other occurrences of pyrophyllite in North Carolina which are listed and described elsewhere in this report have not been sufficiently prospected to indicate their commercial possibilities. However, the four deposits referred to above contain sufficient material to warrant the conclusion that there is sufficient pyrophyllite in the district to furnish reserves for an important mining industry.

#### USES OF PYROPHYLLITE

The uses of pyrophyllite have expanded with the development of mining in North Carolina, no other commercial deposits being known in the United States. The first uses of this material were for grave stones, chimneys, fire places and stove linings. As early as 1856, however, the industry showed appreciable expansion and other uses were being found for the finished product. In that year Emmons<sup>55</sup> described the deposits and pointed out that, besides its local uses, pyrophyllite was a good substitute for chalk, and as a base in cosmetics.

As the industry has grown the finished product has entered into competition with talc until at the present time it is used in most cases for the same purposes as talc, and it is very probable that in many cases the consumers do not recognize that they are using pyrophyllite instead of talc.

During the years 1927 and 1928 there has been considerable interest in pyrophyllite as a ceramic material. The R. T. Vanderbilt Company has been advertising it along with their standard clays for ceramic uses. Dr. G. R. Shelton of the Department of Ceramic Engineering at State College, Raleigh,

<sup>55</sup> Emmons, E., "Geology of the Midland Counties of North Carolina," pp. 52-54, 1856.

N. C., has carried on some preliminary investigations as to its possible uses in ceramic bodies. While his investigation is of a preliminary nature and his results have not been published, they do indicate that pyrophyllite has real value in certain ceramic bodies. It can be substituted for certain clays and it also seems to have the quality of being less abrasive on the dies in the molding of floor tile.

Below is given as complete a list of uses of the pyrophyllite from North Carolina as it has been possible to obtain. No special attempt has been made to get the specifications for the pyrophyllite required for each use. Those interested in further possible uses of pyrophyllite should see Ladoo's<sup>56</sup> report on "Talc and Soapstone."

The uses of North Carolina pyrophyllite are as follows: roofing paper manufacture; cotton cordage; textile manufacture; rubber industry; soap manufacture; pipe covering compounds; pottery and porcelain; asbestos industry; paint manufacture; toilet preparations; bleaching industries; crayons and pencils; and sheet asphalt. The color and fineness of the product depends on the particular use to be made of it.

In 1899 Pratt suggested that the impure pyrophyllite on the dumps might be used as a material for the manufacture of fire brick and other refractories. There has recently been further discussion along this line but nothing definite has been done. This possible use seems to be a promising field for investigation.

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<sup>56</sup> Ladoo, R. B., Op. cit. pp. 64-88.

## THE MINES AND PROSPECTS

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### DEPOSITS ALONG DEEP RIVER BETWEEN INDIAN AND BUFFALO CREEKS

The most extensive zone or band of pyrophyllite lenses, known in North Carolina, begins on Indian Creek about two miles directly north of Carbonton, Chatham County, and extends in a southwest direction into Moore County, along Deep River, to the point where the Norfolk Southern Railroad crosses Buffalo Creek. Along this band, which is some 10 miles long, are the oldest as well as some of the most promising mines and prospects in the State. These outcrops are all found in a normal fragmental volcanic rock of acid composition and along the drag or shear zone produced in the limb of an anticline as the geology was worked out in the field.

*Womble Mine.* About one and one-half miles north of the Norfolk Southern Railroad at Glendon and three-fourths of a mile north of Deep River is the old Womble mine, which is one of the most promising pyrophyllite deposits on this zone. This deposit and the Phillips property which joins it on the southwest were the first occurrences of pyrophyllite discovered in the State. Just when these deposits were first worked is not known. Old grave stones in the vicinity of Glendon show dates between 1840 and 1845. Pyrophyllite mining was well established on the Womble property as early as 1856 as is shown by the detailed description in Emmons' "Geological Report of the Midland Counties of North Carolina," published in that year.

The deposits on the Womble property as outlined by shafts, pits and open cuts is about 1,800 feet long and 500 feet wide. The pyrophyllite has a well developed cleavage which strikes north 55 to 60 degrees east and dips from 45 to 70 degrees to the northwest.

The mineral body has been formed in a normal acid volcanic tuff. The foot wall, the full length of the deposit, is a volcanic breccia, which in places is rich in iron, chiefly hematite. The amount of iron present makes the breccia look much like a low grade iron ore and for this reason it is commonly known as iron breccia. The hanging wall rock is a normal, medium to fine tuff with a small amount of rhyolite near the southwest end. On

the foot wall side and associated with the iron breccia is a large amount of the dark green mineral chloritoid. This mineral which occurs as tiny grains 1 to 2 m.m. in diameter passes by gradations into the pyrophyllite body and disappears in the pure pyrophyllite. The chloritoid is present in small amounts in the impure masses in the pyrophyllite body and to a limited extent in the hanging wall rocks. Some of it has weathered to chlorite. Quartz is abundant in the deposit. It occurs as small veins or stringers, some of which are parallel to the chistosity while a great many cut across the cleavage. Quartz is also present as irregular masses or nodules in the impure pyrophyllite and as large cherty or milky mass throughout the deposit.

The pyrophyllite, which is of the massive or foliated variety, varies from white, yellowish white, green, gray to almost black in color. The colors other than white are doubtless due to iron stain and should disappear or diminish with depth.

The deposit is not only lenticular along the strike but seems to have an interval lenticular structure as well. Lenses of pure pyrophyllite occur along with lenses of quartz or lenses of only partly altered country rock.

The total width of the pyrophyllite schist is 500 feet or even more in places but by no means is all this material of commercial grade. Much prospecting has been done on the property by shaft, pit, and open cut, none of which have reached a greater depth than 50 or 75 feet. These test pits show good pyrophyllite the whole length of the property. The most extensive work has been done on the northeast end of the deposit where a pit or quarry 400 feet long, 40 to 60 feet deep and 75 to 100 feet wide has been opened. Good material has been found throughout this pit. At the north end of this pit and below its level a tunnel has been started from the north or hanging wall side across the mineral body. In this tunnel the pyrophyllite seems to have a width of some 200 feet and to be of better grade than that in the pit. The body of commercial pyrophyllite in this deposit probably varies from 100 to 200 feet in width. Under the old methods of mining and milling not more than one-fourth of this was saved. With proper milling equipment it seems that not more than one-third of the material mined should go on the dump before milling. While much of the pyrophyllite exposed in the open cuts is discolored, the length and width of the min-

eral body are sufficient to warrant the conclusion that to a depth of 300 or 500 feet a large tonnage is available.

*Phillips Mine.* Adjoining the Womble property on the southwest and separated from it only by a public road is the old Phillips property now being developed by the United Talc and Crayon Company. This property which is approximately 1,500 feet long shows no marked geological differences from the Womble mine described above. The foot wall is a continuation of the iron breccia found on the Womble property while the hanging wall is in part medium to fine tuff and in part rhyolite. The chloritoid is present along the foot wall of the deposit but not in as great abundance at every point as in the Womble mine. The other features such as strike, dip, color, structure and variety of pyrophyllite are so similar to those in the Womble mine as to require no special description.

The property has been prospected almost its entire length by open cuts which in most places are not over 10 or 15 feet deep. On the southwest end of the property an open cut has been extended northeast into the pyrophyllite body some 100 feet with a face some 30 feet high at the northeast end. This deeper pit, as well as the open cuts continuing the whole length of the mineral body, while not exposing a large amount of pyrophyllite indicates that there is an abundance of commercial though slightly colored material in the deposit. The open cuts are not over 25 or 30 feet wide and are not so directed as to indicate the width of the mineral body, but the indications are that it will vary around 100 feet.

About 1902 a grinding mill was built on the southwest end of this property. This mill which was of small capacity was burned late in 1927. The United Talc and Crayon Company have satisfied themselves that they have an abundance of commercial pyrophyllite on this property and have built a modern grinding and concentration mill on the Norfolk Southern Railroad at Glendon, one and one-half miles away.

*Snow Prospect.* The Snow prospect formerly referred to as the Rogers Creek Mining Company property, lies about 2,000 feet northeast of the Womble mine. The prospect is located on the west side of a small stream which flows into Rogers Creek a short distance to the south.

The main prospect consists of an open cut which has been made on the northeast face of the hill which rises gradually to an elevation of over 100 feet above the branch. The cut ex-

tends to the southwest along the pyrophyllite body a distance of 75 feet with sufficient slope to drain it to the northeast. It has a depth at the southwest end of 30 to 40 feet and a width of about 60 feet.

The pyrophyllite exposed is yellowish to white in color and of the compact foliated variety. It has a well developed cleavage which strikes northeast and dips at an angle of about 70 degrees to the northwest. Some of the best pyrophyllite in the open cut shows the fragmental texture which was characteristic of the original rock before replacement.

The mineral body is found in a normal acid volcanic rock. The foot wall is an acid volcanic breccia with fragments up to 3 or 4 inches in diameter. The brecciated foot wall is about 150 feet wide. The hanging wall is a medium textured tuff. Chloritoid and chlorite are present in small amounts as minute grains.

Prospecting, other than the cut referred to above, has been done on a small scale at several places close by, but not in a sufficiently systematic manner to indicate the exact size of the mineral body. The indications are that the mineralized zone at this point is 400 or 500 feet wide and 1,200 to 1,500 feet long. It seems very reasonable that systematic prospecting over the whole length and width of the mineral body would show the presence of a large and promising deposit of pyrophyllite.

*Jones Prospect.* About one mile northeast of the Snow prospect, and near the line between Moore and Chatham Counties, in a dense woods on the property of Mr. A. J. Jones, prospecting has been done. Along the surface between the two prospects are to be seen minor indications of pyrophyllite, none of which have been prospected.

On the Jones property an open cut has been made on the northeast slope of a small hill and just above a small stream. This opening which extends across the trend of the pyrophyllite is about 100 feet long and varies from 2 to 6 feet in depth. Good pyrophyllite, somewhat discolored, is to be seen all along the open cut. Just how wide or how long the mineral body may be, cannot be determined from the old open cut. Except for the discoloration the quality of the pyrophyllite seen is promising.

*Currie Place.* About one-half a mile northeast of the Jones prospect and near where the road from Haw Branch crosses the county line prospecting has been done on the farm of C. L.

Currie. The work done consists of a few open pits, none of which are over 4 or 5 feet long or 3 feet deep. Impure pyrophyllite was seen in some of these but it will take considerable more prospecting to indicate how much pyrophyllite may be found there.

*Oldham Prospect.* About  $1\frac{1}{2}$  miles northeast of Currie's and some 2 miles northwest of Carbondon, near Line Creek in Chatham County, prospecting has been done on the farm of David Oldham. The work done consists of five or six shallow pits some 15 feet deep and 20 to 30 feet long dug across the strike of the formations. Openings were made just a few hundred feet south and about 1,000 feet west of Oldham's home. In both places the country rock is a much altered acid volcanic tuff. A few hundred yards to the south of these pits the tuff grades into a breccia.

In both sets of open cuts, impure, foliated pyrophyllite, varying from yellowish to almost black in color, was found. It occurs as irregular seams associated with and conforming to the cleavage in the rocks. Two or three carloads of impure pyrophyllite are said to have been shipped from these openings for tests as a refractory material. No material of commercial grade is to be seen in the cuts or on the dumps, but sufficient pyrophyllite is present to make the locality interesting.

*Dowd Farm.* About one-half a mile north of Oldham's, on the farm of C. M. Dowd some prospecting for pyrophyllite was done at the same time the Oldham place was prospected. The old pits have been filled up and nothing of importance can be seen. Near the Dowd home some of the rock outcrops contain small amounts of pyrophyllite schist and it may be that prospecting would show something of interest.

*Andrews Farm.* Between Oldham's farm and Indian Creek there are a few small occurrences of pyrophyllite schist, none of which have been prospected. Along the south bank of Indian Creek, some 3 miles north of Carbondon, on the farm of Bascomb Andrews, prospecting for pyrophyllite is said to have been done. One or two pits dug in a pasture have been filled up. Nothing was seen to indicate the presence of commercial pyrophyllite.

*Bates Mine.* About one-half a mile southwest of the Phillips property and some two miles from Glendon, immediately along the east bank of Deep River where the river turns rather abruptly to the south is the Bates mine. Prospecting here is said

to have been started in 1903. A mill was built in 1904 and operations continued until 1919 when the mine and mill were closed.

The development work done consists of two open cuts and a shaft on the footwall side and a large open cut on the hanging wall side of the property. The footwall consists of an acid volcanic breccia composed of fragments one to two inches in diameter. The hanging wall is a rhyolite somewhat sheared and weathered immediately along the mineral body. The total width of the mineralized zone is about 500 feet. Sufficient prospecting was not done to definitely indicate the length.

On the footwall side and right along the zone of breccia two open cuts were made, one on either side of a small stream about 600 feet east of the river. Each of these cuts were some 20 to 30 feet wide, 20 feet deep and 30 feet long. Small amounts of good pyrophyllite were found. Between these open cuts and the river a shaft was sunk to a depth of 60 feet and drifts run out. An excellent grade of compact non-foliated pyrophyllite was found in this shaft.

On the hanging wall side an open cut 250 feet long was made on the south side of a prominent hill across the strike of the formations. At the north end of this opening another cut was opened at right angles to the first, the two combining in the shape of the letter T. The width of the open cut was some 20 feet and the maximum depth about 40 feet. A tunnel was driven from the open cuts a short distance into the hillside. No commercial pyrophyllite was found in these openings. The operations were abandoned because of a lack of sufficient commercial material.

*Jackson Place.* Between the Bates mine and McConnell the Deep River flows along and back and forth across the pyrophyllite zone. If pyrophyllite were present along this line, it has been made inaccessible. However, in the bends of the river on both sides there are occasional outcrops of pyrophyllite schist. The most important of these is on the Jackson place on the south side of Deep River, some 2 miles north of the Norfolk Southern Railroad about 3 miles west of Glendon.

The rock in which the pyrophyllite schist occurs is an acid volcanic tuff. The prospect pits are located just a few hundred feet from the contact between the tuff and a true slate. Two or three irregular open cuts which have a maximum depth of some

15 or 20 feet are to be seen. While considerable pyrophyllite occurs in the schistose tuff at this point, there is no material of commercial grade in sight.

*McConnell Mine.* Some 5 miles southwest of the mines near Glendon and one-half a mile east of McConnell is an old prospect known as the McConnell mine. Prospecting here consists of an open cut about 400 feet long, which extends across the strike of the formations near the contact between the tuff and a normal slate on the south. This open cut is some 10 to 15 feet wide and probably 15 feet deep as a maximum. When last visited the old cut had weathered and fallen in badly but some indications of good pyrophyllite could be seen. Just how important the deposit is cannot be determined without more systematic prospecting. Signs of pyrophyllite schist can be seen for some distance to the northeast.

*Harrison Prospect.* About  $1\frac{1}{2}$  miles southwest of Harrison and some 4 miles southwest of McConnell, off the zone being described, is a small body of pyrophyllite schist. The schist which lies in tuff near the contact between the tuff and slate was found in re-opening an old gold mine. Small amounts of practically pure pyrophyllite were seen on the dump.

*Will Crawford Property.* For some three miles to the southwest of McConnell, an occasional outcrop of pyrophyllite schist can be seen but no more prospecting of importance is found until the property of Will Crawford is reached near where the Norfolk Southern Railroad crosses Buffalo Creek. Here a number of old trenches are to be seen which cut across the strike of the formation. None of these reach a depth of more than 5 or 6 feet. Considerable pyrophyllite schist is to be seen here. No material of commercial quality was found on the dumps or in the open cuts.

#### DEPOSITS ALONG CABIN CREEK

Beginning about  $1\frac{1}{2}$  miles north of Hemp on Cabin Creek and continuing in a southwest direction for a distance of some 5 miles, is a band or zone of pyrophyllite on which the most important mine in the State is located. The rocks along this line consists of a normal acid volcanic tuff. The strike varies from north 30 to 35 degrees east and the dip varies from 50 to 70 degrees to the northwest. Pyrophyllite schist outcrops at a number of points along this band but only one deposit is known to be of commercial value at present.

*Standard Mineral Company.* The property of this company is located about 2½ miles southwest of Hemp and about 1½ miles south of the Norfolk Southern Railroad. Pyrophyllite is said to have been discovered on this property about 1888 when in the course of gold mining operations a tunnel was driven into a hill side. The vein encountered at that time was only about 10 feet wide and little effort was made to work it. In 1918 Mr. Paul Gerhardt gave one of his neighbors permission to haul cross ties across his property. It was noticed that the wagon wheels brought up a fine white material. On investigating he found what later proved to be a body of pyrophyllite and pyrophyllite schist some 150 feet wide.

The pyrophyllite body as it is known today begins on Cabin Creek just south of the old Cagle gold mine and extends southwest a distance of nearly a mile. The most important part of this body is on the southwestern end and consists of some 2,000 feet along the surface. The mineralized zone is about 200 feet wide. Near the center of this zone is a vein of practically pure pyrophyllite 30 feet wide. Some 50 feet to the east of the main vein is a small vein 10 feet wide. About 220 feet west of the main 30 feet vein is the small vein first discovered in 1888.

The deposit occurs in a medium textured acid volcanic tuff which has been strongly sheared and possesses a well defined cleavage which strikes north 20 to 30 degrees east and dips from 50 to 70 degrees to the northwest. Underground operations show the hanging wall to consist of 75 feet of silicified tuff grading into a normal unaltered tuff. On the footwall side the rock consists of a silicified tuff about 110 feet wide which gradually grades into an unaltered tuff. Both the main mineral body and the 10-foot body to the east dip with the cleavage at an angle of about 70 degrees to the northwest. Operations to a depth of 200 feet show the pyrophyllite body to be pitching to the northeast at an angle of less than 70 degrees. The angle of pitch, while not definitely proved, seems to be between 50 and 60 degrees.

Mining is carried on entirely by shaft. The present shaft which is 200 feet deep was sunk on the southwest end of the deposit in barren ground 120 feet west of the main pyrophyllite vein. From this shaft a drift was cut across the mineral body to determine its width and also to determine how much of it might be workable material. From the cross drift another drift has been cut along the main vein to the northeast a dis-

tance of 280 feet and the pyrophyllite stopped out. At present only the main, or 30-foot vein is being worked. Ninety per cent of the material taken out of the vein goes into the finished product. The impurities consist of small lenses of silicified tuff and numerous small quartz veins which cut the vein at all angles. An occasional small grain of chloritoid is to be seen.

The company carried out an extensive diamond drilling test in the spring of 1928 to determine the extent of the deposits. Holes set at such an angle as to cut the mineral body at a depth of 300 feet show that for a distance of 2,000 feet along the strike there is a body of pyrophyllite 30 feet wide at that depth. This means a tremendous tonnage of pyrophyllite in the body.

There is in operation on the property a modern grinding mill which is being improved to keep pace with the industry.

*Sanders Property.* About 5 miles northeast of Star and a few hundred yards from the point where Cotton Creek enters Cabin Creek, on the farm of Mrs. Bettie Sanders, is an outcrop of pyrophyllite that can be traced for 800 to 1,000 feet along the surface. Pyrophyllite is found on two prominent ridges which extend back from the creek 500 to 800 feet. The country rock is a medium textured volcanic tuff with a well developed cleavage which strikes north 30 degrees east and dips 40 to 50 degrees to the northwest. Numerous small quartz veins cut the country rock at all angles.

Scattered through this rock are varying amounts of pyrophyllite chiefly of the radiating variety. Small amounts of flake and foliated pyrophyllite are also present. On the point of the ridge on the southwest end of the property are two old pits. These pits which are some 5 or 6 feet deep and 10 feet long are said to have been dug as gold prospects. Both show pyrophyllite in considerable amounts. The mineral which is chiefly of the radiating variety is yellowish to greenish in color on account of the great amount of iron stain near the surface.

#### MONTGOMERY COUNTY

*Cotton Stone Mountain.* Pyrophyllite has been known to occur near Troy in Montgomery County since Emmons published his Report on the Geology of the Midland Counties. Many text books also carry references to pyrophyllite on Cotton Stone Mountain.

This so-called mountain is simply a prominent hill which rises gradually to a height of some 200 feet above the neighboring

stream valley. The hill consists of two prominent points or domes with a hollow between, producing a saddle. The greatest elongation is about north 70 degrees west. The country rock is an acid volcanic tuff which has a well defined cleavage developed in it. The cleavage strikes north 45 to 55 degrees east and dips 50 to 70 degrees to the northwest. Numerous small quartz veins are found over most of the mountain.

Pyrophyllite, chiefly of the radiating variety, occurs abundantly on this hill. The mineral body or bodies seem to be elongated almost at right angles to the strike of the cleavage in the rocks. The total length in a northwest-southeast direction is about 2,500 feet. On the northwest, the width of the mineralized zone is about 600 feet. On the southeast end it narrows down to about 300 feet. On the northwest and more prominent point of the hill, three prospect pits have been dug, presumably for gold, as they are all along quartz veins. In these pits and on the dumps much pyrophyllite can be seen. The material in the pits and on the surface is yellow to red in color, due to the great amount of iron stain present.

In addition to the occurrence on Cotton Stone Mountain, pyrophyllite of the foliated and radiating varieties have been reported along Little River for several miles to the north and west. The reported occurrences along Little River have not been studied in detail.

#### RANDOLPH COUNTY

*Gerhardt Deposit.* About 4 miles almost directly west of Staley, Randolph County, is the Gerhardt prospect which appears to be one of the most important undeveloped deposits in the State. The pyrophyllite outcrops on the south side of a small stream in a bold deposit which has risen to a height of some 150 or 200 feet above the level of the stream.

The mineral body has been formed in an acid volcanic tuff. On the hanging wall side the pyrophyllite ends rather abruptly against a body of volcanic ash. On the footwall side the mineral body grades into a medium textured volcanic tuff. The deposit as outlined by outcrops and prospecting is about 750 feet long and 250 feet wide. The strike of the cleavage in the deposit is about north 65 degrees east while the dip varies around 65 to 70 degrees to the northwest.

The deposit contains massive, flake, and fibrous pyrophyllite. The flake and fibrous varieties are present in abundance along the hanging wall side but towards the center and footwall the massive variety is found almost exclusively. On the weathered boulders of the outcrop the massive variety stands out in irregular knots or lumps, producing the irregular type of pitted surface often seen where solution has been active on a rock surface. These irregular knots, contrary to expectation, are composed of the finest pyrophyllite. Impurities present consist of cherty masses of quartz scattered through the body and some chloritoid near the footwall side. This body doubtless contains a large amount of commercial pyrophyllite.

#### ALAMANCE COUNTY

*Holman's Mill.* No detailed study of Alamance County has been made and little is known of the mineral resources of the county. Soapstone has been reported about one mile south of Holman's mill between that place and Snow Camp. No examination of the occurrence, which is said to be of considerable size, has been made. Pyrophyllite is commonly called soapstone in the localities where it occurs. The writer has not examined any so-called soapstone deposit in the slate belt that did not prove to be pyrophyllite. If a deposit occurs as reported it may prove to be pyrophyllite.

#### ORANGE COUNTY

Pyrophyllite has been known near Hillsboro, Orange County, for some forty years. Specimens have been collected from time to time but no material of workable quality has been reported from the county.

*Hillsboro.* At the point where Highway No. 14 to Chapel Hill forks off from Highway No. 10, a little less than one mile east of the Courthouse, pyrophyllite schist is to be seen in the road cut, and in the south bank of the Eno River a few hundred feet to the northeast. Not more than 100 or 200 feet from the forks of the roads and just east of Highway No. 14 radiating and needle-like crystals of pyrophyllite associated with quartz may be found on the surface. On a small stream just to the west of the point where the roads fork is an old mill site several feet below the level of the roads. Some of the rock on this old mill site contains considerable amounts of chloritoid. Both the

pyrophyllite schist and the radiating pyrophyllite contain considerable grit and are badly iron stained. No prospecting has been done and the width of the mineralized zone could not be determined. A general examination of the immediate vicinity failed to indicate the presence of other outcrops.

*University.* A sample containing radiating and needle-like crystals of pyrophyllite has been received recently from near the Southern Power Company's auxiliary steam station, about  $1\frac{1}{2}$  miles northeast of University, a station on the Southern Railway, where train connection is made for Carrboro and Chapel Hill. The sample is highly iron stained and contains much grit. Nothing is known as to the outcrop from which it came.

#### GRANVILLE COUNTY

Beginning about  $1\frac{1}{2}$  miles north of Stem, a station on the Southern Railway, and continuing for a mile or more in a northeast direction is a zone of pyrophyllite on which several outcrops are to be seen. The outcrops all occur in a medium textured volcanic tuff of acid composition. To the west of the outcrops an occasional exposure of rhyolite is to be seen. The outcrops occur along the top of a prominent ridge, the southwestern end of which is known as Bowling's Mountain.

*Harris Prospect.* Bowling's Mountain and its elongation to the northeast make a prominent ridge in the landscape. The western slope of this mountain and ridge is steeper than the eastern slope, due to the down cutting of a small stream which flows immediately along its western side.

On the southwest end of the ridge and near the western slope is the Harris prospect. Here an open cut, 15 to 20 feet long, 6 feet wide and 6 to 10 feet deep, was opened several years ago on an outcrop of radiating or needle-like crystals of pyrophyllite. The material in the cut contains impurities in the form of grit and iron stain. Prospecting has not been sufficient to indicate the quality or quantity of pyrophyllite present. A general inspection of the vicinity indicated that impure material may be seen over an area 50 feet or so wide by 300 to 500 feet long.

*Other Outcrops.* About 1,000 feet almost north of the Harris prospect, in an old road cut a short distance east of the small stream referred to above, an outcrop of pyrophyllite schist some 40 feet wide may be seen. The schist, which is impure and iron

stained, strikes north 35 degrees east and stands almost vertical. Along the west side of the outcrop the schist contains small amounts of chloritoid.

Some 250 feet to the north of the schist outcrop, small amounts of crystalline pyrophyllite in the form of needles and radiating masses may be seen, associated with veins of quartz. The material which occurs in small amounts over a width of some 50 feet, contains considerable grit and is highly iron stained.

*North End of Ridge.* On the north end of the ridge under discussion and some half a mile from the outcrop just referred to is another exposure of rock in which pyrophyllite may be seen. The exposure is a bold outcrop of rock just east of a small stream. Pyrophyllite occurs irregularly distributed through the rock in small amounts. No prospecting has been done and it is impossible to get any accurate information from the weathered rock surface. Scattered over this rock surface in irregular masses, pure massive pyrophyllite may be seen. The surface of the rock resembles a solution surface with the pyrophyllite forming the outstanding masses. Without prospecting, it is impossible to state whether the outcrop has any commercial possibilities or not.

Pyrophyllite has been reported as occurring on another prominent hill nearby but no examination was made of the outcrop.

## CHAPTER V

### GENERAL SUMMARY

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The rocks of the Carolina slate belt consist of a series of volcanic-sedimentary formations more or less alike throughout the extent. The rocks, as indicated by detailed studies of smaller areas in different parts of the belt, consist of an interbedded series of formations composed chiefly of slate, volcanic tuff, bands and lenses of volcanic breccia, and minor flows of rhyolite and andesite. The whole series have been much folded and thrown, apparently, into a synclinorium. In the process of folding they were much metamorphosed, sheared, mashed and altered so that it requires diligent searching to find rocks that are at all fresh or that in any fair degree represent the true unaltered types.

The following detailed account of the rocks covers especially the Deep River region as shown in Figure 1. The statements made here will apply in general to all parts of the slate belt and especially to those portions where pyrophyllite is found.

#### THE ROCKS

The rock formations identified and mapped in the Deep River region (Fig. 1) include the following: (1) Slate; (2) Tuff of dacitic and rhyolitic character; (3) Rhyolite flows; (4) Volcanic breccia; (5) Andesite; (6) Diabase dikes.

The slate is a fine-grained, bluish to greenish rock composed of varying amounts of land waste and volcanic ash. Chemical analysis shows it to be different from a normal slate in composition but its structure and texture are such that in many cases it is practically impossible to tell it in the field from an ordinary slate. It has a wide spread extent, being second in amount only to the acid volcanic tuff. It underlies extensive areas in the northern and eastern parts of the regions studied.

The most important rock in the district is an acid volcanic tuff of rhyolitic and dacitic composition. It varies in areal distribution from narrow bands and lenses to large bodies that extend the entire length of the district and which varies in width from a few hundred feet to more than a mile. The tuff may be divided into two varieties, (1) a fine-grained variety and

(2) a coarse-grained type. In most cases the fragmental nature of the fine tuff can be seen only under the microscope. It varies from a fine-grained ash-like material on one hand, which is very closely related to the slate, to a dense flint-like or "gun flint" variety on the other, which grades into the coarse tuff. The acid fine tuff may be considered transitional between the slates and the acid coarse tuff.

The coarse acid tuff is made up of angular rock fragments and broken phenocrysts which can be seen with the naked eye.

In places the acid tuff is highly schistose and an area northeast of Hemp has been converted to a material much like a sericite schist. All the pyrophyllite bodies are found in various phases of the acid tuff.

The rhyolite is a material similar in color and structure to that in the rest of the slate belt. It is dark bluish in color and is in most cases free from phenocrysts and shows pronounced flow structure. It is found only in two small areas in the district. One of these is about one mile north of Glendon and the other is on Wet Creek near the southwest end of the district.

Volcanic breccia of three distinct types occurs in the district. These are acid breccia, iron breccia, and basic breccia. The acid volcanic breccia is much like the tuff in composition, but is more coarsely fragmental. It consists in part of a brecciated tuff and in part of a brecciated rhyolite.

The iron breccia differs from the acid breccia only in containing more iron. The typical exposure of this rock is along the footwall of the pyrophyllite mines near Glendon.

The basic volcanic breccia is made up largely of brecciated andesitic material.

Corresponding to the acid flows and tuffs of the district there are found southeast of Hemp and north of Highfalls two small areas of andesite. This rock is in most part massive, dark green in color, and seldom shows good fragmental texture. In thin section the rock is represented by both an amygdaloidal and a massive phase. It grades on one hand into acid tuff and on the other into basic breccia.

Dikes of diabase are abundant, cutting all the formations. Two distinct types are present. One is a dark-colored, heavy, tough rock that is high in olivine. The other is a fine-grained dark gray rock made up chiefly of augite and plagioclase feldspars.

## STRUCTURE

The structure of the rocks in the district is fairly complex. No faults of any magnitude were found within the area, but complex folding has taken place on a large scale. The rocks of the district have apparently been thrown into a closely compressed synclinorium that strikes northeast-southwest with the slates occupying the troughs of the synclines and the tuffs occupying the crests of the anticlines. The tuff is evidently much less folded than the slate due in a large measure probably to its more massive and open texture, so that it did not set and fold like a fine sediment.

## AGE

In the field work nothing was found that definitely indicated the age of the rocks. Most writers who have discussed the slate belt in recent years have classed the formations as pre-Cambrian in age. In this report both the volcanic rocks and the mineral bodies found in them have been considered as belonging to that period. The diabase dikes are of Triassic age.

## ECONOMIC GEOLOGY

The pyrophyllite bodies are found in every case in rocks of an acid composition. They have doubtless been formed along lines of shearing due to folding. They are typically oval to lenticular in structure both as seen along the surface and in their internal structure. They have suffered much compression and deformation since their formation, though no prominent folding could be seen.

The chief minerals found in the pyrophyllite bodies are pyrophyllite, quartz, pyrite, chloritoid, and sericite with a few accessory minerals common to a tuff or due to ordinary changes during metamorphism. The development of the pyrophyllite has been preceded by much silicification and the development of chloritoid in the bodies that were formed near the areas of iron breccia. The deposits of pyrophyllite have doubtless been formed by a metasomatic replacement of an acid tuff or breccia, the events probably taking place in the following order: 1, silicification of the tuffs and breccias; 2, development of pyrite along with the silicification; 3, development of chloritoid in those bodies near the iron breccia; 4, development of pyrophyllite by replacement of the silicified tuff; 5, development of sericite soon after or along with the pyrophyllite. Evidence that the

deposits have been developed by replacement are as follows: 1, gradational contacts between the pure pyrophyllite and the country rock; 2, preservation of structures of the primary rocks, such as bedding planes of the finer tuffs and fragmental outlines of breccia, in the mineral bodies; 3, presence of masses of country rock only partly altered and apparently unattached in the pyrophyllite bodies; 4, introduction of some elements and the removal of others; 5, lack of any noticeable change in the volume of the original rocks; 6, massive nature of the pyrophyllite.

Experiments in dehydration showed that the pyrophyllite retained some of its water at a much higher temperature than sericite does.

There seems to be a close association of the pyrophyllite with some of the old gold mines of this part of the slate belt. The gold deposits have been attributed to hot solutions that came up from below. This association seems to indicate that the gold and pyrophyllite were probably formed by the same sort of solutions. Although no igneous rocks were found in the area it seems that the deposits were formed by hot solutions, probably in part at least, of igneous origin, under conditions of intermediate temperatures and pressures.

A careful consideration of the origin, occurrence, mineral associations, and close relations of some of the pyrophyllite deposits to old gold mines in the region seem to warrant the conclusion that pyrophyllite in paying amounts may be found to a minimum depth of 500 feet. If pyrophyllite does occur to that depth it seems to indicate, that with the use of modern milling and concentrating machinery, there is sufficient material in the more promising deposits of the area to supply an important industry for years.

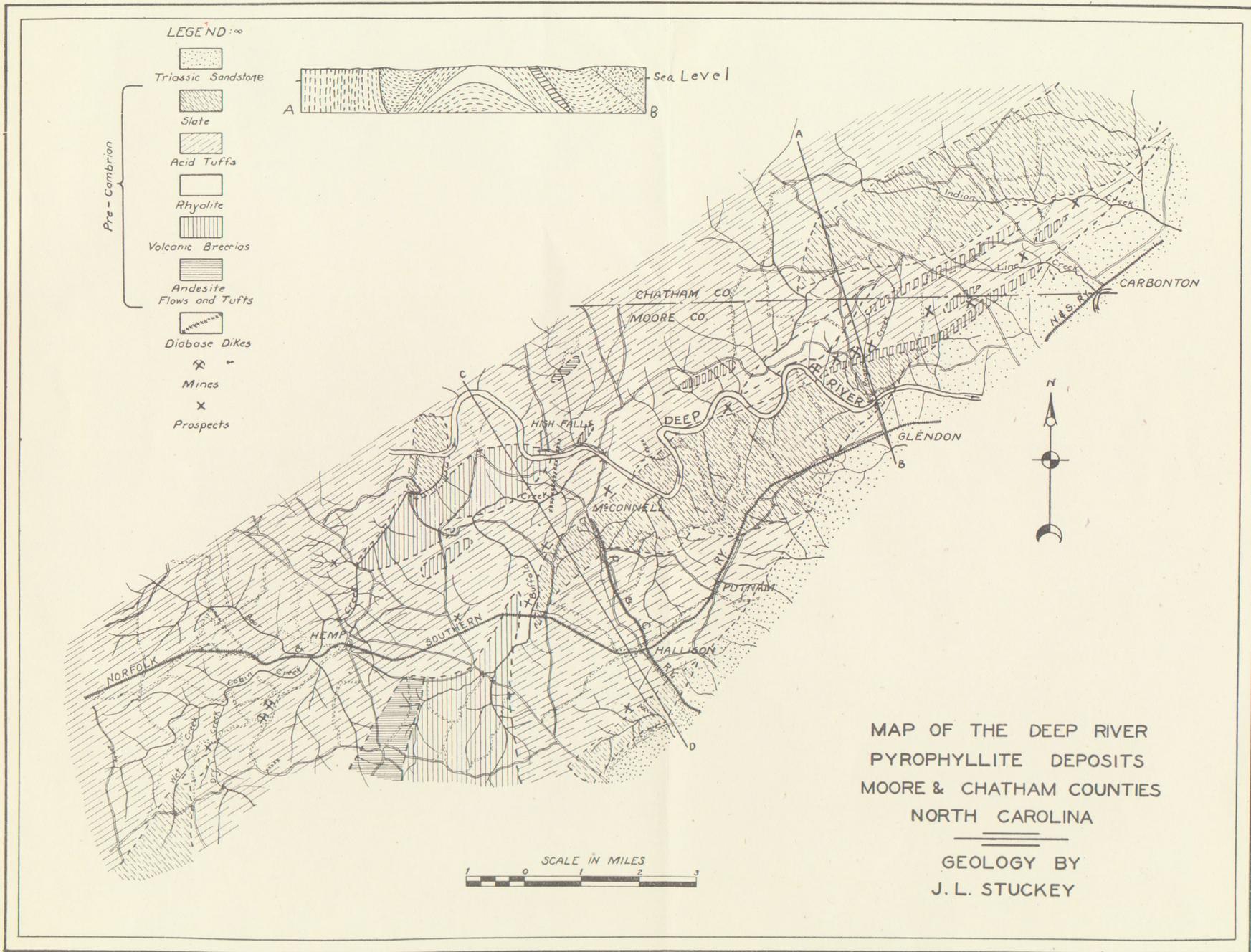


FIGURE 1.—MAP SHOWING THE DEEP RIVER PYROPHYLLITE DEPOSITS.