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NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT

R. BRUCE ETHERIDGE, DIRECTOR

DIVISION OF MINERAL RESOURCES

JASPER L. STUCKEY, STATE GEOLOGIST

BULLETIN NUMBER 48

RESIDUAL KAOLIN DEPOSITS OF THE SPRUCE PINE DISTRICT, NORTH CAROLINA

OCT 2 6 1981

BY

JOHN M. PARKER III

PREPARED BY GEOLOGICAL SURVEY, U. S. DEPARTMENT OF THE INTERIOR
IN COOPERATION WITH THE
NORTH CAROLINA DEPARTMENT OF CONSERVATION AND DEVELOPMENT

RALEIGH
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CONTENTS

CONTENTS—Con.

ILLUSTRATIONS

FIGURES

PLATES

LETTER OF TRANSMITTAL

Raleigh, North Carolina
February 12, 1946

To His Excellency, HON. R. GREGG CHERRY,
Governor of North Carolina.

SIR:

I have the honor to submit herewith, manuscript for publication as Bulletin 48, "Residual Kaolin Deposits of the Spruce Pine District, North Carolina," by J. M. Parker, III.

North Carolina has been, for a number of years, the leading producer of residual kaolin in the United States. This report has been prepared with special reference to the reserves of kaolin available in the area covered. The data available in this report, when used in connection with information available in previous publications of this Department, should be of great value to the kaolin producers and potential ceramic industry of the State.

Respectfully submitted,

R. BRUCE ETHERIDGE,
Director.

PREFACE

Three previous reports relating to the kaolin deposits of the State have been published by the North Carolina Geological and Economic Survey, predecessor to the North Carolina Department of Conservation and Development:

(1) Bulletin 13, "Clay Deposits and Clay Industry in North Carolina," pp. 50-70, 1897, by H. Ries.

(2) Economic Paper 34, "Feldspar and Kaolin Deposits," pp. 185-289, 1914, by A. S. Watts.

(3) Bulletin 29, "The Kaolins of North Carolina," 1925, by W. S. Bayley.

These reports were prepared for the purpose of giving information on both the geology and uses of North Carolina kaolins.

The present report has been prepared in cooperation with the United States Geological Survey, by Dr. J. M. Parker, III, of that organization. The field work on which this report is based was done in the spring of 1942, at a time when the possibilities of producing aluminum from white clays were of tremendous importance due to war conditions. As a result, this report deals with the kaolin reserves of the Spruce Pine district of North Carolina with special reference to the occurrence of kaolin and its possible use in the production of aluminum.

Any possible need of aluminum from kaolin was removed by the successful termination of World War II. The information contained in this report, however, is too valuable to lose, particularly that dealing with the geological setting and the reserves of kaolin in the State. North Carolina kaolins have had a wide use for many years in making china, semi-porcelain and porcelain, mosaic and other tile, and in the manufacture of spark plugs and glass melting pots. A new use is its employment as a raw material in making spun glass. Recent improvements in the refining of kaolin assure to the trade ample supplies of blended kaolin of uniform quality which is equal to the best imported kaolin.

It is believed that the information contained in the present report, when studied in connection with Bulletins 40 and 44, of this Department, and entitled respectively "Manufacturing China Clay Opportunities in North Carolina," and "Economic Opportunities for Producing Semi-Porcelain Dinnerware in North Carolina," will be of great value to the kaolin and potential ceramic industry of the State.

JASPER L. STUCKEY,
State Geologist.

RESIDUAL KAOLIN DEPOSITS OF THE SPRUCE PINE DISTRICT, NORTH CAROLINA

By John M. Parker III

ABSTRACT

The residual kaolin deposits of the Spruce Pine district in Avery, Mitchell and Yancey counties, North Carolina, were examined to determine their suitability for aluminum ore. These deposits lie midway between the aluminum reduction plants at Alcoa, Tennessee, and at Badin, North Carolina, about 175 miles by railroad from each. They are readily accessible, lying near the railroad or good highways. The principal deposits were formed by chemical weathering of small irregular stocks of granite, which were intruded during the late Paleozoic into steeply dipping pre-Cambrian gneisses and schists. They are composed of kaolin mixed with partly decomposed oligoclase and microcline, unaltered quartz and muscovite. Ferromagnesian minerals are practically absent except for occasional spots of iron and manganese oxide resulting from the decay of garnets. All the known deposits occur where the granite bodies underlie the strath of the North and South Toe Rivers and their tributaries. Prolonged decomposition during an earlier, incomplete erosion cycle, rather than under present circumstances, appears to have been responsible for the kaolinization. In favorable locations the decomposition has extended downward as much as a hundred feet but most of the deposits can not be worked deeper than 40 or 50 feet. Deposits in the lower and central parts of the strath are usually capped with stream sediment from 1 to 30 feet thick, while marginal deposits have an overburden of 3 to 10 feet of stained residual soil. The deposits are interrupted by many small and large inclusions of country rock. Inclusions and walls of hornblende gneiss are especially detrimental, as serious iron oxide stain is usual near them. The washed kaolin produced from these deposits runs 37 percent or more in alumina and under one percent in ferric oxide. Because of the uniformity of the deposits special emphasis was placed on obtaining as exact and reliable estimates as possible of the amount available. The Brushy Creek deposits were estimated to contain between 1½ and 3 million tons of washed kaolin, the Gusher Knob deposits between 450,000 and 1,250,000 tons, the Spruce Pine group

between 700,000 and 1,600,000 tons, and the Newdale-Lunday group between 400,000 and 1,300,000 tons; the total for the district is between 3 and 7 million tons. On the basis of quality, size and accessibility the first three groups are considered potential sources of aluminum ore; the fourth is submarginal in this respect.

INTRODUCTION

PURPOSE OF INVESTIGATION

The purpose of the present investigation was to appraise the clay resources of North Carolina as possible aluminum ores. Recent research and pilot-plant experimentation have developed technologic methods of extracting aluminum from silicates, especially high-alumina clays, on a large scale. The tremendously expanded use of aluminum in defense and war production has drained heavily on the known bauxite deposits in the United States, while the acute shipping shortage has limited importation of foreign bauxite. In order to alleviate this threatened shortage and to develop, if possible, adequate sources of aluminum ore within the United States, an expanded program by the Geological Survey and the Bureau of Mines, United States Department of the Interior, was set up by special Congressional appropriation to study bauxite, alunite, and high-alumina clays. This report results from an investigation by the U. S. Geological Survey of the residual kaolins of western North Carolina as a part of this larger program. The study was directed especially toward obtaining specific and reliable estimates of the tonnage available.

SUMMARY OF PREVIOUS WORK

A survey of the geologic literature indicated that the only clays in North Carolina of a suitable quality for aluminum ore and in sufficient quantity to be of importance were the residual kaolins in the mountain sections, especially those in Avery, Mitchell and Yancey counties. These deposits have been described by Ries[1] [2] [3], Watts[4], Bayley[5], Hunter and Mattocks[6], and

[1] Ries, Henrich, Clay deposits and clay industry in North Carolina: North Carolina Geol. Survey Bull. 13, pp. 50-70, 1897.

[2] Ries Heinrich, The clays of the United States east of the Mississippi River: U. S. Geol. Survey Prof. Paper 11, 298 pp., 1903.

[3] Ries, Heinrich, Bayley, W. S., and others, High grade clays of the eastern United States: U. S. Geol. Survey Bull. 708, pp. 18-79, 1922.

[4] Watts, A. S. Mining and treatment of feldspar and kaolin: U. S. Bur. Mines Bull. 53, 170 pp., 1913.

[5] Bayley, W. S., The Kaolins of North Carolina: North Carolina Geol. and Econ. Survey Bull. 29, 132 pp., 1925.

[6] Hunter, C. E., and Mattocks, P. W., Geology and kaolin deposits of Spruce Pine and Linville Falls quadrangles, North Carolina: Tennessee Valley Authority, Division of Geology Bull. 4, pt. 1, pp. 10-23, 1936.

Hunter[7]. Publications on related subjects in the same area include those of Keith[8], Sterrett[9], Maurice[10], Kesler and Olson [11], and Olson[12]. F. L. Hess of the Bureau of Mines prospected part of the Gusher Knob deposits but the results were not published. Detailed descriptions of many mines and prospects, and of the general occurrence and origin of the clay, have thus long been available, but estimates of reserves in the district have been lacking or very rough. The most specific is that of Hunter[13], giving fifty one million tons of crude kaolin in Avery, Mitchell, and Yancey counties. His estimates for the individual deposits were not published but have been communicated personally. They served as a guide to the most promising localities.

LIMITS AND METHODS OF INVESTIGATION

Only the larger and more accessible occurrences of kaolin in the district were studied. To constitute a practicable source of aluminum ore, a clay deposit had to meet the following specifications, established by the Bureau of Mines:

1. The deposit must be located within 150 miles of an existing aluminum reduction plant.
2. The deposit must contain at least one million tons of clay.
3. The clay must be at least 15 feet thick.
4. The clay must run over 35 percent Al_2O_3 and under 1½ percent of Fe_2O_3.
5. The overburden must not be thicker than the clay.

The deposits in the Spruce Pine district which gave any promise of meeting these requirements were studied in considerable detail. Preliminary work indicated that only two localities were likely to be large enough in themselves, but that a number of smaller deposits fairly close to each other might as a group fulfill the necessary conditions. Consequently the field work was concentrated on four groups of deposits, two closely spaced ones (Brushy Creek and Gusher Knob) where the productive areas were only a few hundred feet from each other, and two dispersed groups (Spruce Pine and Newdale-Lunday) with the units a few miles apart.

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7 Hunter, C. E., Residual alaskite kaolin deposits of North Carolina: Am. Ceramic Soc. Bull., vol. 19, no. 3, pp. 98-103, March, 1940.

8 Keith, Arthur, U. S. Geol. Survey, Geol. Atlas, Mount Mitchell folio (no. 124), 10 pp., 1905.

9 Sterrett, D. B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, 342 pp., 1923.

10 Maurice, C. S., The pegmatites of the Spruce Pine district, North Carolina: Econ. Geology, vol. 35, nos. 1 and 2, pp. 49-78 and 158-187, 1940.

11 Kesler, T. L., and Olson, J. C., Muscovite in the Spruce Pine district, North Carolina: U. S. Geol. Survey Bull. 936-A, 38 pp., 1942.

12 Olsen, J. C., Economic Geology of the Spruce Pine pegmatite district, North Carolina: North Carolina Dept., Cons. and Devel. Bull. 43, pt. 1, 1944, pt. 2, 1945.

13 Hunter, C. E., op. cit., p 102.

The field work occupied nearly four months between February 18 and June 11, 1942. It started with detailed areal mapping to outline the areas underlain by granite, from which the kaolin has been formed by chemical weathering. For much of the Spruce Pine quadrangle this had already been done, during recent (1939-1941) study of the pegmatites by the U. S. Geological Survey and the North Carolina Department of Conservation and Development[15]. Concurrently data were collected concerning where and to what depths the granite was sufficiently decomposed to yield kaolin in commercially important amounts. These data were obtained by observing exposures along streams, roads, railroads, and elsewhere, by noting the character of the soils, and by examining hundreds of prospect holes, open pits, mine shafts and adits. In wooded areas, boring with a soil auger gave valuable information not otherwise obtainable. Active kaolin pits and worked-out mines were studied to learn what geologic and topographic factors favored exploitable deposits. This experience aided in making reasonable estimates where more reliable data could not be secured.

ACKNOWLEDGMENTS

The investigation was carried out under the supervision of Dr. G. R. Mansfield, at that time Geologist in charge, Section of Areal and Nonmetalliferous Geology, U. S. Geological Survey. The manuscript was reviewed by Dr. H. M. Bannerman and Dr. V. T. Allen. Dr. J. L. Stuckey, State Geologist of North Carolina, gave valued suggestions concerning both the field work and the report. Mr. F. E. Smith, manager of the Harris Clay Company, cooperated throughout the study with information about particular deposits and the district as a whole. Mr. W. B. Deneen, manager of the Carolina China Clay Company, supplied information about the Bear Creek deposits especially. Mr. Richard Janatka, superintendent at Kaolin, Incorporated, furnished logs of borings and a map of the Brushy Creek area, and allowed the use of laboratory equipment in making density determinations. Mr. C. E. Hunter and Mr. H. S. Rankin of the Regional Products Research Division, Commerce Department, Tennessee Valley Authority, contributed details of the former's clay investigation in the district. Mr. F. L. Hess of the U. S. Bureau of Mines allowed the use of the available records of his prespecting of the Gusher Knob deposits. Many residents of the district aided with information of various sorts.

[15] Olson, J. C., op. cit.

GEOGRAPHY OF DISTRICT

LOCATION

The kaolin deposits investigated lie in what is referred to as the Spruce Pine district, the most important center of mica, feldspar, and kaolin production in North Carolina. The deposits are scattered over an area extending about sixteen miles east-west and eight miles north-south, in parts of Avery, Mitchell, and Yancey counties. The area lies in the Linville Falls, Spruce Pine, and Micaville 7½′ quadrangles, nearly midway of the State in a north-south direction and near its western border.

TRANSPORTATION

The Carolina, Clinchfield and Ohio Railroad runs across the middle of the district following the valley of the North Toe River. A spur line, the Black Mountain Railroad, runs from Kona to Micaville, Burnsville, and Bowditch. The Clinchfield connects with the Southern Railway System at Johnson City, Tennessee, and at Marion, North Carolina.

Good paved roads traverse the area. U. S. Highway No. 19-E runs through Spruce Pine westward and southwestward to Asheville, and northeastward to eastern Tennessee and western Virginia. North Carolina Highway No. 26 connects southward with the main east-west route at Marion. Many other well-graded dirt and gravel roads give easy access to most parts of the area. All important kaolin deposits are near good, mostly paved, roads.

TOPOGRAPHY

The Spruce Pine district lies in the Blue Ridge physiographic province, near its southeast boundary and just west of the main divide. The drainage is to the northwest by the North and South Toe Rivers, upper tributaries of the Tennessee River system. The topography is subdued-mountainous, with ridges and valleys of very irregular shape and distribution. Summits are rounded or flat, slopes steep, and valley bottoms usually narrow. Elevations range from 2,245 feet on the North Toe River at the north edge of the Micaville quadrangle (pl. 4) to 5,307 on Big Bald or Yellow Mountain; local relief is commonly a thousand feet.

A well-developed strath or old erosion level is represented by areas of wide, flat valley bottoms, by sediment-capped terraces, and adjacent gently rolling country along the North Toe River and its larger tributaries. Its altitude is 2,500-2,700 feet in the Micaville quadrangle, but it gradually rises upstream to 2,600-2,800 feet in the Spruce Pine and 2,750-2,950 feet in the Linville Falls quadrangle. Small tributaries like Threemile Creek (pl. 2) and English Creek (pl. 4) flow at the strath level, as do the upper portions of larger tributaries like Bear Creek and even a part of the upper North Toe River in Avery county. Farther downstream in the Micaville quadrangle all but the smallest streams have incised the strath, the North Toe and South Toe Rivers having cut gorges 200 to 300 feet into the strath terrace.

The strath is far from flat-topped everywhere; in most places it has a relief of 100 or even 200 feet. This, however, contrasts with the ruggedness of surrounding areas. The upper boundaries usually merge by gradually steepening slopes into the ridge or mountain sides and are consequently ill-defined. The lower boundaries are often sharp where the steep sides of the entrenched valleys intersect the strath, but where ingrown meanders have formed gradual slip-off slopes, the land may descend evenly to river level. In some places the strath can be seen to include two or more terrace levels. In the Brushy Creek area three levels are clear, (1) the present floodplain of the North Toe River at an altitude of about 2,625 feet, (2) a wide flat sediment-covered terrace of about 70 acres extent at 2,700 to 2,740 feet, and (3) narrow flat-topped ridges without sediment cap at 2,800 to 2,850 feet. Near Spruce Pine, however, the situation is less clear. Here a terrace near 2,700 feet is evident but with perhaps three others between 2,600 and 2,800 feet. Near Gusher Knob one terrace lies about 100 feet above the flat bottom of Threemile Creek, which is not incised. The lower and central portions of the strath, where not dissected by recent erosion, are blanketed by river sediment, presumably the remnants of floodplain deposits. These portions tend to be fairly flat and to slope gently toward the larger streams. These flat areas are trenched by recent gullies and small valleys. The upper marginal portions of the strath have little or no blanket of sediment.

The physiographic history of the district has not been worked out in detail, but the strath is presumably of the same age as that described around Asheville.

GEOLOGY OF DISTRICT

FORMATIONS

Most of the Spruce Pine district is underlain by pre-Cambrian sedimentary and igneous rocks which have been profoundly altered by regional (dynamic) metamorphism. They were later intruded and further modified by late Paleozoic silicic igneous stocks, dikes and sills.

Nearly all of the Spruce Pine area is shown on the geologic map of the Mt. Mitchell quadrangle (Folio 124) but on this map all of the rock types described in the present report are included in two formations.

METAMORPHIC ROCKS

The older metamorphic rocks include principally mica gneiss, mica schist, and hornblende gneiss. These are generally conceded to be pre-Cambrian in age. Their relative ages are not certain though the hornblende gneiss is probably younger than the others.

Mica gneiss.—The mica gneiss is a moderately fine- and even-grained rock containing both muscovite and biotite with quartz and feldspar. Small red garnets are common in many places, and in a few localities kyanite needles are abundant. The banding is regular and even, small bands showing great persistence longitudinally. Two dolomitic marble layers included in this series indicate a sedimentary origin for at least a part of it.

Mica schist.—The mica schist consists mainly of fairly coarse flakes of muscovite, with minor amounts of biotite, quartz and a little feldspar. Red garnets from 0.1 to 0.5 inch in diameter are abundant, and some bands, especially in the Micaville quadrangle, contain much kyanite.

Hornblende gneiss.—Hornblende gneiss is interbanded with both of these rocks; sometimes in layers only a few inches across and sometimes as a great series hundreds of feet thick. This gneiss usually consists of small black hornblende needles oriented in planes (with linear orientation in these planes less common), and separated by bands of quartz and feldspar. Garnets are rarely found. In places the rock is a coarse hornblende amphibolite almost without other minerals. Alteration has developed some zones with much biotite or chlorite. The mineralogical and chemical composition, together with the form and relations of the hornblende gneiss, suggest that it originated from femic volcanics and intrusive sills.

Injection gneiss.—In some places near the granite intrusions (see below) mica schist and perhaps also mica gneiss and hornblende gneiss have been injected and permeated on a large scale by granitic material, forming a distinctive rock partly of metamorphic and partly of igneous origin. The addition of much magmatic material was accompanied by recrystallization and coarsening of the original constituents. This injection gneiss is characterized by coarse silvery muscovite leaves separated by lenses of quartz and feldspar. On surfaces parallel to the foliation the rock looks like a mica schist, but on cross breaks the dominance of quartz and feldspar is apparent, with the mica enclosing fat pods of igneous material. Veins of quartz and stringers of pegmatite abound. Injection proceeded so far near some intrusions as to separate the mica folia into shreds isolated in quartz and feldspar, so that the gneiss may grade into normal mica-bearing granite. With distance from the intrusion the amount of injected material may be so small that the typically lumpy foliation surfaces are not developed, and the rock grades into normal schist or gneiss.

IGNEOUS ROCKS

Two periods of igneous intrusion have affected the area. The earlier intrusions were ultrabasic, and probably pre-Cambrian in age. The later ones were highly silicic; analysis of their radioactive minerals has indicated a late Paleozoic age.

Ultrabasic intrusives.—The earlier intrusives include dunite and pyroxenite, and have in part been altered to soapstone and talc schist. The dunites have been described recently by Hunter[16].

Granite.—All the previously mentioned formations have been intruded by granite. These igneous bodies appear to be irregular stocks (pls. 2, 4), but the depth of exposure is insufficient to determine whether or not they are floored. The stocks crop out over areas of very irregular shape and from a few hundred yards to one or even two miles across. With these bodies are many smaller steeply dipping sill-like masses, dikes, and stringers. All were included by Keith[17] with mica gneiss and schist in the Carolina gneiss formation. Watts[18] seems to have been the first to recognize this rock as distinctly different from others in the

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[16] Hunter, C. E., Forsterite olivine deposits of North Carolina and Georgia: North Carolina Dept. Cons. and Devel. Bull. 41, 117 pp., 1941.
[17] Keith Arthur, U. S. Geol. Survey Geol. Atlas, Mount Mitchell folio (no. 124), p. 2-3, 1905.
[18] Watts, A. S., op. cit., p. 106.

area. He correctly described it as granite, composed of feldspar, quartz and mica only, and generally occurring as sills. Nevertheless, by many this rock was subsequently regarded as being the same as the pegmatite. F. L. Hess and Hunter[19] introduced the use of "alaskite" for this granite because of its lack of black minerals, but the name is not retained here because the dominent feldspar does not correspond to that of the type rock to which the term was originally applied. This rock was also called alaskite by Olson[20] but he noted that the composition was not "strictly in accord with published analyses of alaskite," and his terminology is not followed in this report.

The granite is coarse-textured, grains averaging about half an inch in width. Its uniformity and simplicity of composition are notable. In general oligoclase constitutes nearly half of the rock, microcline and quartz each about a quarter, and a small amount of muscovite the remainder. Iron-manganese garnets are quite abundant in places but are not usual. Biotite is rare. No other iron-bearing minerals are found, so the kaolin derived from the granite is usually entirely free of iron stain. Hunter[21] gives the following chemical analyses, furnished by Minpro Laboratory, Tennessee Mineral Products Corporation, Spruce Pine, North Carolina:

ANALYSES OF SPRUCE PINE GRANITE ("ALASKITE")

	No. 1 (%)	No. 2 (%)
SiO_2	73.96	74.30
Al_2O_3	15.77	15.50
Fe_2O_3	0.33	0.30
CaO	1.30	0.90
K_2O	3.74	4.56
Na_2O	4.57	4.15
Ignition loss	0.31	0.26
Total	99.98	99.97

Pegmatite.—Many hundreds of pegmatite dikes, lenses, and irregular elongate masses transect all the rocks of the district. In width they range from less than an inch to a hundred or more feet; in length from a few feet to perhaps a mile. They are found within the granite bodies, especially near their margins, as well as in the gneisses and schists. In the latter they conform in general to the foliation but in places cut across, and have sharp

[19] Hunter, C. E., op. cit., (1940) p. 98.
[20] Olson, J. C., op. cit., p. 22.
[21] Hunter, C. E., op. cit., (1940). p. 100.

contacts. Pegmatite in the granite usually occurs as irregular streaks and lenses with indistinct walls grading into the granite. The pegmatite is distinguished from the granite by its much coarser texture, more variable composition and unusual minerals.

Like the granite, the pegmatite also consists mainly of plagioclase feldspar (oligoclase), microcline, quartz, and muscovite, but in addition often contains biotite, garnet, apatite, beryl, tourmaline, thulite, allanite, columbite, samarskite, uraninite, and others. It contrasts with granite in often having a higher proportion of microcline. Thus, since plagioclase weathers more quickly and thoroughly than microcline, the pegmatitic portions may yield less clay and more hard feldspar.

STRUCTURE

The various gneisses and schists of the district are complexly interbanded and succeed one another apparently without systematic repetition. Bands of one variety range from a few feet up to half a mile in width, and in places taper rapidly along their strike. One variety fingers out into another along the strike and parallel sections only a few hundred yards apart match very poorly. The regional strike is northeast; the dips are mostly steep to the southeast.

The regional northeast trend has been greatly disturbed near the granite intrusions, so that diverse strikes and dips are found. Since most of the intruded rocks were foliated and steeply dipping, the granite contacts in general are concordant, but many detailed exposures show cross-cutting relations. Those contacts which parallel the regional strike tend to be simple curves, whereas those which run across the strike are "saw-toothed" with projecting dikes and sills.

A vast number of inclusions of the earlier rocks, especially of injected gneiss, are found in the granite. These range in thickness from a few inches or feet up to 2,000 feet. They are very irregular and angular in shape but tend to be slab-like because of their foliation. The slabs usually stand steeply on edge, in positions about parallel to the foliation of the nearest wall, but diverse positions are also found. Some have been complexly crumpled and most are well impregnated with igneous material and cut by veins and dikes. The majority of the inclusions were doubtless detached from the walls but some are probably the remnants of roof pendants. The large number of inclusions, their angular shapes and sharp contacts (showing only moderate recrystallization and no assimilation), all suggest that erosion has barely unroofed the granite stocks. The fact that the granite is exposed mostly at low altitudes and rarely on the highest ridges supports this inference. The tremendous number of pegmatite dikes and quartz veins in the areas between the granite bodies further suggests that much of the district is underlain at depth by granite.

Faulting is indicated by slickensided fracture surfaces coated with manganese oxide. The impossibility of identifying and matching key beds leaves the displacements unknown in most localities, but they appear to be minor. Faults are fairly numerous in all types of rocks.

Regular tectonic joint systems are rare but locally occur, mainly in hornblende gneiss. Irregular fractures and expansion joints parallel to the local land surface are common, especially in the granite.

KAOLIN DEPOSITS

HISTORY AND PRODUCTION

Kaolin from western North Carolina is reported by Kerr[22] to have been mined by the Indians and exported to England during the early part of the 17th Century. In 1767-1768 Josiah Wedgewood sent T. Griffiths from England to Ayoree Mt. near Cowee Town on the Tennessee River (apparently the Iotla Bridge section about 5 miles northwest of Franklin, in Macon county) to obtain white clay. Griffiths cleared out an old pit from which clay had been taken "long before"[23] and "loaded five wagons with five tons of clay," which after much difficulty was shipped from Charleston, South Carolina, to England. At the time of Kerr's report (1880), no clay was being mined though its value was recognized.

Modern kaolin mining started in the southwestern part of the State near Webster, in Jackson county, about 1888. The deposits in this section, derived from pegmatite dikes rather than large granite bodies, were small, though many were very rich. Some portions are said to have been so nearly pure kaolin that the material was sold without washing. For many years Jackson, Macon, and Swain counties supplied almost all of North Carolina's production but these deposits are now practically exhausted and have not been mined for about twenty years.

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[22] Kerr, W. C., The mica veins of North Carolina: Am. Inst. Min. Eng. Trans., vol. 8, p. 462, 1880.

[23] Griffiths, T., Through South Carolina for clay in 1767, being the narrative of an English gentleman, T. Griffiths, who made this journey, mining the first kaolin in America: Ceramic Age, vol. 14, no. 5, pp. 165-169, November 1929.

The earliest mines opened in the Spruce Pine district evidently were those along upper Bear Creek, worked about 1904. No operations in the district are mentioned by Keith[24] in 1897-1901, or by Ries[25] in 1903. About 1905 or 1906 the Bear Creek deposit near the North Toe River and Penland was opened by C. J. Edgar Company and was later worked for 11 years by Harris Clay Company. Sometime previous to 1918 it was abandoned but was later reopened and is still being worked by the Carolina China Clay Company. In 1913 this deposit and one on Beaver Creek were the only ones operating in the district, though prospects were known in the Gusher Knob, Grassy Creek, Spruce Pine, Boonford, and Micaville areas. The large Sparks mine of the Harris Clay Company at Minpro was opened in 1914 and produced until about 1938 when a new pit was opened about a thousand feet to the northeast. The Spruce Pine mine on the southeast edge of town, probably the largest clay excavation in the district, was opened in 1916 but is now abandoned. In 1918 Bayley[26] reported eight active mines, only three of which were in Jackson and Haywood counties, the others being in the Spruce Pine district. Two of these were near Micaville, opened about 1914 by Harris Clay Company and since then largely worked out. The small Flukens Hill deposit was opened early in 1919 and was worked for about two years. The Lunday deposit was being prepared for operations in 1920 and an improved plant was completed here in 1936. This deposit was not being worked in June 1942 but preparations for reopening it were in progress. The Grassy Creek deposits were being operated in 1936 but have subsequently been abandoned and the plant removed. The very large deposits at Brushy Creek were intensively prospected in the early 1930's and the modern plant of Kaolin, Incorporated, constructed, operations starting in May 1937.

Deposits being operated in June 1942 included:

Brushy Creek, by Kaolin, Incorporated
New Minpro, by Harris Clay Company
Bear Creek, by Carolina China Clay Company

The production of kaolin in North Carolina during the last twenty years is tabulated below; data are from Mineral Resources of the United States (U. S. Geological Survey) and Minerals Yearbooks, (U. S. Bureau of Mines). The division of the total between the Spruce Pine district and that in the southwest part of the State is not known. In recent years, probably

[24] Keith, Arthur, op. cit., 1905.
[25] Ries, Heinrich, op. cit. (Prof. Paper 11), 1903.
[26] Bayley, W. S., op. cit. (Bull. 29), p. 34.

since about 1922, the whole production has come from the Spruce Pine district. Figures for the total production of kaolin from North Carolina are not available.

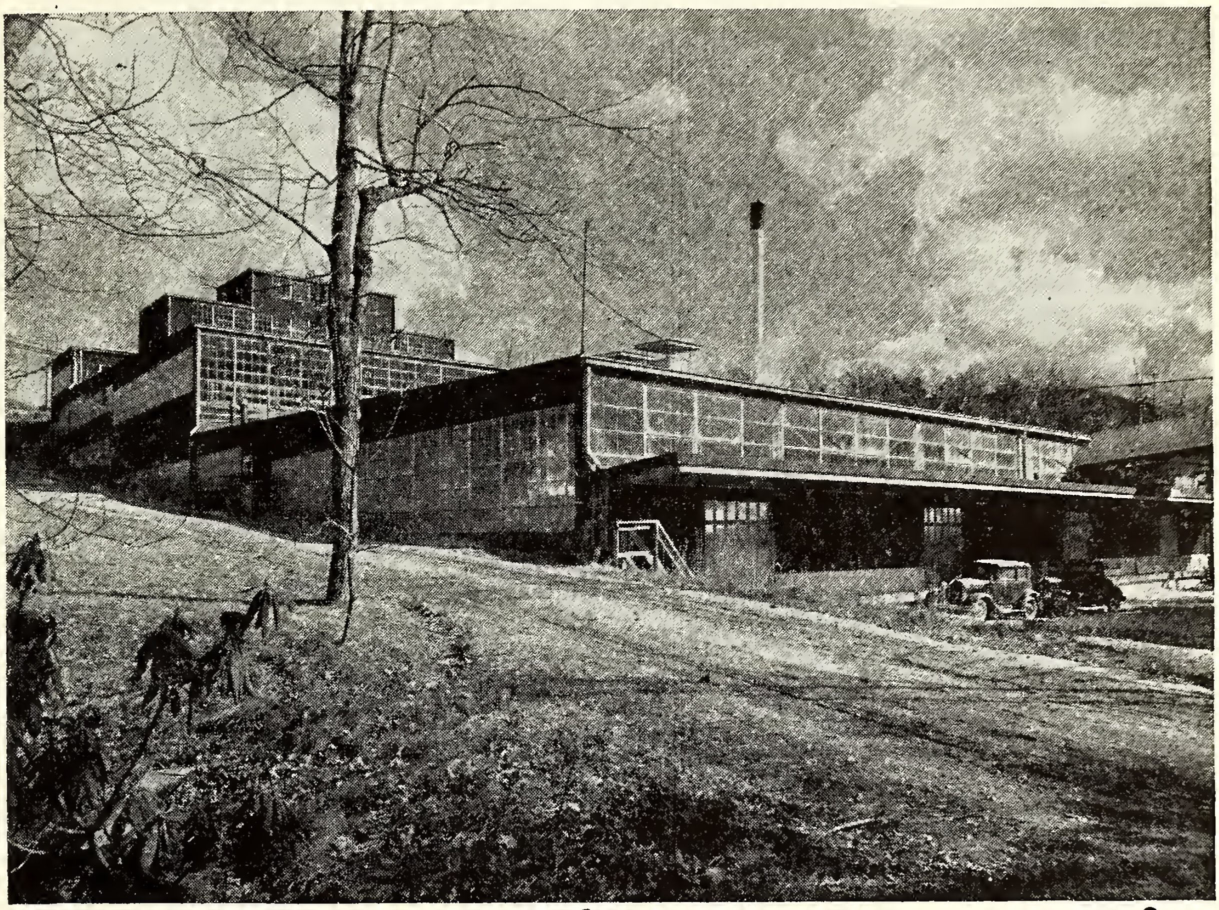

Fig. 1.—Plant of Kaolin, Incorporated, near Spruce Pine, N. C.

KAOLIN PRODUCED IN NORTH CAROLINA

Year	*Short tons*	*Value*
1921	11,681	$188,825
1922	14,586	214,552
1923	23,673	369,398
1924	16,858	277,418
1925	18,799	309,833
1926	20,719	331,487
1927	20,334	327,638
1929	19,788	298,841
1929	17,678	282,672
1930	24,674	391,432
1931	12,234	195,596
1932	6,857	102,865
1933	6,878	102,714
1934	7,146	106,742
1935	8,162	118,972
1936	8,657	126,353
1937	a	a
1938	a	a
1939	11,308	165,896
1940	14,602	202,642

a Only three producers. Figures cannot be revealed.

GEOLOGIC SITUATION AND ORIGIN

ROCK TYPES

The residual kaolin deposits of the Spruce Pine district were formed by chemical weathering of feldspathic rocks. Surface water containing carbonic, organic and other acids percolated down through the rocks where conditions were favorable and converted the feldspar to kaolin.

All of the rocks of the district are deeply weathered except on the steeper slopes where the loose products of weathering are removed by creep and rain wash about as fast as formed. Most of the rocks contain appreciable feldspar but only granite and pegmatite contain sufficient amounts to yield large proportions of clay not contaminated with objectionable impurities. Though many of the pegmatites are deeply decomposed, they are relatively small. Some deposits of this type have been worked in this district but all mining of them is now abandoned. Probably because of the analogy with the pegmatite-kaolins in southwestern North Carolina and because of the coarseness of the Spruce Pine granite, the deposits near Spruce Pine have until recently been considered derived from pegmatite also. Watts[27] did remark that the pegmatite at the Penland deposit was very fine-grained and not unlike a granite in texture. Hess and Hunter[28] have made it clear that the large deposits now being worked were formed from enormously larger granite ("alaskite") bodies. The location of commercially important kaolin deposits in the district is thus primarily controlled by exposures of the granite.

FRACTURES

The depth to which kaolinization has penetrated appears to depend mainly on topographic conditions (see p. 22). Another factor of importance, but one difficult to evaluate, is the amount of fracturing of the granite. The area seems not to have been subjected to important compressive stress since the late Paleozoic intrusions but vertical movements have recurred. Though the granite is not much distorted, in places it is somewhat shattered and cut by minor faults. Irregular expansion cracks are common and in some places systematic joints are developed. These openings have undoubtedly aided kaolinization and help account for variations in its degree where the topographic situations appear to be alike.

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[27] Watts, A. S., op. cit., p 148.
[28] Hunter, C. E., op. cit., (1940) p. 100.

Of similar effect, though different in origin, is the rude platy flow structure found in places, where similar orientation of mica flakes and small inclusions give the granite a rough foliation. These surfaces of easy parting have opened, allowing free access to ground water.

INCLUSIONS

Many inclusions of mica schist, injection gneiss, hornblende gneiss, and, less commonly, mica gneiss are encountered in the granite. Consequently all of the clay deposits are more or less interrupted by horses of "slate". Their number and size seriously impair the value of the deposit in places and always constitute a mining problem. They also are weathered and contain clay, but in addition have much quartz, opaque mica and limonite. If mixed with the kaolin they introduce objectionable impurities which are expensive or impossible to remove. Furthermore, iron oxide formed by weathering of the inclusions may spread into the surrounding kaolin and ruin large portions.

OVERBURDEN

The overburden on the kaolin deposits is of two kinds: residual soil and stream sediment. In general the first is found on those portions of the deposits which are at highest altitude and farthest from the major streams.

The residual soil overlying the granite is a brown sandy clay, not very plastic, with flakes of clear muscovite up to a quarter of an inch across. Rough pieces of quartz are mixed throughout and lie on the surface. Pegmatitic zones yield larger flakes and sheets of muscovite and big boulders of gray quartz. The upper foot or so contains much organic matter. Minor amounts of partly decayed feldspar occur where kaolinization has not been deep. The brown limonite stain lessens with depth so that the overburden grades downward through light brown into uncontaminated white sandy kaolin. The thickness of stained soil overburden is usually four to six, and seldom over ten, feet.

Kaolin areas at lower altitudes and near the rivers generally have a capping of water-laid sediment, which is a portion of the strath or strath terrace. The bulk of the capping is unconsolidated brown silt and clay, with gravel and sand layers. In general the lower part contains much gravel, but the bottom may be gravel, sand or clay. The gravel pebbles usually are subrounded; well-rounded ones are not common. Some boulders over a foot in diameter were observed but most are smaller. The clay layers are very plastic, in contrast to the residual soil derived from granite. The whole deposit is heavily stained with iron oxide and in part is cemented by it. Stratification is irregular, with scour and fill, and cross bedding. The thickness ranges from a few feet to nearly thirty, and may vary rapidly laterally as both the upper and lower surfaces are irregular. The deposit thins out away from the streams as the strath surface rises, so that only the lower and central portions of the strath are now blanketed with sediment.

TOPOGRAPHIC SITUATION

The kaolin deposits thus far mined lie at low altitudes and near the rivers and roads. The reason is clear from plates 2 and 4, where it can be seen that all deposits investigated lie within the areas of the low incised strath bordering the major streams. A tabulation of the altitudes of all the deposits showed the range to be from 2,500 to 3,000 feet, the great majority falling between 2,550 and 2,800 feet. Those along the upper reaches of the river are higher than those farther downstream, in agreement with the strath altitudes. The tops of the deposits range from 65 to 345 feet above the nearest stream. The bottoms extend down to the stream level, mainly where the stream flows at or near the strath level. Where the strath is deeply intrenched, as near Lunday, the bottom of the deposit may be as much as 200 feet above the local drainage.

The slope of the land surface over the deposits is gentle. Some deposits have nearly level tops, especially where capped with terrace sediment. Most, however, slope irregularly toward the streams with grades of about 6 to 25 percent (roughly 3½ to 14 degrees). In a few places the slope is as steep as 40 percent (22 degrees) near the upper limits of the deposit, but on slopes as steep as this the clay is thin.

The depth of kaolinization varies considerably from place to place, ranging from 10 or 20 feet to 60 or 70 feet. The old Sparks pit at Minpro has been reported mined in places to a depth of 135 feet below the surface. The average depth all over the various producing pits, however, would probably be not over about 40 feet. The lower limit of kaolinization must have been the local water table, and evidently its position during the time of strath erosion rather than its present position mainly determined the depth. This conclusion is drawn from the facts that at the Lunday deposit, where the South Toe River has trenched the strath in a deep gorge, the bottom of the deposit is about 200 feet above river level and 1,500 feet horizontally from it, whereas at the Brushy Creek deposit, where the North Toe River flows at strath level, the bottom is about 15 or 20 feet above river level and 2,000 feet distant. In the first instance several deep tributary valleys run so close to the deposit that circulation of ground water must be possible at lower levels than the bottom of kaolinization, while in the second case the two depths must practically coincide. Thus, most of the weathering responsible for the kaolin probably occurred during the long strath erosion period, though kaolinization has doubtless penetrated somewhat more deeply in the shorter time since rejuvenation.

The strath has been considerably dissected since uplift stimulated erosion. In most places the main streams and the tributaries have cut into it, leaving flattish remnants between them. The resulting even-topped gently sloping ridges lying between the smaller tributaries (and underlain by granite) are typical locations for kaolin deposits. The flatter the top and the greater the area, the better the chance for a good deposit. The presence of a sedimentary capping indicates that no kaolin has been removed by erosion in post-strath time, but its absence is not a discouraging sign.

COMPOSITION

The Spruce Pine kaolins, being residual deposits, contain the resistant minerals of the granite plus its weathering products. The quartz is little affected, though sharp edges of grains may be blunted by solution. The muscovite remains fresh, though clay may penetrate the cleavage planes. The feldspar is more or less thoroughly, but seldom completely, altered to clay, so that partly decomposed grains and lumps remain. Under the conditions which prevailed, the plagioclase was more quickly and thoroughly attacked than the microcline. This is strikingly shown by many weathered perthite crystals where the plagioclase laminae have been altered and removed, leaving the hard potash spar in sharp relief. As a consequence, the "sand" which is removed in washing the kaolin contains more potash than soda spar, though the reverse is true in the granite. Since the pegmatitic zones commonly have a higher proportion of microcline than the normal granite, they may remain harder than the rest of the deposit. Muscovite-plagioclase pegmatites yield sheet mica and rich clay zones. Garnet crystals become specks and spots of limonite with fine stained mica or chlorite. This is one of the most objectionable impurities because almost impossible to remove, and where abundant may ruin the deposit.

When inclusions of mica schist and injection gneiss are mined with the koilin, quartz and coarse mica with little iron stain is introduced but this can be removed with little difficulty by washing. The less common mica gneiss inclusions may yield finer mica and an injurious amount of limonite. The worst inclusions are those of hornblende gneiss, which weather to a fine-grained mixture of limonite and clay. This is almost impossible to remove by washing and such inclusions have to be carefully avoided in mining. Disseminated limonite stain, concentrated along and near fractures, is often found near hornblende gneiss inclusions and under terrace cappings.

Though feldspar may constitute nearly three-fourths of the granite, the percentage of clay derived by weathering of this rock is never this great because of incomplete decomposition. In some deposits formed from pegmatite, a recovery of 40 percent or more has been made, but in those derived from granite a recovery of 20 to 22 percent is high. In most cases the recoverable kaolin is appreciably less, 15 percent being common, and some deposits are operated on as little as 8 or 10 percent. Washing eliminates all impurities from the clay except a little of the finest mica and quartz. Two chemical analyses of washed kaolin, quoted from Hunter[29] and furnished by Harris Clay Company and Kaolin, Incorporated, of Spruce Pine, follow:

ANALYSES OF WASHED KAOLIN SAMPLES

	No. 1 (%)	No. 2 (%)
SiO_2	47.94	46.18
Al_2O_3	37.02	38.38
Fe_2O_3	0.60	0.57
TiO_2	0.02	0.04
CaO	0.30	0.37
MgO	0.07	0.42
K_2O	1.25	0.58
Na_2O	0.06	0.10
ZrO_2	-----	0.08
Ignition loss	13.03	13.28
Total	100.29	100.00

[29] Hunter, C. E., op. cit., (1940). p. 102.

These analyses are typical of the washed product obtainable. Published analyses show the following ranges in composition:

SiO_2	45 to 49 percent
Al_2O_3	36 to 40 percent
Fe_2O_3 (& FeO)	0.1 to 0.8 percent
TiO_2	Trace to 0.1 percent

Any of the kaolins in the Spruce Pine district are reported[30] capable of being washed to yield 37 percent or more Al_2O_3, and that even those too stained for ceramic use would not have over 1¼ percent Fe_2O_3.

MINING AND PROCESSING

The overburden is easily removed by drag-line scrapers or power shovels. The clay is mined in part by power shovels and loaded into trucks which carry it to the plant. At Kaolin, Incorporated, trucks, and a drag-line scraper, deliver the clay to a belt conveyor in the center of the pit, which transfers it to the top of the mill. Other deposits are mined hydraulically; a water jet washes the clay and fine associated minerals to the bottom of the pit, where the slip is raised by bucket elevator to a flume running down to the plant. Some hand work with pick and shovel may be necessary to remove undesirable portions. Large inclusions are mined around and left standing, often precariously, while smaller ones are loaded separately and dumped with the overburden. It is suggested[31] that overhead cableways could be profitably constructed to bring clay from distant deposits to a central plant.

The kaolin is separated from the associated minerals by a complex procedure involving grinding, washing, screening, settling, and flotation. Details of modern methods are found in papers by Grout[32 33], Trauffer[34] and Hubbell[35]. Recoveries usually range from 8 or 10 percent to 15 or 17 percent. An important byproduct is fine ground mica. Other possible products which are not now saved, are quartz and potash feldspar for ceramic purposes.

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[30] Smith, F. E., Harris Clay Company, personal communication.
[31] Janatka, Richard, Kaolin, Incorporated, personal communication.
[32] Grout, J. R., Jr., Better china clay from improved benefication: Eng. and Min. Jour., vol. 138, no. 7, pp. 341 and 352, July 1937.
[33] Grout, J. R., Jr., A new process North Carolina kaolin refinery: Am. Ceramic Soc. Bull., vol. 16, no. 10, pp. 387-390, October 1937.
[34] Trauffer, W. E., Processes kaolin by foreign method: Pit and Quarry, vol. 32, no. 6, pp. 41-44, December 1939.
[35] Hubbell, A. H., Mining and washing kaolin in western North Carolina: Eng. and Min. Jour., vol. 144, no. 1, pp. 51-53, 65, January 1943.

RESERVES

TOTALS FOR THE DISTRICT

The amount of crude kaolin in Avery, Mitchell, and Yancey counties was estimated by Hunter[36] at 51 million tons. His figures[37] for each individual deposit are summarized in Appendix A. The finished kaolin available was estimated at about 4½ million tons.

The estimates from the present investigation are given in the accompanying tables. Since some of the quantities involved could not be determined accurately by surface work and shallow borings, but depended in part on judgment, the tables include two sets of figures giving the probable and possible amounts. The "probable" figures are conservative but not minimum, the "possible" figures optimistic but not extreme. The amount of washed kaolin available in the four groups of deposits investigated is calculated to be between 3 and 7 million short tons.

APPRAISAL OF DATA

In order that the degree of reliability of the estimates may be appraised, the means of obtaining the data are explained and the sources and limits of error of each item evaluated below.

Areas.—The areas underlain by clay were determined by surface observations and soil auger borings. This information was plotted on topographic maps (scale 1/24,000; contour interval 50 feet) and limit lines drawn. These lines are doubtless incorrect in places but could be made truly accurate only by borings spaced at intervals of 50 feet or less all over the areas. For the Brushy Creek deposits these lines were transferred to a larger scale (1/2,400) map (pl. 3). On this the sizes of the kaolinized areas were determined by drawing triangles and parallelograms within the limit lines, scaling their dimensions and calculating. For the other deposits the outlines of the areas were traced from the field maps onto quadrille paper (20 by 20 lines per inch) and the number of included squares counted. In the cases of squares lying partly within the limit lines, those more than half inside were counted as wholes and those more than half out were omitted. The mean of horizontal and vertical counts was used. The errors in figuring the sizes are thought to be less than the inevitable errors in locating limit lines.

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[36] Hunter, C. E., op. cit., (1940). p. 102.

[37] Communicated personally by Mr. Hunter, through the courtesy of Mr. H. S. Rankin, Regional Products Research Division, Commerce Department, Tennessee Valley Authority.

Thicknesses.—Data on the thicknesses of kaolin available below the overburden are variable in their reliability. For much of the Brushy Creek area very good borehole logs were available. For deposits adjacent to active or abandoned clay workings good determinations could be made. Elsewhere exposures in mine and prospect drifts helped greatly. Soil auger borings in prospecting pits and gullied roads were deep enough to supply minimum data. Oral information from operators, workmen and others was considered where it seemed dependable. In some places, however, reasonable guesses based on experience elsewhere had to be made from the topographic situation. Neither tops nor bottoms of the deposits are planes, so that a greater thickness of clay is encountered in one part than in another. The values used are average for the whole producing area, less than may be expected in central and upper parts and more than near the margins. To determine the thickness with certainty would require systematic, closely spaced, deep drilling entirely through the deposits. Lack of certainty as to this quantity was the main reason for computing probable and possible amounts. The ranges given are reasonably sure to bracket the true thicknesses.

Inclusions.—Data on the volume of the deposit occupied by inclusions were especially difficult to obtain. Where possible the inclusions were mapped and their areas excluded. In places where a good many boreholes had been put down rough calculations were possible. Examination of active and worked out deposits was particularly useful. Because this amount depended so much on judgment it is expressed as a percentage. This deduction amounts to a "factor of safety" to take care of unpredictable inclusions, large quartz veins, and hard slightly kaolinized areas. The less that was known about a deposit the higher this factor was set, and it probably runs high, for the entire district.

Densities.—Samples of known volume were taken by using a section of heavy iron pipe (diameter 7 inches, length 5.8 inches) with one edge beveled. A smooth surface on the clay was leveled off and the pipe driven down till flush with the surface. The surrounding clay was dug away to the level of the pipe's lower edge and the enclosed clay bagged. The sample was weighed, moisture content determined, the dry weight and density computed. Seven determinations from varying situations in four deposits were made. They ranged from 69 to 85 and averaged 77 pounds per cubic foot. These figures are probably slightly low because the jarring while driving the pipe loosened the clay somewhat. For deposits where determinations were not made, 80 pounds per cubic foot was used. The Harris Clay Company uses 90 and Hunter and Mattocks used 85 pounds per cubic foot.

Recoveries.—Information on the average recovery obtained from deposits which had been or were being worked was supplied by the operators. For others estimates were made by comparing the clay with that of worked deposits. This item is thought to be pretty dependable.

Most of the computations were made by slide rule and so are not exact. Their order of accuracy, however, is as high as that of the quantities concerned.

DISTRIBUTION AND GROUPING

Four groups of deposits in the Spruce Pine district were investigated as possible sources of aluminum ore. Two of these, the Brushy Creek and Gusher Knob, are compact groups of deposits, each derived from a single granite mass. Both lie in western Avery county, mainly in the Linville Falls quadrangle but extending westward into the Spruce Pine quadrangle (pl. 2). The other two groups, Spruce Pine and Newdale-Lunday, include groups of deposits mostly derived from different granite bodies. Though scattered, they are close enough together to supply a centrally located plant. The Spruce Pine group lies in Mitchell county, in the south-central part of the Spruce Pine quadrangle (pl. 4). The Newdale-Lunday group lies in Yancey county near the center of the Micaville quadrangle (pl. 4).

INDIVIDUAL DEPOSITS AND GROUPS

BRUSHY CREEK GROUP

The Brushy Creek deposits (pls. 2 and 3) were first worked in May 1937 by Kaolin, Incorporated, after extensive prospecting by boreholes and adits. By 1942 a pit on the western edge, about 1.7 acres in area and up to 43 feet deep, had been excavated. The amount of kaolin produced must exceed 10,000 tons.

The deposits fall into three subgroups. (1) The part lying adjacent to the active pit (pl. 3, areas 1-6 inclusive) is flat-topped and at a little over 2,700 feet altitude. Its overburden of terrace sediment ranges in thickness from 4 to 28 feet, averaging 16 feet. Kaolin up to 40 feet thick has been penetrated in places, though five boreholes encountered hard granite after

19 to 35 feet of clay. (2) The part to the northeast lying along Brushy Creek (areas 8-20, 30-32 inclusive) is uneven and steeper, reaching in places up to 3,000 feet altitude. The overburden here, except along the lower edges, is residual soil and stained kaolin, ranging from 2 to 25, and averaging about 6 feet in thickness. Over 60 feet of clay is known in places. Only a small section of Brushy Creek (areas 19 to 20) along the north side of

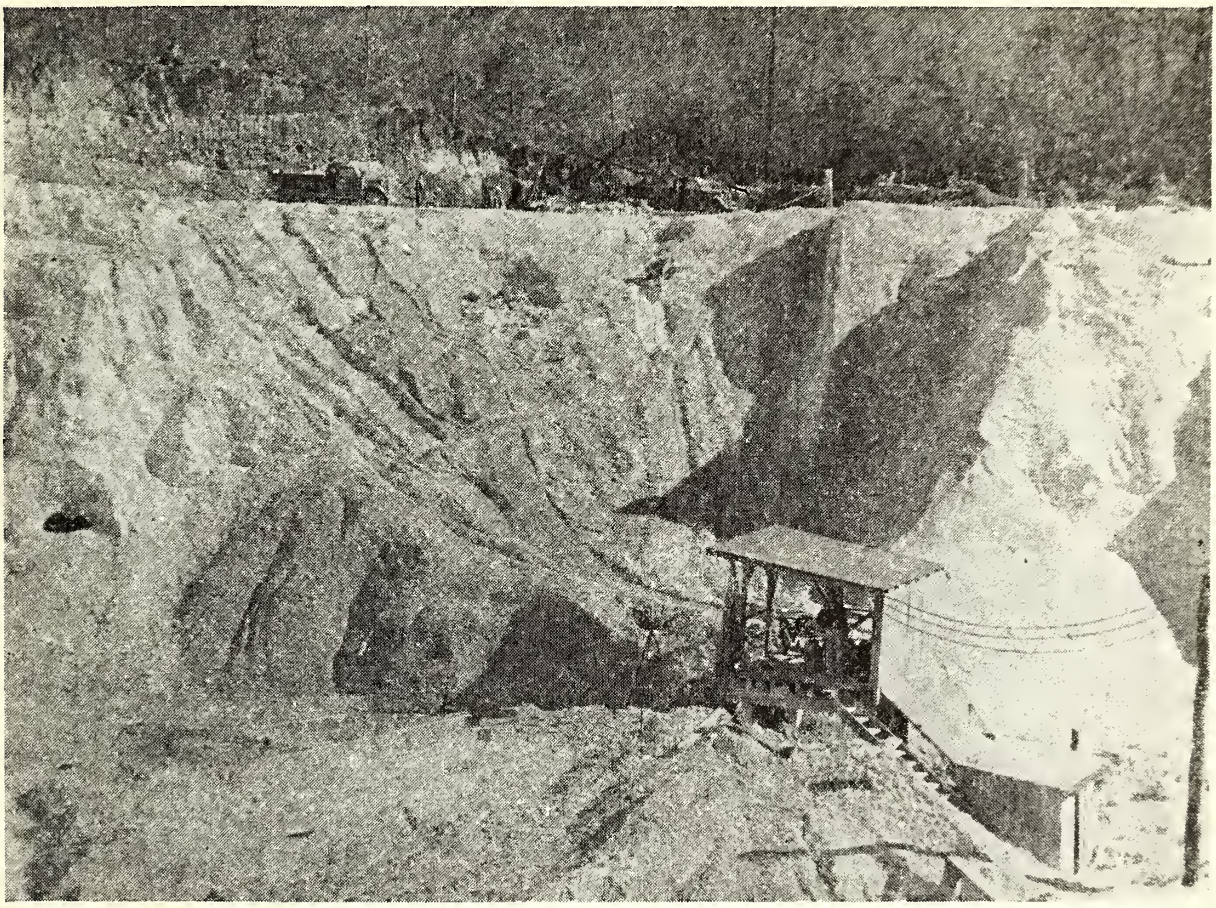

Fig. 2.—Mine of Kaolin, Incorporated, near Spruce Pine, N. C. Note thick overburden of stratified gravel, sand, and clay in left background.

Mill Ridge slopes gently enough for commercial clay. (3) On the south side of Mill Ridge toward Laurel Creek (areas 21-29) a maximum of 54 feet of kaolin has been determined. This subgroup is like the second in having rough, steeper slopes and being at higher altitude. The residual soil overburden in the part prospected averages 11 feet in depth.

The kaolin of the Brushy Creek deposits is of good quality. Stain from garnets or from hornblende gneiss inclusions is rare. Hard potash spar and large quartz veins are abundant in the clay. The mill recovery averages 15 percent but samples have yielded up to 24 percent. The quantity of clay in the various areas of the deposits is given in Table 1. The total for the group is between 1½ and 3 million tons of washed kaolin.

TABLE 1. KAOLIN RESERVES IN BRUSHY CREEK GROUP OF DEPOSITS

Deposit	Area (sq. ft.)	Thickness (ft.)		Inclusions (percent)		Density (lbs. per cu. ft.)	Weight—Crude (short tons)		Recovery (percent)		Weight—Washed (short tons)	
		Probable	Possible	Probable	Possible		Probable	Possible	Probable	Possible	Probable	Possible
Brushy Creek												
No. 1	231,000	40	60	10	5	77	320,166	506,930	15	18	48,025	91,206
2	142,800	40	60	20	10	77	175,929	287,000	15	18	26,389	53,500
Sum 1-2											(74,414)	(144,706)
3	392,725	35	45	20	10	77	423,357	613,750	15	18	63,504	110,500
4	760,000	30	40	20	10	77	702,240	1,052,500	15	18	105,336	189,700
5	1,120,000	30	40	14	10	77	1,112,496	1,552,500	18	20	200,249	310,400
6	528,200	20	30	20	10	77	325,371	549,000	15	18	48,806	98,800
Sum 3-6											(417,895)	(709,400)
7	(uncertain)											
8	154,000	25	40	30	20	77	103,757	213,000	17	20	17,639	42,600
9	651,200	40	50	20	10	77	803,000	1,127,500	17	20	136,500	225,500
Sum 7-9											(154,139)	(268,100)
10	792,000	35	45	20	10	77	853,776	1,234,000	15	18	128,066	222,100
11	301,500	25	40	20	10	77	232,155	418,000	15	18	34,823	75,300
12	247,500	25	50	20	10	77	190,575	343,000	15	18	28,586	61,800
Sum 10-12											(192,475)	359,200)(
13	367,330	20	35	10	5	77	254,560	471,000	15	18	38,184	84,800
14	677,980	25	40	10	5	77	587,300	991,000	15	18	88,095	178,400
Sum 13-14											(126,279)	(263,200)
15	543,200	30	40	15	10	77	533,286	752,500	15	18	79,993	135,300
16	293,440	30	40	15	10	77	288,084	407,000	15	18	43,213	73,300
Sum 15-16											(123,206)	(208,600)
17	253,000	30	40	15	10	77	248,382	351,000	15	18	37,257	63,250
18	540,500	30	40	15	10	77	530,636	749,000	15	18	79,595	134,800
30	302,500	20	30	30	15	77	163,047	297,000	15	18	24,457	53,500
31	280,000	30	40	25	15	77	242,550	366,500	15	18	36,382	66,000
32	113,750	30	40	25	15	77	98,536	149,000	15	18	14,780	26,820
Sum 17, 18, 30,	31, 32										(192,471)	(344,370)
19	657,400	30	45	20	10	77	606,887	1,025,000	10	15	60,689	153,800
20	281,200	30	45	20	10	77	259,829	438,000	10	15	25,984	65,750

Sum 19-20											(86,672)	(219,550)
21	460,000	20	40	25	15	77	265,650	602,000	12	18	31,878	108,300
22	118,300	15	40	25	15	77	51,238	155,116	12	18	6,149	27,950
23	418,600	35	50	25	10	77	422,961	725,000	12	18	50,754	130,500
24	266,950	25	35	20	10	77	205,551	324,000	12	18	24,666	58,400
25	326,250	35	50	20	15	77	351,697	534,000	12	18	42,204	96,200
26	266,800	35	40	30	15	77	251,659	349,000	12	18	30,199	62,820
27	220,800	25	40	30	15	77	148,764	289,000	12	18	17,852	52,100
28	50,525	20	30	20	10	77	31,123	52,575	12	18	3,735	9,475
29	76,375	25	40	25	10	77	55,133	105,850	12	18	6,616	19,070
Sum 21-29											(214,053)	(564,815)
											1,580,604	3,081,941

The Brushy Creek deposits are not near a railroad but lie just a few hundred yards from a concrete road (U. S. Highway No. 19-E). The distance to the nearest shipping point on the railroad, Spruce Pine, is five miles. The different deposits of the group are easily accessible to the present plant of Kaolin, Incorporated, now being operated by Harris Clay Company, except for areas 21-29 inclusive; a road or aerial cableway would have to be constructed to reach them.

This deposit appears to be the largest and best in the district. A good deal of prospecting has been done in several parts of the area, though not all of the information obtained is now available or usable. The borings were in part haphazardly distributed and elsewhere not spaced closely enough. Some parts have not been bored at all and others not deep enough to make sure of the thickness. Enough work has been done, to justify belief that this deposit meets the requirements for aluminum ore. More definite information on the individual parts is desirable, especially those along upper Brushy Creek and along Laurel Creek. Completely reliable estimates of tonnage would require good logs of several hundred systematically distributed boreholes, spaced not over 50 feet apart, and each penetrating to unaltered granite.

GUSHER KNOB GROUP

A number of promising kaolin-bearing areas lie southeast of Gusher Knob, extending from three-quarters of a mile to two miles east of Ingalls (pl. 2). Though clay prospects in this vicinity have been known for thirty years, no kaolin has yet been produced. The western part of the deposit was prospected in 1936 by F. L. Hess[38] of the Bureau of Mines and C. E. Hunter of Tennessee Valley Authority. About 80 holes were bored and at least three shafts sunk.

The deposits underlie gently sloping, broad-topped ridges on the northwest side of Threemile Creek. These ridges are the dissected remains of a sediment-capped stream terrace lying about a hundred feet above the flat creek bottom. The overburden of gravel, sand, and clay is only two or three feet thick at its lower edge. Farther up on the ridges it increases to more than six feet in thickness. The sediment cap thins out at still higher altitudes and comes to an end at about 2,900 feet. Above this altitude four or five feet of residual soil covers the clay.

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[38] Notes on three shafts and about a dozen boreholes, with unlocated sections of the drilled area, were supplied by Mr. Hess.

TABLE 2. KAOLIN RESERVES IN GUSHER KNOB DEPOSITS

Deposit	Area (sq. ft.)	Thickness (ft.)		Inclusions (percent)		Density (lbs. per cu. ft.)	Weight—Crude (short tons)		Recovery (percent)		Weight—Washed (short tons)	
		Probable	Possible	Probable	Possible		Probable	Possible	Probable	Possible	Probable	Possible
Gusher Knob No. 1	1,860,000	30	50	40	20	80	1,339,200	2,976,000	15	18	200,880	535,680
2	320,000	25	40	40	20	80	192,000	409,600	15	18	28,800	73,728
3	350,000	25	40	40	20	80	210,000	448,000	15	18	21,500	80,640
4	770,000	30	50	40	20	80	554,400	1,323,000	15	18	83,160	221,760
5	270,000	20	30	40	20	80	129,600	259,200	15	18	19,440	46,700
6	1,050,000	30	50	50	20	80	630,000	1,680,000	15	18	94,500	302,400
											458,280	1,260,908

The distribution of kaolinized granite was difficult to determine accurately because of the thickness and extent of the overburden. The limit lines drawn are consequently less certain than in most other localities. The western boundary may lie farther west than indicated and nearly all lines are subject to revision. The western half of the area seems to be underlain by a fair-sized granite body with some inclusions, whereas to the east dikes with intervening septa of gneiss and schist appear to prevail. Large supplies of kaolin are more certain in the western than the eastern parts. The amount of inclusions is problematical but apparently large. Information is most reliable on areas 1, 2, and 3 and least so on area 6.

The clay is of good average quality, in part stained from hornblende gneiss but not unduly so. Kaolinization has been thorough, so that recoveries of 15 to 18 or perhaps even 20 percent may be expected. The broad expanse of flat terrace favors a good depth of clay and 90 feet has been reported[39] in one place. Between 450,000 and 1,250,000 tons of refined kaolin are estimated to be available in the Gusher Knob deposits (Table 2).

The deposits lie adjacent to a good asphalt road (North Carolina Highway No. 194) and eight miles from the railroad at Spruce Pine.

The Gusher Knob deposits appear to be the second most favorable ones in the district. While they probably would yield less total kaolin than the Spruce Pine group, they have the advantage of compact distribution. The topographic situation is especially favorable to deep and thorough kaolinization. The principal uncertainty lies in the areal extent and distribution of granite and pegmatite; a large and systematic boring program is essential to determine these facts.

SPRUCE PINE GROUP

This dispersed group (pl. 4) includes deposits in four compact subgroups as well as several other possible small sources not carefully investigated. The total washed kaolin available (Table 3) in the group is estimated to be between 700,000 and 1,600,000 tons. Taken as a group, these deposits are large enough and close enough together to satisfy the aluminum ore requirements. Three kaolin plants are located in the area, the Harris Clay Company plants at Spruce Pine and at Minpro, and the Carolina China Clay Company plant half a mile east of Penland.

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[39] Smith, F. E., Harris Clay Company, personal communication.

Spruce Pine deposit.—Much of this deposit on the southeast edge of the village of Spruce Pine (pl. 4) has been mined out between 1916 and about 1936 by Harris Clay Company. Much clay remains, however, in two areas to the south of the old pits. The site was abandoned because the clay contained enough iron to spoil it for high-grade ceramic use. The amount of iron, however, is less than the tolerance for aluminum ore. The overburden is principally terrace sediment, up to about 12 feet thick in places. Iron stain has been carried downward by ground water from this cap, as well as developed from garnets and hornblende gneiss inclusions. The depth of kaolinization is reported by Hunter and Mattocks[40] to extend below river level (85 feet) in places. Bayley[41] reports, however, that the material was too hard to mine below 85 feet. A thickness of 58 feet of clay below the overburden was measured at the northwest side of the west pit and of 69 feet at the southwest corner of the long east pit. The total thickness may be somewhat greater as the pits are now in part filled with waste. The recovery of washed kaolin is low, about 10 or 12 percent. In the two sections of this deposit between 150,000 and 300,000 tons of washed kaolin remain. The deposit is readily accessible, as it lies within 300 yards of the railroad. Part of the old plant has been removed but the mica recovery portion is still in operation.

Grassy Creek deposits.—The Grassy Creek deposits (pl. 4) lie about two miles south of Spruce Pine. Three good-sized pits have been mined by Harris Clay Company but have been abandoned since 1936. A large area in this vicinity is underlain by granite, not only on the east side of Grassy Creek around the old pits but also up Silver Run and Graveyard Creek to the west. Superficially the prospects look good in this area but kaolinization has been neither deep nor thorough. The old pits expose fairly hard granite within 20 feet of the surface. In many places the clay is too hard to penetrate with a soil auger for more than four or five feet. Much partly decomposed feldspar is found in the soil. A large area on the north side of Graveyard Creek has big boulders of granite lying on the ground and several outcrops occur. The whole area doubtless contains a good deal of clay, probably 300,000 to 500,000 tons in the five sections outlined, but the yield would be low and the operation proportionately expensive. A large part of the clay is badly stained by decomposed garnets. The overburden is mostly residual soil four to five

[40] Hunter, C. E., and Mattocks, P. W., op. cit., p. 19.
[41] Bayley, W. S., op. cit. (Bull. 29), p. 95.

TABLE 3. KAOLIN RESERVES IN THE SPRUCE PINE GROUP OF DEPOSITS

Deposit	Area (sq. ft.)	Thickness (ft.)		Inclusions (percent)		Density (lbs. per cu. ft.)	Weight—Crude (short tons)		Recovery (percent)		Weight—Washed (short tons)	
		Probable	Possible	Probable	Possible		Probable	Possible	Probable	Possible	Probable	Possible
Spruce Pine												
No. 1	770,000	50	70	20	10	75	1,155,000	1,820,000	10	12	115,500	218,400
2	475,000	30	50	20	10	75	427,500	801,500	10	12	42,750	96,200
Sum Spruce Pine 1-2											(158,250)	(314,600)
Grassy Creek												
No. 1a	500,000	25	40	15	10	83	440,937	747,000	10	12	44,094	89,640
1b	1,550,000	15	25	15	10	83	868,750	1,447,500	10	12	86,875	173,750
2	250,000	15	25	25	10	83	116,719	233,500	10	12	11,672	28,450
Silver Run												
No. 1	1,130,000	20	30	10	10	83	844,110	1,265,000	10	12	84,411	152,000
2	700,000	20	30	10	10	83	522,900	783,500	10	12	52,290	94,100
Graveyard Creek	250,000	25	35	10	10	83	233,437	326,812	10	12	23,344	39,250
Sum Grassy Creek Nos. 1a, 1b, 2; Silver Run Nos. 1-2; Graveyard Creek											(302,686)	(577,190)
English Creek												
No. 1	945,000	30	50	20	10	80	907,200	1,700,000	10	12	90,720	204,000
2	365,000	25	40	20	10	80	292,000	525,600	10	12	29,200	63,072
3	190,000	20	30	10	10	80	136,800	205,200	10	12	13,680	24,624
4	560,000	20	35	25	10	80	336,000	706,000	10	12	33,600	84,720
5	275,000	15	30	10	10	80	148,500	297,000	10	12	14,850	35,640
Sum English Creek Nos. 1-5											(182,050)	(412,056)
Bear Creek												
No. 1	880,000	30	50	30	15	75	693,000	1,402,500	10	12	69,300	168,500
2	920,000	30	45	30	15	75	724,500	1,320,000	10	12	72,450	158,400
Sum Bear Creek Nos. 1-2											(141,750)	(326,900)
											784,736	1,630,746

feet deep, through gravelly sediment occurs near the center of the valley. A concrete road, North Carolina Highway No. 26, running through the area makes it readily accessible.

English Creek deposits.—The English Creek valley (pl. 4) a mile southwest of Spruce Pine is largely underlain by partly kaolinized granite. No clay has been produced here, though a part (section no. 1) has been prospected. The overburden is residual soil five or six feet deep. Large irregular inclusions are numerous. The quality of the clay appears to be good. Between 180,000 and 400,000 tons of washed kaolin could be produced from five sections in the area. U. S. Highway No. 19-E skirts the north edge of the productive area and fair dirt roads run near all parts. The distance to the railroad at Spruce Pine is about 1½ miles.

Bear Creek deposits.—The Bear Creek deposits (pl. 4) lie near the North Toe River east of Penland between Bear and Little Bear Creeks, and about 2½ miles northwest of Spruce Pine. Six large pits have been worked since 1905 or 1906 and two are now (1942) operated by Carolina China Clay Company. The west side has been worked out except for two small areas south of the long pit. The oval hill in the central portion has been prospected and found workable in most places. The overburden is mainly residual soil one to ten feet deep. The thickness of clay is variable, being 60 feet in one pit and only 25 feet in another next to it. Inclusions mainly of hornblende gneiss, stained areas, quartz veins, and hard areas are numerous. Recovery is low, in part 15 percent but mostly 8 or 10 percent. Between 140,000 and 320,000 tons of washed kaolin are estimated to lie in these deposits. The pits are within 200 to 300 yards of the railroad and the present plants are beside the tracks. An asphalt road, North Carolina Highway No. 26 skirts the east and north sides.

Miscellaneous deposits.—Several other deposits (pl. 4) are known near Spruce Pine but were not investigated in detail as the outlook for large quantities of kaolin was poor.

The earliest workings in the Spruce Pine district were along upper Bear Creek near Bear Creek church. Some additional good clay remains here in several spots but no important tonnage.

At Minpro a large pit is now being operated by Harris Clay Company. This was opened about 1938 and has been mined very rapidly to a depth of some 40 feet. The granite is quite hard at 30 feet and in some places at less depth. Much quartz from pegmatites and hard microcline is encountered. The reserve of clay here is very small. Fifteen hundred feet to the north-northwest in the vicinity of an old pit some additional supply might be obtained.

On the low ridges on both sides of Pine Branch and Sullins Creek, a mile and a half northwest of Spruce Pine, kaolinized granite is exposed at a number of places. The granite bodies are very irregular and the inclusions large and numerous. A number of small pits with low recoveries might be opened in this general vicinity.

In the southern part of the town of Spruce Pine, underlying Harris High School and adjacent areas, much partly kaolinized granite is exposed. The area is too built up, however, to be a practicable source.

Kaolin has also been produced up Beaver Creek, a mile and a half northeast of Spruce Pine, but important additional supplies here are unlikely.

NEWDALE-DUNDAY GROUP

The deposits in the Micaville quadrangle (pl. 4) are smaller and more scattered than elsewhere in the district. Four subgroups were investigated and four other deposits were visited. The total quantity of kaolin (Table 4) in the group is estimated to be between 400,000 and 1,300,000 tons. This group is submarginal in respect to the requirements for aluminum ore. The Harris Clay Company plant at Lunday is in the area.

Newdale deposits.—Five possible deposits, none of which has been developed, lie around Newdale in the south central part of the Micaville quadrangle (pl. 4). A great many mica pits and drifts in most of the area expose good clay. The depth of kaolinization in many places is shallow, so that the smaller tonnage estimates are doubtless the more accurate. Inclusions, mostly of schist and injection gneiss, are numerous. The overburden of residual soil and stained clay is seldom over six feet deep. The recovery should be low, probably 10-12 percent. The quantity of clay estimated to be available is between 300,000 and 900,000 tons (Table 4). The deposits lie within 500 yards of U. S. Highway No. 19-E. The nearest point on the railroad is Boonford, 2½ miles north-northeast of Newdale, reached by a good dirt road, North Carolina Highway No. 80.

Butler Gap deposits.—Three small areas northwest of Butler Gap (pl. 4) give indications of clay. The deposits lie a little

TABLE 4. KAOLIN RESERVES IN NEWDALE-LUNDAY GROUP OF DEPOSITS

Deposit	Area (sq. ft.)	Thickness (ft.)		Inclusions (percent)		Density (lbs. per cu. ft.)	Weight—Crude (short tons)		Recovery (percent)		Weight—Washed (short tons)	
		Probable	Possible	Probable	Possible		Probable	Possible	Probable	Possible	Probable	Possible
Newdale												
No. 1	1,700,000	30	60	30	10	80	1,438,000	3,670,000	15	18	214,200	660,600
2	450,000	25	50	30	20	80	315,000	720,000	10	15	31,500	108,000
3	330,000	10	25	30	10	80	92,400	297,000	10	15	9,240	44,600
4	460,000	25	50	20	10	80	368,000	828,000	10	15	36,800	124,200
5	230,000	30	50	30	15	80	197,200	391,000	10	15	19,720	58,700
Sum of Newdale Nos. 1-5											(311,460)	(996,100)
Butler Gap	440,000	25	50	50	20	80	220,000	352,000	10	15	22,000	52,800
Boonford	580,000	30	50	30	10	80	487,000	1,044,000	10	15	48,700	156,600
Lunday												
No. 1	280,000	30	50	35	25	80	218,400	420,000	10	15	21,840	63,000
2	170,000	20	40	35	25	80	88,400	204,000	10	15	8,840	30,600
3	370,000	25	50	35	25	80	240,400	555,000	10	15	24,040	83,250
Sum Lunday Nos. 1-3											(54,720)	(176,850)
											436,880	1,382,350

half a mile southeast of the Newdale group and are reached fair dirt road, the upper end of which is in bad condition. ay has been produced here. The granite bodies are rela- small dikes. The lowest one, farthest northwest, appears well kaolinized. The other two have steeper slopes and in feldspar and granite in the soil, so the clay is probably w. The overburden is residual soil three or four feet thick. sions are numerous. The clay is of average quality; be- 20,000 and 50,000 tons (Table 4) might be produced.

onford deposit.—A large lens of granite half a mile south- of Boonford (pl. 4) has been well kaolinized. No clay has produced here yet. The overburden is shallow (4-5 feet)

Fig. 3.—Mine of Harris Clay Company near Lunday, N. C.

ual soil. The clay appears to be of good quality. Between 0 and 150,000 tons (Table 4) exists in the deposit. North ina Highway No. 80 passes close to the deposit.

nday deposits.—Clay production near Lunday in the center Micaville quadrangle (pl. 4) started about 1921. Hydraulic g was employed at first, in the eastern part of the deposit. t five acres have been mined and approximately 50,000 tons of refined kaolin produced (Grout[42 43]). In 1936 a new process refinery was completed and excavations started adjoining the old pit on the west. The deposit was formed from several closely spaced and partly coalescing dikes and sills. Inclusions or dividing septa of hornblende gneiss are very numerous and some parts of the clay are iron stained. Pegmatitic streaks with hard microcline are common. The overburden is residual soil and stained clay from four to six feet thick. Between 30,000 and 90,000 tons (Table 4) of washed clay is available along the margins of the present pit and in a hill 800 feet to the northeast (area 2). Many smaller dikes of granite and pegmatite occur in the vicinity but most are too small or too slightly kaolinized to be important. A lenticular dike 0.7 mile southwest of the pit (area 3) probably would yield 25,000 to 40,000 tons (Table 4). The main deposit is near the plant of the Harris Clay Company, part of which is a thousand feet from the pit and the rest half a mile away on the other side of the North Toe River beside the railroad. The deposit may be reached from Micaville, four miles south, by a fair dirt road.

Miscellaneous deposits.—A number of smaller deposits in the Micaville quadrangle (pl. 4) would furnish some additional clay.

Near the southeast corner of the quadrangle, where U. S. Highway No. 19-E crosses Crabtree Creek, two deposits are known. The Rice scrap mica plant is working a small deposit south of the road and west of the creek. This deposit includes much hornblende gneiss, is badly stained, and would have a low clay yield. Half a mile east on the other side of the creek and mostly north of the highway is an undeveloped deposit. Inclusions are large and numerous. A fairly important though distant additional supply may exist here.

Three-quarters of a mile east of Micaville and just south of the main highway hydraulic mining of scrap mica is in progress. Clay considerably stained from hornblende gneiss inclusions is exposed at several places in the vicinity but only small amounts could be produced.

Along Snow Creek in the northeast part of the quadrangle a small deposit is known. Bayley[44] estimated its reserves as about 20,000 tons of refined kaolin. The small size of the deposit and its distance from the others make it of doubtful importance.

[42] Grout, J. R., Jr., op. cit., (July 1937.).
[43] Grout, J. R., Jr., op. cit., (October 1937.).
[44] Bayley, W. S., op. cit., (Bull. 708), p. 63.

SUMMARY AND CONCLUSIONS

The investigation shows that the residual kaolin deposits of the Spruce Pine district constitute a potential source of aluminum ore provided that a suitable process for extracting alumina from kaolin on a commercial basis is developed. These deposits lie nearly midway between the aluminum reduction plants at Badin, North Carolina, and at Alcoa, Tennessee, about 175 miles by railroad from each. Though by no means as large as many sedimentary clay deposits, nor as high in alumina content as some, washed kaolin from the Spruce Pine deposits meets the established specifications and averages 37 percent or more in Al_2O_3 and under one percent Fe_2O_3. The depth of minable kaolinized granite is rarely as little as 15 feet and is frequently as much as 50 feet. The overburden is comparatively shallow, averaging between 5 and 10 feet, and is almost never as thick as the clay. Two groups of deposits will yield over a million tons of washed kaolin and two others may do so.

The Brushy Creek deposits are much the largest and most favorable. Between 1½ and 3 million tons could be produced from a comparatively small area. A large and efficient washing plant is already operating. The distance to the railroad is five miles by a paved road.

The Spruce Pine group is second in regard to tonnage available, containing between 700,000 and 1,600,000 tons. The individual parts of this group, however, are separated from each other by from one to three miles, necessitating considerable hauling if worked from a central plant. All but one of the parts is less than a mile from the railroad.

The Gusher Knob deposits, though smaller than the Spruce Pine group, have the advantage of being a compact group. They may possibly yield over a million tons but they are eight miles from the railroad.

The Newdale-Lunday group is the lest favorable source. It may possibly yield a million tons but it is not likely to do so. The individual parts are so scattered that much hauling, in part over poor crooked roads, would be involved. The largest deposits are three miles from the railroad, though some smaller ones are nearer.

The total refined kaolin available in the district is estimated to be between 3 and 7 million short tons.

APPENDIX A

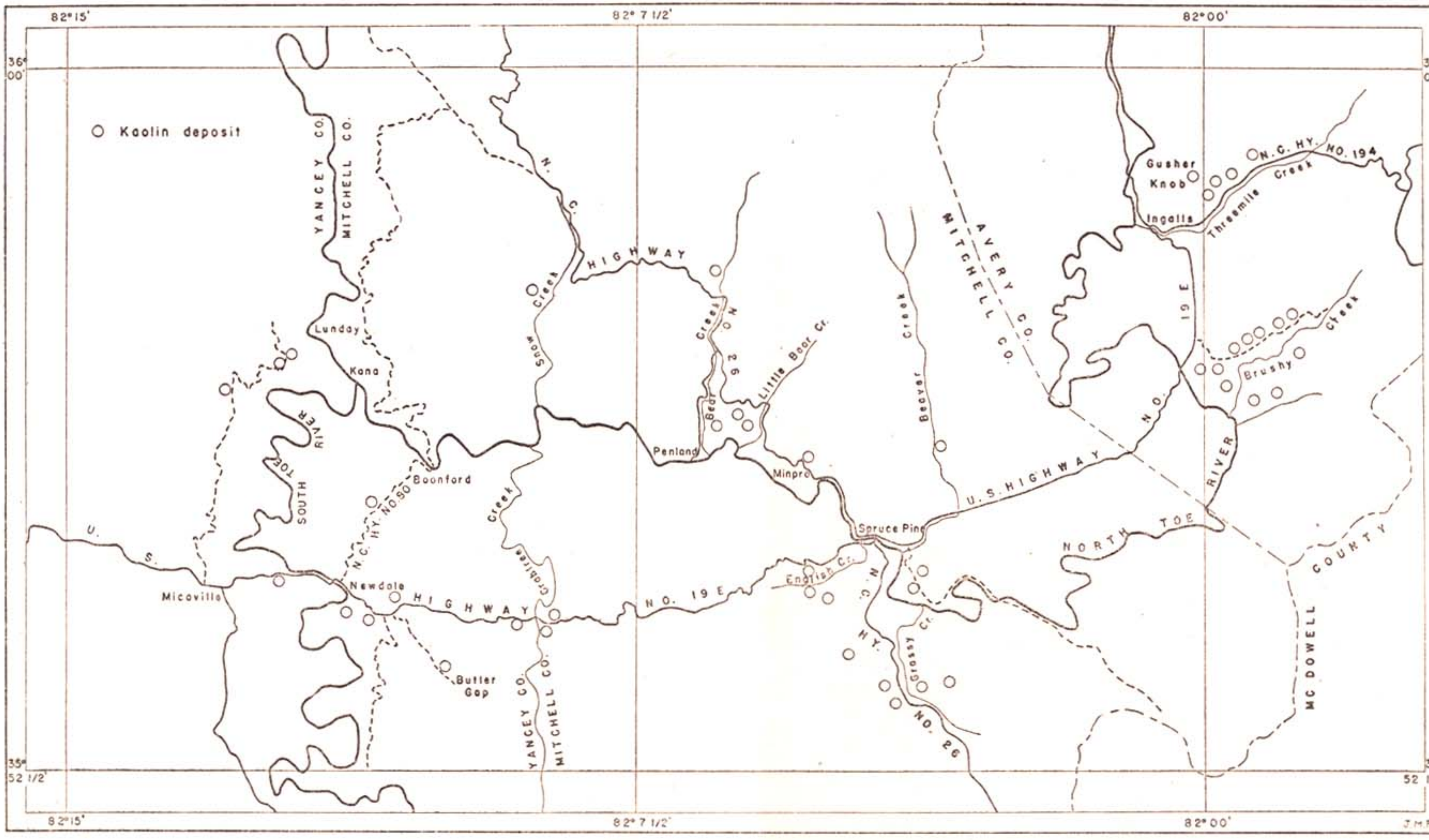
ESTIMATES OF KAOLIN RESOURCES OF SPRUCE PINE DISTRICT, NORTH CAROLINA, MADE BY C. E. HUNTER AND P. W. MATTOCKS, REGIONAL PRODUCTS RESEARCH DIVISION, COMMERCE DEPARTMENT, TENNESSEE VALLEY AUTHORITY

		Crude (short tons)	*Refined (short tons)*
AVERY COUNTY			
GUSHER KNOB			
Area	?		
Depth	?		
Deductions	?		
Yield	15%	3,304,800	567,816
BRUSHY CREEK			
Area	3,000 by 2,000 feet		
Depth	60 feet		
Deductions	10% stained		
	25% hard		
Yield	12%	10,200,000	1,224,000
MITCHELL COUNTY			
GRASSY CREEK			
Area	?		
Depth	?		
Deductions	?		
Yield	10%	4,600,000	460,000
GRAVEYARD CREEK			
Area	1,000 by 600 feet		
Depth	70 feet		
Deductions	25% (inclusions)		
	10% (hard and stained)		
Yield	10%	1,205,875	120,587
ENGLISH CREEK			
Area	?		
Depth	?		
Deductions	?		
Yield	11%	1,987,654	218,641
SPRUCE PINE			
Area	?		
Depth	?		
Deductions	?		
Yield	12%	850,616	102,074
SULLIVANS (PROBABLY SULLINS) BRANCH			
Area	?		
Depth	?		
Deductions	?		
Yield	11%	108,561	11,941

		(short tons) Crude	(short tons) Refined
LITTLE BEAR CREEK—PENLAND			
Area	2,000 by 1,000 feet		
Depth	65 feet		
Deductions	?		
Yield	11%	3,633,750	399,712
LEDGER GROUP			
Area	?		
Depth	?		
Deductions	?		
Yield	?	323,000	?
CRABTREE CREEK (EAST SIDE)			
Area	1,000 by 600 feet		
Depth	90 feet		
Deductions	20% (inclusions)		
Yield	14%	1,836,000	257,000
YANCEY COUNTY			
RICE PROPERTY AT CRABTREE CREEK			
Area	1,800 by 500 feet		
Depth	50 feet		
Deductions	⅓ (inclusions)		
Yield	9%	1,275,000	114,750
BUTLER GAP			
Area	800 by 400 feet		
Depth	60 feet		
Deductions	25%		
Yield	9%	612,000	55,080
MAYBERRY PROPERTY, ON SOUTH TOE RIVER NEAR HALL'S CHAPEL			
Area	4,000 by 300 feet		
Depth	30 feet		
Deductions	25% 10%		
Yield	7%	1,032,750	72,292
NEWDALE (NORTHEAST)			
Area	2,000 by 900 feet		
Depth	70 feet		
Deductions	25%		
Yield	12%	4,016,250	481,850
DENEEN PROPERTY, NEWDALE (SOUTH)			
Area	2,300 by 400 feet		
Depth	60 feet		
Deductions	50%		
Yield	9%	1,251,200	112,608
MICAVILLE			
Area	1,800 by 400 feet		
Depth	65 feet		
Deductions	?		
Yield	10%	248,634	24,863

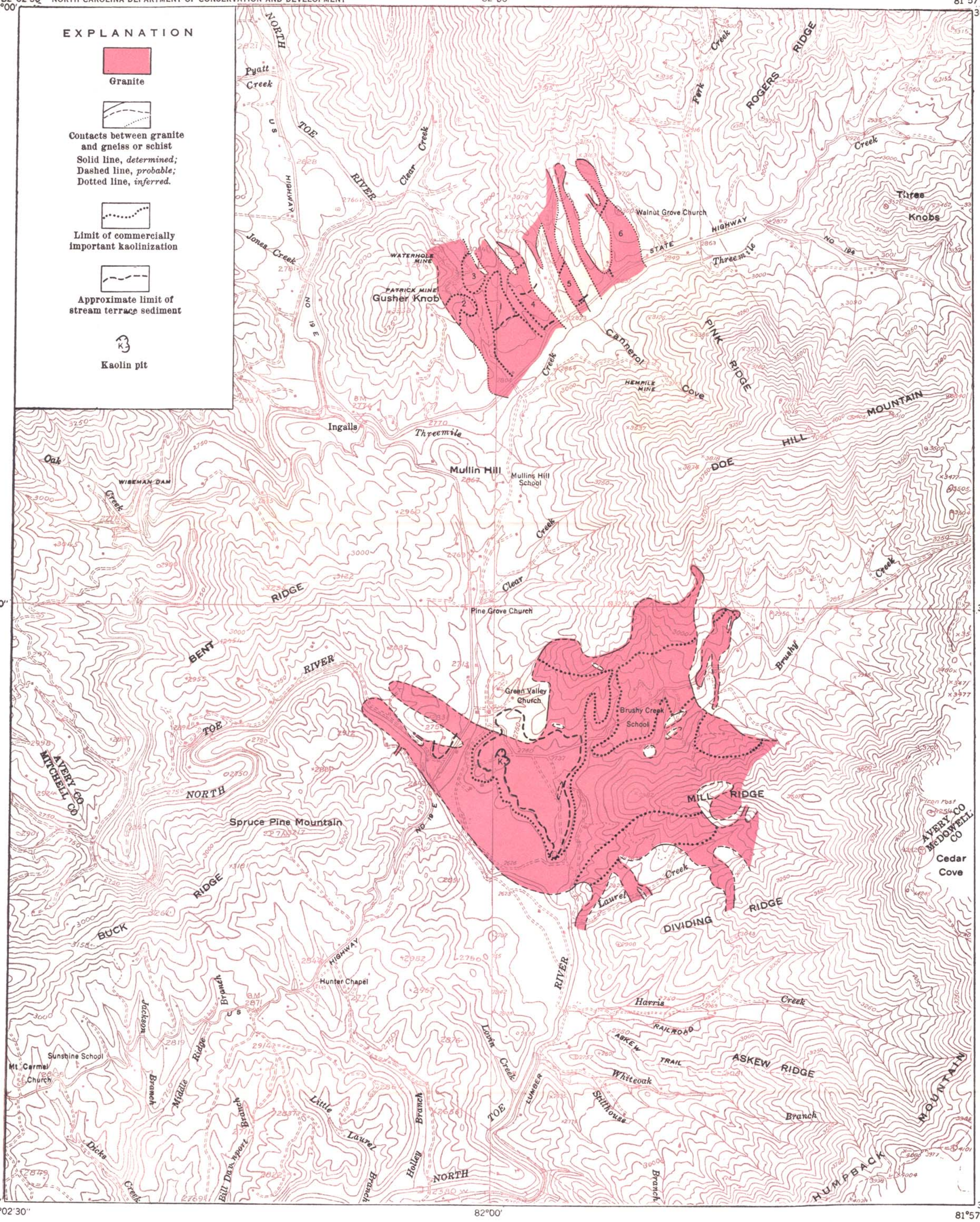
BOONFORD			
Area	?		
Depth	?		
Deductions	?		
Yield	12%	1,518,000	182,160
LUNDAY			
Area	200 by 600 feet		
Depth	60 feet		
Deductions	⅓		
Yield	10%	1,224,000	122,400
Other smaller deposits are not included in this list			
TOTALS		39,228,090	4,518,774

(All calculations used a density for the crude clay of 85 pounds per cubic foot.)



MAP OF THE SPRUCE PINE DISTRICT, NORTH CAROLINA, SHOWING LOCATIONS OF KAOLIN DEPOSITS

1 0 1 5 Miles



BASE FROM THE SPRUCE PINE AND LINVILLE FALLS NORTH CAROLINA QUADRANGLES UNITED STATES DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY

MAP OF THE GUSHER KNOB—BRUSHY CREEK DISTRICT, NORTH CAROLINA, SHOWING GRANITE BODIES AND KAOLIN DEPOSITS

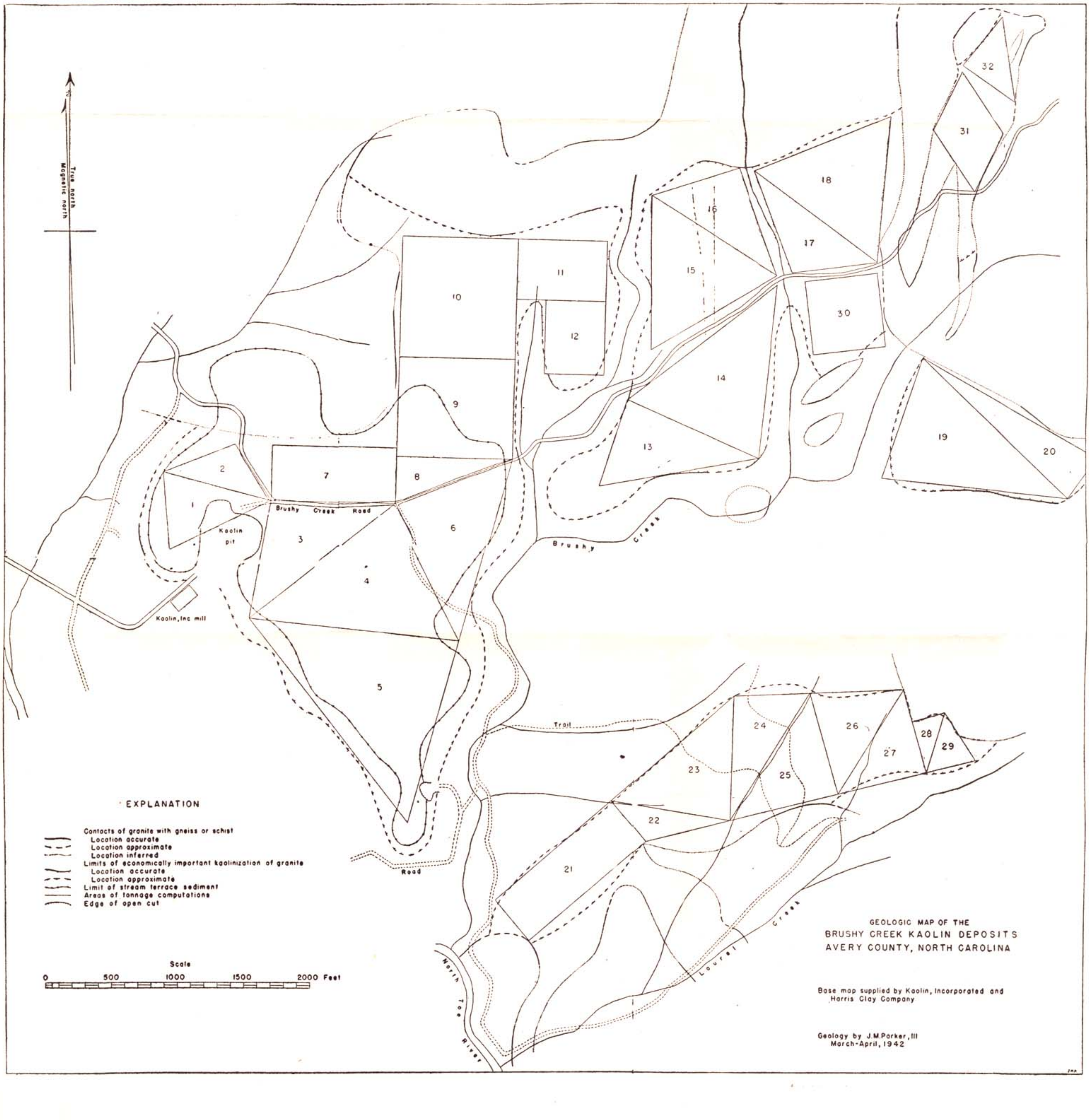
Geology by John M. Parker, III.
Surveyed in 1942

0 ½ 1 2 MILES
0 5,000 10,000 FEET

Contour interval 50 feet
Datum is mean sea level

UNITED STATES DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY
IN COOPERATION WITH
NORTH CAROLINA DEPARTMENT OF CONSERVATION AND DEVELOPMENT

STATE BULLETIN 48, PLATE 3



UNITED STATES DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY
IN COOPERATION WITH
NORTH CAROLINA DEPARTMENT OF CONSERVATION AND DEVELOPMENT

BASE FROM THE MICAVILLE AND SPRUCE PINE NORTH CAROLINA QUADRANGLES
UNITED STATES DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY

MAP OF THE SPRUCE PINE–MICAVILLE DISTRICT, NORTH CAROLINA, SHOWING GRANITE BODIES AND KAOLIN DEPOSITS

0 ½ 1 2 3 MILES
0 5,000 10,000 15,000 FEET

Contour interval 50 feet
Datum is mean sea level

Geology by John M. Parker, III.
Surveyed in 1942