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NORTH CAROLINA GEOLOGICAL AND ECONOMIC SURVEY

JOSEPH HYDE PRATT, DIRECTOR

BULLETIN No. 29

THE KAOLINS
OF NORTH CAROLINA

BY

W. S. DAYLEY, Ph.D.

PROFESSOR OF GEOLOGY, UNIVERSITY OF ILLINOIS

PREPARED IN COOPERATION WITH THE UNITED STATES
GEOLOGICAL SURVEY



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LETTER OF TRANSMITTAL

CHAPEL HILL, N. C., September 1, 1921.

*To His Excellency, CAMERON MORRISON,
Governor of North Carolina.*

SIR: There is herewith submitted for publication as Bulletin 29 of the publications of the North Carolina Geological and Economic Survey a report on THE KAOLINS OF NORTH CAROLINA, by Prof. W. S. Bayley.

When it is considered that the clay products represent nearly 50 per cent of the value of the mineral production of the State, it will be realized that any report treating the clays of the State will be of interest and value to a large percentage of the mineral producers of the State.

The work on which the present report is based was prepared in co-operation with the United States Geological Survey.

Yours respectfully,

JOSEPH HYDE PRATT,
Director.

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PREFACE

There have been two previous reports published by the Survey relating to kaolins of North Carolina; (1) Bulletin 13, on *The Clays of North Carolina*, by Prof. Heinrich Ries, which gives a short description of the kaolins*; and (2) in Economic Paper 34 on the *Mining Industry*, which gives a description of the feldspar and kaolin deposits, by Prof. A. S. Watts.† The present report has been prepared by Prof. W. S. Bayley of the University of Illinois and is intended to bring together such information as the Survey has been able to obtain relating to the kaolins of the State, including description of deposits that are being operated, and prospects, particularly those that give indication of containing commercial quantities of kaolin. The deposits have been sampled and the kaolins tested as to their ceramic value.

The field work on which the present report is based was done during the summer of 1918, covering a period of about four weeks. During this time all the productive mines in the State were visited and samples of their crude and washed products were sent to the clay-testing plant of the U. S. Bureau of Mines at Columbus, Ohio, for examination. The results of the tests are incorporated in the report. Explorations of high grade clays that had not hitherto been examined were also visited, and, in those cases in which the material looked promising, were also sampled and the samples sent to Columbus for testing. Many other prospects were likewise visited, but since they had already been tested and described by Professor Watts in his report on the *Mining and Treatment of Feldspar and Kaolin in the Southern Appalachian Region*‡ their material was not sampled for further testing. However, for the sake of completeness these prospects are again described in the following pages and the results of the tests made by Professor Watts are reprinted.

*Bull. 13, N. C. G. & E. S., 1867, pp. 55-76.

†Economic Paper 34, N. C. G. & E. S., 1914, pp. 183-286.

‡U. S. Bureau of Mines, Bull. 53, Washington, 1913.

The author wishes to acknowledge his indebtedness to the operators of the kaolin mines and the owners of the undeveloped prospects for their courtesy to him during the field season, to Professor Watts for his help during the writing of the paper, and to Mr. R. T. Stull, Director of the Experiment Station at Columbus, for the painstaking care with which he has followed up the tests and communicated their results.

Professor Watts's bulletin has been drawn on for a great deal of information, due credit for which is acknowledged in the text.

The long delay in publishing the report was due to press of work during the war and scarcity of labor for carrying out the tests after its conclusion.

JOSEPH HYDE PRATT,
Director.

THE KAOLINS OF NORTH CAROLINA

By W. S. BAYLEY, PH.D.

INTRODUCTION

The term, clay, is applied to natural deposits of earthy materials that are plastic when wet, and which, if heated to redness, or higher, become hard and rock-like.¹ Clays consist mainly of small particles of many kinds of minerals, mixed with colloidal material which may be of either organic or inorganic origin.

With reference to origin, they may be residual or transported. The former are produced by the decomposition of rocks, and the removal of the soluble products of their decomposition. The insoluble products that are left behind, if they are of the proper kinds, constitute the clay. Residual clays are in the places where they were formed. They are closely related to the rocks with which they are associated, both in composition and in shape of outcrop. They contain particles of those constituents of the parent rocks which did not suffer alteration during the clay-making process, and occupy, in general, the same shaped areas as those of the rocks on which they lie.

Transported clays are those whose components have been moved from their place of origin and deposited elsewhere, through the agency of water, ice or the air. The most common transporting agency is water in the form of streams. The clay material may be deposited along the sides or in the bottoms of creeks or rivers or it may be carried into lakes, bays or the sea and deposited on their bottoms. These are the sedimentary clays. All sedimentary clays are stratified and most of them exhibit other structural features, the characters of which depend upon the conditions under which they were deposited. Those deposited in lakes, bays and seas are in broad, thin lenses or beds, conforming in general with the slopes of the bottoms on which they were laid down. They are interstratified with layers of sand, pebbles, shell-rock and perhaps of other substances.

The clays deposited on the sides of rivers cover their flood plains or occur in terraces. Because they were deposited in flowing water the finest sediments cannot settle, except in protected spots. Conse-

¹Hess, H., *Clays, Their occurrence, properties and uses*. 2d edition, John Wiley & Sons, N. Y., p. 1, 1914.

quently most terrace clays are more or less sandy. Moreover, since the material gathered by a stream comes from various sources, many of which may not yield clay-making minerals, the sedimentary clays of this type are very varied in character, and they may possess almost any color.

The finest clay particles may be carried out to sea where they may be deposited in quiet water. If the sources of such clays furnish kaolinite unmixed with dark fibrous or flaky materials the resulting clay beds will consist of white clay of uniform character and often of great purity. Pure, white sedimentary clays are not known to occur in commercial quantities in North Carolina, though they are abundant in South Carolina. Sedimentary clays are not related to the rocks on which they lie either in composition, or in the shapes of their deposits.

Since the sedimentary clays are not discussed in this report their further characterization is not necessary.

Ries groups clays as follows:

A. Residual clays.

I. Kaolins or china clays (white-burning).

(a) Veins, derived from pegmatites.

(b) Blanket deposits, derived from igneous or metamorphic rocks occupying broad areas.

II. Red-burning residual clays.

B. Colluvial clays; deposits formed by wash from A.

C. Transported clays.

I. Deposited in water (mechanical sediments).

(a) Marine clays or shales.

1. Ball clays (white-burning).

2. Fire clays (buff-burning).

3. Impure clays.

(b) Lacustrine clays.

(c) Flood-plain clays.

(d) Estuarine clays.

II. Glacial clays.

III. Wind-formed deposits.

IV. Chemical deposits.

High-grade clays include those that are white-burning and, in addition, those plastic white clays that may be used satisfactorily in their unburned condition for certain purposes, such as the filling of paper

and cardboard. Practically all the high grade clays in North Carolina are residual, i.e., they are kaolins or china clays, in the sense in which these terms are employed by Ries. There are also a few white sedimentary clays known, but their value has not yet been determined. Only one of this class is referred to, though several others are described that may upon further study be found to belong with it.

DISTRIBUTION OF HIGH-GRADE CLAYS IN NORTH CAROLINA

The kaolins of North Carolina are limited in their occurrence to that portion of the State west of a line running along the east side of Warren County and southwest to the State line near Rockingham (see map, Pl. II). This is the "fall line." The clays east of this line are not like the kaolins nor can they be used for the same purposes as these. They are all transported, and except in one known instance are of low grade. They are not discussed in this report. That portion of the State west of the "fall line" is separable mainly into two physiographic divisions—the Piedmont Plateau to the east and the Appalachian Mountain area to the west. The line dividing these is at the base of the Blue Ridge, passing diagonally through the State from the west side of Surry County southwest to the center of Polk County. A small area of the Coastal Plain, which lies east of the "fall line," covers parts of Richmond, Anson and Montgomery counties, but this is somewhat broken by outliers of the Piedmont Plateau.

The mountain area is characterized by strong relief, due mainly to the differences in rate of weathering of the rocks exposed to the action of the atmosphere. Its topography consists of mountain chains and broad plateaus and deep, narrow intervening valleys.

Between the mountains are the plateaus to which the surface has been reduced by long weathering and denudation, and it is on the slopes just above these surfaces where the weathering has been deepest, that the best deposits of kaolin occur. The areas immediately bordering the main streams have been reduced to nearly level plains. These plains have been cut into by the rivers and now stand from 100 to 300 feet above the present streams. On their surfaces the rocks are deeply decomposed and where they contained feldspathic rocks these are deeply changed to kaolin. Unfortunately, however, most of these deposits have been buried under debris of many kinds and are now beyond the reach of observation.

On the Piedmont Plateau the topography is less emphatic than that in the mountain division. The country is rolling, with low, rounded hills separated by broad, shallow valleys. All the rocks are deeply decayed, but the slopes are so low that much of the product of decay has been left upon them. Materials from different sources have intermingled, and the entire surface is covered with a deep mantle of mixed detritus that obscures the narrow belts of kaolin that result from the decomposition of pegmatite dikes. Where feldspathic granites or other feldspathic rocks occur over large areas these may give rise to deposits of kaolin (the "blanket deposits" of Ries) that are so large, that by their very massiveness they may reveal themselves on the surface. Because of its striking appearance, the kaolin, even when much mixed with other materials, may be recognized, and, because it may migrate down slopes, in many cases it may appear to cover a very much larger area than the deposit beneath. The deposits of this type are usually not as good as those made from pegmatites because the rocks from which they originated usually contained a good deal of material that did not become kaolinized, and, consequently, the resulting decomposed product is not as pure a kaolin as that produced from the more purely feldspathic pegmatites. There are a few kaolin deposits known to exist on the plateau areas in North Carolina but the most promising ones are in the mountain area.

No reference has been made to the possibility of the occurrence of clays along the river courses. In North Carolina as in all other regions the rivers have brought down much of the decayed products of the rocks in their upper courses and have spread them along their banks. Since many of the rivers in this State flow through districts in which there is much kaolin they have brought down large quantities of this substance and have deposited it mingled with other substances on their flood plains. Much of this deposit is clay, but since it contains many ingredients besides kaolinite, it is an impure clay which is not available for the purposes for which the purer kaolin is employed, and consequently it is referred to only incidentally in these pages. Much of it may be employed in the manufacture of stoneware but most of it is too impure even for this purpose.

High-grade clays of North Carolina may for convenience be separated into (1) those occurring in the mountain district, (2) those occurring in the Piedmont Plateau. Only those in the mountain district have been developed in a commercial way.

KAOLINS IN THE MOUNTAIN DISTRICT

The kaolins of the mountain districts are all, so far as known, residual products resulting from the decay of pegmatites that are so abundant as dikes cutting the schistose rocks and granites which constitute the surface rocks of these districts. The dikes are of different widths and lengths. They are not continuous for long distances and consequently have the character of very narrow lenses. They often lie with their long directions parallel to the schistosity of the rocks with which they are associated, and which in turn is parallel to the trend of the mountain ridges in their vicinity. Since most of the ridges run in a general northeast direction, most of the dikes also trend in this direction. In a few cases the dikes cut across the structure of the schists; but in these cases the cross-cutting dikes are usually offshoots of main dikes that follow the schistosity. The largest deposits of kaolin are as a rule the results of the decomposition of the larger dikes, and therefore have a northeast trend. The cross-cutting dikes are smaller than those running parallel to the structure of the schists and have given rise to smaller deposits of kaolin.

Pegmatite

The relations of the pegmatites to the neighboring rocks are so well described by Sterrett¹ that we may quote his description almost without modification. After stating that the pegmatites of North Carolina occur mainly in the Roan gneiss, which is a series of hornblendic gneisses and schists, and in the Carolina gneiss which is nonhornblendic, he says:

Pegmatites occur in irregular masses, streaks, lenses, augen, or balls, some of them having no visible connection with other pegmatite bodies. They range from a fraction of an inch up to many yards in thickness. . . . Horses, or inclusions of wall rock, are common in pegmatite. Some of them are in the form of bands or sheets parallel to the walls, and the schistosity of these bands is also parallel to the walls. They range from an inch or two up to several feet in thickness, and their length may be many times their width. Elsewhere they occur as irregularly shaped masses, from a few inches up to several feet thick. . . . In some places the horses are partly pegmatized by streaks of pegmatite ramifying through them and by the development of considerable feldspar and quartz through their mass. In such places no sharp line can be drawn between the pegmatite and the original horse.

¹Sterrett, Douglas B., Mica deposits of North Carolina. N. C. Geol. & Econ. Survey Economic Paper No. 23, p. 37, 1911, and U. S. Geol. Survey Bull. 430, p. 601, 1910.

Pegmatite is closely allied to granite in composition. As in granite, the essential constituents are feldspar and quartz, with more or less mica and other accessory minerals. Though hornblende is rather a common mineral in granite, it is less so in pegmatite. Orthoclase and microcline are the most common varieties of feldspar found in pegmatite. In many places, however, a variety of plagioclase, either albite or oligoclase, makes up part or all of the feldspar component. The feldspar occurs in masses and rough crystals, some of them with a diameter of several feet.

Quartz assumes various forms and positions in the pegmatite. In many places it bears much the same relation to the feldspar and mica as in granite, the three minerals being thoroughly mixed with one another; but the individual grains are many times larger than in ordinary granite. Not uncommonly the quartz and feldspar assume a graphic granite texture in a portion of the pegmatite. Another common feature is the occurrence of large separate masses of quartz occupying various positions in the pegmatite. Such quartz masses may be irregular in form and but little influenced by the shape of the pegmatite or inclosing wall. Many of them, however, lie in bands or sheets parallel to the walls. There may be one or more of these quartz bands constituting varying proportions of the pegmatite. Their thickness ranges from a fraction of an inch up to six or more feet. Many of them are lenticular in shape, the length varying from four or five to twenty or more times the thickness. In numerous places these quartz streaks or veins are persistent through the whole length of the pegmatite exposed. Some inclose feldspar or mica bodies; others do not. The quartz of these segregations is massive and generally granular, though locally crystallized. If crystallized, it may be translucent or clear and of a dark, smoky or light color. It is generally rather pure and does not contain feldspar or mica in appreciable quantity.

Muscovite is the common mica of pegmatite. Biotite occurs in moderate quantity in a few deposits, and in smaller amounts in many others.

The mica occupies various positions in the pegmatite. Where the rock has a typical granitic texture the mica may be found evenly distributed through it. More commonly the larger crystals will be found either in clusters at intervals through the "vein" in places connected by streaks of small crystals, or collected along one or both walls of the pegmatite, with some of the crystals partly embedded in the wall rock. Where there is a quartz streak within the pegmatite, the mica occurs on either or both sides of it. The mica may be partly embedded in the quartz or be scattered through the remaining portion of the pegmatite, which generally is composed largely of feldspar. . . .

The quartz may occur as equidimensional grains uniformly distributed through the dike or it may be intergrown with the feldspar forming a "graphic granite." Further, it may be found as large, separate, irregular masses free from mica and feldspar, occupying almost any position in the dike. In the kaolin mines these constitute the greater part of the "rock" or "horses" so frequently encountered in mining. Finally, the quartz may lie in bands or sheets parallel to the dike

walls. These may be extremely thin or they may be six feet or more in width. They may be long lenses or they may be persistent throughout the entire portion of the dike exposed. They sometimes enclose a little feldspar or mica, but usually do not do so. Watts¹ declares that some of the dikes may represent a series of intrusions and publishes a diagrammatic sketch of one which he calls typical, that shows bands of quartz near the two walls, and within these bands of mineral-bearing pegmatite, bands of richly feldspathic pegmatites and a center of massive feldspar, with lenses of quartz along its sides. The writer has had no opportunity of seeing any of these. The dikes he has seen are nearly uniform in structure throughout.

The other minerals frequently accompanying the dikes are garnet, beryl, tourmaline and other rarer compounds.

Origin of Kaolin

The kaolin, which so frequently grades into partly decomposed, but easily recognizable, pegmatite as to leave no doubt that the two are parts of the same geological mass, presents in the field the same textures as the pegmatites from which it was derived. In some places the crude clay consists of a structureless mass of kaolinite surrounding irregularly round quartz grains of the same shapes as those in the granular pegmatites. In other places the quartzes are sharp-edged and wedge-shaped, like the particles of this mineral in graphic granite and the structure of the mass is exactly like that of undecomposed coarse graphic granite. Lenses of mica and micaceous decomposition products occupy the same relations to the kaolin and quartz as do muscovite and biotite in ordinary pegmatites. These relations indicate clearly that the kaolin occupies the place of the feldspar in the pegmatite—a conclusion that is established as correct by the fact that much of the feldspar in many dikes, especially at moderate depths, is white and opaque and very unlike pink or yellowish translucent variety in fresh dikes. The opacity and whiteness is due to the presence of a small quantity of kaolin in the otherwise unaltered feldspar. As the quantity of kaolin increases, the characters of feldspar disappear and a uniform mass of kaolin results. Often this retains the cleavage of the feldspar from which it was derived, but otherwise its character is entirely different.

Analyses of fresh and altered feldspars show clearly the nature of the change.

¹Watts, A. S., Bur. of Mines Bull, 53. p. 14, 1913.

ANALYSES OF FELDSPARS FROM NORTH CAROLINA

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	BaO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
1. Fresh microcline.....	65.37	17.92	.02	.17	tr	-----	2.10	13.05	tr	.17	98.80
2. Fresh orthoclase.....	64.30	19.64	.06	tr	tr	17	1.32	14.00	tr	.50	100.01
3. Semi-kaolinized orthoclase.....	62.47	21.00	.05	tr	tr	30	.60	13.62	tr	1.40	99.44
4. Semi-kaolinized orthoclase.....	60.47	23.45	.10	tr	tr	-----	.65	12.10	tr	3.60	100.37

1. Plumtree Mica Mine, Plumtree, N. C. Watts, A. S., Bureau of Mines Bulletin, 53, p. 103, 1913.
2. Southern Clay Co. Mine, Franklin, N. C. Idem., p. 68.
3. Southern Clay Co. Mine, Franklin, N. C. Idem., p. 112.
4. Isinglass Hill Mica Mine, Rutherfordton, N. C. Idem., p. 114.

ANALYSES OF NORTH CAROLINA CRUDE KAOLINS

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	H ₂ O	Total
A. Springer Pit, Webster.....	62.40	26.51	1.14	.57	.01	.98	-----	8.80	100.66
B. Brindle Prospect, West's Mill.....	53.10	33.06	1.18	.38	.08	.83	-----	11.32	99.95
C. Steele Prospect, Bostic's Mills.....	68.15	19.99	1.86	.13	.16	2.85	-----	4.70	98.01
D. Steele Prospect, Bostic's Mills.....	70.63	21.81	1.46	.20	.29	1.45	-----	4.04	99.99
E. Steele Prospect, Bostic's Mills.....	73.70	16.03	1.57	.38	.47	1.90	-----	4.33	98.38

- A. Contains also .25 moisture. Ries, H., N. C. Geol. Survey Bull. No. 13, p. 82, 1897.
- B. Idem., p. 63.
- C. Contains also .17 moisture. No. 21 of Ries. Idem., p. 67.
- D. Contains also .08 moisture. No. 20 of Ries. Idem., p. 67.
- E. Whiter than D. No. 22 of Ries. Idem., p. 67.

No. 1 was a sample of fresh microcline. No. 2 was a milk-white orthoclase taken from beneath a kaolin deposit. It contained about 3 per cent kaolinite. No. 3 was taken from nearer the surface than No. 2. It contained 8 per cent kaolinite. No. 4 was taken from the east side of a dike where the material was partially protected by a layer of quartz. It contained 23 per cent kaolinite.

Analyses of the crude kaolins differ from those of the semi-kaolinized feldspars mainly in the relative proportions of their constituents. There is often more SiO_2 shown in the analyses of the kaolins, but this is easily accounted for by the presence of quartz in the pegmatite. With the loss of K_2O and Na_2O there is a gain of Al_2O_3 and H_2O , and the change is progressive. The final stage in the process is shown in the analyses of the refined kaolins. Nearly all the quartz has been washed out, and what is left is mainly the result of the alteration of feldspar—a mixture of substances that approaches in composition that of the mineral kaolinite, which is unquestionably the largest component of the mixture.

ANALYSES OF NORTH CAROLINA REFINED KAOLINS

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
Theoretical for Kaolinite	46.3	39.8							13.9	100.00
1. Kaolinite crystals from Belle Mine, Ouray Co., Colo.	46.35	39.59	.11		.15				13.93	100.13
2. English China Clay M. B. XXX	46.60	39.60	.10				.21		13.03	99.54
3. English China Clay M. B. XXX	48.10	41.00	.10	tr	tr		.21		10.13	99.56
4. Porcelain Clay from Sennewitz, Germany	64.87	23.83	.83	.50			1.39		8.36	99.78
5. Hog Rock Mine, Webster	46.95	37.73	.15	tr	tr	.18	.60	.05	13.99	99.65
6. Hog Rock Mine, Webster	45.70	40.61	1.39	.45	.09		2.82		8.98	100.39
7. Hog Rock Mine, Webster	46.47	38.82	.89	.25	.28		.75		13.34	100.80
8. Springer Pit, Webster	45.78	36.46	.28	.04	.50		.25		13.40	99.84
9. Roda Mine, Syla	46.41	38.46	.07	.07	.00	.17	.42		14.40	100.00
10. Buchanan Prospect, Syla	46.30	39.06	.20	tr	tr	.11	.60	.04	13.77	100.06
11. Forest Hill Mine, Syla	49.20	37.58	.17	tr	tr	.13	.47	tr	12.53	100.08
12. Old Sprucepine Mine, Sprucepine	45.56	38.65	.41	.08	.05	.55	.80	.10	13.90	100.10
13. Old Sprucepine Mine, Sprucepine	45.20	38.45	.45	tr	tr	.00	.65	tr	14.80	99.55
14. Tolley Mica Mine, Sprucepine	46.35	38.30	.25	tr	tr	.00	.41	tr	14.00	99.84
15. Harris Mine, Penland	45.61	38.63	.46	.08	.08	.66	.90	tr	13.57	99.99
16. Wilson Mine, Micaville	46.51	39.91	.11	.00	.00	.10	tr		12.28	100.01
17. Hand Mine, Woodrow	46.41	37.76	.70	.09	.00	.17	.55		13.46	
18. Piedmont Tin Min. Co., Lincolnton	48.50	37.35	.85	tr	tr	.32	1.02	tr	12.00	100.04
19. Southern Clay Co., Franklin	46.67	39.07	.11	tr	tr	.11	.25	.02	13.22	99.45
20. Harris Clay Co., Bryson	46.95	37.24	.40	tr	tr	.24	.49	.05	14.10	99.47
21. Kinsland Mine, Waynesville	50.64	35.57	.25	tr	tr	.08	1.70	.03	11.90	100.34
22. Gurney Clay Co., Franklin	44.00	40.79	.11	tr	tr	.07	.55	tr	14.72	100.34
23. McGuire Prospect, Franklin	46.35	39.00	.30	tr	tr	.00	.50	tr	14.00	100.15
24. Raby Mica Mine, Franklin	46.90	38.60	.25	tr	tr	.26	.39	tr	13.80	100.30
25. J. J. Smith Prospect, Franklin	48.05	37.69	.31	tr	tr	.02	.91	tr	12.55	99.53
26. West Prospect, West Mills	48.92	36.37	.37	tr	tr	.11	.29	.02	12.70	98.78
27. Brindle Pit, West Mills	45.41	39.56	.86		.45	.09	.03		13.58	100.00
28. Elisabeth Smith Prospect, Burnsville	45.95	39.20	.05	tr	tr	tr	.50	tr	13.10	98.53
29. North Carolina Mining and Mfg. Co., Syla	44.08	36.26	1.86	.20	.43		.50		13.56	99.96
30. Steele Prospect, Bostic's Mills	71.12	19.61	2.18		.17	.08	2.48		4.33	99.97
31. Steele Prospect, Bostic's Mills	49.33	35.90	3.15		.31	.14	3.15		8.00	99.98

1. Contains also .15 F. Hillebrand, W. F., U. S. Geol. Survey Bull. 419, p. 296, 1910.
2. Commercially dried. Collins, J. H., Min. Mag., vol. 7, p. 208, 1887.
3. Dried over sulphuric acid. Contains also .02 organic matter. Idem., p. 209.
4. Quoted from Ries, N. C. Geol. Survey Bull. 13, p. 69, 1897.
5. Washed in laboratory. Watts, A. S., Bur. Mines Bull. 53, p. 131, 1913.
6. Commercially washed. Contains also .35 moisture. Ries, H., N. C. Geol. Survey Bull. 13, p. 61, 1897.
7. Commercially washed. Dried at 212° F. Analyzed by N. P. Pratt in 1917. Furnished by Harris Kaolin Co.
8. Commercially washed. Contains also 1.08 FeO and 2.05 moisture. Ries, H., Economic Geology. 4th edition, N. Y., John Wiley & Sons, 1916, p. 178.
9. Commercially washed. Dried at 212° F. Analyzed by N. P. Pratt in 1917. Furnished by Harris Kaolin Co.
10. Washed in laboratory. Watts, A. S., Bur. Mines Bull. 53, p. 154, 1913.
11. Washed in laboratory. Idem., p. 155.
12. Commercially washed. Dried at 212° F. Analyzed by N. P. Pratt in 1911. Furnished by Harris Kaolin Co.
13. Washed in laboratory. Watts, A. S., Bur. Mines Bull. 53, p. 151, 1913.
14. Washed in laboratory. Contains also .03 BaO. Idem., p. 152.
15. Commercially washed. Dried at 212° F. Analyzed by N. P. Pratt in 1911. Furnished by Harris Kaolin Co.
16. Commercially washed. Calculated to 100% of dry material. Analyzed by N. P. Pratt in 1914. Analysis furnished by Harris Kaolin Co.
17. Commercially washed. Calculated to 100% of dry material. Analyzed by Geo. Steiger. Contains also .04 P₂O₅ and 1.10 moisture. The Fe₂O₃ includes also FeO.
18. Washed in laboratory. Watts, A. S., Bur. Mines Bull. 53, p. 146, 1913.
19. Washed in laboratory. Idem., p. 89.
20. Washed in laboratory. Idem., p. 126.
21. Washed in laboratory. Contains also .07 BaO. Idem., p. 158.
22. Washed in laboratory. Idem., p. 135.
23. Washed in laboratory. Idem., p. 137.
24. Washed in laboratory. Idem., p. 139.
25. Washed in laboratory. Idem., p. 142.
26. Washed in laboratory. Idem., p. 145.
27. Calculated from analysis of crude clay. Ries, H., N. C. Geol. Survey Bull. 13, p. 63, 1897.
28. Washed in laboratory. Watts, A. S., L. c. p. 127.
29. Washed in laboratory. Ries, H., N. C. Geol. Survey Bull. 13, p. 59, 1897.
30. Washed in laboratory from crude clay, No. D. Idem., p. 68.
31. Clay material in No. 30. Calculated from analysis by subtracting insoluble component and recalculating to 100%. Idem., p. 68.

Kaolinization Processes

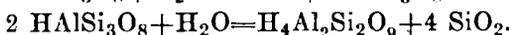
Alteration of feldspars. Kaolin produced from feldspar is formed in three ways¹; (1) by the action upon it of hot ascending gas and solutions containing fluorine, born and perhaps other active reagents; (2) by the action of water upon feldspathic rocks underlying swamps or moors, where the rocks are subjected to the action of the substances dissolved in the swamp water, especially CO₂ and organic acids; (3) by the action of percolating ground water traveling downward from the surface and carrying with it dissolved CO₂ and organic matter. The kaolins of the mountain districts of North Carolina are believed² to have originated as the result of the third process, i.e., they were produced by the weathering of feldspathic dikes. Deposits of the first type are not known within the State. Those of the second type may be represented by the occurrences at Bessemer City (p. 115), Bostic's Mills (p. 121) and Statesville (p. 119) where the crude clay covers wide areas rather than long, narrow areas as in the mountain districts.

Orthoclase when it changes to kaolin loses SiO₂ and K₂O and adds H₂O in the following amounts:

	SiO ₂	Al ₂ O ₃	K ₂ O	H ₂ O	Total
Orthoclase.....	64.86	18.29	16.85	.....	100
Losses.....	43.24	.....	16.85	.....	60.09
Adds.....	.....	.....	.....	6.36	6.45
Kaolin.....	21.62	18.29	.....	6.36	46.27

or in chemical symbols: $2\text{KAlSi}_3\text{O}_8 - 4\text{SiO}_2 - \text{K}_2\text{O} + 2\text{H}_2\text{O} = \text{H}_4\text{Al}_2\text{Si}_2\text{O}_9$.

The alteration of orthoclase may be effected by pure water, with the production of potash, colloidal aluminous silicates, colloidal silica and kaolinite.³ Upon hydrolysis by water the feldspar yields KOH and an unstable silicate which easily parts with some of its silica and is converted into kaolinite, thus:



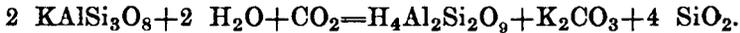
The process is hastened by the addition of H₂SO₄ or CO₂. When CO₂ is present, as it always is in freshly fallen rain, and in water that

¹Stremme, H., *Handbuch der Mineralchemie*. Theodor Steinkopff, Dresden und Leipzig, Bd. II. pp. 130-134, 1914.

²W. S. Bayley, *Kaolin in North Carolina, with a brief note on hydromica*, *Econ. Geol.* Vol. XV, p. 230, 1920.

³Cameron, F. K., and Bell, J. M., *Bur. Soils, U. S. Dept. Agri. Bull.* 30, 1905.

has passed through decomposing organic matter, the process may be indicated by the equation:



The colloids exist as gels in the mixture of kaolinite, quartz, feldspar and other undecomposed remnants of the original rocks that constitute the crude clay.

Ashley¹ has shown that the plasticity of clay depends upon the presence of colloids. Variations in the plasticity of clays that look alike are due in large measure to the proportions of their components that are in colloidal form. Consequently the ordinary chemical analysis of a clay is of very little value as indicating the quality of its plasticity.

A high percentage of Al_2O_3 may be suggestive of high plasticity since it may indicate the presence of colloidal aluminous silicates, but if other colloids than this are present the content of Al_2O_3 is not particularly significant. Even a comparatively low aluminous clay may be markedly plastic if colloidal silica or organic colloids are present in large quantity.

Since orthoclase or microcline treated with a solution of CO_2 is slowly decomposed and K_2O is dissolved from it in excess of its proportion in the undecomposed mineral, it is clear that by long continued action of carbonic acid all the K_2O may be extracted, since the potassium may combine with the free acid, forming K_2CO_3 which is drained off. The SiO_2 formed during weathering separates partly, at least, as a colloid which is soluble in the alkaline solution of K_2CO_3 , and thus may be drawn off from the mass of decomposition products leaving the insoluble kaolinite and remnants of the unaltered minerals behind. Thus the kaolin is proportionately enriched, by the filling with kaolinite of the spaces left by the removal of the silica and the mass loses its porosity and becomes compact. Even though some of the K_2O may combine with some of the silica to form a soluble potassium silicate, or a colloidal potassium silicate compound, the same enriching process will take place, since the soluble silicate will drain off and the colloid will either be decomposed by the excess of CO_2 or, if undecomposed, will deposit in the pores between the kaolin flakes and will thus tend to compact the kaolin and render it more plastic.

In many veins there are places where the kaolin appears as a uniformly compact mass almost entirely free from quartz or undecomposed feldspar. It may be that these represent places where the pegmatite was composed entirely of feldspar or where the quartz was so fine grained that it is not noticeable in the residual mass. However, since

¹Ashley, H. E., U. S. Geol. Survey Bull. 388, pp. 9-11, 59, 1909.

a mass of orthoclase produces only 52 per cent of its weight or 61 per cent of its volume of kaolinite, while a given mass of the compact clay often contains 90 per cent of kaolinite, it is plain that the silica which always accompanies the production of kaolinite from feldspar must have been removed in solution and the remaining kaolin compacted or there must have been an enrichment of the kaolin mass by the migration into it of kaolin material from other portions of the vein.

Few deposits contain on the average more than 40 per cent of kaolin, even where all the feldspar has been decomposed. In most cases the feldspars in pegmatites are associated with quartz, mica, hornblende and to a less extent with beryl, garnet, tourmaline and other still rarer minerals. All of these with the exception of quartz decay with greater or less rapidity and some of them, as, for instance hornblende, may yield a hydrous aluminous silicate and colloidal silica. Thus the constituents of the original pegmatite may contribute to the kaolin decomposition products that may affect it in a favorable or an unfavorable way depending upon the nature of the substances and the conditions under which they were decomposed.

Under the conditions favorable to the production of kaolinite from orthoclase, albite, if present, forms compounds analogous to those produced from orthoclase. Where the process has continued to completion the result is the same as in the case of orthoclase and microcline and the albite has no deleterious effect upon the product. Where the process is less complete grains of albite may remain undecomposed, with the result that the kaolin may contain notable quantities of feldspathic sand.

Alteration of minerals other than feldspar. The quartz of the original pegmatite suffers little change in the weathering process. In many cases it remains in the kaolin as distinct grains of the same shapes and sizes as those in the pegmatite. In other cases, however, the residual grains are more or less rounded. Their sharp edges are smoothed off and their surfaces may have become pitted as though they had suffered some solution. Indeed, it is probable that they have in all cases undergone solution to some extent, though perhaps only in exceptional cases is the solution marked. In the latter cases the quartz has a pebbly appearance and the crude kaolin may look very much like a conglomerate composed of water-worn pebbles in a fine-grained sediment. The solution may be due to the action of the alkaline carbonates produced during the weathering of the feldspar, since it is a well-known fact, that quartz is appreciably dissolved by alkalies. If the quartz in the original rock was in fine grains some of it may be completely dissolved but much of it may, nevertheless, remain as grit or sand in the kaolin.

Beryl changes to mica and to kaolin. If it changes to mica it is apt to form fine scales which are difficult to separate from the scaly kaolinite flakes and thus may injure the refined product.

Biotite, hornblende, tourmaline and any other ferriferous minerals that may be present may be altered to a number of compounds among which may be chlorite or other hydrated micaceous minerals, limonite or other ferruginous hydroxides, or to a ferruginous carbonate. In the presence of abundant oxygen the hydroxides are apt to form; and these stain the kaolin with a brown or yellow color. In the absence of much oxygen ferrous carbonates are produced. As these are soluble in carbonated water they may be drained from the deposit and carried off. Thus, near the surface where the percolating water was furnished with abundant oxygen, staining by iron salts is rather common, whereas with depth the stains decrease, except where crevices furnish canals along which the water may flow readily, and at groundwater level the kaolin is practically free from stains. The chlorite and other micaceous decomposition products may form dark nests in the midst of the clay. They are objectionable because of the difficulty of separating them in the refining process. Their fine scales are apt to float off and be carried into the settling vats where the kaolin is collected. The most objectionable components of the kaolin are the decomposition products of the garnets. When these are decomposed they give rise to chlorite and other micaceous products that are often colored reddish brown by iron hydroxides or other iron compounds. The heaviest particles may be separated from the kaolin in the washing process, but some of the lightest material floats over with the slip and is distributed through the refined kaolin, often impairing its value to a serious degree. In the clay-bank the presence of the decomposed garnets is revealed by the presence of little circular brown spots. Where the spots are few the clay containing them may be removed by hand-sorting before the crude material is sent to the washer. Where abundant there is no recourse for the miner but the abandonment of that part of the mine in which they occur.

The muscovite changes so slowly that it may be picked by hand from the kaolin, and much of it is so slightly altered that it may be placed on the market as sheet, punch or ground mica, depending upon the dimensions of the plates.

Near the surface, however, in many places the mica is more or less altered and at some localities it has lost its characteristic features. It has become opaque and brittle and has assumed the color and luster of beaten tin and is often stained red by iron hydroxides. Even when

bleached by hydrochloric acid it remains opaque except on thin edges where it is translucent. Under the microscope, between crossed nicols, the altered mica is discovered to be much less strongly doubly refracting than fresh muscovite. Plates thin enough to be transparent have no effect on the sensitive tint, and give no axial figure. Thicker ones, that are yellow and translucent, produce a slight modification of the sensitive tint and give a faint uniaxial optical figure that is negative. Fairly thick plates are dark reddish yellow and nearly opaque. These exhibit colors between crossed nicols and give fairly distinct axial figures. Flakes viewed at right angles to the cleavage, extinguish parallel to their cleavage and show bright colors between crossed nicols.

Under high magnification the very thin plates show no distinctive features. They are very light yellow and apparently homogeneous except for the presence of a few tiny transparent or translucent particles. The plates that are thick enough to be nearly opaque are dark reddish yellow and appear to contain numerous small flakes and particles of various kinds, but it is probable that these are deposits in the cleavages of the mica rather than within the mica itself.

It is impossible to decide whether the altered mass is a definite mineral or not, but it appears more probable to the writer that it is an aggregate of tiny decomposition products embedded in a matrix containing a residual of muscovite. It appears to be one of the "hydromicas" that are so frequently described as occurring in clays.

An analysis of a particularly good specimen from the Herren property at Waynesville, yielded Mr. George Steiger of the U. S. Geological Survey, the following result:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O	TiO ₂	Moist	
40.79	29.98	8.07	2.48	2.71	.45	.38	3.47	9.34	1.28	1.20	100.15

Attempts to indicate this by a chemical formula are unsatisfactory, as the result is so complex that it is difficult to consider it as representing any single mineral. If the material is regarded as a mixture, its mineral composition, calculated from the analysis on the assumption that the Fe₂O₃ is in limonite, the TiO₂ in rutile and FeO in a ferruginous serpentine, may be:

Kaolinite	43.34
Muscovite	34.04
Serpentine	11.41

Quartz, or some other form of SiO_2	1.08
Limonite	8.90
Rutile	1.28
	100.05

It is certain that the source of the limonite is outside the original mica, and it is probable that some of the kaolinite has also originated elsewhere and has migrated into the cleavage cracks in the altered mineral. Consequently, the figures given do not represent the composition of a "hydromica" that has resulted solely from the alteration of muscovite. They, however, indicate the probable composition of most of the hydromica occurring in kaolin and show that this substance differs from muscovite in the presence of much less K_2O , and possibly Al_2O_3 , and of much more H_2O . Most of the original muscovite has broken down into kaolinite and minerals closely related to serpentine, and most of its K_2O has been carried off in solution.

Distribution of kaolin in the veins. As kaolinization progresses downward from the exposed surface the completeness of the process becomes less and less as depth from the surface increases until the proportion of undecomposed material becomes so great that deeper mining is impracticable. Although at this depth the feldspar is partly kaolinized, the quantity of undecomposed feldspar in the mass is so great that a crowbar cannot be forced into it without the aid of hammer blows. The quantity of kaolin in the mass is there so small that it will not carry the increased cost of preparing it for market.

The depth at which this occurs varies in different dikes but in those well up on slopes the depth at which profitable mining is no longer possible is at about 95 feet from the exposed surface. The purer kaolin is at about water level and above this kaolinization is practically complete. When the water level is reached in mining the kaolin becomes so plastic that it is difficult to maintain the shafts, and for this and other reasons the mining operations become so expensive that the shaft has to be abandoned unless some method of drainage can be perfected. In consequence of this fact deposits high up on slopes are apt to be minable to greater depths than those at their bases or on plains, since in these latter situations the water level is nearer the surface. Usually the best kaolin in any deposit is found at about the level of the ground water. Below this level the completeness of the kaolinization rapidly diminishes with depth and in many cases a few feet below the water level the dike material has been protected from alteration to such an

extent that the dike might be used as a source of feldspar. Possibly another illustration of protection is the fact that in general a dike is richer in kaolin near its foot wall than near its hanging. This suggests alteration by downward percolating water. The hanging wall, especially if composed of schists, protects to some extent against the downward flowing water, whereas at the foot wall the water flow is more abundant.

While it is true that the completeness of kaolinization of the feldspar in the different parts of any given dike are as stated, nevertheless it is also true that other conditions affect the thoroughness of its alteration. Fresh feldspar and completely kaolinized feldspar occur at the same elevation and near each other in neighboring dikes. Watts¹ calls attention to the fact that at Penland, a dike in an advanced stage of kaolinization was being worked for kaolin a few years ago and 50 yards distant another containing fresh feldspar was being worked for this mineral. In this case, however, he states "the kaolin deposit is not well defined and appears to have been disturbed by a slide, whereas the fresh feldspar is in a well defined dike." It is not apparent why the kaolin at Penland is regarded as a slide. A sketch map of the occurrence is given in Fig. 11 on page 101. However, in one of the shafts from which kaolin was taken a distinct dike of pegmatite about two feet wide may be seen cutting diagonally through the kaolin and the material of this dike is practically unchanged. In this case the feldspar of the small dike is microcline and not orthoclase. Evidently the microcline resisted decomposition more successfully than the orthoclase and is therefore nearly intact. It is probable that some of the contrasts in the degree of alteration of neighboring dikes may be due to differences in the character of their feldspar.

Preparation of Kaolin and By-Products

A thorough system of washing should remove all the objectionable constituents from the crude kaolin and yield a refined product of a nearly constant composition. The latter condition is more easily reached than the former. In the case of one mine the product was maintained at a constant standard during at least five years, as indicated by the figures below which show the limits of variation in the shipments of refined kaolin between the years 1890 and 1895. The analyses² were made by N. P. Pratt on material dried at 212 degrees F.

¹Watts, A. S., Bur. of Mines Bull. 53, p. 17, 1913.

²Furnished by Harris Kaolin Co., Dilleboro.

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO	MgO	K ₂ O	Na ₂ O	H ₂ O
46.47	38.82	.89		.28	.25	.75		13.34
46.47	38.14	.36		.50	.09	.64		13.61

The removal of objectionable constituents¹ is not so well accomplished. Quartz and small quantities of feldspar are nearly always present in the refined kaolin and sometimes a large proportion of the more objectionable components. It is probable that washing alone, no matter how carefully done, will never succeed in removing all of the iron hydroxides, since some of these are colloidal in character, but a more careful washing than is now practiced in the State would unquestionably remove more of the heavy iron-stained particles and much of the quartz that now finds its way into the refined product. Analyses² of the crude and washed kaolins from the Springer pit, near Webster, give some idea of the improvements effected by washing an unusually good crude clay.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO	MgO	Alk.	H ₂ O	Moist	Total
Crude	62.40	26.51	1.14	.....	.57	.01	.98	8.80	.25	100.66
Washed	45.78	36.46	.28	1.08	.50	.04	.25	13.40	2.05	99.44

The crude material contained 15.61 per cent quartz and 18.91 per cent feldspar and the washed material 6.60 per cent of the two components.

Most pegmatite dikes consist in large part of quartz so that the average quantity of kaolinite in their decomposed portions is usually much less than 40 per cent, and in most cases is so low that the deposits are not workable throughout with profit. However, there are richer pockets scattered through the dike mass and it is upon these that the miner depends for his commercial success. He necessarily passes by the poorer portions and removes the richer ones.

In some of the deposits there is a great deal of quartz which is in such fine grains that it passes the sand wheels used to remove the coarse components from the crude kaolin. This may pass into the mica trough and settle. If not mixed with much mica it may be used in scouring soaps and other cleansers. It is not sharp enough for sand-

¹See Plate I, for arrangement of washing plant.

²Ries, H., N. C. Geol. Survey Bull. No. 13, p. 62, 1897.

paper and rarely pure enough for use in glass making. In a few instances the coarser quartz, when fairly uniform in size, has been used for roofing, but with what success is not known.

Much of the mica that was present in the original pegmatites has remained unaltered during the kaolinization of the feldspar and now occurs embedded in the crude clay. That which is in large flakes or aggregates of flakes is in many cases easily separable from the kaolin by hand and if clean and uniform in structure, it may be put on the market as "sheet mica" or "punch mica," depending upon its size. Indeed, some of the mines are now producing mica of this kind. Since in any case it must be removed from the mine and separated from the kaolin, the small additional expense required to save and sort it is warranted by the price at which it can be sold. In some pegmatites the mica is in very fine scales. Moreover, some of the coarser mica found in most dikes is so severely pounded and torn in the processes of refining the crude clay that it is shredded into fine particles. The quantity of fine mica that passes the sand wheels is often very great. Much of it drops to the bottom in the mica troughs but the fine scales float out in the slip that goes to the settling tanks. By placing screens of the proper mesh in the sluice carrying the slip most of this mica might be saved and sold as "ground mica." At the Sprucepine Mine an excellent grade of ground mica is now being saved at very little cost.

Prospecting

All the deposits of kaolin now being operated within the State are on the slopes of hills in the mountain district, but unquestionably good deposits exist also in less exposed situations. That these have not been explored is due to a number of conditions, among them the fact that they are not so easily detected because usually covered by waste from the slopes. On slopes the debris produced by weathering is removed almost as rapidly as it is formed, and the white kaolin is exposed to view. At the base of slopes the narrow kaolin masses are covered by creep or wash from the overhanging hills and are frequently nearly completely obscured.

In some places on flats or low slopes, where the kaolin cannot be seen, its existence beneath the soil may be inferred from the presence of large fragments or boulders of quartz on the surface. The boulders result from the decomposition of coarse pegmatites, as there are no other rocks in this portion of the State that yield large quartz boulders upon weathering. Consequently the presence of quartz boulders sug-

gests decomposed pegmatites, and since the decomposition of pegmatites often produces kaolin, it follows that the presence of the boulders on the surface usually indicates the presence of kaolin beneath the surface.

After the existence of kaolin has been determined it is desirable to ascertain its extent before undertaking any serious development to prove its value. This is done with an auger welded to a section of steel pipe long enough to enable the operator to penetrate the deposit at least 30 feet. The auger holes should be sunk at intervals of about 15 feet in a series of lines at right angles to one another until enough area has been covered to establish definitely the width of the deposit and its general direction. Care should be taken to make sure that its actual limits have been reached before abandoning the cross-boring. It must be remembered that quartz horses are common in many of the deposits, and that they will stop the auger as effectually as wall rock. Before abandoning the cross-boring a large enough number of holes should be sunk to rock to establish the fact that the limit of the deposit has been reached in that direction. After proving the width of the dike, holes should be bored along its length through a distance that will leave no doubt as to its magnitude. These should be closely spaced along the borders of the deposit, but may be more widely spaced within its borders.

After having determined that the size of the deposit is sufficient to warrant working, provided the quality of the kaolin seems satisfactory, it is necessary to obtain as nearly as possible an average sample for study. This is best done by driving a tunnel from the face of a slope into the deposit and cross-cutting, care being taken to grade the tunnel so that it will readily drain. Samples should be taken from the entire length of the walls of both tunnel and cross-cut, omitting only those portions occupied by horses so large that they would have to be left during mining. With this exception, all horses should be sampled as well as the pure kaolin, so that the sample may represent a fairly complete section of the walls throughout the entire extent of the mass that would be removed in mining. The sample thus obtained should be added to by the results of horizontal borings at definite intervals into the walls on both sides of the tunnel and cross-cut and by vertical borings into the overhead and foot. The samples should be preserved in bags and with each bag there should go a record explaining exactly how the sample was obtained and from what part of the deposit it was taken. This is important, as different portions of a deposit often yield materials with different properties, and it may be desirable to know something of the probable proportions in which they exist.

Watts¹ calls attention to several precautions which must be borne in mind in attempting to estimate the value of a deposit. He notes that in vertical boring the auger usually cuts the deposit obliquely, since most dikes have a distinct dip, and therefore may strike a narrow band of undesirable material, which, because of its loose texture and brittleness, may furnish fragments that may make the band seem wider than it really is. Care must be taken in lifting the auger that it may not tear off pieces of such a band, invalidating the sample. When boring from the surface he found it advisable to use a larger bit for penetrating the overburden and then to pack the sides of the hole with the aid of a smooth, round pole before boring into the kaolin, in order to prevent particles of the overlying clay or sand from falling into the sample and contaminating it.

After the several samples have been collected, one or more general samples should be made up by mixing the individual samples in their proper proportions and these general samples should be subjected to the tests that have been prescribed for determining the value of a kaolin for the purposes for which kaolins are used. A chemical analysis is not necessary, but a burning test is essential in case the kaolin is to be used in making whiteware of any kind.

Uses of North Carolina Kaolins

The kaolins of North Carolina are used in making china, semi-porcelain and porcelain, mosaic and other tile and in the manufacture of spark plugs and glass-melting pots.

Their principal use is in the mix for burning into the various grades of china and other whiteware. It constitutes from 2½ per cent to 15 per cent of the mix, the other ingredients usually being English ball and china clay, Florida kaolin, and often clays from other domestic sources. Some potters describe it as very satisfactory when not introduced into the mix in large quantity. Others declare that its use is objectionable in the manufacture of fine ware, but that if better cleaned it would be the equal of any English clay. In some instances it contains too much grit; in others it is contaminated with particles of yellow material, which appear as tiny black specks in the finished ware. In a few cases it is apparently slowly replacing imported clay; in others its use is gradually being abandoned. One of the largest users reports that in the practice at his kilns it burns to a greenish body marred by black dots, and that as the demand for perfect ware

¹Watts, A. S., Bureau of Mines Bull. 53, p. 20-21, 1913.

is pressing he is compelled to diminish the quantity he has been using and is substituting for it English china clay. In one case, however, satisfactory ware is being produced from a mix containing only American clays. In this North Carolina kaolin constitutes about 20 per cent of the mix.

It is evident that while in the practice of some potters the kaolin from this State gives satisfactory results, in most cases it is not entirely satisfactory and consequently is used sparingly. It may be that with a change in the formulas at some of the potteries the quantity of North Carolina kaolin that could be introduced into the mix might be considerably increased. Nevertheless, a more certain means of extending its use would be to change the method of washing the crude clay sufficiently to assure the removal of all the grit and other ingredients that are so objectionable to the potters.

One of the most promising uses of kaolin is in the manufacture of glass-melting pots. So far as is known commercial tests of the applicability of North Carolina kaolins to this purpose have not been successful. Certain of the kaolins, however, have been used in making porcelain pots for optical glass, but this of course is a special use.¹

DEPOSITS IN THE MOUNTAIN DISTRICT

Kaolins from Pegmatite

All the deposits of kaolin in North Carolina now being worked are in the mountain district and all of them are residuals from pegmatites. Besides these there are many other similar deposits which are not being worked. Some of them are too small for profitable exploitation; others, though large, are not favorably situated with respect to railroads; others are owned by parties who are prevented from developing them by lack of financial means and others are being held in reserve by the owners of the present active plants. There are also other deposits, some of which are promising, that have not been brought to the attention of the public and many others the extent of which is not known because they have never been explored. All that are known are discussed. Many of them have been examined, but many others have not been seen. The facts concerning these are gleaned from earlier reports, to which reference is made in each case. The locations of all of them are indicated on the accompanying map (Pl. II) by figures, identical with those prefixed to the names of the deposits in the text.

¹A. V. Bleining. Bureau of Standards Technologic Paper No. 144, pp. 47-51, 1920.

The active mines of the State are eight in number, located in Haywood, Jackson, Mitchell and Yancey counties. There are three others now inactive, but partly equipped for operation in Swain, Haywood and Mitchell counties and a score or more of promising deposits that might possibly be developed into producing properties under favorable conditions.

Deposits in Swain County

Swain County contains no operating mines, though four have been operative in the past. Of these three have been permanently abandoned. The fourth is temporarily closed. Besides there are other deposits that have been described.

(b) PAYNE AND SULLIVAN MINE

Near Bryson

J. H. Sullivan, Asheville, N. C.

The Payne and Sullivan Mine is four miles southwest of Bryson near Yalaka Creek (see Fig. 1). The openings are a short distance from those formerly worked by the Carolina Clay Company at the head of Buckner Branch. The Carolina Clay Company's deposit was worked out some years ago but other dikes of kaolinized pegmatite have long been known to exist in the neighborhood and it is on one of these the Payne and Sullivan Mine has been opened. At the old mine the dike is reported¹ to have been 16 feet wide. It strikes N. 15° E. and dips 75° S.E. It was rich in kaolin near the foot wall, but became progressively poorer toward the hanging near which the dike material was nearly all sand. There were pockets of garnet-colored sand in the kaolin and streaks of wall rock. A sample taken from across the entire width of the dike yielded 22 per cent of kaolin with a refractory value of 1,650° C.

The Payne and Sullivan Mine is further south on the top of a steep slope. The mine has been closed down for several years. The buildings of the washing plant are still standing in fairly good repair but all the machinery has been removed. It is stated by one of the present owners that the former lessees, who built the plant, operated the mine but a short time. They took out material that yielded about 250 tons of washed kaolin, of which they shipped 100 tons. The remaining 150 tons is still in the storage sheds. When the mine was worked water was pumped 320 feet. The crude clay was trammed 300 feet from the mouth of the pit and sent down a chute to the refining plant at the bottom of the slope. The refined kaolin was hauled in wagons to a private road known as the Yalaka Railroad, and there loaded on stan-

¹Watts, A. S., L. c., p. 124.

ard cars. When the mine is reopened it is intended to send the crude material from the old pit to the plant by a flume, to join the various new openings by a tramway already partly constructed and to sluice their product with that of the old opening.

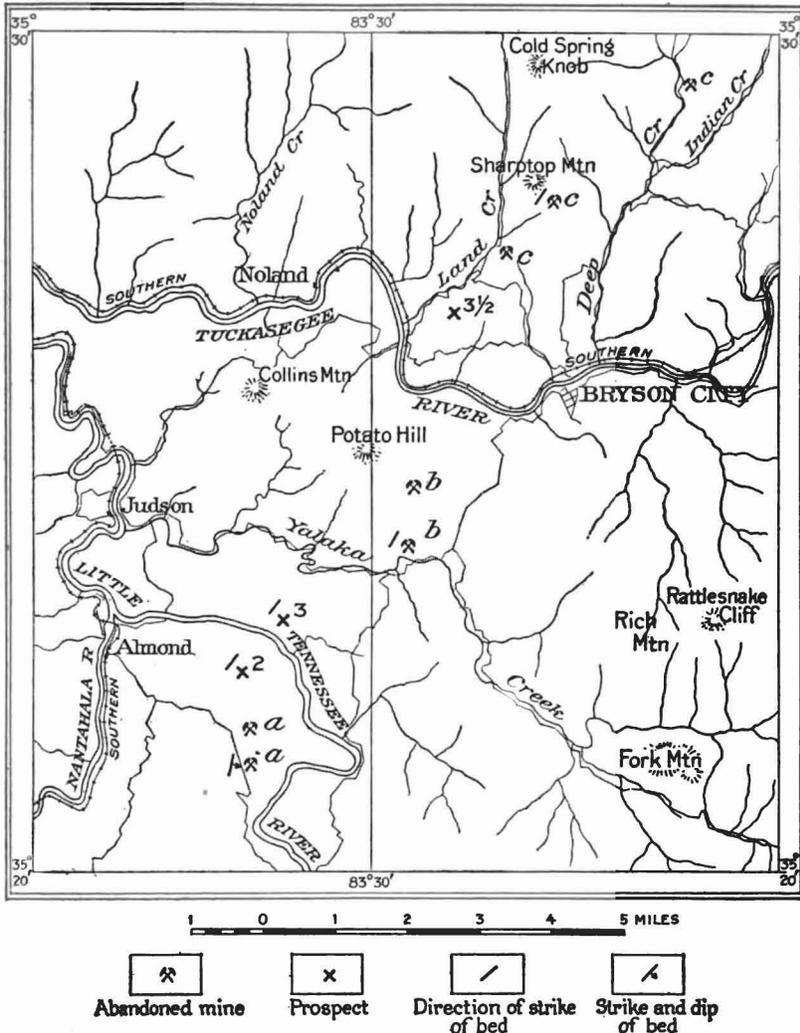


Fig. 1. Sketch map of kaolin deposits near Bryson, N. C.
 Lower case letters refer to abandoned mines.
 Figures refer to prospects and explorations.
 Letters and figures correspond to those in the text and on Plate II.

There are at present two main openings on the property and a number of shafts, tunnels and test pits, nearly all of which expose excellent clay. The old pit is known as No. 1. A newer pit about

half a mile further northeast is No. 2. Wherever exposed the clay appears to be in a dike that strikes about N. 20° E., or rather a series of ramifying dikes with a general northeasterly trend. In pit No. 1 the width of the deposit is 40 or 45 feet, in pit No. 2 about 20 feet and in a shaft and tunnel 375 feet south of pit No. 2 the maximum width of clear kaolin is six feet.

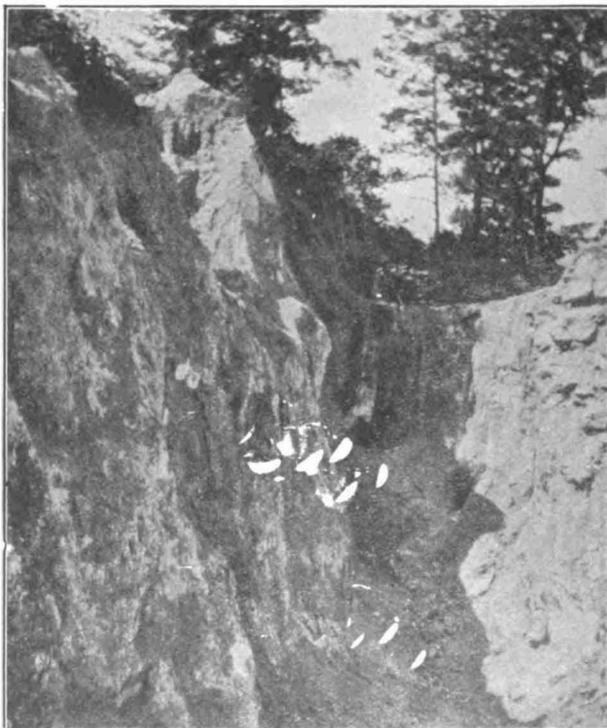


Fig. 2. Open pit, No. 1. Payne and Sullivan Mine, near Bryson. Looking southwest. The width of the pit represents approximately the width of the kaolinized dike that has been removed.

Pit No. 1, which is 190 feet long and 40 feet wide, is an open cut along the strike of the dike. Its southeast wall is granite. Its contact with the kaolin is vertical so far as it has been uncovered. The northwest wall is in kaolin crossed by narrow horses of quartz and feldspar, but its east 50 feet is an intermixture of small streaks of clay in an undecomposed mass of quartz and feldspar. The opening consists of a terrace at its southwest end and along the west end of the north side about 40 feet above the bottom of the pit. The kaolin has been

worked out to the bottom of the pit by open cut methods to a depth of about 65 feet from the original surface, and at the time the mine was abandoned material was being removed from the terrace with the aid of two shafts. At the west end of the terrace is a cliff 40 feet high (see Fig. 2), that is pierced by a tunnel. Both cliff and tunnel expose kaolin traversed by many vertical streaks of quartz one inch wide.

The clay occurring in this pit is dense and white. It is contaminated by little masses of partially decomposed feldspar, grains of quartz, soft crystals of partially decomposed muscovite and hard, black streaks of what is believed to be psilomelane or some other hard manganese oxide or hydroxide.

Pit No. 2 is a small open cut across a thoroughly kaolinized dike, about 26 feet wide, exposing a surface of pure white clay. (See Figs. 2 and 3). A tunnel has been driven into the face of the dike extending back about 30 feet along its strike. Just beyond the end of the tunnel the dike ends in the face of a steep slope which cuts it off. In the tunnel the relations of the dike to the country rock are well shown. On its north wall the pegmatite sends irregular tongues into the granite

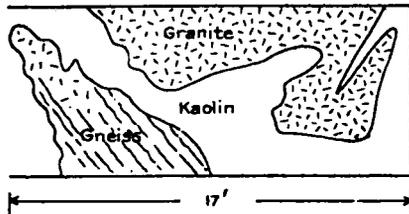


Fig. 3. Sketch illustrating relations of kaolin and country rock, north wall of tunnel. Pit No. 2, Payne and Sullivan Mine.

and gneiss as illustrated in Figure 4, and on the south wall the same relations are shown in a less marked degree. Indeed, everywhere on the property the rock streaks occurring in the kaolin appear to be masses between tongues of kaolinized pegmatite.

The crude clay of pit No. 2 is like that of pit No. 1 but it contains more coarse quartz in sharp fragments and very little sand and mica. In some places in the tunnel it possesses a distinct graphic struc-

ture. The quantity of clay in sight in this pit is estimated to be sufficient to yield 1,000 tons of washed kaolin. In this estimate no account has been taken of the amount of crude clay in the extension of the dike southwest of the pit, since its length in this direction has not been explored.

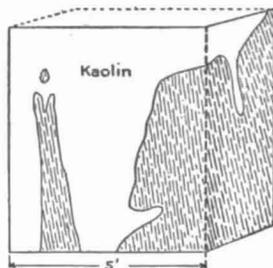


Fig. 4. Sketch showing relations of kaolin and mica schist at end of cross-cut near pit No. 2, Payn and Sullivan Mine.

Between pits No. 1 and No. 2 are many smaller openings, some of which have exposed excellent white, almost porcelain-like clay, containing as visible impurities only an occasional coarse mica flake and a few sand particles. A boring in the bottom of the most promising shaft penetrated 39 feet of this kind of clay.

Watts collected a sample representing the full width of the dike in pit No. 1, which yielded to laboratory washing methods 22 per cent of kaolin with a refractory value of 1,650° C. and a color of grade 5.¹ Its shrinkage² was 3.8 per cent when dried at 110° C. and its total shrinkage 10.2 per cent when fired at 1,350° C. The tensile strength of briquettes dried at 110° was eight pounds per square inch.

Substituted for English China clay in the standard porcelain mixture and fired at 1,350° C. the result had a color described as of grade 5, a translucency of .65 and the transmitted light was yellow. The absorption of the fired mass was 2.2 per cent. Briquettes dried at 110° C. shrank

¹The color of the kaolin is its color after firing at 1350° C. It was checked against the standard English china clay referred to below. This was given a color value of grade 5, and lighter shades were valued as grades 4 to 1, the latter being the whitest.

²Shrinkage was determined by Watts (p. 55) by making wedges of the material to be tested and measuring them before and after drying and after firing; or by measuring before and after drying and after firing impressions made upon them by a die.

2.4 per cent; when fired at 1,350° C. the shrinkage was 13.5 per cent. The color remained unchanged under the raw lead and fritted glazes.¹

The U. S. Bureau of Mines tested samples from pit No. 1 (No. 2.04) and pit No. 2 (No. 2.05). The result of these tests were as follows:

SCREEN TESTS

Clay	20M*	20-65M	65-100M	100-200M	Thru 200M
2.04	0.53	36.56	7.85	12.40	42.64
2.05	1.16	32.31	9.43	15.07	42.01

*20M, 20-65M, etc. refer to the screens used.

MOISTURE PRESENT

2.04=4.91%
2.05=3.56%

WATER OF PLASTICITY AND DRYING SHRINKAGE

Clay No.	Water of Plasticity per cent	Volume Drying Shrinkage per cent
2.04	41.63	20.13
2.05	43.84	21.56

¹The standard porcelain mixture consists of 20 per cent standard feldspar, 30 per cent standard quartz and 50 per cent of English china clay, having the composition:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	TiO ₂	Total
46.86	38.10	.30	.46	.48	1.18	.30	.00	100.10

This kaolin has a refractory value of 1690° C. and burns to a porous white mass at 1250° C.

The standard porcelain mixture becomes vitreous white at 1,310° C. Its color after burning is of grade 5 and its translucency is .65. The shrinkage on drying at 110° C is 3 per cent and upon firing at 1,310° C. is 12.6 per cent additional. The total shrinkage 1,310° C. is thus 15.6 per cent.

In determining translucency, wedges of the porcelain mixture were "fired to the maturing temperatures of the standard feldspar and tested by determination of the maximum thickness, expressed in centimeters, at which can be detected a No. 20 wire on the face of the trial next the lamp (16 candle power) with the lamp three inches distant from the trial." (Watts: Bureau of Mines Bull. 53, pp. 55-56.)

THE KAOLINS OF NORTH CAROLINA

PER CENT VOLUME SHRINKAGE WHEN FIRED TO DIFFERENT TEMPERATURES

Clay No.	1170° C	1210° C	1250° C	1290° C	1330° C	1350° C
2.04	17.27	25.09	33.33	37.26	48.35	-----
2.05	14.25	25.99	-----	40.06	-----	42.42

PER CENT APPARENT POROSITY WHEN FIRED TO DIFFERENT TEMPERATURES

Clay No.	1170° C	1210° C	1250° C	1290° C	1330° C	1350° C
2.04	39.64	34.64	24.20	20.45	20.55	-----
2.05	36.69	29.04	-----	7.88	-----	3.02

COLOR WHEN FIRED

2.04 Good white
2.05 Good white

SOFTENING TEMPERATURES

Clay No.	Cone.	° Cent.	° Fah.
2.04	34	1740	3164
2.05	34	1740	3164

The other two mines in Swain County that were formerly worked but which are now abandoned were the Harris Mine near Bryson and the Hewitt Mine near Almond. Both are reported to have been worked out and there is no present prospect of their being reopened.

(c) HARRIS MINE

Near Bryson

Harris Kaolin Company, Dillsboro, N. C.

The Harris Mine was two and one-half miles north of Bryson, on the east flank of Sharptop Mountain. It was in a dike 40 to 60 feet wide in which were many bands of wall rock. The strike of the dike is N. 20° E., and is crossed by faults at intervals of about 150 feet. It is irregularly kaolinized, and in some places is stained yellow. In

1911 this deposit had been worked to a depth greater than 35 feet, yielding a clay that when washed produced 22 per cent of white kaolin. In 1913, it had been about worked out, and the plant had been abandoned.

A similar deposit¹ was opened about one mile southwest, but was abandoned after a few months work and a new opening was made three miles farther northwest near Deep Creek. The refractory value of the washed kaolin was given by Watts as above 1,730° C. Its color when fired was grade 3. (See footnote, p. 39). Dried at 110° C. it shrank 4 per cent, and fired at 1,350° C. its total shrinkage was 12.8 per cent. The tensile strength of the material dried at 110° was 14 pounds per square inch.

The standard porcelain mixture made with this kaolin when fired at 1,350° C. had a color of grade 3, a translucency of .63 and the transmitted light was cream colored. Its absorption was 3.3 per cent. The mixture dried at 110° shrank 2.8 per cent, and fired at 1,350° its shrinkage was 11.8 per cent. The color was unaffected by the raw lead and fritted glazes.

(a) HEWITT MINE

Near Almond

F. R. Hewitt, Asheville, N. C.

The Hewitt Mine² at different times during its activity operated a number of openings in a belt running north and south at a distance of about two miles east of Almond on the Murphy Branch of the Southern Railway. Keith has noted that the pegmatite which gave rise to the kaolin occurs as small, round masses in graywackes and schists of the Great Smoky Conglomerate formation which is Cambrian in age. This is unusual since in all other cases of kaolinized pegmatite the wall rocks are gneisses and schists of pre-Cambrian age. Six deposits were mapped. The mine at the time of Keith's visit was working the deposits two and one-half miles southeast of Almond on the east side of the road between this village and Needmore. The clay was being taken from the top and the southern slope of a small ridge. Test pits and a short tunnel proved its extent for about 450 feet in a north-south direction. About a mile further north is another kaolin

¹Watts, A. S., L. c., pp. 109 and 125.

²Keith, Arthur. U. S. Geol. Survey, Geol. Atlas, Nantahala folio, (No. 143), p. 8, 1907.

deposit and one-fourth mile west still a third one. Other deposits have been opened up by test pits two miles southwest and one and three-fourths miles northeast of the Hewitt Mine. At the last indicated locality there are two separate veins and the kaolin in them is at least 50 feet deep. Later the deposit¹ on the west side of the road was opened. This was abandoned a few years ago and the entire plant has been closed. At this place a dike 20 to 30 feet wide, striking north and dipping 75° E. had been removed for a distance of 275 feet and to a depth of 40 to 60 feet. The pegmatitic material was incompletely kaolinized.

The crude kaolin from this deposit had a refined kaolin content of 20 per cent. The refined product was slightly off color.² Its refractory value was 1,650° C. The shrinkage of the kaolin in drying at 110° C. was 3.8 per cent, and upon firing at 1,350°, 8.7 per cent. The tensile strength of briquettes dried at 110° was six pounds per square inch.

The porcelain mixture fired at 1,350° was of grade 6 color, was yellow by transmitted light, possessed a translucency of .66 and an absorption of 1.9 per cent. The drying shrinkage was 2 per cent and firing shrinkage 13.2 per cent. The color of the porcelain was not affected by the raw lead and fritted glazes.

2, 3. HYDE AND MESSER PROSPECTS Near Almond

Two other openings in the neighborhood of the Hewitt Mine are referred to by Watts as the Hyde and the Messer prospects.

The Hyde prospect is two and one-fourth miles north of east of Almond and one-fourth mile north of the Little Tennessee River. It may be the locality referred to by Keith as being one and three-fourths miles northeast of the Hewitt Mine. The deposit is in the form of an expanded lens covering an area of one and one-half to two acres. It was opened by five test holes and two tunnels, in one of which a width of twenty feet of kaolin was exposed. The lens is apparently pockety. It possesses no uniform dip, but is very irregular. The crude material³ taken from the tunnel yielded 19 per cent of kaolin, which had a refractory value of 1,670° C. and a color, when fired, as of grade 6. The washed kaolin dried at 110° C. showed a shrinkage of

¹Watts, A. S., L. c., p. 119.

²This is described by Watts as of grade 6. (See foot-note p. 39).

³Watts, A. S., L. c., p. 119.

4.2 per cent and fired at 1,350° C. a shrinkage of 8.8 per cent. The tensile strength of the material dried at 110° was eight pounds per square inch.

A porcelain mixture with this kaolin, fired at 1,350° C. is grade 6 color. The resulting porcelain has a translucency of .64 and an absorption of 2.2 per cent. By transmitted light it is yellow. When dried at 110° C. the mixture shrinks 2.1 per cent, and when fired at 1,350° C., 8.8 per cent. The color is unaffected by the raw lead and fritted glazes.

The Messer prospect is two miles south of east of Almond, and one-half mile south of the Little Tennessee River at an elevation of 200 feet above the river. A dike is cut by two tunnels on opposite sides of a knoll and 25 feet below its crest. This dike appears to have a north strike and the dip where exposed is vertical. Mr. Watts² states that the kaolin is of fair quality, but it contains many narrow streaks of stained material.

EVERETT PROSPECT

Near Bryson

The only other tested deposit³ in the county is the Everett prospect near Land Creek, two miles northwest of Bryson. This deposit is in a dike, perhaps nine feet wide, of semi-kaolinized material in which are some large quartz masses. The material yielded 28 per cent kaolin of grade 3 color and possessing refractory value above 1,730° C. When dried at 110° C. it shrank 4.3 per cent and when fired at 1,350° C., 12.6 per cent. The tensile strength of the material dried at 110° was 15 pounds to the square inch.

A porcelian mixture fired at 1,350° C. was grade 3 color. Its translucency was .65 and the absorption 4.7 per cent. By transmitted light it was cream colored. Dried at 110° C. mixture shrank 3 per cent and when fired at 1,350° C., 12.2 per cent. The Color of the fired mass was unaffected by the raw lead and fritted glazes.

Deposits in Macon County

There are no clay operations in Macon County during the present time. Formerly two mines, near Franklin, were active producers, but for various reasons they have been closed within the past few years. One is still equipped for refining kaolin. The plant of the other has

¹Watts, A. S., L. c., p. 120.

²Watts, A. S., L. c., p. 125.

been completely destroyed. There are, however, a number of promising prospects (Fig. 5) in the northeast quarter of the county, but their only outlet to the market is via the Tallulah Falls Railway of the Southern Railway system, which is roundabout.

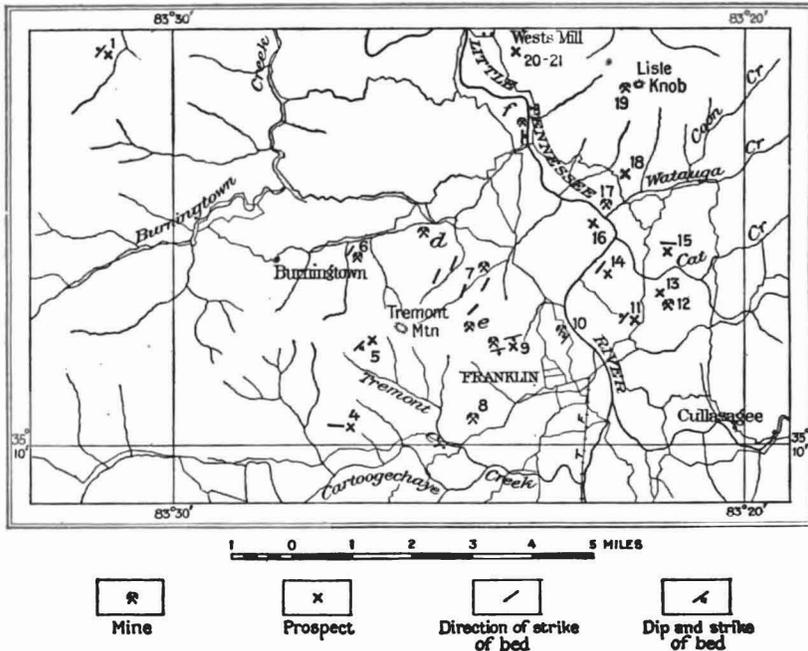


Fig. 5. Sketch map of kaolin deposits near Franklin. Capital letters refer to active mines. Lower case letters refer to abandoned mines. Figures refer to prospects and explorations. Letters and figures correspond to those on Plate II.

(d) PORTER PROPERTY

Near Franklin

J. A. Porter, Franklin, N. C.

The Porter property was formerly worked by the Gurney Clay Company as the Gurney Mine. It is situated four miles northwest of Franklin and three miles east of Burningtown on Iotla Creek. The shape of the pit, which has an average width of about 35 feet and is 400 feet long, indicates that the deposit is a narrow lens, but since the width varies widely it is evident that the kaolin was pockety. Watts,¹ in describing the mine when in operation, states that "the

¹Watts, A. S., L. c., p. 133.

kaolinized dike forms an expanded lens averaging about 200 feet in width and 300 feet in length already proven. . . . The lens consists of bands varying in kaolin content," but by mining the entire width of the dike a uniform product was obtained. At first mining was by shafts, some of which were 100 feet deep, but this proved so expensive that the open cut method was resorted to. The mine was worked about four years, producing about 250 tons of merchantable kaolin monthly. It was abandoned in 1914 not because of lack of

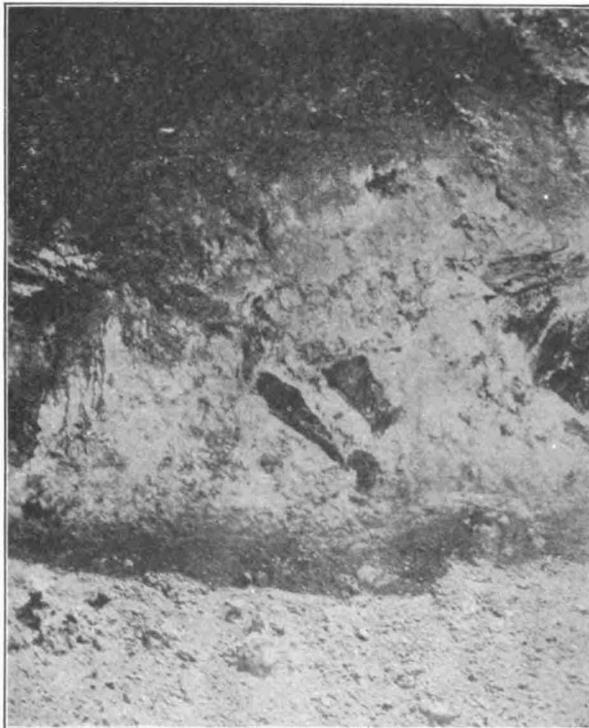


Fig. 6. East wall of Gurney Clay Company's pit, near Franklin. Showing inclusions of country rock in kaolin.

material but in consequence of the lack of demand for kaolin in that year and because a red stain was developing in the output, which was caused by decomposed biotite, that it was found impossible to separate from the clay in mining and which necessarily had to be removed by hand-picking at a cost which was as great as the cost of mining. The time required for sorting limited the output of the plant to 250 tons

monthly, though its capacity was 500 tons.¹ Mr. Gurney believes he now has a method for eliminating the stained clay, which should enable the deposit to be operated successfully.

It is not possible to study the relations of the clay to the rock in the pit at present because its walls are covered by wash. It can be seen, however, that there are several branching dikes. There are indications that the kaolin is crossed by horses of partly decomposed feldspar and coarse quartz, and where the walls are exposed there are small veins of kaolin in the country rock and seemingly fragments of rock in the clay. (Fig. 6.) The fragments are probably portions of the country rock that had been surrounded by pegmatitic material. Muscovite bunches are common in the kaolin in many parts of the mine. In some parts it was so abundant that it was saved as a by-product. Biotite is also present but in smaller quantity. It is usually associated with quartz. That much quartz was mined with the clay is indicated by the fact that the waste heaps consist mainly of large fragments of the mineral. The overburden was not over ten feet in thickness anywhere. Its average thickness was about six feet. According to Watts the yield of the deposit was almost 30 per cent of kaolin.

The crude clay was white. As mined it contained a great deal of mica and quartz and much of it was stained red. Mr. Watts reports that kaolin washed from the crude clay taken from the richer pockets to have the following composition:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
44.00	40.79	.11	tr	tr	.07	.55	tr	14.72	100.24

The crude clay was washed and pressed in a plant a few hundred yards from the pit and when dried was hauled by teams to Franklin. It was sold under the name "Totla brand" and was used by many of the potters in the Ohio Valley.

The buildings of the washing plant are still in good repair but some of the machinery has been removed.

According to Watts the kaolin washed from samples collected by himself, had a refractory value above 1,730° C. Its color after firing was grade 1 and its tensile strength when dried at 110° C. was 27.5 pounds per square inch. Air-dried briquettes at 110° C. suffered a shrinkage of 5.4 per cent, and upon firing at 1,350° C. a shrinkage of 11.9 per cent.

¹Communicated by Mr. J. W. Gurney in letter dated Aug. 14, 1918.

A porcelain mixture made with this kaolin when fired at 1,350° C. was grade 1 in color. It possessed a translucency of .72 and the absorption was 6.5 per cent. The light transmitted through it was cream-white. The shrinkage at 110° C. was 3.2 per cent and at 1,350° C. was 12.4 per cent. Under the glazes used the color was not affected.

(e) JOHNSTON PROPERTY

Near Franklin

W. R. Johnston, Sylvester, Ga.

The Johnston property was formerly worked by the Southern Clay Company. It was operated only two years when the lease was surrendered, the plant dismantled and the company dissolved. One of the causes of the abandonment of the mine was the difficulty of handling the water. There were a number of openings on the northeast flank of Tremont Mountain, the principal one being about one mile northwest of Franklin postoffice.

At present little can be seen on the surface. Most of the workings have fallen in and covered their walls. About half a mile back of the main workings mica is now being taken from some of the old shafts and tunnels and they have been cleaned out. Three of the openings expose kaolin for a breadth of about ten feet, but much of this is badly stained near the surface. With increased depth, however, the staining diminishes and at 25 feet underground the clay is uniformly white. It contains many bunches of large mica plates which, as has been stated, are now being removed for sale.

The main workings consist of an open pit 400 feet long and 50 feet wide and a shaft 125 feet deep to water. The walls of the pit are nearly vertical and its trend is a little north of east. The crude clay contained some coarse quartz and a great deal of fine mica, beside clumps of large plates, like those that are being mined further to the northeast. This was saved and sold. The fine mica was separated during the process of washing the clay and was thrown aside. Large dump heaps on the site of the old plant are composed almost exclusively of fine white mica scales which might possibly have been saved and sold as ground mica.

It is reported by Mr. Johnston that about 4,000 tons of refined clay were sold and that it was used in the manufacture of whiteware and tile.

Mr. Watts¹ visited the mine just before the plant was abandoned. He reports that the main pit was on a well-defined pegmatite dike 16 to 20 feet wide, striking N. 90° E. and dipping 70° S. The wall rock is gneiss and was divided through its middle by another quartz

¹Watts, A. S., L. c., p. 142.

band. It contained small pockets of dark red sand and isolated pieces of weathered biotite surrounded by zones of stained clay three or four inches thick. Watts thinks the cost of mining was unnecessarily high because all material was removed by shafts. The overburden varied from 5 to 25 feet. The shafts were sunk vertically on the deposit, passing through the belt of quartz, and reaching the clay by cross-cuts.

For a depth of 25 feet the kaolin was of a high grade. Lenses of feldspathic sand appeared at about this level, but below this to a depth of about 80 feet "the kaolin content of the dike is in excess of what would be expected from the kaolinization of average pegmatite, and approaches very closely the theoretical maximum from the decomposition of feldspar." Below the 80-foot level semi-kaolinized feldspar began to appear and at the 100-foot level nearly pure fresh orthoclase occurred. The deposit was reasonably uniform for about 120 feet along its strike, but it disappeared almost completely on the east slope of the hill. A second dike is parallel to the first one and 30 yards south of it, but the kaolin in it is so stained as to be unmarketable. A number of other deposits scattered over the property are too small to be of value.

The greatest difficulty in the mining of the clay was due to the great quantity of water encountered in the shafts. At 60 feet in depth the removal of the water became a "considerable problem" and at the depth of 100 feet about half the time of operation was spent in hoisting the water to the surface in buckets. No attempt seems to have been made to get rid of the water in any other way than by bailing.

The crude clay taken from the main dike yielded by washing 40 per cent of white kaolin with the composition:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
46.67	39.07	.11	tr	tr	.11	.25	.02	13.22	99.45

The refractory value of the washed kaolin was above 1,730° and its color was grade 1. Dried at 110° C., its tensile strength was 25 pounds per square inch, its shrinkage 4 per cent, and when fired at 1,350° C., 11 per cent.

The standard mixture with this kaolin, fired at 1,350° C., was pure white. Its translucency was .93 and its absorption 7 per cent. The transmitted light was white. Its shrinkage at 110° C. was 3.4 per cent, and when fired at 1,350° C. was 9.9 per cent. Its color remained unaltered under glazes.

9. CUNNINGHAM PROSPECT

Near Franklin

C. C. Cunningham, Franklin, N. C.

Across a valley from the east end of the Johnston property, where the main dike of kaolin is reported to have disappeared (see above), the dike reappears on the property of Mr. C. C. Cunningham, where it was worked through a number of shafts and pits as a source of mica. One shaft 25 feet deep penetrated 10 feet of overburden and 15 feet of clay. A boring in its bottom went through 35 feet more of similar clay. Two other shafts 25 feet deep and a third 60 feet deep also exposed clay all the way under the overburden. It is thought that the depth of the kaolinization increases toward the east. Mr. Cunningham reports that borings and test pits outline a dike 22 feet wide and at least 1,500 feet long. It strikes a little north of east and dips about vertical. There is a great deal of mica in the clay and considerable quartz. It is possible that the kaolin and mica might be mined together.

(f) IOTLA MINE

Near Franklin

Chapman and Gudger, Asheville, N. C.

The Iotla Mine, or the Franklin Kaolin and Mica Company's mine, is four and one-fourth miles north of Franklin on the west side of Little Tennessee River, at Iotla Bridge. The place is now abandoned. It was originally worked for mica and later for kaolin. Watts,¹ in his description of the mine shortly after it was abandoned, states that the development consisted of 10 tunnels and 12 shafts, some of the latter of which are 120 feet deep. The dike had been mined for 550 feet in length and for a width that varied between 10 and 100 feet. Although layers of sugar quartz bordered the kaolin and a streak ran through the center of the dike, the crude clay contained very little quartz. A sample taken by Watts from one of the shafts yielded 42 per cent of white kaolin of excellent quality.

It is probable that when the property was worked for kaolin it was not on a very large scale as there is no evidence that any large quantity of material was ever removed from the ground. Moreover, all the dumps consist almost exclusively of mica. The most accessible part of the mine at present is a tunnel 150 feet long at the base of the hill, near the river. It is nearly all the way in a white clay, cut here and there by rock horses and crossed by numerous streaks of muscovite crystals and groups of crystals. The clay surrounding the mica crystals contains a comparatively small amount of quartz sand

¹Watts, A. S., L. c., p. 133.

and abundant tiny white mica flakes. Farther up on the hill-slope are six or seven other tunnels and a shaft in clay, and near the top of the hill is a large tunnel through clay, mica and quartz. It is reported by men who have worked on the property that mica was much more plentiful near the top of the hill than lower down, and that the quality of the kaolin was better at the lower levels.

From the large number of pits and shafts scattered over the property it would seem natural to infer that there are present numerous small dikes of pegmatite and many small pockets of kaolin. Some of the largest appear to be promising.

The sample collected by Watts from the only shaft that was open at the time of his visit was carefully washed and tested. Its color was grade 1 and its refractory value above 1,730° C. When dried at 110° C. its shrinkage was 5.2 per cent and when fired at 1,350° C. was 12.4 per cent. The tensile strength of the material dried at 110° C. was 24 pounds per square inch.

When made up into the standard porcelain mixture and fired at 1,350° C. the translucency was .72, the absorption 6.2 per cent and color of grade 1. The transmitted light was cream-white. When the mixture was dried at 110° it shrank 5.2 per cent and when fired at 1,350° C., 12.8 per cent. The color was not changed under the usual glazes.

Of the many other deposits known to exist in Macon County only a few have been prospected in a way to furnish any idea of their value. Most of them were originally opened as mica mines and, as is commonly the case in this situation, the value of the kaolin was completely disregarded. Moreover, most of them are so far from the railroad that the expense of marketing their product would be prohibitive, unless several of them in the same neighborhood should develop into much larger deposits than now seems probable.

5. MCGUIRE EXPLORATION

Near Franklin

W. B. McGuire, Franklin, N. C.

The two localities that appear to offer the best prospects are the McGuire and the Ferguson explorations.

The McGuire exploration is about three and one-half miles west of Franklin on the southwest slope of Tremont Mountain. The deposit is on a dike 18 feet wide that strikes northeast and dips 80 degrees southeast. Mr. J. H. Pratt made an examination of the property in 1915 and reported that at various places over an area of about two miles a number of openings have exposed kaolin, but only at a few places in commercial quantities. The most important of these are

two tunnels. One, 72 feet long, runs N. 40° E., penetrates kaolin for 22 feet and then enters country rock. At the contact of the kaolin and country rock a drift extends E. 10° S. for a distance of 15 feet. The original pegmatite has been almost completely kaolinized; the only unaltered rock observed in the dike is a little feldspar associated with a band of quartz. In the kaolin is a little scattered mica and an occasional nest of "decomposed garnet." A second tunnel 200 yards S. 50° E. from the first one starts at the contact of the dike and the country rock and follows the hanging wall for 108 feet. At a point 56 feet from the mouth of the tunnel is a cross-cut running N. 30° E. crossing the dike which is 18 feet wide. The kaolin cut by the cross-cut is like that cut by the drift from the first tunnel. Assuming that the deposit is continuous between the two tunnels and that kaolinization has extended to a depth of 100 feet, Pratt estimates 18,000 tons of washed kaolin present, provided the yield is 30 per cent of the crude clay.

About 900 feet in a direction S. 60° E. from the tunnel is a shaft 20 feet deep, that cuts 12 feet of kaolin like that in the tunnels. To the east and the west of the shaft are exposures of kaolinized material for a distance of one and one-fourth miles, but only at one point is it exposed in promising quantity. This is at a tunnel in the woods west of the shaft. It is cut into a hill 120 feet, and at this point it encountered the foot wall of a dike which was again exposed in a shaft 30 feet or more above the tunnel. At the extreme western end of the property a shaft on the top of a little hill rising 60 feet above a creek struck clay at a depth of 30 feet. Another shaft 86 feet from this one struck clay at the same elevation and several small pits exposed it in other places. These indicate the presence of a mass of kaolin about 100 feet broad. Its other dimensions were not disclosed. Some of the kaolin is stained by iron oxide but otherwise it is good.

Mr. McGuire reports considerable boring on the property since Pratt's visit, but he cannot give details as to the results.

Mr. Watts¹ sampled the material in the dikes, and found that in a washing test it yielded 42 per cent of a cream-colored kaolin, which analyzed:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
48.35	39.00	.30	tr	tr	.00	.50	tr	14.00	100.51

¹Watts, A. S., L. c., p. 137.

Mr. Lillibridge, of the American Encaustic Tiling Company, for whom some of the boring was done, states in a letter to the writer that the kaolin is of a sufficiently high standard to meet the requirements of wall-tile manufacturers.

The kaolin can be economically mined as there is a good supply of water for all purposes, and a down grade to a good road.

Its color was grade 3 and its refractory value above 1,730° C. The tensile strength of the material dried at 110° C. was 27.5 pounds per square inch, and its shrinkage 5.7 per cent. When fired at 1,350° C. it shrank 10.5 per cent.

The standard porcelain mixture made up with this kaolin shrank 3.2 per cent when dried at 110° C. When fired at 1,350° C. its shrinkage was 14.2 per cent. The translucency of the burned batch was .72, its absorption 5.4 per cent and its color grade 3. The light transmitted through it was cream-colored. The usual glazes did not affect its color.

Most of the remaining deposits known to exist in Macon County have been described by Watts. They have nearly all been explored sufficiently to uncover unquestionable kaolin in reasonable quantities, but none have been worked.

1. SMITH PROSPECT

Near Franklin

The Smith prospect¹ on Little Tellico Creek, nine miles northwest of Franklin, is a completely kaolinized dike exposed by a 40-foot tunnel and an open pit. Where opened, the dike is 75 feet above the creek. It is nearly 200 feet wide, but is interrupted by several horses of wall rock, so that the width of the pegmatite is only about 50 feet. Its strike is northeast, and its dip 80° northwest. The material sampled yielded 39 per cent of kaolin with a refractory value of 1,670° C., and a composition as follows:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
48.05	37.69	.31	tr	tr	.02	.91	tr	12.55	99.53

The color of the washed kaolin was of grade 4. The tensile strength of the material dried at 110° C. was 20.5 pounds per square inch and its shrinkage 6.8 per cent. When fired at 1,350° C. the total shrinkage was 12 per cent.

¹Watts, A. S., L. c., p. 141.

The porcelain mixture made up with this Kaolin showed a shrinkage of 3.2 per cent when dried at 110° C., and 12.4 per cent when fired at 1,350° C. The burned porcelain showed a translucency of .71 and transmitted cream-colored light. The absorption was 4 per cent and color of grade 4. The color remained unaltered under the raw lead and fritted glazes.

6. CHALK MICA MINE

Near Burningtown

Watts describes the Chalk Mica Mine¹ as being six miles northwest of Franklin and two miles north of the Franklin-Burningtown road, but on the map accompanying the Watts report it is placed three and three-fourths miles northwest of Franklin and one-fourth mile south of the road named. The deposit is said to strike N. 30° E. and to dip vertical. It has been proven for 50 yards by a tunnel, which exposes excellent kaolin, and by an open cut in a sandy kaolin. A sample averaged from the two exposed portions gave 35 per cent of kaolin with a refractory value above 1,730° C. Its color was of grade 3, and its tensile strength when dried at 110° C. was 15.5 pounds per square inch. Its shrinkage at 110° C. was 5.7 per cent and at 1,350° C was 13.7 per cent.

The porcelain mixture of which this kaolin is a component showed a shrinkage of 3 per cent when dried at 110° C. and 14.8 per cent when fired at 1,350° C. The fired mass had a translucency of .65 and transmitted cream-colored light. Its color was grade 3, and its absorption 6 per cent. With both the raw lead and fritted glazes the porcelain assumed a pale green tint.

4. LENOIR PROSPECT

Near Franklin

The Lenoir prospect² is three and three-fourths miles south of west of Franklin, near the Franklin-Andrews road. A dike 20 feet wide is exposed on the slope of a hill by two tunnels. Its strike is west and dip vertical. Its material is crossed by small streaks of iron-stained sands and is penetrated by narrow seams of feldspathic substance, and it contains small pockets of micaceous minerals. A sample yielded 38 per cent of white kaolin with a refractory value above 1,730° C. Its tensile strength at 110° C. was 20 pounds per square inch. Its shrinkage at the same temperature was 6.4 per cent and at 1,350°, 14.9 per cent. When fired its color was of grade 1.

When introduced into the standard porcelain mixture the shrinkage of this was 3.6 per cent when dried at 110° C., and 11.6 per cent

¹Watts, A. S., L. c., p. 132.

²Watts, A. S., L. c., p. 136.

when fired at 1,350° C. The translucency of the fired mixture was .67, its color of grade 1 and its absorption 7.1 per cent. The transmitted light was cream-colored. Under the raw lead and fritted glazes the color was unchanged.

7. RABY MICA MINE

Near Franklin

The Raby Mica Mine¹ is two and one-half miles northwest of Franklin, on the northeast slope of Tremont Mountain. The dike with its stringers has an aggregate width of about 300 feet. It strikes N. 10° E. The stringers average about 15 feet wide. They have been explored for a distance of 500 feet by tunnels. Other dikes have been prospected one-fourth mile to the northwest, one-fourth mile to the northeast, and one-fourth mile to the east. A sample of the material from the first deposit yielded 45 per cent of kaolin with a refractory value above 1,730° C. Its composition was:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
46.90	38.80	.25	tr	tr	.26	.39	tr	13.80	100.23

The color of the washed kaolin was of grade 3 when fired at 1,350° C. When dried at 110° its tensile strength was 21.5 pounds per square inch, and its shrinkage 6.25 per cent. Fired at 1,350° C. the shrinkage was 13.5 per cent.

The shrinkage of the porcelain mixture made with this kaolin was 2.2 per cent at 110° C., and 13.2 per cent when fired at 1,350° C. The translucency was .71, the absorption 6 per cent and the color of grade 3. The transmitted light was cream-colored. Under both the raw lead and fritted glazes the body color was pale green.

8. PORTER MICA MINE

Near Franklin

The Porter Mica Mine,² one and one-half miles south of west of Franklin, is an old one abandoned some time ago. The dumps contain kaolin of fair quality, but no record of the dimensions of the deposit is obtainable.

10. MOORE MICA MINE

Near Franklin

The Moore Mica Mine³ is one mile north of Franklin, about 80 feet above the Little Tennessee River. It was opened by two tunnels and two shafts that do not cut the main dike. One shaft exposes an over-

¹Watts, A. S., L. c., p. 139.

²Watts, A. S., L. c., p. 138.

³Watts, A. S., L. c., p. 138.

burden of 20 feet and 9 feet of kaolin that is very free from impurities and low in quartz. A part of the dike, however, is not completely kaolinized. Its strike is N. 40° E. and its dip 85° N.W. The sample contained 34 per cent of white kaolin, with a refractory value above 1,730° C. When dried at 110° C. the tensile strength of this kaolin is 28 pounds per square inch and its shrinkage 7 per cent. When fired at 1,350° C., its color was of grade 1 and its total shrinkage 15.7 per cent.

The porcelain mixture with this kaolin shrank 3 per cent at 110° and 12 per cent at 1,350° C. The color of the fired mixture was of grade 1, its translucency was .64, and its absorption 7.6 per cent. The transmitted light was cream-white. Under raw lead and fritted glazes the color was pale green.

11. LYLE PROSPECT

Near Franklin

The Lyle prospect¹ is one and one-half miles northeast of Franklin, near the Dillsboro road. It is on a dike 15 feet wide that strikes northeast and dips 75° northwest. It has been opened for a depth of only 10 feet, exposing a great variation in kaolinization. The material collected from the least weathered portion of the deposit yielded 26 per cent of cream-colored kaolin of a refractory value 1,690° C. Its color when fired was grade 3. Its shrinkage at 110° C. was 5.2 per cent and when fired at 1,350° C., 15.8 per cent. The tensile strength of the kaolin dried at 110° C. was 16 pounds per square inch.

When made into the standard porcelain mixture the shrinkage at 110° C. was 3.3 per cent and when fired at 1,350° C., 12.8 per cent. The fired mass had a color of grade 3, a translucency of .67, and absorption of 3.1 per cent. Its transmitted light was cream-colored. The raw lead and fritted glazes produced no change in color.

12. KASSON MICA MINE

Near Franklin

At the Kasson Mica Mine² two miles northeast of Franklin is a dike with many stringers from 6 to 16 feet in width that have been worked for mica. The main dike strikes N. 40° E. and dips 75° N.W. to 80° S.E. Where exposed the pegmatite is thoroughly kaolinized and much kaolin is on the dumps. The kaolin is badly iron-stained from altered biotite and it contains pockets of garnet-colored sand. A sample taken from the dumps, when washed, yielded 41 per cent of pink kaolin with a refractory value above 1,730° C. It is possible that by careful selection a better colored product might be obtained. Enormous quantities of what was once high-grade kaolin

¹Watts, A. S., L. c., p. 137.

²Watts, A. S., L. c., p. 135.

now lie on the dumps ruined by mixture with fragments of wall rock. When dried at 110° C. the shrinkage of the sample collected by Watts was 4.7 per cent, and when fired at 1,350° C., 14.1 per cent. The tensile strength of the dried material was 18 pounds per square inch.

When introduced into the porcelain mixture and dried at 110° C. the shrinkage was 3.2 per cent, and when fired at 1,350° C., 13.3 per cent. The fired product had a translucency of .71, an absorption of 5.6 per cent and a color of grade 3. The transmitted light was cream-colored. Under the usual glazes the tint assumed was a very pale green.

13. BILLINGS PROSPECT

Near Franklin

D. M. Billings, Franklin, N. C.

A few hundred yards northeast of the Kasson Mine is a tunnel on land belonging to Mr. D. M. Billings of Franklin. It was originally dug for mica, but is reported to have penetrated good kaolin. The tunnel has caved so that it is impossible to enter it. The dump at its mouth consists of rock fragments and books of mica, but no kaolin. It is possible that this is one of the outlying openings of the Kasson Mine.

15. FRANK PROSPECT

Near Dean

At the Frank prospect¹, three miles northeast of Franklin, near Dean, a dike of kaolinized pegmatite strikes west. It varies from 12 to 15 feet in width. It has been opened by shafts and a tunnel. The material exposed is sandy, but it yields 31 per cent of a white kaolin, of a refractory value above 1,730° C. The color of this, when fired, was of grade 3 and its tensile strength when dried at 110° C. was 18 pounds per square inch. Dried at 110° C. it shrank 5.4 per cent, and fired at 1,350° C. its shrinkage was 15.1 per cent.

The porcelain mixture made up with this kaolin shrank 3 per cent when dried at 110° C. and 13.2 per cent when fired at 1,350° C. The fired product possessed a translucency of .63 and an absorption of 4.9 per cent and a color of grade 3. The transmitted light was cream-colored. Under the raw lead and fritted glazes the body assumed a pale green tint.

16, 17, 18. MYERS, SLOAN AND SANDERS PROSPECTS

Near Franklin

The Myers prospect² is two and three-fourths miles north of Franklin and one-half mile southwest of the Sloan deposit. It is opened by small pits for a distance of 25 feet. The maximum width of the de-

¹Watts, A. S., L. c., p. 132.

²Watts, A. S., L. c., p. 133.

posit is 12 feet, but it has been penetrated only five feet in depth and consequently the character of the kaolin could not be determined.

The Sloan prospect is about midway between the Myers and Sanders prospects, about three miles north of Franklin. The deposit developed by a single open cut 50 feet above the Little Tennessee River is eight to ten feet wide, strikes northeast and dips 80° northwest. The dike is completely kaolinized, but it contains much fine quartz, a narrow quartz band along its hanging wall and much stained mica near its foot wall. A sample¹ yielded 30 per cent of kaolin with a refractory value above 1,730° C.

The Sanders prospect² is three and three-fourths miles north of Franklin and one-half mile northeast of the Sloan prospect. The dike exposed here when Watts visited the property strikes north 20° west and its visible kaolinized portion was about 20 feet wide. It was clearly defined by quartz bands along its walls, and by seams of partly decomposed pegmatite 8 to 15 feet wide. (See also description of Ferguson property, below.) It had been opened by a tunnel 120 feet long from which was taken a sample, which when washed yielded 29 per cent of kaolin with a refractory value above 1,730° C.

Mr. Watts reports the kaolins from the Sloan and Sanders properties and the porcelain mixtures containing them to have the following properties:

Kaolins	Sanders	Sloan
Color, after firing.....	Grade 3	Grade 3
Tensile strength at 110° C., per square inch.....	14 lbs.	22 lbs.
Shrinkage at 110° C.....	4.5%	6.4%
Total shrinkage when fired at 1350° C.....	13.8%	15.2%
Porcelain Mixtures		
Shrinkage at 110° C.....	3.4%	3.2%
Total shrinkage when fired at 1350° C.....	13.5%	12.3%
Translucency of fired mass.....	.69	.69
Absorption of fired mass.....	5.3%	7.1%
Color of fired mass.....	Grade 3	Grade 3
Color of transmitted light through fired mass.....	Cream	Cream
Color under raw-lead and fritted glazes.....	Pale green	Pale green

14. FERGUSON EXPLORATION

Near Franklin

J. W. Ferguson, Waynesville, N. C.

The Ferguson property is about four miles northeast of Franklin, near Watauga Creek. The property, which is probably the same as the Sanders prospect, has been explored by a tunnel running

¹Watts, A. S., L. c., p. 141.

²Watts, A. S., L. c., p. 140.

northeast into the side of a ridge. The tunnel cut 95 feet of kaolin in which is a 20-foot horse of partially altered feldspar and streaks of quartz. Near the end of the tunnel is a cross-cut about 50 feet long, all in excellent clay. That on the northwest side of the tunnel contains considerable coarse mica that is probably merchantable. There is also a little feldspar that might also prove of value. Near the end of the tunnel is a shaft 14 feet deep and in the bottom of this a boring 20 feet deep to hard rock. Since the mouth of the tunnel is 45 feet below the top of the ridge it is safe to assume the depth of the kaolinization to be 70 feet.

A sketch showing the distribution of the borings with reference to the tunnel is given in Figure 7. It is evident that they do not outline

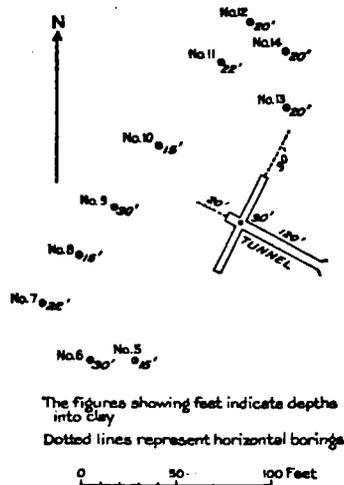


Fig. 7. Sketch map of borings on Ferguson property, near Franklin.

the deposit. On the assumption that it has been proven for a length of 200 feet, a width of 48 feet and a depth of 60 feet, and that 25 per cent of the kaolin in the crude material is recoverable, the amount of refined kaolin obtainable from the deposit is about 6,500 tons.

The kaolin in the tunnel is snow-white and free from grit and visible impurities of all kinds, except the large flakes of mica already referred to. That on the old dump at the mouth of the tunnel is slightly stained.

Since the deposit where exposed is near the top of a slope 70 feet above its base, mining would be comparatively easy. Abundant water is available near by. It could be pumped to the top of the ridge and used for sluicing the crude clay to a washer situated in the valley 70 feet below.

Samples of the crude kaolin (2.06) were tested by the U. S. Bureau of Mines. The results of these tests were as follows:

SCREEN TESTS

Clay No.	20M*	20-65M	65-100M	100-200M	Thru 200M
2.06	0.85	17.48	7.27	11.03	63.36

*20M, 20-65M, etc. refer to the screens used.

MOISTURE PRESENT

2.06—3.31%

WATER OF PLASTICITY AND DRYING SHRINKAGE

Clay No.	Water of Plasticity Per Cent	Volume Drying Shrinkage Per Cent
2.06	39.03	22.58

PER CENT APPARENT POROSITY WHEN FIRED TO DIFFERENT TEMPERATURES

Clay No.	1170° C	1210° C	1250° C	1290° C	1330° C	1350° C
2.06	65.68	31.72	-----	-----	-----	3.02

PER CENT VOLUME SHRINKAGE WHEN FIRED TO DIFFERENT TEMPERATURES

Clay No.	1170° C	1210° C	1250° C	1290° C	1330° C	1350° C
2.06	32.12	25.24	-----	-----	-----	48.63

COLOR WHEN FIRED

Clay No. 2.06 Fair white

SOFTENING TEMPERATURES

Clay No.	Cone	° Cent.	° Fah.
2.06	33½	1730	3146

19. ROCHESTER MICA MINE

Near Franklin

The Rochester Mica Mine¹ is on Lisle Knob, five miles north of Franklin. It is 150 feet east and 25 feet above the fresh pegmatite worked by the Lisle Knob Mica Mine. The Rochester dike is thoroughly decomposed to a high-grade kaolin containing many small iron garnets. It strikes N. 10° E. and dips 80° N.W.; is five to ten feet wide and is uniform in character. It is exposed about 60 feet below the crest of the mountain by a tunnel for 40 feet along its strike. A carefully selected sample contained 44 per cent of kaolin with a refractory value above 1,730° C. Its color after firing was of grade 2 and its tensile strength when dried at 110° C. was 24 pounds per square inch. Its shrinkage at 110° C. was 6.2 per cent and during firing at 1,350° C. was 13.8 per cent.

The porcelain mixture with this kaolin shrank 2.6 per cent at 110° C. and 13 per cent at 1,350° C. The translucency of the fired product was .70, its color of grade 2 and its absorption 5.8 per cent. The transmitted light was cream-colored. With the glazes the color changed to a very pale green.

20, 21. WEST AND BRYSON PROSPECTS

Near West's Mill

The West prospect² is one-fourth mile southeast of West's Mill, on a dike about 25 feet wide that strikes west and dips 80° south. The deposit is opened by two tunnels, 25 and 45 feet below the crest of the hill through which the dike cuts. The West prospect is on the east slope of the hill and the Bryson prospect on its west slope, 75 feet below the crest. At the Bryson locality the dike is said to strike northwest and to dip vertically, but Mr. Watts states that it is undoubtedly the same dike as that exposed on the West property. At the West prospect the pegmatite is not completely kaolinized. A sample taken from it yielded 29 per cent of kaolin with a refractory value of 1,730° C. The composition of the washed material was:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
48.92	36.37	.37	tr	tr	.11	.29	.02	12.70	98.78

The Bryson prospect³ is just west of the West prospect near West's Mill. The deposit is on a dike 15 feet wide, that may be the exten-

¹Watts, A. S., L. c., p. 140.

²Watts, A. S., L. c., p. 145.

³Watts, A. S., L. c., p. 131.

sion of that at the West prospect.¹ It is opened by a tunnel 120 feet long at a level 50 feet lower than the opening at the West prospect. The material is well kaolinized, yielding 38 per cent of kaolin with a refractory value above 1,730° C.

The character of the kaolin washed from samples obtained from these two properties is recorded by Watts as follows:

	Bryson	West
Kaolins		
Color, after firing.....	Grade 2	Grade 3
Tensile strength per square inch when dried at 110° C.....	28 lbs.	24 lbs.
Shrinkage at 110° C.....	6.6%	7.0%
Shrinkage when fired at 1350° C.....	17.3%	18.0%
Porcelain Mixtures		
Shrinkage at 110° C.....	3.4%	3.6%
Shrinkage at 1350° C.....	14.0%	14.2%
Color at 1350° C.....	Grade 2	Grade 3
Translucency after firing at 1350° C.....	.68	.66
Absorption after firing at 1350° C.....	4.5%	4.3%
Color by transmitted light after firing at 1350° C.....	cream	cream
Color under raw-lead and fritted glasses.....	pale green	pale green

An occurrence of kaolin near West's Mill is referred to also by Ries.² It is not known whether it is identical with one of the two described by Watts from the same vicinity or not. It is mentioned as being on the land of George Brindel. The kaolin is stated to be of remarkable whiteness and to burn to a pure white color. It is very fine-grained, free from grit and shows a few scattered white mica scales. It began to fuse at 2,300° F. (1,260° C.) and vitrified at 2,600° F. (1,427° C.).

The crude kaolin had the composition shown in I and the soluble clay substance was calculated to have that shown in II. The proportions of clay substance, quartz and feldspar present in the crude material were estimated to be 83.39 : 14.98 : 1.58.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O K ₂ O	TiO ₂	H ₂ O	Total
I	53.10	33.06	1.18	.38	.08	.83	-----	11.32	99.95
II	45.41	39.56	.86	.45	.09	.03	-----	13.58	100.00

¹In his description of the West prospect Mr. Watts states that the strike of the dike on the Bryson property is N. W. and its dip vertical; but in his account of the Bryson prospect he states that it "has the same strike as that on the West prospect," which is stated to be west.

²Ries, H., N. C. Geol. Survey Bull., No. 13, p. 62, 1897.

The deposit is well up on the slope of a hill which has been reduced by open-cut work to three terraces above the valley level, on the upper two of which mining is going on. The deposit is a series of pockets of rich kaolin separated by narrow lenses and streaks of quartz and by layers of gneiss. In the aggregate, so far as it has been developed it is 900 feet long and 250 feet wide at its broadest, diminishing at one place to 100 feet in width and again widening to 200 feet. It is cut diagonally by a spur of quartz-mica rock 400 feet long and 30 feet wide. West of this there are other deposits 15 to 20 feet wide separated from the larger deposit by several hundred feet of gneiss. Still further west a new deposit about 300 feet long and 100 wide has recently been opened. It is separated from those to the east by 250 to 300 yards of gneiss and is apparently entirely independent of them.

The depth to which kaolinization has progressed differs markedly in different parts of the mine. The maximum depth at which mining has gone is 125 feet from the original surface. This depth has been reached partly by open cuts and partly by shaft. Because of the pockety character of the deposit a reasonable estimate of the reserve is impossible.

The walls of the deposit are not well exposed. They appear to be decomposed Carolina gneiss. The quartz-mica rock that penetrates the large deposit is mainly a mass of quartz streaked with little tongues of pegmatite containing pockets of decomposed feldspar, clumps of mica, small masses of limonitic material that may have come from hornblende or tourmaline and nodules of soft brown and black flaky limonite, and of oxides of manganese.

The deposits at this place evidently represent a large dike and several smaller parallel ones trending about northeast and dipping nearly vertical. The dikes are irregular in width and the feldspar and quartz, in the main one at least, is irregularly distributed.

The crude clay is distinctly cream-colored when first mined but it becomes darker when dried out and exposed to the air. This darkening is apparently due to the oxidation of some iron compound. Besides kaolin the clay contains a great deal of fine white mica and fine sand, a little decomposed feldspar, occasional reddish yellow stains and a few concretionary nodules of mixtures of limonite and psilomelane or wad. These nodules are usually small but many of them have diameters of about an inch. They are readily separable from the kaolin in the refining process, consequently manganese is rarely reported in analyses of the commercial product. The material from different pockets differs in character but a uniform product is main-

tained by careful mixing. The greatest variation in the composition of shipments made between 1890 and 1894 is represented by the following figures:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO	MgO	K ₂ O	Na ₂ O	H ₂ O
.00	.68	.53		.22	.16	.14		.27

Three analyses of the washed kaolin from this mine are available. They represent the production in 1890, 1896 and 1912.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
1	45.86	40.75	1.39	.45	.09	2.83			9.01	100.38
2	46.47	38.82	.89	.28	.25	.75			13.34	100.80
3	46.95	37.73	.15	tr	tr	.18	.60	.05	13.99	99.65

1. Ries, H., N. C. Geol. Survey Bull. 13, p. 61, 1897.

2. A portion of the iron is in the form of FeO. Analysis furnished by Harris Kaolin Co.

3. Watts, A. S., Bureau of Mines Bull. 53, p. 131, 1913. Washed in laboratory.

The crude kaolin passes through agitators, sand wheels, the usual tanks and screens, is pressed and dried and is hauled by horse tram four miles on a narrow guage road to a siding at Dillsboro on the Murphy Branch of the Southern Railway.¹

The output of the plant is about 2,500 tons annually. The kiln is provided with 3,000 feet of 2-inch pipe and the drying sheds have a storage capacity of from 600 to 700 tons.

The Hog Rock kaolin is well known to nearly all the whiteware potters of the middle west. It has been used by them in the manufacture of china and porcelain. It has also been employed in making tile, and is now being tested for use in glass-melting pots. For some years it has constituted a part of the mix from which is made the binder in carborundum wheels.

Samples of the crude kaolin and of the porcelain mixture tested by the U. S. Bureau of Mines gave results as follows:

¹For details of mining and refining methods see Watts, L. c., p. 129, and for a description of the mine in 1896 and of the character of the kaolin then produced, see: Ries, H., N. C. Geol. Survey, Bull. 13, p. 59, 1897.

KAOLIN

When subjected to the screen test:

38.60% was left on the 20 mesh screen.

7.08% was left on the 65 mesh screen.

.65% was left on the 100 mesh screen.

5.80% was left on the 200 mesh screen.

47.87% passed through the 200 mesh screen.

The kaolin is white, short and sandy. It dries well, but the corners of bars tear.

The quantity of tempering water in terms of dry clay is 44.78%.

The volume shrinkage on drying in terms of dry clay is 20.92%.

The calculated corresponding linear shrinkage is 7.49%.

The moisture factor on a dry basis is 1.10.%

The deformation temperature is cone 33½.

When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is ----	37.1%	37.0%	36.81%	30.92%	24.9%
No. of bars tested	3	6	3	3	3
The volume shrinkage in terms of dry clay is ----	16.0%	18.9%	17.88%	24.07%	30.7%
The corresponding linear shrinkage is -----					11.5%
No. of bars tested	3	5	3	3	3
Color-----	Good white	Good white	Very good white	Very good white	Very good white

PORCELAIN MIXTURE

The mixture makes poor bars and works poorly in jig.

The quantity of tempering water in terms of dry mixture is 30.81%.

The volume shrinkage on drying in terms of dry mixture is 16.99%.

The calculated corresponding linear shrinkage is 6.02%.

The modulus of rupture in lbs. per sq. in. is 224.1.

When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is ----	25.7%	25.88%	20.61%	2.49%	.02%
No. of bars tested	3	3	3	3	3
The volume shrinkage in terms of dry volume is --	15%	16.38%	19.22%	39.57%	32.15%
The corresponding linear shrinkage is -----					12.13%
No. of bars tested	3	3	3	3	3
The modulus of rupture in lbs. per sq. in. is -----	2988	3135	3405	6582	4576
Color-----	White, very slightly tinted with cartridge-buff	Same as at 1190°	White, very slightly gray	Same as at 1370°	

B. RHODA MINE

Near Webster

Harris Kaolin Company, Dillsboro, N. C.

The Rhoda Mine is in Jackson County about seven and one-half miles southeast of Dillsboro and five miles southeast of Webster on the south side of the Tuckasegee River opposite the mouth of Cany Fork. The plant in which the clay is filtered and pressed is on the south side of the river, one mile east of Webster. The washer is near the mine.

In his report on this mine Watts¹ declares that the dike which gave rise to the kaolin "cuts diagonally a low ridge and has a northeasterly strike. A broad band of sugar quartz follows the south wall which is very crooked. The extent of the dike has been proven more or less by test pits, but the chief exposure is by a long tunnel driven from the west slope of the hill. This tunnel passes through a broad band of low-grade pegmatite material into a band having a low quartz content," where a shaft was sunk. An average sample from the shaft contained 26 per cent of kaolin. Since Mr. Watts's visit the mine has been sufficiently developed to show two dikes, 20 and 40 feet wide, separated by 40 feet of rock. The deposit is pockety and the character of the clay in the different pockets varies somewhat. There are at present (1918) five active shafts, the products from which are mingled in the flume going to the washers so that the washed kaolin is an average of the whole. In this way the mine's output is kept approximately uniform. It is estimated that the crude kaolin yields about 25 per cent of refined product. The depth of the workable clay is about 50 feet on the lower slopes of the ridge and more than 100 feet on its upper slopes. The estimated reserve is about 10,000 tons in that portion of the deposit that has been developed, but it is plain that its entire extent has not yet been explored.

The crude kaolin is white and somewhat sandy. It contains some fine mica, some sand, a few tiny black specks, large fragments of quartz and partly decomposed feldspar and a few large flakes of muscovite. Near the wall of the western vein are many black streaks of a decomposed mineral; and near the surface red clay streaks and bunches and streaks of soft black manganese compounds spoil the kaolin, but the main mass of the clay is free from stain and dark streaks. Running through the mass, however, are veins of mica imbedded in red clay. Much of the mica is stained and therefore useless, but seven or eight tons of rough material are separated monthly and put on

¹Watts, A. S., Bur. of Mines Bull. 53, p. 156, 1913.

the market as cut and scrap mica. It is noticeable that the better mica and the better clay are found together and that where the mica is poor the kaolin also is apt to be inferior.

An analysis of the washed kaolin as furnished in 1917 yielded¹:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	Ign	Total
46.41	38.46	.07	.00	.07	.17	.42	14.40	100.00

The crude clay is carried to the washer by a flume. The slip is pumped to a pipe which carries it to a flume, through which it flows by gravity to a tank on the top of a hill, then by gravity syphon to the top of another hill one and one-half miles distant and finally by another flume three miles to the settling tanks at the plant on the river. After being pressed it is carried by motor trucks three miles to a siding of the Southern Railway at Sylva. The mine and plant are operated by electricity generated by water power. The capacity of the plant is about 2,000 tons of refined clay annually, with the average amount of labor available. Under pressure it might be increased about 25 per cent. The kiln is supplied with 5,200 feet of 2-inch pipe and provision is at hand for the storage of 600 tons of refined kaolin.²

The users of the Rhoda kaolin are the same as those of the Hog Rock product. Indeed, the kaolin of either mine is often substituted for that of the other.

The results of tests of the crude and washed kaolin and of the corresponding porcelain mixtures as reported by the Clay Testing Station of the Bureau of Mines are:

KAOLIN

The refined kaolin furnished by the plants is gritty. It dries well, but the corners of bars tear slightly. That washed from the crude kaolin dries well and makes good bars.

When subjected to the screen test:	<i>Crude</i>	<i>Refined</i>
There was left on the 20 mesh screen.....	21.82%	.00%
65 mesh screen.....	9.56%	.00%
100 mesh screen.....	1.20%	.00%
200 mesh screen.....	4.43%	1.75%
There passed through the 200 mesh screen.....	62.99%	98.25%
Plasticity.....	Fair	Fair
The quantity of tempering water in terms of dry clay was.....	41.57%	46.51%
The volume shrinkage on drying in terms of dry clay was....	23.47%	23.23%
The calculated corresponding linear shrinkage is.....	8.53%	8.44%
The moisture factor on a dry basis is.....	1.61%	1.658%

¹Furnished by Harris Kaolin Co., analyst: N. B. Pratt.

²In a letter to Mr. A. S. Watts dated Jan. 20, 1921, Mr. S. W. Enloe of the Harris Kaolin Co., states that the Rhoda Mine has now been abandoned.

The deformation temperature is cone.....	34	35
The porosity in terms of burned volume when burned at		
1190° is.....	34.6 %	37.2 %
1250°.....	34.6 %	35.8 %
1310°.....	32.2 %	36.4 %
1370°.....	28.21 %	33.4 %
1410°.....	21.6 %	23.6 %
The volume shrinkage in terms of dry clay when burned at		
1190°C. is.....	18.29 %	20.6 %
1250°C.....	20.9 %	21.6 %
1310°C.....	22.14 %	21.6 %
1370°C.....	25.33 %	25.94 %
1410°C.....	30.5 %	33.1 %
The corresponding linear shrinkage at 1410°C. is.....	11.42 %	12.54 %

The tests on porosity and volume shrinkage are based on three bars at each temperature.

The color of the burned bars was good white in all cases, in a few instances showing a silvery luster in consequence of the presence of small mica flakes.

PORCELAIN MIXTURE
with crude kaolin

The mixture is gritty. It works fairly well in mold and jig, and dries fairly well.

The quantity of tempering water in terms of dry mixture is.....	31.85 %				
The volume shrinkage on drying in terms of dry volume is.....	19.88 %				
The calculated corresponding linear shrinkage is.....	7.13 %				
The modulus of rupture in lbs. per sq. in. is.....	299.9				
When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is.....	26.3 %	25.82 %	21.31 %	11.88 %	.05 %
No. of bars tested	3	3	3	3	3
The volume shrinkage in terms of dry volume is.....	15.8 %	19.42 %	18.83 %	26.58 %	31.64 %
The corresponding linear shrinkage is.....					11.91 %
No. of bars tested	3	3	3	3	3
The modulus of rupture in lbs. per sq. in. is.....	2334	2886	3610	3873	7260
Color.....	Good white	Good white	Very good white		

with refined kaolin

The mixture is short. It makes fair bars, but its jiggering is rather hard. It dries well.

The quantity of tempering water in terms of dry mixture is.....	30.74 %				
The volume shrinkage on drying in terms of dry mixture is.....	17.84 %				
The corresponding linear shrinkage is.....	6.34 %				
The modulus of rupture in lbs. per sq. in. is.....	264.3				
When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is.....	24.1 %	23.51 %	15.56 %	7.03 %	.0 %
No. of bars tested	3	2	3	3	1
The volume shrinkage in terms of dry volume is.....	14.9 %	18.99 %	22.92 %	27.57 %	32.2 %
The corresponding linear shrinkage is.....					12.15 %
No. of bars tested	3	2	2	3	3
The modulus of rupture in lbs. per sq. in. is.....	2771	3679	3630	6765	6463
Color.....	Very good white	Same as at 1190°		White	White

28, 30. ASHE AND HARRIS PROSPECTS Near Webster
Harris Kaolin Company, Dillsboro, N. C.

Two other deposits near Webster have been tested by boring but have not otherwise been explored. One, known as the Ashe property, is about five miles southeast of Dillsboro, in the gap in the mountain about one mile west of Painter. There is nothing known definitely about the deposit except that it was once opened by a pit on a vein reported to be about 15 feet wide. Borings indicated that the area underlain by kaolin is 200 feet by 21 feet and that the deposit contains about 10,000 tons of refined product.

The other explored deposit is about one-half mile south of the plant of the Rhoda Mine on the south side of a hill. The productive area is 400 feet by 50 feet in extent. It contains about 15,000 tons of kaolin like that at the Hog Rock Mine.

The remaining deposits that have been reported as existing in the vicinity of Webster have not been explored. They have been discovered during explorations for mica or have been opened by single test pits or tunnels.¹

27. COWAN PROSPECT Near Webster

The Cowan prospect² consists of a test hole one-half mile southeast of Webster and just west of the old nickel-refining plant. It exposes some high-grade kaolin. The extent of the deposit, however, cannot be determined because of the heavy overburden that covers all the rocks in this vicinity.

24. HALL MINE Near Webster

The Hall Mine³ was one-half mile west of Webster on a low ridge south of the Tuckasegee River. It is on a dike with several stringers varying in width from 10 to 20 feet. The dike strikes N. 40° E. and dips vertical. It is opened by a tunnel 60 feet long that follows its strike and by a shaft 20 feet deep.

Samples taken from across the tunnel yielded 24 per cent kaolin with a refractory value above 1,730° C. Its color after firing was grade 4. Its tensile strength at 110° C. was 18 pounds per square inch and its shrinkage 4.9 per cent. When fired at 1,350° its shrinkage was 12.4 per cent.

The shrinkage of the porcelain mixture with this kaolin was 3.1 per cent at 110° C. and 13 per cent at 1,350° C. The fired mass had

¹In January 1921 the Harris Kaolin Co. was opening a new deposit about one-half mile N. of the Hog Rock Mine. Its extent at that time had not been fully determined.

²Watts, A. S., Bur of Mines Bull. 53, p. 159, 1913.

³Watts, A. S., L. c., p. 159.

a translucency of .68, an absorption of 4.6 per cent, and a color of grade 4, and this color remained unchanged under the glazes. The color of the transmitted light was cream.

31. LONG MICA MINE Near Webster

The Long Mica Mine¹ is four miles southeast of Webster, near the mouth of Wayehutta Creek. Two tunnels and an open cut expose an irregular pegmatite dike that strikes N. 70° E. Its width is 10 to 20 feet, but it is interrupted by inclusions of the wall rock. A sample taken from the richer part of the dike gave 35 per cent kaolin with a refractory value above 1,730° C.. Its color after firing was of grade 2. Its tensile strength at 110° C. was 20 pounds to the square inch, and its shrinkage 4.1 per cent. When fired at 1,350° C. its shrinkage was 11.2 per cent.

When introduced into the standard porcelain mixture the shrinkage of the mass was 3 per cent at 110° C. and 13.8 per cent at 1,350° C. The color of the fired mass was of grade 2, its translucency .69, and its absorption 6 per cent. Under the glazes used the color became a very pale green.

(i) SPRINGER PIT Near Webster

The Springer pit was being operated in 1896, but was evidently abandoned shortly thereafter. A drift had been run into the side of a hill one-half mile northeast of Webster on the land of William Buchanan. This cut a vein of kaolin 25 feet wide striking N. 15° W. About 50 tons of crude material had been removed at the time the prospect was visited by Ries. The clay contained coarse fragments of quartz and feldspar, but was otherwise free from impurities. Its analysis yielded 66.14 per cent clay, 15.61 per cent quartz and 18.91 per cent feldspar. The washed kaolin analyzed 45.78 per cent SiO₂; 36.46 per cent Al₂O₃; 1.36 per cent iron oxides; 13.40 per cent H₂O; and .79 per cent other substances, besides 2.05 per cent moisture. It was white and began to fuse at 2,350° F. (1,288° C.). Analyses of the crude and washed kaolin are given by Ries.²

The Kaolin Manufacturing Company, also, had a mine³ near Webster which was operating in 1900, but it was soon thereafter abandoned.

29. FOREST HILL MICA MINE Near Cullowhee

The Forest Hill Mica Mine⁴ is one and one-half miles southwest of Cullowhee on a dike with a northeast strike and a vertical dip. It

¹Watts, A. S., L. c., p. 159.

²Ries, H., N. C. Geol. Survey Bull. 13, N. C. p. 61, 1897.

³Pratt, J. H., The Mining Industry in N. C. during 1900. N. C. Geol. Survey Ec. Paper 4, p. 28, 1901.

⁴Watts, A. S., L. c., p. 155 and 116.

varies from eight to ten feet in width and is accompanied by many thick stringers. Another dike is exposed by a pit 100 yards further northwest and a natural exposure of kaolin occurs one and one-half miles south, near Speedwell. The dike first referred to is opened by numerous tunnels driven in the search for mica. It exhibits various stages of kaolinization, but its material is free from impurities with the exception of a little quartz.

A sample yielded 31 per cent of kaolin with a refractory value of 1,730° C. The composition of this kaolin and that of the feldspar with which it is associated, which is probably similar to that from which the kaolin was derived, are as follows:

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
Kaolin.....	49.20	37.58	.17	tr	tr	.13	.47	tr	12.53	100.08
Feldspar.....	63.35	20.07	.15	.03	tr	1.11	13.70	tr	.90	99.31

The feldspar consists of 81.8 per cent orthoclase, 9.5 per cent albite, 8.2 per cent kaolinite and .5 per cent quartz.

The shrinkage of this kaolin when dried at 110° C. was 4 per cent and its tensile strength 16 pounds per square inch. When fired at 1,350° C. its color was grade 2, and its total shrinkage 9.7 per cent.

When used in the porcelain mixture this shrank 1.4 per cent at 110° C. and 11.6 per cent at 1,350° C. The color of the fired mass was grade 3, its translucency .73, and its absorption 5.5 per cent. Under the glazes used it assumed a very pale green tint.

22. COLE AND BLACK EXPLORATION

Near Birdtown

A. B. Cole, Bryson, N. C.

The Cole and Black prospect is about seven miles northeast of Bryson and three-quarters mile southeast of Birdtown, about one-half mile east of the Oconalufy River and the Appalachian Railway along its side. The location has been prospected by a series of test pits and several shafts.

The most important opening is a shaft 12 feet in diameter and 27 feet deep, at the bottom of which is a boring of equal depth. The upper 12 feet of the shaft are in clay overburden and a mass of dark schist (probably a micaceous, hornblende gneiss) folded into a syncline that can be traced east for some distance forming a capping above the kaolin and separating it from the clay overburden on the surface. Below the capping the kaolin is continuous to the depth reached by the auger. The kaolin is on the whole very white, but it is streaked

by yellow and red stains near the top. Further down it is said to be free from stains, but only its upper part can now be seen. It contains coarse quartz fragments and is crossed by comparatively large horses of the same mineral. Sand and black mica are also present in it but not in large quantities. The strike of the bottom of the syncline is N. 20° E. and this is also the strike of the kaolin deposit indicated by the lines of pits. Where wall rock can be seen its dip is southeast at a high angle. Three other shafts and a tunnel mark the extension of the dike for at least 300 feet along its strike.

A little farther to the west is another series of openings, consisting of several test pits and two shafts, 20 feet deep and 57 feet deep. The walls of these are not visible but on their dumps is considerable sandy kaolin mixed with quartz and black mica. The deposit marked by this series of openings is parallel to the more easterly one and is evidently on an independent dike.

Although very little definite information can be gathered from the prospecting, it has proven a great quantity of kaolin. It, however, has not shown that the kaolin is in deposits large enough to be of commercial importance. It may exist in a number of small pockets. If systematic borings around the first shaft described above should outline a reasonably large deposit it might be worked economically by tramming 500 yards, sluicing to a washer placed a little below the mine and sluicing by gravity to a settling plant on the river 400 yards distant. It would be necessary to pump water about 200 feet to the mine and to flush the sluice leading to the washer.

(g) AMERICAN LAND AND DEVELOPMENT CO. Near Dillsboro

In the *Mining Industry* for 1903 a deposit was reported¹ as in the process of development by the American Land and Development Company, at Barkers Creek on the Murphy Branch of the Southern Railway. Cross-cuts, pits and shafts had uncovered material of good quality and in considerable quantity. The analysis of a sample by F. F. Hunt gave $\text{SiO}_2=44.66$; $\text{Al}_2\text{O}_3=39.90$; $\text{Fe}_2\text{O}_3=\text{tr}$; $\text{Alk}=.68$ and $\text{H}_2\text{O}=14.28$. Total, 99.52. The Encaustic Tiling Company, of Zanesville, Ohio, tested a small quantity and declared it to be satisfactory for tile and whiteware. Evidently the place was abandoned, for Watts,² ten years later, maps a kaolinized pegmatite three-fourths mile east of Barkers Creek that apparently trends east-west. North of this 200 yards is a lense of pegmatite that had been penetrated by a tunnel.

¹Pratt, J. H., *The Min. Indus. of N. C. during 1903*, p. 60, 1904.

²Watts, A. S., *Bur. of Mines Bull. 53*, p. 128, 1913.

It is exposed in a semi-circular area five feet in diameter and is covered by an arch of gneiss. An abandoned mica mine in which is kaolinized material was also noted at a point one-fourth mile northwest of Barkers Creek. These various occurrences were then known as the Allison prospect. No opinion of the quantity of kaolin present was hazarded.

23. CAGLE GAP MICA MINE

Near Dillsboro

The Cagle Gap Mica Mine,¹ one mile southwest of Dillsboro, in a pit alongside the road opened a 15-foot dike striking N. 20° E. The central eight feet of the dike is poorly kaolinized, but near the walls is good sandy material that yielded 21 per cent kaolin with a refractory value over 1,730° C. Its color after firing was grade 4. Its tensile strength at 110° C. was 16 pounds per square inch and its shrinkage 5.8 per cent. At 1,350° C. the shrinkage was 13.3 per cent.

The porcelain mixture made up with it shrank 2.8 per cent when dried at 110° C. and 12.6 per cent when fired at 1,350° C. The translucency of the fired mass was .65, its color of grade 4 and its absorption 5.4 per cent. The color was unaltered under the raw lead and fritted glazes.

(h) NORTH CAROLINA MINING AND MANUFACTURING Co. Near Sylva

The North Carolina Mining and Manufacturing Company was operating near Sylva prior to 1901. Ries² describes the mine as being two miles south of Sylva on the mountain slope on a dike striking about N. 45° E. and from eight to ten feet wide. The walls are a decomposed gneiss. Even as early as 1896 a 50-foot shaft had been sunk on it and drifts from this had been run in both directions along the vein. That running to the east was 150 feet long with two offsets of 16 feet each; that toward the west was short. The clay was very fine-grained and white. Its analysis is quoted on p. 201. Watts,³ writing about 15 years later, after the location had been abandoned, states that the development comprised two openings on a dike 8 to 18 feet wide. There is a surface cut of 200 feet about 20 feet deep, and on the new surface thus made are five shafts of unknown depth from which mica was taken. Samples taken from the only portion of the vein now exposed gave 26 per cent of white kaolin, with a refractory value above 1,730° C.

In the neighborhood of Beta there are several openings from which kaolin has been taken. In only one case, however, has any been shipped.

¹Watts, A. S., L. c., p. 129.

²Ries, H., N. C. Geol. Survey Bull. 13, p. 53, 1897.

³Watts, A. S., L. c., p. 156.

(j) HARRIS MINE

Beta

This is an old opening on the south side of the railroad about one-half mile west of Beta Station, from which a few years ago the Harris Clay Company obtained a few hundred tons of marketable kaolin. The place, however, was not operated long.

26. LOVE PROSPECT

Near Beta

Another opening, known as the Love prospect,¹ was on a low isolated hill on the north side of the railroad about a mile east of Beta. There are a number of test holes on the hill but they are now filled so that the extent of the deposit cannot be determined. From the character of the material on their dumps it is inferred that the kaolin is of fair quality.

25. ROSS PROSPECT

Beta

The most promising prospect near Beta is about one-half mile southwest of the railroad station on the west slope of the hill south of the railroad. It is now known as the Ross prospect, but is probably the same as the Buchanan prospect described by Watts.² The principal openings are about 400 feet above Scott Creek. They comprise a number of test pits near the top of the ridge extending in a northeast direction, and several tunnels and shafts below these on its west slope. Only one of the tunnels is now open to inspection. This is more than 200 feet long, with a right angled turn about 125 feet from its mouth. Watts reports that it is believed that there are at this place several dikes varying in width from 10 to 18 feet, striking N. 40° E. and dipping 80° N.W. Of the two principal dikes, the upper one has been opened by a few test pits and the lower one, one-eighth mile further west, by shafts 25 feet deep and by two tunnels. The material of both dikes contains lenses of garnet-colored sand mixed with altered biotite. Samples taken from the lower dike yielded 40 per cent kaolin, with a refractory value above 1,730° C. Its analysis gave:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	H ₂ O	Total
46.30	39.06	.20	tr	tr	.11	.60	13.77	100.08

Inspection of the main tunnel shows walls of white clay crossed by many bands of quartzose pegmatite three to four feet wide running in all directions. The pegmatite is pretty thoroughly decom-

¹Watts, A. S., L. c., p. 123.²Watts, A. S., L. c., p. 154.

posed but its content of quartz is so high that much barren rock would have to be removed in mining. In most places the kaolin contains considerable quartz and mica, but some of the masses between the bands of pegmatite consist of nearly solid, dense kaolin. At 200 feet from the mouth of the tunnel is a pit that was not crossed, but the walls beyond exhibited what appeared to be wide clean exposures of clay.

Samples taken from the best pockets differ from those presenting the average of the walls, exclusive of the pegmatite veins, only in that the better samples are almost free from mica and coarse grains of quartz. The average sample is lumpy, while the selected samples are nearly uniform in structure. Both are gritty but the grit in the better sample is so fine as to be scarcely visible, while that in the average sample consists of quartz grains with diameters of one-eighth to one-fourth inch. Moreover, they are aggregated into little groups with mica flakes, forming lumps. Since the cracks between the grains are badly stained by iron compounds that have infiltrated and oxidized, the crushing of the lumps seriously discolours the clay. The better sample is pure white when first taken, but upon standing in a dry atmosphere it turns pinkish or pinkish yellow, possibly through the oxidation of iron salts. The sample contains no visible impurities except tiny grains of sand.

The kaolin washed by Watts from the sample collected by him was grade 3 in color after firing. Its tensile strength when dried at 110° C. was 28.5 pounds per square inch, and its shrinkage 5.4 per cent. Its total shrinkage at 1,350° C. was 13.9 per cent.

When introduced into the porcelain mixture this shrank 3 per cent when dried at 110° C. and 13.1 per cent when fired at 1,350° C. The translucency of the fired mass was .64, its color was grade 3 and its absorption 5.3 per cent. Under the glazes the color assumed a pale green tint.

NORTH CAROLINA KAOLIN COMPANY

Near Addie

In the *Mining Industry of North Carolina* for 1901 mention is made of the mine of the North Carolina Kaolin Company,¹ near Addie, which was in operation during 1900 and 1901 but no information is given as to its exact location nor the quantity or quality of the kaolin in its deposit.

¹Pratt, J. H., N. C. Geol. Survey Ec. Paper 4, p. 28, 1901, and 6, p. 85, 1902.

NATIONAL ABRASIVE MANUFACTURING COMPANY

Near Hall

In the same report¹ for 1900 and again for 1901 reference is made to a kaolin deposit near Hall which had at that time been developed to a slight extent by the National Abrasive Manufacturing Co. It is stated that the clay is of good quality and gives indications of occurring in large quantity.

32. WAYEHUTTA MICA MINE

Near Willets

The Wayehutta Mica Mine² was on the northwest slope of Black Mountain, three miles south of Willets. An irregular dike strikes N. 70° E. with a variable dip. It is 50 feet wide and has a 10-foot horse of wall-rock near its center, and a massive quartz band along its south wall. It is opened by four tunnels of which one penetrates kaolin. The crude material sampled contained 33 per cent kaolin with a refractory value above 1,730° C. and a color of grade 2, after firing. Dried at 110° C. it shrank 4.6 per cent and had a tensile strength of 12.5 pounds per square inch. When fired at 1,350° C. it shrank 12.3 per cent.

The porcelain mixture containing this kaolin shrank 3.6 per cent when dried at 110° C. and 12.6 per cent when fired at 1,350° C. The fired mass had a translucency of .64, a color of grade 2, and its absorption was 7.1 per cent. No change of color was noticeable under the glazes used.

Deposits in Haywood County

There is one active mine in this county and a number of deposits that have been explored to a slight extent, but not sufficiently to warrant a statement as to their commercial importance.

(C) HAND CLAY COMPANY

Near Woodrow

Harris Kaolin Company, Dillsboro, N. C.

The Hand Clay Company's deposit is about one mile southeast of Woodrow on the Pigeon River Division of the Tennessee and North Carolina Railroad, a short branch connecting with the Murphy Branch of the Southern Railway system. Woodrow is six miles south of West Canton, and the plant is connected with the railroad at Woodrow by a narrow gauge tram using cars drawn by mules. The deposit was formerly worked by the Hand Clay Company, with headquarters at Canton, N. C., but the Harris Kaolin Company has recently purchased the entire interests of the former company and is now operating both mine and plant.

¹Pratt, J. H., N. C. Geol. Survey Ec. Paper 4, p. 29, 1901, and 6, p. 86, 1902.

²Watts, A. S., L. c., p. 160.

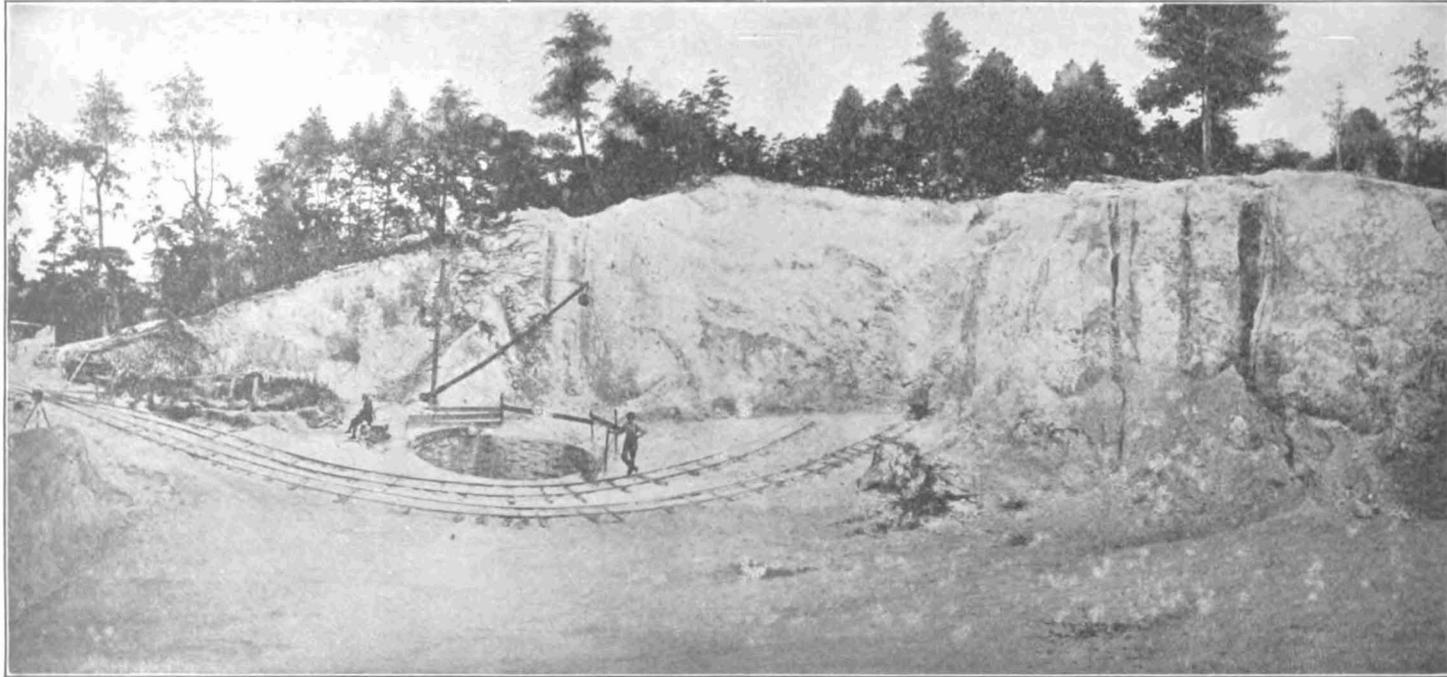


Plate I. Panoramic view of north cut in Hand Clay Company's Mine, near Woodrow, N. C. Showing shaft and horse of rock, which is bordered on both sides by kaolin. (Photograph furnished by Dr. J. C. Hand).

The deposit is well up on a hill slope affording a convenient grade for the sluicing of the crude material to the refining and compressing plant in the valley. It is being worked (in 1918) by two open cuts 20 feet deep and 90 feet wide and by two shafts of which one (in March, 1919) was 92 feet deep and still in workable clay. Explorations consisting of 39 borings distributed over an area 450 feet long and 120 feet wide indicate a workable deposit at least 450 feet by 90 feet with an overburden of not more than five feet. Two tunnels, 55 and 125 feet long cutting across the deposit show a fairly uniform character of clay, broken here and there by streaks of quartz. The thickness of the deposit is not known as the augers penetrated to depths of only 30 feet but most of the holes bottomed in hard clay. The present workings show a thickness of at least 90 feet of workable material. If we assume the average thickness to be 60 feet, the quantity of crude clay available for extraction is 90,000 cubic yards or 135,000 tons. If 20 per cent is saved as refined kaolin the reserve is about 27,000 tons. If the average depth of the workable clay is assumed to be 90 feet, the calculated reserve rises to 40,000 tons.¹ In making this estimate no allowance has been made for the presence of a horse of flint that shows in the two pits and on the map of explorations (Pl. I). This may disappear with depth or it may expand; at present there is no means of inferring its underground extension, though recent shaft work in the south pit indicates that it is "playing out."

The walls of the deposit are not clearly defined, because excessive weathering has broken down the rock so that its character is not now recognizable. Keith,² in the *Pisgah Folio*, maps the country rock as Carolina gneiss, which is in accord with the heavily micaceous weathering products in the overburden. The clay deposit is evidently a dike striking about northeast and dipping about 85° southeast. In general it was pretty uniform in composition, but in one place, at least, it was crossed by a mass of quartz which now appears as a horse in the kaolin. (See Pl. I.)

The crude clay is white and finely granular and free from coarse quartz. It contains an abundance of quartz sand and is discolored here and there by small brownish yellow stains similar to those seen on the sides of cleavage cracks in semi-kaolinized feldspar. In addition there are present numerous very small flakes of white mica and

¹Work accomplished since the Harris Kaolin Company came into the possession of the property makes it seem probable that the reserve is much greater than this, but how much greater is not known. The deposit extends northeast beyond the Hand Company's line, which crosses the northeast end of the present pit, and in this extension is probably a large additional reserve.

²Keith, Arthur, U. S. Geol. Survey Folio 147, 1907.

small crystals and large groups of crystals of the same mineral. Inspection indicates that the yellow stains are most frequent in the neighborhood of the mica plates and especially around the larger crystals and groups of crystals and in the cleavage cracks between their plates where infiltration has carried iron compounds and deposited them. The mica itself within the kaolin appears to be almost wholly unchanged except comparatively near the surface where it has become red and opaque and has lost its elasticity. Even when bleached by treatment with strong hydrochloric acid it remains opaque except on thin edges where it is apparently only slightly doubly refracting, if not entirely isotropic. It has lost completely its homogeneity and has been changed to an aggregate of tiny transparent or translucent particles which in the mass appear white and opaque, as if they were kaolinite. They are, however, so lacking in definite characteristics that their nature has not been determined (compare pp. 25-27). When examined under the microscope there are seen to be present in the kaolin also numerous particles of partially kaolinized feldspar, small plates of reddish yellow decomposed muscovite, flakes of a brown pleochroic mica, that may be biotite, little aggregates of brown-stained kaolinite, and a few highly refracting grains that may be zircon. Some of the biotite flakes contain slender black needles, like the rutile needles frequently seen in the biotite of igneous rocks.

The washed clay as put upon the market consists mainly of kaolinite material in flakes and granules, considerable quartz in irregular grains, a small quantity of kaolinized feldspar, an occasional frayed flake of muscovite, and many fibers of the same material, and here and there a little plate of slightly pleochroic brown mica. The greater part of the kaolinite particles measure about .01 to .03 millimeter in diameter, but they are often grouped together into clumps with diameters of six or eight times as great as the diameters of the individual grains. However, between these grains are others of smaller size, their average diameter being about .004 millimeter. The quartz, mica and feldspar are usually in much larger grains, often measuring .06 to .08 millimeter. A few of the clumps of kaolin are stained yellowish brown and also some of the feldspar.

An analysis of a selected sample of the crude clay gave the result shown in I. In II the analysis is calculated to 100 per cent of the dry material. In III is the analysis of a specimen of the washed kaolin, and in IV this is calculated to 100 per cent of the dry sample.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO	MgO	Na ₂ O	K ₂ O	P ₂ O ₅	Ign.	Moist	Total
I	37.92	28.75	.02	.00	.06	.04	.04	-----		9.68	23.50	100.00 ¹
II	49.58	37.53	.02	.00	.06	.05	.05	-----		12.66		100.00
III	46.41	37.76	.70	.00	.09	.17	.55	.04		13.46	1.10	100.28 ²
IV	46.80	38.07	.71	.00	.09	.17	.55	.04		13.57		109.00

In analysis I it is clear that some one of the constituents was determined by difference, and therefore, if there is an error in the analysis it is not discoverable. On the assumption that all the alkalis are in mica and that the figure for combined water (ignition) is .5 per cent too low, the mineral composition of the selected crude clay is as in line A below. The calculated mineral composition of the washed clay is shown in B.

	Kaolinite	Quartz	Mica	Limonite	Serpentine	Water	Total
A	93.39	5.44	1.01	.02	.14		100.00
B	92.80	2.06	3.72	.71	.19	.48	100.00 ³

During the winter of 1918-19 alterations made in the plant resulted in a slight betterment of the refined product. A complete analysis of the improved product is not available, but determinations of the silica and combined water, made by Mr. J. M. Lindgren of the University of Illinois, yielded 46.70 per cent SiO₂ and 13.72 per cent combined water. These figures indicate that there was effected a slight increase in the quantity of kaolinite in the refined kaolin and a notable decrease in the quantity of quartz present. A microscopic examination of recently refined material confirms this inference. The newly refined material is only slightly gritty. A very little quartz is visible under the microscope and this is in extremely small grains. There are occasional rutile particles present and a few shreds of hydromica. The kaolinite, which naturally makes up the greater part of the mass, is in small plates, a few larger, irregular groups of plates and a fair number of worm-like aggregates. The material is much more uniform in grain than that refined before the changes were made—the large grains of quartz, mica and feldspar that were present in the earlier product (p. 79) being almost entirely absent from the recent product.

¹Analyst: N. P. Pratt. Atlanta Ga. Aug. 1917. Furnished by Harris Kaolin Co.

²Analyst: Geo. Steiger. U. S. Geol. Survey. July 14, 1919. Sample obtained from kiln, August 1918

³Including .04% P₂O₅.

The plant which is near the mine is well equipped with the usual washing and filtering apparatus. Its production during the past few years has been at the rate of 2,400 tons of refined kaolin annually; but with abundant labor it is thought the output might be doubled. Changes made in the plant during the winter (1918-19) may reduce its capacity to a slight extent, but the quality of the output has been improved. These changes consist in the lengthening of the mica troughs to 700 feet and the replacement of 100-mesh sieves by six others of 130-mesh. The kaolin is heated by 8,782 feet of 2-inch pipe and storage space is provided for six cars of dry kaolin.

The clay from this mine has been used in making china, porcelain and other types of whiteware. It is introduced into mixtures of imported and other domestic clays to the extent of 2½ to 15 per cent. Letters from the Bureau of Standards under dates of December 5, 1917, and March 6, 1918, declared it to be of good grade for pottery purposes. When burned to cone 8 the material was still a very excellent white. The sample submitted was fine, as much as 94.61 per cent passing the 300-mesh sieve. When introduced in the proportion of 28 per cent into a porcelain mixture and fired in the biscuit to cone 8 and in the glaze to cone 4 a vitrified body of "a very satisfactory white resulted."

The results of tests recently made by the Clay-testing Station of the Bureau of Mines upon the washed kaolin and the corresponding porcelain mixture were:

KAOLIN

When subjected to the screen test:

.0 was left on the 20 mesh screen.

.02% was left on the 65 mesh screen.

.04% was left on the 100 mesh screen.

.60% was left on the 200 mesh screen.

99.34% passed through the 200 mesh screen.

The kaolin is white. It is not very plastic, but makes good bars.

The quantity of tempering water in terms of dry clay is..... 47.5 %

The volume shrinkage on drying in terms of dry clay is..... 28.91%

The calculated corresponding linear shrinkage is..... 10.75%

The moisture factor on a dry basis is..... 1.56%

The deformation temperature is cone 34.

THE KAOLINS OF NORTH CAROLINA

When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is-----	39.4 %	39.4 %	37.67%	31.4 %	27.2 %
No. of bars tested	3	3	3	3	3
The volume shrinkage in terms of dry clay is-----	17.1 %	19.3 %	19.66%	27.3 %	31.0 %
The corresponding linear shrinkage is-----					11.63%
No. of bars tested	3	3	3	3	3
Color-----	Very good white		Same as at 1190°		

PORCELAIN MIXTURE

The porcelain mixture shows little plasticity, is hard to mold and jiggers with difficulty. It dries well.

The quantity of tempering water in terms of dry mixture is-----	33.41%
The volume shrinkage on drying in terms of dry mixture is-----	20.96%
The calculated corresponding linear shrinkage is-----	7.54%
The modulus of rupture in lbs. per sq. in. is	231.9

When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is-----	27.4 %	25.43%	22.89%	4.97%	.05%
No. of bars tested	3	3	3	3	3
The volume shrinkage in terms of dry volume is--	16.1 %	19.72%	17.79%	30.48%	32.42%
The corresponding linear shrinkage is-----					12.27%
No. of bars tested	3	3	3	3	3
The modulus of rupture in lbs. per sq. in. is-----	2359	3937	3115	4316	6680
Color-----	Very good white	As at 1190°	White	White	White

There are no other kaolin deposits in Haywood County that are more than prospects. Of these, however, there are five, three of which are southwest of Canton and the other two near Waynesville.

33. HERREN PROSPECT

Near Hazlewood

J. P. Herren, Waynesville, N. C.

One of the two deposits near Waynesville is well up toward the top of a spur at the southwest end of Lickstone Mountain, on the property of J. P. Herren of Waynesville, about four and one-half miles south of this city and three and one-half miles southeast of Hazlewood. There are several openings on the property, but they are now filled with debris and difficult to study. The largest was so made that it furnishes a vertical section 12 feet long that originally exposed a surface 12 feet high of which 7 feet was kaolin. The lower portion of the section is now covered by fallen material. That part now visible shows an

almost horizontal contact between mica schist and a very quartzose stained kaolin that exhibits the structure of a pegmatite. It is cut by little quartz stringers and contains masses of decomposed black mica, flakes of decomposed white mica and sharp-edged fragments of quartz. (See sketch, Fig. 9.) Other openings a few hundred yards south of this show the same cap rock and the same kind of kaolin. At a distance of about 12 feet from the foot of the cliff in the larger

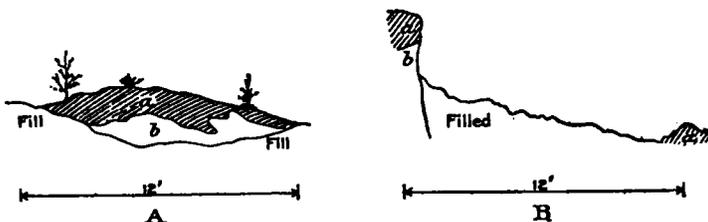


Fig. 9. Sketch illustrating relations of kaolin and rock at the Herren pit.

A. Vertical wall. a. Schist
B. Cross-section. b. Kaolin

pit is an exposure of mica schist which is apparently the foot wall of the dike. If this is so both foot and hanging are very flat, and their contacts with the dike are very irregular. When the pit was opened a little mica was taken from near the foot wall. No kaolin was mined nor were any tests of its quality made. Samples obtained from that portion of the vein now exposed would give no fair idea of its value. (See also pp. 25-27.)

The deposit is not very near the railroad but there is abundant water in the vicinity for sluicing.

35. KINSLAND MINE

Near Clyde

The other prospect near Waynesville, the Kinsland Mine, is evidently an old mica mine.¹ It is nine miles northeast of Waynesville, just beyond the bridge over Pigeon River. It was opened by a number of shafts and tunnels on a dike 75 feet wide divided by several lenses of only partly decomposed pegmatite. The masses of kaolin between these are from six to eight feet wide and they have a high quartz content. The dike strikes N. 40° E.

A sample collected by Watts from one of the shafts gave 27 per cent of kaolin with a refractory value of 1,670° C. Its analysis yielded:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	BaO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
50.64	35.57	.25	tr	tr	.07	.08	1.70	.03	11.90	100.24

¹Watts, A. S., Bur. of Mines Bull. 53, p. 153, 1913.

The color of the washed kaolin, after firing, was grade 5. Its shrinkage at 110° C. was 4.4 per cent and its tensile strength 8 pounds per square inch. When fired at 1,350° C. the shrinkage was 9.8 per cent.

Introduced into the porcelain mixture the shrinkage of this was 1 per cent at 110° C. and 13.6 per cent at 1,350° C. The translucency of the fired mass was .76, its color grade 5 and its absorption 2.6 per cent. Under the glazes used its color showed no change.

The three prospects that have been described as being in the neighborhood of Canton were developed to such a slight extent that their exact locations cannot now be identified.

36. SONOMA PROSPECT

Near Woodrow

The Sonoma¹ prospect has already been referred to in the description of the Hand Mine. In 1907 it consisted of a single pit 15 feet deep on the top of a ridge three-fourths mile south of Sonoma. The kaolin exposed by the pit was white and very little surface-stained. It was mixed with a moderate amount of fine quartz and a little mica. The size of the deposit was not determined, but it was thought to have a northerly strike.

34. RETREAT PROSPECT

Near Woodrow

Another prospect, of which nothing further was ever reported, was on Flora Creek, about one-half mile from its mouth where it enters the west fork of Pigeon River, near Retreat.² Here in 1907 the kaolin had been exposed by three small pits on opposite sides of a little ridge. Two of the pits are in a north-south line directly across the foliation of the associated gneiss. This was taken to indicate that the strike of the deposit is in that direction for a distance of at least 200 feet. The kaolin, like that at Sonoma was mixed with quartz and a little mica, and was of a clear white color.

37. RHODARMER PROSPECT

Near Canton

A third prospect³ in this neighborhood is referred to several times in the reports on the mining industry of North Carolina as being two miles southwest of Canton on the land of J. B. Rhodarmer, but its more exact location is not recorded. The kaolin is reported to be of good quality and apparently in quantity, since it has been penetrated by a shaft to a depth of 18 feet.

¹Keith, Arthur, L. c., p. 7, 1907.

²Keith, Arthur, L. c., p. 7, 1907.

³Pratt, J. H., N. C. Geol. Survey Econ. Paper 6, p. 86, 1902.

Deposit in Madison County**39. SETH FREEMAN PROSPECT** Near Marshall

In Madison County but one prospect is recorded. This is the Seth Freeman prospect¹ on a dike 100 feet wide on Trail Branch of Sandy-Mush Creek, four miles south of Marshall. The strike is N. 40° E. and dip 20° S.E. The dike consists of alternate layers of semi-kaolinized pegmatite and wall rock.

A sample that had the appearance of fine white sand contained 37 per cent kaolin. Watts¹ classes it as semi-kaolinized feldspar.

Deposit in Henderson County**38. VALENTINE PROSPECT** Near Etowah

G. H. Valentine, Hendersonville, N. C.

Mr. G. H. Valentine reports a deposit of kaolin close to the west bank of French Broad River, in Henderson County, one and one-fourth miles north of Etowah. It is known to be from 50 to 75 feet wide and more than 10 feet deep, but its length has not been determined. Several small excavations have been made in it, and the grade for the public highway cuts it. Most of the clay is white, but in some places it is pink or salmon colored. The deposit is a few hundred yards from the river, and about 50 feet above it, and is near a mountain brook that might furnish all the water needed in mining. Connection with Etowah on the Toxaway Branch of the Southern Railway is by a road two miles long which is used for heavy hauling by trucks to within a distance of one-fourth mile from the deposit.

The sample furnished by Mr. Valentine is a white gritty powder, that becomes only slightly sticky when moistened with a little water. When shaken with water the mass rapidly separates into a sediment and a thin fluid of a very pale gray, almost white color. The sediment consists of small sharp-edged transparent quartz grains and larger masses of grains that are cemented by kaolinite, particles of material stained by limonite and a few fragments of other substances some of which are organic. The unwashed powder is composed of comparatively few small kaolinite flakes, fragments of rosettes and worm-like aggregates of the same mineral, many clear, colorless quartz fragments, flakes and groups of grains and a few particles that may be partially kaolinized feldspar. A few of the quartz grains are large, measuring about .3 millimeters in their longest dimensions, but the diameters of most are between .05 and .07 millimeters.

¹Watts, A. S., L. c., p. 118.

The sample is mainly a fine quartz sand with a comparatively small proportion of kaolinite. Whether it is residual or sedimentary in origin cannot be determined from its appearance. If sedimentary, its components have not been carried far, since the quartz grains show little or no evidence of rounding. The material is in an area underlain by Henderson granite which "upon complete decay . . . produces a yellowish or reddish clay, which is frequently leached out nearly white. This is mixed with sand and fragments of rock on the mountain sides and is of no great depth."¹ It is possible that material of this kind partly assorted by water would result in a product resembling the sample, which is very much like the samples from Richmond and Montgomery counties in this State and from near Abbeville in South Carolina.

Deposits in Buncombe County

Only two deposits of kaolin have been explored in this county, and neither has shown promise of being of commercial value.

41. DILLINGHAM PROSPECT Near Jupiter Mrs. A. B. Dillingham, Weaverville, N. C.

On the Dillingham property, four and one-half miles northwest of Weaverville and about two miles south of Jupiter, on Flat Creek, is a deposit of kaolin the character of which is not known. The deposit is now covered by soil and the land above it is under cultivation.

40. SNIDER PROSPECT Near Asheville

A second deposit is reported by Watts² as existing on the north bank of the French Broad River, about three and one-half miles northwest of Asheville. It is known as the Snider prospect. It consists of a dike eight to ten feet wide broken by several horses of rock. It strikes N. 30° E. and dips 75° S.E. The clay is sandy and it carries a large quantity of fine white mica, but since it is exposed to a depth of only 16 feet the sample probably does not represent the true character of the deposit. Other dikes in the vicinity indicate the presence of other deposits.

The crude clay yields 9 per cent of fine mica and 24 per cent of white kaolin, of a refractory value above 1,730° C. The color of the fired kaolin is of grade 3. Its tensile strength when dried at 110° C. was 24 pounds per square inch. Its shrinkage at 110° C. was 4.2 per cent, and at 1,350° C., 14 per cent.

¹Keith, A., U. S. Geol. Survey Folio No. 147 (Pisgah), p. 4, 1907.

²Watts, A. S., L. c., p. 120.

The shrinkage of the porcelain mixture made with this kaolin was 3 per cent at 110° C. and 12.8 per cent at 1,350° C. The fired mass had a translucency of .67, a color of grade 3 and an absorption of 4.8 per cent. Raw lead and fritted glazes do not affect its tint.

Deposits in Yancey County

The kaolin openings in Yancey County consist of two operating mines, several promising explorations and a number of slightly developed explorations. The working mines (in 1918) were the Wilson and Wyatt mines near Micaville. The Job Thomas Mine on the north slope of Chestnut Mountain was operating in 1918 but it was abandoned early in 1919. The crude kaolin from the first two mines was shipped from the settling plant at Lamonti on the Black Mountain Railroad. That of the Job Thomas Mine was shipped from the plant at Intermont on the Carolina, Clinchfield and Ohio Railroad.

The locations of all the known deposits in this county are shown in Figure 10.

In 1920 preparations were being made by the Harris Kaolin Company to develop a new property near Lindsay.

D. WILSON MINE

Near Micaville

Harris Kaolin Company, Dillsboro, N. C.

The Wilson Mine is one mile southwest of Micaville and the settling plant one mile northeast of the same village. The mine is operating two open cuts on the same deposit, with one shaft in each. Watts¹ states that the dike on which the mine is opened varies in width between 30 and 100 feet and that it has been proven for a distance of about 700 feet by numerous shafts and tunnels. A sample obtained from a tunnel yielded him 28 per cent of kaolin.

There is nothing of special geological interest to be seen in the present pits. The overburden is the usual red clay and its thickness is only from three to eight feet. Except for the thin veneer of overburden around its top the walls of the pit are almost entirely in kaolin. At one place rock shows for a few feet but otherwise only white clay is visible. From the present development it appears probable that the deposit varies in width between 18 and 75 feet and that the merchantable kaolin is from 30 to 50 feet deep. Its strike is N. 60° E. and its dip about 85° S.E.

The kaolin is very light cream-colored. It contains fine flakes of white mica, sand, quartz fragments and a little biotite that prevents

¹Watts, A. S., L. c., p. 147.

the separation of the fine white mica as a commercial product. On the other hand there are many streaks and isolated clumps of coarse white mica scattered through the mass, and from these are saved about \$100 worth of sheet and punch mica monthly. An analysis of the washed kaolin made in 1914, when the mine was first opened, gave the results¹ in line I. In line II the same result is calculated on the basis of material dried at 212° F.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ , FeO	CaO	MgO	Na ₂ O	K ₂ O	Loss on Ign.	Moist	Total
I	42.89	36.62	.10	.00	.00	.09	tr	12.28	8.22	100.00
II	46.53	39.91	.11	.00	.00	.09	tr	13.38	-----	100.02

The Wilson clay has been used with success in the manufacture of china and semi-vitreous porcelain of all types. About 15 per cent usually goes into the mix with six or seven other clays in the manufacture of semi-vitreous ware and a little less in that used in the manufacture of table china, the major portion of the mix being English china and English ball clays, aside, of course, from flint and spar.

The crude clay is trammed to the washer, which is situated about 300 feet from the mouth of the pits, and at a little lower level. After emerging from the washer the slip passes through three sets of sieves of 90, 100 and 110 meshes and is sluiced one and one-fourth miles to the settling plant at Lamonti on the Black Mountain Railroad. Both plant and washer are run by electric power generated at the plant. The capacity of the plant is about 400 tons monthly, but this is rarely reached because of scarcity of labor. The capacity of the kiln is two cars and there is storage for 30 cars of dry kaolin.

At the time of his visit, when the mine was little more than a prospect, Watts collected a sample from the best developed tunnel on the property. This kaolin when washed had a refractory value above 1,730° C. Its color, when fired, was grade 2. Its tensile strength, after drying at 110° C. was 24 pounds per square inch and its shrinkage at 110° C. was 4.2 per cent. When fired at 1,350° C. it shrank 13.2 per cent.

Introduced into the porcelain mixture this shrank 3.2 per cent at 110° C. and 13.6 per cent at 1,350° C. The color of the fired mass was grade 2, its translucency .72 and its absorption 4.3 per cent. Under the glazes used it exhibited a very pale green tint.

¹Analysis made by N. P. Pratt. Courtesy of Harris Kaolin Company.

E. WYATT MINE

Near Micaville

Harris Kaolin Company, Dillsboro, N. C.

The Wyatt Mine is a new opening about one mile northeast of Micaville. It is across the stream from the Lamonti plant where the output of the mine will be prepared for shipment.

In September, 1918, the mine consisted of several openings on the side of a hill about 600 feet south of the Lamonti plant and about 100 feet above it. Toward the east end of the property are two veins separated by 50 feet of rock. About 600 feet southwest of the eastern opening, which is a shallow pit, the two veins unite and form a single one 70 feet wide. In a tunnel a short distance south of the pit a width of 35 feet of kaolin is exposed. It contains streaks of mica and of red-stained material and is intersected by a nearly horizontal horse of red clay. At the end of the tunnel the kaolin fingers out in thin stringers, but 34 feet beyond there is more kaolin which is said to be 22 feet wide. According to Mr. Hise, the superintendent of the property, these two veins unite 300 feet southwest of the tunnel into a single wider vein. He states that the system of veins can be followed 1,100 feet. The kaolin is covered by four feet of overburden and the average depth of the workable clay, as revealed by borings, is 42 feet. In some places the depth to hard rock is 60 feet.

Only about 10 carloads of clay had been washed to September, 1918, but preparations were being made for systematic operation. The washer is on the hill near the mine. The slip is sluiced down to the plant at Lamonti where it is mixed with that from the Wilson Mine. The mixed kaolin is to be the standard commercial product.¹

F. JOB THOMAS MINE

Near Toecane

Intermont China Clay Company, Toecane, N. C.

The Job Thomas Mine has been worked since 1914 by the Intermont China Clay Company, the postoffice address of which is Erwin, Tenn., or Toecane, N. C. The mine is three and one-half miles southwest of Toecane on the north side of Chestnut Mountain. The deposits are pockety and therefore difficult to work, so that it is proposed to abandon the mine as soon as a new source of clay is developed.²

The crude clay is of the same general character as that of the Wilson Mine. It is light cream-colored and contains the usual sand,

¹In a letter to Mr. Watts, written in January, 1921, by Mr. B. B. Royal, Superintendent of operations for the Harris Kaolin Company at Sprucepine, the Wyatt Mine is referred to as only a pocket of white clay that was operated for one year.

²The mine was abandoned early in 1919, and a new mine was opened on Flukin Ridge.

fine mica and red streaks that are found in all the crude kaolin of this district. The overburden consists of from three to eight feet of red clay.

The washer is near the mine. After passing through the usual troughs and screens the slip flows by gravity in a flume two and one-half miles to the compressing plant at Intermont, on the railroad three miles south of Toecane. Here it passes through six sets of 100-mesh screens to the settling tanks, and thence through the kiln and presses to the cars on a short spur of the Carolina, Clinchfield and Ohio Railway. The capacity of the plant is 400 tons of refined kaolin monthly. The storage capacity of the sheds is 30 cars and the capacity of the kiln two cars.

The kaolin from the Job Thomas mine has been used in the manufacture of china. In a few cases it is mixed with other domestic kaolins but more commonly with Florida and English china clays and English and domestic ball clays, especially in the mix used for making porcelain.

(k) CLAY PRODUCTS COMPANY

Near Toecane

Formerly the Clay Products Company operated a pit about 100 yards from the Job Thomas Mine. It was probably on a parallel dike. The deposit was small and pockety. A tunnel traversing it exposed good kaolin, intersected, however, by many schist streaks. The place was never sufficiently developed to prove its value. It was worked a year, producing about 40 tons of refined kaolin that had been washed by hand, and was then abandoned.

Several other prospects in Yancey County are promising as sources of kaolin and a few others are known to exist but have not been thoroughly tested, so that it is not possible to give any safe estimate of their importance.

42. ELIZABETH SMITH PROSPECT

Near Burnsville

Miss M. P. Smith, Asheville, N. C.

Perhaps the most promising prospect is that on the property of Misses E. E. and M. P. Smith of Asheville, N. C., and Mrs. George R. Calvert of New York. The deposit is situated one and one-half miles east of Burnsville, alongside the Black Mountain Railroad. It was formerly worked for mica, during the search for which numerous holes were dug and a shaft 40 feet deep was sunk. The shaft cut three or four feet of overburden and 35 feet of kaolin. It was abandoned because of caving. A tunnel 100 feet long also exposed kaolin. There is abundant water available for use of a mine and washing plant.

Watts¹ in his description of the deposit states that it is on a dike 25 to 35 feet in width, striking N. 20° E. and dipping irregularly. The kaolin incloses lenses of semi-kaolinized material but on the whole the dike is well kaolinized. Tunnels connected by a cross-cut expose nearly the entire width of the dike, six feet of well kaolinized pegmatite adjoining its west wall, nine feet of semi-kaolinized material towards its center and 20 feet of kaolin adjoining its east wall. Test pits indicate that the dike may extend about half a mile.

Samples taken from the tunnel gave 44 per cent of washed kaolin of a very light cream-color and a refractory value of 1,730° C. An analysis of this gave:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	BaO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
45.95	39.20	.05	tr	tr	.03	tr	.50	tr	13.10	98.83

The samples seen by the writer are pure white and contain very little grit. Large lumps break with a distinct cleavage and thus indicate that the part of the dike from which they came was an almost pure aggregate of coarse-grained feldspar. Close inspection reveals a few grains of quartz sand, an occasional flake of fine mica and a rare minute spot of some yellow earthy material. Under the microscope the largest quartz grains seen had diameters of .1 to .15 millimeter. The mica is in very tiny flakes and shreds, with diameters of not more than .025 millimeter. A few stained kaolin clumps and the usual tiny flakes of this mineral were the only constituents noted. The sample is an especially pure kaolin.

Offers have been made to mine the kaolin on a royalty basis, but the amount of royalty tendered was not attractive enough to the owners to warrant them in signing a contract. If the property is worked muscovite may be produced as a by-product.

Watts reports the samples collected by him to have had a refractory value above 1,730° C. Bars dried at 110° C. had a tensile strength of 29.5 pounds per square inch and a shrinkage of 4.4 per cent. Fired at 1,350° C. the shrinkage was 12.9 per cent.

The standard porcelain mixture with this kaolin as a component had a shrinkage of 3.4 per cent when dried at 110° C. and of 14 per cent when fired at 1,350° C. The resulting porcelain had a translucency of

¹Watts, A. S., L. c., p. 127.

.70 and the transmitted light was cream-colored. Tested under the fritted and raw lead glazes it had a very pale green tint.

43. THOMAS EXPLORATION Near Micaville
Harris Kaolin Company, Dillsboro, N. C.

The Thomas prospect is a deposit that is being held in reserve by the Harris Kaolin Company. It has been tested by tunnels and shafts, but has not yet been exploited. It is expected that the clay will be refined at the Lamonti plant. The deposit is about one and one-half miles north of Micaville and about one mile northwest of Lamonti. The dike in which the deposit exists strikes N. 45° E. Watts¹ states that at the time of his visit, there had been driven a tunnel along its strike, at the end of which a shaft had been sunk. Both tunnel and shaft had exposed good kaolin. It was not then possible to determine the width of the dike nor to estimate the size of the deposit. Since that time the place has been more thoroughly explored, revealing two dikes 60 and 175 feet wide and at least 1,000 feet long. The various shafts and tunnels on the property have uncovered good kaolin containing a little sand and white and black mica and crossed by streaks of red mica, which is apparently of the proper size and in sufficient quantity to be of commercial importance at greater depths. The deposits are also penetrated by horses of rock. The overburden varies in thickness from 4 to 12 feet. If half of the clay can be removed the yield of the deposit in refined kaolin may be 50,000 tons.

The kaolin is thought to be of the same quality as that at the Wilson Mine. A flume line from the property to Lamonti has already been surveyed and electric line poles are up but not strung. Water will be pumped from a creek to the mine, 150 feet higher, and the slip will flow to the plant by gravity all the way.

If the property is worked muscovite may be produced as a by-product.

50. YOUNG PROSPECT Near Boonford

Another promising deposit is the Young prospect² three-fourths mile west of Boonford on a dike 30 feet wide, divided in the middle by a 4-foot horse of wall rock. The dike strikes N.E. and dips 85° S. Only a very short distance has been explored along its strike. The portion of the dike northwest of the horse is more profoundly decomposed than its southeast portion. The material is free from impurities "except for a very small amount of garnets and occurring in small

¹Watts, A. S., L. c., p. 147.

²Watts, A. S., L. c., p. 123.

pockets." Samples taken from the walls of a tunnel yielded 22 per cent of kaolin having a refractory value of above 1,730° C. Its color, after firing, was of grade 2. When dried at 110° C. its shrinkage

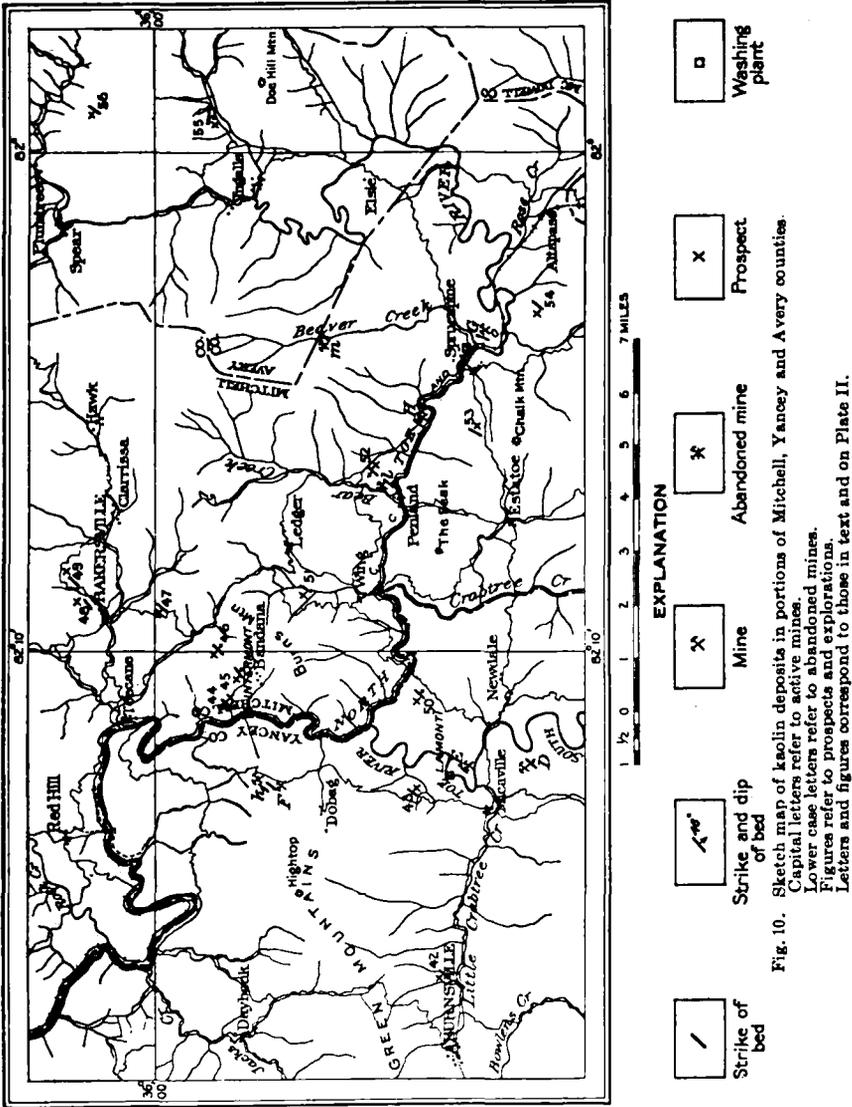


Fig. 10. Sketch map of kaolin deposits in portions of Mitchell, Yancey and Avery counties. Capital letters refer to active mines. Lower case letters refer to abandoned mines. Figures refer to prospects and explorations. Letters and figures correspond to those in text and on Plate II.

was 4.8 per cent and its tensile strength 22 pounds per square inch. Fired at 1,350° C. its shrinkage was 12.6 per cent.

The porcelain mixture made with this kaolin when dried at 110° C. had a shrinkage of 4 per cent and when fired at 1,350° C. a shrink-

age of 12.4 per cent. The fired mass had a translucency of .76, a color of grade 2 and an absorption of 6 per cent. Its color was unchanged under the raw lead and fritted glazes.

DEPOSITS NEAR BURNSVILLE. Of the two¹ remaining deposits one is one-half mile northeast of Burnsville and the other two and one-half miles east of the same village on the south side of the road to Micaville. Both are old mica mines, on the dumps of which kaolin can be seen. Nothing has been learned of the sizes of the deposits.

Deposits in Mitchell County

In Mitchell County there are at present three producing mines; others have been productive at some time in the past. One deposit is being held in reserve for future operation. One other has been explored sufficiently to establish its value and a dozen others are at present only prospects. (For locations see Fig. 10.)

The producing mines are the Sparks and Sprucepine at Sprucepine, and the Flukin Ridge near Toecane. The Snow Creek deposit near Wing is held in reserve.

The Penland Mine, formerly operated by the Harris Clay Company, on the property of Colonel Bailey at Penland is temporarily abandoned.

The Bailey deposit on the Firescald property at Penland has been prospected with promising results.

G. SPRUCEPINE MINE

Sprucepine

Harris Kaolin Company, Dillsboro, N. C.

The present openings of the Sprucepine Mine are situated on the slope of a hill about three-fourths mile southeast of Sprucepine Station on the Carolina, Clinchfield and Ohio Railroad, near the mouth of Beaver Creek. The settling tanks and pressing plant are on the railroad near the station.

The deposits now being operated were first opened in 1916. Before that time the product was obtained from a deposit situated two and three-fourths miles north of Sprucepine near the head of Beaver Creek and was sluiced to the plant on the railroad. The old mine² was on a large lens of kaolinized material that had a general trend toward the northwest. Where worked the dike is about 120 feet wide, but its northeast part for a width of 50 to 70 feet was much richer in

¹Watts, A. S., L. c., p. 126 and 127.

²Watts, A. S., L. c., p. 150.

kaolin than the southwest part. A stringer 25 feet east of the lens has a width of 20 feet and a strike nearly north. The mine was worked to a depth of 75 feet when it was abandoned because no longer profitable.

When washed the crude material yielded 24 per cent of cream-colored kaolin and about $2\frac{1}{2}$ per cent of fine mica, of which 35 per cent was finer than 100-mesh. The kaolin had a refractory value of over $1,730^{\circ}$ C. Its composition is shown in I. In II is the result of an analysis made by N. P. Pratt¹ in 1911. In the sample was 5.4 per cent of mica and free silica.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
I	45.20	38.45	.45	tr	tr	.00	.65	tr	14.80	99.55
II	45.56	38.65	.41	.05	.08	.55	.80	.10	13.90	100.10

The present mine consists of two openings about 500 feet apart. The one to the west (No. 1) has been worked two years and the eastern one (No. 2) since March, 1918. No. 1 opening has been operated by open cut to a depth of 30 feet, and by shafts to a further depth of 55 feet. At this depth dynamite is used to loosen the material and beyond this depth it is unprofitable to mine. The kaolin from this opening is light cream-colored. The overburden composed of red clay and broken rock is from six to ten feet thick. The crude kaolin contains the usual impurities, i.e., quartz, mica, black lumps of manganese oxides and here and there small masses of stained clay. The dike in which it occurs is believed to strike about north, but its walls are not clearly enough revealed to warrant a definite opinion.

In No. 2 pit two shafts were down 30 feet in August, 1918. Both were so wet that pumping was necessary to keep them in condition to be worked. The kaolin obtained from this pit differs from the product of No. 1 in being white instead of cream-colored. It, however, contains the same impurities as the latter but in somewhat different forms. The quartz is in sand grains and also in little round fragments, like pebbles. The appearance of their surfaces suggest that they have been corroded. The mica is in very fine flakes. In the washing of the kaolin the mica is separated from the slip by 100-mesh sieves. About 1,000 pounds are saved daily and sold as ground mica

¹Furnished by the Harris Kaolin Company.

to rubber roofing manufacturers. The other impurities are nodules of soft black material probably manganese oxides, and streaks of yellow clay.

The deposit at this place is probably large. It has not yet been sufficiently developed to uncover distinct walls, nor is it known how deep kaolinization has proceeded. The kaolin, however, is cut by horses of red clay, some of which are 15 feet wide. These probably represent decomposed rock, which may pass into well-defined rock at greater depths than have thus far been reached. Borings around the open pit in which the shafts are situated have shown nothing but kaolin and streaks of yellow or red clay.

The crude clay is cleaned in washers situated near the pits and the resulting slips are sluiced in a common trough to the settling, drying and filtering plant on the railroad. They are thoroughly intermingled before they reach the settling tanks and in this way a uniform product is assured.

Steam power is used at the mine and washers and electricity at the plant. At present the electricity is generated by coal, but it is proposed to build a dam in the Toe River to furnish power with which to produce current for this mine and the Sparks Mine, which is under the same control and for the plants at both mines.

The present capacity of the mine and plant is about 5,500 tons annually, with abundance of labor, but this output is not always reached. With the completion of the dam it may be possible to install labor-saving appliances, in which case the output may be increased. The kiln is furnished with 5,700 feet of 2-inch steam pipe. The storage capacity of the sheds is 1,000 tons.

The users of the Sprucepine kaolin include most of the potters who use also the kaolin from the Hog Rock and Rhoda mines near Webster. In the manufacture of china and whiteware a mixture is made with imported clays and clays from Florida or Tennessee or with clays from both these sources. The Sprucepine kaolin is a favorite among most of the potters who use it. Some of them employ it to the extent of 15 per cent of the total mix and are contemplating increasing the quantity used in order to decrease the amount of imported clay now employed, while others report that they are gradually substituting for it some of the domestic clays from other sources. One potter declares that he uses no imported clay but makes his mix entirely of domestic material. The Sprucepine kaolin is also used in the mix of domestic clays employed in making spark plug and other types of porcelain. Some of the most important manufacturers prefer it to foreign clay

for these purposes, whereas others declare that they could not use it alone for semi-vitreous porcelain, as it would shrink badly. However, practically the whole output of the mine goes to whiteware and electrical porcelain factories.

Tests of the mixed crude products from the two pits and of the mixed washed product, and of the corresponding porcelain mixtures were made by the U. S. Bureau of Mines, with the results tabulated below.

KAOLIN

The washed kaolin is reported to be very gritty, to be short and to make poor bars. That from the crude sample was sandy and possessed little strength. The corners of bars tear.

	<i>Crude</i>	<i>Washed</i>
When subjected to the screen test:		
there was left on the 20 mesh screen-----	21.58%	not
65 mesh screen-----	17.39%	tested
100 mesh screen-----	1.16%	
200 mesh screen-----	57.95%	
there passed through the 200 mesh screen-----	1.95%	
The quantity of tempering water in terms of dry clay was-----	36.69%	43.8 %
The volume shrinkage on drying in terms of dry clay was-----	16.01%	14.11%
The calculated corresponding linear shrinkage is-----	5.65%	4.94%
The moisture factor on a dry basis is 1.317%.		
The deformation temperature is cone-----	32.5----	32
The porosity in terms of burned volume when		
burned at 1190°C. is-----	35.7 % (3)	45.95% (3)
1250°C.-----	37.2 % (3)	46.3 % (6)
1310°C.-----	36.02% (3)	44.87% (3)
1370°C.-----	30.04% (3)	40.82% (3)
1410°C.-----	18.7 % (3)	29.1 % (3)
The volume shrinkage in terms of dry clay when		
burned at 1190°C. is-----	14.7 % (3)	10.7 % (3)
1250°C.-----	15.8 % (3)	10.1 % (5)
1310°C.-----	16.5 % (2)	14.0 % (3)
1370°C.-----	23.25% (3)	22.26% (3)
1410°C.-----	27.6 % (3)	24.5 % (2)
The corresponding linear shrinkage at 1410°C. is....	10.21%	8.94%

The tests on porosity and volume shrinkage were made on the number of bars as indicated in parentheses.

The color of the burned bars made from material washed from the crude sample was silvery white at all temperatures. That of the bars made from the kaolin washed at the plant was very light buff at all temperatures but 1410°, at which it was ivory yellow.

PORCELAIN MIXTURE

The mixture made with the washed kaolin is short and slippery. It molds with difficulty.

	<i>Mixed</i>	<i>Mixed</i>
	<i>Crude</i>	<i>Washed</i>
The quantity of tempering water in terms of dry mixture is---	26.36%	31.36%
The volume shrinkage on drying in terms of dry mixture is----	12.01%	15.92%
The calculated corresponding linear shrinkage is-----	4.17%	5.61%
The modulus of rupture in lbs. per sq. in. is-----	245	92.1
The porosity in terms of burned volume when		
burned at 1190°C. is-----	23.2 % (3)	27.0 % (3)
1250°C.-----	18.49% (3)	18.44% (3)

1310°C.....	10.17%	(2)	15.75%	(3)	
1370°C.....	1.33%	(3)	7.43%	(3)	
1410°C.....	.04%	(3)	.09%	(3)	
The volume shrinkage in terms of dry volume when					
burned at 1190°C. is.....	11.67%	(3)	15.6%	(3)	
1250°C.....	23.01%	(3)	21.95%	(3)	
1310°C.....	28.53%	(2)	20.0%	(2)	
1370°C.....	28.57%	(3)	30.58%	(3)	
1410°C.....	41.5%	(3)	31.57%	(3)	
The corresponding linear shrinkage at 1410°C. is.....					
	16.4%		11.88%		
The figures in parentheses show the number of bars tested.					
The modulus of rupture in lbs. per sq. in. when					
burned at 1190°C. is.....	2037				
1250°C.....	4015		3412		
1310°C.....	4238		3917		
1370°C.....	7735		5845		
1410°C.....	6442		5074		
Color, when burned at.....					
Mixed crude	1190°C. Good white	1250°C. White tinged with light buff	1310°C. Fair white	1370°C. Gray	1410°C. Gray
Mixed washed	Pale ocherous salmon	Light buff	Light buff	Pale olive gray	Pale olive buff

H. SPARKS MINE

Near Penland

Harris Kaolin Company, Dillsboro, N. C.

The Sparks Mine is on the Clinchfield and Ohio Railroad about two miles northwest of Sprucepine and about midway between this village and Penland.

The deposit is on the slope of a hill several hundred feet above the compressing plant which is at the foot of the hill on the railroad. The mine was opened in the early part of 1914 and has been operating ever since. The main vein strikes about north. It is about 100 feet wide and is known to extend 1,000 feet north and south. A spur branches from the main vein to the northeast. This varies in width between 65 and 75 feet and is several hundred feet long. Another vein, 47 feet west of the main vein and parallel to it is 30 feet wide.

The mine is worked in the usual way by open cut and shafts. In August, 1918, there were being operated two shafts about 20 feet deep. Others, from 45 to 50 feet deep, had been abandoned because of water and the hardness of the rock at their bottoms. The overburden of red clay and rock fragments is from six to ten feet thick.

The crude kaolin is white and coarse. It contains abundant rounded quartz fragments, bunches of white and dark mica, quartz stringers and much sand. On the walls of the shafts can be seen coarse quartz, quartz stringers and dark and light mica flakes in bunches forming

streaks through the clay and abundant smaller plates of white mica scattered indiscriminately through the purer kaolin. Much of the darker mica is evidently badly decomposed, and some may itself be partially decomposed muscovite. A great deal of the white mica is fresh and in plates large enough to be of commercial value. This is separated from the kaolin by hand and sold as punch and sheet stock.

The users of the Sparks kaolin (usually known as Penland kaolin because billed from this station) are the same as those of the Sprucepine product, the kaolin from both mines being practically the same in character. (See pp. 94-97.) The potters of whiteware and semi-porcelain employing it in mixtures report that as furnished to them in carload lots, it burns to a very white body. It is used in proportions of 10 to 16 per cent in the dry mix. It is also said to stand a very high fire and to be entirely satisfactory for the purpose to which it is put. The tile manufacturers employ it with New Jersey ball clay, flint and feldspar, and since a uniform quality has been furnished, through the method of mixing the products from different pockets, it has given such good results that it has in some factories replaced completely the imported kaolin.

The capacity of the mine and plant is about 5,500 tons annually, but scarcity of labor has prevented this figure being reached during the past few years. The kiln is provided with 5,400 feet of 2-inch pipe. Storage capacity is provided for 600 tons.

The washed kaolin taken from the shipping stock of the plant and the porcelain mixture made with it were tested by the U. S. Bureau of Mines. The results of the tests are tabulated below.

KAOLIN

When subjected to the screen test:

0 was left on the 20 mesh screen.

0 was left on the 65 mesh screen.

0 was left on the 100 mesh screen.

2.92% was left on the 200 mesh screen.

97.08% passed through the 200 mesh screen.

The kaolin is sandy and short. It dries well without cracking, but bars made from it tear at the corners.

The quantity of tempering water in terms of dry clay is 44.48%

The volume shrinkage on drying in terms of dry clay is 20.20%

The moisture factor on a dry basis is352%

The deformation temperature is cone 32.

	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is	39.8 %	39.7 %	37.97%	35.52%	28.5 %
No. of bars tested	3	3	3	3	3
The volume shrinkage in terms of dry clay is	18.1 %	18.4 %	20.3 %	24.98%	28.0 %
No. of bars tested	3	3	3	3	3
Color	Clear white	White tinged with light buff	Good white	Good white	Good white

PORCELAIN MIXTURE

The porcelain mixture is short and sandy. It worked poorly in mold and jigger, and bars made of it tear on edges and crack badly.

The quantity of tempering water in terms of the dry mixture is	28.5 %
The volume shrinkage on drying in terms of the dry mixture is	16.57%
The modulus of rupture in lbs. per sq. in. is	221.9

	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
When burned at	1190°C.	1250°C.	1310°C.	1370°C.	1410°C.
The porosity in terms of burned volume is	26.2 %	26.01%	20.01%	5.08%	.4 %
No. of bars tested	3	2	3	3	3
The volume shrinkage in terms of dry volume is	15.5 %	19.63%	18.95%	29.84%	31.4 %
No. of bars tested	3	2	3	3	3
The modulus of rupture in lbs. per sq. in. is	2582	3282	3357	6804	5236
Color	White	White tinged with light buff	White	Light pearly gray	Light pearly gray

(1) PENLAND MINE

Near Penland

Col. I. H. Bailey, Bakersville, N. C.

The Bailey property between Bear Creek and Toe River contains two distinct areas underlain by kaolin in the neighborhood of Penland and the Carolina, Clinchfield and Ohio Railroad. One of these was formerly operated as the Penland Mine by the Harris Clay Company of Dillsboro. This is on the railroad about half a mile east of Penland Station. It was abandoned a few years ago. The other is three-fourths mile northeast of Penland and about three-fourths mile from the old Penland Mine. This is known as the Firescald property or the "New deposit."

The western area, comprising the old Penland Mine was worked by the Harris Clay Company for eleven years and previous to this by the C. J. Edgar Company. The area covers 21 acres. The openings from which the clay was taken are on a hill slope about 70 feet above the railroad. The washers were near the pits and the compressing plant at the railroad. The deposit was worked by open cut to a depth of 30 feet and by shafts to a further depth of 60 feet and for a maximum length of 400 feet. At the depth of about 60 feet the rock

became so hard that it had to be dynamited before it could be raised. The overburden was of the usual character and of a very moderate thickness—about six to eight feet.

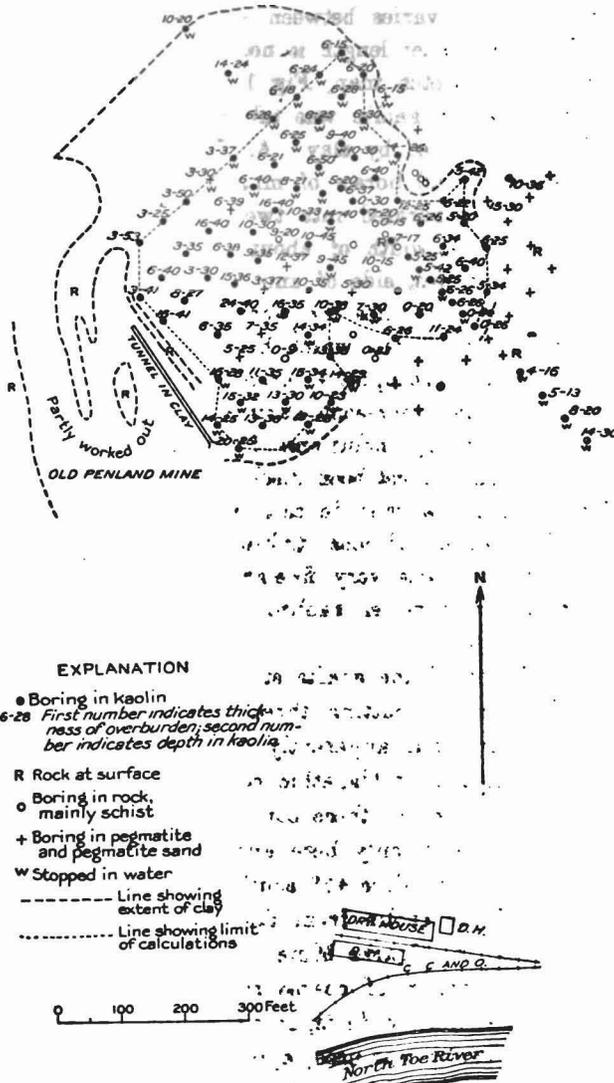


Fig. 11. Map of borings at Penland Mine, Penland.

Although no definite wall can be seen, Watts¹ states that at the time of his visit the southeast wall was well defined, but on the northwest side of the deposit "the dike material grades gradually into a

¹Watts, A. S., U. S. Bur. Mines Bull. 53, p. 148, 1913.

hard, granite-like rock producing little or no kaolin." On the map furnished by Mr. B. B. Westphalen, engineer of the Bailey Lumber Company, owner of the mineral rights, the strike of the eastern wall of the worked deposit varies between northwest and north and the general trend of its greater length is north, turning to the east at its northern end. (See sketch map, Fig 11.) The maximum width of the opening from which kaolin was taken is about 200 feet but this space was not all occupied by clay. As a matter of fact the clay is traversed by several small horses of micaceous schist, and toward the north the deposit is separated into two parts by a central horse of the same schist with a width of about 80 feet. Moreover, the east wall of the pit is the west side of another horse, or at any rate of a strip of schist which separates the worked deposit from another one that has not been opened, but which has been bored sufficiently thoroughly to prove that it occupies a large area. Whether the different deposits are united and represent parts of a single great, branching pegmatite dike, divided by inclusions of rock, or whether they are on independent dikes has not yet been disclosed by the mining operations. Watts, referring to the worked deposit only, described it as occurring in the form of an expanded lens striking N. 25° E. He states that the original pegmatite was very fine-grained and that much of the kaolin retains its structure, as kaolinization has not been sufficiently thorough to destroy it.

On the side of one of the shafts still open are to be seen several small dikes of pegmatite cutting through the clay. They not only retain their structure, but apparently have escaped kaolinization to such an extent that their feldspathic component is still recognizable as fresh microcline. One of these consists of quartz and a partially decomposed feldspar with only here and there a flake of muscovite. It is three feet wide, and dips 45° southeast.

The character of the kaolin from the old Penland Mine was very much like that from the Sparks Mine. The crude clay, however, contained a larger proportion of coarse rounded quartz fragments and pieces of partially kaolinized feldspar and about a like proportion of mica. The refined kaolin was used, apparently with satisfaction, by a number of whiteware and china potteries and by makers of vitrified tile in the Ohio River Valley. It was often substituted for the clay of the Sprucepine and Sparks mines. Like the kaolin of these mines it was not used alone, but in mixtures with Florida, Tennessee and English china clays.

Samples of the crude kaolin taken by Watts from the workings yielded 22 per cent of kaolin with a refractory value of 1,730° C. Its color was of grade 4 when burned at 1,350° C. Its shrinkage when dried at 110° C. was 3.4 per cent and its tensile strength was 12 pounds per square inch. When fired at 1,350° C. its shrinkage was 11.6 per cent.

When made up into a porcelain mixture the shrinkage of the mass at 110° C. was 3.2 per cent, and when fired at 1,350° C. was 13 per cent. The fired material had a translucency of .62, a color of grade 4 and an absorption of 5 per cent. Under the raw lead and fritted glazes the color was changed to a pale green.

Northeast of the old Penland openings and separated from them by a thin wall of rock is the area referred to above as having been explored by borings that cover about four and two-thirds acres. The borings are in lines running northeast and northwest and at intervals of about 50 feet. The overburden averages in thickness not more than seven or eight feet and the depth of the clay penetrated varies from 20 to 45 feet. On the assumption that the average thickness of the clay is 30 feet and that the average yield of commercial kaolin is about 20 per cent of the crude tonnage the productive capacity of the bored area is about 70,000 tons of refined clay. It is probable, however, that the thickness of the kaolinized material is greater than 30 feet and it is possible that the yield of merchantable kaolin from the crude clay might run higher than 20 per cent.

52. FIRESCALD PROPERTY

Near Penland

Col. I. H. Bailey, Bakersville, N. C.

The "New deposit" on the Firescald property is three-fourths mile northeast of the old Penland Mine. It has been tested by boring over about 15 acres by 200 holes at irregular intervals. The reserve on this area is estimated to be about 250,000 tons of commercial clay, on the assumption that the whole area is occupied by kaolin, that the thickness of the deposit is 30 feet and that the crude kaolin will yield 20 per cent of the refined product. A sketch map of the distribution of the borings and thickness of overburden and clay disclosed by them is reproduced in Figure 12. The original was furnished by the owners of the property.

The material from the borings on the Firescald area has been tested by several potters and other parties and has been reported as being

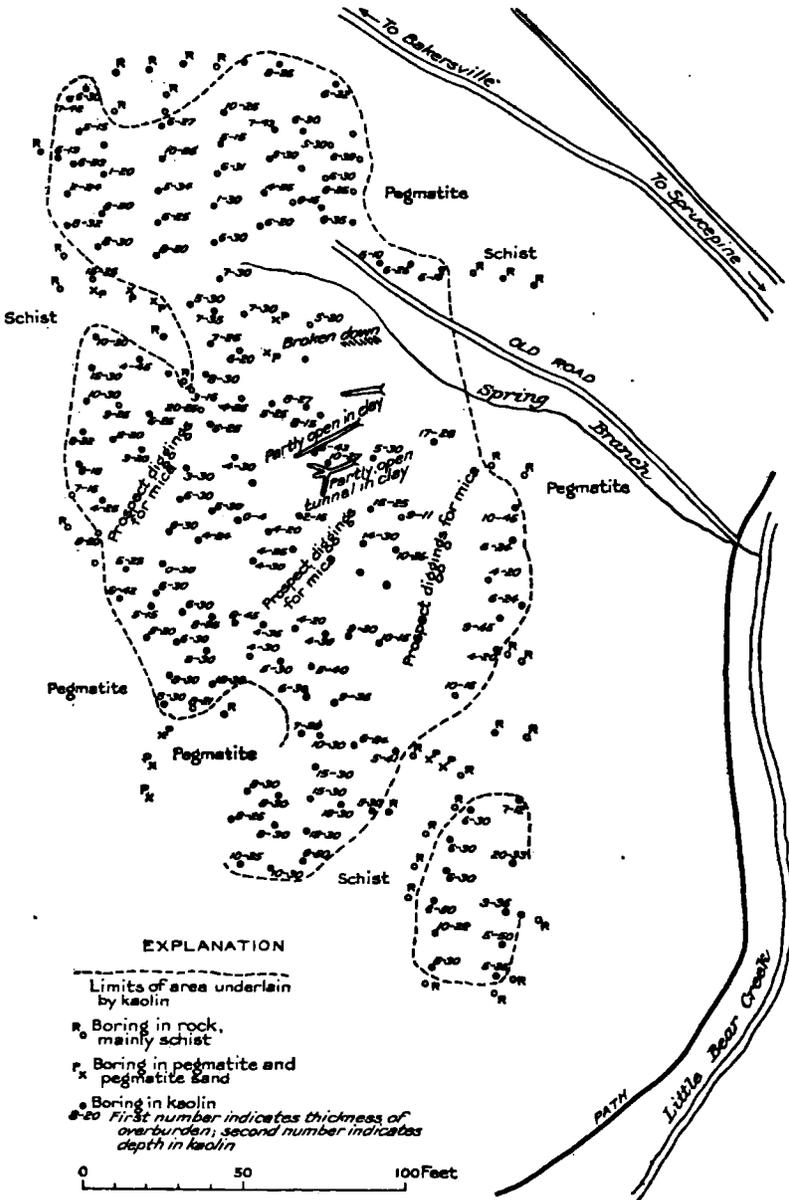


Fig. 12. Map of borings on Firescald property, near Penland.

similar to the Hog Rock kaolin, but of course it has not been tried on a commercial scale.

No properties in Mitchell County other than those described above have ever been worked for kaolin on a commercial scale. There have, however, been many workings for mica and in some of these considerable kaolin of good quality has been encountered. Besides there have been a few explored for kaolin alone.

51. SNOW CREEK DEPOSIT

Near Wing

Harris Kaolin Company, Dillsboro, N. C.

On Snow Creek, about one and one-half miles north of Wing post-office and about two miles north of Phillip Station on the Carolina, Clinchfield and Ohio Railway, is said to be a deposit of kaolin in a dike striking a little east of north and dipping about 75° northwest. It has been tested by a shaft which penetrates excellent kaolin to a depth of 35 feet, and by borings at intervals of 20 feet. Most of the borings go to a depth of 40 feet in clay. The Harris Kaolin Company, owners of the mineral rights, declare that the deposit is at least 300 feet by 150 feet, and the clay is much like that at Sprucepine. The estimated reserve calculated on the basis of a 20 per cent yield is about 20,000 tons of refined kaolin. The slip could easily be delivered at the railroad by a flume.

46. FLUKIN RIDGE PROSPECT AND MINE

Near Toecane

The Flukin Ridge Mine was opened in the early part of 1919, after the writer's visit to the locality. The deposit consists of a series of openings that were originally made in the search for mica. They are on the top of Flukin Ridge, a northwest spur from Burns Mountain, two and one-fourth miles southwest of Bakersville, and about one and one-half miles east of the plant of the Intermont China Clay Company on the Carolina, Clinchfield and Ohio Railroad at Intermont, about two miles south of Toecane, with which it may readily be connected by a flume. Watts¹ describes the area as containing a large number of dikes of partially decomposed pegmatite striking N. 50° E. and dipping 65° S.E. He states that tunnels and shafts had been dug over an area one-half mile long and one-eighth mile wide, and that "at one point a considerable quantity of fine white kaolin is encountered. There are, however, occasional streaks of fresh feldspar and on all sides of the lens there is semi-kaolinized material; these facts justify the assumption that the kaolin is merely an isolated lens and would not justify the equipment of an extensive outfit for handling it, although

¹Watts, A. S., L. c., pp. 108 and 121.

the presence in the neighborhood of other isolated kaolin deposits would justify the sinking of shafts and the removal of this kaolin to a central washing plant."

In 1915 the place was explored for kaolin by extending old tunnels and by boring. At the time of the writer's visit the shafts were inaccessible and the tunnels were accessible for only short distances from their openings. The borings are not mapped. It is, however, reported by representatives of the Intermont China Clay Company that the borings indicate a vein 200 feet wide, including a few horses of rock, and 900 feet long. Near its southwest end a rock wedge penetrates it and splits it into two parts the dimensions of which are not known. The best clay is said to be near the foot wall where it is white, dense and free from streaks of mica. Elsewhere there are streaks of mica and quartz which increase toward the hanging wall. In one of the shafts put down near the center of the deposit fair to good kaolin shows in the walls to a depth of 72 feet, and a boring made in its bottom penetrates 11 feet more of good clay. A cross-cut 46 feet from the bottom of the shaft toward the hanging wall is also all in kaolin. It is estimated that the quantity of refined clay that the deposit will yield is about 75,000 tons. It is proposed to sluice the slip to the settling plant at Intermont, on the railroad. The length of the flume necessary for this would have to be about three and one-half miles.

A sample was taken from the walls of a tunnel, near the hanging wall of the dike where the clay is much interrupted by mica streaks. It is probable that if the deposit is worked mica may be obtained as a by-product.¹

The other properties in this vicinity that might contribute to a washer on a flume line between Flukin Ridge and Intermont are the old Benner Mica Mine, the Sink-hole Ridge prospect and the P. H. Howell prospect. The first two are on Sink-hole Ridge, three miles southwest of Bakersville and about three-fourths mile southwest of Flukin Ridge. Neither of these places was seen. Watts, however, visited them and describes what he saw.

44. HOWELL PROSPECT

Near Toecane

The Howell deposit² is on a dike occupying the crest of a ridge three miles south of Toecane. Its strike is N. 45° E. and its dip 80° N.W.

¹The property was taken over by the Harris Kaolin Company in June, 1919, and opened at the old shaft referred to above. A washer, operated by electricity, has been erected on the site. The crude kaolin, which is quite sandy, is passed under two sand wheels and through 300 feet of mica troughs and then is flumed to the settling plant at Intermont on the railroad, where it is pressed. The yield is from 17 to 20 tons daily of No. 2 product. After operating it about a year and a half the company is now (February, 1921,) expecting to abandon the site.

²Watts, A. S., L. c., p. 157.

The width of the dike varies from 8 to 18 feet. Its kaolinization is on the whole well advanced, but there are present some only partly decomposed lenses. The wall rock is a brown gneiss.

A sample taken from across the dike yielded 31 per cent of kaolin of a refractory value of 1,710° C., and a color, when fired, of grade 2. When dried at 110° C. its tensile strength was 17 pounds per square inch, and its shrinkage 3 per cent, and when fired at 1,350° was 12.7 per cent.

The porcelain mixture with this kaolin as a component shrank 3.4 per cent when heated to 110° C. and 13.1 per cent when fired at 1,350° C. The fired mass had a color of grade 2. Its translucency was .69 and its absorption 5.9 per cent. Under the raw lead and fritted glazes the color became a very pale green.

45. BENNER MICA MINE

Near Toecane

The Benner Mica Mine¹ is on a broad dike composed mainly of semi-kaolinized material. To the northwest, however, a portion of the dike has been isolated from the remaining part by a broad band of rock, and on this portion four shafts have been sunk in a good plastic kaolin. It is reported by those who had worked in the shafts that the width of the deposit was only a few feet and that its length was not known to be greater than a few rods. The strike of the dike is N. 60° E. and its dip 75° S.E.

47. AMERICAN MICA AND MINING COMPANY

Near Bakersville

The American Mica and Mining Company opened a mine for mica on the brow of a hill one mile south of Bakersville and two and one-half miles southeast of Toecane.² It is in an isolated lens of kaolinized pegmatite 12 feet wide striking northeast. A shaft 300 yards farther to the southwest exposes five or six feet of clay. Otherwise the deposit has not been developed. Borings show no dike material between the openings. The clay is of good quality, but is evidently in too small quantity to be of value.

48, 49. MCKINNEY PROSPECTS

Near Bakersville

The Aaron McKinney prospect³ is on a dike three-fourths mile northeast of Bakersville and three miles east of Toecane. The dike is 30 feet wide, but is divided by two horses of rock six or eight feet thick. The dike is known to extend 300 feet in a northeast direction and to dip nearly vertical. This is thoroughly kaolinized, but it con-

¹Watts, A. S., L. c., pp. 117 and 121.

²Watts, A. S., L. c., p. 121.

³Watts, A. S., L. c., p. 122.

tains many small pockets of stained mica. The deposit has been opened by three tunnels and several test pits. From these a sample was taken which yielded 32 per cent of nearly pure white kaolin, with a refractory value above 1,730° C.

The continuation of this dike was opened as a mica mine by Johnson McKinney, but the shafts are now closed and the character of the kaolin at this point is not known.

The washed kaolin from the Aaron McKinney property had a color of grade 2 when fired. Upon drying at 110° C. it shrank 4.4 per cent, and upon firing at 1,350° C., 12.9 per cent. The tensile strength of the dried material was 28 pounds per square inch.

When made up into a porcelain mixture the shrinkage of the mass was 2.8 per cent at 110° C. and 10.6 per cent when fired at 1,350° C. The fired mass had a color of grade 2. Its translucency was .61 and its absorption 4.25 per cent. Under the glazes the color became a pronounced green.

53. TOLLEY MICA MINE

Near Sprucepine

Two other deposits near Sprucepine might possibly at some future time supply material to the plant at this place. One of these, the Tolley Mica Mine,¹ is on the north side of the Sprucepine-Micaville road, one mile west of Sprucepine. It consists of a dike 25 to 35 feet wide, with numerous stringers. It has been proven for 300 feet and is opened by a shaft, said to be 45 feet deep, and a drift 32 feet long from the 20-foot level.

The material of the dike appears to be uniform in character throughout. It is white but sandy. The crude clay yielded 30 per cent of kaolin with a refractory value above 1,730° C.

An analysis of the washed product gave:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	BaO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
46.35	38.80	25	tr	tr	.03	tr	.41	tr	14.00	99.84

The color of the washed kaolin, after firing, was of grade 2. When dried at 110° C. its shrinkage was 5.4 per cent and its tensile strength 8 pounds to the square inch. When fired at 1,350° the shrinkage was 10.9 per cent.

The porcelain mixture including the kaolin had a shrinkage of 3.4 per cent at 110° C. and 14 per cent at 1,350° C. The translucency of

¹Watts, A. S., L. c., p. 152.

the fired mass was .71, its color of grade 2 and its absorption 7.3 per cent. Under the glazes used the mass acquired a very pale green tint.

54. WISEMAN PROSPECT

Near Sprucepine

The other deposit that has been described¹ as occurring near Sprucepine is two miles southeast of the village on a partly kaolinized dike striking northeast and dipping nearly vertical. "The half adjoining the southeast wall is incompletely kaolinized, but kaolinization of the northwest half is well advanced." The entire deposit, however, is sandy. Adjoining the dike on the southeast is a narrow belt of coarse granite-pegmatite which is apparently unaltered.

The material from the northwest part of the dike yielded 21 per cent of white kaolin, with a refractory value of 1,730° C. The color of the washed kaolin is described by Watts as of grade 2. When dried at 110° C. its tensile strength was 17 pounds to the square inch and its shrinkage was 3.2 per cent. When fired at 1,350° C. the total shrinkage was 11.9 per cent.

The porcelain mixture with this kaolin as an ingredient, when dried at 110° C. shrank 3.8 per cent and when fired at 1,350° C., 13 per cent. The translucency of the fired mass was .76, its absorption 3.7 per cent. Its color is unaltered by the glazes used.

Reserves in Yancey and Mitchell Counties

An estimate of the quantity of available kaolin present in the known deposits of Mitchell, Yancey and neighboring counties is of little value. Undoubtedly there is a large quantity of crude kaolin in the ground. The unknown factor relates to its distribution. It cannot be determined from the slight development of most of the deposits how much of the material can be mined with profit, even under the most favorable condition, since the dimensions of the individual deposits are not known. In the case of the deposits that are now being exploited and of those that have been explored by boring, it may be estimated that the reserve is over 400,000 tons of commercial kaolin. This is a much lower figure than that arrived at by the owners of some of the kaolin properties in this area, but in their estimates it has been assumed that all the kaolin in the ground can be removed, which is not the case.

¹Watts, A. S., L. c., p. 153.

Deposits in Avery County

Only two deposits have been described from Avery County, and neither is known to be important. Both are near Spear which is on the North Toe River, about eight miles north of Sprucepine. Even if they prove to be large they are too far from transportation lines to be of value at the present time.

55. OLLIS PROSPECT

Near Spear

The Ollis prospect¹ is three-fourths mile northeast of Ingalls and about three miles a little east of south of Spear and Plumtree. Its nearest shipping points would be Pineola, six miles to the northeast, and Sprucepine, six and one-half miles to the southwest. The deposit occurs in a broad lens of pegmatite which has been proven for a width of 100 feet and a length of 750 feet along a ridge. Its strike is west and dip 80° south. The material, which is exposed by numerous shafts and tunnels, yielded 36 per cent of kaolin with a refractory value above 1,730° C. and a color, after firing, which Watts describes as of grade 5. The washed kaolin shrank 4.6 per cent when dried at 110° C. and in this condition had a tensile strength of 17 pounds per square inch. The shrinkage when fired at 1,350° C. was 9.6 per cent.

The standard porcelain mixture containing this kaolin showed a shrinkage of 3.6 per cent at 110° C. and 12.2 per cent at 1,350° C. The translucency of the fired mass was .68, its absorption 3.6 per cent and its color of grade 5. This color was unchanged under the raw lead and fritted glazes.

56. WISEMAN PROSPECT

Near Spear

The other deposit, at the Wiseman prospect,² is on Fort Creek, a branch of Three-mile Creek. It is about two and one-half miles southeast of Spear and Plumtree and about five miles west of Pineola, its nearest potential shipping point.

Tunnels and shafts expose a dike 20 feet wide in some places and in others a series of stringer dikes only a few feet wide. The general strike of the main dike is N. 40° E. The material, which varies in its degree of kaolinization, is remarkably free from impurities. It yielded 37 per cent of a very white kaolin with a refractory value above 1,730° C. When dried at 110° C. it shrank 7.4 per cent, and when fired at 1,350° C. 17.4 per cent. The color of the fired kaolin was of grade 1. Its tensile strength after drying was 17.5 pounds per square inch.

¹Watts, A. S., L. c., p. 151.

²Watts, A. S., L. c., p. 153.

The porcelain mixture containing this kaolin shrank 4.4 per cent when dried at 110° C. and 14.4 per cent when fired at 1,350° C. The color of the fired mass was of grade 1, its translucency .72, and its absorption 8.3 per cent. The glazes used did not affect the color.

Deposits in Ashe County

60. SOUTH HARDIN MICA MINE Near Beaver Creek

Watts has referred to the South Hardin Mica Mine,¹ one and one-fourth miles southwest of Beaver Creek as a prospective source of kaolin. The mine was on a dike from six to ten feet wide, striking N. 40° E. and dipping 60° S.E. In the open cut, shafts and tunnel from which the mica was taken is much kaolinized feldspar, but none of it was sufficiently decomposed to be plastic, although it is reported that in the old shafts, now entirely closed by slides, a good grade of plastic kaolin was exposed.

61. JESSE BARE PROPERTY Near Jefferson

Another deposit in this county is known only by its samples. It is on the property of Jesse Bare, Sr., near the mouth of Dog Creek, four and one-half miles east of Jefferson. It has been opened by two trenches two feet deep in solid clay. One trench is ten feet long and two and one-half feet wide, and the other six feet long and four feet wide. The overburden is three feet thick. Mr. Bare writes that the deposit is on top of a flat, smooth ridge, and that it occupies about an acre, to judge by the distribution of the lumps turned up in plowing.

The sample sent is in very hard white granular porous masses that absorb a great quantity of water without disintegrating. Careful examining with a hand lens reveals many transparent colorless quartz grains in a white structureless cement. Here and there a larger quartz grain is embedded in the mass and a few little groups of stained grains. When shaken with water and allowed to stand for a few minutes a sediment settles that consists almost exclusively of grains of quartz and a white opaque material which is taken to be kaolinized feldspar because the particles are bounded by planes, which appear to be the result of cleavage. No other constituents are observable when the crushed kaolin is viewed under the microscope. The quartz grains, which are jagged in outline, vary from .3 to .15 millimeter in diameter. They are comparatively few as compared with the grains of kaolinized feldspar. These are almost nonpolarizing. They are often straight-

¹Watts, A. S., L. c., p. 123.

edged, but occasional grains are subangular. The smallest particles are kaolin plates. They are not very abundant. An occasional wisp of muscovite is noted, but only very rarely.

From the appearance of the material in the hand specimen and under the microscope it is inferred that it is an incompletely kaolinized, very feldspathic pegmatite. Even after being shaken with water for a long time it is only partially disintegrated. Professor Parmelee, after examining the sample, reports that it does not seem to be practicable to treat it by the ordinary washing process.

66. ELLERS AND JONES DEPOSIT

Near Bina

The Ellers and Jones deposit is near the top of a hill about three-fourths mile north of Bina and one-fourth mile east of the Virginia-Carolina Railroad. It is only partially developed by a number of short trenches and small pits, none of which expose the entire width of the vein. The maximum width uncovered by any trench is seven feet. The vein has been traced for about 100 yards, but surface signs indicate a much greater length.

The kaolin at the surface is a pale creamy white. It is uniform in character and nearly free from grit. It was originally a pegmatite cutting schists parallel to their foliation. It will wash easily and yield a large proportion of refined product.

KAOLINS IN THE PIEDMONT PLATEAU

Although all of the kaolin deposits of North Carolina that are now being exploited are in the mountain district, nevertheless there are known to be others in the Piedmont Plateau that may prove to be of commercial importance when they have been thoroughly explored. A few are the result of the alteration of pegmatites. These are similar to the deposits in the mountain district. Others have apparently resulted from the alteration of granites, of schistose feldspathic rocks or of slates. Those derived from slates are of no great importance from the point of view of this report. While some of them may be employed for some of the purposes for which kaolins are usually used, most of them are so impure that they will not burn white. They are referred to in the following pages only when their description is necessary to complete the discussion of certain properties on which white-burning kaolins occur.

The residual kaolins derived from granites and schistose feldspathic rocks are usually less compact than those derived from pegmatites. They are generally fine-grained, powdery and very quartzose. They rarely contain large fragments of quartz, or large pieces of partially

kaolinized feldspar. They cover comparatively broad areas and when derived from schists they often occur as layers between layers of very impure clay or of only slightly decomposed rocks. The dips of the layers may be high or low, depending upon the attitude of the series of rocks of which they are a part. If the original rock layer was thick the thickness of the kaolin will depend upon the depth to which kaolinization has proceeded. If the original layer was thin the resulting kaolin layer must also be thin. In prospecting it is important to determine the thickness of deposits of this kind by actual test or by calculations based upon observations of dip.

The processes by which the granites and feldspathic schists were changed to kaolin were the same as affected the pegmatites, and therefore, they need no special discussion. See p. —.)

Besides the kaolins there are also to be a few deposits of sedimentary clays in the Piedmont area, but they are not white-burning and consequently cannot be employed for the purposes for which kaolins are used.

Kaolins from Pegmatite and Granite

The only kaolin deposits in the Piedmont Plateau that are believed to be derived from pegmatite are in a few old mica mines that have been abandoned, with the exception of one in a tin mine near Lincolnton and a small deposit at Bessemer City. Only that at Bessemer City was visited. A deposit that is believed to have come from granite is also at Bessemer City.

Deposits in Rutherford County

57. ISINGLASS HILL MICA MINE Near Rutherfordton

Only one deposit in Rutherford County was reported by Watts¹ as of possible importance. This is at the Isinglass Hill Mica Mine three miles north of Rutherfordton, where a dike 6 to 50 feet wide has been proven for a distance of one-fourth mile and to a depth of 20 feet along the crest of a low ridge three miles north of Rutherfordton. It strikes N. 20° E. and dips 80° N.W. Its hanging wall is more thoroughly kaolinized than its foot wall, the dike being divided in the middle by a band of sugar quartz one to three feet wide. The clay contains sharp particles of smoky quartz, a few crystals of garnet, and nodules of asbolite or wad.

¹Watts, A. S., L. c., pp. 148, 114.

Material from the west portion of the dike gave 42 per cent of kaolin with a refractory value of 1,730° C., and a color, after firing, of grade 5. When dried at 110° C. its tensile strength was 8 pounds per square inch, and its shrinkage 2.8 per cent. When fired at 1,350° the shrinkage was 11.3 per cent.

Made up into the porcelain mixture the shrinkage was 2.2 per cent upon drying at 110° C. and 12.4 per cent when fired at 1,350° C. The fired mass had a translucency of .64 and an absorption of 8.8 per cent. Its color was of grade 3, and was unaltered under the raw lead and fritted glazes.

Deposits in Cleveland County

From Cleveland County two mica mines have been reported, in both of which is considerable kaolin, but not certainly in sufficient quantity to be of commercial value.

58. GREEN MICA MINE

Near Shelby

The Green Mica Mine,¹ seven miles northwest of Shelby, was worked for mica in 1870 and again in a small way later. The old shafts indicate the existence of a 12-foot wide dike with numerous parallel stringers striking about N. 70° E. and dipping 75° N.W. It is reported that much excellent kaolin was exposed in the shafts, but none was seen, as the workings have all collapsed.

59. TOM BAXTER MICA MINE

Near Fallston

The Tom Baxter Mica Mine,² three miles southeast of Fallston and four miles northwest of Waco, is an old mica mine that was explored by shafts over an area about 40 feet long. The dike on which the work was done can be traced for about 200 feet in a general N. 60° E. direction. Its width is reported to be almost 100 feet. The shaft dumps show considerable very fine kaolin. The workmen formerly employed at the mine state "that at about 30 feet they found kaolin practically free from quartz, and in one shaft reached a depth of 47 feet, but the dike material was so soft and caved so badly that the mine was abandoned."

Samples taken from exposed portions of the dike gave 49 per cent of white kaolin with a refractory value above 1,730° C. This kaolin showed a shrinkage of 4.4 per cent at 110° C., and when dried at this temperature its tensile strength was 8 pounds per square inch. When fired at 1,350° C. it possessed a color of grade 2 and a shrinkage of 12.2 per cent.

¹Watts, A. S., L. c., p. 150.

²Watts, A. S., L. c., p. 149.

The porcelain mixture made up with this kaolin shrank 1.6 per cent when dried at 110° C. and 10.8 per cent when fired at 1,350° C. The fired mass had a translucency of .73. Its absorption was 8.1 per cent and its color of grade 2. This color was unaffected by the glazes used.

Deposits in Gaston County

62, 63. J. A. SMITH PROPERTY

Bessemer City

In Gaston County the only deposits of clay that have been examined are those on the property of Mr. J. A. Smith, Bessemer City. Two openings are inside the city limits. One of these is a shaft 30 feet deep near the railroad station. It is now boarded up, but the walls can be seen to be in white clay underlying an overburden of about seven feet of red clay. The sample, which it is said by Mr. Smith, was taken from the side of this shaft 18 feet from the surface, is a white kaolin that dried into a powdery mass. It contains some sand, a little mica and the usual black streaks. A boring in the bottom of the shaft went down 12 feet further, all in clay. Wells in the vicinity of the shaft all passed through similar clay. Several carloads of material were shipped from these openings, two of which went to a tile manufacturer who made from it a cream-colored translucent product.

About 1,800 feet northeast of the shaft is another opening which is now partially filled. It is a pit showing on its wall a 16-foot band of kaolin which is said to be separated from another band 10 feet wide by a horse of red clay. Mr. Smith declares that he has borings which indicate the existence of a belt of clay 300 feet wide interrupted by horses of clay. The west wall of the visible deposit is apparently a decomposed gneiss as are also the horses of clay. Other walls are not visible. A short distance from this pit borings are reported to have been made that outlined a dike 160 feet wide with walls on both sides. Nearly all the holes that penetrated kaolin showed it to extend to a depth of at least 35 feet. The structure of the clay in the pit suggests a residual deposit. It is crossed by little quartz veins and by streaks of yellow stain. Mr. Smith believes he has proven a series of dikes from 10 to 200 feet wide striking N. 22° E. and dipping vertically. There is no reason to doubt this conclusion though no evidence was at hand to confirm it.

Another deposit, one and one-half miles northeast of the city near Long Creek, is of an entirely different character. It is exposed in a long gully from 10 to 30 feet deep. At the upper end of the gully its floor is over numerous large granite boulders. Further south these become friable and beyond, where the gully becomes deeper, they are

partially disintegrated and covered with a layer of clay. Still further south the gully is deep and clay extends to its bottom. The granite ends in a steep slope over which a little wet-weather stream cascades (Fig. 13). About 100 feet down stream from the last boulder is an exposure of schist which is separated from the granite by a deep deposit of white clay. In the bottom of the gully and in its walls at this place some of the kaolin seems to be sedimentary, but on the whole it presents the texture of the granite, i.e., it contains quartz grains of the same sizes and shapes of those in the granite, a few streaks of black earthy substance that may be some decomposed ferruginous mineral such as biotite, augite or hornblende. The components are arranged like those of the granite, the feldspar of the rock being replaced by kaolin in the clay. The conditions suggest a concentration of kaolin at the base of a granite slope by the washing of the decomposition products of the granite into a depression between granite and schist. The deeper kaolinization of the granite at this point, and the consequent development of the steep slope is probably due to the presence here of the contact surface between granite and schist. Plainly the greater part of the kaolin is a residual deposit, which is the result of the decomposition of granite. Where seen there is an overburden of from six to seven feet of red clay.

A sample of the clay was taken from a hole on the east side of the bottom of the gully and from a strip of its west wall 25 feet long. It is a plastic white kaolin containing grains of quartz, feldspar, white mica, a few specks of black earth and a few yellow streaks.

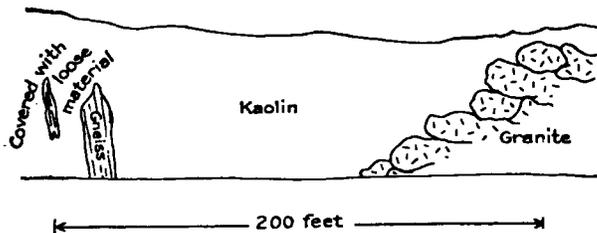


Fig. 13. Longitudinal section of kaolin deposit on Smith property, near Bessemer City.

There is unquestionably a large quantity of kaolin in the neighborhood of this locality, but it is probably irregularly distributed. Whether it is capable of being worked economically cannot be determined without a pretty thorough exploration. Water is abundant for washing and the locality is only one and one-half miles from the Atlanta Branch of the Southern Railway on a road that could easily be put in excellent condition for trucking.

Samples from the shaft (A), near the railroad station at Bessemer City and from the gully one and one-half miles northeast of the city (B) were submitted to the Mining Experiment Station of the Bureau of Mines at Columbus for testing. The sample from the shaft was furnished by Mr. Smith.

The report on the two samples is as follows:

	A	B
When subjected to the screen test:		
there was left on the 20 mesh screen.....	2.220%	44.56 %
there was left on the 65 mesh screen.....	.932%	11.66 %
there was left on the 100 mesh screen.....	.932%	3.65 %
there was left on the 200 mesh screen.....	8.840%	13.07 %
passed through the 200 mesh screen.....	87.080%	27.06 %
Quantity of tempering water in terms of dry clay.....	40.52 %	34.49 %
Volume shrinkage on drying in terms of dry clay.....	4.17 %	13.10 %
Calculated corresponding linear shrinkage.....	1.41 %	4.57 %
The moisture factor on a dry basis is.....	.299%	.585%
The deformation temperature is.....	cone 30	cone 32

Sample A white. It possesses little or no plasticity. It is dusty when dry, and bars made from it chip easily. It lacks clay substance and contains much mica.

Sample B is white and fairly plastic. It contains a good deal of mica, but its dry strength is fair.

When burned at the temperatures.....	1190°	1250°	1310°	1370°	1410°
The porosity of A in terms of burned volume is.....	45.3 %	49.22%	46.41%	28.4 %	18.1 %
No. of bars tested.....	3	3	2	3	3
The volume shrinkage in terms of dry clay is.....	5.1 %	7.58%	13.7 %	29.8 %	36.6 %
The corresponding linear shrinkage is.....					14.1 %
No. of bars tested.....	2	3	3	3	3
The color is.....	White	White	White	White	White
The porosity of B in terms of burned volume is.....	41.9 %	44.2 %	42.02%	27.9 %	25.1 %
No. of bars tested.....	3	5	3	3	3
The volume shrinkage in terms of dry clay is.....	12.2 %	12.71%	16.63%	21.8 %	25.7 %
The corresponding linear shrinkage is.....					9.45%
No. of bars tested.....	3	5	3	3	3
The color is.....	White	White	Light ivory yellow	Light ivory yellow	Light ivory yellow

Deposits in Lincoln County

64. PIEDMONT TIN MINE

Near Lincolnton

At the old Piedmont Tin Mine of the U. S. Tin Company, two and one-half miles southeast of Lincolnton the dikes carrying the cassiterite are fairly well kaolinized. These dikes occur¹ in a belt striking N. 20° E. and dipping 80° N.W.

¹Graton, L. C., U. S. Geol. Survey Bull. 293, pp. 42 and 51. 1906.

The dike rock is a coarse-grained pegmatite composed mainly of quartz, several feldspars, muscovite, a colorless somewhat brittle mica that may be margarite and grains of cassiterite. Between the components are films of iron hydroxides that produce an orange-red stain. All the dike material is more or less kaolinized with the formation of a reddish yellow sandy product in which there are numerous plates of colorless mica, grains of quartz and crystals of cassiterite. Where the original material was nearly pure feldspar the resulting kaolin consists of kaolinite, small scales of mica, a very little quartz sand and a few crystals of cassiterite.

Watts¹ declares that all the dikes contain some good kaolin and that the material in the one known as the "Jake vein" is fairly free from stain. When washed the crude clay from this vein yielded 26 per cent of kaolin, with the composition:

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	TiO ₂	H ₂ O	Total
48.50	37.35	.85	tr	tr	.32	1.02	tr	12.00	100.04

Since the decomposed pegmatite is washed to obtain the tin ore it is possible that it might prove profitable to save the washings and separate the kaolin.

The refractory value of the kaolin washed from the sample collected by Watts was 1,710° C. When dried at 110° C. its tensile strength was 16.5 pounds to the square inch and its shrinkage 4.4 per cent. When fired at 1,350° C. its color was of grade 5 and its shrinkage 8.1 per cent.

The porcelain mixture made with it shrank 2.2 per cent at 110° C. and 13 per cent when fired at 1,350° C. The translucency of the fired mass was .78, its absorption 3.5 per cent and color of grade 5, and this color was not affected by the raw lead and fritted glazes.

Kaolins from Schistose Rocks

Only a few deposits of the white powdery kaolin believed to be derived from schistose rocks have been examined by the writer. Samples of others which were not visited were furnished by the owners of the properties on which the deposits occur. The deposit near Troy was not visited nor were any samples from it seen. But from the descriptions of it given by Ries there is no doubt that it is like some

¹Watts, A. S., L. c., p. 146.

of the deposits that are referred to below. Consequently Ries's description is abstracted (p. 125), in the belief that it furnishes an idea of the character of the material in these other deposits.

Deposit in Catawba County

65. ERVIN DEPOSIT Near Catawba

In Catawba County, on the State Central Highway, three miles east of Catawba village, on the property of E. A. Ervin is a deposit of white powdery clay that has been used locally as whitewash. The clay appears for a couple of hundred yards down the bottom of a stream. Up stream it is reported to be about 30 feet wide. At the lower end the color gradually changes to blue and dark gray.

The sample taken from the upstream end of the deposit is very much like the material from Mr. Valentine's deposit in Henderson County (p. 85). It is a very fine-grained gritty powder composed of spicules and irregular sharp-edged quartz particles rarely over .02 millimeter in their largest diameter and numerous small flakes and fragments of aggregates of flakes of kaolinite. There are occasional quartz grains measuring .1 millimeter, but they are extremely rare. If sedimentary its components have traveled a very short distance, as many of the quartz spicules are extremely slender.

Deposit in Iredell County

67. CASHION AND FURCHES DEPOSIT Near Statesville H. V. Furches, Statesville, N. C.

Only one deposit has been reported in Iredell County. This is along the Charlotte Branch of the Southern Railway one mile south of Statesville on land belonging to Messrs. J. T. Cashion and H. V. Furches. The property is undeveloped, but cuts on the railway and on the highway one-fourth mile west of the railroad expose a white kaolin.

On the east side of the railroad right-of-way a section of about 160 feet is exposed and between this and the track are a couple of shallow pits. The section is in alternating schists and kaolin. At its north end a width of 20 feet of kaolin is shown, followed to the south by 20 feet of quartz, 110 feet of kaolin and finally schists. (See Fig. 14.) The schists are alternating mica schists and quartz-feldspar schists full of garnets. These are interlayered with what appear to be sheared pegmatites. The feldspar in all the schists is kaolinized and one layer between slightly decomposed mica schists consists of a well-defined

kaolin. The strike of the schist series is N. 10° W. and its dip 75° E. East of the railroad schists outcrop here and there, but in a well dug 500 yards east of the rails clay was struck at about 12 feet.

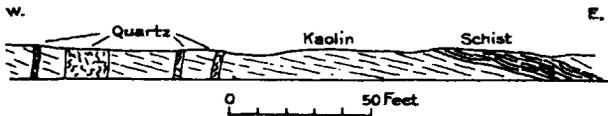


Fig. 14. Sketch illustrating relations of kaolin and schists at Cashion and Furbes deposit, near Statesville.

The clay exposed in the cut north of the schists is very sandy. It contains in addition to the sand tiny flakes of dark and light mica, little masses of soft black material that may be a manganese oxide and little yellow spots that may represent decomposed garnets. The kaolin has an ill-defined structure parallel to the structure of the schists to the south and is crossed by vertical, or nearly vertical, veins of quartz. Most of these are narrow but at the north end of the cut one is 20 feet wide. The schist mass, as one passes north in the cut, appears to disintegrate gradually, changing to layers of red brown clay and white clay, with the white clay becoming more abundant toward the north as though the clay-producing layers became thicker in that direction. Pits near the track show a cleaner and whiter clay than that in the cut. It was from one of these pits that the sample was taken.

It is probable that the clay represents a thick layer in the schist series, but whether it was a feldspathic schist or a sheared pegmatite running parallel to the foliation of the schists was not determined. Nor is the thickness of the kaolin known. It has already been stated that kaolin exists in a road cut about one-fourth mile west of the railroad. Near this place a well was dug passing into white clay at a depth of six feet and continuing in it for 55 feet. Between the well and the railroad are no exposures and no explorations so that it is impossible to determine whether a single layer is continuous through this distance or whether there are several layers separated by schists that are not kaolinized. The distribution of the kaolin is rather widespread. If its origin is as suggested it must occur on the surface in belts striking about north.

The kaolin from a pit at the railroad is white and pulverulent. It contains a comparatively few fragments of quartz, a good deal of sand, very small masses of soft brown clay, an occasional mica flake and a few specks of a soft black substance.

The characteristics of the crude kaolin as reported by the Mining Experiment Station of the Bureau of Mines at Columbus, Ohio, are given below:

When subjected to the screen test:

- 14.2 % is left on the 20 mesh screen.
- 25.56% is left on the 65 mesh screen.
- 6.55% is left on the 100 mesh screen.
- 18.14% is left on the 200 mesh screen.
- 34.55% passes through the 200 mesh screen.

The kaolin is white and fairly plastic. It is rather short but is moldable.

The quantity of tempering water in terms of dry clay is 41.92%
 The volume shrinkage on drying in terms of dry clay is 17.5 %
 The calculated corresponding linear shrinkage is 6.2 %

When burned at	1190°	1250°	1310°	1370°	1410°
The porosity in terms of burned volume is	46.9 %	40.5 %	44.9 %	36.5 %	34.6 %
No. of bars tested	3	3	5	3	3
The volume shrinkage in terms of the dry clay is	9.4 %	16.2 %	11.2 %	18.3 %	23.6 %
The corresponding linear shrinkage is					8.58%
No. of bars tested	3	3	6	3	3
Color	White		White	White	White

The moisture factor on a dry basis is 1.79.

The deformation temperature is cone 33.

Deposits in Richmond County

71. STEELE EXPLORATION

Near Ellerbe

R. L. Steele, Rockingham, N. C.

The only deposits that have been reported in Richmond County are about two and one-half miles northwest of Ellerbe on the Norfolk and Southern Railway near Bostic's Mills. The property on which the clay occurs consists of 38½ acres owned in fee by Robert L. Steele, Sr., and mineral rights on 230 additional acres. When worked a few years ago it was operated under the name of the Steele Kaolin Works with headquarters at Rockingham. As long ago as 1897 Ries¹ referred to openings in kaolin on the property of Mr. Steele, but none of these openings can be identified with those seen by the writer in 1918. However, since it is evident that the clay occurs over a fairly wide

¹Ries, H., N. C. Geol. Survey Bull. 13, p. 65, 1897.

area, it is probable that the conclusions of Ries with respect to the quality of the kaolins seen by him would apply nearly as well to those taken from the openings examined in 1918.

Ries states that the clay appears for a distance of 50 feet in a roadside ditch one mile south of Bostic postoffice, and again on the opposite side of the road at the base of a hill. Between the two is a red clay resulting from the decomposition of a schist. Test pits sunk east of the road disclose a fine-grained clay containing comparatively few angular fragments and scattered stains of iron. Another series of pits one mile further west, across a shallow valley, uncovers another deposit of whiter material. In no case was the overburden more than one and one-half feet thick or the kaolin less than nine feet thick.

The clay from the eastern pits (I) was a fine-grained kaolin with a little coarse grit. It slakes slowly but completely to a fine-grained mass. A workable paste shrank 4 per cent on drying and 9 per cent in burning. Air-dried briquettes showed an average tensile strength of 10 pounds per square inch. Incipient fusion began at 2,250° F., vitrification at 2,500° F., and viscosity at 2,700° F. The burn was to a dense body with a pale yellow tint. A sample from another pit (II) suffered slightly less shrinkage. The average tensile strength of its briquettes was 13 pounds, and incipient fusion began at 2,300° F. In other respects it was like the first sample. The kaolin from the western pits (III) was a somewhat porous, fine-grained white clay with comparatively little grit. In most respects it was nearly like the material from the eastern pits.

Analyses of the crude samples (in the order described) gave:

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Alk	H ₂ O	Moist.	Total
I	70.63	21.81	1.49	.20	.29	1.45	4.04	.08	99.99
II	68.15	19.99	1.86	.13	.16	2.85	4.79	.17	98.01
III	73.70	16.03	1.57	.38	.47	1.90	4.33		98.38
IV	71.12	19.61	2.18	.17	.08	2.48	4.33		99.97

Samples I and III were washed. The first gave 40 per cent of settlings and the second 35 per cent. The washed sample I had the same properties as the crude sample, the analysis of which is given in line IV. Washed sample III was pure white, but it burned to a body with a faint yellowish tint. In all respects the washed material acted like the crude sample, except that its briquettes had an average tensile

strength of only 8 pounds to the square inch. The calculated mineral composition of each of the four samples of which the analyses are given follows:

	I	IV	II	III
Clay substance.....	47.14	54.30	49.30	36.05
Feldspar.....	16.13	1.82	9.20	} 62.33
Quartz.....	36.73	43.85	41.50	
Specific gravity.....	2.41		2.52	2.43

The openings that may be seen now are widely separated. One on a crossroad running east from the main road north from Ellerbe is on a dense gray, massive, sticky clay that contains lines of limonite nodules, most of which are hollow or partly filled with red clay. Other nodules are concretions of quartz fragments, sand grains and flakes of mica cemented into elongate masses about one and one-half inches long and half as thick. Since the clay, where exposed, has a horizontal upper surface it resembles very closely a sedimentary deposit. Close examination of the walls of the pit, however, reveals the presence of a system of cross joints, such as appear in a sheared rock, and a number of tiny quartz veins that intersect the clay in nearly vertical planes. The exposure is too limited to furnish much evidence as to the origin of the clay, but because of the vertical quartz veins and the presence on the main road of rocks that might well be the source of such a clay, it is believed that the gray clay is a residual deposit resulting from the alteration of a sheared clay shale or slate or perhaps a sheared volcanic rock. The hollow limonite nodules might be explained as having been formed during the alteration of the slate to clay and the sandy concretions as having been originally little lenses of sand in the otherwise argillaceous rock. About 20 tons of the crude material was washed in a home-made washer and sold as a filler for cheap cotton goods. The unwashed clay burns gray. It probably would make good stoneware.

On the main road, near Ellerbe, chocolate and ocher-colored clays are exposed in the ditches. They are extremely fine-grained, very slightly gritty and massive, but when broken apart many of the lumps show a distinct schistosity. It is said by Mr. Steele that a little of the yellower variety has been burned and sold as ocher. The clays of both colors are associated with jointed rocks that may be shales or slates as they readily fall apart into lozenge-shaped fragments, some of which consist partly of yellow clay. The freshest rock

that was seen in place is presumably a pale gray clay slate, almost the same color as the gray clay at the pit. Although distinctly slaty it is nevertheless very soft as though a very compact clay.

It is apparent that the country about Ellerbe is underlain by slates or sheared volcanics varying in composition, and that the different colored clays on the road are the results of their decomposition. The gray clay is possibly of a similar origin. It may have originated from a less ferruginous rock than those that gave rise to the colored clays, or during its formation the iron compounds may have been leached out, in part forming the concretions found scattered through it. These concretions when treated with HCl leave residues of white kaolin of the same shapes as the original nodules, indicating that the nodules were not present in the original rock, but were secreted after or during the production of the kaolin.

West of the main road about one and one-half miles west of the pit in the gray clay is another opening on a hill covered with quartz boulders. No rock was seen in place. The pit has partly caved, but in some places around its sides can be seen a very white, compact clay which, when it dries, breaks down into a very fine white powder that is quite gritty. When mixed with water it becomes very pale grayish white. The material, when examined microscopically, is seen to consist mainly of small splinters, and tiny dust-like particles of quartz with diameters of .003 to .02 millimeter and small flakes of kaolin of about the usual size, .004 millimeter. No other constituents were noted, except here and there a shred of decomposed mica. From the nature of the kaolin, its similarity in physical characters (except color) to the yellow and chocolate clays in its neighborhood, and its likeness, to the Overton (p. 127) and Eames (p. 126) clays, it is inferred that it is residual and that it was formed from some rock that occupied a fairly broad area, and not from a pegmatite dike. At Candor and Troy the original rock was probably a feldspathic volcanic. At Ellerbe there may have been a series of volcanics or of alternating slates and volcanics.

Mr. Steele declares that borings about 30 or 40 feet apart over 25 acres penetrated from 0 to 35 feet of sand and clay overburden and found underlying white and colored clays. Some borings found only colored clay, others only white clay, and others mixtures of the two. The holes were not located with the view of determining the areal distribution of either kind, consequently no estimate can be made of the quantity of the white clay available.

Neither one of the pits is now being operated. The eastern pit was worked in 1903, the clay being used mainly for cotton and paper filling. Only a small quantity was marketed, perhaps 150 or 200 tons. It was teamed fourteen and one-half miles to Rockingham. It could now be hauled by truck four miles to Norman and shipped by the Norfolk-Southern Railroad.

A sample of the white clay from the western pit was submitted to the Bureau of Mines for testing. The results of the tests are as follows:

When subjected to the screen test:

- .626% is left on the 20 mesh screen.
- .359% is left on the 65 mesh screen.
- .294% is left on the 100 mesh screen.
- .681% is left on the 200 mesh screen.

98.04 % passes through the 200 mesh screen.

The kaolin is cream colored and it molds with difficulty. Its dry strength is fair.

The quantity of tempering water in terms of dry clay is ----- 27.95%

The volume shrinkage on drying in terms of dry clay is ----- 2.80%

The calculated corresponding linear shrinkage is ----- .84%

When burned at	1190°	1250°	1310°	1370°	1410°
The porosity in terms of burned volume is -----	22.9 %	24.55%	13.82%	2.8 %	.8 %
The volume shrinkage in terms of the dry clay is -----	22.8 %	22.13 %	31.0 %	35.3 %	34.5 %
The corresponding linear shrinkage is -----					13.2 %
No. of bars tested	3	3	3	3	3

The moisture factor on a dry basis is .302%.

The deformation temperature is cone 23.

The surface colors of the burned bars are light buff at the lower temperatures, olive buff at 1,370° and drab at 1,410°. The body colors at the lower temperatures are the same as the surface colors, but in the bar burned at 1,370° the color is pale purplish gray and in that burned at 1,410° a pale Quaker drab.

Deposits in Montgomery County

Three deposits of white clay have been reported in Montgomery County but none have been exploited, though one, that near Candor, is in an old gold mine.

69. UNNAMED DEPOSIT

Near Troy

The first locality in Montgomery County at which kaolin has been reported is in the neighborhood of Troy.¹ It is described by Ries as being four miles west of Troy, and is near the Eames exploration. No account of the method of occurrence of the material is given, but

¹Ries, H., N. C. Geol. Survey Bull. 13, p. 64, 1897.

from the description of its character it may be inferred that its occurrence was similar to that of the Candor and Eames deposits, to be described later. Ries obtained two samples, one a gray kaolin and the other a white one. The darker sample yielded 40 per cent of kaolin upon washing. Both white and dark washed samples burned to a buff color and neither was suitable for the manufacture of whiteware. Since the characters of the Eames and Overton deposits are probably the same as those of the Troy deposits an abstract of Ries's account is given in full.

The dark washed kaolin made into a workable paste with water shrank 3 per cent in drying and an additional 10 per cent in burning. The average tensile strength of air-dried briquettes was 9 pounds per square inch. Incipient fusion took place at 2,100° F., vitrification at 2,300° F., and viscosity at 2,500° F.

The white washed kaolin shrank 3 per cent in drying and 9 per cent in burning. Air-dried briquettes showed an average tensile strength of 10 pounds per square inch. The reaction in the furnace was the same as for the dark variety.

Analyses of the white (I) and the dark (II) kaolins are given as follows:

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Alk	H ₂ O	Moist	Total
I	63.10	23.33	2.97	.15	.09	1.90	7.65	.75	99.94
II	86.03	6.46	2.14	.17	.04	1.00	2.90	.53	99.27
III	90.13	4.99	1.86	.13	.01	1.03	1.93	.48	100.56

The dark washed sample contained 20.83 per cent clay substance, 2.34 per cent feldspar and 76.20 per cent quartz, and the white washed sample 58.92 per cent clay substance, 5.81 per cent feldspar and 35.27 per cent quartz. The specific gravity of the former was 2.32 and of the latter 2.34. The analysis of the crude dark is given in line III.

68. EAMES PROSPECT

Near Mount Gilead

P. M. Eames, Mount Gilead, N. C.

The exploration of P. M. Eames is five miles northwest of Mount Gilead, to the left of Lowder's Ferry road. Very little is known about the deposit. Mr. Eames, judging by the distribution of the outcrops, states that the clay covers about 700 acres. Only a shallow opening two feet deep has been made in it, and it was from this that a sample was taken.

The sample looks very much like that from the Iola Mine at Candor. It is a very fine, gritty, flour-like material of a very pale grayish white color. Mixed with water it becomes buff-gray and exhibits almost no tendency to cohere. After washing carefully in a test tube a fine-grained pale buff residue is left which apparently consists entirely of quartz grains.

The crude material is made up mainly of small quartz grains, with diameters between .02 and .04 millimeter. In addition there are a few particles of rutile, hydromica and stained feldspar and a very few tiny plates of kaolinite. The quartz is in little sharp-edged splinters, in subangular grains, in very irregular shaped particles and in a very few cases in rounded grains. Evidently the material has not been carried far from its source. It may be a residual mass, like that at the Iola Mine from which most of the kaolinite has been removed.

In its present condition the material represented by the sample is not a practical source of kaolin.

70. OVERTON DEPOSIT

Near Candor

A. J. Overton, Candor, N. C.

The Candor deposit is at the old Iola Gold Mine which is two and one-half miles west of Candor and eight miles southeast of Troy. At the mine mineralized quartz veins are associated with a slaty rock which Hafer¹ believes may be a sheared andesite. The kaolin is reported by Mr. A. J. Overton, the owner of the land, as occurring over ten acres under an overburden of about eight feet of sand and gravel. The mine shaft that has penetrated it is 60 feet deep, and there are drifts 100 feet long at its bottom.

The sample furnished is a loose, very light pinkish gray, gritty, flour-like mixture of very fine quartz and kaolin. The few lumps occurring in it are distinctly schistose, as though the original material from which the clay was made was a fine-grained schistose or slaty rock, as, for instance, a sheared felsite.

Mixed with water it forms a distinctly cream-colored paste, and the coarse, gritty residue left after washing the crude material is flesh-colored, and it contains comparatively large iron-stained grains.

Under the microscope the principal constituents visible are rough quartz grains of all sizes from the most minute to those .2 millimeter in length. Perhaps the greatest number have diameters between .05 and .06 millimeter. Besides these are a few white opaque grains with straight edges that may be altered feldspar grains and a fair quantity

¹Mining World. Vol. 28, p. 332, 1903.

of small kaolinite particles of about the size of the smallest quartz particles. Occasionally there is a shred of kaolinite .06 millimeter long but most particles are less than .004 millimeter across.

Prof. C. W. Parmelee of the Ceramics Department of the University of Illinois, to whom a sample of the crude clay was submitted for examination, reports that it gives a residue of 25 per cent sand on a 100-mesh screen. The washed clay is white. When wet it is plastic but the mass is "short." When burned to cone 6 (1,250° C.) it yields a light cream-colored product that is highly absorbent and so soft that it is easily scratched with a knife.

It is noticeable that the washed samples of the three kaolins from Montgomery County contain a great deal of fine quartz, in which respect they differ markedly from the kaolins that are known to have originated by the decomposition of pegmatites. It is probable that all were derived from fine-grained rocks.

Kaolin Resources

The aggregate of all the kaolin deposits in North Carolina is very great. Unfortunately, however, the expense of preparing the material for market precludes the use of many of them because of their small size. So far as now known only a few of them contain sufficient crude material to warrant the construction of the washing plants necessary to fit this for market. From the data now at hand it is probable that there is enough material known to exist to furnish about 625,000 tons of refined product. The annual output of the State is 16,000 tons; consequently the supply is probably sufficient to last 39 years at the present rate of production. But because of lack of labor the production is less than the capacity of the plants to handle it. With plenty of labor the output may be increased 50 per cent. Moreover, as the methods of preparing the kaolin for market are improved, there will unquestionably be an increase in the demand for the refined product and an enlargement of the plants to take care of the increased demand, and the life of the reserve will become correspondingly shorter.

A glance at the map (Pl. II), however, will show that the deposits now known center around a few points, notably Dillsboro, Sprucepine and Micaville. It is possible that the most attractive deposits occur in these areas. It is more probable, however, that the discovery of a few good deposits near these centers has encouraged the search for others in the same neighborhoods, and that this is the explanation of their peculiar distribution. It is known that pegmatite dikes are

scattered rather uniformly through the mountain district. The distribution of the mica openings corroborates this view. There is no reason to believe that the kaolinized dikes are less widely distributed than those that are being worked for mica. But kaolin will not bear as high transportation costs as will mica, consequently the deposits of kaolin to be profitable must be close to the railroad, while deposits of mica may be more distant. There are large areas in the mountain districts that have not been explored for kaolin, because of the difficulty of getting the product to market. It is probable that these areas contain deposits, which, except for the cost of transportation to the railroad, would furnish as profitable sources of kaolin as some of those now being exploited. With the extension of the system of hard roads into remote mountain regions the use of trucks will be more feasible and the cost of transporting the refined kaolin will decrease. Exploration of the mountains will then become a more attractive proposition, and unquestionably, as a consequence, new sources of kaolin will be discovered. It is impossible to make any estimate of the probable amount of material these new sources will contribute to the State's output. It can only be stated that there may be found enough kaolin in deposits now unknown to lengthen the life of kaolin industry several times beyond that indicated by the size of the reserve now known.

Miscellaneous Clays—Sedimentary

During the course of the work on the kaolins the attention of the Survey was called to the existence of what was supposed to be high-grade white clay at a number of different localities. Samples from some of the deposits proved to be kaolin. These have been referred to in preceding pages. From others the samples are of light colored earthenware clay, and from others coarse clay that is of value only as brick clay. All are sedimentary. None of the deposits were visited, so that knowledge of them was obtained only by correspondence. As a matter of record a few of what appear to be the best of the sedimentary deposits are referred to below.

White Clay

GERHARDT DEPOSIT

After the field work on the kaolins and clays of the State was finished a specimen of white clay was received from Mr. Paul Gerhardt from a deposit about 60 miles south of Hemp, Moore County. The material is a very pale cream-colored plastic clay. It contains a few iron stains and numerous rootlets. There is a little fine-grained grit which appears

to be an integral part of the clay and an occasional large grain of sand that may have been washed in from the surface.

Mr. Gerhardt writes that the deposit is a large one, has been proven to a depth of 16 feet and is connected by a good road with the railroad.

Professor Parmelee reports that the sample furnished by Mr. Gerhardt leaves a residue of 5 per cent of sand on a 100-mesh screen. The washed clay is white. When wet it is plastic but very short. For this reason it is unsuitable for use alone in the manufacture of clay products. At cone 6 (1,250° C.) it burns to a light buff color, the body being highly absorbent.

Stoneware Clays

RHODES DEPOSIT

Near Lincolnton

From a number of sources word has been received that there are several white clay deposits in the vicinity of Newton and Lincolnton, Lincoln County, that are workable. Inquiry in Lincoln, however, indicated that the clays referred to are light colored sedimentary clays that are used for making jugs, crocks and other forms of earthenware. The only deposit of which samples were seen is on the property of Mr. D. P. Rhodes, four and one-half miles northwest of Lincolnton, in the bottom land of South Fork River. The clay, when dry, is light grayish buff, hard, and it is stained here and there by reddish brown streaks. It is clearly not a kaolin.

LINEBERGER AND TODD DEPOSIT

Near Mount Holly

Another deposit of nearly the same kind of clay occurs on the property of Messrs. R. E. Lineberger and William Todd, six miles north of Mount Holly, in Gaston County. It is on the second terrace of the Catawba River. The details concerning its extent have not been learned but from the general descriptions of those who have examined it, there can be little question but that it is large. It has been used by local potters in the manufacture of about 100,000 white jugs. The clay is buff color and is not of "high grade" as the term is used in this report.

A sample of this clay was tested by the Bureau of Mines at its Columbus station with the following result:

When subjected to the screen test:

- 1.26% was left on the 20 mesh screen.
- 6.16% was left on the 65 mesh screen.
- 2.87% was left on the 100 mesh screen.
- 11.25% was left on the 200 mesh screen.
- 78.46% passed through the 200 mesh screen.

The kaolin is very plastic and sticky and is slippery when too wet. It molds well and possesses a good dry strength.

The quantity of tempering water in terms of dry clay is.....	33.39%
The volume shrinkage on drying in terms of dry clay is.....	37.4 %
The calculated corresponding linear shrinkage is.....	14.5 %
The moisture factor on a dry basis is.....	4.36%
The deformation temperature is cone 29, final.	

When burned at	1190°	1250°	1310°	1370°	1410°
The porosity in terms of burned volume is.....	7.1 %	7.92%	6.36%	3.6 %	13.9%
No. of bars tested	3	3	3	3	3
The volume shrinkage in terms of the dry clay is..	23.1 %	27.99%	29.4 %	28.6 %	15.4 %
The corresponding linear shrinkage is.....					5.42%
No. of bars tested	2	3	3	3	3

The surface colors of the bars burned at the different temperatures are:

1190°	1250°	1310°	1370°	1410°
Pecan brown	Vinaceous tawny	Vinaceous	Cocoa brown	Wood brown

The body colors at 1190° and 1250° are the same as the surface colors, but the body colors of the bars burned at the higher temperatures are very dark grays or black.

MILLS DEPOSIT

Near Tryon

Mr. Thomas C. Mills reports the occurrence of clay three miles north of Tryon on the Columbia, Spartanburg and Asheville Branch of the Southern Railway, in Polk County, at the foot of Tryon Mountain. The sample seen is of an iron-stained, buff, coarse clay which is fairly plastic when wet. It was taken from a narrow gully. "The deposit is visible for about 50 feet along the gully and is from two to three feet below the surface. About one-eighth mile east of the gully the clay is again visible near the surface."¹ When stirred with water and put through a 150-mesh screen it leaves a residue of 40 per cent sand. The material passing the screen is sufficiently plastic to be easily moulded into briquettes, which, burned at cone 6 (1,250° C.), yields a light tan colored product that is fairly well vitrified, but is crossed by numerous shrinkage cracks. According to Professor Parmelee this clay in its washed condition is suited for the manufacture of ordinary stoneware and chemical stoneware.

72. BENNETT PROSPECT

Near Leaksville

In Rockingham County, three miles south of Leaksville, Mr. W. J. Bennett reports a white clay on land owned by him. The deposit has not been seen, but a sample was obtained from Mr. Bennett, who states that it represents the material from two openings about 400 yards apart. No particulars have been learned as to the method of occurrence of the clay, but from its character it is evident that it is of sedimentary origin.

¹Quoted from letter of Mr. Mills, dated March 26, 1919.

The sample is of a light gray, finely granular and slightly gritty clay that becomes very sticky when treated with water. It slakes readily, forming a light gray viscous fluid from which a considerable quantity of sand separates upon standing. This consists of small, clear, sharp-edged quartz particles and larger rounded white or light gray grains, that appear to be aggregates of quartz and feldspar. If carefully washed it might serve as filling for cheap cotton goods, linoleum, etc. In its natural condition it would probably make good stoneware. It is not a high-grade white clay or kaolin such as that used in the manufacture of whiteware.

The deposit is within three miles of the terminus of the Danville and Western Railway.

SHELTON DEPOSIT

Near Parkersburg

Mr. Amos Shelton reports boring through a deposit of compact white clay, when digging a well ten miles southwest of Parkersburg, Sampson County. Samples of the clay have not been seen, but since Sampson County is on the Coastal Plain it is possible that the deposit may be similar to some of the deposits in the Cretaceous series in South Carolina.

WYATT DEPOSIT

Near Faith

Mr. J. T. Wyatt writes that a deposit of white clay exists four and one-half miles south of Salisbury, near Faith in Rowan County. It is two miles from the Southern Railway. Some of it has been used in making white smoking pipes. Samples were not seen.

PYROPHYLLITE PROSPECT

Near Glendon

Mr. John S. Honeycombe reports the existence of a large deposit of china clay near Glendon, Moore County. This "china clay," according to Mr. Honeycombe, is pyrophyllite and not kaolin. A sample possesses the optical properties of pyrophyllite.

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