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MINING AND TREATMENT OF FELDSPAR AND KAOLIN

IN THE SOUTHERN APPALACHIAN REGION

BY

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PREFACE.

Apart from the fuel and metal-mining industries of the United States, no one of the various branches of mineral technology is more important to our domestic economy than are the ceramic arts. Aside from the manufacture of crockery, household china, and bric-a-brac, the development of the white-ware industry with reference to the production of plumbers' sundries, tile, and faced brick is of the utmost importance to the country. Its development will have an increasing influence on fireproof construction and proper sanitation, and therefore will lessen our unparalleled fire losses and help conserve the public health.

According to statistics compiled by the United States Bureau of Foreign and Domestic Commerce, there were imported into the United States during the 12 months ending June 30, 1912, china and porcelain valued at $9,515,851. In addition, 235,438 tons of kaolin or China clay were brought in to be manufactured into various forms of white ware. This kaolin displaced a like amount of domestic raw material, which, if properly handled, has no superior.

The kaolin, feldspar, and quartz industry of the United States is one of small operators, few of the mines being on a scale that warrants the employment of expert technical control. The extensive reduction of existing waste, the preparation of a standard product, and the marketing of guaranteed material become possible only when the losses are understood and the just requirements of the purchaser are realized. This bulletin has to do with the primary source of material used in the manufacture of white ware, and especially with this material as it occurs in the southern Appalachian region.

Investigations of kaolin, feldspar, and quartz were undertaken by the Bureau of Mines with the following objects in view:

(*a*) To discover the wastes and the possible by-products incident to production and point out methods for their recovery;

(*b*) To encourage efficiency in mining and treatment, with the hope of enlarging the output and of increasing the quality and uniformity of the product;

(*c*) To study the hazards of the industry, both as regards accident risks and health conditions;

(*d*) To determine by actual tests the physical constants and the general classification of the material from the various working deposits;

(*e*) To study the influence of impurities and to outline the precautions necessary in order to obtain from the crude material the highest possible grade of product.

Among other conclusions, Mr. Watts indicates that the raw material from the region studied has no superior for color, but that there is great need of some central depot at which the output of many small mines may be mixed and graded under the supervision of a trained ceramic chemist. Such control would insure the manufacturer receiving a product of known physical constants and would also insure a constant and ready market for the product. Mr. Watts has further called attention to the large quantities of first-quality kaolin now thrown away in mica mining; to the loss, in washing kaolin, of many tons of valuable flake mica that might be easily recovered; to ocher of excellent quality not now utilized; and to the fact that there is exposed on the dumps and worked-out dikes at least 200,000 tons of semikaolinized feldspar which, under proper technical control, might easily be utilized by potters.

The bureau's investigations have already progressed far enough to show that there can be no doubt of the United States being fully able to supply nearly all of the kaolin required for domestic consumption and that in quality the kaolin now available in the Appalachian region is excelled by none.

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MINING AND TREATMENT OF FELDSPAR AND KAOLIN IN THE SOUTHERN APPALACHIAN REGION.

By A. S. Watts.

INTRODUCTION.

Throughout the Appalachian Mountains there are dikes of coarse granite or pegmatite, which were intruded into other rocks. These pegmatite dikes contain feldspar, quartz, white mica (muscovite), black mica (biotite), and other minerals, such as beryl, garnet, and tourmaline. The investigation here reported has to do only with the dikes of the southern Appalachian region, in which the abundance of each mineral is as in the order given above.

The pegmatites of this region are in every stage of alteration from those in which the feldspar is fresh to those in which the feldspar has decomposed to kaolin. The muscovite (white mica) shows no evidence of alteration, although most of the other associated minerals show traces of disintegration where the feldspar is completely kaolinized. At many places mining for mica has been done in dikes in which the feldspar is completely kaolinized, though the only evidences of disintegration in the mica are clay stains which are sometimes noted between the outside laminæ.

Mining in these pegmatite dikes antedates history, traces of prehistoric workings and some crude mining implements of stone having been unearthed by recent operations. The prehistoric mining is generally supposed to have been for mica, although investigations fail to show that the aborigines put the mica obtained to any particular use except for ornaments, a few mica ornaments having been found in mounds in this region.

The search for kaolin or semikaolinized feldspar is a plausible explanation of these prehistoric workings; all of them were in pegmatite that is more or less altered, and seemingly stopped only when the pegmatite became too hard to permit working with crude stone implements. The dumps do not represent the amount of material that one would expect, from their extent, the workings to have produced. The kaolin obtained was doubtless conveyed to the coast and sold to English traders for use in the manufacture of some of the early

English porcelains. Mention is made of this fact in various English records. An important fact bearing on this hypothesis is the recording, on December 6, 1744, of an application for an English patent for the production of porcelain from an earthy mixture produced by the Cherokee Nation in America. This was to be mixed with a frit formed by melting together sand and potash.[a] The earthy mixture was known as "unaker" by the Cherokee Indians, and doubtless derived its name from the Unaka Mountains which bound North Carolina on the northwest and in the foothills of which these pegmatite dikes occur in large numbers. The reference to this material as a mixture precludes the possibility of its being a pure kaolin, as pure white clay was known to the English prior to 1744; it was probably a mixture of kaolin, feldspar, and quartz, which are the products of all these altered dikes.

Modern working of these dikes for mica began in 1867 in Jackson and Haywood Counties, and a short time later the mines in Yancey and Mitchell Counties were opened. The modern working of these dikes for kaolin did not begin until about 1888, when kaolin mines near Webster, Jackson County, N. C., were opened.

In mining for mica in these dikes little or no attention has been given to the preservation or utilization of the associated materials, and likewise in mining for kaolin little or no attention has been given to saving the mica except where it occurs in large blocks. Mica mines throughout this district are surrounded by dumps of dike material, many of which contain thousands of tons. The kaolin in these dumps is practically valueless because it is so mixed with wall rock that its separation is impossible. Where the dike material is unaltered, it is in most cases broken into small fragments and so mixed with associated wall rock that only by tedious hand sorting can the feldspar be separated.

Early mining in these dikes was practically all of the "gopher" or "ground-hog" type, a low, narrow tunnel being driven in the mica-bearing band in the pegmatite dike. Where the mica is abundant the tunnel is widened and a room is cut out to enable the miners to remove all the mica at hand. When the pocket is worked out the narrow tunnel is continued along the strike of the dike. The miner brings to the surface only as much of the dike material as is necessary in order to leave a passage through which he may crawl. Once a room is worked out it is immediately packed full of the dike material removed in continuing the tunnel, and the wall rock or any pocket of stained kaolin encountered is thus mixed with what is otherwise valuable material and the whole is rendered worthless. If the mine is in unaltered pegmatite the miners generally fill these rooms with a

[a] Burton, Porcelain; its nature, art, and manufacture, p. 233.

mixture of material from the walls and the dike. To reopen these mines and recover the material filling these rooms, and to sort the material thus obtained, would doubtless prove a more expensive operation than to mine the material from undisturbed deposits.

Even to-day in recently operated mica mines in this district no care is being taken of the dike material and much valuable kaolin and feldspar is being lost.

If the dike material is properly sorted when mined, the cost of operating is only slightly increased and the full value of the material can be realized.

Lack of a market is given as a reason for the neglect of the dike material. The importance of commercial kaolin-washing plants and feldspar-grinding plants is thus evident.

With a cost of from $2 to $3 per ton for washing kaolin and a selling price of $9 to $10 per ton, it seems plausible that in the districts where mica is mined a price could be paid for crude kaolin, based on the actual kaolin content, that would encourage the mica miner to remove the kaolinized dike material with care and to deliver it later to the washing plant.

The same is true of many of the mica mines in unaltered pegmatite. The cost for crushing and pulverizing feldspar should not exceed $3 per ton, and with the ground potash-feldspar and mixed feldspars selling at $8 to $12 per ton a miner should receive enough for crude feldspar to pay a large proportion of the cost of mining. He probably could pay the cost of operating the mine from sales of crude feldspar or kaolin, so that the mica would be obtained without cost and hence be pure profit. Thus mica mining could be made a safe instead of an uncertain and unsatisfactory business. Even though the feldspar is albite (soda feldspar) it should have a value of $5 to $8 per ton when ground.

Some pegmatite dikes are of such low feldspar content as to be valueless or are so located that the cost of hauling is prohibitive, but these are the exceptions rather than the rule.

With the establishment of pottery and kindred ceramic industries in the South the dike products will become more easily marketable and their use will make possible a grade of ware not approachable by the use of even the finest foreign materials.

AREA INVESTIGATED.

The extent of the area investigated is shown approximately by Plate I.

Starting at Rome, Floyd County, Ga., and Dallas, Paulding County, Ga., as the southwest extremes, the belt of dikes producing feldspar, kaolin, and quartz follows a general northeast direction, but does not become of commercial importance until the northeast slopes of the Nantahala Mountains are reached. The dike belt here broadens and covers the territory from Clayton, Rabun County, Ga., to Bryson, Swain County, N. C. Here the first kaolin mining in the belt was done. The belt narrows gradually until it reaches Waynesville, Haywood County, N. C. Northeast of this point there are few dikes until Burnsville, Yancey County, N. C., is reached. Here the belt widens to about 20 miles and includes the Sprucepine (Pl. II), Penland, and Bakersville districts where operations are now extensive. Northeast of this district the dikes are less altered, only one dike of kaolin of any value being found until the Virginia line is crossed. Beyond this line the dikes are scarce and of little value until Bedford County, Va., is reached, where several important dikes produce both kaolin and feldspar. The investigation ended at Lynchburg, Va.

THE COWEE DISTRICT.

The Cowee district (Pl. III) lies northeast of the Nantahala Mountains and covers Macon, Jackson, and Swain Counties and a small part of Haywood County, N. C. The dikes here are very numerous and most of them are in an advanced state of kaolinization. In Macon County sixteen separate samples of kaolin, three samples of semikaolinized feldspar, and five feldspar samples were taken. In Jackson County eleven kaolin samples, three semikaolinized-feldspar samples, and three feldspar samples were taken. In Swain County six kaolin samples and one semikaolinized-feldspar sample were taken. In Haywood County five kaolin samples were taken.

THE MOUNT MITCHELL DISTRICT.

The Mount Mitchell district includes Yancey, Mitchell, and Avery Counties. Here the dikes are in all stages of kaolinization. In Yancey County five kaolin samples and two feldspar samples were taken. In Mitchell County eleven kaolin samples, two semikaolinized-feldspar samples and eight feldspar samples were taken. In Avery County two kaolin samples and three feldspar samples were taken.

Other mines or prospects outside these centers were studied, but most of them may be considered unimportant, although a few of the isolated dikes might be operated to advantage.

PEGMATITE DIKES.

OCCURRENCE.

The materials investigated are associated with or form a part of a coarse granite, or pegmatite, which occurs throughout the Appalachian Mountains.

A discussion of the origin and geologic occurrence of the dikes does not properly belong in this treatise. However, geologists agree that within the area covered by this investigation the pegmatites exist as dikes intruded into other rocks, probably in the fluid state, and, because the intrusion naturally occurred along the planes most easily fractured, the dikes lack uniformity in both direction and size.[a] They are lens-shaped, often pinching out within a few yards from a mass many yards wide to one only a few inches wide. The same is true of the perpendicular dimensions, although not to so pronounced a degree.

The majority of the dikes studied have high dips, 65 to 80 degrees. The general direction of the dikes is northeast, but many of the large dikes appear to strike due north or due east.

The entire area covered by this investigation is rough and mountainous, the level areas being confined to narrow river valleys and a few small plateaus. Most of the dikes now worked are well up on the mountain sides and some workable dikes have been found in the crests of mountains. Similar dikes are found, however, as low as the level of the river beds and are apparently no more advanced in kaolinization than are those at higher levels.

Every dike studied is intruded into a micaceous gneiss. This gneiss seems to have withstood weathering about as well as the intruded material, the wall rock being disintegrated about the same degree as the dike where kaolinization has occurred.

CONSTITUENTS.

The pegmatite of these dikes consists of feldspar and quartz in more or less intimate mixture, the rock varying in texture from fine-grained granite to intermingled masses of pure feldspar and pure quartz. In no case, however, has either mineral been found alone and the ratio of quartz to feldspar seems reasonably constant. Associated with the quartz and feldspar are mica (both muscovite and biotite), garnet, beryl, tourmaline, and small quantities of other minerals.

STRUCTURE.

The structure of some dikes is peculiar and leads one to believe that they may represent a series of intrusions.

Because of their irregular structure and the indistinctness of the walls, some very wide dikes can hardly be recognized as such. Such rock masses are undoubtedly great lenses formed at favorable positions along the strike of a dike. A fact worth noting in connection with these great lenses is that they are uniformly lower in feldspar and kaolin than are the better-defined and narrower dikes. A typical expanded-lens formation is shown in *A*, Plate IV. A section

[a] Bastin, E. S., Feldspar deposits of the United States: U. S. Geol. Surv. Bull. 420, 1910, p. 10.

of a typical dike of the region studied is shown in figure 1, and a view of a dike in *B*, Plate IV.

The material adjoining the hanging wall is nearly always quartz in a distinct band which may be a few inches or several feet thick. Next this quartz there is generally either a feldspar-rich pegmatite or a narrow band of feldspar-lean pegmatite carrying garnet, tourmaline, and other minerals. Adjoining this pegmatite is found the massive feldspar if such a band occurs in the dike. Adjoining the massive feldspar, if such occurs, one may expect to find a narrow band of massive quartz, or isolated lenses of quartz. Adjoining this

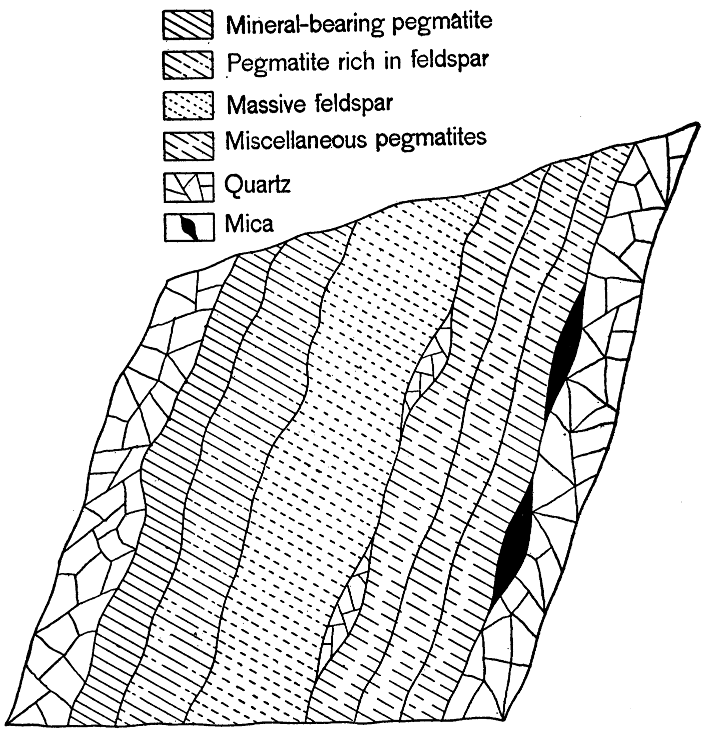
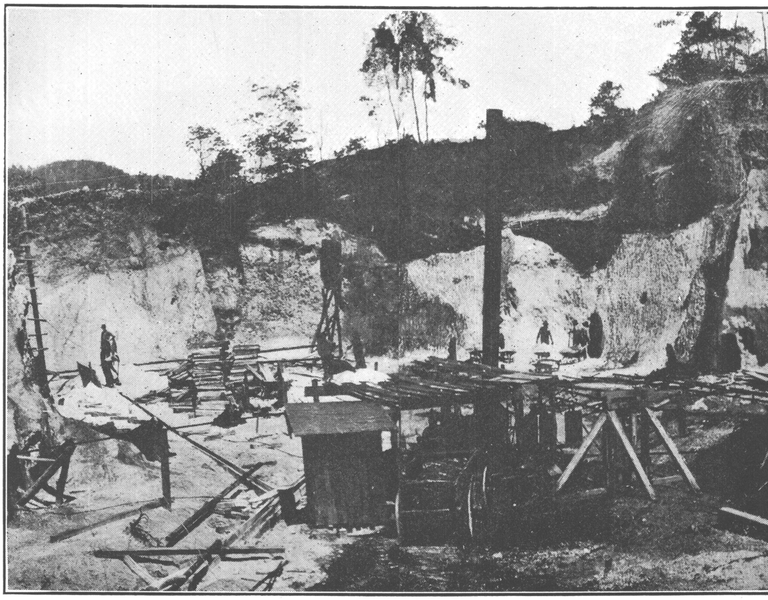
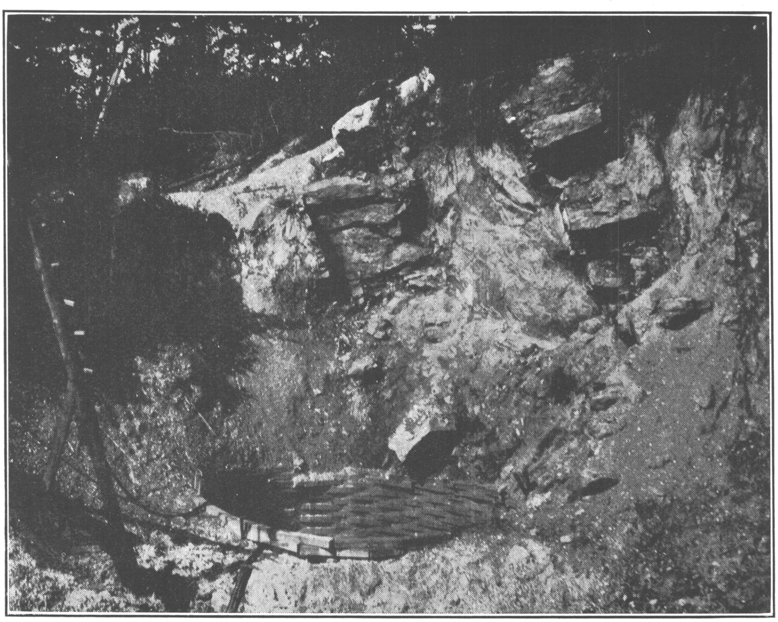


FIGURE 1.—Vertical section of a typical pegmatite dike.

are two or more bands of pegmatite, each band being distinct in size of grain and in percentages of quartz content and impurity. Generally these are next the quartz band along the wall. The mica generally occurs between the last pegmatite band and the quartz band, although it is not uncommonly found between the feldspar and pegmatite along the hanging wall. In fact the mica is rarely found continuously between any two given bands, and although the general position of the mica-bearing band rarely changes from one wall to the other in any one dike, the irregularity of the band makes mica mining an uncertain business.



A. TYPICAL EXPANDED-LENS FORMATION, SHOWING THE IRREGULAR SURFACE LINE OF THE KAOLIN.



B. KAOLINIZED DIKE, SHOWING TWO QUARTZ BANDS, ONE ADJOINING THE HANGING WALL ON THE RIGHT, THE OTHER NEAR THE CENTER.

Oxide of iron occurs as a stain in infiltrated surface clay, and is often so securely set in the crevices of broken bands that no amount of washing will remove it. Fortunately it seldom penetrates more than a few yards. Where a dike has kaolinized to any extent there occur pockets of iron-stained sand and inclosed lenses of iron-bearing micaceous gneiss which is altered to the same extent as the pegmatite and must be removed with great care, as it is exceedingly friable and its finely divided iron oxide content has enormous coloring power.

Garnets are rarely found as the sole impurity in pegmatite. With them are generally associated mica, either muscovite or biotite or both, and often beryl and tourmaline. Garnets are rare in the feldspar-rich bands, but are more plentiful in bands that are made up of quartz and mica. Many dikes that are rather low in feldspar would present industrial possibilities were it not for the iron garnets and the fine biotite mica that they carry. Beryl, on the other hand, is found almost entirely in those bands high in feldspar and low in quartz. Tourmaline, like beryl, is most abundant in the feldspar-rich bands. Manganese and cobalt as earthy oxides, generally wad, are associated with most of the dikes studied.

The quartz band that adjoins the hanging wall or footwall in most of the dikes is broken, apparently from cooling strains, and in the crevices thus formed occur the deposits of wad referred to above. The wad is brown or black, either powdery material loosely filling the crevices or nodules adhering to the quartz. Only in two instances was this material found intermixed with feldspar or kaolin. At one point in Macon County, N. C., a few nodules of wad were found in the kaolin bed, and in the Isinglass Hill kaolin mine these nodules are common.

Cassiterite (oxide of tin) is found associated with a kaolinized pegmatite dike at Lincolnton, Lincoln County, N. C., but this dike and the Isinglass Hill mine lie outside the district directly under investigation, both being south of the Blue Ridge Mountains. However, their occurrence and structure are so similar to those of the dikes being studied that it seems permissible to mention them here.

With the exception of the cassiterite and the wad in nodular form disseminated throughout the dike, the minerals mentioned above are common to every pegmatite dike studied and the problem of their removal or utilization confronts every present or prospective operator.

KAOLINIZATION.

The term kaolinization is used to signify the process of decomposition of feldspars and the recombination of some of the decomposition products to form kaolin. The process is as follows:

Kaolinization.

	By molecules.				By weight.			
Feldspar	1 K_2O	1 Al_2O_3	6 SiO_2		17 K_2O	18.4 Al_2O_3	64.6 SiO_2	
Loss by H_2O solution	1 K_2O				17 K_2O			
Insoluble decomposition products		1 Al_2O_3	6 SiO_2			18.4 Al_2O_3	64.6 SiO_2	
Kaolin		1 Al_2O_3	2 SiO_2	[a] 2 H_2O		18.4 Al_2O_3	21.5 SiO_2	[a] 6.44 H_2O
Free silica			4 SiO_2				43.1 SiO_2	

[a] Water of combination.

We thus see that of 100 parts of potash feldspar decomposed, 17 parts of potash are lost by solution and 43 parts of silica and 46.44 parts of kaolin remain; the kaolin is made up of 40 parts obtained from the feldspar (18.4 of alumina, and 21.6 of silica) plus 6.44 parts water of combination absorbed. The total of the insoluble products (plus the water of combination) is 89.44 per cent of the feldspar decomposed. A bed of residual kaolin (kaolinized feldspar) should therefore contain (minus the potash and plus the water of combination in the kaolin formed) 51.92 per cent kaolin and 48.08 per cent free silica.

This is on the assumption that the deposit is pure feldspar, but such an assumption is rarely true. In the area investigated the feldspars of the pegmatites are mixed with varying amounts of quartz. Other minerals are also present in small quantities, so that to find a kaolinized dike averaging 40 per cent pure kaolin is exceptional.

It rarely happens that the kaolin and quartz products of the feldspar disintegration are evenly distributed throughout the residual deposit. The tendency seems to be for the kaolin to filter down through the quartz particles until it has formed a compact mass where it packs together into a bed that may run 92 to 93 per cent kaolin. Below this bed in the decomposed dike lies another stratum of quartz sand which with depth becomes progressively richer in kaolin until another bed of nearly pure kaolin is encountered.

The extent of this process of disintegration and concentration varies in different dikes and in different localities, but the process is more or less evident in every dike studied.

As the extent to which kaolinization by weathering has progressed in the dikes examined varies inversely with the depth, it is not surprising to note that the plasticity of the kaolin decreases with the depth of a dike until the proportion of semikaolinized material becomes so great that deeper mining for kaolin is unpractical. This semikaolinized material, if devoid of plasticity, acts like feldspar or quartz sand in the washing process and may all be removed by the mica troughs and screens.

The depth at which this nonplastic material becomes noticeable in the dikes studied can be roughly set down at 40 to 45 feet, although the richest and apparently most plastic kaolin is always found when the present water level is reached. It is doubtful if this kaolin is really more plastic than the rich pockets met at higher levels, but it appears so owing to the excess of water that it carries. In some dikes the kaolin content of a decomposed dike steadily increases until water level is reached, and in such cases the deposit at that point is very rich.

The feldspar in the dikes is in all stages of decomposition, from fresh feldspar to perfect kaolin. The present topographic location seems to be no guide in determining the extent to which the kaolinization of a dike has progressed. Fresh feldspar and completely kaolinized feldspar lie almost side by side and at the same elevation. On Tremont Mountain, Macon County, N. C., fresh feldspar and kaolin deposits are only a few hundred feet apart at the same level. The two dikes are identical in structure, each having a vertical horse of pure quartz in the center, and narrow veins of mica-bearing pegmatite along the hanging and foot walls. At Penland, Mitchell County, N. C., a dike in an advanced state of kaolinization is being worked for kaolin, and 50 yards distant a dike containing fresh feldspar is being worked. In this case, however, 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. Near Jasper, Pickens County, Ga., a kaolinized dike follows the crest of a low ridge, while 100 yards distant and 50 feet lower is a dike with fresh feldspar.

Many other similarly associated dikes of feldspar and kaolin are mentioned in the description of the mines and prospects investigated.

PROSPECTING AND SAMPLING.

PROSPECTING FOR FELDSPAR AND QUARTZ.

Prospecting for feldspar and quartz is necessarily done either by open cuts or tunnels. The country rock is generally no more disintegrated than the pegmatite, so that the auger is useless. Wherever the pegmatite is rich enough in feldspar to justify mining, there are likely to be outcropping bands of quartz in place by which the presence and the direction of the dike are indicated. The first task, therefore, if the overburden is light, is to dig a trench exposing the full width of the dike.

The iron stains caused by infiltration from the overburden may extend several feet into the deposit and necessitate the removal of a considerable amount of the surface of the dike before satisfactory samples can be taken.

In determining the extent of the dike it is necessary to run cuts across the strike at intervals. The surface of the dike should be removed at least until fresh feldspar is exposed and each of the various bands should be measured and sampled across its entire face.

If these cuts are made at 50-foot intervals and the various bands occur in the same order and are approximately the same size there is little need of testing at shorter intervals, but if any irregularity occurs it is wise to reduce the distances between trenches to not more than 25 feet.

The trenches can in most cases be cut by plow and the material removed by scraper, although some hand labor is always necessary.

Where the overburden is so heavy as to render its removal impractical, the driving of a "tunnel" adit or crosscut may be necessary. This work is not different from that of driving any rock-tunnel of the same size, although the tunnel should be driven as far as practical from the heavy flint band which is badly ruptured in order to eliminate the danger from working in broken ground. By clearing the face a cross section of the dike can be obtained and by running a 25 or 50 foot tunnel and then crosscutting, a second face on the same cross section can be exposed.

It is also advisable wherever possible to crosscut the dike at two or more levels in order to ascertain whether the structure varies with depth. Care should be exercised in driving tunnels that enough slope is allowed for proper drainage and that sufficient headroom is provided for convenient operation. The quartz bands running with the feldspar may be prospected in the manner just described and in most cases the two can be conveniently worked together, the quartz being reached by crosscuts from the main entry.

SAMPLING OF FELDSPAR AND QUARTZ.

The full face of the dike should be exposed and each band measured. The sample can be most satisfactorily obtained by using a sampling cloth of generous size and, with a geologist's edged hammer, or a chisel and hammer, making a cut of uniform depth and width across the entire face. As is suggested in connection with the sampling of kaolin, the various bands should be sampled separately so that any undesirable material may be eliminated. For average samples of the entire deposit one has only to refer to the record of width of the various bands and to blend the separate samples proportionately.

For chemical and physical tests it is necessary to reduce a portion of the samples to a fine powder. The sample taken should be reduced to one-half inch size, spread evenly on a smooth sampling cloth or a large smooth paper, thoroughly mixed, and then quartered; if necessary the quarter taken may be crushed to one-eighth-inch size, thoroughly mixed and requartered, the mixing and quartering being repeated until a sample of suitable size for fine pulverizing is obtained. This sample should be pulverized in a hard porcelain or agate mortar until all of it passes a 120-mesh sieve.

PROSPECTING FOR KAOLIN.

Within the area studied very little prospecting has been done except the "ground-hog" mica mining, and this has resulted from exposure of mica-bearing ledges on the surface.

Dikes are so irregular that only by the most thorough prospecting can the extent of a deposit be ascertained.

The surface indications are mainly confined to scattered quartz bowlders except where a gulley exposes kaolin or pegmatite in place. A typical example of a bowlder-strewn surface is shown in *A*, Plate V. The white quartz bowlders, which were once a band of the dike, have alone withstood disintegration and are scattered over the surface.

Where such indications are found the prospector should bore with a standard wood auger welded to sectional steel pipe. If he finds kaolin, the boring should extend at least 30 feet into it. As a resistant flint band may be encountered at any time owing to nearly all dikes not being vertical, testing with the auger is often very unsatisfactory. The auger holes should be sunk at intervals of not more than 10 feet until the general direction of the dike is definitely determined and, if possible, its width and extent are ascertained. A great number of holes are certain to be sunk that can not be completed owing to auger striking hard quartz rock or penetrating loose sand. It is practically impossible even by putting water into the hole to remove the borings from a sand bed.

When the presence of a considerable deposit has been established, it will be found much more satisfactory and also more economical to open a tunnel or sink a shaft into the deposit than to investigate further by boring. Unless the deposit is to be worked at once, shaft sinking is not recommended except where the deposit is a great distance from the face of the hill. A tunnel can be cut quickly and easily at 25 to 35 feet below the top of the deposit and if it has a very slight grade it will drain the deposit down to that level. Samples should be carefully taken completely across the dike by means of a crosscut to one side of the deposit and by horizontal borings opposite this crosscut. By frequent horizontal borings the exact width of the dike may be ascertained, and the grade of material in the different vertical bands be determined. By a little overhead stoping to make room for handling the auger, borings in the floor of the tunnel can be made to any desired depth.

A prospecting tunnel should be not less than 6 feet high with an arched roof, but need not be more than 3 feet wide. If a flint horse is encountered it may be easily broken through or may be followed on either side, as it invariably runs parallel to the dike although its face is often more or less irregular.

Such a tunnel, if properly cut, will not cave for many years; several of the tunnels examined are still open and in good condition though driven 20 years ago and not repaired since.

The objections to shafts are the tendency to cave and to fill with débris, and the staining of the walls by surface waters. Furthermore, a shaft becomes a collecting point for subsurface water, the walls become soft, and it is practically impossible to do any sampling unless the water is removed by buckets, which is very expensive.

In the region examined auger holes soon become choked, and it is often more economical to bore a new hole than to reopen an old one; hence boring does not provide any means of permanently opening kaolin deposits for testing.

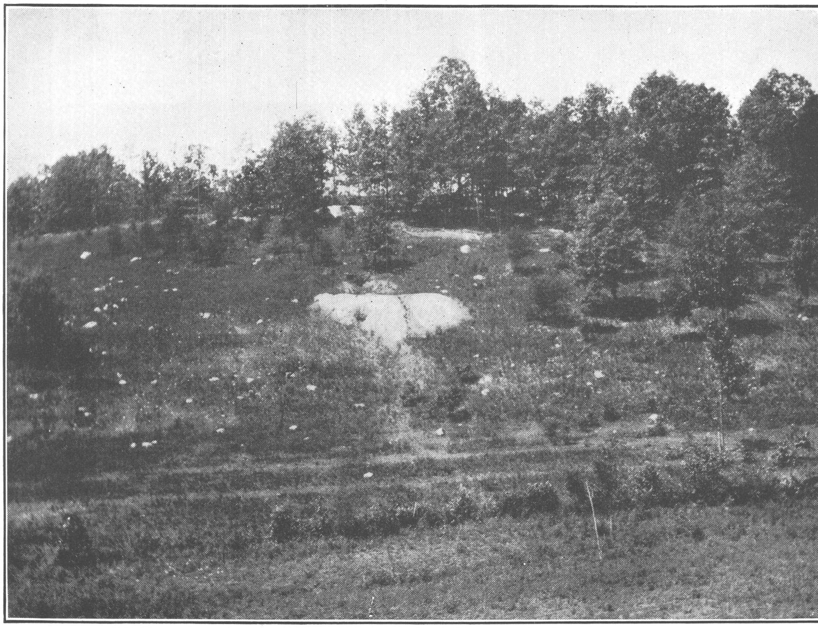
It must be borne in mind that the dimensions of the bands in a face are no criterion of what may be expected even a few yards beyond, hence the extent of the bands throughout the area tested alone can be considered in any prospecting report. This statement applies to horizontal rather than vertical dimensions although the latter are also subject to variation, especially those of the kaolin.

SAMPLING THE KAOLIN DEPOSIT.

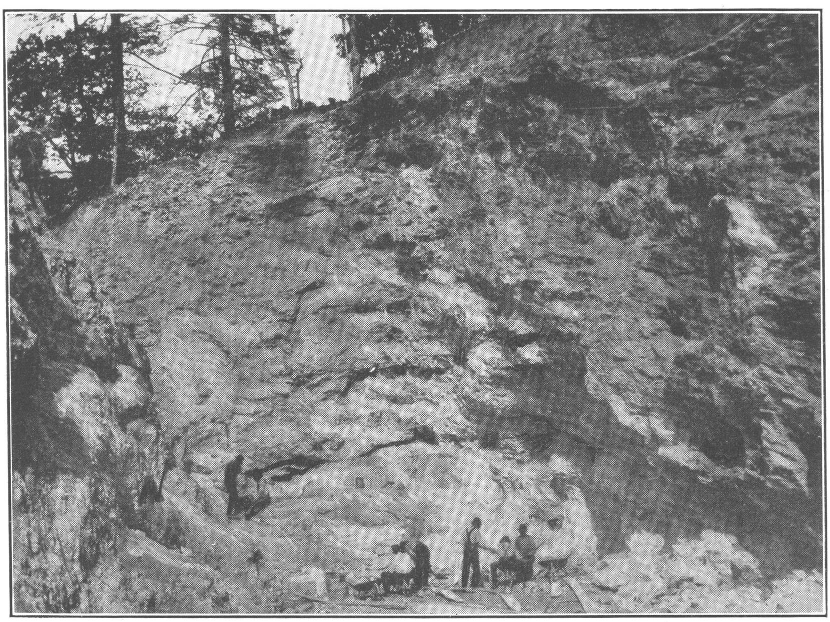
The method of taking the samples for test is of the utmost importance. Even after the deposit has been carefully proved throughout its length and depth, a lack of care in sampling may render the data obtained of little value.

When samples are taken by boring from the surface the author has found it advisable to use a larger bit for boring through the overburden. To prevent any particles of overburden falling in, the sides of the hole should be well packed with a smooth round pole or sapling before boring into the deposit begins.

A careful record should be made of the appearance of each sample as it is removed from the auger and in case a sample looks notably different it should be kept separate. Not over 5 feet of borings should be sampled into one bag, as the mixing of large samples may lead to wrong conclusions. In vertical sampling the sampler should remember that he usually cuts the deposit obliquely and may strike a narrow band of undesirable material that could be removed in mining. The borings from such a band because of its loose texture and the



A. TYPICAL SURFACE INDICATIONS OF A DISINTEGRATED PEGMATITE DIKE. THE WHITE BOULDERS ARE DERIVED FROM A QUARTZ BAND IN THE DIKE.



B. OPEN-CUT MINING FOR FELDSPAR.

tendency of the auger to tear off particles when raised and lowered may make the band seem thicker than it really is.

A careful record should be kept of all samples, the point at which taken and the depth being noted. The importance of taking complete notes should be constantly borne in mind.

In sampling a tunnel the problem of obtaining satisfactory samples is much simpler but the tendency to collect false samples is even greater than in sampling by bore holes from the surface.

Where a large area of material is exposed, the tendency is to go to that section which appears most promising and to take the samples there. The most satisfactory method of sampling a tunnel is to divide it into 5 or 10 foot sections and sample each separately. As the dike bands vary horizontally rather than vertically, it is always advisable to sample the crosscuts, and in sampling these, as in sampling auger holes, much care must be observed to prevent a narrow band of impure material from being given more importance than it deserves.

First, clean the face exposed in one side of the crosscut with a shovel. Then sample each band separately across its full width. If stained material is encountered, its approximate extent can be determined and a sample preserved for test. In some dikes the kaolin shows peculiar variations in tint that can not be detected after washing.

The preservation of these samples separately is very important, since, as will be shown, different portions of the deposit may possess different physical properties, thus rendering a blending advantageous. Also it is possible, if desired, to blend the different samples in the same proportions in which they exist in the deposit, and thus obtain a sample representative of the entire deposit.

TESTING THE SAMPLES.

FELDSPAR.

Feldspars may be divided into three classes, as follows:

Potash feldspars, including orthoclase and microcline. Their composition is $KAlSi_3O_8$, their specific gravity is 2.56.

Soda feldspar, known as albite. Its chemical composition is $NaAlSi_3O_8$, its specific gravity is 2.605.

Lime feldspar, known as anorthite. Its chemical composition is $CaAl_2Si_2O_8$, its specific gravity is 2.765.

In addition there are mixtures of these feldspars, as follows:

Potash-soda feldspar, known as anorthoclase, which is a mixture of equal parts of potash and soda feldspars.

Soda-lime feldspars, known as plagioclase feldspars, which vary in composition from a mixture of 6 parts soda feldspar and 1 part lime feldspar to 1 part soda feldspar and 6 parts lime feldspar.

If the feldspar is pure, its value in the industries is indicated in a very satisfactory manner by a chemical analysis. If, as is the case in nearly all pegmatites, the feldspar is intimately mixed with a number of other minerals in varying proportions, a chemical analysis is often decidedly misleading. If a quantity of feldspar is freed from associated minerals, an analysis can be obtained that will indicate which of the feldspars is present.

For the process of chemical analysis of feldspar, see United States Geological Survey Bulletin 422. If a mixture exists, a microscopic study of the sampled material shows conclusively what minerals are present and also their fineness and their relations; it is therefore a valuable aid in classification.

If the consumer knows what minerals are present and knows their average proportions, the task of readjusting his mixtures to suit conditions is not a serious one, provided the associated minerals do not introduce some undesirable colorant.

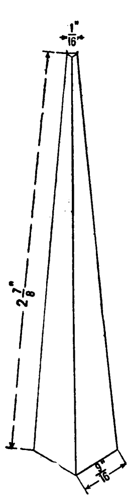


FIGURE 2.—Standard cone for deformation test.

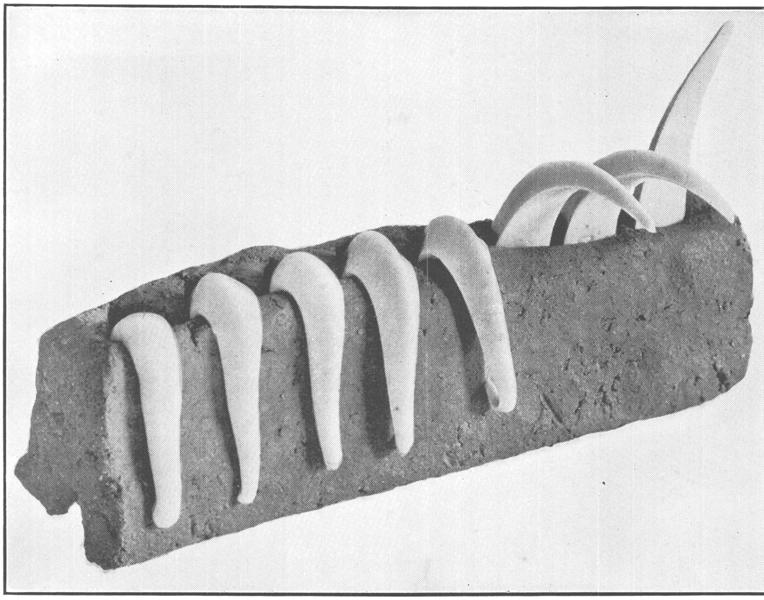
THE DEFORMATION POINT AND ITS DETERMINATION.

Since feldspars are fusible, their activity as solvents depends on temperature. The determination of the deformation point of a feldspar is a matter of importance.

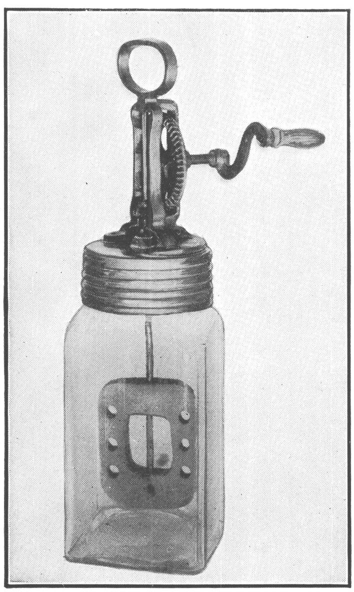
The deformation point of a feldspar is determined as follows:

The feldspar is pulverized to an impalpable powder, as explained under "Sampling." This powder is mixed with just sufficient starch paste or dextrin solution to permit of its being formed by pressure into a cone. The size of the cone for temperatures up to 1,450° C. has been standardized (Seger cones are shown in *A*, Pl. VI) and in practice is a three-sided pyramid with sides $2\frac{7}{8}$ inches long and the faces $\frac{9}{16}$ inch at the base and $\frac{1}{16}$ inch at the top, as shown in figure 2.

This cone is comparable with the standard pyrometric cones manufactured in Germany and in the United States, which are guaranteed to melt at definite temperatures under exact heating conditions. These cones, composed of mineral mixtures, act under fire in a manner more or less similar to the feldspars, kaolins, and quartzes, in the standardization and firing of which thev are chiefly used.



A. SEGER CONE.



B. HOUSEHOLD CHURN AS LABORATORY AGITATOR IN KAOLIN WASHING.

Seger cones and their deformation temperatures.

Cone No.	Deformation temperature.	Cone No.	Deformation temperature.	Cone No.	Deformation temperature.
	°*C.*		°*C.*		°*C.*
1	1,150	13	1,390	25	1,630
2	1,170	14	1,410	26	1,650
3	1,190	15	1,430	27	1,670
4	1,210	16	1,450	28	1,690
5	1,230	17	1,470	29	1,710
6	1,250	18	1,490	30	1,730
7	1,270	19	1,510	31	1,750
8	1,290	20	1,530	32	1,770
9	1,310	21	1,550	33	1,790
10	1,330	22	1,570	34	1,810
11	1,350	23	1,590	35	1,830
12	1,370	24	1,610	36	1,850

Cones similar to the Seger cones are made for temperatures below 1,150° C., but for testing feldspars, kaolins, and quartzes such cones are unimportant.

For temperature determination, other forms of pyrometers are also used.

THERMOELECTRIC PYROMETER.

The thermoelectric pyrometer is an instrument for ascertaining the temperature in an oven or kiln. It consists of a thermoelectric couple, made by fusing a platinum wire and a wire composed of 90 per cent platinum and 10 per cent rhodium, which is exposed to the temperature. The difference in temperature between the hot and the cold junctions of these two wires is proportional to the electric current generated, and this is recorded on a galvanometer. The deflection of the galvanometer varies with the current generated, and the dial of the galvanometer, being scaled in centigrade degrees, permits the operator to read directly the temperature of the furnace. Such an instrument is reliable to 3° C. under ideal laboratory conditions and is reliable within 5 to 10 degrees under factory conditions. The electric pyrometer is highly satisfactory for use in testing feldspars, but as the deformation of a feldspar is a pyrochemical process, in which heat and time are factors, the time consumed in heating the sample to the deformation temperature should be considered in expressing the deformation temperature of any feldspar or feldspar mixture.

The thermoelectric pyrometer deteriorates rapidly at temperatures above 1,500° C.; hence for testing kaolins and quartzes Seger cones or some form of heat-radiation or optical pyrometer must be used.

HEAT-RADIATION PYROMETER.

In the heat-radiation pyrometer the heat radiated from an incandescent body, in the furnace or kiln, is focused upon a thermocouple and the electromotive force generated is indicated by the deflection of an attached galvanometer, which is read upon a dial scaled in centigrade degrees. The precautions that the operator must consider in operating such a pyrometer are to have the incandescent object focused sharply upon the thermojunction and to have the image so focused of greater size than the junction.

Such a pyrometer is reliable only within 10° C. under the most favorable conditions; hence its use is little, if any, more satisfactory for temperature measurements than are the pyrometric cones.

OPTICAL PYROMETERS.

The optical pyrometer of La Chatelier consists of a telescope that carries a small comparison lamp attached laterally. The image of the flame of this lamp is projected on a mirror at 45 degrees placed at the principal focus of the telescope. The images of the object viewed and of the comparison flame are side by side and are brought to equal intensity by suitable adjustment of the instrument. Under the most favorable conditions this instrument is subject to any error of vision of the operator and for high temperatures should hardly be expected to give results more accurate than 10° C.

As the deformation of feldspars may in some cases be completed within a temperature range of 5° to 8° C., the use of thermocouples or optical pyrometers does not furnish a graphic comparison. Seger cones placed side by side with the sample to be tested is by far the most satisfactory method of comparison, although it is always advisable to use a thermocouple or optical pyrometer to check the temperature of the deformation.[a]

The cone of material of which the deformation point is to be determined is placed on a fire-clay slab to which it is made fast by means of a fusible slip or by packing clay about the base. If clay is packed about the base care must be used that the cone be set not more than one-fourth inch in the clay lest the deformation be retarded. If the deformation temperature is to be determined by means of cones, these should be placed about the cone to be tested and as near as possible without danger of contact when deformation begins. If the cones are not set exactly vertical, care must be taken that the same slant be given to all, otherwise the results will not be comparable.

As the rate of fusion is an important factor, the cones should be closely watched and the time at which each standard cone is exposed

[a] For more complete explanation of Seger cones, see "Seger's Collected Writings" (Am. Trans.), vol. 1, pp. 224–229; also Prof. Paper 11, and Bull. 54, U. S. Geol. Surv.

For electrical, radiation, and optical pyrometers, see "High-Temperature Measurements," by La Chatelier, Boudouard, and Burgess.

Waidner, G. W., The temperature work of the Bureau of Standards: Jour. Ind. Eng. Chem., vol. 2, 1910, p. 49. Waidner, G. W., and Burgess, G. K., Platinum resistance thermometry: Bureau of Standards Scientific Paper 124, 1909, 82 pp.

Shook, —, Radiation pyrometry, I, Met. Chem. Eng., vol. 10, 1912, pp. 238, 334, and 534; Calibration of radiation pyrometers: Op. cit., p. 416; Determination of very high temperatures: Op. cit., p. 478.

Wilson, —, A practical note on thermo-electric pyrometers: Electrochem. Met. Ind., vol. 7, 1909, p. 116.

to the heat should be recorded as well as the time at which its point reaches the level of its base, thus forming a semicircle. A similar record for the cone of the material being tested enables one to state, by referring to the standard-cone record, the temperature of the beginning of deformation and also the temperature at which its point reaches the level of its base. The range of temperature between these two stages of deformation is very important as indicating the range of temperature within which the material under test will be valuable as a flux in pottery manufacture.

COLOR.

Feldspar, as found in nature, has various tints and shades, but the fused material, to possess much value, must be almost colorless. Until a feldspar has been heated past the deformation point and come into quiet fusion it generally remains opaque. The opacity may be due to bubbles disseminated through the mass, or to some opaque impurity not taken into solution by the feldspar. The presence of an impurity that discolors is far more objectionable than one that merely opacifies although for many uses a feldspar that is opaque after fusion is very objectionable.

No classification of colors and shades of feldspar has been attempted. For the standardization of the feldspars in the following investigation a high-grade Maine feldspar was accepted as standard color.

This standard Maine feldspar has the following composition:

Chemical analysis of standard Maine feldspar.

[Analysis by Ohio Geological Survey.]

SiO_2	71.75
Al_2O_3	16.70
Fe_2O_3	.14
TiO_2	.03
CaO	.25
MgO	
Loss on ignition	.35
K_2O	8.59
Na_2O	2.99
	100.80

This analysis indicates a mineral composition as follows:

Mineral composition of standard Maine feldspar.

Microcline	50.3
Albite	27.25
Kaolin	5.08
Free silica	17.37
	100.00

The high content of free silica and the kaolin content cause this feldspar to remain opaque to a much higher temperature than it would otherwise, but the low ferric-oxide content insures a fusion practically free from color.

To classify the feldspars, the fused specimens are placed side by side and by comparison with the standard feldspar and with one another a color scale is devised in which each specimen has its place. By repeating this several times the danger of error is reduced to the minimum and by having two or more persons duplicate tests, the personal error is largely eliminated. The errors possible from this system are many and the absence of any standards of color for such work is the only justification for its use.

THE IMPURITIES OF FELDSPAR.

QUARTZ.

The presence of quartz in feldspar offered for sale has long been considered unpermissible, even though the user expected to add quartz to the mixture later. This stand was taken because of the fear that the feldspar would be adulterated enough to reduce its solvent action seriously. The impression has also prevailed that even small additions of quartz to feldspar would greatly increase the amount of heat necessary to fuse the mass to a liquid state. As exact data on this subject were absolutely lacking, the author carried on an investigation with additions of pure quartz to a pure feldspar, an analysis of which follows:

Feldspar used in deformation study of feldspar-quartz mixtures.

Composition.		Theoretical microcline.
H_2O	0.17	
SiO_2	65.37	64.75
Al_2O_3	17.92	18.34
TiO_2	Trace.	
Fe_2O_3	.02	
CaO	.17	
MgO	Trace.	
K_2O	13.05	16.90
Na_2O	2.10	
	98.80	99.99
Specific gravity	2.57	2.56

These materials were ground separately to pass a 200-mesh screen. They were then ground together until thoroughly mixed and made into cones similar to the pyrometric cones of commerce against which they were to be tested. They were burned in an updraft testing kiln with a muffle 7 by 8 by 18 inches deep. Gas was the fuel, and an even temperature throughout could be maintained by slow and careful increase of gas pressure. The following is the record of the test burn:

Twenty hours was consumed in reaching cone 7 temperature, 1,270° C. Eight hours additional was consumed in raising the temperature to cone 9, 1,310° C.

With the rate of deformation of cone 8, 1,290° C., and cone 9, 1,310° C., as standards, figure 3 shows the relative temperatures and speed of deformation of the various mixtures of feldspar and quartz up to and including 35 per cent quartz.

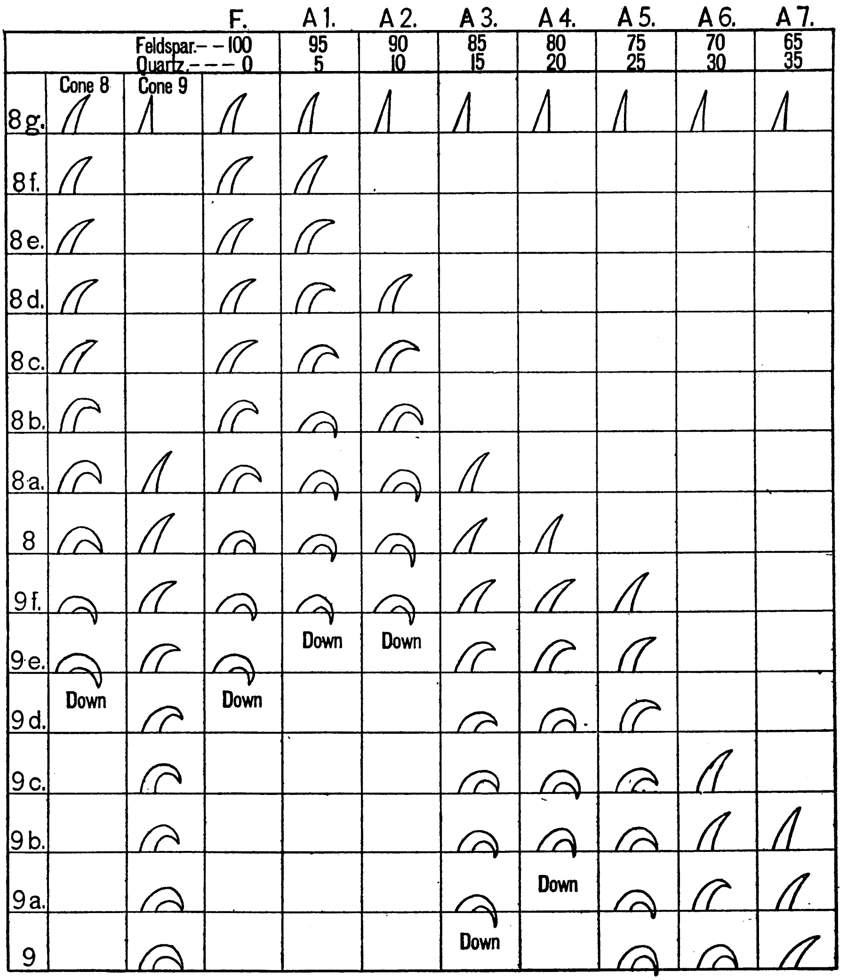


FIGURE 3.—Deformation of feldspar-quartz cones, showing relative temperatures and speeds.

Note that even though 30 per cent of the mixture is quartz, the deformation temperature is raised less than two cones, or 40° C. This is not in accordance with the work of Simonis,[a] who found that a mixture of 70 per cent feldspar and 30 per cent quartz had a defor-

[a] Sprechsaal, 1907, pp. 403-406.

mation temperature of cone 14, 1,410° C., which is about 100° C. higher than his deformation point for pure feldspar.

This difference in results can be accounted for only by the fact that the feldspar used in the Simonis's tests was pure potash feldspar, whereas the feldspar used in these tests carries more than 2 per cent Na_2O.

The important point brought out by this investigation is the fact that the user can not be certain that he is obtaining pure feldspar by testing the material alone in the kiln in the manner ordinarily practiced. A mixture of 95 per cent feldspar and 5 per cent quartz begins to deform at the same temperature as pure feldspar, but becomes fluid much more quickly than pure feldspar. A mixture of 90 per cent feldspar and 10 per cent quartz deforms at a temperature approximately 5° C. higher than does pure feldspar, but becomes liquid before the pure feldspar has begun to lose shape.

No eutectic indications are noticeable in the original fusion of feldspar-quartz mixtures, unless one so construes the fact that the mixture of 95 per cent feldspar and 5 per cent quartz began deforming when the feldspar began and completed deformation before the pure feldspar. To determine if there is any eutectic indication in feldspar-quartz fusions, mixtures of pure feldspar and quartz were fused together in the above proportions and after reducing the fusions to 200-mesh powders they were made into cones which were tested against standard pyrometric cones as before.

The same order of fusibility is noted in this firing as was recorded in the firing of the original mixtures. F and A1 begin to deform at cone 5, 1,230° C., but, as was noted in the firing of the mixtures, A1 deforms more rapidly and touches the plate when F is only half down. A2 begins to deform after F and A1 have started but overtakes F when nearing the plate. A3, A4, A5, A6 deform in regular order. A7 was an imperfect cone and no reliable observation of it could be made but A6 was deformed so that it touched the plate before cone 7 started to deform.

IRON OXIDE.

Iron oxide is so well known as a dangerous impurity in feldspar that a discussion of it seems almost unnecessary. Only 1 per cent gives the feldspar a decided yellow cast and it must be eliminated even though hand sorting is necessary.

MUSCOVITE.

As muscovite is present in nearly every feldspar-bearing dike in the district studied, it is important to know what influence it exerts on the deformation point and color of the feldspar. For this purpose a series of feldspar-muscovite mixtures was made and tested in the same manner as the feldspar-quartz mixtures. The muscovite and the feldspar were both ground to pass a 200-mesh sieve. Figure 4 shows the results of this test. The results are especially interesting in view of the fact that muscovite has the composition, $K_2O.3Al_2O_3.6SiO_2.2H_2O$, and contains the same elements as feldspar; but by virtue of its higher alumina content it is more difficultly fusible, being reported by Rieke[a] as deforming with cone 13.

In figure 4 it will be noted that C1, containing 5 per cent of muscovite, begins to deform before any other mixture tested. The order in which the various mixtures deform is regular, C4 being the last to begin to deform. The rate of deformation, however, appears to be just the reverse of this, since C4 deforms until it touches the

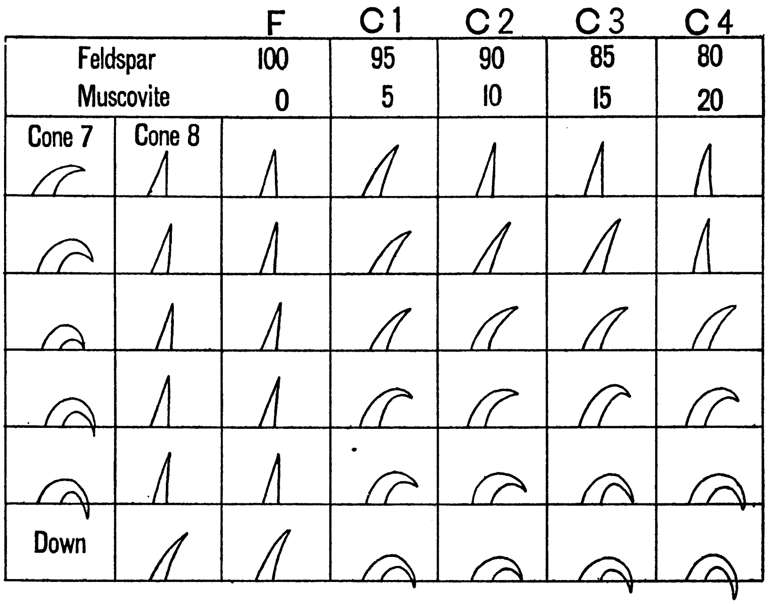


FIGURE 4.—Deformation of feldspar-muscovite cones, showing relative temperatures and speeds.

plate before any other of the series. Note also that as C1, which has the slowest rate of deformation, touches the plate F, which is pure feldspar, shows the first indication of deformation. Thus it appears that additions of finely ground muscovite to a potash feldspar lower the deformation temperature, and the rate of deformation increases with the increase in muscovite.

The influence of muscovite upon the color of the feldspar is really the most important consideration in the presence of muscovite, although the proportions present in any deposit known would hardly average 1 per cent. A specimen containing this percentage is scarcely distinguishable from pure feldspar. The tint produced by

[a] Rieke, —, Sprechsaal, 1908, p. 578.

the muscovite is a pale drab, which is the same as is imparted to porcelains by the ball clay and hence would not be noticed.

BERYL.

The presence of crystals of beryl in the pegmatite dikes and the fact that they are found chiefly associated with the portions richest in feldspar made it necessary to ascertain what effect this mineral exerts upon the industrial value of feldspar.

For this purpose a series of mixtures of microcline and beryl was prepared, ground to 200-mesh fineness, and made into cones. These cones were tested in the same manner as were the feldspar-quartz and feldspar-muscovite mixtures, and the results are shown in figure 5.

Beryl has the following composition: $3BeO.Al_2O_3.6SiO_2$.

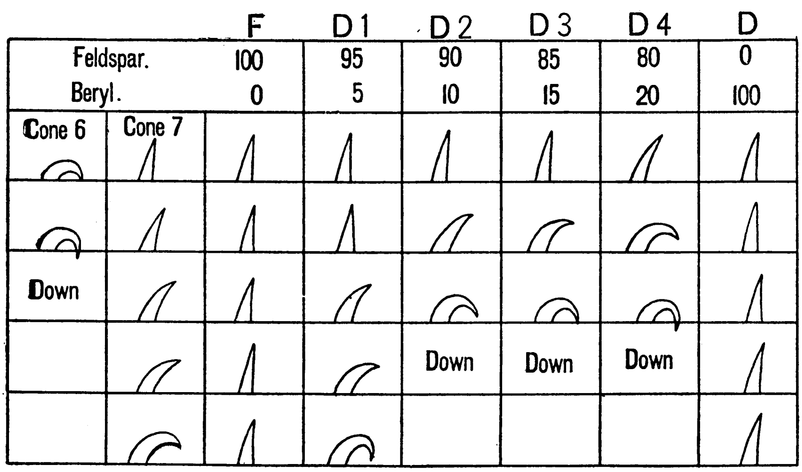


FIGURE 5.—Deformation of feldspar-beryl cover, showing relative temperatures and speeds.

The first of this series to deform is D4 which begins to deform as cone 6 touches the plate. The mixtures D3, D2, and D1 follow quickly after D4. The feldspar-beryl mixtures continue to deform in the order in which they start, the first to begin deforming being the first to touch the plate. The entire series deforms completely within less time than one cone temperature range, starting at cone 6, touching and extending to cone 7, not quite touching the plate. This series indicates that the deformation temperature decreases with increase of beryl content, at least to 20 per cent where the series ended. As a test cone of pure beryl was tested with this series and was heated to the temperature of cone 8 without deforming, a eutectic is indicated between feldspar and beryl. A study of the fired cones indicates slightly more deformation in the D3 mixture, but as this was not apparent during deformation its significance is difficult to determine.

BIOTITE.

In the dikes investigated, the biotite is generally finely divided and rarely occurs in pegmatite rich in feldspar. Where present in such quantity as to make the sorting and cobbing of the entire deposit necessary it is doubtful if the expense of such work would be justified. Where present as isolated laths or crystals, such portions of the deposit may be rejected and the remainder made marketable. The presence of biotite in any quantity renders the feldspar unmarketable except as low-grade. The injurious constituent of biotite is iron, the content of which varies greatly.

GARNET.

The influence of andradite (calcium-iron garnet; composition, $3CaO.Fe_2O_3.3SiO_2$) on the deformation point and color of feldspar was investigated. Brush and Penfield[a] report the fusibility of this mineral as lower than orthoclase. The results of the investigation indicate that a mixture of 5 per cent andradite and 95 per cent feldspar deforms at a temperature at least one cone lower than does pure feldspar. This percentage of andradite imparts to the fused feldspar a seal-brown color that does not show any diminution in intensity at higher temperatures. When 1 per cent andradite is used the color imparted is pale brown or green, depending on kiln conditions during the test.

TOURMALINE.

An investigation of the influence of tourmaline on the deformation point and color of feldspar was made. The mineral has a very complex and variable composition: $R_9Al_3BOHSi_4O_{19}$. It fuses usually at a much lower temperature than feldspar, although its composition may make it as refractory as orthoclase. The tourmaline found in the dikes studied must contain an appreciable amount of iron since a mixture of this 5 per cent tourmaline and 95 per cent feldspar produces a strong golden-brown glass at cone 10, and deforms at the same temperature as feldspar.

MANGANESE AND COBALT OXIDES.

An investigation of the influence of manganese and cobalt in the form of wad on the deformation point and color of feldspar was next made. At low temperatures a mixture containing 5 per cent of the wad has a color varying from brown to deep wine, but as the temperature increases the color fades because of the volatilization of manganese dioxide until at cone 10 only a pale lavender tint remains.

[a] Brush, G. J., Determinative Mineralogy, revised by S. L. Penfield, p. 269.

SUMMARY.

From the foregoing it is apparent that neither muscovite or beryl need be feared as impurities in feldspar, in regard to either their color or effect on the temperature of deformation.

The presence of iron garnets in feldspars must be carefully avoided because even when present in very small amounts they ruin the color of the fused feldspar.

Tourmaline ranks next to iron garnets as an injurious impurity in the dikes investigated, and while not so powerful a colorant as iron garnets, it should be carefully avoided on account of the undesirable color which it imparts.

Wad imparts an intense purple-brown color at temperatures below cone 8, but at this temperature the color is reduced to a faint amethyst hue, hence its presence is not so serious, as the color imparted tends to neutralize the yellow color of iron, especially if cobalt is present with the manganese.

PROPERTIES OF FELDSPAR IN PORCELAIN MIXTURES.

The rôle of feldspar in the porcelain mixture is that of a cementing material or solvent, its activity depending upon the temperature attained in the firing process. If the temperature only softens the feldspar the latter can do nothing more than bond the quartz and kaolin with which it is intimately mixed. If the feldspar is heated until it becomes fluid, it can take into solution part of the quartz and kaolin, and thus form a more or less homogeneous mass. Impurities in the feldspar may not appear greatly injurious in their action when the feldspar is tested alone, but may materially affect the speed of reaction and other properties of the feldspar when used in porcelain mixtures.

The action of a feldspar in porcelain mixtures is the only safe and proper basis for judging its industrial value. Experience has proved that it is not essential that the proportions of a porcelain mixture for testing be industrially correct but rather that those proportions be selected which will cause the ingredients to display most pronouncedly any faults that they possess. Thus an excess of feldspar will increase the tendency to warp and also to produce bad colors. For practical test, the following proportions have been found most satisfactory: Feldspar, 20 per cent; kaolin, 50 per cent; and quartz, 30 per cent, mixed with 50 grams of water.

A standard for each of these materials should be selected from the best material on the market and should be thoroughly tested as to its physical and chemical properties. From these standard materials a standard trial or blank should be prepared in the proportions given above and this standard trial should be tested in exactly the same manner as the mixture containing the material under test.

STANDARD PLASTIC TRIALS.

The standard plastic trials are produced by mixing the materials in the proportions given above. Especial attention should be given to the thorough mixing of these materials into a homogeneous mass, as otherwise the trial lacks uniformity and is unreliable. After being thoroughly mixed and kneaded the material is formed by jiggering or by pressing into molds in such a manner that a product of varying thickness will be obtained.

For this trial a wedge-shaped rectangular block, which may be any desired length, is most satisfactory. If one edge is sharp and the other three-fourths inch thick the trial can be used for translucency and color tests; and by impressing the face with a metal die a record of linear shrinkage may also be obtained. Care should be observed that this mark for shrinkage or identification does not interfere with the translucency test.

For testing the feldspar a mixture should be prepared in every way similar to the standard trial or blank, except that the feldspar to be tested should be substituted for the standard feldspar. In the molding of trials the process employed in producing the standard trials must be carefully duplicated if comparable data are expected. All test pieces should be conspicuously marked to insure identification.

As soon as trials are removed from the molds they should be placed where they may dry without warping, and when thoroughly dry the drying shrinkage may be determined by measuring with calipers the impression made by the die.

FIRING.

The firing of the trials now takes place. The temperature attained should be that to which the feldspar will probably be subjected in commercial work. For convenience this temperature may be safely assumed as about that at which in the deformation of the trial the point reaches the level of the base, as described under deformation-point determination.

VITRIFICATION RANGE.

Vitrification range is that range of temperature within which the feldspar being tested produces a vitreous body that does not warp. The vitrification range of feldspar is determined by means of a bar $\frac{1}{2}$ by $\frac{1}{2}$ by 6 inches composed of a mixture similar to the standard porcelain mixture, except that the standard feldspar is replaced by the feldspar being tested.

This bar, after thorough drying, is so placed in the kiln that it is supported 1 inch from each end, leaving the 4 inches in the middle unsupported. The temperature at which warping begins marks the highest temperature that is practical for this feldspar in this proportion and is considered the maximum temperature of the vitrification range. The minimum temperature of the vitrification range is determined by firing to various temperatures the trials containing the feldspar being tested; they are then carefully weighed dry, and after standing for 24 hours in pure water are removed, carefully dried on the surface only, and reweighed. The increase in weight indicates the absorbed water. The minimum temperature which renders the trial nonabsorbent is the minimum temperature of the vitrification range.

COLOR.

In the absence of a standard system of measuring color, the method employed is by comparison, using the standard porcelain mixture made and fired under comparable conditions as a standard.

TRANSLUCENCY.

Translucency is determined by placing the wedge-shaped translucency trials over a 1-inch hole in a box that contains a 16-candle-power electric lamp of constant brilliancy. The maximum thickness of the trial, expressed in centimeters, through which a No. 20 wire can be detected on the face of the trial next the lamp, with the lamp 3 inches distant, is taken as the measure of translucency.[a]

SHRINKAGE.

Shrinkage is determined by measuring the length of the die impression made in the translucency wedge. The total shrinkage is the difference between the original length and the length after firing.

TEST UNDER GLAZE.

An important property of all feldspars is their influence upon the color of the body, both unglazed and glazed. Many porcelain bodies are of faultless color when unglazed, but when covered with a clear glaze the defects of the ingredients appear and the body as viewed through the glaze is so badly off-color that the commercial value of the ware is greatly reduced. Tests under glaze are therefore of much importance, and since the glazes used are of two classes—namely, raw-lead and fritted—it is advisable whenever possible to apply to the once-fired trials a thin coat of glaze. For convenience it is desirable to place a small quantity of each glaze upon the same trial or test piece in order that the effects of the different glazes may be most clearly compared. A small portion of the trial should be left unglazed in order that the effect that glazing has on the color may be determined by comparison.

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[a] See Trans. Am. Ceram. Soc., vol. 13, 1911, pp. 104-105.

For tests of materials in porcelain mixtures under glazes, those glazes should be chosen that are most likely to be used with the materials in commercial work.

For this test the following glazes are found satisfactory and are recommended for use at temperatures between cone 02 and cone 2—that is, approximately, 1,110° to 1,190° C.

Raw-lead glaze.

Molecular formula.

$$\left.\begin{array}{l}0.6\ PbO\\0.1\ K_2O\\0.15\ CaO\\0.15\ ZnO\end{array}\right\}0.15\ Al_2O_3 .1.5\ SiO_2$$

Composition of batch by weight.

White lead	51.81
Potash feldspar	18.60
Whiting	5.02
Zinc oxide	4.20
Kaolin	4.32
Flint	16.05
	100.00

This material is ground with water enough to produce a thin paste and is applied as a coat of uniform thickness to all the test pieces to be compared.

Fritted glaze.

Molecular formula.

$$\left.\begin{array}{l}0.13\ K_2O\\0.25\ Na_2O\\0.25\ ZnO\\0.25\ CaO\\0.12\ PbO\end{array}\right\}0.22\ Al_2O_3\left\{\begin{array}{l}1.25\ SiO_2\\.50\ B_2O_3\end{array}\right.$$

Composition of batch by weight.

Melted frit	37.02
Potash feldspar	31.02
White lead	13.30
Zinc oxide	8.70
Kaolin	9.96
	100.00

Frit.

Molecular formula.

$$\left.\begin{array}{l}0.5\ Na_2O\\0.5\ CaO\end{array}\right\}\quad\left\{\begin{array}{l}0.58\ SiO_2\\1.00\ B_2O_3\end{array}\right.$$

Composition by weight, raw.

Borax	69.25
Whiting	18.13
Flint	12.62
	100.00

This frit is melted to a glass and then ground to pass a 150-mesh sieve. The ground melted frit is added to the glaze in the proportion given above, and the mixture is thoroughly ground before being applied to the trials. The fritted glaze is generally applied in a thinner coat than is necessary for the raw-lead glaze.

BLANK OR STANDARD TRIAL FOR FELDSPAR.

The blank or standard trial for feldspar consists of the standard porcelain mixture, and contains the standard feldspar, kaolin, and quartz in the proportions specified.

The standard feldspar has a chemical composition as follows:

Composition of standard feldspar.

H_2O	0.35
SiO_2	71.75
Al_2O_3	16.70
Fe_2O_3	.14
TiO_2	.03
CaO	.25
MgO	....
K_2O	8.59
Na_2O	2.99
	100.80

The standard feldspar has a deformation temperature range of 1,300° to 1,320° C. When fused, it becomes a milky glass without any yellow tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces a vitreous mass at 1,310° C. and at 1,350° C. shows no indications of warping.

The color is a vitreous white without any distinguishable cream or blue tint.

At 1,350° C. the feldspar produces a translucency of 0.65, and a total shrinkage of 15.6 per cent, 3 per cent of which is drying shrinkage and 12.6 per cent firing shrinkage.

KAOLINS.

Kaolin, or white-burning residual clay, varies more or less in its physical and chemical properties, depending on the rock of which it was a disintegration product. When freed from the other residual material with which it is almost invariably mixed, its chemical composition approaches very closely that of the mineral kaolinite.

Kaolinite has the formula $Al_2O_3.2SiO_2.2H_2O$, which, expressed in percentages, is as follows:

Composition of kaolinite.

SiO_2	46.3
Al_2O_3	39.8
H_2O	13.9
	100.0

Specific gravity, 2.6.

An ultimate chemical analysis, by which the percentage of each component of the kaolin is determined, is valuable as indicating the impurities present and the proportions in which the various components are present, but without additional data in regard to the physical properties and the mineral composition of the kaolin one can form little idea from such an analysis of the actual commercial value of the material. The following analyses show how similar may be the chemical composition of a kaolin, a fire clay, and a ball clay.

Analyses of North Carolina kaolin, fire clay, and ball clay.

[Analyses of kaolin and fire clay by Ries. Analysis of ball clay by Edward Orton.]

Constituent.	North Carolina kaolin.	Fire clay.	Ball clay.
SiO_2	45.40	45.29	48.94
Al_2O_3	37.34	40.36	36.69
Fe_2O_3	1.92	.51	.35
CaO	.44	.037	.47
MgO	.20	.015	.71
Alkalies	.52	.136	1.28
Water of combination	13.96	13.608	12.14
Total	99.78	99.956	100.58

The physical tests show the following results:

Physical tests of North Carolina kaolin, fire clay, and ball clay.

Material	North Carolina kaolin.	Fire clay.	Ball clay.
Shrinkage	*Per cent.* Air 4 Fire 8.5 Total 12.5	*Per cent.* Air 6 Fire 3 Total 9	*Per cent.* Air 8 Fire 11 Total 19
Color	White.	Gray.	Cream.

It is generally understood that the content of iron oxide is a gage of the color of the burned clay, but here is a kaolin with 1.92 per cent oxide of iron burning a pure white, although a fire clay with 0.51 per cent oxide of iron burns gray and a ball clay with 0.35 per cent oxide of iron burns cream.

The shrinkage also shows the same great variation, the ball clay having more than twice the shrinkage of the fire clay and the kaolin falling between them. The tensile strength of these clays varies as greatly as their other properties. In the air-dry state the fire clay will hardly hold itself together and is generally worked with some more plastic clay as a bond. The kaolin may hold 40 to 45 per cent of nonplastic material together, but even when pure it has too little bonding strength and must be handled carefully. The ball clay is remarkably tough and will carry 70 to 80 per cent nonplastic material and produce a strong air-dry product.

From the foregoing statement it is apparent that for the comparison of clays from widely differing sources the chemical analysis has only a limited value. However, where the clays being compared are of similar origin the chemical analysis is of great value and may furnish a means of explaining otherwise unaccountable irregularities. For the processes of chemical analysis of clay see United States Geological Survey Bulletin 422, "The analysis of silicate and carbonate rocks," by W. F. Hillebrand. Manifestly the chemical analysis is valuable only when the samples have been taken so as to fairly represent the deposit.

When, as in the present case, the material under investigation is not completely altered, the rational analysis is a valuable aid. Pure kaolin is known to be decomposed by sulphuric acid, but feldspar and quartz are only slightly, if at all, attacked in a carefully made rational analysis. This difference furnishes a means of dividing the feldspathic material and quartz from the kaolin. Mica, if present, causes confusion because it is decomposed by sulphuric acid and hence is taken out with the kaolin.

RATIONAL ANALYSIS OF CLAY.

BOLLENBACH METHOD.[a]

One gram of the clay is placed in a 400-c. c. Erlenmeyer flask of good glass. Twenty cubic centimeters of water and a few drops of sodium hydroxide are added and the mixture thoroughly cooked. The mixture is cooled rapidly and 10 to 15 c. c. of concentrated sulphuric acid is added cautiously. The flask is shaken vigorously while the acid is being added, to insure its thorough distribution. If the liquid becomes dark in color, indicating the presence of organic matter, 1 to 3 c. c. of nitric acid is added.

The flask should now be covered with a small filter funnel and placed on a sand or air bath, where it will heat very gradually. Particles of clay that in the cooking become attached to the sides of the flask should be returned to the liquid by carefully shaking the flask.

[a] Bollenbach, H., Rational analysis of clay: Sprechsaal, 1908, No. 25, pp. 340-343, No. 26, pp. 351-354.

Toward the end of the cooking the flask becomes filled with white sulphuric-acid fumes. As soon as the fumes are visible the flask should be removed from the fire. The solution should be carefully diluted with water to three times its volume and cooled. Ammonium hydroxide is added drop by drop, the flask being shaken to insure thorough mixing, until the solution smells distinctly of ammonia or an added indicator shows a permanent alkaline reaction. The precipitate is transferred to a large filter and washed thoroughly with hot water. Dilute hydrochloric acid is added to the precipitate to dissolve the aluminum and iron hydroxides and the calcium and magnesium carbonates. The solution is collected in a 250-c. c. graduated flask, cooled, and filled up to the mark. After thorough shaking, 100 c. c. is drawn off with a pipette and cooked to dryness in a platinum dish. The dry residue is heated one-half hour at 120° C.; any silica that has been taken into solution by the digesting with hydrochloric acid is thus rendered insoluble. After cooling, the residue is moistened with 5 to 10 c. c. of concentrated hydrochloric acid and allowed to stand a few minutes. By adding hot water, the chlorides of aluminum, iron, and calcium are dissolved. The silica is filtered off, washed, ignited, and weighed. The iron and alumina are precipitated from the filtrate by the addition of ammonium hydroxide. The precipitate is filtered off, washed, ignited to constant weight, and weighed as $Al_2O_3 + Fe_2O_3$.

In most cases there is no calcium present in the precipitate. Only when the clay contains more than 20 per cent calcium carbonate is a reprecipitation of the alumina and iron necessary. If iron is present in small amount, its separate determination is unnecessary. If present in excess of 1.5 per cent, it should be determined volumetrically in another 100 c. c. of the original solution.

The clay substance is calculated from the amount of Al_2O_3 found. Since only two-fifths of the original gram was used in this determination, it is necessary to multiply the Al_2O_3 found by 6.336 to find the amount of clay substance in the original 1-gram sample.

The calcium may be precipitated from the filtrate after the alumina and iron precipitate has been removed and calculated as lime, or if the ultimate analysis so indicates, as gypsum.

The mica in mica-bearing clays may be calculated from the alkali present, the alkali being determined by the method devised by J. Lawrence Smith.

DETERMINATION OF FELDSPATHIC MATTER BY CALCULATION FROM SILICA PRESENT IN THE SILICEOUS RESIDUE.

The siliceous residue from the sulphuric-acid treatment described above has been carefully washed, dried, and weighed. Five times its weight of normal sodium carbonate is added and is thoroughly mixed in a 20 to 30 gram platinum crucible. The crucible is covered and placed over a small Bunsen flame until the mass is heated through, when the flame may be gradually increased, but care must be taken that no violent boiling occurs. After the fusion is practically complete and the liquid becomes quiet, the crucible should be placed over the blast lamp for a few minutes. Then the crucible is removed from the flame and by carefully tilting it from side to side the mass is distributed over the inside of the crucible and not allowed to solidify in a cake in the bottom. After cooling, the crucible containing the fused material is placed in a beaker with some water and chemically pure hydrochloric acid is added in excess. The beaker is covered and placed on the water bath, where it is digested until disintegration is complete. The contents of the beaker and crucible are now transferred to a platinum or porcelain dish, the particles adhering to the crucible being loosened by the aid of a blunt glass rod. The solution is evaporated to dryness on the water bath, redissolved in concentrated hydrochloric acid, and, after heating 15 minutes, diluted with an equal amount of water and again evaporated to dryness. The dry residue is soaked with hydrochloric acid for 15 minutes, then diluted with an equal amount of water, covered, and placed on the water bath for one-half hour, after which it is diluted with water and filtered. The liquid should be decanted onto the filter and the silica that is left in the bottom of the dish should be washed onto the filter with cold water or dilute hydrochloric acid. After thorough washing with hot water, the silica is removed to a crucible and ignited by a strong blast for 20 to 30 minutes; then cooled and weighed. The calculation of feldspathic matter proceeds as follows:

The original amount of siliceous residue minus the silica just determined gives the flux and alumina present in the feldspar, that is—

$$\text{siliceous residue} - SiO_2 = RO + Al_2O_3.$$

In potash feldspars the following proportion obtains:

$$(RO + Al_2O_3) : \text{feldspar} = 1 : 2.837,$$

and, since the potash feldspar is always used in such calculations, it is only necessary to multiply the difference between the total siliceous residue and the silica as determined by 2.837. The result is the feldspathic matter in the siliceous residue and the remainder of the siliceous residue may safely be considered as free silica.

This method has been employed in ceramic determinations and has been found thoroughly satisfactory where a rational analysis only is desired.

DETERMINATION OF FELDSPATHIC MATTER BY CALCULATION FROM ALUMINA PRESENT IN THE SILICEOUS RESIDUE.

For this determination the same process is followed as for the determination from silica present. The filtrate from the silica, however, is brought to boiling in a large beaker of good glass and NH_4OH is added carefully until the odor indicates an excess. Boiling is continued for a few minutes, the precipitate is allowed to settle, and the alumina and iron oxide are filtered quickly and washed with hot water. In filtering, the precipitate should be allowed to settle and the clear liquid decanted off first, as otherwise the filtering of the alumina is a slow process. The precipitate is dried, ignited, and weighed as $Al_2O_3 + Fe_2O_3$. The iron oxide, if present in large amount, as indicated by a heavy dark-brown precipitate, should be determined separately as outlined in the ultimate analysis, but in most instances it may be safely included with the alumina.

The ratio of the Al_2O_3 to total potash feldspar is 1:5.451.

The feldspar thus calculated is deducted from the total siliceous residue and the difference is considered as free silica.

In case the feldspar present is unaltered, a microscopic investigation will disclose the fact and will also reveal the presence of mica, quartz, and other impurities. The rational analysis indicates the degree of kaolinization in that it divides the soluble from the insoluble portion. The microscopic analysis indicates whether the alkali should be figured as feldspar or as mica, or as neither.

IMPURITIES OF KAOLIN.

Kaolins produced by alteration of the feldspars of the dikes in the region investigated naturally vary more or less because of variations in the composition of the dikes and the extent of kaolinization.

The most serious impurity in these dikes, as in all kaolin deposits, is iron stain, which is present in two forms, as explained in the description of the dikes. The iron stain from infiltrated surface water is not serious, but when iron-bearing gneiss or schists occur as inclosed masses in the kaolinized dike, its removal without contaminating the surrounding material demands great care.

Muscovite alters slowly and it is generally found in the fresh state. Where present as large crystal masses it can be easily removed and made a source of profit in connection with kaolin mining. Where present as very small crystals or where the large masses have been broken by improper mining or refining methods its complete separation from the kaolin is difficult, and its presence may reduce the market value of the kaolin considerably. The separation of this fine mica will be discussed later.

Biotite alters much more readily than muscovite, but in the kaolinized dikes studied it is rarely disintegrated to such an extent as to impair seriously the value of the kaolin. When finely divided or broken into small fragments its separation from the kaolin is as difficult as is the separation of muscovite and its presence affects the market value of kaolin even more seriously than does muscovite.

The iron garnets of the original rock are generally completely altered in the residual mass and show as brown spots in the white finely divided quartz and kaolin. Since their coloring power is enormous the presence of a great number of such spots renders that part of a deposit valueless, since the garnets disintegrate with the kaolin in water and stain the entire product. When not too numerous these brown spots may be removed by hand sorting, which is of course an expensive operation.

REFRACTORY VALUE OF A KAOLIN.

The refractory value of a kaolin is determined by the same method as is used for determining the deformation point of a feldspar. In fact the difference between the two tests is mainly a matter of relative temperatures.

The form used for determining the refractory value is a cone of smaller dimensions than that used for feldspar studies. Its height is 1 inch and the cross section of its base is $\frac{5}{16}$ inch. (See fig. 2, p. 22.) It terminates in a point. The placing and testing of the cones and the recording of the refractory values are the same as set down for the feldspar tests and need not be repeated. Seger cone 35 is pure kaolin and has a deformation temperature of 1,830° C. Crude kaolins, however, rarely possess a deformation temperature as high as this and the purest specimens rarely withstand a higher temperature than cone 34 (1,810° C.), hence it is wise to place cones with deformation temperatures of 1,700° to 1,830° C. in the furnace with the trial, and thus determine at one test what may otherwise require several tests.

Beryl, if present in a kaolin deposit, is not detectable except where the deposit is not completely kaolinized and the crystallization of the beryl renders it noticeable. It seems to display about the same resistance to weathering as does the feldspar.

Tourmaline is not found in any kaolinized dike studied, and no record of its effect on the color of kaolin is available except as stated (see p. 31). If present in a deposit of feldspar or kaolin tourmaline would demand attention and careful removal, as its staining power is about the same as that of biotite mica.

Manganese and cobalt oxides are found directly associated with the kaolin in only one deposit within the region studied and there they are present in such small quantity as not to affect the market value of the deposit.

Aside from the effect on the kaolin of the associated minerals just discussed, the most serious consideration is the effect of the degree of kaolinization. This does not affect the color of the kaolin but does affect its vitrifying and its deformation temperature, its plasticity, and especially its shrinkage. Since the shrinkage must be provided for in making all clay products, any variation in it is a serious matter.

SHRINKAGE.

In the kaolin deposits studied the variation in shrinkage appears to be the most serious hindrance to greater development and for that reason demands careful investigation. Within the region investigated the variation in shrinkage of material from deposits being worked ranges from 6 to 11.4 per cent. An especially selected highly kaolinized sample has a shrinkage of 15.6 per cent.

To prove that the variation in shrinkage is actual and not due to differences in test conditions, commercial samples were taken at the various washing plants. The combined-water content and the degree of fineness were determined, and the samples were made into trials and fired together to cone 6.

The data obtained, which are shown in the accompanying table, prove conclusively that every kaolin in the list has been thoroughly washed. There is no relation, however, between combined-water content and shrinkage, nor between shrinkage and the amount of free water necessary to work the kaolin.

Relative shrinkage of commercial kaolins.

Deposit.	Combined-water content.	Material finer than 200 mesh.				
		Per cent.	Water required to work.	Shrinkage, wet to 110° C.	Shrinkage, 110° C. to 1,250° C.	Total shrinkage.
	Per cent.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
83	12.2	99.10	52	4.8	5.7	10.5
80	12.1	99.73	42	4.0	5.6	9.6
37	12.1	98.01	56	4.4	5.4	9.8
39	12.1	99.73	49	5.0	6.4	11.4
16	12.1	99.73	54	1.0	5.0	6.0
57	13.7	96.72	49	2.6	5.4	8.0

For the purpose of determining whether the shrinkage varies uniformly with depth in a deposit a series of samples was taken at points near the surface of several especially well-exposed deposits. Another series of samples was taken from the lowest accessible mining level of the same deposits. The accompanying table shows the combined-water content, the proportion of the various-sized grains in the sample taken, and the shrinkage at the various stages of manufacture.

Variation of physical properties of kaolins with depth of deposit.

Deposit.	Location in deposit.	Combined-water content.	Coarser than 100 mesh.	Between 100 and 200 mesh.	Material finer than 200 mesh.		
					Shrinkage, wet to 110° C.	Shrinkage, 110° to 1,330° C.	Total shrinkage.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
K3	Bottom	14.20	24.10	8.14	3.6	5.4	9.0
K3	Top	13.00	6.56	10.34	2.8	6.8	9.6
K9	Bottom	12.64	22.51	6.02	5.0	6.8	11.8
K9	Top	11.32	46.80	7.16	6.0	6.4	12.4
K58	Bottom	12.83	82.53	5.07	4.4	7.4	11.8
K58	Top	11.69	75.40	8.29	3.0	4.8	9.8
K12	Bottom	10.00	42.20	8.08	4.4	9.2	13.6
K12	Top	10.33	21.44	5.00	3.6	5.4	9.0
K82	Bottom	11.26	29.52	13.00	3.6	7.6	11.2
K82	Top	11.17	15.30	5.60	4.4	6.0	10.4

A study of this table indicates that there is a marked variation in shrinkage between the top and the deeper portions of these dikes, but in general the variation is not so great as that between different deposits. The variation in deposits is as marked in this series of samples as it is in the commercial samples.

For the purpose of determining the influence of fineness of grain on the shrinkage, a number of samples were washed through a 100-mesh sieve and through a 150-mesh sieve and separated by elutriation. The materials obtained from the samples were made into test wedges and fired at cone 9 for 24 hours.

The results show that one of the kaolins washed through a 100-mesh sieve has a shrinkage of 10 per cent. If washed through a 150-mesh sieve the same kaolin has a shrinkage of 11.6 per cent. If subjected to a floating separation so that 33 per cent of the 150-mesh material is removed, the shrinkage is increased to 12.2 per cent.

Another kaolin treated in a similar manner had a shrinkage of 9.8 per cent when a 100-mesh sieve was used, 12.4 per cent when a 150-mesh sieve was used, and 12.8 per cent when 30 per cent of the coarsest of the material finer than 150-mesh was removed.

These results show the direct effect exerted by size of grain on the shrinkage.

In many deposits all the material passing the 100-mesh sieve is practically pure kaolin, hence it is possible, in case the size of grain may safely be increased, to lessen the shrinkage by using sieves with coarser mesh.

COLOR.

The color of kaolins has never been standardized and hence the classification of samples in regard to color can, for the present, be only temporary. The real values of this classification must be assigned after a standard process has been devised and accepted.

For the present investigation the following process has been chosen as permitting of the easiest correlation to any standard color scale that may be adopted later.

A quantity of kaolin absolutely free from stain of any description from the region examined was selected by careful hand picking. A part was carefully washed in distilled water and made into briquets by identically the same process used in making the samples tested. These briquets were fired with the samples and thus a color standard was provided which for convenience is called grade 1.

The selected kaolin has the following chemical composition:

Composition of kaolin taken to obtain grade 1 color.

H_2O	13.22
SiO_2	46.67
Al_2O_3	39.07
Fe_2O_3	.11
TiO_2	.02
CaO	trace.
MgO	trace.
Na_2O	.11
K_2O	.25
	99.45

A standard English china clay was taken as the standard kaolin against which these kaolins must be checked in standard porcelain mixtures, and this china clay was prepared in a manner similar to that just described and is given a color value of grade 5.

This English china clay has a chemical composition as follows:

Composition of English china clay taken for grade 5 color.

H_2O	12.42
SiO_2	46.86
Al_2O_3	38.10
Fe_2O_3	.30
CaO	.46
MgO	.48
Na_2O	.30
K_2O	1.18
	100.10

The color classification was based upon these two standards and extended beyond grade 5 when necessary.

In order to provide as nearly as possible a uniform surface for the study of the color of the samples, the color trials are all struck off to a smooth surface with a spatula.

The classification of the various sampled kaolins has been accomplished by a series of optical studies. After each study the samples are thoroughly mixed together and the following day again classified.

A classification based on three trials with the same results has been accepted as final.

This method is recognized as faulty because of optical errors, but is the most satisfactory one available pending the establishment of a standard color scale for kaolins.

TENSILE STRENGTH.

The tensile strength of the kaolin is determined in the following manner:

The washed kaolin is mixed with water to form a thick paste, in which condition it is poured on a damp plaster slab. When "leather" dry (approximately 12 per cent moisture) it is cut by means of a sharp die into blanks of the shape and size of a cement briquet, as shown in figure 6.

These blanks are pressed into a standard cement-briquet mold and set away to air-dry. After air-drying the briquets are tested on a standard cement-testing machine for air-dry tensile strength.

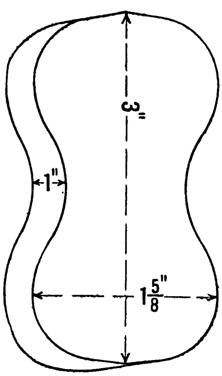


FIGURE 6.—Cement briquet.

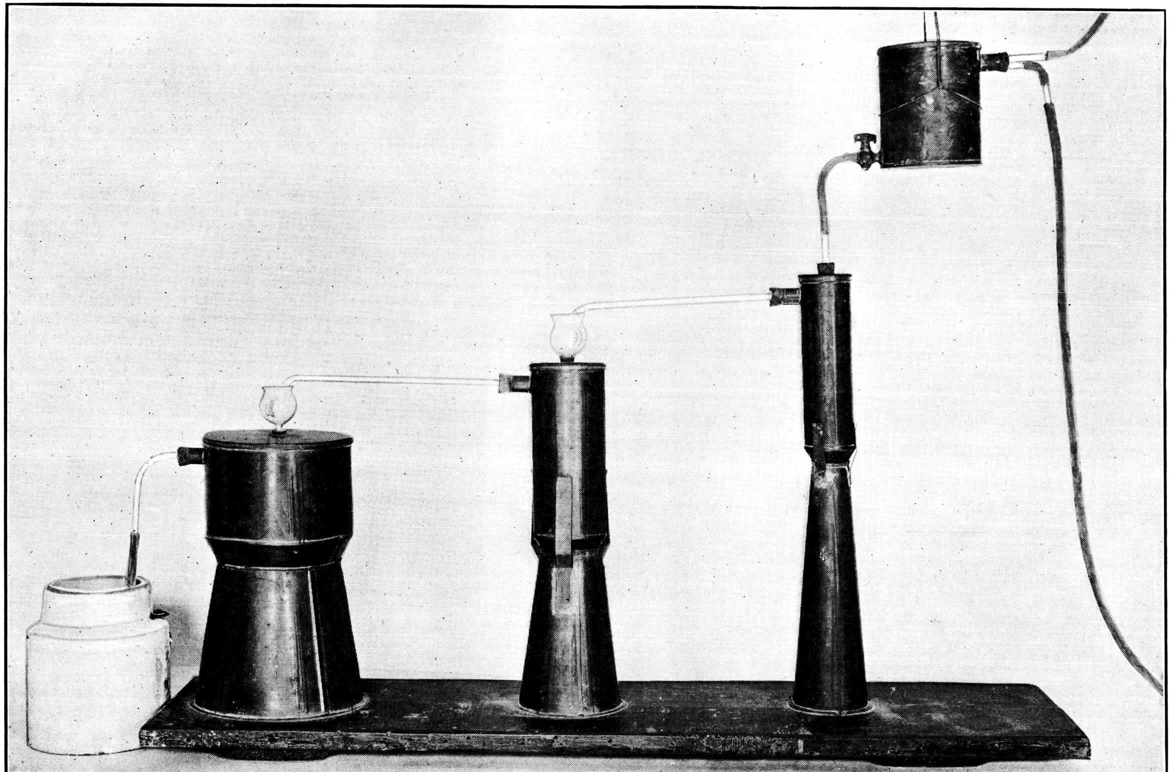
LABORATORY WASHING PROCESS FOR KAOLIN.

In preparing kaolin for testing, the problem is to wash the small samples in the laboratory in such a manner that they may possess the same physical properties as the kaolin from the same deposits washed in a commercial plant. Therefore in order to devise a suitable laboratory process, mechanical analyses were made of crude kaolin from various deposits being worked in the region under investigation. These analyses are compared with mechanical analyses of the washed kaolin from the same deposits.

After an investigation of the various other apparatus for the mechanical analysis of clays, the Schultze apparatus was selected because it is the most readily adjusted and especially because it is simple, so that the average operator can construct and operate such an apparatus if he desires and thus test the deposits that he has sampled before he commences commercial mining.

SCHULTZE ELUTRIATION APPARATUS.

The Schultze elutriation apparatus consists of a series of three jars of diameters 5, 7.5, and 15 c. m., respectively, with conical bases and straight sides. A quantity of kaolin is placed in the smallest jar into the base of which water under a given head is admitted. (See Pl. VII.) The current rising through the jar conveys all particles



SCHULTZE ELUTRIATION APPARATUS.

that it can support into a tube connecting with the base of the second jar. This jar being of greater cross-sectional area, the water rises through it at a slower rate than the water in the first jar. Some of the particles supported by the current in the first jar, and carried over to the second, are too heavy for the weaker current in the second jar and fall to the bottom. The overflow from the second jar is conveyed by a tube to the base of the third jar, which is of greater diameter than the second jar. In this jar the separation of still smaller particles is effected and material fine enough to be supported by the current flowing up through the third jar is conveyed to a

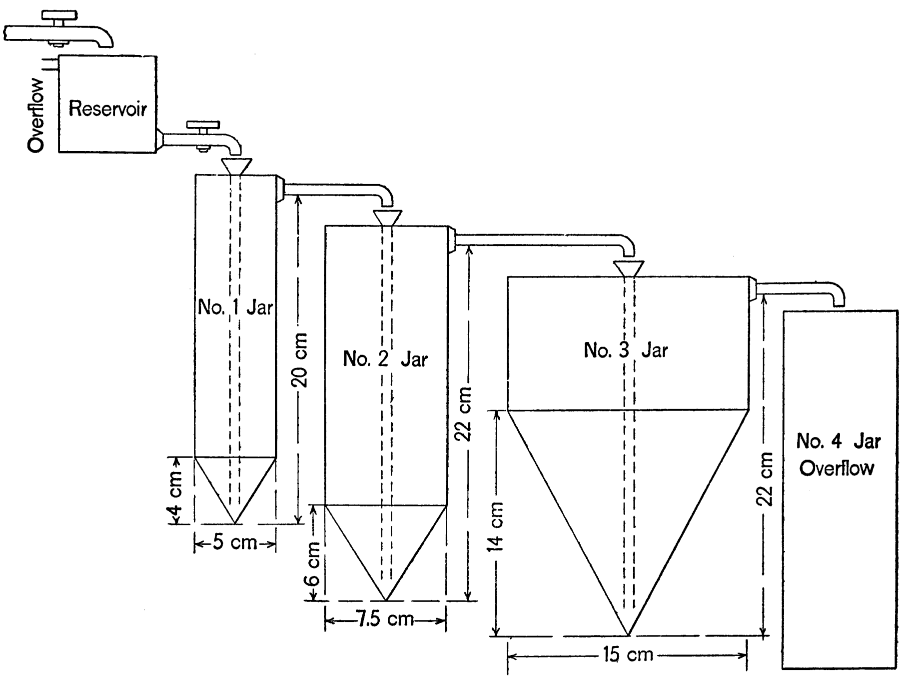


FIGURE 7.—Schultze elutriation apparatus: Flow, 4.4 c. c. per second: hydraulic values, No. 1 jar, 0.225; No. 2 jar, 0.100; No. 3 jar, 0.025.

fourth jar, where it settles. In this way the original sample is divided into four portions that differ in fineness.

Since the particles removed by the different jars of this apparatus will be determined by their size, shape, and specific gravity, and also by the rate of flow of water in the apparatus, the various divisions of particles are expressed in hydraulic values.

The hydraulic value of a given particle of any material is the rate of vertical flow of water, expressed in cubic centimeters per second, necessary to sustain that particle in suspension in water.

The hydraulic value is determined as follows:

$$\text{Hydraulic value} = \frac{\text{Volume overflow per second expressed in cubic centimeters.}}{\text{Cross-sectional area of elutriator expressed in square centimeters.}}$$

The Schultze apparatus, when operated with a flow of 4.42 cubic centimeters of water per second, has the following hydraulic values:

Hydraulic values.

No. 1 jar=0.225
No. 2 jar=0.100
No. 3 jar=0.025

The receptacle for maintaining a constant head of water flowing into the first jar is shown above the elutriation jars. A constant head of 50 centimeters ($19\frac{11}{16}$ inches) was maintained for the following investigation, and a flow through the apparatus of 265 cubic centimeters per minute was also maintained.

The material, before introduction into the elutriation apparatus, was passed through a sieve of 200 meshes per linear inch, thus removing all coarse material.

The residues in the different jars were carefully measured and found to vary in the first jar from 0.00205-inch diameter for mica particles to 0.000274-inch diameter for kaolin, quartz, and feldspar particles. In the second jar the residue varied from 0.000685-inch diameter for mica particles to 0.000137-inch for kaolin, quartz, and feldspar particles. In the third jar the residue varied from 0.000274 inch for mica particles to 0.000069-inch for kaolin, quartz, and feldspar particles.

The overflow jar contained particles of a maximum size of 0.000274 inch.

Mechanical analyses of crude and washed kaolins.

Deposit.	200-mesh residue.		No. 1 Schultze residue.		No. 2 Schultze residue.		No. 3 Schultze residue.		No. 4 Schultze residue.	
	Crude.	Washed.	Crude.	Washed.	Crude.	Washed.	Crude.	Washed.	Crude.	Washed.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
83	18.00	....	8.04	....	28.55	....	48.13	....	15.06	....
83	....	0.895	....	0.194	....	17.784	....	81.465	....	0.505
80	6.00	....	6.00	....	22.39	....	52.266	....	20.32	....
80	....	.27	....	.64	....	.517	....	75.26	....	23.40
16	57.915	....	9.73	....	48.60	....	24.84	....	16.85	....
16	....	.265	....	.135	....	23.82	....	74.46	....	1.535
39	27.505	....	2.11	....	41.187	....	52.43	....	4.257	....
39	....	.265	....	.817	....	23.56	....	74.207	....	1.397
57	81.05	....	9.928	....	50.44	....	17.578	....	22.052	....
57	....	3.275	....	.09	....	8.618	....	63.302	....	28.00
37	9.475	....	7.02	....	25.48	....	67.06	....	.54	....
37	....	1.99	....	.92	....	25.48	....	72.15	....	1.50

DISCUSSION OF ANALYSES OF WASHED KAOLINS.

A study of the mechanical analyses of the washed kaolins indicates that only one sample has more than 3 per cent coarser than 200 mesh, or 0.005 inch diameter, and in this sample the very fine material is in excess of any other samples tested. The material remaining in the No. 1 jar is in every case less than 1 per cent and the material remaining in the No. 2 jar is in three cases between 23.5 and 25.5 per cent of the material finer than 0.005 inch diameter.

The proportion of material remaining in the No. 3 jar varies from 72 to 77 per cent with one exception, when it falls to 63 per cent, but this is more than compensated for in this case by the exceptional amount passing over into the No. 4 jar.

Too fine a line of division is not permissible, as is indicated by the study of size of particles in the various jars.

It may therefore be safely assumed that with regard to the proportion of grains of the different sizes the various washed kaolins produced within the district studied do not display any marked variation.

A glance at the mechanical analyses of the crude kaolins indicates that the separation by a 200-mesh screen does not make the product comparable with the washed product in any case. With but one exception the amount of residue in the No. 1 jar is 6 per cent or over and may run as high as 11 per cent, as against less than 1 per cent in the washed product.

The proportion of the crude kaolin that remains in the No. 2 jar is, in all but one case, far in excess of that found in the washed kaolins. Thus it appears that the washing process employed in the region investigated removes practically all that material of the No. 1 jar classification and a considerable amount of that belonging to the No. 2 jar classification. It will be noted that some factory-washed kaolins yield a lower percentage of material in No. 4 jar than is obtained in that jar from crude kaolin of the same deposit. The shortage in No. 4 jar corresponds to an excess in No. 3 jar. This difference may be explained by the fact that throughout this region alum is used as an aid in concentrating the slip; the fine particles are thus coagulated and settle more readily than they would otherwise.

The proportion of the No. 2 jar classification that must be removed in order to obtain absolutely comparable results varies with different deposits; hence the establishment of a uniform process for the duplication of all the washed kaolins is not to be considered and a single uniform process must be accepted and followed for all kaolins.

In order to determine whether the residues in the different jars of the Schultze apparatus vary in physical properties, a quantity of average crude kaolin was screened through a 200-mesh sieve, then mechanically analyzed, and the residues tested. The results were as follows:

Physical tests on Schultze elutriator residues.

	No. 1 jar.	No. 2 jar.	No. 3 jar.	No. 4 jar.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Combined-water content	12.31	13.48	13.37	14.19
Minimum free water for molding	....	56.6	53.3	46.0
Air shrinkage of briquets made with minimum water	....	.6	.6	4.0
Total shrinkage at 1,300° C. of briquets made with minimum water	....	5.4	6.6	12.2

The physical properties apparently do not vary greatly with the size of grain except with regard to shrinkage, and this is excessive only in the very fine material. Provided the percentage content of the No. 4 jar remains constant, any variation in content of the No. 2 and No. 3 jars will not seriously affect results.

A microscopic study of the different divisions of particles indicates that mica is present only in the No. 1 and No. 2 jars, and in No. 2 jar is present only as a few scattered particles. Quartz is also present in No. 1 and No. 2 jars, but its presence in No. 2 jar does not exceed 1 per cent.

Feldspar is present in decreasing quantity from jar No. 1 to jar No. 3, being present in No. 3 only as a few scattered particles that do not show any cleavage lines and are apparently far advanced in kaolinization.

Since the object of washing is merely to remove impurities, and especially those of relatively large dimensions, it seems logical to remove all the coarse material possible by sifting. In commercial operations the sieve is used to supplement elutriating and floating. Thus the plates of mica present in the crude kaolin are treated for a longer time with the kaolin and fine sand and are more broken and pulverized, resulting in a greater amount of fine mica in the finished product than if the sieve were used first.

As a guide to the selection of a sieve for the separation of the coarse particles from kaolin prior to elutriation, sieve tests were run on five kaolins from the region investigated. The data obtained are as follows:

Sieve separations of crude kaolins.

Test.	Residue on 40-mesh sieve.	Residue on 100-mesh sieve.	Residue on 150-mesh sieve.	Residue on 200-mesh sieve.	Material finer than 200-mesh sieve.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
A	61.30	15.93	6.50	2.60	22.67
B	28.14	24.75	6.58	.50	40.03
C	20.00	16.32	15.32	1.75	46.61
D	12.25	21.62	9.30	2.56	54.27
E	....	31.82	5.26	1.24	61.68

From this investigation it appears that the proportion of coarse material removed by a sieve of 200 meshes per linear inch in addition to that removed by a sieve of 150 meshes per linear inch may not be expected to exceed 2.6 per cent, and this additional amount of coarse material would hardly influence the operation of the elutriator. A microscopic study of the residues indicates that both the 150-mesh and the 200-mesh residues consist largely of mica; hence the removal of mica prior to elutriation is desirable. A sieve of 200 meshes per linear inch is recommended by the author and will be used for ensuing investigations. However, the use of a sieve of 150 meshes per linear inch is permissible, and if the crude kaolin contains much rough and coarse material such a sieve will be found much more durable than a finer one.

The operation of an elutriator for washing kaolins is based on the supporting power of a rising current of water, and since the quantity of water necessary increases as the cross-sectional area of the cylinder, it is advisable to use a cylinder of as small diameter as can be operated conveniently. The grade of material removed can be regulated entirely by the velocity or rate of flow of the current of water.

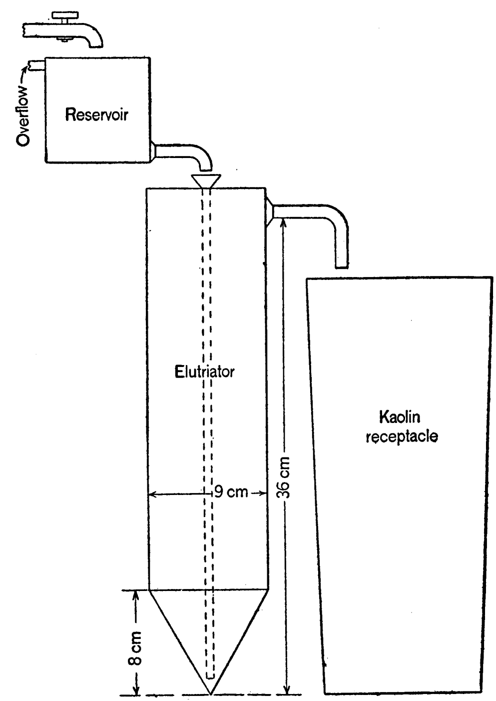


FIGURE 8.—Laboratory elutriator operated at different rates of flow: Flow, 859 c. c. per minute, hydraulic value, 0.225; flow, 800 c. c. per minute, hydraulic value, 0.209; flow, 700 c. c. per minute, hydraulic value, 0.183; flow, 650 c. c. per minute, hydraulic value, 0.170; flow, 600 c. c. per minute, hydraulic value, 0.157; flow, 500 c. c. per minute, hydraulic value, 0.131.

The elutriator designed especially for and used in these investigations is shown in figure 8.

The hydraulic value of the smallest particles desired to be removed from the crude kaolin lies between 0.225 and 0.100.

To determine the capacity of this elutriator, it was operated at various hydraulic values between these two extremes, and mechanical analyses of the kaolins obtained were made by means of the standard Schultze elutriator. The results are as follows:

Mechanical analyses of kaolin washed by laboratory elutriator operated at different velocities.

Flow through cylinder per minute.	Hydraulic value.	Mechanical analyses of product by standard Schultze elutriator.			
		No. 1 residue.	No. 2 residue.	No. 3 residue.	No. 4 residue.
C. c.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
859	0.225	5.23	31.38	30.4	33.00
800	.209	2.42	27.31	30.075	40.20
700	.183	2.07	21.31	34.85	41.77
650	.170	.48	19.83	36.18	43.51
600	.157	.02	15.03	36.88	48.07
500	.131	.025	10.17	39.53	50.275

A study of the results shows that for this elutriator a hydraulic value of about 0.170 or 650 cubic centimeters per minute will give a product practically free from particles of the No. 1 Schultze elutriator size and will also remove 37 per cent of the largest particles in the No. 2 Schultze elutriator classification. The product should very closely resemble the average washed kaolin of the region, and the process will be accepted as standard elutriation for these kaolins.

LABORATORY KAOLIN-WASHING PROCESS IN DETAIL.

Based on the foregoing investigations, the following process was worked out as a substitute for the kaolin washing commercially practiced in the region investigated:

One pound (453.6 grams) of the crude kaolin is weighed out and carefully sifted into about 1½ pints (850 c. c.) of distilled water or filtered rain water, and the whole thoroughly stirred and allowed to stand until the kaolin has completely slaked. If the lumps do not slake readily it may be necessary to employ a disintegrator, but this should never be a ball or tumbler mill, as such a mill tends to pulverize the mica present. When the use of a disintegrator is necessary, an agitator with a speed of not over 50 revolutions per minute is recommended.

For laboratory use a modern household churn of small capacity (see *B*, Pl. VI) makes an excellent agitator. The kaolin to be disintegrated should be allowed to stand for an hour in distilled or rain water and then washed into the agitator. The agitator should never be run fast enough to move the large lumps of quartz and mica which have settled to the bottom. When the material on the bottom of the agitator is free from kaolin particles, stirring should cease and the contents of the agitator should be emptied into a porcelain dish or enameled steel pan of suitable capacity.

After standing for a few minutes the coarse material will settle to the bottom, and the kaolin-bearing water may be decanted or poured on a sieve of 150 or 200 meshes per linear inch. If the slip or kaolin-bearing water is slowly poured on the sieve and the latter slightly agitated the slip will pass through without difficulty, leaving the coarse material on the sieve. If, on the other hand, the contents of the agitator are dumped on the sieve at one time, the coarse particles will clog the holes and the operation of the sieve will prove difficult and often impossible without the aid of stirring the sediment on the sieve surface with the hand. Such hand stirring, or rubbing of material through the sieve, is to be strongly condemned. It not only forces through the sieve particles larger than the normal dimensions of the apertures, but it permanently distorts the apertures, so that the sieve has both large and small openings and is rendered worthless.

After all the particles possible have been shaken through, the sieve should be removed from the dish and placed over another dish or pan, into which it will fit snugly. In this pan should be placed about a pint of water, and by a shaking motion the sieve should be washed from below. Such washing will remove the fine particles much more quickly than placing the water on the sieve with the residue.

The sieve containing the coarser material should be allowed to dry; the coarse material when dry should be weighed and its weight recorded.

The two pans of washings should be mixed. They are then ready for elutriating.

The laboratory elutriator should be adjusted so that exactly 650 cubic centimeters (18.3 ounces) of water passes through the cylinder in a minute. The flow may be regulated by a valve or pinch-cock on the tube that conveys the water from the reservoir to the cylinder. When all is in readiness, the cylinder should be emptied of water and the kaolin sample which has passed the 150 or 200 mesh sieve should be poured into it; the dish in which it was contained should be well rinsed and the rinsings added to the kaolin in the cylinder. The water may then be started and the elutriation begun. The results may easily be irregular if the flow of water varies in the least, and every precaution should be taken to insure a steady flow. The reservoir is for this purpose. Elutriation should continue until the overflow from the cylinder shows no sediment after standing several minutes. The finest portions pass out of the elutriator with the first 8 or 10 liters. As this fine material settles very slowly, it is advisable to keep the first 2 gallons separate from the later flow which contains less fine material and hence settles more quickly. The remainder may be collected into one large receptacle and in a few hours will generally settle, so that practically all the water may be poured or decanted off and the residue added to the receptacle containing the first 2 gallons of the washings, and all stirred thoroughly together.

This material may be pressed free from water by means of a small laboratory filter press. If such apparatus is not available, a satisfactory substitute is a canvas bag about 8 by 14 inches in size, strongly sewed to prevent ripping and provided with a loop for suspension. The kaolin slip after being well agitated is poured into the bag, which is either hung up to drain or pressed free from water by weights. Care should be exercised when the weights are applied to avoid a sudden large increase of pressure, as a leak thus started will be found difficult to stop.

After the water is removed the kaolin has only to be dried and weighed. The residue remaining in the cylinder may also be dried and weighed and this, together with the residue on the sieve, constitutes the waste material of the washing process. The total weight of these three dried residues should equal the weight of the original sample. The weight of dry kaolin obtained by this process should indicate the productiveness of the deposit, provided the sample tested is fairly representative of the deposit.

PROPERTIES OF KAOLIN IN PORCELAIN MIXTURES.

The rôle of kaolin in all pottery mixtures is that of a plastic bond in the forming of waves and its bonding action continues through the drying process. In firing, the kaolin, by its high refractory value and its resistance to the solvent action of the feldspar, enables the mass to retain its form, although the particles of kaolin may be enveloped in fluid feldspar so completely that the mass becomes translucent and appears homogeneous. Hence the testing of kaolins in porcelain mixtures must consist of tensile tests and translucency tests in addition to the determination of vitrification range, color, and shrinkage.

For kaolin tests in pottery mixtures, the same proportions of material are used as for feldspar tests in pottery mixtures, that is—

Pottery mixture for kaolin tests.

Feldspar, 20 parts by weight.
Quartz, 30 parts by weight.
Kaolin, 50 parts by weight.

The feldspar and quartz are standard materials and the kaolin is the material being tested. The materials are all in the form of impalpable powders and are mixed together with just enough water to produce a plastic mass capable of being formed as desired. The mass must be thoroughly mixed to homogeneity, as otherwise the product is worthless.

TENSILE TEST.

For tensile tests the method of testing is the same as outlined for tensile tests of the kaolin alone. The tensile strength of the kaolins investigated is so low that when it is reduced by the addition of nonplastic feldspar and quartz the briquets are too weak to support the clamps for testing. Hence such a test is impossible unless some plastic clay is added to give strength to the mixture, and in that event a test would represent the bonding strength of the added clay, so that for the particular kaolins under investigation no tensile test in pottery mixtures is practical. This statement is not to be considered as applying to kaolins generally, as most kaolins possess measurable tensile strength, and this is an important factor in considering the amount of plastic clay that must be added in order to produce an industrially valuable mixture.

TRANSLUCENCY TEST.

For translucency tests the process outlined for a similar test of feldspar is recommended. The test mixture described above is molded into wedges which are fired to the maturing temperature 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 with the lamp 3 inches distant from the trial. This test is very important, for American kaolins vary greatly in the property of producing translucent bodies with a given mixture of standard feldspar and quartz, and in the color they impart to such bodies. Some kaolins produce pottery bodies which are white both in reflected and in transmitted light, but most American kaolins produce pottery bodies which are pale cream in reflected light and a decided cream in transmitted light.

VITRIFICATION RANGE AND ABSORPTION.

The kaolins investigated do not produce nonabsorbent porcelains at commercial temperatures, hence the absorption at 1,350° C. is substituted for the vitrification range.

THE GRADING OF COLOR.

The grading of color of the kaolins in standard porcelain mixtures has been accomplished by comparison and the most absolute white, free from tint, that was obtained in this investigation is given a value of 1. The standard trial, which to all intents and purposes is pure white, has been given a value of 5, the other kaolins when used in the porcelain mixtures receiving the value based on the class in which they fall by ordinary optical study.

SHRINKAGE.

To determine shrinkage the wedges are measured before and after drying and after firing, or preferably a die of known length is lightly impressed in the face of the newly made briquets or wedges. By measuring these impressions after drying and burning, the shrinkage can be easily and quickly determined.

TESTS UNDER GLAZE.

Since the color of a kaolin under glaze can not be predicted from the color unglazed, the glazing of kaolins in order to determine their industrial value is very important.

It is advisable to use test pieces of the sample kaolins in the standard porcelain mixture. These test pieces have previously been fired to vitrification and any fault in color of the kaolin is intensified. The same glazes are used for these tests of kaolins as are specified for similar tests of feldspars in the porcelain mixture. The glazing of these trial pieces demands extra care since vitreous porcelain has smooth surfaces, and unless great care is exercised and the glaze is very thick the greater portion of the glaze will run off the trial or at least mix with the other glaze test on the same trial piece. Warming the trials is a great aid in preventing this difficulty. In firing these glazed trials the same care must be exercised as with the glazed feldspar trials or the glazes on fusing will run off the trials or run together.

BLANK OR STANDARD TRIAL FOR KAOLIN.

The blank or standard trial for kaolin consists of the standard porcelain mixture and contains the standard feldspar, kaolin, and quartz in the proportions specified.

The standard kaolin used is an English china clay having the following composition:

Composition of English china clay used for standard kaolin.

Combined water	12.42
SiO_2	46.86
Al_2O_3	38.10
Fe_2O_3	.30
TiO_2	.00
CaO	.46
MgO	.48
K_2O	1.18
Na_2O	.30
	100.10

This kaolin has a refractory value of 1,690° C., and burns to a porous white mass at 1,350° C.

Properties in standard porcelain mixture.

In the standard porcelain mixture in which this kaolin is used the mass becomes vitreous at 1,310° C. The color is a vitreous white of grade 5. The translucency is 0.65 and the total shrinkage is 15.6 per cent, which consists of 3 per cent drying and 12.6 per cent firing shrinkage.

QUARTZ.

Quartz theoretically is pure crystalline silica, but in nature it is rarely found absolutely pure. The dikes studied contain sugar, smoky, and transparent quartz.

The sugar quartz is most abundant and is most widely distributed, being common throughout the region investigated. It generally forms the outside bands of a dike and also the quartz band or lens along the middle of many dikes. Some bands of sugar quartz are 4 to 12 feet wide and hundreds of yards long. It is seldom sufficiently disintegrated to fall to pieces, but often has to be broken with a sledge or an explosive before it is reduced to pieces of convenient size for handling. It is crystalline, pure white, and opaque, due to innumerable vesicles of gas liberated at the time of crystallization and to fractures subsequent to crystallization. It is practically pure silica, showing by analysis an average of 99.3 per cent SiO_2.

Smoky quartz is found only in the vicinity of Sprucepine, Mitchell County, N. C. Wherever present it is in narrow bands or lenses in the pegmatite and not in an outside band adjoining the country rock. It is invariably badly ruptured, being easily broken by the fingers into small needle-like particles with sharp edges. It consists of an aggregate of particles of varying color intensity and in the mass presents a mottled appearance. The smoky tint has a decided brown cast in some particles, whereas in other particles it tends to an amethystine purple. Some writers state that this color is due to the presence of manganese; others that it is due to the presence of organic matter. Whatever may be the source of the color it disappears completely at between 350° and 400° C. When a solid piece of this smoky quartz is heated, the color fades uniformly throughout. By heating smoky quartz, A. W. Wright [a] obtained a gas of the composition CO_2, 98.33 per cent, and N_2, 1.67 per cent. On further heating this gas gave a brown precipitate which partly dissolves in alcohol. By more intense heating this brown residue volatilizes with a strong bituminous odor similar to that given off by burning cannel coal. The quartz residue is pure white. This smoky quartz, therefore, may safely be looked on as a colorless quartz so far as its influence in ceramic mixtures is concerned.

The transparent quartz is found in this district only as a component of pegmatite. It exists as quartz grains intermixed with the feldspathic material and in most instances is so intergrown with the feldspar that separation is impossible. The specific gravity of quartz is 2.65; the specific gravity of potash feldspar is 2.54, and of soda feldspar 2.60, which may be increased by the presence of calcium in the feldspar. Hence a successful mechanical separation is impossible.

[a] Am. Jour. Sci., vol. 21, 1881, art. 24.

The transparent quartz separated in the washing of kaolin is generally so mixed with mica and other impurities that its recovery by cleaning would not be commercially practicable.

The sugar quartz is therefore the only pure silica present in commercial quantity in the region investigated. When pure its refractory value is cone 34 (1,810° C.). With the small amount of impurity present its deformation point or refractory value is about cone 32 or 33, that is, 1,780° C.

COLOR.

Fired alone to cone 12 the quartz gives a pure white opaque mass with no strength and no trace of cementing action.

In mixtures with pure feldspar (microcline) the quartz opacifies the feldspar, apparently due to finely divided quartz in suspension.

When added to mixtures of feldspar and kaolin the quartz changes the color in vitreous ware from blue white to pure white, and at the same time tends to change the texture from glassy to granular without, however, reducing the translucency of the mass. In fact, additions of ground quartz up to a given quantity for a given temperature tend to increase translucency. The mechanical strength of a vitreous body is increased by additions of ground quartz up to a given quantity, dependent on the maturing temperature of the body.

SEMIKAOLINIZED FELDSPARS.

The name "semikaolinized feldspar" is used to designate all those deposits of material that have so altered that they can no longer be classified as fresh feldspar but on the other hand have developed no plasticity and hence can not be classified as kaolin.

The location of the deposits of such material is divided into two classes, (*a*) isolated bands, (*b*) semikaolinized dikes.

(*a*) In kaolinized dikes containing many bands of widely differing material there are always found one or more bands that have withstood weathering and that produce no kaolin. Such bands are invariably found to consist of semikaolinized feldspar. These bands are lenticular and the presence of a broad exposure of such material is no indication that all the surface of the dike will consist of this material.

In dikes containing semikaolinized material, the mining of the kaolin necessitates the removal of these hard bands and heretofore they have been thrown aside as refuse together with quartz bowlders and other undesirable foreign material.

(*b*) In dikes that are apparently completely kaolinized on the surface, mining to about 100 feet exposes less altered material, and the degree of kaolinization decreases with depth until fresh feldspar is reached. Thus in such dikes the semikaolinized feldspar lies below the kaolin and above the fresh feldspar. Although its alkali content increases downward the variation is generally not so abrupt as to cause difficulty, and with care in mining and with proper mixing of the mined material a uniform product should be easily produced.

This semikaolinized feldspar is peculiar in that in 16 such deposits sampled no semikaolinized soda feldspar was found, every deposit being potash feldspar with a maximum soda (Na_2O) content of 1.11 per cent. Furthermore, the potash (K_2O) content is higher than in most feldspar, being 14.40 per cent in one specimen, and the alumina (Al_2O_3) content is invariably higher than is theoretically required either in the potash or soda feldspar.

The foregoing observations seem to justify the conclusion that these semikaolinized feldspars found in lenses or bands in an otherwise kaolinized dike represent a material that contains more potash and alumina than the associated bands and, being more resistant to weathering, has remained only slightly altered while the remainder of the dike has completely broken down.

The presence of an excess of Al_2O_3 and also the presence of combined water indicates the progress of weathering and doubtless the giving up of some alkali. The fact that no fresh feldspar that carries more potash than these semikaolinized feldspars is found in this district would indicate that weathering has removed the Na_2O, if any alkali has been removed. This removal of the soda portion of the feldspar before that of the potash portion might be expected from the weaker resistance to weathering of soda feldspars.

The semikaolinized material below the upper kaolinized part of the dikes also shows this high potash content and low soda content. Here is additional proof that weathering has affected the soda-bearing material first.

Examination of the kaolin above the semikaolinized part of a deposit fails to disclose more than a small percentage of Na_2O, the K_2O content always being in excess, hence the Na_2O, if leached out, must have been completely removed from the dike.

The potash content, in the samples taken, varies from 1.7 to 14.4 per cent K_2O, the amount of combined water varying inversely as the alkali content. As the samples were taken to represent the average composition of the portion of the dike sampled, no information as to the rate of alteration can be obtained from their study but the data at hand indicate that in deposits containing 50 per cent or more of the original alkali content the proportion of combined water present may be taken as a fair criterion of the proportion of alkali removed.

The alkali content would be expected to control the deformation temperature provided the other ingredients remain reasonably constant. Although a small change in alkali content seemingly affects the deformation temperature only slightly, the combined water content is a reliable indicator of the deformation point of the semikaolinized feldspar. Thus it appears that the change in deformation temperature is due not only to the proportion of alkali

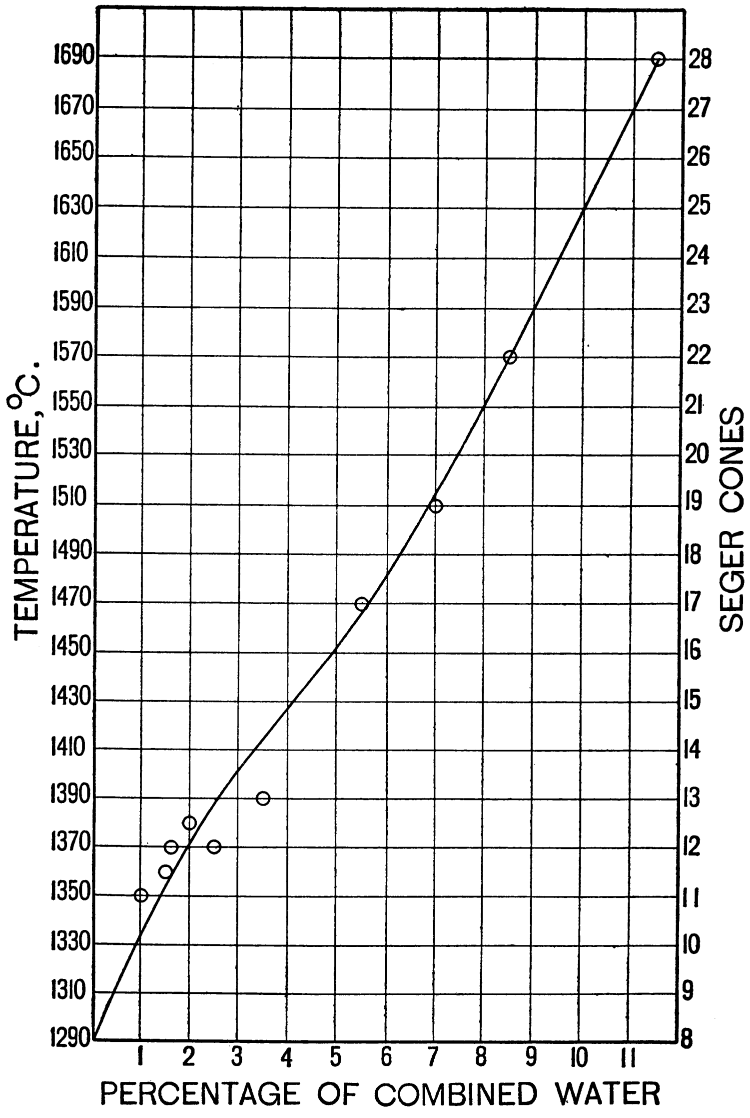


FIGURE 9.—The deformation temperature of semikaolinized feldspar plotted against the combined-water content.

and other elements present, but also to the mineral form in which these elements exist. Figure 9 indicates the consistent increase in deformation temperature with increased combined-water content. In this figure are plotted data from 10 of the best exposed deposits coming under this classification.

The lack of better agreement is doubtless due to the fact that when a dike is exposed to the elements for any time the alkalies leach from its surface and the taking of representative samples is rendered difficult, even though the surface material be removed for several feet.

A peculiarity of all these semikaolinized feldspars is their gradual deformation. The softest of the specimens tested were vitreous and highly translucent for 50° C. before they deformed. Some of the harder specimens were vitreous for almost 100 degrees.

Another physical property to be considered in connection with a study of these materials is shrinkage in firing. When fired at 1,330° C. the specimens that are only slightly kaolinized shrink 15 per cent. With greater kaolinite content the shrinkage decreases, until in specimens containing 60 per cent kaolinite the shrinkage is only 10.75 per cent. With increased kaolinite content the shrinkage increases again, until in specimens showing a content of 14 per cent combined water but no plasticity the shrinkage ranges from 12.5 to 15.25 per cent.

This peculiarity in shrinkage is explained as follows: In the slightly kaolinized specimens the excessive shrinkage results from vitrification, whereas in the specimens nearing complete kaolinization the shrinkage is due to the grains being very fine.

The deposits containing little or no alkali, but having no plasticity and forming the refractory end of this series, can possess little or no interest for the ceramist owing to their great shrinkage.

For the deposits containing one-half or more of their original alkali content, a ready market should be found in the pottery industry. The majority of these semikaolinized feldspars may be crumbled in the fingers, and at best a very light grinding would suffice to reduce the material to an impalpable powder. Thus the cost of grinding would be only a small proportion of the ordinary cost. An additional advantage of these materials is their pure color, which should make them especially suitable for raising the quality of cheaper soda feldspars that are too much colored to be easily marketable.

These semikaolinized feldspars are merely mixtures of the materials ordinarily employed in pottery bodies, and in some instances the plasticity of the fully developed kaolin is the only essential lacking in order to produce a perfect porcelain.

For example, a semikaolinized feldspar has the following chemical composition:

Composition of a semikaolinized feldspar.

H_2O	2.78
SiO_2	64.59
Al_2O_3	20.80
K_2O	11.83
	100.00

Recalculation to mineral components gives the following composition by weight:

Mineral components of a semikaolinized feldspar.

Component.	K_2O.	Al_2O_3.	SiO_2.	H_2O.	Percentage of total.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
Analysis	11.83	20.80	64.59	2.78	100
Feldspar	11.83	12.84	45.33	....	70
		7.96	19.26	2.78	
Kaolinite	....	7.96	9.26	2.78	20
Quartz	....	....	10.00	....	10

Thus it is apparent that this material, which has a chemical composition unlike any regularly employed feldspar, is really merely a mixture of 70 parts microcline feldspar, 20 parts kaolinite, and 10 parts quartz, or flint. In fact, the production of a feldspar free from impurity or associated minerals is very difficult and expensive, and very little feldspar is sold that does not contain an appreciable amount of free quartz; hence the kaolinite component is the only new factor introduced.

SUBSTITUTION OF SEMIKAOLINIZED FELDSPARS FOR FELDSPARS.

Although the value of semikaolinized feldspar, as a substitute for feldspar in pottery, has never been exploited, it should be one of the most valuable products of these dikes. It contains practically pure potash feldspar, and if the small amount of kaolin and free silica present is taken into account in the compounding of the body it can be readily seen that a porcelain of longer heat range could be produced than is possible where the ordinary mixed potash and soda feldspar of commerce is used. The color of these semikaolinized feldspars is generally superior to the feldspars of commerce.

For example, let us consider a porcelain of the following composition by weight:

Feldspar	16
Kaolin	45
Flint	39
	100

If a semikaolinized feldspar of the composition

Feldspar	70
Kaolin	20
Free silica or flint	10
	100

is used, the 16 per cent of feldspar in the porcelain is to be supplied by 70 per cent of the semikaolinized feldspar, the kaolin thus introduced being $\frac{20}{70}$ of 16 or 4.57 per cent and the flint $\frac{10}{70}$ of 16 or 2.29 per cent. The total semikaolinized feldspar being thus $16+4.57+2.29=22.86$ per cent semikaolinized feldspar. The 45 per cent of kaolin in the body composition is reduced thus 4.57 per cent, which leaves 40.43 per cent to be introduced as pure kaolin. The flint or free silica in the body composition is 39 per cent, but 2.29 per cent is introduced in the semikaolinized feldspar, hence there remains to be introduced as flint 36.71 per cent. The mixture for the porcelain mentioned above will thus be made up as follows, by weight:

Semikaolinized feldspar	22.86
Kaolin	40.43
Flint	36.71
	100.00

This simple recalculation shows that these semikaolinized feldspars may be made a valuable addition to American ceramic materials. It must be borne in mind that the feldspar thus introduced is potash feldspar and it must replace potash feldspar only. In case the feldspar to be replaced is a mixed potash and soda feldspar, this semikaolinized feldspar should be used to replace the potash feldspar only and soda feldspar should be used to replace the soda feldspar. This replacement can be made with considerable saving, because soda feldspar has a lower market value than potash feldspar.

The use of this semikaolinized material would require the making of careful and thorough tests before its introduction, but to the technically trained man the substitution of this material for commercial feldspar is a simple problem, and the advantages to be gained by the improvement in color and increased heat range would more than repay any inconvenience caused.

The tests for vitrification range, color, shrinkage, and translucency, when this material is substituted for a feldspar, should be made in the same manner as in testing a feldspar.

When it is hoped to substitute some of the more refractory semikaolinized material, only the least plastic kaolin should be replaced and great caution should be taken lest the mixture be made too friable and weak after drying.

Another market for this material, which contains a considerable amount of potash, may arise if potash is ever commercially extracted from feldspar.

MINING AND REFINING THE PRODUCTS OF THE PEGMATITE DIKES.

FELDSPAR.

MINING BY OPEN-CUT.

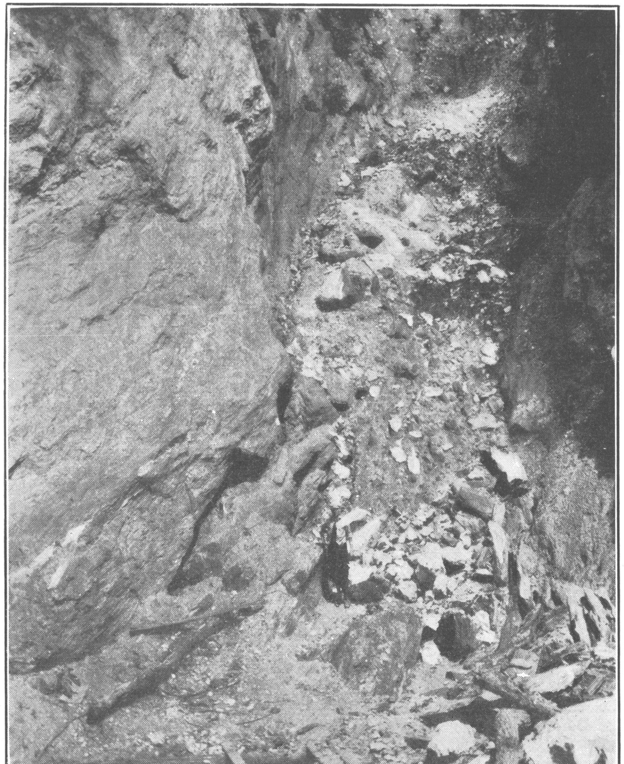
The mining of feldspar by open-cut is the simplest form of quarrying. The dike is exposed by removing the overburden along a slope and the material is broken down by wedging where practical but usually by drilling and then blasting with dynamite. The different bands of the dike are generally well defined, and hence there is no difficulty in selecting material and the elimination of any undesirable bands is left until the material is sorted for shipment. The wall rock of the fresh feldspar dike is generally solid and no danger of slides exists except where walls are loosened by blasting. The open-cut is generally kept level to the face of the hill to facilitate drainage even though the quarry products are necessarily removed from a higher point. When the quarry extends below the outlet level, pumps are used to handle the water. No difficulty is encountered, since the water is allowed to drain into a central pool, where it settles before it is pumped. (See *B*, Pl. V, and *A*, Pl. VIII.)

The products of the dike are removed by wheelbarrow or by horse and cart to a point outside the quarry where sorting and cobbing are carried on.

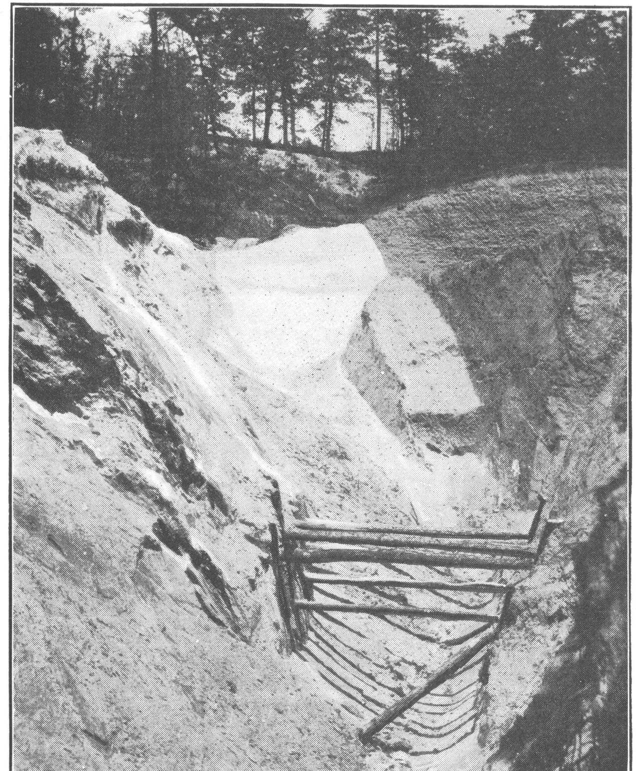
TUNNELING AND STOPING.

Where feldspar alone is the product of a dike, tunneling and stoping have never been used within the district under investigation, but where mica is found in paying quantity in the dike, this method of mining is not uncommon. The practice is to run a drift or tunnel into the dike at as low a level as convenient. This drift is continued along the dike until the latter pinches out or the mica becomes too poor and scarce for mining. A vertical cut is then made just inside of the point where the tunnel cuts the dike. This is sometimes carried up for about 12 feet in order to give two benches for working, although ordinary practice in this district is not to work more than 6 feet high at a time. This bench is cut out directly above the old tunnel and when the material is all removed another bench is cut above. In order to facilitate mining, it is customary to build "lofts" of rough timbers above two or three benches and upon them to build platforms for reaching the dike material. Mining is done almost exclusively by drilling and blasting and only the valuable material is removed from the mines, the refuse being dumped into the worked-out area below or heaped in abandoned "lofts."

By thus working from below, the maximum efficiency of the explosives is obtained and the cost of mining is kept low. The drainage



A. OPEN-CUT MINING FOR MICA IN A PEGMATITE DIKE, BOTH WALLS BEING SOLID ROCK.



B. OPEN-CUT MINING FOR KAOLIN. THIS DIKE CONTAINS NO QUARTZ BANDS, DIFFERING THEREIN FROM MOST DIKES IN THIS DISTRICT.

of the mine is natural, since the entrance tunnel is the lowest point opened. Where the feldspar is removed from such workings an ordinary mine car is employed, running on a track to the point where stoping begins. The material is generally dumped from above into a hopper built at this point.

REFINING.

Where the dike contains an excessive proportion of quartz or when the feldspar mined must be of extra quality, the dike product is all hand sorted as cobbed. In cobbing the feldspar is cleaned of all quartz and other associated minerals by means of light hammers and the pure feldspar in irregular lumps is ready for crushing and pulverizing.

CRUSHING AND PULVERIZING.

Crushing and pulverizing is a simple process. If the feldspar is slightly altered it is occasionally calcined to remove the combined water, but ordinarily it is broken with sledges or with a jaw crusher to about 2-inch sizes and fed into a "chaser" mill. This mill consists of two buhrstone wheels 3 to 5 feet in diameter and about 1 foot thick, which are attached to the ends of a horizontal axle that is pivoted in the center. The wheels travel around on a buhrstone bed and the feldspar is crushed between the bed and the wheels. The crushed material is screened and the coarse material returned to the chaser mill, while the fine material is fed to ball mills. The latter are steel-barrel tumbler mills 6 to 7 feet long and of about the same diameter. They are lined with hard wood or silica blocks and are charged with French flint pebbles 2 to 3 inches in diameter. The revolving of the mill causes the pebbles to roll or slide, thus pulverizing the feldspar.

The pulverized feldspar is rarely screened, but the degree of fineness is determined by testing small samples of the material, and the length of the grinding period is depended on to give the desired pulverization. If the pegmatite carries mica the pulverized material should be screened through a fine sieve to remove any unpulverized material.

KAOLINS.

REMOVAL OF OVERBURDEN.

Removal of the overburden is one of the most important and at the same time one of the most neglected details of kaolin mining in the Southern Appalachian region. The method commonly used is to remove just enough overburden to expose the dike and to proceed at once to mine the kaolin. No provision is made for removing surface water during rains, and the invariable result is that more or less overburden is washed into the excavation, staining the walls and otherwise reducing the value of the kaolin in the upper part of the deposit. As the dikes in this region generally dip from 70 to 80 degrees from the horizontal and often toward higher ground, due provision must be made in removing overburden if the upper portion of the dike is to be mined by open-cut, so that the walls need not be too nearly vertical or undercutting become necessary in order to mine all the dike material.

The nature of the overburden influences greatly its tendency to slide and wash, but throughout the region it has been found advisable to slope all overburden walls not less than 30 degrees from the vertical. A level space equal to at least one-half the thickness of the overburden should be maintained around shafts as a protection against slides. This space should never be less than 10 feet wide in order to provide for the safe and economical handling of timbering material for the shafts and for dumping buckets of mine products well away from the shaft mouth.

The method of drainage found most efficient and economical is an ordinary ditch dug as close to the foot of the overburden walls as safety permits. This ditch should be at least 1 foot deep. It should be cut starting in a V above the last-opened shaft and follow the two walls to a point far enough beyond the operating shafts to insure the flow of surface water into a natural drainage way without soaking or running into a refilled shaft and thence into the part of the dike being worked. Much of the present trouble from water in shaft mining could be eliminated by providing and maintaining proper surface drainage. In removing overburden, it is never advisable to remove material much below the top of the dike, even though the material be much stained, because the dike material is loose and will allow surface water to seep down from the drainage ditches. Where the overburden is very porous it may prove advisable to place wooden troughs in the drainage ditches and to fill in closely on the bank side to insure the surface water running into the trough.

MINING KAOLINS FROM DIKES.

In the region studied kaolin is mined by two methods, namely (*a*) open-cut and (*b*) shaft mining.

In most cases the most economical results are obtained by combining the two methods, mining by open-cut for 20 to 30 feet next to the surface and by shaft below.

KAOLIN MINING BY OPEN-CUT.

Where the inclosing walls are solid and the dike is nearly vertical, it is sometimes practical to mine the entire deposit by open-cut, especially if the overburden is thin and the deposit follows the face of a hill. The kaolin can thus be worked in benches and handled by carts with much more econcmy than by shaft mining. (See *B*, Pl. VIII.) Removal of overburden well beyond the area of operation and careful sloping of the walls of the cut will leave little danger from slides. It must be borne in mind that in such an operation the dike is attacked from the side and not across the face, and in order to obtain a uniform product every bench must be worked across its entire width at the same time.

A more economical method of open-cut mining and one that is more certain to bring satisfactory results is to remove the wall rock on the lower side and thus expose the dike from the top to the lowest workable level. The dike is then cut through its entire width from top to bottom and benching proceeds on the two sides of this cut or, if advisable, on one side only. (See *A*, Pl. IX.) The drawback to this method is the high cost of exposing the dike from top to bottom in case the depth of mining reaches or exceeds 80 feet and the slope of the hill does not exceed 45 degrees. Many dikes are only 10 to 12 feet wide, so that the expense of removing the great quantities of wall rock in order to reach the kaolin becomes too great in proportion to the value of the product. Moreover some expense will also be incurred in open-cutting by reason of the necessity of sloping the back of the cut after the dike has been removed in order to prevent slides. The cost of removing the wall rock and of sloping the wall of the uphill side of the cut must be placed against the cost of timber and timbering in shafts and the other items incident to shaft mining in considering the mining methods to be adopted at a dike.

Mining by open-cut demands the removal of much more associated material than does shaft mining and is to be considered when a sufficient cash outlay is possible to provide the necessary equipment for the economical removal and transport of the refuse.

KAOLIN MINING BY SHAFT.

Where the shaft method alone is used the only surface preparation necessary is provision for diverting surface water from the shafts. At many mines no overburden is removed although at some the removal of part of the overburden is advisable in order to obtain a level area about the shaft mouth. The shafts in this region vary from 14 to 20 feet in diameter and from 40 to 110 feet in depth.

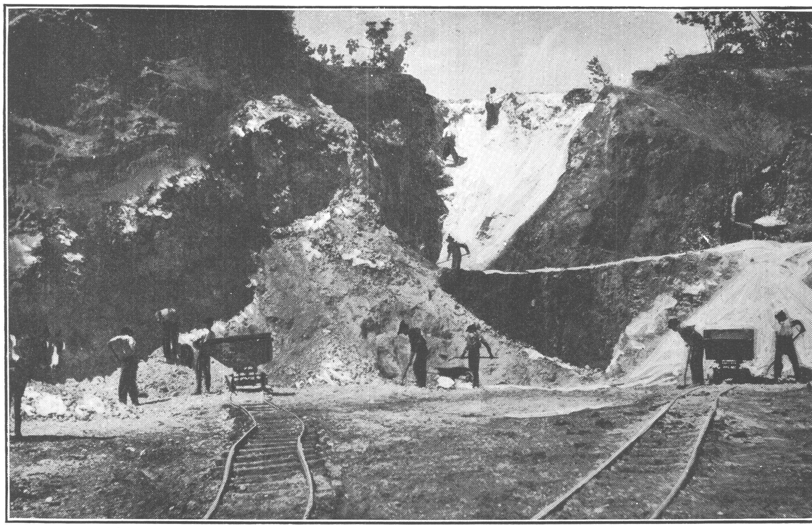
The proper place for a shaft in a dike is a matter to be decided by the operator, but since the majority of the dikes dip 70 to 80 degrees and are only 10 to 20 feet wide, the general practice is to start the shaft in the hanging wall adjacent to the dike, so that the shaft cuts the dike on the hanging-wall side 2 or 3 feet below the surface, and on the footwall side from 50 to 75 feet below the surface according to the dip of the dike. Such procedure often necessitates the removal and handling of an amount of waste equal to or greater than the amount of dike material handled, but sinking and timbering a vertical shaft is so much simpler than sinking and timbering a slope that the operators throughout this district employ the shaft system exclusively. The dike material and the disintegrated gneiss that forms the walls are both friable, so that timbering has to be placed as rapidly as the shaft is sunk.

Sinking is done in the following manner: The shaft is sunk 4 feet, carefully trimmed to form a circle of the desired diameter, and timbering, which is really the most important part of the process, is begun. (See *A*, Pl. X.) The timbers are of yellow pine or oak; they are 4 by 6 inches and generally 30 inches long, and are beveled on the ends to form key blocks. The timbers are placed beginning at the bottom of the 4-foot hole, and the joints are staggered as in bricklaying, thus forming a solid structure. (See *B*, Pl. IX.) Every fourth ring of timbers is spiked to the next lower ring in order to prevent any tendency to twist. When the timbers of the first level are in place, the shaft is dug 4 feet deeper, the timbering in place being supported by the material immediately below it, which is left in place until all other material has been removed. This material is next removed and the timbering is supported temporarily by short props while the next set of timbers is placed.

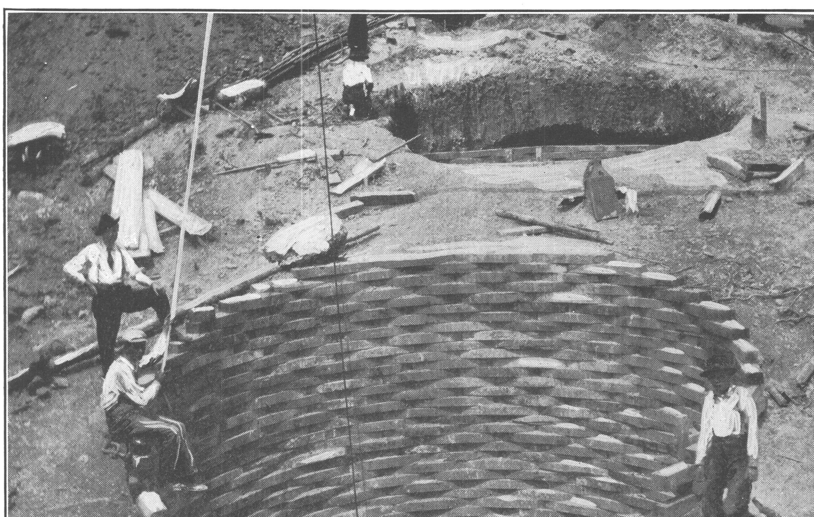
In placing these key blocks the final block completing a circle is put in by digging away the rock wall for a few inches, thus permitting the key to be placed from behind. The opening behind this block is then filled with waste and packed to prevent the block from kicking out. When the timbering has reached the bottom ring of the set above such packing is impossible, hence the final key block for the top ring of each set is cut 4 inches short, and after being placed, a short piece of 4-inch by 4-inch timber is driven into the opening left and is spiked tight. Sinking then proceeds as before. Each 4-foot slice of timbering always being placed as soon as the material from a level is removed.

Owing to the danger of contamination by contact with the iron-stained material constituting the walls of the dikes, the removal of the kaolin should not proceed simultaneously with the removal of wall rock. The kaolin in a given level should be carefully removed and sent to the surface before the wall rock of that level is disturbed. This is not the practice in all mines, but is followed in most shaft mines.

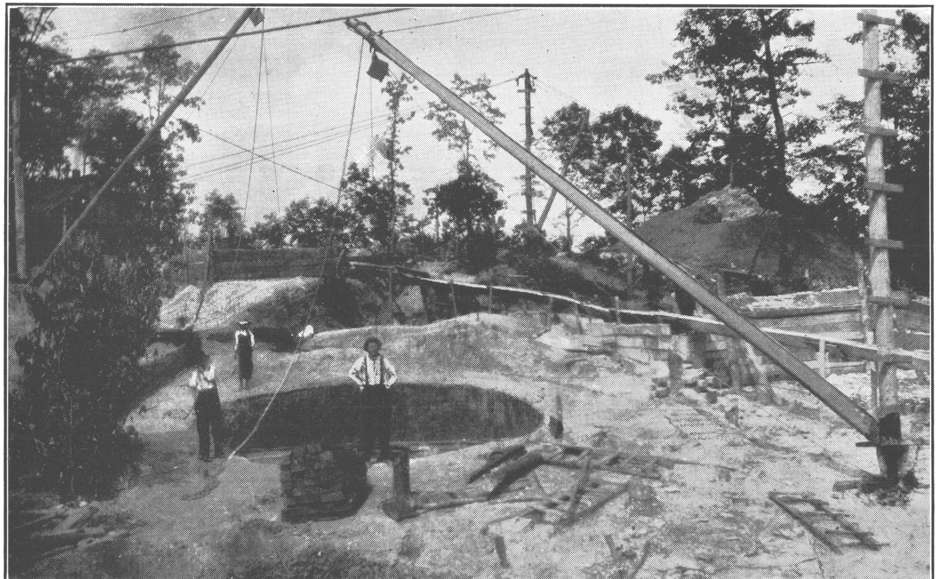
Where a dike incloses small lenses of waste material these should not be disturbed while kaolin is being mined, but should be taken out separately, as they generally contain much iron oxide, and a large amount of valuable kaolin may be injured by mixture with a little of the waste. Different buckets are generally used for handling kaolin and waste.



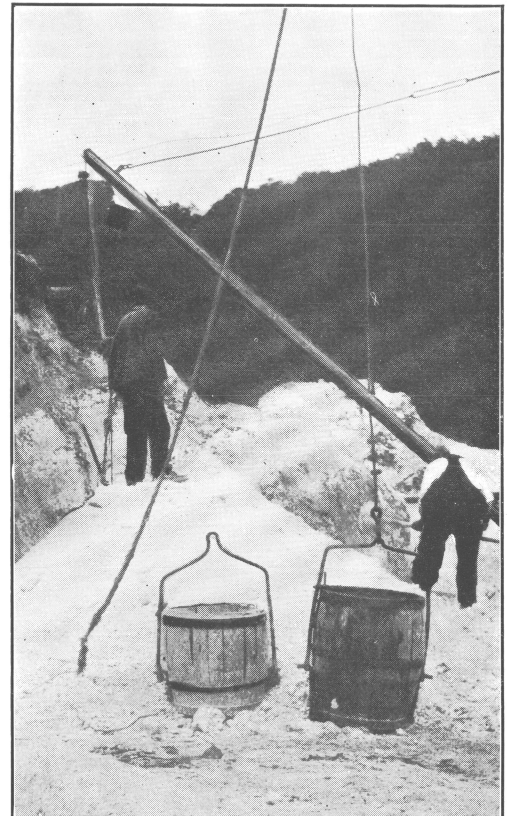
A. OPEN-CUT MINING FOR KAOLIN, SHOWING BENCH MINING AND THE DUMP-CAR SYSTEM.



B. SHAFT ON HILLSIDE FOR MINING KAOLIN. THE CRIBBING IS HIGHER ON ONE SIDE THAN ON THE OTHER, THUS EXPOSING SOME TIMBER ENDS.



A. SHAFT MINING FOR KAOLIN. THE FLUME FOR CRUDE KAOLIN IS IN THE BACKGROUND.



B. BUCKETS USED IN RAISING THE MATERIAL IN SHAFT MINING. THE ONE ON THE RIGHT IS FOR HOISTING WATER.

One of the greatest difficulties in shaft mining is the removal of the quartz lenses that are sometimes found along the middle of a dike and which must be removed from within the shaft area. The use of explosives is unsatisfactory because the quartz is more or less fractured, making the successful placing of a shot difficult. Breaking the quartz by sledge is slow and expensive. but has been found the safest and most economical method.

When a shaft has reached the lowest level at which the dike yields kaolin in commercial quantities, robbing and filling begin. Short tunnels are run into the dike from the bottom of the shaft. When the valuable material has been mined by these tunnels as far as is considered safe without timbering, the pillars between the tunnels are carefully removed and the area which has been emptied of kaolin, both within and without the shaft, is filled with waste from adjacent shafts or with that which was stored on the surface when the shaft was sunk.

As soon as a level has been thus robbed and filled the timbering from the level next above is removed and that level is robbed and filled in the same manner. The operation.is continued level by level until the surface is reached. In this way every pound of kaolin is removed, and since the shaft timbers are recovered the cost of mining by this process is reduced to the minimum.

For hoisting at shafts ordinary derricks are used throughout the region. Masts and booms are made from native timber with the ends banded to prevent splitting.

The type of bucket used holds about 500 pounds of dike material and is made from an oil barrel by cutting off the upper third. For hoisting water a whole oil barrel is used. A substantial wrought-iron hoop is placed about the bulge; a broad wrought-iron band, which passes under the bottom, is fastened to this hoop, and at these joints the handle of the bucket is connected. (See *B*, Pl. X.) To hold the bucket upright a heavy iron peg is attached to its side and extends above its rim. A heavy wrought-iron ring that encircles the handle of the bucket drops over this peg. The bucket is dumped by lifting this ring. The center of gravity of the bucket is so near the points where the handles are attached that the bucket dumps easily.

The drum hoists are exclusively used at shafts. In some cases horse power is used, but steam-driven hoists are used at the majority of mines. At one mine electricity has been used for operating hoists, and has proved very satisfactory.

Masts and booms of native timber are generally employed and cables are of $\frac{5}{8}$-inch stranded steel. Guys are generally of $\frac{3}{8}$-inch stranded steel.

COMBINATION OF OPEN-CUT AND SHAFT MINING.

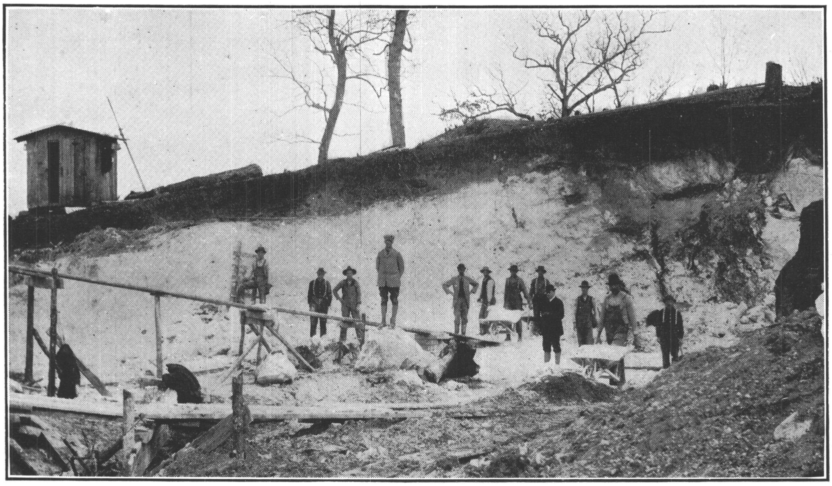
Many dikes are too narrow to justify mining by open-cut. Moreover, the necessity of removing the overburden by an uphill or very long haul, as well as special conditions, may make mining exclusively by open-cut unpractical. The manner of mining must be determined for each deposit, regard being given existing conditions. Even though the entire dike can not with economy be mined by open-cut, the upper portion for a depth of 30 to 40 feet may be mined by open-cut with far less expense than by shaft. When an open-cut is not more than 30 feet deep, sloping the walls is not expensive, and the overburden and waste removed will generally suffice to fill the shafts sunk into the lower portions of the dike. The practice is to remove overburden before shaft sinking only when the material removed can be utilized for filling a shaft from which all valuable material has been mined.

Working the upper part of a deposit by open-cut also reduces the cost of shafting because it exposes the dike and shows its width, thus insuring the shaft being sunk at the most advantageous point. (See *A* and *B*, Pl. XI, and Pl. XII.)

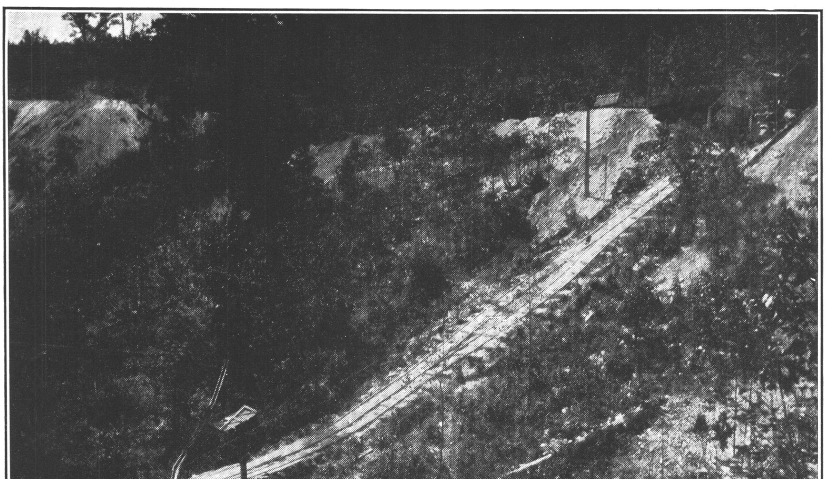
REMOVAL OF WATER FROM KAOLIN MINES.

One of the most expensive items that the miner of kaolin in this region has to consider is the removal of water from the workings. The dikes are generally free from water to a depth of about 40 feet, but below this depth the seepage of water from the walls and from the dike itself often increases to an actual flow, and in many cases the inrush of water has driven the miners from the workings and stopped mining. In the earlier operations for mica it was customary to sink shafts to as near the water level as was considered safe, and drift along this level until a flow of water was encountered, then the shaft was abandoned and a new one sunk at no great distance. The mica found in the vicinity of the water is claimed to be especially free from faults and of the finest color.

In kaolin mining the same in general is true. The finest quality of kaolin is generally found in the area between the level at which the first water is encountered and the level at which the flow becomes a menace to mining. Within the region studied the refilling of shafts on account of an excessive flow of water has resulted in leaving behind enormous amounts of kaolin of the highest grade. The remining of this abandoned material can be accomplished only at great expense, since the shafts are filled with refuse which must be removed before the abandoned material can be reached. The cost of such an operation would be prohibitive.



A. OPEN-CUT MINING FOR KAOLIN, SHOWING IRREGULAR SURFACE OF DEPOSIT.



B. TYPICAL GRAVITY TRAMWAY.

SHAFT MINING AFTER THE OPEN-CUTTING.

Only the simplest methods have been used to remove water from kaolin mines, the uniform practice being to bail the water into barrels and hoist it to the surface. This practice requires no great outlay for special machinery, but delays the other mining operations and thus reduces the daily output of the shaft, which results in increasing the cost per ton of material produced. Moreover, the seepage of water into the shaft from all directions loosens the ground and increases its tendency to cave and slip.

The use of pumps for handling water has met with little success because the deposits contain much exceedingly fine sand which is carried in suspension by the water and cuts out the valves of pumps very rapidly. The height to which the water must be elevated varies from 50 to 120 feet, which precludes the employment of suction pumps or steam siphons. The running of tunnels at or below the level where water is encountered is the natural method of draining workings, but it has been tried at only one mine in the district and there was only a partial success, because although the deposit covered many acres of land the drainage tunnel was run into the deposit at only one point and no branch tunnels were run to assist in draining the more distant parts of the deposit. The tunnel, however, removed the greater proportion of the water, so that by occasional bailing mining could be carried on without great annoyance. At a mine in a similar dike outside this region the dike has been cut by numerous tunnels, all of which drain to a central sump or cistern, and the water is removed by pumps provided with filters for excluding sand. The mine is thus kept dry and mining is greatly facilitated.

The situation of a majority of these dikes is ideal for drainage from below. Most of them lie well above the present water courses and most of the hills slope so abruptly that few tunnels would have to be driven more than 100 yards before reaching dike material. After reaching the dike, the cost of running the drainage tunnel would be little, if any, more than the cost of mining the kaolin in other parts of the dike. To insure the maintenance of an open drainage way timbering would be advisable. The tunnel should be continued well into the dike and a number of branch tunnels should be run to the extreme limits of the deposit. The capacity some deposits have for holding water indicates that the complete drainage of a dike by tunnels can not be accomplished in a few days, but a number of weeks or even months may be required. The cutting of the drainage tunnel should therefore be started as soon as possible after the trend and general extent of the deposit are determined. When such a tunnel is run below the level at which kaolinization is complete, it may be advisable to place a shot of dynamite in the ends of each crosscut tunnel and thus rupture the formation, permitting the water more easily to drain away.

CONVEYING THE CRUDE KAOLIN TO THE WASHING PLANT.

The method of conveying the crude kaolin to the washing plant is of necessity influenced by the situation of the mines and the washing plant. At every mine except one studied in this region the mouth of the shaft or the floor of the open-cut is well above the washing plant.

The method generally used is by flume, a stream of water being diverted into a V or U shaped trough (see Pl. XIII), into which the crude kaolin is shoveled. In most cases the flume is carried into the mine, so that the crude kaolin on removal from the shaft or bench may be shoveled directly into the flume and a second handling is unnecessary. In some cases, however, the flume is carried only to a point below the mine and the crude kaolin must be conveyed from the mine to the head of the flume. For this purpose a tramcar system has been used at two mines and is reported satisfactory. At one mine the tramcar system is supplemented by a gravity incline with cars. (See *B*, Pl. XI.)

In constructing a flume for transporting crude kaolin, caution must be exercised to avoid no abrupt turns and drops in order to prevent the small blocks of mica, which exist everywhere in kaolinized dikes, from being broken into thin sheets and flakes by the battering they would receive. If the small blocks of mica are not broken they are readily removed with the coarse material by the sand wheels. The chief advantages of transportation by flume are that it is economical and coarse lumps of kaolin are disintegrated before they reach the washer. (See Pl. XIII.)

REFINING THE KAOLIN.

CLAY WASHERS.

The first step in refining the crude kaolin is accomplished by the washer. This is really a disintegrator, since its chief service is so to agitate the kaolin-bearing material that the kaolin may be separated from the quartz and other waste materials. A washer, shown in figure 10, consists of a rectangular box measuring approximately 3 by 3 by 10 feet. Lengthwise through this box passes a shaft to which are attached a number of arms that extend almost to the sides of the tank. The shaft is belt driven by a pulley attached at the intake end of the washer and revolves at about 200 revolutions per minute. Washers are generally operated in batteries of two, the material to be disintegrated passing directly out of one into the other.

PLANT FOR WASHING KAOLIN. *a*, FLUME; *b*, MICA TROUGHS; *c*, DRYING SHED.

SAND WHEELS.

From the washers the crude kaolin passes to the sand wheels. Each wheel revolves in a narrow tank about 10 feet long and 6 feet high. To the spokes of the wheel are attached cast-iron scoops each having a sloping end. As the wheel revolves, charges of coarse material not disintegrated by the washer are scooped up from the bottom of the tank. Figure 11 shows perspective of sand wheel and appurtenances. The kaolin mixed with this waste material drains away as a scoop rises and when the scoop reaches the highest point of its circuit the coarse material slides out, is diverted by the sloping end in the scoop, and falls outside the tank. The kaolin and any other very fine material pass directly through the sand wheel and into the

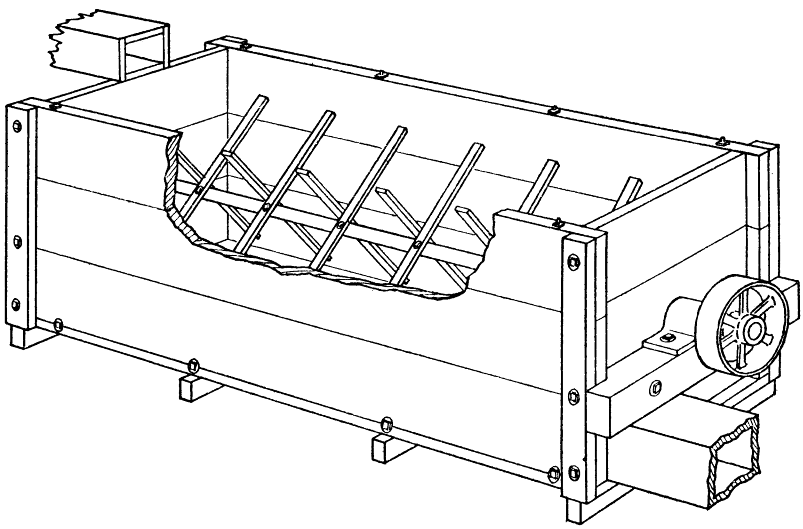


FIGURE 10.—Clay washer for kaolin.

sand trough. In the Southern Appalachian region two sand wheels are generally used with two washers and at many plants they are arranged in two sets, the crude kaolin passing through a washer to a sand wheel and thence through another washer and through another sand wheel into the sand trough. In *A*, Plate XIV, streams of water are shown impinging upon the scoops as they are elevated, which loosen the material packed against the walls. The number of washers and sand wheels necessary to separate all the kaolin from the material mined can be determined only by actual test.

The kaolin comes from the sand wheels thoroughly stirred and at such a rate of speed that much coarse waste is carried in suspension. To prevent this waste passing into the mica troughs, the sand trough or sand box is introduced.

THE SAND TROUGH.

The sand trough is made in two different styles, the broad trough and the square tank.

The broad trough, about 2 feet wide and 20 to 30 feet long (see *B*, Pl. XIV), is placed absolutely level and the flow of the kaolin-bearing slip is retarded by its distribution and the length of the trough. A barrier 4 to 8 inches high placed at the outlet end of the trough assists in retarding the flow. The coarse sand and the bulk of the coarse mica that passed the sand wheel are thus removed

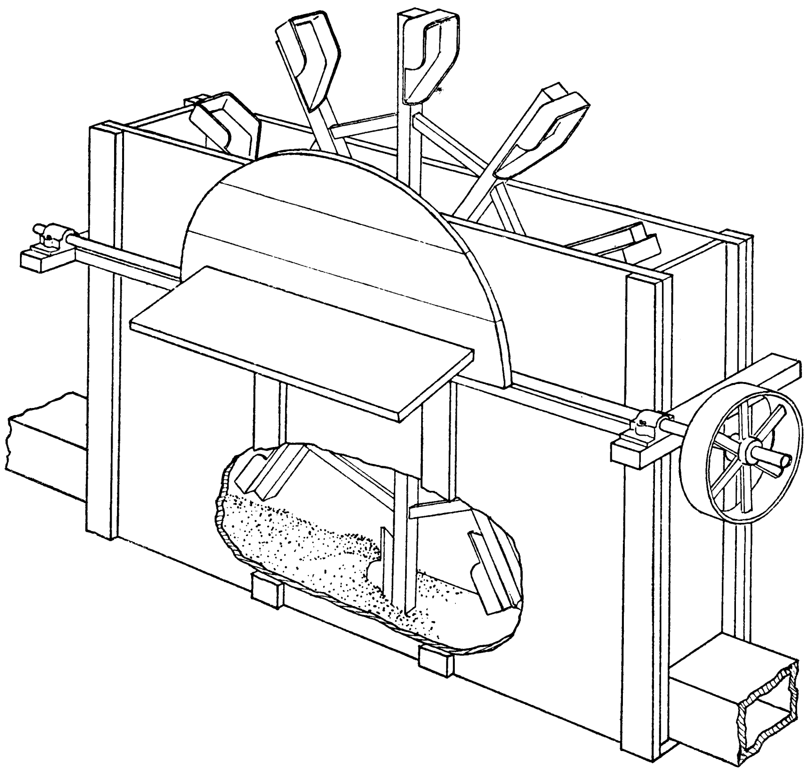
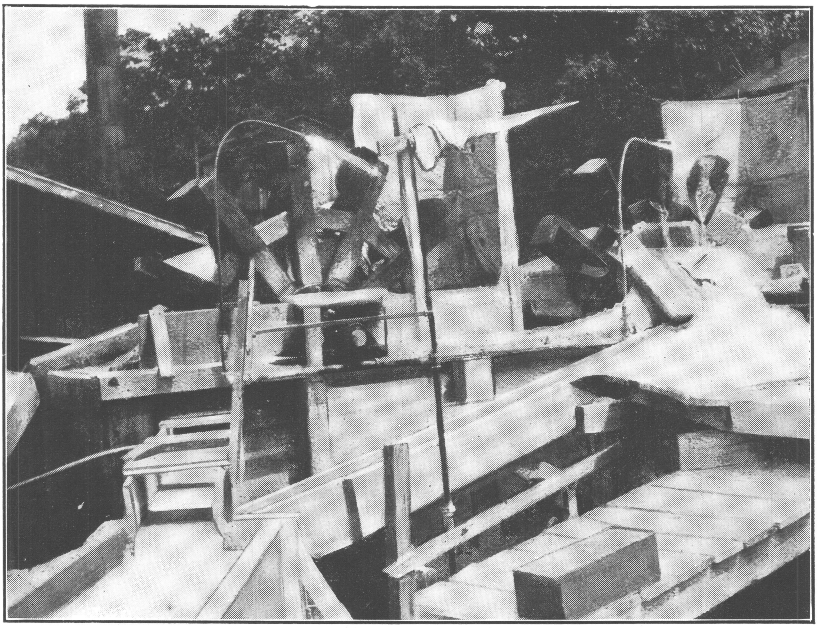


FIGURE 11.—Sand wheel in tank, broken away to show trough.

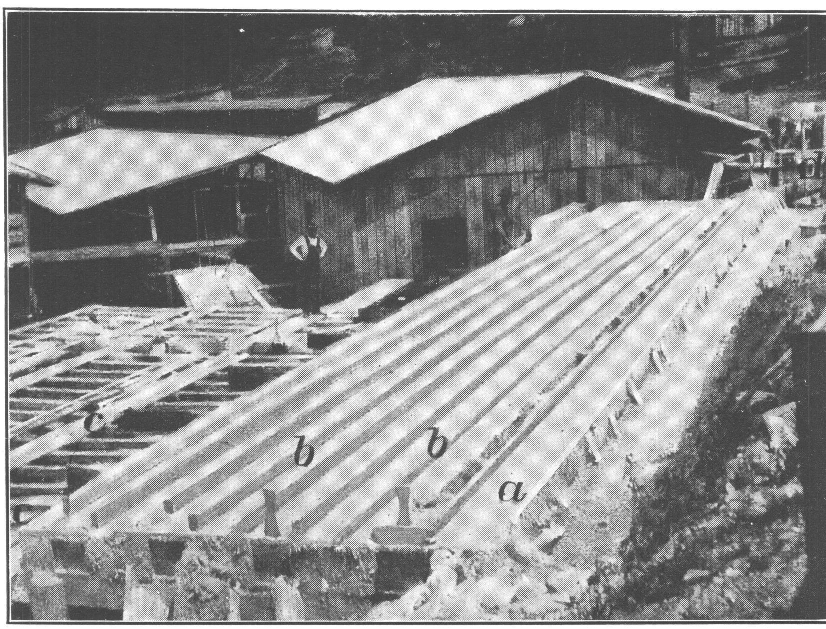
by settling and the fine material passes to the mica troughs. A workman with a shovel is kept busy removing coarse material from the trough.

The construction of a sand box or square tank, if one is used instead of the sand trough, is as follows:

The fine material from the last sand wheel passes through a short trough into one end of a tank 6 feet long, 5 feet wide, and 1 foot deep. The outlet of this tank is 3 inches below the top and is placed either at right angles to the intake or at the same end of the tank as the intake. Thus the entering stream of kaolin-charged water expends



A. SAND WHEELS IN OPERATION.



B. TANKS AND TROUGHS AT A WASHING PLANT: *a*, SAND TROUGH; *b*, MICA TROUGHS; *c*, CONCENTRATING TANKS; *d*, SAND WHEEL.

its force in the volume of water in the tank and the material that does not settle in making the turn of 45 degrees or more floats off through the outlet into the mica troughs. (See *B*, Pl. XIV.) The material that settles is removed from the bottom of the tank with a scoop shovel.

THE MICA TROUGHS.

The mica troughs are the most important apparatus in a kaolin washing plant. They are constructed in several different designs, although their purpose is in every case the same—that is, the removal of the fine mica and sand.

The individual troughs are U-shaped and are generally 1 foot wide, 1 foot deep, and 40 to 50 feet long. They are built in batteries, the kaolin slip passing out of one tank into the next, back through that to its extreme end, and thence into the next trough of the battery. Much of the velocity of the kaolin-charged water is expended before the mica troughs are reached, and in order to keep the water moving the troughs are arranged in either of two ways: Each trough may have a drop of 1 inch from end to end, or each trough may be built absolutely level, with a drop of 1 inch between the troughs. In either case the fall is sufficient to maintain a flow. The number of troughs in the battery determines the grade of the product. By adjusting the slope of each trough or the drop between troughs, the grade of product may be regulated. The operation of the mica troughs is necessarily periodic, since to attempt to remove sediment during operation would result in floating off some material already settled and that the troughs are intended to eliminate. The usual way is to use the troughs for about 5 hours continuously, then discontinue the flow of crude kaolin and run clear water through the troughs for 15 to 20 minutes. Then the regular outlet from the troughs is closed and another outlet, which leads to the waste piles, is opened. By means of broad scrapers the sediment in the troughs is pushed out into the waste heap. Then the troughs are flushed clean with water and are ready for operation again. Cleaning takes about an hour and is done during the dinner hour and after the plant closes in the evening.

An arrangement of the mica troughs that is commonly used in washing clays in England, but is not employed in the United States, is to run the kaolin slips from the sand box into a broad basin from which mica troughs radiate in fan shape, each trough increasing in diameter toward the outer end and thus decreasing the flow. The method of operation and cleaning is the same as that described.

From the mica troughs the kaolin passes over a screen for removing any very thin flakes of mica that have floated through the troughs.

THE SCREEN.

There are three general types of screens—stationary, vibrating or sliding, and revolving.

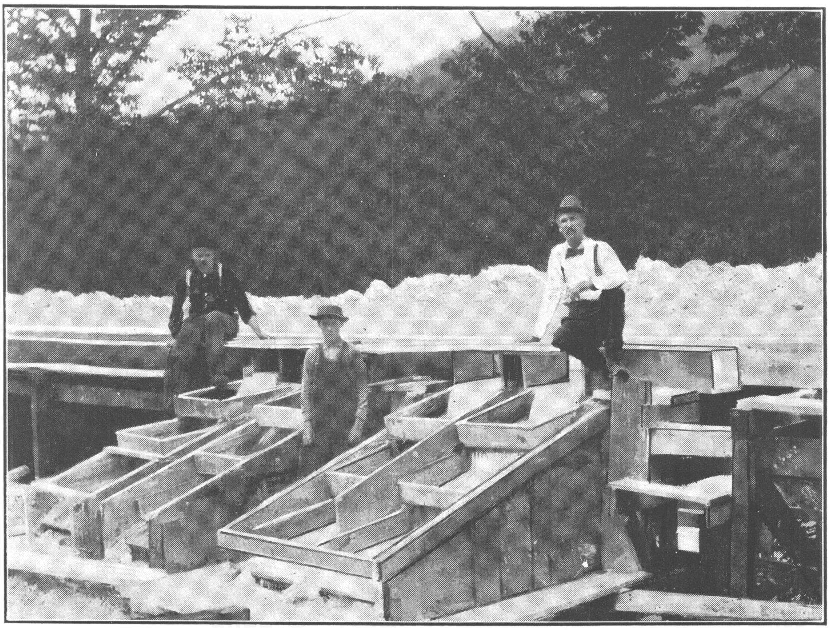
The stationary screen is most commonly employed in the region studied. (See *A*, Pl. XV.) The screens are arranged in batteries, each screen sloping about 10 degrees and discharging onto a similar screen placed about 6 inches lower. The excess material from the second screen overflows onto a third, and so on. Three screens are generally most efficient in a battery; if necessary, the kaolin slip is divided and a double, or a larger, battery is put in. The screens are simply built, consisting of box frames about 4 inches high, with brass wire attached to the bottom. An opening 2 inches wide across the lower end of a screen permits the excess material to flow onto the next screen. From the bottom screen the waste falls into a trough which may be emptied when convenient. These screens are all above a concrete or wooden basin, from which the material that passes through the screens runs into concentrating tanks.

The vibrating or sliding screen is suspended above a basin and shaken or slid rapidly back and forth by means of an eccentric or similar device, so that the coarse material is kept moving toward one end of the screen while the fine material and liquid passes through into the basin. The worst fault of this type of screen is that its rapid vibration tends to tear the mica flakes into pieces, which pass through the screen with the washed kaolin.

The revolving screen is a nearly horizontal revolving cylinder, covered with fine screen. Into one end the kaolin slip is run. As the cylinder revolves the slip passes many times around its circumference, the fine kaolin passing through the mesh, while the coarse material gradually works toward the outlet. By adjusting the slope of the cylinder the number of revolutions is regulated through which the material must pass before reaching the outlet. A spray of water from above washes loose any material adhering to the screen and materially increases the capacity. Such a screen requires little power and has been found very efficient. The material that passes through runs into a concentrating tank.

CONCENTRATING TANK.

The concentrating tank is merely a reservoir or a series of reservoirs (see *B*, Pl. XV) in which the kaolin slip stands until it has settled sufficiently to permit drawing off the excess water. Settling is very slow in some cases, and to hasten settling it is customary throughout the region to introduce a flocculator, in the form of alum, into the slip as it passes into the concentrating tanks. The alum in lump form is placed in a muslin bag suspended in the trough leading



A. BATTERY OF STATIONARY KAOLIN SCREENS.

B. END VIEW OF KAOLIN-CONCENTRATING TANKS.

from the screen. After settling, the excess water is siphoned off and the thick kaolin slip is run into an agitator.

AGITATOR.

The agitator, which is shown in figure 12, is a large cylindrical tank, in the center of which is a shaft with radiating paddles. The paddles stir the kaolin slip into a homogeneous mixture, and in this condition it is pumped from the agitator into the presses.

PUMP.

The pump used for filling the presses is a simple piston or plunger pump, driven by belt or occasionally by steam direct. The valve

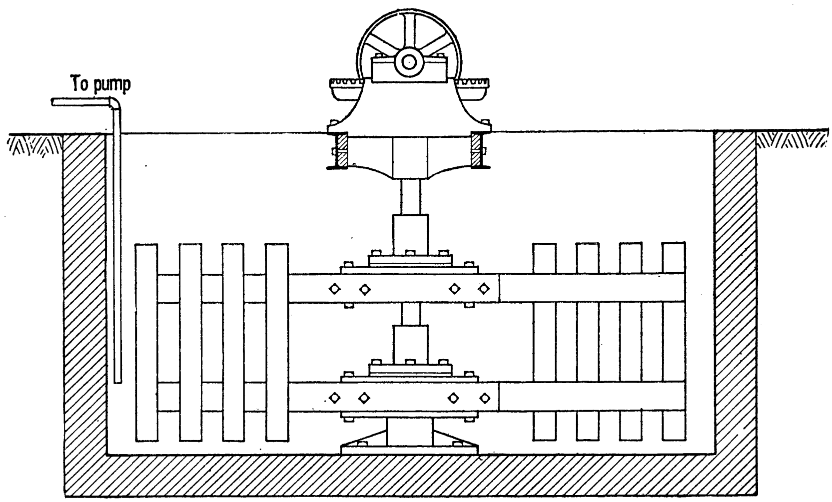


FIGURE 12.—Agitator used in refining kaolin.

and valve seats have to be made of material that will resist abrasion. Valves of rubber and valve seats of bronze are commonly used. An overflow is provided in order that the rate of pumping may be kept at the maximum and the time for filling the presses be reduced to the minimum.

PRESSES.

The presses were formerly made of wooden plates 30 inches square and 2 to 3 inches thick, hollowed out on each side for a depth of one-half to three-fourths inch. Canvas was stretched over the surfaces and the plates were set in batteries of 50 to 75. To introduce the slip into the openings between the plates, a groove was made through the rim of each plate on the top side, so that when two plates were placed together the opening left was just sufficient to receive a small iron pipe. To allow the water to pass out after being forced through the canvas, a series of small holes was bored through the rim along the lower edge of the plate and in the face of each plate grooves were cut leading to these outlets. The pressure on these wooden presses never exceeded a few pounds and the removal of water from kaolin slip by their use was very slow.

All of the plants now operating in the region investigated use a filter press having a heavy cast-iron and steel frame and heavy cast-iron plates. (See *A*, Pl. XVI.) The kaolin slip is introduced through an opening in the center of the plates and the canvas covering is sewed securely about these openings. The outlets for water are the same as in the old wooden presses, but are more numerous. With the presses now used the kaolin slip may be introduced at much higher pressure, and in most cases a pressure of 100 to 120 pounds per square inch is maintained in finishing the filling of a press. After the press is filled with solid kaolin the pump is stopped, the screw that holds the press plates together is withdrawn, and the cakes of pressed kaolin are removed. The cakes are not absolutely dry, but contain from 8 to 20 per cent water, hence additional drying is necessary before the kaolin is ready for shipment.

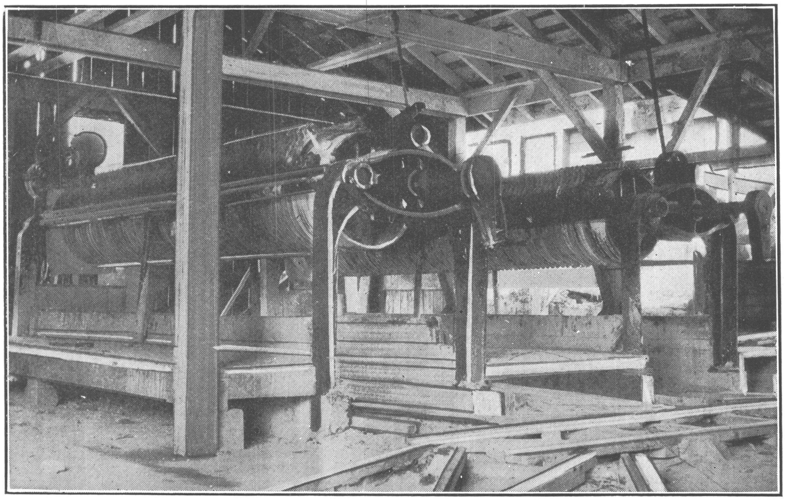
DRIERS.

The final drying of kaolin is accomplished by three different devices: Open-air driers, steam driers, and tunnel driers.

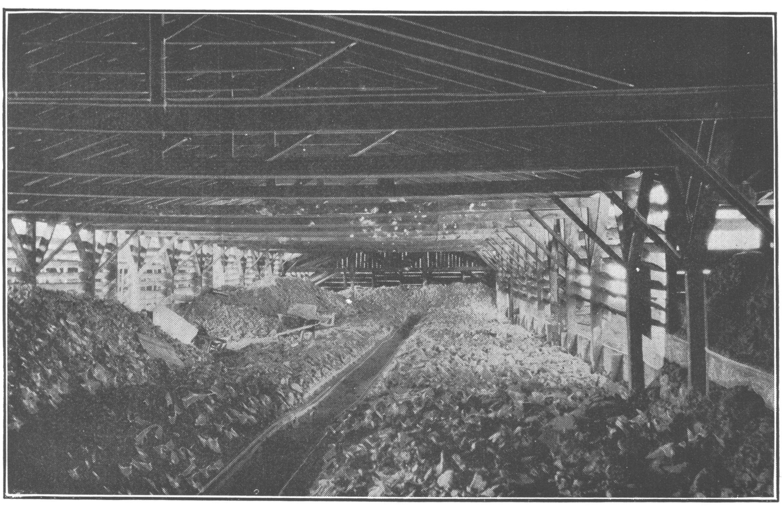
An open-air drier consists merely of a building containing racks on which the kaolin cakes may be exposed to the air and the moisture gradually evaporated.

A steam drier consists of an open building, on the floor of which are placed steam pipes connected at one end with heaters. (See *B*, Pl. XVI.) The damp kaolin is dumped directly upon these pipes, where it dries. When dry, the kaolin is shoveled off the pipes and is loaded directly into cars or wagons for shipment.

The tunnel drier is a device borrowed from modern brick making. On removal from the filter press the cakes of damp kaolin are loaded upon rack cars, which hold about 1 ton each. These cars are run into the drier, which is so constructed that the cars run by gravity toward the outlet. As a car of damp kaolin enters the drier a car of kaolin that has been dried is taken from the opposite end. The method of heating the air for this type of drier varies. The system used in this region is to force the air by fan through steam coils and into the drier.



A. ELEVATED FILTER PRESSES.



B. STEAM DRYER, SHOWING CAR TRACK IN CENTER AND KAOLIN ON THE STEAM PIPES, WHICH ARE LAID DIRECTLY ON THE FLOOR.

FAILURES IN KAOLIN MINING IN THE REGION INVESTIGATED; CAUSES AND REMEDIES.

INSUFFICIENT PROSPECTING.

The failure of the majority of kaolin-mining plants erected in the southern Appalachian region is due chiefly to insufficient or improper prospecting before the establishment of the plant.

The exposure of a small quantity of high-grade kaolin has resulted in the erection of a plant before the extent of the deposit was definitely determined. After the deposit has proved small or of inferior quality, and in case no other deposit in the district could be efficiently handled by the washing plant owing to its location, the plant is closed and perhaps dismantled, but stands as a warning to future prospectors for kaolin.

Had a thorough investigation of the deposit shown kaolin in commercial quantities, and had the prospects of kaolin from neighboring deposits been ascertained, the plant could have been so placed that its success as an investment would have been assured.

INEFFICIENT MINING METHODS.

Another cause of failure in many kaolin-mining enterprises throughout this district is the inefficiency of the mining methods employed. The removal of overburden by shafts instead of by open-cuts, the sinking of shafts where bands of quartz are known to exist and must be cut, inability to cope with water in shafts, and the necessary abandoning of much valuable kaolin on this account, are all causes which, combined, have resulted in many failures. Failure to cope with such difficulties can be charged only to poor engineering, since many mines have successfully operated under exactly similar conditions.

OPERATING BELOW CAPACITY OF PLANT.

A third cause of failure throughout the region is the common practice of operating at less than maximum capacity. In a majority of the ventures that failed the mines did not produce sufficient material to operate the washing plant to its capacity and no strenuous effort was made to increase their output. Consequently the operation of the washing plant and many other fixed charges had to be prorated against a reduced production, which changed the balance from profit to loss. Some of these poorly balanced operations have been due to the deposit proving smaller than at first supposed, but in such an event only one course is open to the operator—the deposit must be worked to the maximum capacity of the, equipment and when it is exhausted other deposits must be sought.

The difficulties confronting the operator of large kaolin deposits are thus shown to be not inherent obstacles but rather the result of poor engineering practice.

WASTEFUL PRACTICES IN REFINING THE KAOLIN.

Several wasteful practices in refining kaolin are prevalent throughout this district. The worst are discussed below.

CRUSHING AND PULVERIZING MICA IN CRUDE KAOLIN.

The common practice of dumping all small blocks of mica into the flume, where they are battered about on the journey to the washing plant, results in mixing with the kaolin much fine mica that is removed with difficulty; in many cases this mica is not removed but lowers the grade of the kaolin produced.

LACK OF BLENDING FACILITIES.

The common practice of rushing the kaolin from the mine to the washing plant provides for no blending of material from the various parts of the workings before washing. The small settling tanks and concentrating tanks provide little opportunity for blending large quantities of material. The natural result is a variation in physical properties of shipments from the same deposits, and this discourages confidence in the material produced.

VARIATION OF SLIP DENSITY IN THE SAND AND MICA TROUGHS.

The irregularity with which material is fed into the washing apparatus results in a variation in the density of the slip. When the kaolin slip is dense it may carry a large amount of sand and mica beyond the mica troughs and into the settling tanks. When the slip is thin, all sand and mica quickly settle out in the troughs and only the finest kaolin reaches the settling tanks. Thus the regulation of the crude material fed into the washing plant is an important point if a uniform product is desired.

OPERATION OF SMALL DEPOSITS.

The development of the kaolin industry in this region is dependent upon the utilization of the kaolin from the small dikes, those that are worked at present for mica only and from which the kaolin is wasted. Several of these deposits if worked with due regard for kaolin as well as mica would produce almost as much kaolin as some operating kaolin plants, but in the majority of cases the output would be from 1 to 5 tons per day.

CENTRAL KAOLIN-WASHING PLANT.

The handling of this quantity of material would not justify the erection of a power-operated washing plant in most instances, but where several extensive mica mines are producing kaolin as a waste product, a commercial kaolin-washing plant of moderate size could doubtless be operated with profit, the crude kaolin being bought at a price based on its kaolin content. A thorough blending system would be necessary in order to insure a uniform product, and ample storage would be required to carry reserve stock in order to make blending possible. The uncertainties of kaolin mining would be eliminated from such a venture, and since the costs of operating the necessary plant are easily determined, the enterprise should make a safe investment. However, the utilization of kaolin by a central washing plant is only practical when the plant is within a few miles of the source of supply; otherwise the expense of hauling the enormous amount of associated dike material to the washing plant would make the venture unprofitable.

Where the kaolin supply is scattered over a large area and operations can not be conveniently centralized, the only plan available is to concentrate the kaolin and sell it, either as washed kaolin or as concentrated crude kaolin.

Where time is not an important consideration, the washing of kaolin may be successfully accomplished without the use of any machinery and a product equal to the best machine-washed kaolin produced.

HAND WASHING KAOLIN.

Hand washing of kaolin is copied in part from similar operations in Cornwall, England, and has been altered to suit the conditions in the region investigated. The crude material is placed in a shallow level tank measuring approximately 4 by 20 feet. Water is admitted at one end and passes out at the other, the material meanwhile being vigorously stirred with shovels to loosen the hard kaolin which adheres. The water from the tank enters a sand-settling trough measuring approximately 2 by 50 feet by 1 foot deep. In passing this the coarse sand settles and the fine material passes out at the opposite end, which is partly closed by a gate 8 or 10 inches high. The material that settles must be stirred occasionally to liberate any kaolin caught in it. From the sand trough the kaolin slip passes into the mica troughs, which are similar to those used in all kaolin-washing plants and are approximately 1 foot wide and in 50-foot sections, either eight or ten sections being used. The depth of slip in these troughs is regulated by the flow of water, as ordinarily they contain no retarding strips. These troughs are built in batteries side by side.

The slip flows from one trough to the next, back and forth, and at the end flows onto a series of screens which are so built that the overflow from the first screen passes onto the second and then onto the third.

The size of screen must be selected especially for the work in hand. Some crude kaolins can be cleaned of the last traces of floating mica by the use of the 100-mesh screen, whereas others require the 120-mesh screen or even 150-mesh screen to remove the finest mica. The mesh stated is the number of meshes per linear inch.

Thus a great proportion of the mica not settled in the troughs is removed and the refined kaolin passes into the concentrating tanks, which should be approximately 30 by 10 feet by 6 to 8 feet deep. There should be two, so that slip may be introduced into one tank while the other is in use. When a tank is filled the slip should be allowed to stand until the kaolin has settled completely to a thick paste and the clear water can be siphoned off. After removal of the water, the kaolin paste is transferred to shallow evaporating tanks, approximately 30 by 10 feet, and not more than 2 feet deep. Here the material may remain until any desired degree of drying has been reached. Much time will be saved, however, if the material is removed as soon as it will hold together and exposed upon open-air drying racks. In the Cornwall district the material when dry enough to move with a shovel is transferred to the top of a tile-covered oven approximately 100 by 5 feet in area and consisting of two long flues. Here the last traces of water are removed. The material after drying is marketable kaolin.

Material that has been once washed for kaolin may be wisely removed from the washing tank and, after air-drying, may be rewashed, often to produce considerable marketable kaolin.

PRECAUTIONS FOR THE HEALTH AND SAFETY OF WORKMEN.

Labor conditions throughout the southern Appalachian region are satisfactory, the demand for workmen being supplied by native laborers. Most of the small mines are operated for mica only and the workmen work on a percentage basis and thus assume their own risk. The precautions for the safety of the workmen thus employed are few, but long acquaintance with this kind of work enables the miner to judge the condition of walls and roof, and therefore accidents in small mines in this district are rare. In mica mines the entering shaft is generally cribbed, but beyond this no timbering is done except where a mass of roof cracks or a wall shows unmistakable signs of giving way. Mining methods in most of the small mines have improved very slowly. Black powder for blasting has been replaced by 40 per cent dynamite in most mines and fuse has been replaced by electric detonators in some places. No artificial ventilation of mines is used in this district and in few instances is it required. Where "ground-hog" mining methods are practiced, the difficulty of removing even the small amount of dike material which must be taken to the surface makes it economical to open new surface connections at short intervals. Hence a number of outlets to most mines are provided and ventilation is assured.

The most dangerous practice in connection with small mining operations in this district is the building of lofts in stoping. These lofts are constructed of small hewn timbers and are loaded to the crushing point with refuse material. The miner is often required to pass under such lofts daily or hourly and during blasting the danger of these old lofts collapsing becomes very great, as the timbers are rotten from the damp atmosphere of the mine.

In mining kaolin by shafts timbering is carefully done and there is little or no danger from the collapse of timbering.

The robbing of the dikes in the neighborhood of the shafts is effected by means of short tunnels which are seldom timbered, as the danger from caving is very small. The tunnels rarely reach 10 feet in length and are about 4 feet wide, hence the miner would have little difficulty in escaping in case the roof or walls collapsed. The material in these short tunnels rarely caves, no doubt because the robbing of the dike is never attempted until the full depth to which the dike is workable has been reached. Thus the surrounding dike material has ample opportunity to drain before being disturbed.

A precaution that is generally neglected throughout this district is the erection of substantial guard rails about the mouths of open shafts. It is necessary in the removal of material for several men to work constantly about the mouths of the shafts, often leaning over the open shafts, and a misstep is almost certain to result in a man falling in. No barrier is provided about the mouth of the open shafts to prevent refuse material rolling in and falling upon the workmen below. After the shaft is sunk to the maximum depth and the robbing of the dike begins, the workmen, if warned of the falling of something into the shaft, may seek refuge in the short tunnels, but in shaft sinking no such escape is possible.

Each shaft is provided with a ladder from bottom to surface for the use of workmen who do not wish to enter and leave the shaft by means of the buckets. The ladders, although seldom used, are generally kept in good repair. The buckets are made of barrels strongly banded with steel hoops and additionally reinforced with bands of iron passing completely under the bottom. The hoisting cable in the larger operations is $\frac{5}{8}$-inch or $\frac{3}{4}$-inch steel cable, and the maximum capacity of the buckets is about 600 pounds. Where the buckets are operated by hand windlasses hemp cable is used for hoisting, and this is never less than $\frac{7}{8}$ inch in diameter. The load lifted is never more than 400 pounds. The cables used are carefully inspected by the operators at frequent intervals, as they fully realize the damage that would result from the breaking of a cable with the workmen directly below.

The general health of workmen in the region is excellent, and although they are much exposed to the weather when operations are continued throughout the winter months, little sickness is reported. The health of workmen employed about kaolin-washing plants is fully up to the average. No injurious results are to be expected from such labor and none is reported. Workmen employed in the handling of kaolin that has been artificially dried are forced to work in a somewhat dusty atmosphere, but no case of injury to health has been recorded, although workmen have been continuously employed in this work for many years.

POOR ROADS.

One of the greatest hindrances to the development of the mining industry of this region is the poor roads. Throughout the district between the Blue Ridge and the Great Smoky Mountains few improved roads exist. Within the past five years an effort has been made to reduce the grade on many of the roads and thus lessen the excessive washing each winter. This washing ruins every road with a steep grade, and each spring a great amount of grading must be done before the roads are fit for hauling. Road building in many sections is nothing more than "brushing," which consists of filling the gulleys with brush and covering the brush with soil. The brush prevents washing to some extent, but the water collects in the soft soil to make miry places. The soil consists principally of weathered gneiss carrying much chlorite and other micaceous material, which is a poor road foundation, and until the building of roads is undertaken in a more substantial manner the hauling of material for a great distance will be difficult, if not impossible. In some districts granitic material is available and the pegmatite material from the dikes has been used to a limited extent, but the use of these materials is very limited except in the vicinity of some of the larger towns. The best roads in this district are the creek beds, which in many places furnish a solid, although rough road, always passable except in time of freshet. During a short period in winter, when the ground is frozen, hauling can be done with reasonable economy over all roads.

The summer season during which hauling is possible lasts about six months, from May to November, varying from year to year.

The transport of the dike materials except by railroad must therefore be more or less periodic, depending upon the weather and season. This fact is considered in hauling lumber throughout this region, and the work is so arranged that no great inconvenience results. The same plan could be followed by kaolin miners, and storage might be provided at the plant and railroad so that operations could be continued during the seasons when roads are blocked.

The difficulty of haulage may at many mines be overcome by careful selection of the site for the washing plant so that the washed kaolin may be floated a large part of the distance to the railroad, there pressed and dried, and then by a short haul delivered to the shipping point.

MICA AS A BY-PRODUCT OF KAOLIN MINING.

At many pegmatite dikes that have been worked for kaolin no attempt has been made to save any mica found except such as promises to cut first-class sheet mica or at least high-grade electric mica.

Large amounts of mica that is not sound have been either thrown on the dump or allowed to remain in the crude kaolin to be pulverized, and thus increase the proportion of the most injurious constituent in the washed kaolin.

Solid crystals of mica that are too small to promise sheet material, but are solid and would produce first-grade small "punch mica," have been wasted in many places where kaolin has been mined, and are now buried under other refuse material, which makes later recovery practically impossible. Such mica varies in size from 1 inch to 2½ inches in diameter, and blocks weighing one-fourth to 1 pound are frequently noted in the dumps about the kaolin mines, particularly in the refuse from the sand wheels. The collecting of this material has never been attempted by mechanical means, but its removal by hand sorting would be perfectly feasible if the refuse from the sand wheels were conveyed by a broad picking belt to the dump. Such solid mica is always marketable for "punch mica"; from it small disks are "punched," or cut by die, and are used as insulators in electrical appliances. The mica that is not solid is useful only for "grinding mica," and of this the supply in recent years does not equal the demand.

In addition to this coarse mica, a large amount of fine mica, partly broken from larger blocks and partly in the form of small crystals, is carried past the sand wheels and collects in the sand-settling trough or tank. The amount obtained by experiments in Macon County, North Carolina, would indicate that a screen of coarse mesh introduced either at the inlet or outlet of the sand-settling trough would yield a good quantity of mica of small size which, by washing, could be freed from sand and made suitable for grinding mica.

In most plants for washing kaolin in this region the screens at the outlet of the mica-settling troughs yield little else but mica mixed with a small amount of kaolin. The rewashing of this material removes the fine kaolin, and the mica may, by a small amount of grinding, be prepared for market.

Nearly all marketed kaolins from this district contain fine mica. This could be removed to a great extent by the use of finer screens and a thinner slip in washing. The mica that would thus be recovered has been estimated to be worth more than twice that of an equal amount of the kaolin in which it forms an impurity.

The size of this waste mica varies in different portions of this district, as does also the color, although the luster seems to be uniformly good.

The territory west of Cowee Mountain in Macon County and the Tuckasegee River district of Jackson County yield chiefly coarse mica, except where pulverized by the washing process. The fine mica recovered in these territories is in the refuse from the sand wheels and in the sand troughs.

In Swain County, North Carolina, the white pegmatites yield a considerable amount of fine mica in the sand troughs and a small amount in the mica troughs and screens, although this district is not rich in fine white mica.

The expanded lenses of the territory about Sprucepine, Mitchell County, N. C., are chiefly productive of mica finer than the size removed by sand wheels. The sand-settling tank, the mica troughs, the screen refuse, and even the washed kaolin itself contain much mica of small size, and the color of this mica is very good, being green mica in many cases and of high luster. The narrow, more sharply defined dikes in this neighborhood do not yield much small mica. Fine mica of good quality was also noted in deposits in Buncombe County, North Carolina, and in Pickens County, Georgia, at the southwest extreme of the region investigated.

GRINDING MICA FOR WALL PAPER, ELECTRICAL INSULATION, AND LUBRICATION.

Although a large amount of sheet mica for use in stove fronts and for electrical purposes is shipped each year from this district, an enormous amount of mica is mined annually that is not solid and is valuable only as grinding mica.

The method of grinding mica is unique, since the process is shredding rather than abrasion. The process in detail is as follows: The coarse mica is washed by passing it through a revolving cylindrical screen upon which water plays and thus any fine sand is washed away. The washed mica scrap collects in a tank of water and any refuse that floats is carried off by the water, which constantly overflows the tank.

The mica-grinding mill into which the mica next goes is a cylindrical wooden vat 3 feet high and approximately 3 feet in diameter with a wall 6 to 8 inches thick, built of wooden blocks set with the end of the grain toward the inside to present a wearing surface. The grinder is a wooden wheel about 6 inches thick that fits loosely inside the vat. This wheel is built of ordinary plank cut to present as much end grain as possible and spiked together to give the desired thickness. It is attached to a heavy vertical shaft in the center of the vat and is rapidly revolved by steam or water power. The pressure of the wheel on the material in the vat is maintained by a pressure spring from above.

The operation consists of charging the mill with washed scrap mica and adding just enough water to provide the desired lubrication. The wheel is then started and pressed down until it takes a firm hold upon the mica. The friction of the wheel against the mica scrap causes the sheets of mica to be forced between the laminæ of adjoining sheets and thus the large blocks and sheets are gradually torn to pieces and reduced to the pulverized mica of commerce. After 8 to 10 hours the mill is emptied, and by a flotation system similar to that used for removing mica from kaolin the fine mica is separated. The coarse mica is returned to the mill and the fine mica is allowed to settle and the water drawn off. The mica is then removed to drying tables where it is spread to dry. After drying it is placed in regular bolting machines similar to those used for bolting flour; the last trace of coarse material is removed and returned to the grinding mill. One such grinding mill will produce from 250 to 400 pounds of 160-mesh mica per day, hence many mills are necessary for a large output.

When no water is used with the mica in grinding, the process is more rapid, but the product lacks the luster of the wet-ground mica and is marketable only for lubrication products and for use in electrical insulation.

The supply of mica for this industry has been obtained up to the present time from operating mica mines, with occasional supplies brought in from abandoned mica sheds where refuse material has accumulated.

The supply is, however, not equal to the demand, and each year is finding the operators of mica-grinding mills working farther into the mountains in search of material. The material that must be ultimately used, and which it is safe to predict will equal in quality the present material, is the refuse mica from the kaolin plants. This material constitutes in some places more than 15 per cent of the total deposit, and in washing the kaolin more than 65 per cent of the coarse material that passes the mica-settling troughs is pure white mica. Thus the process of obtaining this material must change soon from a search for coarse material for grinding to a utilization of the partly ground material already at hand and now being discarded as waste.

ANALYSES OF FELDSPAR, SEMIKAOLINIZED FELDSPAR, KAOLIN, OCHER, SCHROETTERITE, QUARTZ, AND WAD.

Analyses of feldspar, semikaolinized feldspar, kaolin, ocher, schroetterite, quartz, and wad are presented below. These analyses have been collected from various sources as the references indicate. Elements other than those mentioned were not sought by the analysts.

Analyses of feldspars.

Mine.	H_2O.	SiO_2.	Al_2O_3.	Fe_2O_3	TiO_2.	CaO.	MgO.	BaO.	Na_2O.	K_2O.	Total.
Witherspoon mica mine, Ashe County, N. C.[a]	0.90	64.48	19.43	0.01	Trace.	Trace.	Trace.	0.00	1.84	13.19	99.85
Avery Meadow mica mine, Avery County, N. C.[b c]	......	62.95	19.66	......	......	Trace.	......	......	7.64	8.39	......
Plumtree mica mine, Avery County, N. C.[a]	.17	65.37	17.92	.02	Trace.	.17	Trace.	.00	2.10	13.05	98.80
Lisle Knob mica mine, Macon County, N. C.[a]	.30	65.40	20.70	.10	Trace.	1.60	Trace.	.00	6.10	6.00	100.20
McGuire Prospect, Macon County, N. C.[a]	.60	63.90	19.97	.15	Trace.	.05	Trace.	.70	1.01	13.20	99.58
Southern Clay Co. mine, Macon County, N. C.[a]	.50	64.30	19.64	.08	Trace.	Trace.	Trace.	.17	1.32	14.00	100.01
Carolina Mineral Co. (Albite), Mitchell County, N. C.[a]	1.00	64.92	22.28	.21	Trace.	1.60	Trace.	.00	9.20	1.10	100.31
Carolina Mineral Co. (Microcline), Mitchell County, N. C.[a]	.30	65.68	19.08	.14	Trace.	Trace.	Trace.	.00	2.08	13.09	100.37
Cloudland mica mine, Mitchell County, N. C.[b c]	......	65.18	21.60	......	......	.64	......	......	8.35	.04	......
Cook mica mine, Mitchell County, N. C.[a]	.40	64.93	19.45	Trace	Trace.	.05	Trace.	.00	2.54	12.46	99.83
Flat Rock mica mine, Mitchell County, N. C.[b c]	......	65.15	19.04	......	......	.12	......	......	7.00	7.28	......
Wiseman mica mine, Mitchell County, N. C.[b c]	......	64.85	19.90	......	......	.00	......	......	10.04	2.91	......
Granite from Mitchell County, N. C.[a]	.90	75.10	15.57	.47	.03	1.10	Trace.	.00	2.86	3.49	99.52
Ray mica mine, Yancey County, N. C.[a]	.20	68.18	20.12	.05	Trace.	.85	.05	.00	9.38	.66	99.49
Do.[b c]	......	63.55	20.20	......	......	Trace.	......	......	6.65	8.73	......
McNichols Co. mine, Bedford County, Va.[a]	.10	68.75	18.56	.03	Trace.	1.25	Trace.	.00	4.29	6.85	99.83

[a] Analysis by Prof. D. J. Demorest, Ohio State University.
[b] Elements not mentioned were not sought.
[c] Analysis by the North Carolina Geological Survey.

Analyses of semikaolinized feldspars.

[D. J. Demorest, analyst.]

Mine.	H_2O.	SiO_2.	Al_2O_3.	Fe_2O_3	TiO_2.	CaO.	MgO.	BaO.	Na_2O.	K_2O.	Total.
Forest Hill mica mine, Jackson County, N. C.	0.90	63.35	20.07	0.15	Trace.	0.03	Trace.	0.00	1.11	13.70	99.31
Moore mica mine, Macon County, N. C.	2.05	63.74	20.90	.12	Trace.	Trace.	Trace.	1.10	.19	11.70	99.80
Southern Clay Co. mine, Macon County, N. C.	1.40	62.47	21.00	.05	Trace.	Trace.	Trace.	.30	.90	13.62	99.74
Seth Freeman prospect, Madison County, N. C.	5.42	65.05	22.39	.29	.12	Trace.	Trace.	.30	.21	6.53	100.31
Flukin Ridge mica mine, Mitchell County, N. C.	1.34	63.32	20.45	.07	Trace.	Trace.	Trace.	.00	.80	14.20	100.18
Isinglass Hill mica mine, Rutherford County, N.C.	3.60	60.47	23.45	.10	Trace.	Trace.	Trace.	.00	.65	12.10	100.37
Harris Clay Co., Bryson City mine, Swain County, N. C	.94	63.60	20.40	.32	Trace.	Trace.	Trace.	.00	.50	14.40	100.16

Analyses of kaolins.

[D. J. Demorest, analyst.]

Mine.	H_2O.	SiO_2.	Al_2O_3.	Fe_2O_3	TiO_2.	CaO.	MgO.	BaO.	Na_2O.	K_2O.	Total.
Kinsland mine, Haywood County, N. C.	11.90	50.64	35.57	0.25	0.03	Trace.	Trace.	0.07	0.08	1.70	100.24
Buchanan prospect, Jackson County, N. C.	13.77	46.30	39.06	.20	.04	Trace.	Trace.	.00	.11	.60	100.08
Forest Hill mica mine, Jackson County, N. C.	12.53	49.20	37.58	.17	Trace.	Trace.	Trace.	.00	.13	.47	100.08
Harris Clay Co., Dillsboro mine, Jackson County, N. C.	13.99	46.95	37.73	.15	.05	Trace.	Trace.	.00	.18	.60	99.65
Piedmont Tin Mining Co., Lincoln County, N. C.	12.00	48.50	37.35	.85	Trace.	Trace.	Trace.	.00	.32	1.02	100.04
Gurney Clay Co., Macon County, N. C.	14.72	44.00	40.79	.11	Trace.	Trace.	Trace.	.00	.07	.55	100.24
McGuire prospect, Macon County, N. C.	14.00	46.35	39.00	.30	Trace.	Trace.	Trace.	.00	.00	.50	100.15
Raby mica mine, Macon County, N. C.	13.80	46.90	38.60	.25	Trace.	Trace.	Trace.	.00	.26	.39	100.20
J. J. Smith prospect, Macon County, N. C.	12.55	48.05	37.69	.31	Trace.	Trace.	Trace.	.00	.02	.91	99.53
Southern Clay Co., Macon County, N. C.	13.22	46.67	39.07	.11	.02	Trace.	Trace.	.00	.11	.25	99.45
West prospect, Macon County, N. C.	12.70	48.92	36.37	.37	.02	Trace.	Trace.	.00	.11	.29	98.78
Harris Clay Co., Sprucepine mine, Mitchell County, N. C.	14.80	45.20	38.45	.45	Trace.	Trace.	Trace.	.00	.00	.65	99.55
Tolley mica mine, Mitchell County, N. C.	14.00	46.35	38.80	.25	Trace.	Trace.	Trace.	.03	.00	.41	99.84
Harris Clay Co., Bryson City mine, Swain County, N. C	14.10	46.95	37.24	.40	.05	Trace.	Trace.	.00	.24	.49	99.47
Elizabeth Smith mica mine, Yancey County, N. C.	13.10	45.95	39.20	.05	Trace.	Trace.	Trace.	.03	Trace.	.50	98.83

Analyses of ocher, schroetterite, sugar quartz, and wad.[a]

[D. J. Demorest, analyst.]

Material and locality.	Loss on ignition.	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	Na_2O.	K_2O.	Mn_3O_4.	CaO+NiO.	CuO.
Ocher, Yonce prospect, Macon County, N. C.	13.59	15.40	16.25	51.00	0.30	......	......	......	......	......
Schroetterite, Jackson County, N. C.	28.10	21.90	49.60	.30	......	......	0.10	......	......	......
Sugar quartz, Macon County, N. C.	.10	99.32	.49	Trace.	......	......	......	......	......	......
Wad, Macon County, N. C.	15.30	33.20	24.60	4.00	.25	......	......	21.80	0.75	0.50

[a] Elements not mentioned were not sought.

FELDSPAR MINES AND PROSPECTS.

GEORGIA.

DALLAS. OLD TURNER MICA MINE. MICROCLINE.

This mine is 5 miles north of Dallas, Paulding County, Ga. The nearest shipping point is Dallas. The workings are one-fourth mile north of the farmhouse on two knolls. The openings are pits that have long since caved, making attempts at investigation unsatisfactory. Two bands of pegmatite are visible on one knoll, but both contain much coarse quartz and do not exceed 18 inches in diameter. A broad band of feldspar, reported to be present in these workings, could not be reached, owing to the condition of the pits.

Samples of the pegmatite taken from the exposed part of the dike show a deformation temperature ranging from 1,305° to 1,325° C., and fuse to a clear glass with a slightly yellow tint.

Properties in standard porcelain mixture.

In the mixture fired at 1,300° C. the feldspar shows vitrification, but at 1,350° no warpage. The color is the same as the standard trial. Fired at 1,350° in the mixture, this feldspar has a translucency of 0.62. The transmitted light is cream colored; the plastic molded shrinkage green to 1,350° C., 15.5 per cent. Under the raw-lead and fritted glazes the color is unaltered.

JASPER. DAVIS MICA MINE. MICROCLINE.

This mine is 4½ miles south of Jasper, Pickens County, Ga. The nearest shipping point is Jasper. It is an open pit, originally 6 by 8 by 8 feet deep. The caving of walls and washings from surrounding fields have practically refilled the pit so that there is little opportunity to study the formation. The pit is located in an open lot 25 feet above a small brook and is surrounded on all sides by much higher ground.

The mine is in a pegmatite dike about 4 feet wide, has a general north strike, and where exposed an almost vertical dip. No other exposure of this dike is found near by, and hence its industrial importance can not be determined. A kaolinized dike (see p. 118) of similar pegmatite, located one-fourth mile west of this deposit, has practically the same strike and dip.

The dike where exposed consists almost entirely of unaltered feldspar with intergrowths of quartz, giving a graphic structure. The feldspar is milk-white, free from any impurity except minute seams of silica, and a small amount of muscovite mica, which, however, is not much mixed with the feldspar.

The feldspar has a deformation temperature ranging from 1,305° to 1,325° C., and fuses to a clear bright glass.

Properties in standard porcelain mixture.

In the standard porcelain mixture fired at 1,300° C. the feldspar shows vitrification, but at 1,350° no warpage. Its color in the porcelain mixture is practically the same as the standard trial. Any difference in color is in favor of the feldspar. Fired at 1,350° in the mixture this feldspar shows a cream tint and a translucency of 0.65 and a total plastic shrinkage of 15.6 per cent. Under the raw-lead and fritted glazes the color is unaltered.

NORTH CAROLINA.

BAKERSVILLE. BUCKEYE MICA MINE.

This mine (91) is at the head of White Oak Creek, 5 miles southeast of Bakersville, Mitchell County, N. C. This dike is about 8 feet wide, and, near the surface, is almost pure feldspar, but the feldspar apparently forms a lens and pinches out at a depth of about 10 feet, below which is pegmatite. The dike strikes north and dips almost vertically. An inclined tunnel has been driven into this dike and its face is reported to be 40 feet below surface, but this tunnel is filled with water and there is no other way to ascertain whether the lower portions of the dike contain pure feldspar.

BAKERSVILLE. CLOUDLAND MICA MINE. ALBITE.

This mine (92) is on the north face of a spur of Yellow Mountain 400 feet above the Bakersville-Plumtree road, 1 mile south of the road and 5 miles east of Bakersville, Mitchell County, N. C. The nearest shipping point is Toecane, 2 miles west of Bakersville.

This pegmatite dike averages 14 to 16 feet in diameter, the mica running chiefly along the walls. It strikes N. 40° E. and dips 75° SE. Adjoining the walls are numerous bands of pegmatite very low in feldspar and carrying large amounts of garnet, tourmaline, beryl, biotite, mica, and other impurities. This dike has been opened for 120 yards and to a depth of 70 feet in places. The open-cut averages about 35 feet deep. The high-grade feldspar band in the middle of this dike averages about 4 feet thick and has the following chemical composition:

Composition of high-grade feldspar band.[a]

SiO_2	65.18
Al_2O_3	21.60
K_2O	.04
Na_2O	8.35
CaO	.64
	95.81

This feldspar has a deformation temperature ranging from 1,295° to 1,300° C., and produces a milk-white glass when fused.

Properties in standard porcelain mixture.

In this mixture the feldspar produces vitrification at 1,300° C., and at 1,350° shows slight warping. The color is equal to the standard trial. The translucency is 0.69 and the transmitted light is cream colored. The total shrinkage is 15.3 per cent in the mixture fired to 1,350°, 3 per cent drying shrinkage, and 12.3 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

BAKERSVILLE. LICK RIDGE MICA MINE.

This mine (85) is 2 miles northeast of Bakersville, Mitchell County, N. C., on Lick Ridge, a spur of Pumpkin Patch Mountain.

The dike is a mixture of feldspar and pegmatite. The feldspar band in the upper portion of the exposure is as much as 8 feet thick, but

[a] See North Carolina Geol. Surv., Economic Paper No. 6, p. 49.

rapidly narrows and at a depth of about 10 feet practically pinches out, being replaced by pegmatite. The dike strikes north and is exposed about 60 feet. Since the depth of the exposure is only 10 feet, not enough material is exposed to justify an opinion as to the advisability of mining operations and therefore no sample was taken.

BAKERSVILLE. J. T. WILSON MICA MINE.

This prospect (90) is 2 miles southeast of Bakersville, Mitchell County, N. C., on White Oak Creek.

The pegmatite dike is 15 to 18 feet wide and is exposed about 60 feet along the slope of a hill that runs to the northeast. The dike strikes N. 20° E. Along the walls there is mica, but the mica-bearing pegmatite is never more than 4 feet wide, leaving a band of practically pure feldspar. A stream, however, has followed the dike down the hill and has so thoroughly percolated the dike that attempts to obtain satisfactory samples by removing a reasonable amount of the outer portion of the dike failed. No feldspar has been taken out, therefore no sample was taken.

BANDANA. OLD GOUGE MICA MINE. ANORTHOCLASE.

This mine (84) is on a ridge 150 feet above the Bandana-Penland road and 1 mile southeast of Bandana, Mitchell County, N. C. Galax, the nearest shipping point, is 2½ miles distant. This dike is about 3 feet wide where exposed and has been worked for a distance of 60 feet by open-cut. The pegmatite carries little quartz and a few scattered garnets. The mica is found chiefly along the walls. The dike strikes west and dips 75° S. The feldspar sampled is white and of high luster. Its deformation-temperature range is from 1,300° to 1,310° C., and it fuses to a semitransparent glass free from yellow tint.

Properties in standard porcelain mixture.

In this mixture the feldspar produces vitrification at 1,300° C., and at 1,350° produces slight warping. The color is equal to that of the standard trial. The translucency at 1,350° C. is 0.71 and the transmitted light is cream colored. Shrinkage of the plastic molded mixture from green to 1,350° C. is 15 per cent, the drying shrinkage being 3 per cent and the firing shrinkage 12 per cent. Under the raw-lead and fritted glazes the color is unaltered.

BEAVER CREEK. HAMILTON MICA MINE. MICROCLINE.

This mine is 2 miles northwest of Beaver Creek, Ashe County, N. C., on Elk Mountain. The nearest railroad is at Shouns Crossroads 23 miles northwest, too far for haulage.

It is a very coarse pegmatite dike averaging 6 to 8 feet thick, rich in feldspar, but never free from quartz particles. However, the feldspar appears to be uniform in quality. The strike is N. 20° E., and the dip

80° E. The mica is present in some parts of this dike as isolated pockets, in others scattered through the pegmatite, rendering those parts worthless as a source of feldspar. The dike material was sampled where free from mica. The tests gave the following results:

Deformation temperature range, 1,290° to 1,310° C. Color, when fused, free from yellow tint; only a slight milkiness.

Properties in standard porcelain mixture.

In the mixture this feldspar produces a vitreous mass at 1,300° C., and at 1,350° a very slight warping occurs. The color is equal to the standard trial. Fired at 1,350° C. it has a translucency of 0.66 and the transmitted light is cream colored. The total shrinkage is 15.8 per cent, drying shrinkage 3.4 per cent, and firing shrinkage 12.4 per cent. Under the raw-lead and fritted glazes the color is unaltered.

BEAVER CREEK. NORTH HARDIN MICA MINE. MICROCLINE.

This mine is 1½ miles west of Beaver Creek, Ashe County, N. C. The nearest shipping point is Shouns Crossroads, 24 miles northwest. This is too far for road haulage.

It is a narrow dike that has been worked extensively along the surface for mica. The strike is N. 20° E. and the dip 70° to 80° E. The dike averages about 6 feet thick and contains a band of microcline from 1 to 4 feet thick. A narrow band of anorthoclase is also present in a number of places. The wall rock is solid gneiss. The feldspar of this dike is very free from impurities, which are chiefly quartz and mica and a few scattered iron garnets. The microcline has a deformation temperature ranging from 1,295° to 1,310° C. When fused it becomes practically clear and shows no yellow tint.

Properties in standard porcelain mixture.

This feldspar in the mixture produces a vitreous mass at 1,300° C., and at 1,350° shows a slight tendency to warp. Its color is equal to the standard. Fired at 1,350° C. this feldspar produces a translucency of 0.74, and the transmitted light is cream colored. Total shrinkage is 16 per cent, drying shrinkage 3 per cent, and firing shrinkage 13 per cent. Under the raw-lead and fritted glazes the color is unaltered.

BURNSVILLE. RAY MICA MINE. ALBITE.

This mine (72), which has been one of the most productive mica mines in the county, is 3 miles southeast of Burnsville, Yancey County, N. C., on the south face of a ridge that runs off from Black Mountain. The nearest shipping point is Micaville, 4 miles east. The workings are scattered along the slopes of a cove and are all on the same dike, which strikes N. 40° E. and dips 85° SE. The dike has in the center a clean feldspar band averaging 5 feet wide, and numerous narrow bands with more or less quartz on both sides. Some of these narrow bands are separated from one another by thin quartz bands, but a large part of the dike could be hand cobbed and marketed as feldspar.

The upper portion of the mine has been worked by open-cut to a depth of 40 feet, below which shaft mining has been carried on to a depth of 110 feet. The dumps of this shaft consist very largely of marketable feldspar, which was sampled and analyzed with the following result:

Chemical analysis.

H_2O	0.20
SiO_2	68.18
Al_2O_3	20.12
Fe_2O_3	.05
TiO_2	Trace.
CaO	.85
MgO	.05
K_2O	.66
Na_2O	9.38
	99.49

Chemical analysis in 1901.[a]

SiO_2	63.55
Al_2O_3	20.20
K_2O	8.73
Na_2O	6.65
	99.13

The albite, which was exposed in abundance during the summer of 1911, has been tested with the following results:

Deformation temperature range, 1,270° to 1,275° C.; color, when fused at 1,330° C., an opaque white with no yellow tint.

Properties in standard porcelain mixture.

In this mixture the feldspar gives a vitreous mass at 1,275° C. and warps slightly at 1,330° C. The color is slightly bluish by comparison with pure-white trials. Fired at 1,350° C. the translucency is 0.65 and the transmitted light is cream colored. The total shrinkage at 1,350° C. is 15 per cent, which consists of 3 per cent drying shrinkage and 12 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

FRANKLIN. BURNINGTOWN MICA MINE. MICROCLINE.

This mine (18) is 3 miles southeast of Burningtown Bald, Macon County, N. C. The nearest shipping point is Franklin, Macon County, N. C.

The mine is in a pegmatite dike, rich in feldspar, and averages about 8 feet wide, which has in the middle a quartz band varying from 2 feet to 3 feet wide. Other lenses of quartz are numerous. The strike is generally west; the dip 80° N. Mica is found chiefly along the walls, and the main portion of the pegmatite is very clean. Mining has been for mica only. A similar feldspar is found in small quantity in the Wayah Bald mica mines (17), which are 3 miles southwest.

[a] See Economy Paper No. 6, North Carolina Geol. Surv., pp. 49-50.

The mine comprises an open-cut 150 feet long and a tunnel 300 feet long penetrating the dike 125 feet. The pegmatite has a deformation temperature ranging from 1,305° to 1,320° C. Color, slightly milky when fused, but free from yellow tint.

Properties in standard porcelain mixture.

In the standard porcelain mixture this pegmatite gives a vitreous mass at 1,310° C. and warping is very slight at 1,350°. Color is equal to the standard trial. Translucency at 1,350° is 0.65. Transmitted light is cream colored. Shrinkage in the standard plastic porcelain mixture is 15.3 per cent, green to 1,350°. Under the raw-lead and fritted glazes the color is unaltered.

FRANKLIN. CAMPBELL-HIGDON MICA MINE. MICROCLINE.

This mine (47) is 1½ miles west of Watauga Gap on Cowee Mountain, Macon County, N. C. Franklin, Macon County, is 9 miles southwest and Dillsboro, Jackson County, is 12 miles northeast of this mine. Franklin has the advantage of better roads and shorter haul and Dillsboro the advantage of a slightly lower freight rate to northern markets.

The pegmatite is cut by two tunnels, and at one point is 10 feet thick, with a 4-foot quartz band in the center. Owing to a thick overburden of loose ground, mining has been very difficult. Since the most productive workings are partly kaolinized material adjoining the wall rock, the fresh pegmatite has not been thoroughly exposed and its extent can not be estimated. The operations are, however, on a steep mountain side, and the loose material could be economically removed in case open-cut mining for feldspar should be attempted.

The feldspathic portion of this dike has a deformation temperature ranging from 1,305° to 1,320° C., and on deformation becomes a pale milky white without yellow tint.

Properties in standard porcelain mixture.

In this mixture the feldspar produces vitrification at 1,300° C., and at 1,350° shows very slight warpage. The color is similar to the standard trial. The translucency is 0.67 and the transmitted light is cream colored. The shrinkage in plastic mixture, from green to 1,350° C., is 15.7 per cent. Under the raw-lead and fritted glazes the color is unaltered.

FRANKLIN. LISLE KNOB MICA MINE. ALBITE AND ANORTHOCLASE.

This mine (21) is on the southwest face of Lisle Knob, 1½ miles east of the Little Tennessee River and 5 miles north of Franklin, Macon County, N. C., which is the nearest shipping point. The deposit is a pegmatite lens about 30 feet thick and is opened by tunnel for a length of 75 feet and a depth of 35 feet. The strike is N. 10° E. and dip is 80° W. The east half of the lens contains many quartz bands and numerous clusters of iron garnets, but the west half is very clean except for iron garnets, which would necessitate careful sorting to obtain the highest possible grade of product. This lens is covered with about 40 feet of loose overburden, but the wall rock is a solid gneiss.

This deposit was carefully sampled; the feldspar was found to have the following chemical composition:

Chemical composition.

H_2O	0.30
SiO_2	65.40
Al_2O_3	20.70
Fe_2O_3	.10
TiO_2	Trace.
CaO	1.60
MgO	Trace.
K_2O	6.00
Na_2O	6.10
	100.20

The deformation temperature ranges from 1,260° to 1,265° C.; the color after fusion is dull white, free from yellow tint.

Properties in standard porcelain mixture.

In this mixture the feldspar gives a vitreous mass at 1,265° C., and warps slightly at 1,350°. The color is slightly blue by comparison with the standard trial. Translucency is 0.72 and transmitted light is cream colored. Total plastic shrinkage, when fired to 1,350° C., is 15.9 per cent. Under the raw-lead and fritted glazes the color is unaltered.

FRANKLIN. M'GUIRE PROSPECT. MICROCLINE.

This prospect (42) is at the head of McGuire Cove, on the southwest face of Tremont Mountain, 4 miles northwest of Franklin, Macon County, N. C., and 1 mile north of and 500 feet above the Franklin Andrews road. The nearest shipping point is Franklin. The formation is a dike of feldspar 10 feet in diameter where exposed, and bisected vertically by a band of sugar quartz 2 feet thick. This dike strikes southwest and dips south. The wall rock is Carolina gneiss, and at this point is very solid. The deposit is opened the width of the dike, and for a height of 15 feet and a depth of 8 feet into the mountain. An average sample of this deposit shows the following chemical composition:

Chemical composition.

H_2O	0.60
SiO_2	63.90
Al_2O_3	19.97
Fe_2O_3	.15
TiO_2	Trace.
CaO	.05
MgO	Trace.
K_2O	13.20
Na_2O	1.01
BaO	.70
	99.58

The deformation temperature range is 1,315° to 1,330° C. Color is milky when fused, but free from yellow tint.

Properties in standard porcelain mixture.

In the mixture this feldspar gives a vitreous mass at 1,310° C., and at 1,350° no warping is noted. The color is slightly, but positively, superior to the standard trial. Translucency at 1,350° C. is 0.68. Transmitted light is cream colored. Shrinkage in standard plastic porcelain mixture is as follows: Green to 1,350° C., 14.7 per cent. Under the raw-lead and fritted glazes the color is unaltered.

FRANKLIN. NEAL BRYSON MICA MINE. ALBITE.

This mine (20) is on the Franklin-West Mills road, on the east bank of the Little Tennessee River, 6 miles north of Franklin, Macon County, N. C., which is the nearest shipping point. The dike is from 2 to 12 feet wide. It strikes west and dips 70° N. at the east end and 30° S. at the west end. This mine has been worked only for mica, which generally follows the south wall. The dike is a feldspar-rich pegmatite, and has in the middle a quartz band varying in thickness from a few inches to about 3 feet. Mining operations consist of a number of shafts about 70 feet above the road and a tunnel crosscutting the dike at the road level. From the shafts the dike material was removed by stoping until the cutting of the tunnel recently made possible the removal of the material from below. The abandoned stopes in the old workings are filled with feldspar and quartz bowlders, but much feldspar has been dumped about the mouth of the shafts and the entrance to the tunnel.

The feldspar of this dike has a deformation temperature ranging from 1,295° to 1,300° C. As mined, it has a peculiar blue-gray tint but on fusing it becomes a pale-cream enamel.

Properties in standard porcelain mixture.

In this mixture the feldspar gives a vitreous mass at 1,300° C., and only a trace of warping at 1,350°. The color is slightly bluish, but is not discernible except by comparison with pure-white trials. In the porcelain mixture the translucency is 0.65 and the transmitted light is cream colored. The shrinkage, green to 1,350° C., is 15 per cent in standard plastic mixture. Under the raw-lead and fritted glazes the color is unaltered.

FRANKLIN. SHEFFIELD MICA MINE. MICROCLINE.

This mine is 2 miles north of Franklin, Macon County, N. C., on the east bank of the Little Tennessee River, in a dike about 12 feet wide which strikes west and dips 80° N. The dike consists of a number of distinct bands. The one adjoining the south wall is a low-grade pegmatite and carries the mica. A band of pegmatite rich in feldspar joins this on the north, and adjoining this is a band or lens of pure feldspar. This is separated from the north wall by a band of quartz. The feldspar-rich pegmatite where exposed is about 4 feet thick and the feldspar is 2½ feet thick.

Mining is difficult because the mine is below the level of the river during the winter months and water fills all openings.

The deformation temperature range of this feldspar is from 1,315° to 1,330° C. Color, milky when fused but free from yellow tint.

Properties in standard porcelain mixture.

In this mixture the feldspar gives a vitreous mass at 1,320° C., and at 1,350° shows no warping. Color is equal to the standard trial. Translucency fired at 1,350° is 0.67 with a cream tint. Total shrinkage is 14.8 per cent. This consists of 3 per cent drying shrinkage and 11.8 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

FRANKLIN. SOUTHERN CLAY CO. MINE. CRYSTALLINE ORTHOCLASE.

The orthoclase was obtained from beneath the Southern Clay Co. kaolin deposit at Franklin, Macon County, N. C. It occurs as clearly defined orthoclase crystals of milk-white color and was pulverized to pass a 150-mesh brass screen.

Chemical composition.

H_2O	0.50
SiO_2	64.30
Al_2O_3	19.64
Fe_2O_3	.08
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
BaO	.17
K_2O	14.00
Na_2O	1.32
	100.01

This feldspar has a deformation temperature ranging from 1,305° to 1,325° C., and when fused to a glass becomes clear and without a trace of color that can be detected by the eye.

Properties in standard porcelain mixture.

In the mixture this feldspar shows vitrification at 1,300° C., and at 1,350° only a slight warpage. The color is a purer white than that of the standard trial. The translucency is 0.67. Total plastic shrinkage is 13.8 per cent when fired to 1,350°. Under the raw-lead and fritted glazes the color is unaltered.

GALAX. YOUNG AND RAY PROSPECT.

This prospect (74–75) is on the Black Mountain R. R. between Galax, Mitchell County, and Micaville, Yancey County, N. C. The pegmatite is a coarse aggregate of feldspar and quartz with a liberal sprinkling of biotite and garnet. The greatest width of the "deposit" is 200 to 250 yards but approximately one-half of this width is country rock and the remainder comprises lenses and bands of pegmatite of varying widths; the broadest area recorded is four bands, all of impure pegmatite but free from wall material, which has a total width of 75 feet. The only band of pure feldspar recorded is one 6 feet in width in the middle of this 75-foot pegmatite area.

JEFFERSON. COLDIRON PROSPECT.

This prospect is 3½ miles northeast of Jefferson, Ashe County, N. C., and due southeast from the Witherspoon mica mine. The dike where exposed is pegmatite, about 50 per cent feldspar and 50 per cent quartz, and contains few garnets or other objectionable material. The face of the dike for a depth of 15 feet is exposed along the south side of the Jefferson-Spartan road. The width of the dike is 15 to 18 feet. There are no pure feldspar bands and the mine is 25 miles from the railroad. No further examination was made.

JEFFERSON. WITHERSPOON MICA MINE. MICROCLINE.

This mine is on the southeast face of Little Phoenix Mountain, 3½ miles northeast of Jefferson, Ashe County, N. C., and one-half mile north of the Jefferson-Sparta road.

The pegmatite dike is about 10 feet thick and strikes N. 40° E. The dip of the exposed portion is vertical. Mica had been mined at two points about one-fourth mile apart previous to 1901. The dike is chiefly feldspar. The mica is largely in the bands adjoining the wall rock and no associated minerals besides quartz are noted. The feldspar band of this deposit was sampled and analyzed. The chemical composition is as follows:

Composition of feldspar.

H_2O	0.90
SiO_2	64.48
Al_2O_3	19.43
Fe_2O_3	.01
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
K_2O	13.19
Na_2O	1.84
	99.85

The deformation temperature range is from 1,290° to 1,310° C. When fused the feldspar shows only a trace of cloudiness and is free from yellow tint.

Properties in standard porcelain mixture.

In the mixture this feldspar produces a vitreous mass at 1,300° C., and at 1,350° shows very slight, if any, warping. The color is fully equal to the standard trial. Fired at 1,350° C. this mixture has a translucency of 0.72 and the transmitted light is cream colored. Total shrinkage of 15.4 per cent, drying shrinkage 3 per cent and firing shrinkage 12.4 per cent. Under the raw-lead and fritted glazes the color is unaltered.

PENLAND. CAROLINA MINERAL CO. MINE. MICROCLINE AND ALBITE.

A broad lens (110) is exposed on both sides of the North Toe River, one-fourth mile east of the railroad station at Penland, Mitchell County, N. C. The dike that includes this lens strikes about west; on the north side of the river it dips 75° to 80° S., and on the south side 80° to 85° S. The dike is 15 to 35 feet wide and contains isolated lenses of soda feldspar, but most of the dike is microcline. It contains little quartz, which is present chiefly as bands along the walls or as isolated lenses. Mica is found in pockets, and in places garnets are associated with the mica. Uranium-bearing minerals are also present, and many nugget-like masses containing pitchblende have been found in mining operations. Small quantities of beryl also have been found.

Quarrying began in the spring of 1911. Regular quarrying methods have been used so far, tunnels being used for prospecting purposes only. A depth of 50 feet has been reached. The deposit remains uniform to that depth with no indication of narrowing.

An average sample of the microcline constituting this dike was analyzed, and is as follows:

Composition of microcline.

H_2O	0.30
SiO_2	65.68
Al_2O_3	19.08
Fe_2O_3	.14
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
K_2O	13.09
Na_2O	2.08
	100.37

This feldspar has a deformation temperature ranging from 1,290° to 1,310° C. It fuses to a glass with only a trace of milkiness and no yellow tint.

Properties in standard porcelain mixture.

In the mixture this feldspar produces a vitreous mass at 1,295° C.; at 1,350° no warping is apparent. The color is fully equal to the standard trial. When fired at 1,350° C. the translucency is 0.69 and the transmitted light is cream colored. The total shrinkage at 1,350° is 15.6 per cent, 3.6 per cent being drying shrinkage and 12 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

An average sample of the albite in this dike is found to have the following chemical composition:

Composition of albite.

H_2O	1.00
SiO_2	64.92
Al_2O_3	22.28
Fe_2O_3	.21
TiO_2	Trace.
CaO	1.60
MgO	Trace.
K_2O	1.10
Na_2O	9.20
	100.31

The deformation temperature range is from 1,260° to 1,265° C. At 1,350° the feldspar fuses to a dull white mass.

Properties in the standard porcelain mixture.

In the mixture this feldspar produces a vitreous mass at 1,265° C., and at 1,330° there is a slight warping. The color of the porcelain at 1,350° is bluish when compared with the standard trial. The translucency at 1,350° is 0.65; the transmitted light is cream colored. The total shrinkage is 14.8 per cent, which is 2.4 per cent drying shrinkage and 12.4 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

PENLAND. FLAT ROCK MICA MINE. MICROCLINE.

This mine (97) is 1½ miles northeast of Penland, Mitchell County, N. C. The dike is from 8 to 12 feet thick, the center only being pure feldspar, which is from 4 to 6 feet wide. The dike strikes N. 35° E. and dips 80° SE. It is more or less altered to a depth of about 30 feet, below which the material is fresh.

An analysis of this feldspar, made by the North Carolina Geological Survey,[a] is as follows:

Composition of feldspar.

SiO_2	65.15
Al_2O_3	19.04
CaO	.12
Na_2O	7.00
K_2O	7.28
	98.59

This deposit has only recently been worked for feldspar.

PLUMTREE. AVERY MEADOW MICA MINE. ANORTHOCLASE.

This mine (107) is 1½ miles north of Plumtree, Avery County, N. C., and one-half mile west of North Toe River, the nearest shipping point being 8 miles southwest at Sprucepine. It has been worked

[a] See North Carolina Geol. Surv. Economic Paper No. 6, p. 49.

extensively for mica. The coarse pegmatite dike carries a 4-foot band of clean feldspar midway between the walls. There is a band of nearly equal width of high-grade pegmatite adjoining the feldspar. The dike strikes N. 40° W. at the entrance to the tunnels, but farther in the strike varies, although always having a general northwest direction. This feldspar has no undesirable associated minerals, except the quartz and mica, which are not mixed with the feldspar but are confined chiefly to those bands of the dike that adjoin the walls.

The great drawback to the mining of the feldspar is the fact that work would have to be under ground, since the overburden exceeds 50 feet in all places and is more than 100 feet deep over most of the dike.

The chemical composition of the feldspar from this deposit is reported as follows:

Composition of feldspar.[a]

SiO_2	62.95
Al_2O_3	19.66
K_2O	8.39
Na_2O	7.64
	98.64

The feldspar of this deposit was sampled and tested. It deforms only from 1,325° to 1,350° C., which is at least 30 degrees higher than might be expected from the analysis. Its color is slightly creamy when fused.

Properties in standard porcelain mixture.

In the mixture the feldspar produces a vitreous mass at 1,330° C.; it shows no warpage at 1,350° C. Its color, however, is grayish when fired to 1,350° C. Its translucency is 0.60 when fused at 1,350°, and its total shrinkage is 16 per cent. Under the raw-lead and fritted glazes the color is unaltered.

PLUMTREE. JOHNSON MICA MINE. MICROCLINE.

This mine (106) is 2 miles east of Plumtree, Avery County, N. C., on Plumtree Creek. Sprucepine, the nearest shipping point, is 10 miles southwest.

There is a pegmatite dike of variable thickness, containing a band of microcline from 2 to 4 feet wide midway between its walls. The dike strikes northwest and dips 5° to 25° NE.

The feldspar band is very narrow but is free from impurity. The pegmatite band that joins the feldspar is also free from scattered mica and low in quartz.

[a] See Pratt, J. H., "The mining industry in North Carolina during 1901," North Carolina Geol. Surv. Economic Paper No. 6, pp. 49-50.

The feldspar collected has a deformation temperature ranging from 1,270° to 1,290° C. When fused it is practically clear and has no yellow tint.

Properties in standard porcelain mixture.

In the mixture the feldspar produces a vitreous mass at 1,275° C., and no warping at 1,350°. Its color is pure white. When fired at 1,350° C. it gives the porcelain a translucency of 0.73, cream colored, and a total shrinkage of 15.4 per cent, 3 per cent drying shrinkage and 12.4 per cent burning shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

PLUMTREE. PLUMTREE MICA MINE. MICROCLINE.

The mine (103) is one-half mile east of Plumtree, Avery County, N. C., on Plumtree Creek, 8 miles northeast of Sprucepine, which is the nearest shipping point. A pegmatite dike 10 to 15 feet wide was exposed, first by regular open-cut methods and later by hydraulic mining. The overburden ranges from 3 to 6 feet deep. The central portion, averaging 5 to 6 feet wide, is pure feldspar with only a scattering of quartz. The dike strikes N. 25° W. and dips 30° NE. The open-cut and hydraulic mining have exposed a large amount of microcline. The feldspar was sampled and analyzed as follows:

Composition of feldspar.

H_2O	0.17
SiO_2	65.37
Al_2O_3	17.92
Fe_2O_3	.02
TiO_2	Trace.
CaO	.17
MgO	Trace.
K_2O	13.05
Na_2O	2.10
	98.80

The deformation temperature range of this feldspar is 1,270° to 1,290° C. When fused the feldspar is practically clear and without a tint of yellow.

Properties in standard porcelain mixture.

In the mixture the feldspar produces a vitreous mass at 1,270° C., and at 1,350° only a very slight warpage occurs. The color is equal to the standard trial. The translucency when fired at 1,350° C. is 0.65 and the transmitted light is cream colored. Total shrinkage at 1,350° C. is 15 per cent, 3 per cent drying shrinkage and 12 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

SPEEDWELL POST OFFICE. COX PROSPECT. MICROCLINE.

This prospect (63) is in a creek bed on the east face of Panther Knob 1 mile west of Speedwell post office, Jackson County, N. C. The nearest shipping point is Sylva, Jackson County, which is 10 miles north. The feldspathic material is a pegmatite dike which, from the surface indications, carries very little quartz and mica. Its strike is N. 55° E. The commercially valuable feldspathic material exposed has a width of about 6 feet. The sample taken shows a deformation temperature ranging from 1,300° to 1,325° C. When fused this feldspar is clear and free from tint.

Properties in standard porcelain mixture.

In the standard porcelain mixture this feldspar produces vitrification when fired to 1,300° C., and shows no warpage at 1,350°. Fired to 1,350° C., the color is equal to the standard trial, the translucency is 0.69, and the transmitted light is cream colored. The total shrinkage when worked plastic is 15.3 per cent. Under the raw-lead and fritted glazes the color is unaltered.

SPRUCEPINE. AMERICAN GEM & PEARL CO. MINE. MICROCLINE.

A pegmatite dike (102) which has been worked for aquamarine, one-half mile east of the Sprucepine-Marion road and 3 miles southeast of Sprucepine, Mitchell County, N. C., which is the nearest shipping point. The mine is on the slope of a low ridge and has been worked by an incline. In September, 1911, the workings were full of water and their inspection was impossible. Fine orthoclase of a very pale flesh tint predominates in the dump, and the reports of residents agree that the dike averages over 10 feet wide and consists principally of feldspar very free from mica, the chief associated materials being beryl and a little quartz, which occur chiefly along the walls. The wall rock is reported to be solid and to require no timbering. The dike strikes northeast and dips 80° S.

The deformation temperature range of the feldspar is 1,310° to 1,330° C. The feldspar fuses to a glass with little cloudiness and no yellow tint.

Properties in standard porcelain mixture.

In the mixture this feldspar when fired to 1,310° C. produces a vitreous mass which shows no warpage at 1,350°. The color is equal to the standard trial. Fired to 1,350° C., the translucency is 0.66 and the transmitted light is cream colored. The total shrinkage is 15.5 per cent, of which 3 per cent is drying shrinkage and 12.5 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

SPRUCEPINE. COOK MICA MINE. MICROCLINE.

This mine (108) is 2 miles west of Sprucepine, Mitchell County, N. C. Open-cuts lie on the northeast face of a spur of Little Chalk Mountain 400 yards south of North Toe River; 200 yards to the south and 100 feet higher a cut and a short tunnel expose another pegmatite dike. The nearest shipping point is Sprucepine, although the C. C. & O. Ry. follows the opposite bank of the North Toe River.

These dikes strike N. 30° E. and dip 80° SE. The lower dike exposed is broad and shows a band of feldspar 12 feet wide in places and averaging 8 to 10 feet wide. The largest feldspar band is cream-white, but the other smaller bands are pink. There is one small band of albite, but it is separated from the potash feldspar; hence it will cause no trouble in mining. The mica is generally in the flinty bands that adjoin the walls.

The upper dike, 6 to 9 feet wide, contains along the middle a band of feldspar averaging 4 feet wide. All wall rock appears solid. The country rock is gneiss. The cream-white feldspar band of the lower deposit has the following chemical composition:

Composition of cream-white feldspar band.

H_2O	0.40
SiO_2	64.93
Al_2O_3	19.45
Fe_2O_3	Trace.
TiO_2	Trace.
CaO	.05
MgO	Trace.
K_2O	12.46
Na_2O	2.54
	99.83

The deformation temperature range of this feldspar is from 1,290° to 1,310° C. The feldspar fuses to a glass with only a trace of milkiness and no yellow tint.

Properties in standard porcelain mixture.

This feldspar in the mixture produces a vitreous mass at 1,300° C., and at 1,350° shows no evidence of warping. The color is equal or superior to the standard trials. When fired at 1,350° C. the translucency is 0.74 and the transmitted light is cream colored. The total shrinkage is 15.8 per cent, 3 per cent being drying and 12.8 per cent burning shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

SPRUCEPINE. ENGLISH KNOB MICA MINE. MICROCLINE.

This mine (95) is 2½ miles northeast of Sprucepine, Mitchell County, N. C. The property has been worked for mica at various points along the strike of the dike for about 200 feet, the general strike being N. 40° E. This pegmatite seems to be of uniform quality and a large percentage of pure feldspar is found. The width of the feldspar band varies from 5 to 12 feet.

At the present time the workings do not permit sampling at much depth. The surface material, however, indicates a good prospect.

SPRUCEPINE. WISEMAN MICA MINE. ALBITE AND ORTHOCLASE.

This mine (94) is near the head of Beaver Creek, 2 miles north of Sprucepine, Mitchell County, N. C., which is the nearest shipping point.

The tunnels on the southwest slope of the mountain have all caved but one. In this the dike strikes nearly west; the dip varies greatly. The feldspar-rich pegmatite averages not more than 4 feet wide where exposed, but it is low in quartz content and doubtless could be made marketable by some cobbing. Orthoclase is present in small isolated masses, but the greater portion of the dike is albite, of which the analysis follows:

Composition of albite.[a]

SiO_2	64.85
Al_2O_3	19.90
K_2O	2.91
Na_2O	10.04
	97.70

This material has a deformation range of 1,290° to 1,295° C. and fuses to an opaque white mass.

Properties in standard porcelain mixture.

In the mixture this feldspar produces vitrification at 1,295° C., and at 1,330° produces slight warping. The color is slightly bluish when compared with a standard white porcelain trial. When fired at 1,350° C. the translucency is 0.62 and the transmitted light is cream colored. The total shrinkage is 15.4 per cent, of which 3 per cent is drying shrinkage and 12.4 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

GRANITE.

Throughout Mitchell County there are vast areas of coarse granite that contain a high percentage of feldspar. There is always some small mica, but not sufficient to justify mining. There are outcrops in the Sprucepine-Marion road just south of Sprucepine and (100) on the face of Big Chalk Mountain just west of Sprucepine. The granite generally occurs as sills and appears very free from any impurities except the quartz and mica. The general strike is west.

Samples of this granitic material show the following chemical composition:

Composition of granitic material.

H_2O	0.90
SiO_2	75.10
Al_2O_3	15.57
Fe_2O_3	.47
TiO_2	.03
CaO	1.10
MgO	Trace.
K_2O	3.49
Na_2O	2.86
	99.52

[a] See North Carolina Geol. Surv. Economic Paper No. 6, pp. 49-50.

This material has a deformation temperature range from 1,300° to 1,315° C. The micaceous material present is too high in iron and imparts to the pulverized granite when fused a pronounced cream-yellow tint.

Properties in standard porcelain mixture.

This material does not produce vitrification in the mixture until 1,310° C. is reached; at 1,350° warping is detected. The color of the porcelain produced is cream. The translucency when fired at 1,350° C. is 0.62 and the transmitted light is cream-yellow. The total shrinkage is 13.6 per cent, 4.4 per cent drying and 9.2 per cent firing shrinkage. Under the raw-lead and fritted glazes the color is unaltered.

VIRGINIA.

LOWRY STATION. M'NICHOLS CO. MINE. MICROCLINE AND ALBITE.

The mine is on the Thompson place in Bedford County, Virginia, 5 miles south of Lowry Station on N. & W. Ry.

There are two dikes exposed on the west slope of a ridge that runs north and south. The strike is N. 40° E., the dip 75° N. The south dike, where exposed, is about 20 feet wide. In the middle is a band of pure feldspar, varying from 4 to 7 feet wide, with pegmatite on each side. This pegmatite, however, is rich in feldspar, and if care were exercised to eliminate the mica scattered through it much marketable feldspar could be obtained. This south dike is opened 25 feet into the hill, being exposed for a depth of 40 feet and across its full width. The north dike is separated from the south dike by about 30 feet of country rock. The north dike shows no band of pure feldspar but is very rich in feldspar throughout its width of about 10 feet. This pegmatite is very coarsely crystalline and has considerable coarse muscovite scattered through it. Very little material has been removed from this part.

Feldspar from the south dike was analyzed and shows the following chemical composition:

Composition of feldspar.

H_2O	0.10
SiO_2	68.75
Al_2O_3	18.56
Fe_2O_3	.03
TiO_2	Trace.
CaO	1.25
MgO	Trace.
K_2O	6.85
Na_2O	4.29
	99.83

The deformation temperature ranges from 1,260° to 1,265° C. The fused feldspar forms an opaque white mass.

Properties in standard porcelain mixture.

This feldspar in the mixture produces a vitreous mass at 1,265° C.; at 1,350° only slight warping occurs. The porcelain shows a very faint bluish tint. Fired at 1,350° this feldspar produces a translucency of 0.64 and the transmitted light is cream colored. The total shrinkage is 15 per cent, drying shrinkage 3 per cent and firing shrinkage 12 per cent. Under the raw-lead and fritted glazes the color is unaltered.

SEMIKAOLINIZED FELDSPAR MINES AND PROSPECTS.

NORTH CAROLINA.

BAKERSVILLE. FLUKIN RIDGE MICA MINES.

These mines (81) are on a ridge 2½ miles south of Bakersville, Mitchell County, N. C., and one-half mile west of the Bakersville-Ledger road. The nearest shipping point is Toecane, 3½ miles northwest. This ridge contains a large number of dikes of partly decomposed pegmatite, which strike N. 50° E., dip 65° S. Some of these dikes contain a large amount of fine quartz, but others contain very little quartz. No large masses of quartz are exposed in any of the workings. Tunnels and shafts have been dug over an area one-half mile long and one-eighth mile wide and more or less of this semikaolinized material (locally called "flukin") is found in every case.

This material has altered so that it may be crushed to sand with the hand. A dike free from quartz was sampled and analyzed; it showed the following composition:

Composition of semikaolinized feldspar.

H_2O	1.34
SiO_2	63.32
Al_2O_3	20.45
Fe_2O_3	.07
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
K_2O	14.20
Na_2O	.80
	100.18

Calculated from the analysis, the mineral composition of this material is as follows:

Mineral composition of semikaolinized feldspar.

Microcline	84.0
Albite	6.8
Kaolinite	9.2
	100.0

The deformation temperature range of this material is from 1,330° to 1,350° C. The fused material is almost clear but has a slight gray tint.

Properties in standard porcelain mixture.

Introduced on the basis of its calculated mineral constitution, this material gives a vitreous mass at 1,330° C. The color is slightly gray by comparison with a standard trial. Fired at 1,350° C. the material has a translucency of 0.70 and the transmitted light is cream colored. The total shrinkage is 15.4 per cent, 3 per cent being drying and 12.4 per cent firing shrinkage. Fired under the raw-lead and fritted glazes this mass has the same faint grayish tint.

BEAVER CREEK. SOUTH HARDIN MICA MINE.

This mine, which is described under "Kaolins," is 1½ miles southwest of Beaver Creek, Ashe County, N. C. The dike was found to contain, where exposed, only semikaolinized feldspathic materials, which seem to be of very nearly uniform quality. The entire width of the dike was sampled and analyzed; it showed the following composition:

Composition of semikaolinized feldspar.

H_2O	7.30
SiO_2	53.00
Al_2O_3	29.20
Fe_2O_3	.21
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
BaO	.00
K_2O	9.92
Na_2O	.53
	100.16

The mine at the present time is so far from the railroad and the percentage of alkali in the sample taken is so low that the present availability of the material as a substitute for feldspathic material is doubtful. The color, however, appears to be sufficiently good for this purpose. If lower levels should show considerable quantities of semikaolinized material, it doubtless will some day be available as a flux material for pottery. On the other hand, if the dike lower levels prove to be completely altered, as in certain sections which were exposed by the owners but are now closed by caving, the dike may become a source of kaolin.

BRYSON. HARRIS CLAY CO. MINE.

This mine (3) is 2 miles north of Bryson, Swain County, N. C. The dikes from which the kaolin has been obtained are not uniform in degree of kaolinization. Many sections of these dikes are only slightly kaolinized and at a few points fresh feldspar is found. A large amount of this semikaolinized material can be obtained from this mine. This material was sampled and analyzed; it showed the following chemical composition:

Composition of semikaolinized feldspar.

H_2O	0.94
SiO_2	63.60
Al_2O_3	20.40
Fe_2O_3	.32
TiO_2	Trace
CaO	Trace
MgO	Trace.
BaO	.00
K_2O	14.40
Na_2O	.50
	100.16

The deformation temperature range is from 1,330° to 1,350° C., and the material fuses to a slightly milky mass free from yellow tint.

From the above chemical analysis this material is calculated to have the following mineral composition:

Mineral composition of semikaolinized feldspar.

Orthoclase	85.4
Albite	4.2
Kaolinite	9.4
Quartz	1.0
	100.0

Properties in standard porcelain mixture.

Introduced on the basis of its calculated mineral constitution, this material gives a vitreous mass at 1,350° C. and the color is equal to the standard trial. Fired at 1,350° C. the translucency is 0.70 and the transmitted light is cream colored. The total shrinkage is 15.6 per cent, of which 3 per cent is drying and 12.6 per cent is firing shrinkage. Tested under the raw-lead and fritted glazes this porcelain showed no change in tint.

FALLSTON. FRANK BAXTER MICA MINE.

This mine is 13 miles northeast of Shelby and 3 miles southeast of Fallston, Lincoln County, N. C., and 1 mile north of the Thomas Baxter mica mine. It is in a semikaolinized pegmatite dike, as indicated by the dumps, but the workings have fallen in and little idea of the extent of the dike can be obtained. The general strike of the dike as indicated by the shafts is northeast.

A quantity of this semikaolinized material, exposed in one shaft about 12 feet deep, was sampled and tested. It has a combined-water content of 12.4 per cent and when fired to 1,330° C. shrinks 15 per cent. Its refractory value is 1,670° C.

FRANKLIN. GURNEY CLAY CO. MINE.

This mine (29) is 4 miles north of Franklin, Macon County, N. C. The semikaolinized feldspar is exposed by an old tunnel for mica 250 feet southwest of the present workings for kaolin. The material occurs as a lens and has a general north strike. The material is pure white, and resembles kaolin, but possesses a bonelike texture and no plasticity. It contains 13.1 per cent of combined water and has a refractory value of about 1,700° C.

This material is too low in water to be halloysite and hence must be classed as kaolinite.

FRANKLIN. MOORE MICA MINE.

This mine (36) is 1½ miles north of Franklin, Macon County, N. C., on the west bank of the Little Tennessee River.

The dike, which is more or less kaolinized, averages about 9 feet thick; it has a general northeast strike and dips almost vertically. The overburden averages about 25 feet thick. The dike is very free from associated minerals and no large quartz bands are exposed. A portion of this dike is completely kaolinized, but large amounts of the feldspar are only slightly altered. A sample of slightly altered material showed the following chemical composition:

Composition of semikaolinized feldspar.

H_2O	2.05
SiO_2	63.74
Al_2O_3	20.90
Fe_2O_3	.12
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
BaO	1.10
K_2O	11.70
Na_2O	.19
	99.80

The mineral composition calculated from this analysis is as follows:

Mineral composition of semikaolinized feldspar.

Microcline	72.0
Albite	1.7
Kaolinite	17.6
Quartz	8.7
	100.0

The deformation temperature range of this material is from 1,350° to 1,370° C. The material fuses to a slightly milky glass with no yellow tint.

Properties in standard porcelain mixture.

Introduced on the basis of its calculated mineral constitution, the material gives a vitreous mass at 1,350° C.; its color is equal to the standard trial. Fired at 1,350 C. the translucency is 0.68 and the transmitted light is cream colored. The total shrinkage is 15.6 per cent, of which 3 per cent is drying and 12.6 per cent is firing shrinkage. Tested under the raw-lead and fritted glazes this porcelain shows no change of tint.

FRANKLIN. SOUTHERN CLAY CO. MINE.

This mine (40) was worked entirely for kaolin, but throughout the dike lenses of semikaolinized material were found. At the upper levels the semikaolinized material is loose and very light. It has a combined-water content of 8.65 per cent and deforms at 1,590° C., although it is translucent at 1,350° C.

These lenses are hardly large enough to be of industrial importance. Where mining has reached a depth of about 80 feet the dike is only partly kaolinized, and at greater depths the kaolinization decreases until material approaching feldspar in appearance and composition is found.

This slightly kaolinized feldspar was sampled. Analysis showed it to have the following chemical composition:

Composition of semikaolinized feldspar.

H_2O	1.40
SiO_2	62.47
Al_2O_3	21.00
Fe_2O_3	.05
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
BaO	.30
K_2O	13.62
Na_2O	.60
	99.44

The mineral composition of this material is calculated as follows:

Mineral composition of semikaolinized feldspar.

Orthoclase	82.0
Albite	5.0
Kaolinite	8.0
Quartz	5.0
	100.0

The semikaolinized feldspar has a deformation temperature range from 1,350° to 1,370° C. It fuses to a glass only slightly milky and free from yellow tint.

Properties in standard porcelain mixture.

Introduced on the basis of its calculated mineral constitution, this material gives a vitreous mass at 1,350° C., and its color is equal or superior to the standard trial. Fired at 1,350° the translucency is 0.70 and the transmitted light is cream colored. The total shrinkage is 15.5 per cent, of which 3 per cent is drying and 12.5 per cent is firing shrinkage. Tested under the fritted and raw-lead glazes this porcelain shows no change in tint.

In order to determine the effect of washing, a quantity of the material was subjected to the standard laboratory washing process. The residue having a hydraulic value of more than 0.17 was analyzed and found to have the following chemical composition:

Composition of residue of hydraulic value more than 0.17.

H_2O	0.40
SiO_2	63.21
Al_2O_3	21.08
Fe_2O_3	.08
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
BaO	.30
K_2O	14.03
Na_2O	.60
	99.70

The material is thus seen to have lost a part of its kaolinite, thus lowering its deformation temperature. This is further shown by firing since the washed material has a deformation temperature range from 1,340° to 1,360° C.

MARSHALL. SETH FREEMAN PROSPECT.

This prospect is at the junction of Bear Creek and Marshall roads, on Trail Branch of Sandy-Mush Creek, 4 miles south of Marshall, Madison County, N. C., which is the nearest shipping point.

This dike is about 100 feet wide, but with many intruded horses of wall rock, so that few bands occur more than 8 feet thick. The strike is N. 40° E. and the dip 20° SE. The material sampled has the appearance of a fine white sand. It was found to have the following chemical composition:

Composition of semikaolinized feldspar.

H_2O	5.42
SiO_2	65.05
Al_2O_3	22.39
Fe_2O_3	.29
TiO_2	.12
CaO	Trace.
MgO	Trace.
BaO	.30
K_2O	6.53
Na_2O	.21
	100.31

From the chemical analysis this material is calculated as having the following mineral composition:

Mineral composition of semikaolinized feldspar.

Microcline	39.50
Albite	1.80
Kaolinite	37.10
Quartz	21.60
	100.00

Its deformation temperature range is 1,450° to 1,470° C., and it fuses to a slightly milky glass, with a faint yellow tint.

Properties in the standard porcelain mixture.

Introduced on the basis of its calculated mineral constitution, this material gives a vitreous mass at 1,350° C., and the color of the mass shows no trace of the yellow tint noted in the fused material, but is fully equal to the standard trial. Fired at 1,350° C. the translucency is 0.68 and the transmitted light is cream colored. The total shrinkage is 15.4 per cent, 3 per cent being drying and 12.4 per cent firing shrinkage. Tested under the raw-lead and fritted glazes this porcelain showed no change in tint.

MONTVALE. REED MICA MINE.

This mine is 2½ miles southeast of Sapphire and 1 mile northeast of Montvale, Jackson County, N. C.

It is in a dike of slightly kaolinized feldspar about 5 feet thick, but carrying a 2-foot quartz band in the middle. The dike strikes N. 25° E. and dips 40° NW. The feldspathic material is friable, but retains its crystalline structure.

The feldspathic portion of the dike contains 2 per cent of combined water. The deformation temperature range of the material is from 1,355° to 1,370° C. The material becomes a semiopaque mass on fusing.

Properties in the standard porcelain mixture.

This material, tested on a basis of 85 per cent feldspar, 10 per cent kaolinite, and 5 per cent quartz, produces a vitreous porcelain at 1,330° C. The color is cream white. The material has translucency of 0.64 when fired at 1,350° C. The total shrinkage is 15.7 per cent, of which 3 per cent is drying and 12.7 per cent is firing shrinkage. No increase in color intensity is noted under the raw-lead or fritted glazes.

RUTHERFORDTON. ISINGLASS HILL MICA MINE.

This mine is on a low ridge 3 miles north of Rutherfordton, Rutherford County, N. C., adjoining the line of the Southern Railway. There are no shipping facilities nearer than Rutherfordton, however.

This pegmatite dike varies from 6 to 50 feet in diameter and is nearly one-fourth mile long. The general strike of the deposit is N. 20° E. and the dip is 80° to 85° W.

This dike is bisected by a quartz band 1 to 3 feet wide. The portion west of this quartz band is practically pure kaolin, whereas the portion east of it is semikaolinized material. The associated minerals of this dike are a few scattered iron garnets and numerous nodules of wad. The mica is found adjoining the walls, is generally solid, and could be easily removed.

This semikaolinized material was sampled and analyzed; it has the following composition:

Composition of semikaolinized feldspar.

H_2O	3.60
SiO_2	60.47
Al_2O_3	23.45
Fe_2O_3	.10
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
K_2O	12.10
Na_2O	.65
	100.37

From this analysis the mineral composition of the material has been calculated to be as follows:

Mineral composition of semikaolinized feldspar.

Orthoclase	71.5
Albite	5.5
Kaolinite	23.0
	100.0

This material has a deformation temperature ranging from 1,350° to 1,390° C., and fuses to a semiopaque glass with no yellow tint.

Properties in the standard porcelain mixture.

Introduced on the basis of its calculated mineral constitution, this mineral gives a vitreous mass at 1,330° C. The color is fully equal to the standard trial. Fired at 1,350° C. the translucency is 0.70 and the transmitted light is cream colored. The total shrinkage is 15.5 per cent, 3.2 per cent drying and 12.3 per cent firing shrinkage. Fired under the fritted and raw-lead glazes this mass is unchanged in tint.

SYLVA. FOREST HILL MICA MINES.

These mines (64) are 10 miles south of Sylva and 1 mile west of Cullowhee Creek in Jackson County, N. C. The nearest shipping point is Sylva. The mines are in a semikaolinized pegmatite dike situated along the northeast slope of a spur of Panther Knob. This dike is extensive; it has been crosscut for more than 30 feet and tunnels along the strike have been run for more than 100 yards. The dike material is largely feldspar in various stages of decomposition. A large part, however, is only slightly kaolinized and retains the characteristic orthoclase structure and cleavage and its alteration is evidenced only by its friability, it being readily crushed with the fingers. It is pure white in color and is entirely devoid of plasticity, even when pulverized. A quantity of this material was sampled and by chemical analysis found to possess the following composition:

Composition of semikaolinized feldspar.

H_2O	0.90
SiO_2	63.35
Al_2O_3	20.07
Fe_2O_3	.15
TiO_2	Trace.
CaO	.03
MgO	Trace.
K_2O	13.70
Na_2O	1.11
	99.31

This material so closely resembles feldspar that it can be utilized as a flux for fine porcelain. Its mineral composition is, approximately, as follows:

Mineral composition of semikaolinized feldspar.

Orthoclase	81.8
Albite	9.5
Kaolinite	8.2
Quartz	.5
	100.0

The deformation temperature ranges from 1,310° to 1,340° C. When fused the material is free from yellow tint and only very slightly milky.

Properties in the standard porcelain mixture.

When introduced into the mixture in proportions based upon its mineral constitution this material produces a vitreous mass at 1,330° C. The color is equal or superior to the standard trial. The translucency is 0.74 and the transmitted light is cream-white. The total shrinkage is 15.2 per cent, 3 per cent being drying and 12.2 per cent firing shrinkage. No change in color is noted under the raw-lead or fritted glazes.

Another section of this dike shows material more kaolinized. This material contains 6.96 per cent combined water, and has a deformation temperature of 1,510° C.; hence it could be used only in a limited way to replace feldspar as an alkali-bearing material in the porcelain mass. Its color is pure white. By calcination the combined water may be removed, producing a material of low shrinkage. (See also feldspar and kaolin under this name.)

TOECANE. BENNER MICA MINE.

This mine (83) is on the south slope of Sink-Hole Ridge and one-half mile west of Flukin Ridge, Mitchell County, N. C. The nearest shipping point is Toecane, which is 4 miles northwest.

The kaolinized pegmatite dike is broad. Some of it is completely altered to a high-grade kaolin, and a large part apparently lacks only the plasticity to make it perfect kaolin. Very little fine quartz and no large quartz is found in this dike. The strike is N. 60° E. and the dip 75° S. There are four shafts and a tunnel besides numerous pits.

This nonplastic kaolin was sampled and tested. It contains 11.3 per cent combined water, and has a refractory value greater than 1,700° C. When fired alone at 1,330° C. it has a total shrinkage of 15.25 per cent, 3 per cent drying and 12.25 per cent firing shrinkage. Color is pure white, free from specks. The raw-lead and fritted glazes make no changes in the tint of the mass.

BAKERSVILLE. HAWK MICA MINE.

The Hawk mica mine (88) is about 3 miles east of Bakersville, Mitchell County, N. C. Operations were by tunnels, and most of these are now caved and closed. Two tunnels on the south side of the hill show a small dike of semikaolinized feldspar that is much stained by associated iron-bearing clays, but doubtless would be less stained at greater depth. No fresh feldspar or kaolin is exposed in either tunnel.

TULIP POST OFFICE. HOLE MICA MINE.

This mine is on a ridge above Dan River near Tulip, Stokes County, N. C., 16 miles southwest of Stuart, Patrick County, Va., which is the nearest shipping point.

The semikaolinized pegmatite dike nearly 25 feet thick strikes west and dips 30° N. Three bands of quartz, each more than 4 feet thick, occur in this dike, and apparently lie along the walls and midway between. Another band of pegmatite is said to occur below the lowest exposed quartz band, but the opening that exposed it has been refilled. Between these massive quartz bands are numerous pegmatite bands of varying quartz content and some of these narrow bands are much iron-stained, making mining difficult if this stained material must be eliminated.

The two exposed bands of semikaolinized pegmatite were sampled and found to contain 13 per cent and 13.2 per cent, respectively, of combined water. Fired to 1,330° C. the material shrinks 15 to 15.3 per cent and becomes a pale-cream color. Its refractory value is above 1,700° C.

KAOLIN MINES AND PROSPECTS.

GEORGIA.

CLAYTON. MARK BECK PROSPECT.

This prospect is 8 miles east of Clayton, Rabun County, Ga., and 1½ miles south of the Clayton-Highlands road. It has been worked for mica by an open-cut. The dike has a general north strike and dips about 80° E. Where exposed it is about 10 feet wide and contains in the middle a band of sugar quartz from 3 to 4 feet thick. The surface of the dike is almost completely kaolinized, but at a depth of only 10 feet the kaolinization seems to be complete only in spots and at 15 feet the material is only semikaolinized. The dike doubtless is fresh feldspar and pegmatite at no great depth. The present opening is about 30 feet long, and about 5 feet of the dike adjoining the quartz band on both sides is apparently a good grade of feldspar or feldspar-rich pegmatite, the rest of the dike being a low-grade pegmatite.

JASPER. DAVIS MINE.

This mine is 4½ miles south of Jasper, Pickens County, Ga., which is the nearest shipping point. A well-defined dike about 10 feet wide lies along the crest of a low ridge and strikes about north. The maximum overburden is 4 to 5 feet. The dike has been exposed for about 60 feet by an open-cut. The material seems to be very good quality, but the kaolin content seems to vary greatly, as some points appear to be almost pure sand whereas others appear to be almost pure kaolin. No well-defined mica-bearing bands are apparent, but the entire deposit contains a considerable percentage of fine white mica which appears to possess a high luster.

The dike was sampled across its entire face and yielded 27 per cent of kaolin and 12 per cent of fine white mica. The kaolin was tested. It has a refractory value of 1,730° C. and a color of grade 3. The shrinkage at 110° C. was 5.3 per cent and when fired at 1,350° C. was 14.4 per cent. The tensile strength was 20 pounds per square inch.

Properties in the standard porcelain mixture.

In the mixture this kaolin has a translucency of 0.66 and the transmitted light is cream colored. Absorption is 4.8 per cent. The color is grade 3. Dried at 110 C. the shrinkage is 3.5 per cent and fired at 1,350° C., 13.4 per cent. Tested under the raw-lead and fritted glazes the color remains unaltered.

NORTH CAROLINA.

ALMOND. HEWITT MINE.

This mine is 3½ miles south of Almond, in Swain County, N. C., and one-half mile west of the Little Tennessee River. Four exposures have been operated on this property (11–12–13–14). The last opening

(14) operated is a dike which runs north and dips 75° E. It is an impure granite-pegmatite, incompletely kaolinized. The bands are not well defined and the whole mass has reached a state comparable only with sand. In places the overburden has been removed and the dike worked as an open-cut. The dike varies from 20 to 30 feet thick and has been removed for 275 feet into the hill to a depth of 40 to 60 feet. The dike is on a ridge. The material has been removed in dump cars to a steep slope in the hill down which it has been dumped into a stock bin and from this has been removed as required to a field washing plant near by. This washing plant, operated by a 20-horsepower portable engine, consists of two ordinary clay washers and two sand wheels through which the crushed kaolin passes to mica-settling troughs. After passing the mica troughs the kaolin is conveyed by flume to the concentrating plant, which is one-half mile distant on the west bank of the Little Tennessee River. This plant comprises concentrating tanks and a press equipment, including cistern, pumps, and two standard filter presses.

From the presses the kaolin goes to three open-air drying sheds, averaging 100 by 14 feet.

Kaolin from this mine was sampled directly from the dike, and by the laboratory process shows a kaolin content of 20 per cent.

The kaolin has a refractory value of 1,650° C. In color it falls very slightly below the scale established, and for that reason has been called grade 6. The shrinkage in drying at 110° C. is 3.6 per cent and in firing at 1,350°, 8.7 per cent. When dried at 110° C. the kaolin has a tensile strength of 6 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture fired at 1,350° C. this kaolin gives a translucency of 0.66 and the transmitted light is yellow. Absorption is 1.9 per cent. The color is grade 6. The shrinkage when dried at 110° C. is 2 per cent; when fired at 1,350° C., 13.2 per cent. The color is not affected by the application of either the raw-lead or the fritted glazes.

ALMOND. HYDE PROSPECT.

This prospect (9) is in Swain County, N. C., 2 miles east of Almond, on the east side of the Little Tennessee River. The deposit opened is an expanded lens covering practically the whole of a ridge 1½ to 2 acres in area. It is opened by five test holes and two tunnels, at an average elevation of 200 feet above the river, on both sides of the ridge, which has a direction N. 20° E. The lens is very irregular and possesses no uniform dip. The best exposure on this property was in the tunnels, one having a length of 75 feet and exposing a clear width of dike material of only 20 feet. This tunnel was sampled from a point 30 feet from the entrance to the end, a distance of 45 feet. The material at the end is 60 feet below the crest of the ridge.

The material collected was washed by the standard laboratory process and yielded only 19 per cent of kaolin. This kaolin was tested. It has a refractory value of 1,670° C. The color is grade 6. Dried at 110° C. the kaolin shrinks 4.2 per cent and fired at 1,350° C., 8.8 per cent. The tensile strength is 8 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.64 and the transmitted light is yellow. Absorption is 2.2 per cent. The color is grade 6. The shrinkage when dried at 110° C. is 2.1 per cent, and when fired at 1,350° C., 12.8 per cent. Tested under the raw-lead and fritted glazes the color is unaffected.

ALMOND. MESSER PROSPECT.

This prospect (10) is 2½ miles south of Almond, Swain County, N. C., on the west side of the Little Tennessee River. Two tunnels on opposite sides of the knoll and 25 feet below the crest expose a kaolin deposit running across the knoll. The dike appears to have a north strike and the dip where exposed is vertical. The material in these tunnels contains a fair quality of kaolin, but the dike contains a great many narrow streaks of stained material which greatly reduce the value of the deposit at this point. The openings are 200 feet above Little Tennessee River, and undoubtedly the dike at a lower point would show material of a much higher grade.

ASHEVILLE. SNIDER PROSPECT.

This prospect is on a small tract of land 3½ miles west of Asheville, N. C., on the Asheville-Alexander road. It is on the north bank of French Broad River and is 550 yards north of the Southern Railway, which here follows the river. The dike has a total width of 8 to 10 feet where exposed, but contains a number of horses of wall rock. This exposure, however, goes only 16 feet below the surface and can not indicate the dike structure at lower levels. The dike strikes N. 30° E. and dips 75° SE. The material is somewhat sandy and carries a large amount of white mica, most of which is in very small particles, has a bright luster, and is an ideal material for the pulverized-mica industry. Similar dikes along the general strike of this one are exposed for half a mile, but only by small pits, and no statement as to the quality of their material is attempted. The occurrence of a considerable deposit of dikelike formation 1 mile distant was noted, but found to contain a bluish-white sand similar to the deposits in the neighborhood of Almond, Swain County, N. C. The material in the Snider prospect was sampled and yielded 24 per cent of kaolin and 9 per cent of white mica.

The kaolin showed under test a refractory value of above 1,730° C. Its color is grade 3. The shrinkage when dried at 110° C. is 4.2 per cent and fired at 1,350° 14 per cent. The tensile strength of this kaolin is 24 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.67 and the transmitted light is cream colored. Absorption is 4.8 per cent. The color is grade 3. The shrinkage when dried at 110° C. is 3 per cent and fired at 1,350° C. 12.8 per cent. Tested under the raw-lead and fritted glazes the color remains unaltered.

BAKERSVILLE. AMERICAN MICA & MINING CO. MINE.

This mine (89) is in an isolated lens of kaolin on the brow of the hill 1 mile south of Bakersville, Mitchell County, N. C. The dike strikes northeast and shows a width of about 12 feet of good-quality kaolin. Attempts, however, to prove the extent of this material in either direction have failed. The deposit is doubtless an expanded lens of kaolinized material belonging to a dike that is exposed 300 yards to the southwest by a shaft on this same property and there shows 5 to 6 feet of kaolin.

A careful attempt to locate the dike at intermediate points by borings made at 3-foot intervals failed to expose any dike material, and it is therefore concluded that the dike between these points must be very narrow.

BAKERSVILLE. BENNER MICA MINE.

This mine (82) is on the south face of Sink Hole Ridge, 3 miles southeast of Bakersville, Mitchell County, N. C. The greater part of the dike where exposed on this property is semikaolinized material. The northwest part of the dike, however, appears to be isolated by a broad band of wall rock from the rest of the dike, and into this part four shafts have been sunk along the strike. These shafts have been abandoned and at the time of inspection no means was available for getting to the bottom of them.

The material removed from this part of the dike, as indicated by the dumps, is a good plastic kaolin. The width of this kaolin, however, is reported by men who worked in the mine as very narrow, at some places not exceeding a few feet. The length of the exposure developed by the shafts is reported to be only a few rods. Inability to inspect the dike prevented a more complete report.

BAKERSVILLE. THOMAS HOWELL PROSPECT.

This prospect (81) is on Flukin Ridge 2½ miles south of Bakersville, Mitchell County, N. C., and west of the Bakersville-Sprucepine road. This prospect was also sampled for semikaolinized feldspar. (See p. 108.) 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 semikaolinized 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 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, if one were provided.

BAKERSVILLE. AARON M'KINNEY PROSPECT.

This prospect (86) is 1 mile northeast of Bakersville, Mitchell County, N. C., and 3 miles from Toecane, the nearest railroad point.

The dike is about 30 feet wide, including two horses of mica gneiss averaging between 6 and 8 feet thick where exposed. The dike occurs along a ridge and has been proven for about 300 yards. Its strike is northeast and its dip is nearly vertical. The pegmatite of the dike is almost completely kaolinized and contains numerous small pockets of micaceous material heavily stained with iron. The removal of these pockets without contamination of the white kaolin would demand much care in mining. This dike has been opened by two tunnels along and one across the dike, besides a number of test holes. The kaolin material in this dike was sampled; by a laboratory washing process it yielded 32 per cent of kaolin.

This kaolin has a refractory value above 1,730° C. and its color is grade 2. When dried at 110° C. it shrinks 4.4 per cent and when fired at 1,350° C., 12.9 per cent. The tensile strength of this kaolin dried at 110° C. is 28 pounds per square inch.

Properties in standard porcelain mixture.

This material in the mixture when fired at 1,350° C. has a translucency of 0.61 and the transmitted light is cream colored. Absorption is 4.25 per cent. The color is grade 2. Dried at 110° C. the shrinkage of the kaolin is 2.8 per cent, fired at 1,350° C. it is 10.6 per cent. Tested under the raw-lead and fritted glazes this mass shows a pronounced green tint, equally apparent under both glazes.

BAKERSVILLE. JOHNSON M'KINNEY MICA MINE.

This mine (87) is 1 mile northeast of Bakersville, Mitchell County, N. C., and is a continuation of the Aaron McKinney prospect situated due southwest. This mine has been worked more or less for mica but the operations have been entirely by shaft and the openings have all been allowed to fill with refuse, making a sampling of this mine impossible without great expense.

BAKERSVILLE. SINK-HOLE RIDGE PROSPECT.

This prospect consists of irregular dikes, doubtless expanded lenses, occurring in what is known as the Sink Hole, a ridge with a sunken crest, about 3 miles southeast of Bakersville, Mitchell County, N. C., and about 3 miles from Toecane, the nearest railroad station. The property has been thoroughly mined for mica and the more or less kaolinized material in the various dikes has been so mixed with wall rock and other impurities that the opening of a kaolin mine would be almost impossible. The depth of mining in some places reached 40 feet and in others did not exceed 30 feet. The material found is invariably more or less kaolinized but the larger part is high quality as regards color. The present workings are all in a semikaolinized part of the dike and the abandoned workings are completely closed by refuse from the later workings. Consequently this statement on the composition of the dike materials at different points is based on examination of the dumps. The inability to obtain material directly from the dike made further investigation unadvisable.

BEAVER CREEK. SOUTH HARDIN MICA MINE.

This mine is 1½ miles southwest of Beaver Creek, Ashe County, N. C. The pegmatite dike is 6 to 10 feet wide, strikes N. 40° E., and dips 60° SE. It has been exposed by open-cuts and shafts and one tunnel following the strike. The material is kaolinized to a very uniform extent wherever exposed, but in no exposures has kaolinization proceeded far enough to cause the development of plasticity, although it is reported that in old shafts now entirely closed by slides a good grade of plastic kaolin was exposed. However, the dike material which was carefully sampled fails entirely to fall under the kaolin classification, and it is therefore reported as semikaolinized feldspar.

BETA. LOVE PROSPECT.

This prospect is 1 mile east of Beta, Jackson County, N. C., on the north side of the Murphy Branch of the Southern Railway. This prospect is opened on a low isolated hill adjoining the railway and as the test holes are now almost completely filled with refuse no idea of the extent of the deposit can be obtained. However, the dumps from these holes indicate that kaolin of fair quality occurs here.

BOONFORD. YOUNG PROSPECT.

This prospect (76) is 1 mile west of Boonford, Yancey County, N. C. The dike averages about 30 feet in width and contains a 4-foot horse of wall rock in the middle. It strikes northeast and dips

85° S. The material in the deposit adjoining the northwest wall and on the north side of the band of wall rock is very much more advanced in kaolinization than is the material on the southeast side of this band. The entire dike is free from impurities except for a very small amount of garnet sand occurring in small pockets. This dike has been proven for only a short distance, but the surface indications are that it is partly exposed several yards distant along the strike in both directions. However, the topography is so irregular that a thorough proving by test holes and tunnels, if necessary, would alone settle this point.

Material from this dike, where exposed by tunnel, was sampled. By the laboratory washing process this material yielded 22 per cent of kaolin having a refractory value above 1,730° C. and a color of grade 2. When fired at 1,350° C. the shrinkage of this kaolin is 12.6 per cent; dried at 110° C. the shrinkage is 4.8 per cent. This kaolin dried at 110° C. has a tensile strength of 22 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin shows a translucency of 0.76 and the transmitted light is cream colored; absorption is 6 per cent. The color is grade 2 and the shrinkage when dried at 110° is 4 per cent, and fired at 1,350° C., 12.4 per cent. When tested under the raw-lead and fritted glazes no change of tint is apparent in this mass.

BRYSON. CAROLINA CLAY CO. MINE.

This mine (7) is at the head of Buckner Branch, 4 miles southwest of Bryson, Swain County, N. C. It is reported as having been entirely worked out but continuations of the dike or similar dikes (6 and 8) occur both to the north and south of this worked deposit. The dike is about 16 feet wide. It strikes N. 15° E., and dips about 75° W. It is rich in kaolin along the west wall but becomes progressively poorer toward the east wall, along which the dike material is practically all sand. Numerous pockets of garnet-colored sand and bands of the wall rock are noted.

The clay-washing plant erected for use in connection with this mine has fallen into decay but there is doubtless considerable valuable material still at this mine, and certainly on adjoining prospects, which could be washed from this plant.

A sample of the dike material from across the full width of the dike yielded by the laboratory washing process 22 per cent of kaolin. This kaolin was tested and found to have a refractory value of 1,650° C. Its color is grade 5 and shrinkage 3.8 per cent when dried at 110° C., and 10.2 per cent when fired at 1,350° C. The tensile strength is 8 pounds per square inch.

Properties in the standard porcelain mixture.

In the mixture fired at 1,350° C. this kaolin has a translucency of 0.65 and the transmitted light is yellow. Absorption is 2.2 per cent. The color is grade 5. When the material is dried at 110° C. the shrinkage is 2.4 per cent, when fired at 1,350° C. it is 13.5 per cent. Tested under the raw-lead and fritted glazes the color remains unaltered.

BRYSON. EVERETT PROSPECT.

This prospect (5) is on a ridge above Watkins Branch, one-half mile east of the main road and 2 miles northwest of Bryson, Swain County, N. C. The width of the dike could not be determined positively, but from surface indications it is 9 to 10 feet wide. The prospect is due southwest from the Harris Clay Co. mine, and 1½ miles distant. The dike contains very few large flint bowlders, but a considerable proportion of semikaolinized material. The deposit was sampled as thoroughly as possible, and the material collected, when washed by the standard laboratory process, yields 28 per cent kaolin. The refractory value of this kaolin is above 1,730° C. Its color is grade 3; its shrinkage when dried at 110° C. is 4.3 per cent, fired at 1,350° C. 12.6 per cent. The tensile strength is 15 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture fired at 1,350° C. this kaolin has a translucency of 0.65 and the transmitted light is cream colored. Absorption is 4.7 per cent. The color is grade 3. Dried at 110° C. the shrinkage is 3 per cent, fired at 1,350° C. it is 12.2 per cent. Tested under the raw-lead and fritted glazes the color remains unaltered.

BRYSON. HARRIS CLAY CO. MINE.

This mine (2) is on the east slope of a ridge 2 miles north of Bryson, Swain County, N. C. The dike varies from 40 to 60 feet wide, but contains many bands of the material that forms the wall rock. The dike, which is faulted at intervals of about 150 feet, strikes N. 20° E. Its average of flint content is low, but it varies considerably in degree of kaolinization, so that the kaolin content obtained by washing the material of this deposit is less than might reasonably be expected. In many parts of the dike the material is yellow and of low grade in color; spurs of the dike at the same points, however, are of pure material, free from stain. The dike has been practically worked out over the area within which the material was found to contain a commercial quality of kaolin. A similar dike (4) was opened 1 mile southwest, but was abandoned after a few months' work. Good material has been located (1) 3 miles northeast of the Harris mine. Mining was by open-cuts to a depth of about 35 feet and by shafts below. The overburden is handled with wheelbarrows and dump carts, and its removal has been a simple problem because the dike is along the face of a very steep ridge. The kaolinized material was handled in steel hopper cars, by which it was taken to the edge of the slope, where it was emptied into the cars of a gravity railway, by which it was carried a distance of 200 yards down the mountain and there automatically dumped into the storage bins. From these bins it was shoveled by hand into a flume, which was supplied with water from a brook near by. This flume carries the material one-half mile to the washing plant, where the regular system of washers and sand wheels is used to remove the coarse material. The fine material passes to a sand-settling trough and thence to the mica-settling troughs and over a battery of screens into another flume. The washed material, practically pure kaolin, is conveyed 1½ miles to the concentrating plant, which is in the valley. This concentrating plant consists of concentrating tanks and a battery of two filter presses. The pressed kaolin is dried in open-air sheds and is then ready for market.

Samples of the material as mined were taken from the part of the dike being worked in the autumn of 1911. This material washed by the standard laboratory process yields 22 per cent of kaolin. This kaolin was analyzed and found to have the following chemical composition:

Composition of kaolin.

H_2O	14.10
SiO_2	46.95
Al_2O_3	37.24
Fe_2O_3	.40
TiO_2	.05
CaO	Trace.
MgO	Trace.
Na_2O	.24
K_2O	.49
	99.47

The refractory value of this kaolin is above 1,730° C. The color is grade 3. Dried at 110° C. it shrinks 4 per cent, fired at 1,350° C. 12.8 per cent. The tensile strength is 14 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin has a translucency of 0.63; the transmitted light is cream colored. Absorption is 3.3 per cent. The color is grade 3. Dried at 110° C. the shrinkage is 2.8 per cent, fired at 1,350° C. 11.8 per cent. Tested under the raw-lead and fritted glazes the color is unaffected.

BURNSVILLE. KAOLIN OUTCROPS.

One-half mile north of Burnsville, Yancey County, N. C., a small kaolinized dike (68) that is exposed near the road has been worked in a small way for mica. The exposure is not large enough to justify any statement as to the kaolin content.

Two and a half miles east of Burnsville on the road to Micaville is an old mica mine (71). Although the shaft is closed by caving, the material above the mouth of the shaft shows considerable semikaolinized feldspar and some kaolin.

BURNSVILLE. ELIZABETH SMITH MICA MINE.

This mine (69) is 1½ miles east of Burnsville, Yancey County, N. C., on the north side of and 150 yards distant from the Burnsville-Micaville road, and 3½ miles west of Micaville, the nearest shipping point. The dike is from 25 to 35 feet in width, strikes N. 20° E., and has an irregular dip. The deposit contains a number of semikaolinized lenses, but for the most part is well advanced in kaolinization. Of the mine tunnels some have been driven to expose kaolin and others in a search for mica. Those for mica have been neglected and in most instances have fallen in. On the southwest end of the dike are two tunnels about 50 feet long, connected by a crosscut, which exposes practically the entire width of the dike. At this point the dike shows 6 feet of well-kaolinized pegmatite adjoining the west wall, 9 feet of semikaolinized material, and 20 feet of well-kaolinized pegmatite adjoining the east wall. The country rock is completely kaolinized and forms a yellow claylike material. About one-third mile to the north and on the general strike of this dike a somewhat narrower but otherwise similar dike is exposed. At various intermediate points similar dike material is exposed by test holes, indicating that the dike extends the entire distance, although its width and uniformity have not been proven. A smaller dike (70) is exposed by a pit south of the road and one-eighth mile west.

The two kaolinized bands exposed in the tunnel were sampled. When washed they yielded 44 per cent of kaolin, which showed the following chemical composition on analysis:

Composition of kaolin.

H_2O	13.10
SiO_2	45.95
Al_2O_3	39.20
Fe_2O_3	.05
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
BaO	.03
Na_2O	Trace.
K_2O	.50
	98.83

This kaolin has a refractory value above 1,730° C. and the color is grade 2. The shrinkage dried at 110° C. is 4.4 per cent; when fired at 1,350° C., 12.9 per cent. The tensile strength of this kaolin dried at 110° C. is 29.5 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin in the standard porcelain mixture fired at 1,350° C. has a translucency of 0.7 and the transmitted light is cream colored. Absorption is 4.6 per cent, the color grade 2. The shrinkage when dried at 110° C. was 3.4 per cent and fired at 1,350° C. 14 per cent. Tested under the fritted and raw-lead glazes the mass has a very pale green tint that is equally apparent under either glaze.

DILLSBORO. ALLISON PROSPECT.

This prospect (50) is north of Barkers Creek, 3 miles west of Dillsboro, Jackson County, N. C., on a branch one-half mile from the creek. A dike is exposed at three points. These exposures have a general west direction over a knoll and the exposed dike appears to be extremely lenticular. The exposures indicate the presence of kaolinized pegmatite, but the work done does not expose the pure dike material; hence no samples were taken.

At a point 200 yards north (49) on the opposite side of the branch a short tunnel has penetrated a lens of pegmatite which is, where exposed, about 5 feet in diameter and semicircular in shape, the dike material being entirely covered by an arch of mica gneiss. The material thus appears to form distinctly a lens or pocket, and its extent can be proven only by further mining.

At a point one-eighth mile west of Barkers Creek Station a small kaolinized pegmatite dike is exposed in an abandoned mica shaft (48), but the workings have caved and the dike material can not now be reached.

DILLSBORO. ROBERT ASHE PROSPECT.

This prospect is 6 miles from Dillsboro, Jackson County, N. C., and one-half mile south of the main road between Webster and Cullowhee on the south side of Tuckasegee River. The kaolin was opened by a pit in a gap of the mountains, but the pit has completely fallen in and no kaolin is visible. The reported width is 14 feet. A small amount of kaolin is found in the dump, but much of this is only semikaolinized and considerable stained material is noted in connection with the kaolinized pegmatite. Mining for mica has been successful at various points in the neighborhood for a distance of one-fourth mile from this pit, and a more or less regular band of quartz extends in a general north-south direction from this deposit through the mica operations. Considerable further work is necessary to properly expose the kaolin at the old pit.

DILLSBORO. CAGLE GAP MICA MINE.

This mine (53) is 2 miles south of Dillsboro, Jackson County, N. C., and due south of the Dillsboro bridge across Tuckasegee River. The dike is opened in Cagle Gap by a pit at the road side, where it strikes N. 20° E. and is 15 feet wide. The material along the walls is very rich in kaolin and is well kaolinized, but the middle of the dike for a width of about 8 feet is a very low-grade material and is unevenly kaolinized. The entire deposit is rather sandy. The part rich in kaolin was sampled. Washed by the standard laboratory process, it yielded 21 per cent of kaolin. The refractory value of this kaolin is 1,730° C. and the color grade 4. Its shrinkage when dried at 110° C. is 5.8 per cent and fired at 1,350° C. 13.3 per cent. The tensile strength is 16 pounds per square inch.

Properties in the standard porcelain mixture.

In this mixture and fired at 1,350° C. the kaolin gives a translucency of 0.65 and the transmitted light is cream colored. Absorption is 5.4 per cent. The color is grade 4. The shrinkage when dried at 110° C. is 2.8 per cent and fired at 1,350° C. 12.6 per cent. Tested under the raw-lead and fritted glazes the color remains unaltered.

DILLSBORO. HARRIS CLAY CO. MINE.

This mine (60) is 5 miles southeast of Dillsboro, on the Murphy branch of the Southern Railway, Jackson County, N. C., which is the nearest shipping point.

The pegmatite dike is very large, 200 to 300 feet wide and about 800 feet long. It forms a ridge that trends nearly north. In the center of the ridge is a 30-foot band of sugar quartz, adjoining which on the west is a 30-foot band of gneiss. The kaolinized pegmatite next the quartz is very rich in kaolin and averages 25 to 40 feet wide; adjoining it on the east is a wide band of kaolinized pegmatite that has a high quartz content. On the west side of the gneiss band is another wide band of kaolinized pegmatite. As in all pegmatite dikes in this district numerous lenses of quartz and ferruginous sand are scattered through the deposit, but most of these lenses are well defined and may be removed by hand labor without injury to the adjacent material.

Several smaller dikes (59 and 58) averaging 10 to 15 feet wide have been opened on ridges to the west and north of the main dike. All have been opened about 100 feet above Little Savannah Creek.

The country rock of the district is Carolina gneiss which in this section is weathered to a maximum depth of 100 feet, the pegmatite being altered to about the same depth.

The overburden is principally weathered gneiss which has a golden-red color due to iron. Where the dike material is in place at the present surface of the country, this iron stain has filtered into it and rendered it practically valueless for a depth of 4 to 12 feet.

The overburden and the refuse dike material are removed by plow and scraper, which are supplemented by pick and shovel for the last foot above the valuable material. The removal of overburden proceeds usually 6 to 10 feet ahead of mining except where a quartz lens is encountered, when mining is continued up to the face of the quartz. The overburden walls are generally sloped about 70 degrees from the horizontal.

Surface water causes little annoyance because the hillsides are steep and the dike is opened almost in the crest of the ridge.

The method of mining is as follows: An open-cut, about 20 feet deep in the dike, is run along the face of the hill. The material is removed by pick and shovel and loaded into low cars which carry about 1,000 pounds each. They are pushed by hand or drawn by horse along a tramway to the edge of the hill where the material is dumped into a chute and water pumped in, which conveys the crude kaolin to the washing plant in the valley below.

For mining the lower portions of the deposit circular shafts are used. As the dike material at this point is kaolinized to a depth of about 100 feet, heavy timbering is necessary. The key-block system (see p. 68) is used. The material is loosened by pick and shovel, explosives being used only for breaking masses of quartz. The shafts are sunk in benches of about 4 feet. The standard type of hoisting bucket and a drum hoist operated by a horse are used.

At a depth of about 60 feet mining is somewhat hindered by water, which filters into the shaft. This is removed by the buckets in the same manner as the other material. When the bottom of the kaolinized material is reached, the robbing of the dike adjacent begins and proceeds by benches from the bottom to the top of the shaft, the timbering of each bench being removed and the bench being filled with waste from the surface before the level above is disturbed. This robbing and filling is worked in benches of about 4 feet, like shaft sinking.

The crude kaolin is carried by flume to the washing plant, where it passes through two clay washers in succession and then into a long narrow tank in which are two sand wheels. The coarse material removed by the sand wheels passes through a third clay washer and into another long vat in which are two sand wheels. The coarse material removed by these wheels is considered as waste. The kaolin obtained by this second washing is conducted by a trough to the mica troughs, where it mixes with the kaolin from the first battery of washers. The mica troughs are in two batteries, thus dividing the flow of slip. Stationary screens are used above the concentrating tanks. The water removed from these tanks is pumped to the head of the flume line and reused. The concentrated slip is pumped into filter presses. The clay cakes are dried principally in open-air sheds, although a steam drier is provided for "rush" orders.

The dry kaolin is hauled to Dillsboro over a tramroad in cars drawn by horses.

Crude kaolin samples taken from this deposit and washed by the standard laboratory process yielded 49 per cent of kaolin. This kaolin was analyzed. It has the following chemical composition:

Composition of kaolin.

H_2O	13.99
SiO_2	46.95
Al_2O_3	37.73
Fe_2O_3	.15
TiO_2	.05
CaO	Trace.
MgO	Trace.
Na_2O	.18
K_2O	.60
	99.65

This kaolin has a refractory value above 1,730° C. Its color is grade 1. Its shrinkage when dried at 110° is 6.1 per cent; when fired at 1,350°, 12.7 per cent. Its tensile strength is 24 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin when introduced into the mixture and fired at 1,350° C. has a translucency of 0.69 and the transmitted light is cream colored. Absorption is 5.8 per cent. The color of the mass when fired at 1,350° C. is grade 1. The shrinkage at 110° is 3 per cent and when fired at 1,350° C. is 12.6 per cent. When tested under the raw-lead and fritted glazes this mass shows a pale-green tint, equally apparent under each glaze.

FRANKLIN. BRYSON PROSPECT.

This property adjoins the West prospect on the west and is 8 miles north of Franklin, Macon County, N. C. The dike exposed has the same strike as that on the West prospect, but is opened at a level 50 feet lower by a tunnel 120 feet long. A width of nearly 15 feet of kaolin is exposed.

This dike was carefully sampled. Washed by the standard laboratory process the material yielded 38 per cent of kaolin. This kaolin has a refractory value above 1,730° C. and its color is grade 2. Dried at 110° C. its shrinkage is 6.6 per cent and when fired at 1,350° C., 17.3 per cent. The tensile strength is 28 pounds per square inch.

Properties in the standard porcelain mixture.

In the mixture fired at 1,350° C. this kaolin gives a translucency of 0.68 and the transmitted light is cream colored. Absorption is 4.5 per cent. The color is grade 2. The shrinkage when dried at 110° is 3.4 per cent and when fired at 1,350° C., 14 per cent. When tested under the raw-lead and fritted glazes this kaolin shows a very pale-green tint, equally apparent under each glaze.

FRANKLIN. CHALK MICA MINE.

This mine (30) is 2 miles north of the Franklin-Burningtown road and 6 miles northwest of Franklin, Macon County, N. C. The dike is from 15 to 20 feet in width. It strikes N. 30° E.; its dip is nearly vertical. The material varies from a very pure kaolin, exposed in a tunnel, to a very sandy kaolin, exposed in an open-cut 20 yards distant. It has only been proven for a distance of about 50 yards, but there is no reason to doubt that it extends a considerable distance farther south.

This material was sampled to give an average of the deposit so far as exposed and was washed by the standard laboratory process. The sample yielded 35 per cent of kaolin that has a refractory value above 1,730° C. The color is grade 3, but as the sample represented the entire deposit the elimination of a small portion of the poorer material would much improve the color. The shrinkage of this kaolin dried at 110° C. is 5.7 per cent and fired at 1,350° C. is 13.7 per cent. Its tensile strength when dried at 110° C. is 15.5 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.65 and the transmitted light is cream colored. Absorption is 6 per cent, and the color is grade 3. The shrinkage is 3 per cent when dried at 110° C., and when fired at 1,350° C. is 14.8 per cent. Tested under the raw-lead and fritted glazes this mass assumes a pale-green tint, equally apparent under either glaze.

FRANKLIN. FRANK PROSPECT.

This prospect (27) is 2½ miles northeast of Franklin, Macon County, N. C., on the Franklin-Dillsboro road. The dike of kaolinized pegmatite follows a ridge and strikes about west, varying from 12 to 15 feet wide. This dike contains little fine quartz and is covered by only about 8 feet of overburden. It has been opened by a number of shafts and a tunnel, and from the tunnel which offers the best opportunity for sampling an average sample was taken.

This sample when washed by the standard laboratory process yielded 31 per cent of kaolin. The refractory valuo of the kaolin is above 1,730° C., and the color grade 3. When dried at 110° C. it shrinks 5.4 per cent and when fired at 1,350° C. 15.1 per cent. The tensile strength of this kaolin is 18 pounds per square inch.

Properties in the standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.63 and the transmitted light is cream colored. Absorption is 4.9 per cent. The color is grade 3. The shrinkage when dried at 110° C. is 3 per cent and when fired at 1,350° C. is 13.2 per cent. Tested under the raw-lead and fritted glazes this kaolin shows a pale-green tint, equally apparent under either glaze.

FRANKLIN. FRANKLIN KAOLIN TO MICA CO. MINES.

These mines (23) are 4½ miles north of Franklin, Macon County, N. C., at Iotla Bridge on the west bank of Little Tennessee River. Franklin is the nearest railroad station. The mines were originally worked for mica, but have more recently been worked for kaolin, being the first for kaolin west of the Cowee Mountains. The development consists of 10 tunnels and about 12 shafts. Some of the shafts have reached a depth of 120 feet. It contains a number of well-defined bands of sugar quartz and these occur not only along the walls but also midway between the walls. The dike has been worked for 550 feet and varies in width from 10 to 100 feet, approximately. The pegmatite was remarkably low in quartz, yielding a very high-grade kaolin. The deposit is not completely worked out but has been abandoned. Only one shaft is in such a condition that the dike material can be studied, but the product of this mine had gained a reputation for high quality and fine color, and this shaft exposed kaolin which evidently represented a fair average of that in the dike.

This material was sampled and washed by the standard laboratory process and found to contain 42 per cent of kaolin, which has a refractory value above 1,730° C. Its color is grade 1, and its shrinkage when dried at 110° C. is 5.2 per cent and when fired at 1,350° C. is 12.4 per cent. The tensile strength is 24 pounds per square inch.

Properties in the standard porcelain mixture.

In the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.72 and the transmitted light is cream-white. Absorption is 6.2 per cent and color is grade 1. Dried at 110° C. the shrinkage is 3.2 per cent and fired at 1,350° C. the shrinkage is 12.8 per cent. The test under the raw-lead and fritted glazes shows that the color remains unaltered.

FRANKLIN. GURNEY CLAY CO. MINE.

This mine (29) is on the south side of Iotla Creek, 2 miles from the Little Tennessee River and 4 miles north of Franklin, Macon County, N. C.

The kaolinized dike forms an expanded lens, averaging about 200 feet in width and 300 feet in length already proven, located on the north slope of a low ridge. Similar material is exposed in an abandoned mica shaft (28) one-eighth mile northwest. The Gurney mine was opened first by shaft at the lowest point on the north edge of the lens, where the overburden was not more than 2 or 3 feet. Shafts were sunk higher up the hill which show that the overburden does not increase much. However, the cost of shaft mining became so great that open-cut mining was finally adopted. The open-cut has been advanced a depth of 20 to 30 feet into the lens and up to the present little quartz has been encountered. The lens consists of bands varying in kaolin content, some parts being very rich and others very low in kaolin. By mining the entire width of the dike, as nearly as possible, the operator is able to average this material and thus produce a product reasonably uniform in physical properties. Some of the shafts reach a depth of 100 feet, but below this level the degree of kaolinization hardly justifies mining.

The material from the shafts has been hoisted by horse whims. The water, which flows into the shaft rapidly below about 60 feet, has up to the present been removed in buckets, which differ in size only from those for hoisting the dike material. Handling the water in this manner is difficult, and attention is being given to the installation of pumps, but all pumps tested have proven unsatisfactory because the grit in the water rapidly cuts out and ruins the valves.

A tunnel from about the level of the creek bed, which is 100 feet below the open-cut level, is considered, and in this way the mine may possibly be drained effectively.

The material removed from the deposit, whether by open-cut or by shaft, is conveyed to a central point by tramcars and there is mixed in constant proportion and emptied into a flume, the water for which is pumped a distance of 500 yards. This flume conveys the dike material to the washing plant, which consists of two washers and a long trough in which are two sand wheels. From the sand wheels the material passes to a long sand trough and from the sand trough to mica troughs. The mica troughs of this plant are constructed with absolutely no drop from entrance to exit and the removal of the very fine sand and mica is therefore thorough.

From the end of the sand troughs the kaolin slip passes through a battery of stationary screens and then into settling tanks. In the settling process aluminum sulphate is used as an aid in concentration. It is placed in bags and suspended in the trough between the screens and the settling tanks, and is found as effective as the alum employed at other plants through this district. After the excess water is removed the kaolin slip is conveyed to a reservoir and thence pumped into the filter presses.

After leaving the filter presses the kaolin is dried by two systems. One is the standard steam-drier system, in which the steam pipes are placed directly on the floor, and on these pipes the damp kaolin is heaped. These pipes are open at one end so that the steam is under no pressure. The other system of drying is the open-air rack system. A building two stories high has in the upper story racks upon which the kaolin is spread; when dry this kaolin is dumped through the floor into the lower story, which is used for storage. This building has a ridge roof with an opening the full length along the ridge, covered with an additional narrow ridge roof, so that the escaping moisture from the drying kaolin passes off unretarded and does not condense on the underside of the roof as has been the case in some other drying sheds. The steam drier connected with this plant is 150 feet long by 24 feet wide. The open-air drier is 110 feet long by 24 feet wide and four racks high, each rack being 1½ feet deep.

The dike material was carefully sampled and yielded 42.5 per cent of kaolin. However, at the time of this sampling the richer part of the dike only was exposed and the kaolin yield of the entire dike will probably not exceed 30 per cent.

This kaolin was analyzed and found to have the following chemical composition:

Composition of kaolin.

H_2O	14.72
SiO_2	44.00
Al_2O_3	40.79
Fe_2O_3	.11
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
Na_2O	.07
K_2O	.55
	100.24

This kaolin has a refractory value above 1,730° C., and its color is grade 1. Dried at 110° C. it shrinks 5.4 per cent and fired at 1,350° C. it shrinks 11.9 per cent. The tensile strength is 27.5 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture fired at 1,350° C. the kaolin has a translucency of 0.72 and the transmitted light is cream-white. Absorption is 6.5 per cent. The color is grade 1. The shrinkage when dried at 110° C. is 3.2 per cent and when fired at 1,350° C. 12.4 per cent. Tested under the raw-lead and fritted glazes the color is not affected.

FRANKLIN. KASSON MICA MINE.

This mine (46) is 2 miles northeast of Franklin, Macon County, N. C., on the east side of the Franklin-Dillsboro road. The dike and its numerous stringers varying in width from 6 to 16 feet strike N. 40° E. and dip from 75° W. to 80° E. The mine has been worked only for mica but the dike where exposed is completely kaolinized and enormous quantities of high-grade kaolin have been ruined by mixture with wall rock in the dumps. The kaolinized dike is remarkably free from impurities except for small pockets of garnet-colored sand and altered biotite which is badly iron-stained. The presence of this iron stain would demand some care in mining but its coloring power in the burned product is very much less than would be expected from the appearance of the washed clay in which this iron stain is allowed to remain. The portion of the dike that is most completely kaolinized and contains the least proportion of the iron stain was sampled. The sample when washed by the standard laboratory process yielded 41 per cent kaolin which had a pronounced pink color from this stain. The kaolin, however, has a refractory value above 1,730° C. and its color is grade 3. Its shrinkage is 4.7 per cent when dried at 110° and 14.1 per cent when fired at 1,350° C. The tensile strength of this kaolin dried at 110° is 18 pounds per square inch. If the garnet-colored sand and altered biotite were carefully removed the kaolin produced would doubtless be improved in color at least one grade, but owing to the fact that this deposit is worked entirely by tunnels on the ''ground-hog'' system the present exposures are not extensive enough to justify a positive statement as to the possibility of working this dike for higher-grade kaolin.

Properties in standard porcelain mixture.

This kaolin in the mixture fired at 1,350° produces a translucency of 0.71 and the transmitted light is cream colored. Absorption is 5.6 per cent. The color is grade 3. Dried at 110° C. this mass shrinks 3.2 per cent and when fired at 1,350° C. the shrinkage is 13.3 per cent. When tested under the raw-lead and fritted glazes the tint of this mass is a very pale green, equally apparent under either glaze.

FRANKLIN. LENOIR PROSPECT.

This prospect (44) is 4½ miles west of Franklin, Macon County, N. C., on the Franklin-Andrews road. There is a dike averaging about 20 feet wide and exposed on the slope of a hill by two tunnels, one 20 feet below the other. The strike is west, the dip perpendicular. The kaolin exposed in the upper tunnel is free from bands or streaks of other material and has a small content of quartz. The material in the lower tunnel is more or less stained by small streaks of iron-stained sands at frequent intervals in the walls. The dike appears to be incompletely kaolinized in places, streaks of hard material almost approaching feldspar in appearance being encountered at frequent intervals, but most of these streaks are narrow. The lower tunnel contains a number of lenses or pockets of micaceous material embedded in stained kaolin, but they are small and doubtless could be easily removed.

The kaolin from this deposit was sampled. It yielded by washing 38 per cent of kaolin. The shrinkage of this kaolin at 110° C. is 6.4 per cent and at 1,350° C. is 14.9 per cent. The tensile strength at 110° is 20 pounds per square inch. The color is grade 1 and the refractory value is above 1,730° C.

Properties in standard porcelain mixture.

In this mixture the shrinkage at 110° is 3.6 per cent; fired at 1,350° C., 11.6 per cent. The translucency is 0.67 and the transmitted light is cream colored. The absorption is 7.1 per cent. The color is grade 1. Under the fritted and raw-lead glazes the color of the porcelain mixture is not altered.

FRANKLIN. LYLE PROSPECT.

This prospect (37) is 1½ miles northeast of Franklin, Macon County, N. C., on the Dillsboro road. It is a dike about 15 feet wide that strikes northeast and dips 75° NW. There is little fine mica or other impurity in the dike material, but the degree of kaolinization is variable. Proper sampling was impossible because the dike has been opened to a depth of only about 10 feet, and surface drainage may have removed much of the fine kaolin from this part of the dike.

The least-exposed part of the deposit was carefully sampled. The sample contains 26 per cent of kaolin when washed by the standard laboratory process. This kaolin has a refractory value of 1,690° C. and its color is grade 3. Its shrinkage when dried at 110° C. is 5.2 per cent and when fired at 1,350° C. is 15.8 per cent. The tensile strength of the kaolin dried at 110° is 16 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin introduced into the mixture and fired at 1,350° C. gives a translucency of 0.67 and the transmitted light is cream colored. Absorption is 3.1 per cent. The color is grade 3. Dried at 110° the shrinkage is 3.3 per cent and when fired at 1,350° C. the shrinkage is 12.8 per cent. Tested under the raw-lead and fritted glazes there is no change in color.

FRANKLIN. M'GUIRE PROSPECT.

This prospect (43) is 4 miles northwest of Franklin, Macon County, N. C., on a west spur of Tremont Mountain, one-eighth mile south of the McGuire feldspar mine and on about the same elevation. The dike strikes northeast and dips 80° S., it is kaolinized and about 18 feet thick at this point. It is free from associated minerals but contains a small amount of semikaolinized material. There are two tunnels into the dike, but no material has been sold.

The material exposed was sampled and washed. It showed a kaolin content of 42 per cent. This kaolin has the following chemical analysis:

Analysis of kaolin.

H_2O	14.00
SiO_2	46.35
Al_2O_3	39.00
Fe_2O_3	.30
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
Na_2O	.00
K_2O	.50
	100.15

The shrinkage of this kaolin at 110° C. is 5.7 per cent, the tensile strength per square inch 27.5 pounds, the shrinkage when fired at 1,350° C. 10.5 per cent. The color is grade 3 and the refractory value is above 1,730° C.

Properties in standard porcelain mixture.

The shrinkage of this kaolin in the mixture at 110° is 3.2 per cent. When fired at 1,350° it has a shrinkage of 14.2 per cent and a translucency of 0.72; the transmitted light is cream colored. Absorption is 5.4 per cent. The color is grade 3. Under the fritted and raw-lead glazes the color remains unaltered.

FRANKLIN. PORTER MICA MINE.

About 2 miles west of Franklin, Macon County, N. C., is the old Porter mica mine (45). It has long been abandoned and the shafts have caved, preventing any proper sampling of the deposit. The dumps about the shafts show considerable kaolin of fair quality but no record of the dimensions of the dike is obtainable.

FRANKLIN. MOORE MICA MINE.

This mine (36) is 1½ miles north of Franklin, Macon County, N. C., on the west bank of the Little Tennessee River, about 80 feet above the river. The mine is reported to have been opened by tunnels several years ago but is now opened only by two shafts which do not cut the main dike. The section exposed by the shaft is 9 feet wide and shows kaolin very free from impurities and low in quartz. A considerable part of this dike, however, is not completely kaolinized. Where exposed it is covered with about 20 feet of overburden, strikes N. 40° E., and dips 85° N.

The kaolin material was sampled and by the laboratory washing process found to contain 34 per cent of kaolin. The refractory value of this kaolin is above 1,730° C. Its color when fired at 1,350° C. is grade 1; its shrinkage when dried at 110° C. is 7 per cent and when fired at 1,350° C. is 15.7 per cent. The tensile strength of this kaolin dried at 110° C. is 26 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin shows a translucency of 0.64. The transmitted light is cream white. Absorption is 7.6 per cent. The color is grade 1. The shrinkage when dried at 110° is 3 per cent and when fired at 1,350° C. 12 per cent. Tested under the fritted and raw-lead glazes this porcelain mixture assumes a pale-green tint.

FRANKLIN. MYERS PROSPECT.

This prospect (26) is due southwest from the Sloan prospect, about 4 miles below Franklin, Macon County, N. C. It is, however, on the south side of the Little Tennessee River and directly on the line of the strike of the dike on the Sloan prospect. The dike on the Myers prospect follows a low ridge and is exposed by small pits. It is opened at one point for a distance of 25 feet along the strike and shows a maximum width of 12 feet. The depth of the opening is only about 5 feet, which is not enough to properly remove the surface material; hence the actual quality of the dike could not be accurately determined. Indications of this dike continuing in both directions are evident from surface marks, but no work has been done to prove its continuation. As this property is on the south side of the Little Tennessee River its distance by road from the shipping point, which is Franklin, N. C., is about 3½ miles.

FRANKLIN. RABY MICA MINE.

This mine (32) is north of Tremont Mountain and on the west side of Halls Mill Creek, 1 mile west of Burningtown road and 4 miles from Franklin, Macon County, N. C.

The dike with a number of stringers has a total width of almost 100 yards, and strikes N. 10° E. across a ridge which runs almost due west and has a width of about one-fourth mile. The stringers average about 15 feet wide, and have been proven for about 200 feet on each side of the ridge and about 100 feet below the crest of the ridge. The kaolin penetrated by tunnels at low levels shows a higher sand content, undoubtedly because it is material accumulated by a slide or slip from the main body. Dikes of similar structure are exposed by prospect tunnels one-fourth mile north (31) and one-fourth mile east (33). A dike of lower grade (34) is exposed on a north slope one-fourth mile southeast of the Raby mine.

The kaolin material was carefully sampled and by the laboratory washing process yielded 45 per cent of kaolin. By analysis it showed a chemical composition as follows:

Composition of kaolin.

H_2O	13.80
SiO_2	46.90
Al_2O_3	38.60
Fe_2O_3	.25
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
Na_2O	.26
K_2O	.39
	100.20

This kaolin had a refractory value above 1,730° C. Its color when fired to 1,350° C. is grade 3. Its shrinkage when dried at 110° is 6.25 per cent, and when fired to 1,350° C. is 13.5 per cent. Dried at 110° this kaolin has a tensile strength of 21.5 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture when fired at 1,350° C. this kaolin gives a translucency of 0.71 and the transmitted light is cream colored. Absorption is 6 per cent. The color is grade 3. The shrinkage at 110° is 2.2 per cent, when fired at 1,350° C. 13.2 per cent. When the fritted or the raw-lead glaze is applied to the porcelain mixture the color of the body through the glaze appears to be a pale green and is as pronounced under one glaze as under the other.

FRANKLIN. ROCHESTER MICA MINE.

The location (22) is the same as the Lisle Knob mica mine, 5 miles north of Franklin, Macon County, N. C., but there is a kaolinized dike 150 feet to the east and 25 feet above the exposure of the fresh pegmatite dike. This kaolin seems to be remarkably pure and of very fine quality, but the dike contains many small iron garnets, which would make the mining of the kaolin somewhat difficult. The dike strikes N. 10° E. and dips 80° W., like the fresh pegmatite dike, is 5 to 10 feet in width, and seems to be very uniform from wall to wall. It has been exposed by tunnel along the strike for about 40 feet. This tunnel is 50 to 60 feet below the crest of the mountain.

The material was carefully sampled and washed and showed a kaolin content of 44 per cent. The kaolin was tested and found to have a refractory value above 1,730° C. The color is grade 2. The shrinkage when dried at 110° C. is 6.2 per cent and when fired at 1,350° C. is 13.8 per cent. The tensile strength of this kaolin dried at 110° C. is 24 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.70 and the transmitted light is cream colored. Absorption is 5.8 per cent. Its color is grade 2. Dried at 110° C. its shrinkage is 2.6 per cent, and fired at 1,350° C. is 13 per cent. Tested under the raw-lead and fritted glazes the tint of this mass is very pale green, equally apparent under either glaze.

FRANKLIN. SANDERS PROSPECT.

This prospect (24) is south of Lyle Knob and 5 miles north of Franklin, Macon County, N. C., on the road between Iotla Bridge on the Little Tennessee River and the Franklin-Dillsboro road. The kaolinized portion of the dike, about 20 feet wide, strikes N. 20° W. and follows the crest of a low ridge. It is remarkable in that it is clearly defined by quartz bands along its walls. In addition to the 20 feet of kaolin contained in this dike there is also a width of from 8 to 15 feet of low-grade pegmatite material. The dike is opened by a tunnel 120 feet long and was sampled at the face of this tunnel where its full width is exposed. The sample when washed yielded 29 per cent kaolin.

The refractory value of this kaolin is above 1,730° C. and the color is grade 3. The shrinkage when dried at 110° C. is 4.5 per cent, and when fired at 1,350° C. is 13.8 per cent. The kaolin has a tensile strength of 14 pounds per square inch.

Properties in the standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. the kaolin gives a translucency of 0.69 and the transmitted light is cream colored. Absorption is 5.3 per cent. The color is grade 3. Dried at 110° C. the shrinkage is 3.4 per cent, and fired at 1,350° C. the shrinkage is 13.5 per cent. Tested under the fritted and raw-lead glazes it shows a pale-green tint, equally apparent under each glaze.

FRANKLIN. SLOAN PROSPECT.

This prospect (25) is on the north side of the Little Tennessee River, 4 miles below Franklin, Macon County, N. C. The dike is from 8 to 10 feet wide, strikes northeast, and dips 80° NW. It is exposed by only a single open-cut 50 feet above the Little Tennessee River, and a proper study was therefore impossible. The cut is the width of the dike and about 8 feet into the face of the hill. The dike is completely kaolinized but contains a considerable quantity of fine quartz and a narrow quartz band on the northwest side along the hanging wall. There is much stained mica along the foot wall which would demand careful mining if to be eliminated.

The prospect was sampled. The sample washed by the standard laboratory process was found to contain about 30 per cent pure kaolin. The kaolin was tested and has a refractory value above 1,730° C. and the color is grade 3. The shrinkage when dried at 110° C. is 6.4 per cent, and when fired at 1,350° C. is 15.2 per cent. The tensile strength of the kaolin dried at 110° C. is 22 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin introduced into the mixture and fired at 1,350° C. gives a translucency of 0.69 and the transmitted light is cream colored. Absorption is 7.1 per cent. The color is grade 3. Dried at 110° C. the shrinkage is 3.2 per cent, and fired at 1,350° C. is 12.3 per cent. Tested under the raw-lead and fritted glazes the tint of this mass is pale green, equally apparent under each glaze.

FRANKLIN. SMITH PROSPECT.

This prospect (15) is on Little Tellico Creek, 1½ miles southwest of Tellico Creek and 12 miles northwest of Franklin, Macon County, N. C.

The dike, which is completely kaolinized, is exposed by a 40-foot tunnel and by an open pit on a hillside 75 feet above Little Tellico Creek. The dike is nearly 200 feet wide but several broad horses of wall rock reduce the actual width of pegmatite material to about 50 feet. The dike has a general northeast strike and dips 80° W. where exposed. The pegmatite is reasonably free from foreign matter, the associated minerals being muscovite and quartz.

This material was sampled. On washing it yielded 39 per cent kaolin. This kaolin has the following chemical analysis:

Composition of kaolin.

H_2O	12.55
SiO_2	48.05
Al_2O_3	37.69
Fe_2O_3	.31
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
Na_2O	.02
K_2O	.91
	99.53

The shrinkage of this kaolin in drying at 110° C. is 6.8 per cent, and when fired at 1,350° C. is 12 per cent. Its tensile strength dried at 110° C. is 20.5 pounds per square inch. Its color is grade 4, and the refractory value is 1,670° C.

Properties in standard porcelain mixture.

In this mixture the kaolin showed a shrinkage dried at 110° of 3.2 per cent, fired at 1,350° of 12.4 per cent. The translucency at 1,350° C. is 0.71 and the transmitted light is cream colored. Absorption at 1,350° C. is 4 per cent. Color at 1,350° is grade 4. Tested under the raw-lead and fritted glazes the color remains unaltered.

FRANKLIN. SOUTHERN CLAY CO. MINES.

These mines (38 and 35, 41, 39) are on one of the foothills of Tremont Mountain, 1 mile northwest of Franklin, Macon County, N. C., and one-half mile north of the Franklin-Andrews road. They have been worked out since the preparation of this report began, but the deposit and the method of mining are of especial interest and are therefore described. The main workings (41) showed a well-defined kaolinized pegmatite dike, 16 to 20 feet wide, that has a broad band of sugar quartz along the north wall and another quartz band about midway in the dike. The wall rock is gneiss and the contact between the dike and the gneiss is very sharp, the stain from the decomposed gneiss rarely penetrating the dike more than 1 inch. This dike strikes almost due east and dips 70° S.

The kaolinized pegmatite contains as impurities small pockets of garnet sand and isolated patches of weathered biotite that are surrounded by a garnet-colored claylike material. This sand seems to have no tendency to stain adjacent material, but the weathering of the biotite invariably causes a stain for 3 or 4 inches in every direction. Very little sheet mica is found, but large quantities of first-class punch mica in plates from three-fourths inch to 2 inches wide have been removed and rejected with other refuse.

The mining of this dike was very expensive because shafts alone were used, no material being removed by open-cut work.

The overburden varies from 5 to 25 feet. The thick quartz bands in the hanging wall and in the middle of the dike also added much to the cost of mining, as their removal was absolutely imperative in sinking vertical shafts. These shafts were invariably sunk directly into the dike, and because of the dip they passed through it and into the foot wall, so that it was necessary to remove big masses of quartz, sink into the foot wall, and then run a crosscut from the bottom of a shaft in order to reach the kaolin.

The deposit for a depth of 25 feet into the dike shows a high grade of kaolin of fair plasticity. At about this depth irregular lenses of semikaolinized feldspar in the form of very fine sand were encountered in some of the shafts. Below this level much very fine kaolin is found, and 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 the dike material soon changes to semikaolinized feldspar with isolated patches of plastic kaolin, and below the 100-foot level plastic kaolin is rarely found, but the material is a rich kaolinized feldspar containing very little quartz and is remarkably high grade as regards color. At this 100-foot level well-defined and practically fresh crystals of orthoclase are found embedded in the slightly kaolinized material.

This deposit is reasonably uniform for about 120 feet, but disappears almost completely on the east slope of the hill. Another dike which was supposed to promise considerable quantities of kaolin lies parallel to this dike and 30 yards south of it. This dike was explored by pits. The surface material proved to be stained, but as the high-grade material of the main dike was also stained near the surface the owners believed that the small dike would likewise improve in quality with depth. This, however, failed to be the case, and all the dike material was rejected as unmarketable.

On an isolated knoll one-eighth mile northeast of the small dike just described another well-defined dike was exposed by a shaft, but it proved merely an expanded lens and yielded kaolin in commercial quantities for only about 50 feet. Its maximum width was about 15 feet. Numerous other small dikes are on this property, but they were found to be too narrow to be profitably worked by shafts.

Mining was by circular shaft in the ordinary manner of this district, electric hoists being used to remove rock and kaolin from the lower levels.

Below about 45 feet the inflow of water caused great annoyance to the miners, and at 60 feet the removal of the water became a considerable problem. At lower levels the flow continued to increase until at 100 feet at least 50 per cent of the total time of operation was spent in removing the water, which was hoisted in barrels with bands and braces like the half barrels generally used to remove the dike material. The flow of water at times became so great that an extra crew of men had to be employed to enable the kaolin miners to work. Removal of this water in any other way than by bailing was never attempted, and it is not known whether this deposit could have been drained by tunneling, a method that has proved so successful in draining other deposits in this district.

The dike material was conveyed to the washing plant by flumes, the water for which was pumped from the valley below with a 3-cylinder pump. The larger proportion of semikaolinized material found at the lower levels of these shafts necessitated putting in screens to remove the large lumps of hard material which constantly clogged the flume and caused it to overflow. At the washing plant the material passed through two batteries, consisting of one washer and one sand wheel each; the refuse from the first sand wheel went into the second washer, but the kaolin from the first sand wheel went directly to the second sand wheel and not through the second washer. The material from this washing process passed into a shallow sand-settling tank 6 by 6 by 1½ feet deep. The outlet of this settling tank is at an angle of 45 degrees with the intake, thus giving the sand a better opportunity to settle. From this settling tank the kaolin-bearing material was conveyed by troughs to a rotary screen, where the greater proportion of the fine mica was removed. The finest material passed through 12 mica-settling troughs, each 40 feet in length, making the total length 480 feet, before it reached the 140-mesh screen which this company uses. Numerous screens were tested by this company, and the revolving screen was found to be the most efficient and economical for its work.

The kaolin passing through the screen ran into a trough that contained a battery of electromagnets for the removal of any iron that may have been taken up by contact with the machinery in the washing process. From these magnets the material passed over a bed of alum which aided the settling of the clay slip and simplified the removal of the excess water. The material then passed to the settling tanks where the excess water was removed. From the settling tanks the material was pumped into a cistern that was constantly agitated, and from this the slip was pumped to the filter presses, where most of the kaolin was removed. The pressed kaolin from the filter presses was loaded on rack cars, which were run into a tunnel drier heated by hot air obtained by forcing air through steam coils with fans. The floor of the drier has a slight grade, sufficient to cause the cars to move forward when the car next the outlet is removed. The kaolin from the drier was carried by an elevator and conveyer to stock bins adjoining the drier, and from these bins the material was loaded into wagons and hauled 1 mile to the railroad.

The material produced by the principal dike worked on this property was sampled and was subsequently washed by the standard laboratory process. It yielded 40 per cent of kaolin. The material was selected with care and has been accepted as the standard of color value in the classification of kaolins in this district. The analysis of the material is given on page 45, under the color classification of the kaolin. Its refractory value is above 1,730° C., and its color is grade 1. Dried at 110° C. it shrinks 4 per cent, and fired at 1,350° C. it shrinks 11 per cent. The tensile strength is 25 pounds per square inch.

Properties in the standard porcelain mixture.

In the mixture and fired at 1,350° C. this kaolin has a translucency of 0.93 and the transmitted light is white. Absorption is 7 per cent. The color is grade 1. The shrinkage when dried at 1,350° C. is 3.4 per cent, and when fired at 1,350° C. is 9.9 per cent. Tested under the raw-lead and fritted glazes the color remains unaltered.

FRANKLIN. WEST PROSPECT,

This prospect (19) is one-half mile southeast of West Mills and 1 mile north of the Franklin-West Mills road, 8 miles north of Franklin, Macon County, N. C., on the Little Tennessee River.

The dike is approximately 25 feet wide, strikes west, and dips 80° S. Two tunnels run 40 feet into the hill, one 25 feet below the crest of the hill and the other 20 feet below the first. A large part of this dike is not completely kaolinized and carries considerable quartz. Numerous small streaks of stained material similar to the decomposed country rock run through the deposit at various angles. The tunnels in the West prospect are on the east slope of the ridge. On the opposite slope in the Bryson prospect a tunnel 120 feet long and 75 feet below the crest of the hill cuts material which is undoubtedly a part of the same dike, but which strikes northwest. Its dip is practically perpendicular. The kaolin exposed in this tunnel is remarkably clean and free from impurities.

The kaolin exposed on the West prospect was carefully sampled and washed, yielding 29 per cent kaolin. This kaolin was analyzed and showed the following chemical composition:

Composition of kaolin.

H_2O	12.70
SiO_2	48.92
Al_2O_3	36.37
Fe_2O_3	.37
TiO_2	.02
CaO	Trace.
MgO	Trace.
Na_2O	.11
K_2O	.29
	98.78

This kaolin has a refractory value of 1,730° C. Its color when fired to 1,350° C. is grade 3. Its shrinkage on drying at 110° is 7 per cent, and the total shrinkage at 1,350° C., 18 per cent. When dried at 110° this kaolin has a tensile strength of 24 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture fired at 1,350° C. this kaolin has a translucency of 0.66 and the transmitted light is cream colored. Absorption is 4.3 per cent. The color is grade 3. The shrinkage when dried at 110° is 3.6 per cent and fired at 1,350° C. is 14.2 per cent. When tested under the fritted and raw-lead glazes this kaolin shows a pale-green tint, equally apparent under either glaze.

LINCOLNTON. PIEDMONT TIN MINING CO. MINES.

These mines are 2½ miles southeast of Lincolnton, Lincoln County, N.C. There are four distinct dikes of more or less kaolinized pegmatite. These dikes, which strike N. 20° E., contain numerous narrow bands of yellow sand and of gold-colored clay. One dike known as the "Jake vein" is fairly free from stain and possibly contains some good commercial kaolin. These mines have been worked entirely by tunnels, and the dikes have been thoroughly prospected in the same way. The water encountered is diverted to a central point, collected in a pit, and pumped to the surface; in this way the entire dike is drained. The degree of kaolinization of these dikes seems to increase toward the southwest end, and even through the dikes carrying considerable stained material it is likely that kaolin production could be made profitable inasmuch as this kaolin is a by-product in mining cassiterite.

Material from the "Jake vein" was sampled and washed. It shows a kaolin content of 26 per cent. The washed product has a chemical composition as follows:

Composition of kaolin.

H_2O	12.00
SiO_2	48.50
Al_2O_3	37.35
Fe_2O_3	.85
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
Na_2O	.32
K_2O	1.02
	100.04

This kaolin has a refractory value of 1,710° C. Its color is grade 5. Its shrinkage is 4.4 per cent when dried at 110° C., and fired at 1,350° C. 8.1 per cent. The tensile strength when dried at 110° is 16.5 pounds per square inch.

Properties in standard porcelain mixture.

When introduced into the mixture fired at 1,350° C. this kaolin gives a translucency of 0.78 and the transmitted light is yellow. Absorption is 3.5 per cent. The color is grade 5. When dried at 110° this mass shrinks 2.2 per cent., at 1,350° 13 per cent. Tested under the fritted and raw-lead glazes the tint is unaltered.

MICAVILLE. THOMAS PROSPECT.

This prospect (73) is 1 mile north of Micaville, Yancey County, N. C., which is the nearest shipping point. The pegmatite dike is on a very narrow ridge and exposed in such a manner that its width can not be determined from present openings. It strikes N. 45° E. A tunnel 3 feet wide has been driven directly on the strike and a small shaft 40 feet deep has been sunk at the end of this tunnel. In both good kaolin is exposed. At a short distance to the northeast, on a ridge to which this dike is supposed to extend, the material is of good color but contains a proportion of sand. This high sand content is observed in the shallow pit which exposes the dike at the ridge. Various test holes have been dug on this property, but it is not possible to state accurately the width of any of the dikes exposed.

MICAVILLE. WILSON PROSPECT.

This prospect (78) is one-half mile southeast of Micaville, Yancey County, N. C. The dike follows the south and east face of a ridge and varies in width from 30 to 100 feet. It also appears on the west slope of the ridge in several tunnels (77). The pegmatite seems to be well kaolinized, but contains many narrow bands of yellow sand and clay which, however, can doubtless be removed without serious injury to the dike material. This prospect has been proven for about 700 feet by numerous shafts and tunnels and appears to be of uniform quality wherever exposed.

A tunnel midway between the limits of this dike was carefully sampled. The sample when washed yielded 28 per cent of kaolin. This kaolin has a refractory value above 1,730° C. and its color is grade 2. Dried at 110° C. it shrinks 4.2 per cent and fired at 1,350° C. it shrinks 13.2 per cent. It has a tensile strength of 24 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.72 and the transmitted light is cream colored. Absorption is 4.3 per cent. The color is grade 2. The shrinkage dried at 110° C. is 3.2 per cent and fired at 1,350° C. 13.6 per cent. Tested under the fritted and raw-lead glazes this kaolin shows a very pale-green tint, equally apparent under each glaze.

PENLAND. HARRIS CLAY CO. PENLAND MINE.

This mine (98) is on the north side of North Toe River, on a high ridge having a general north trend, and is one-fourth mile east of Penland, Mitchell County, N. C.

The deposit is in the form of an expanded lens 120 to 160 feet wide. It strikes N. 25° E. The pegmatite is very fine grained and has a texture not unlike granite, the kaolinization of a considerable part of the dike not being sufficient to destroy the texture of the original rock. The southeast wall is well defined, but the northwest wall is hardly distinguishable, as the dike material on that side grades gradually into a hard, granitelike rock producing little or no kaolin. The west part of the dike contains numerous irregular streaks of iron-stained material. The mine has been opened for about 400 feet along the strike and for a depth of about 50 feet, below which the kaolin yield is too small to justify mining. About 50 yards beyond the southeast wall of this deposit a dike approximately 10 feet in width and very rich in kaolin has been exposed, but has never been developed.

The dike now being worked was sampled. Washed by the standard laboratory process the sample yielded 22 per cent of kaolin. This kaolin has a refractory value of 1,730° C. Fired at 1,350° C. its color is grade 4. Its shrinkage when dried at 110° C. is 3.4 per cent, and when fired at 1,350° C. is 11.6 per cent. The tensile strength of the kaolin dried at 110° C. is 12 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin introduced in the mixture and fired at 1,350° C. has a translucency of 0.62. The transmitted light is cream colored. Absorption is 5 per cent and color is grade 4. Dried at 110° C. this mass shrinks 3.2 per cent, and when fired at 1,350° C. shrinks 13 per cent. Tested under the raw-lead and fritted glazes the color of this mixture becomes a pale green, equally apparent under each glaze.

RUTHERFORDTON. ISINGLASS HILL MICA MINE.

This mine is 3 miles north of Rutherfordton in Rutherford County, N. C., on the Southern Railway. There is no railroad switch or station nearer than Rutherfordton. This dike varies from 6 to 50 feet wide and is proven for one-fourth mile along the crest of a low ridge. It strikes N. 20° E. and dips 80° W. The dike rock is pegmatite in various stages of kaolinization. The material adjoining the west wall is generally more thoroughly kaolinized than that in the eastern part, the dike being divided in the middle by a band of sugar quartz from 1 to 3 feet wide. The kaolinized pegmatite contains but little fine quartz, but this is smoky quartz in sharp elongated particles. In various parts of the weathered dike are nodules of asbolite, but little or none is found in the band of sugar quartz. This mine has been opened to a depth of only about 20 feet by both shafts and tunnels, the dike structure remaining very uniformly as above described.

The kaolinized half of the dike was sampled and by the laboratory washing process yielded 42 per cent of kaolin, which has a refractory value of 1,730° C. The color of this washed kaolin is grade 5. When dried at 110° it has a shrinkage of 2.8 per cent, and when fired at 1,350° C., 11.3 per cent. The tensile strength when dried at 110° is 8 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin shows a translucency of 0.64 and the transmitted light is cream colored. Absorption is 8.8 per cent. The color of the mass when fired is grade 3, as compared with grade 5 for this kaolin burned alone. When dried at 110° the mass shrinks 2.2 per cent, and when fired at 1,350° C. it shrinks 12.4 per cent. Tested under the raw-lead and fritted glazes the color is unaltered.

SHELBY. TOM BAXTER MICA MINE.

This mine is in Lincoln County, N. C., 12 miles northeast of Shelby and 3 miles southeast of Fallston on the Fallston-Lincolnton road. The nearest shipping point is Waco, 4 miles distant.

The mine has not been worked for several years and the exposure conveys little information as to the extent of the dike. The area in which shafts have been sunk is about 40 feet long, although there are indications of a continuation of the dike in the adjoining fields for 100 feet or more in both directions. The width of the dike is reported to be almost 100 feet. The general direction of the strike is N. 50° to 70° E. Only at one point was it possible to observe the kaolin in place, but the dumps from the mica workings carry considerable very fine kaolin, indicating that there must be some in the deposit. Workmen who were employed in mining mica 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. Water was struck at about 35 feet, and the difficulty of removing it with the crude facilities provided also discouraged the attempt to mine mica.

The one point at which the dike is exposed was carefully sampled. Washed by the laboratory washing process the sample yielded 49 per cent of kaolin, which has a refractory value above 1,730° C. and a color of grade 2. This kaolin dried at 110° shrinks 4.4 per cent and fired at 1,350° C. it shrinks 12.2 per cent. Its tensile strength when dried at 110° C. is 8 pounds per square inch.

Properties in standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin shows a translucency of 0.73 and the transmitted light is cream colored. Absorption is 8.1 per cent. The color of the mass is grade 2. The shrinkage is 1.6 per cent when dried at 110° C. and 10.8 per cent when fired at 1,350° C. Tested under the raw-lead and fritted glazes this mass is unaffected in tint.

SHELBY. GREEN MICA MINE.

This mine is 7 miles northwest of Shelby, Cleveland County, N. C. It was worked for mica about 1870 and again worked in a small way a few years later. The openings were all shafts; these are now completely caved, making satisfactory sampling impossible. The dike, as nearly as could be determined, is about 12 feet thick with numerous stringers running nearly parallel. The strike is about N. 70° E. and the dip approximately 75° W. Bands of sugar quartz from 2 to 4 feet thick occur along the hanging wall. In places the dike material is almost completely kaolinized, and it is reported in the neighborhood that much excellent kaolin was exposed in the shafts. The present exposures, however, are so small and so badly stained from infiltration of surface water that an estimate of the quality or quantity of kaolin available is not attempted.

SPRUCEPINE. HARRIS CLAY CO. SPRUCEPINE MINE.

This mine (96) is 2½ miles north of Sprucepine, Mitchell County, N. C., and on the east side of Beaver Creek.

The vast lens or thick dike of kaolinized pegmatite has an irregular structure. Its general trend is northwest. Where worked the dike is about 120 feet wide but the northeast part for a width of 50 to 70 feet is much richer in kaolin than the southwest. An additional stringer has been located 25 feet east of the lens since the study of this deposit began, having a width of about 20 feet and a general direction north. The material in this small lens or stringer is similar in every way to that of the eastern part of the mine. The pegmatite of the dike is well kaolinized, but its quartz content is very high. The mine has been worked by open cut to a depth of about 20 feet and by shaft to an additional depth of 55 feet, below which the kaolinization of the pegmatite has not advanced far enough to make mining profitable. The dike material is removed from the shafts by steam hoists and piled in heaps at the level of the open-cut. From this point it is shoveled into a flume, the water for which comes from a small mountain stream above the mine, and is flushed one-fourth mile to the washing plant. This plant has two batteries, each consisting of a washer and sand wheel, and from them the material passes to a sand trough and thence to the mica-settling trough. From the latter the clay slip passes through 100-mesh screens into a flume which carries it 2½ miles to the railroad, where the settling and drying plant is located. Here the slip is passed over a second battery of screens to remove any material caught in transit and goes to the settling tanks through a trough in which are suspended bags containing alum to aid concentration. From the settling tanks the concentrated material is removed to agitators and pumped into filter presses, of which this plant has two.

The kaolin from the filter presses goes to either the open-air or the steam drier. The latter is a long building having a floor covered with steam pipes on which the pressed kaolin is piled directly. The steam pipes are closed at one end, whereas in most of the steam drying plants throughout this district the pipes are open at one end and the steam is allowed to escape into the air.

The open-air drier is unique in that it has a removable roof. The kaolin is piled on a simple system of racks, but the roof, which is of the ridge type, is constructed independently of the framework of the building, and rests on a track. When the weather is favorable it can be rolled off entirely, allowing the sun to shine directly on the drying material.

The washing removes a large proportion of fine white mica, the yield of this material being estimated as 8 to 12 per cent of the kaolin produced. From 30 to 40 per cent of the mica separated is finer than 100 mesh and should be directly marketable as pulverized mica.

The deposit was sampled as well as possible to obtain an average of the entire area exposed; it yielded 24 per cent of washed kaolin. This kaolin was analyzed and found to have the following chemical composition:

Composition of kaolin.

H_2O	14.80
SiO_2	45.20
Al_2O_3	38.45
Fe_2O_3	.45
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
Na_2O	.00
K_2O	.65
	99.55

The refractory value of this kaolin is above 1,730° C. and the color grade 3. The shrinkage of the kaolin dried at 110° C. is 4 per cent and fired at 1,350° C. is 12.6 per cent. The tensile strength is 8 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture fired at 1,350° C. the translucency is 0.67 and the transmitted light is cream colored. Absorption is 4.2 per cent. The color is grade 3; the shrinkage is 3.8 per cent when dried at 110° C. and 12.6 per cent fired at 1,350° C. Tested under the raw-lead and fritted glazes the kaolin showed a very pale green tint, equally apparent under both glazes.

SPRUCEPINE. OLLIS PROSPECT.

This prospect (105) is 6 miles northeast of Sprucepine, Mitchell County, N. C., and 1 mile east of the Sprucepine-Plumtree road. There is a pegmatite dike exposed as a broad lens along a ridge proven for a length of 250 yards and in places for a width of 100 feet. The strike is west, the dip 80° S. This dike is exposed by numerous shafts and tunnels and was carefully sampled and washed by the laboratory washing process, yielding 36 per cent of kaolin.

The kaolin content has a refractory value above 1,730° C. Its color is grade 5. Its shrinkage when dried at 110° is 4.6 per cent and fired at 1,350° is 9.6 per cent. The tensile strength of the kaolin dried at 110° is 17 pounds per square inch.

Properties in standard porcelain mixture.

Tested in the mixture and fired at 1,350° C. this kaolin has a translucency of 0.68 and the transmitted light is yellow. Absorption is 3.6 per cent. The color is grade 5. The shrinkage at 110° is 3.6 per cent and at 1,350° C. 12.2 per cent. Tested under the fritted and raw-lead glazes the tint of the mass is unaltered.

SPRUCEPINE. TOLLEY MICA MINE.

This mine (99) is 1 mile southwest of Sprucepine, Mitchell County, N. C., on the Sprucepine-Burnsville road. The dike is exposed to a width of about 25 feet and from surface indications is approximately 10 feet wider. The material in the dike seems to be very uniform, no bands of wall rock being noted. Numerous stringers from this dike are exposed where it crosses the road 50 yards distant. This dike has been proven for 300 feet and is opened by a shaft claimed to have been originally 45 feet but now only 20 feet deep, and by a drift from this shaft at the 20-foot level. The drift runs 25 feet north, then turns and extends 7 feet to the west. The dike material in this dike seems very white but very sandy. The sample collected, when washed by the laboratory process, yielded 30 per cent kaolin.

This has a chemical composition as follows:

Composition of kaolin.

H_2O	14.00
SiO_2	46.35
Al_2O_3	38.80
Fe_2O_3	.25
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
BaO	.03
Na_2O	Trace.
K_2O	.41
	99.84

This kaolin has a refractory value above 1,730° C. Its color is grade 2. Dried at 110° C. it has a shrinkage of 5.4 per cent and fired at 1,350° C. shrinks 10.9 per cent. Dried at 110° C. the kaolin has a tensile strength of 8 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin introduced into the mixture and fired at 1,350° C. has a translucency of 0.71 and the transmitted light is cream colored. Absorption is 7.3 per cent. Its color is grade 2. The mass when dried at 110° C. has a shrinkage of 3.4 per cent and when fired at 1,350° C. 14 per cent. Tested under the fritted and raw-lead glazes this mass acquires a very pale green tint, equally apparent under each glaze.

SPRUCEPINE. WISEMAN PROSPECT.

This prospect (104) is on Fort Creek, a branch of Three-Mile Creek, 3 miles north of Ingalls post office and 8 miles north of Sprucepine, Mitchell County, N. C.

The dike is ruptured by numerous intrusions, which at some points are stringers only a few feet wide; at others, form a single dike about 20 feet wide. The dike strikes N. 40° E. It varies in degree of kaolinization, but is remarkably free from impurities and is also very low in quartz. The workings consist of tunnels and shafts opened to expose the kaolin.

All the exposed material of the main dike was sampled. Washed by the laboratory process, the sample averaged 37 per cent of kaolin. This kaolin has a refractory value above 1,730° C. The color when fired at 1,350° C. is grade 1. Dried at 110° C. this kaolin shrinks 7.4 per cent and fired at 1,350° C. it shrinks 17.4 per cent. It has a tensile strength of 17.5 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin when introduced into the mixture and fired at 1,350° C. gives a translucency of 0.72. The transmitted light is cream colored. Absorption is 8.3 per cent. The color is grade 1. The kaolin, dried at 110° C., shrinks 4.4 per cent; when fired at 1,350° C., shrinks 14.4 per cent. The color is unaffected by the application of either the raw-lead or fritted glazes.

SPRUCEPINE. WISEMAN PROSPECT.

This prospect (101) is on the Marion road, 3 miles southeast of Sprucepine, Mitchell County, N. C. The pegmatite dike, which is more or less kaolinized, has a northeast strike and a nearly vertical dip. The half adjoining the southeast wall is incompletely kaolinized, but kaolinization of the northwest half is well advanced. The entire deposit, however, is very sandy, as is common among kaolin deposits in this immediate vicinity. Adjoining this dike on the southeast side is a narrow ledge of coarse granite-pegmatite which is apparently unaltered.

The kaolinized portion of this dike was sampled and tested with the following result:

In the laboratory washing process it yielded 21 per cent of kaolin. The refractory value of the kaolin is 1,730° C. The color is grade 2.

The shrinkage is 3.2 per cent when dried at 110°, and 11.9 per cent when fired at 1,350° C. When dried at 110° C. this kaolin has a tensile strength of 17 pounds per square inch.

Properties in standard porcelain mixture.

Tested in the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.76 and the transmitted light is cream colored. Absorption is 3.7 per cent. The color is grade 2. The shrinkage when dried at 110° is 3.8 per cent, and when fired at 1,350° C., 13 per cent. The color under the fritted and raw-lead glazes is unaltered.

SYLVA. BUCHANAN PROSPECT.

This prospect (52) is 1½ miles east of Sylva and one-half mile south of the Murphy Branch of the Southern Railway in Jackson County, N. C.

The dikes exposed vary in width from 10 to 18 feet, strike N. 40° E. and dip 80° N. One dike is exposed on or along a ridge that trends north. The overburden at the higher points averages from 2 to 10 feet, but downhill it averages from 15 to 20 feet. The dike at the higher elevation is exposed along the ridge and is one-eighth mile east of the other dike, hence the two are undoubtedly not a continuation of the same dike although very similar as regards appearance and associated materials. In all of these dikes small lenses of garnet-colored sand mixed with altered biotite are found, but their removal under ordinary mining conditions would not cause any difficulty. The higher dike has been opened only by shallow pits, and the quality of the kaolin exposed is doubtless inferior to that obtainable at a little greater depth. The lower dike is well exposed by shafts 25 feet deep and by two tunnels and is of quite uniform structure and width.

The lower dike was carefully sampled. Washed by the standard laboratory method the sample yielded 40 per cent of kaolin. This kaolin has a chemical composition as follows:

Composition of kaolin.

H_2O	13.77
SiO_2	46.30
Al_2O_3	39.06
Fe_2O_3	.20
TiO_2	.04
CaO	Trace.
MgO	Trace.
Na_2O	.11
K_2O	.60
	100.08

This kaolin has a refractory value above 1,730° C. Its color is grade 3. Its shrinkage when dried at 110° is 5.4 per cent, and its total shrinkage at 1,350° C., 13.9 per cent. The tensile strength of this kaolin when dried at 110° is 28.5 pounds per square inch.

Properties in standard porcelain mixture.

This kaolin when introduced into the mixture and fired at 1,350° C. gives a translucency of 0.64 and the transmitted light is cream colored. Absorption is 5.3 per cent. The color is grade 3. The shrinkage of the mass dried at 110° is 3 per cent; fired at 1,350° C., 13.1 per cent. Tested under the fritted and raw-lead glazes the mixture shows a pale-green tint, which is equally apparent under each glaze.

SYLVA. FOREST HILL MICA MINE.

This mine (62) is on the Cox property 10 miles south of Sylva and 1 mile west of Cullowhee Creek in Jackson County, N. C.

The dike has a general northeast strike and a vertical dip. It varies from 8 to 20 feet wide, and a number of stringers of great thickness are visible in the immediate neighborhood. Another dike (65) is exposed by a shallow pit 100 yards to the north of this main dike but 50 feet below. An exposure of kaolin is also seen 1 mile south (66). The dike is in various stages of kaolinization, but is uniformly very free from impurities with the exception of a little quartz; no wide quartz bands were exposed by any of the numerous tunnels that have been driven in search of mica.

The kaolin material was sampled by the laboratory washing process; it shows a kaolin content of 31 per cent. This kaolin has a chemical composition as follows:

Composition of kaolin.

H_2O	12.53
SiO_2	49.20
Al_2O_3	37.58
Fe_2O_3	.17
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
Na_2O	.13
K_2O	.47
	100.08

This kaolin has a refractory value of 1,730° C. Its color when fired at 1,350° C. is grade 2. The shrinkage in drying at 110° is 4 per cent, and when fired at 1,350° C., 9.7 per cent. When dried at 110° this kaolin has a tensile strength of 16 pounds per square inch.

Properties in standard porcelain mixture.

In this mixture when fired at 1,350° C. the kaolin has a translucency of 0.73 and the transmitted light is cream colored. Absorption is 5.5 per cent. The color is grade 3. Dried at 110° C. the kaolin shrinks 1.4 per cent, and fired at 1,350° C., 11.6 per cent. When the fritted glaze or the raw-lead glaze is applied to this mixture the mass assumes a very pale green tint.

SYLVA. NORTH CAROLINA MINING & MANUFACTURING CO. MINE.

This mine (54, 55) is 2 miles south of Sylva, Jackson County, N. C., on the south slope of a mountain. The kaolinized pegmatite dike varies from 8 to 18 feet in width and strikes N. 45° E. There is a surface cut of about 200 feet, about 20 feet deep. From this level shafts have been sunk and material below has been removed. These shafts have been filled and their depth could not be determined, the surface indications only proving their existence. This mine is mentioned in Bulletin No. 13 of the North Carolina Geological Survey, which refers to numerous patches of partly kaolinized material in the dike, and states that several tons of fresh feldspar are reported to have been shipped.

At only one point is the dike material now exposed. This material was sampled and washed and found to contain 26 per cent of kaolin.

The analysis of this kaolin as given by the North Carolina Geological Survey is as follows:

Composition of kaolin.

Moisture	3.07
SiO_2	44.08
Al_2O_3	36.26
Fe_2O_3	1.86
CaO	.43
MgO	.20
KNaO	.50
Combined water	13.56
	99.96

The general run of kaolin taken from this mine and washed by the standard laboratory process is doubtless much lower in iron than is indicated by this analysis since the refractory value is above 1,730° C. and the color is grade 2. Dried at 110° C. it shrinks 5.7 per cent and fired at 1,350° C. 12.6 per cent. The tensile strength is 18 pounds per square inch.

Properties in standard porcelain mixture.

In this mixture fired at 1,350° C. the kaolin gives a translucency of 0.66 and the transmitted light is cream colored. Absorption is 6.1 per cent. The color is grade 2, and the shrinkage is 3.2 per cent dried at 110° C. and 13.3 per cent when fired at 1,350° C. Tested under the raw-lead and fritted glazes it shows a pale-green tint, equally apparent under each glaze.

SYLVA. RODA KAOLIN AND MICA MINE.

This mine (67) is 7 miles southeast of Sylva, Jackson County, N. C., on the south side of the Tuckasegee River opposite the mouth of Cany Fork. The pegmatite dike cuts diagonally a low ridge and has a general northeast 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. At this point a deep shaft has been sunk from the tunnel across its entire width and the portion of the tunnel beyond this point was inaccessible.

The material in the neighborhood of the shaft, consisting of equal portions of the material rich in kaolin and material lean in kaolin, was sampled. Washed by the standard laboratory process the sample contained 26 per cent of kaolin. This kaolin has a refractory value above 1,730° C. Its color is grade 2. Its shrinkage dried at 110° C. is 4.1 per cent and fired at 1,350° C. is 12.7 per cent. The tensile strength is 21 pounds per square inch.

Properties in the standard porcelain mixture.

Introduced into the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.66 and the transmitted light is cream-white. Absorption is 5.7 per cent. The color is grade 2. Dried at 110° C. the shrinkage is 3 per cent and fired at 1,350° C. is 12.2 per cent. Tested under the raw-lead and fritted glazes it shows a very pale green, equally apparent under both glazes.

TOECANE. P. H. HOWELL PROSPECT.

This prospect (80) is 3 miles southeast of Toecane, Mitchell County, N. C., and 1 mile southwest of the forks of Sink Hole road running to Youngs Siding. The dike is on a high ridge along the crest and the general direction of the strike is N. 45° E. The dip is 80° NW. The width varies greatly, different exposures indicating a thickness of from 8 to 18 feet. The kaolinization of the pegmatite is well advanced, but the dike still contains some scattered semikaolinized lenses (79). The wall rock is a brown gneiss which differs distinctly in color from the Roan gneiss, which is the ordinary country rock throughout this district.

The dike was sampled across its entire width. Washed by the standard laboratory process the sample yielded 31 per cent of kaolin. The refractory value of this kaolin is 1,710° C. Its color is grade 2. Dried at 110° C. it shrinks 3 per cent; fired at 1,350° C. it shrinks 12.7 per cent. The tensile strength is 17 pounds per square inch.

Properties in standard porcelain mixture.

In the mixture and fired at 1,350° C. this kaolin has a translucency of 0.69 and the transmitted light is cream colored. Absorption is 5.9 per cent. The color is grade 2. The shrinkage dried at 110° C. is 3.4 per cent and fired at 1,350° C. is 13.1 per cent. Tested under the raw-lead and fritted glazes the mass shows a very pale green tint, equally apparent under each glaze.

WAYNESVILLE. KINSLAND MINE.

This mine is on the Crabtree road, 9 miles northeast of Waynesville, Haywood County, N. C., just beyond the bridge over Pigeon River.

The broad dike is divided into many sections by intruded material, but totals 75 feet in width. In one place where exposed by an old road the general outline of the lenses of harder pegmatite and of wall rock are easily seen. The bands of kaolin material average from 6 to 8 feet wide and generally have a very high quartz content; the quartz is not in solid bands but is scattered through the mass as small angular particles from one-eighth to one-half inch in size. The dike is opened by a number of shafts and tunnels, but most of them have caved badly. One of them still exposes the dike at a depth of about 20 feet where the kaolin, as in the road exposure, shows a rather excessive quartz content. This dike has a general strike N. 40° E. In addition to the exposures already mentioned there is an outcrop on the strike of this dike on a low hill 300 yards distant which shows the same general structure as this deposit.

The kaolin in the shaft was carefully sampled. Washed by means of the laboratory apparatus this sample contained 27 per cent of kaolin. This kaolin was analyzed; it has the following chemical composition:

Composition of kaolin.

H_2O	11.90
SiO_2	50.64
Al_2O_3	35.57
Fe_2O_3	.25
TiO_2	.03
CaO	Trace.
MgO	Trace.
BaO	.07
Na_2O	.08
K_2O	1.70
	100.24

This kaolin has a refractory value of 1,670° C. Its color is grade 5. Its shrinkage at 110° C. is 4.4 per cent. Its shrinkage when fired at 1,350° C. is 9.8 per cent. Its tensile strength when dried at 110° is 8 pounds per square inch.

Properties in standard porcelain mixture.

Fired at 1,350° C. this kaolin in the mixture has a translucency of 0.76 and the transmitted light is cream colored. Absorption is 2.6 per cent. The color is grade 5. Dried at 110° the kaolin shrinks 1 per cent; fired at 1,350° C. it shrinks 13.6 per cent. Tested under the fritted and raw-lead glazes this porcelain mass remains unchanged in tint.

WEBSTER. COWAN PROSPECT.

This prospect is one-half mile southeast of Webster, Jackson County, N. C., just west of the nickel-refining plant at that place. The test hole where the kaolinized material is exposed is near a small branch and the exposure is so small that no idea can be formed of the extent of the dike. The quality of the material, however, is high. No indications of kaolin or of pegmatite dikes are noted on the surface in the neighborhood of this exposure, but the overburden on the hillside is thick enough to hide them.

WEBSTER. HALL MINE.

This mine (57) is directly west of Webster, Jackson County, N. C., on a low ridge above Tuckasegee River and midway between Harris Bridge and Webster Bridge.

The dike has several stringers which vary from 10 to 20 feet in width. It strikes N. 40° E., the dip being almost vertical. It is opened by a tunnel 60 feet long, which follows the strike, and a shaft about 20 feet deep. The shaft, however, has fallen in badly, so that samples could not be taken. The tunnel was sampled across the full width of the dike. The sample when washed yielded 24 per cent of kaolin. The refractory value of the kaolin is above 1,730° C. Its color is grade 4. Dried at 110° C. it shrinks 4.9 per cent, and fired at 1,350° C. it shrinks 12.4 per cent. The tensile strength is 18 pounds per square inch.

Properties in standard porcelain mixture.

In this mixture fired at 1,350° C. the kaolin has a translucency of 0.68 and the transmitted light is cream colored. Absorption is 4.6 per cent. The color is grade 4. The shrinkage of the kaolin dried at 110° C. is 3.1 per cent and fired at 1,350° C. is 13 per cent. Tested under the raw-lead and fritted glazes the color remains unaltered.

WEBSTER. LONG MICA MINE.

This mine (61) is one-fourth mile northeast of the mouth of Wayehutta Creek and 4 miles southeast of Webster, Jackson County, N. C.

The irregular pegmatite dike strikes N. 70° E. Mining has been entirely for mica and two tunnels have been run into the hill, only one having been opened at the time of the visit. An open-cut directly above this tunnel exposes the surface of the dike. The width of this dike varies from 10 to 20 feet and is considerably broken by intrusions of wall rock. The dike is well advanced in kaolinization but contains considerable streaked material similar to infiltrated surface stain.

The richer part of the dike was sampled, care being taken to obtain material free from stain. The sample washed by the standard laboratory process yielded 35 per cent of kaolin. The refractory value of this kaolin is above 1,730° C. Its color is grade 2. Its shrinkage when dried at 110° C. is 4.1 per cent and fired at 1,350° C. 11.2 per cent. The tensile strength is 20 pounds per square inch.

Properties in standard porcelain mixture.

In this mixture fired at 1,350° C. the kaolin has a translucency of 0.69 and the transmitted light is cream colored. Absorption is 6 per cent. The color is grade 2. The skrinkage when dried at 110° C. is 3 per cent and fired at 1,350° C. 13.8 per cent. Tested under the raw-lead and fritted glazes the kaolin shows a very pale green tint, equally apparent under each glaze.

WILLETTS STATION. WAYEHUTTA MICA MINE.

This mine (56) is on the west face of Black Mountain near the head of Wayehutta Creek and 3 miles south of Willetts Station, Jackson County, N. C.

The irregular pegmatite dike strikes N. 70° E. and has a varying dip. The dike where exposed seems to be about 50 feet wide with a 10-foot horse of the wall rock near the center. A massive quartz band occurs along the south wall. The openings are four tunnels, only one of which penetrates kaolin material in commercial quantity. These tunnels are all on the steep slope of the ridge 300 feet or more above the road and 40 to 60 feet below its crest.

The kaolin material was sampled. Washed by the standard laboratory method the sample yielded 33 per cent of kaolin. This kaolin has a refractory value above 1,730° C. Its color is grade 2. Dried at 110° C. it shrinks 4.6 per cent, and fired at 1,350° it shrinks 12.3 per cent. The tensile strength of the kaolin dried at 110° is 12.5 pounds per square inch.

Properties in standard porcelain mixture.

When tested in the mixture fired at 1,350° C. this kaolin has a translucency of 0.64 and the transmitted light is cream colored. Absorption is 7.1 per cent. The color of the porcelain mixture is grade 2. The shrinkage at 110° is 3.6 per cent and when fired at 1,350° C. 12.6 per cent. When tested under the fritted and raw-lead glazes no change of tint is noticeable.

VIRGINIA.

LYNCHBURG. RADFORD PROSPECT.

This prospect is 1¼ miles northeast of Forest Depot, Bedford County, Va., and 10 miles southwest of Lynchburg.

The pegmatite dike varies from 6 to 15 feet wide and is reported to have been proven for nearly 500 feet by auger borings. For 300 yards along the strike of this dike a narrow band of semikaolinized material is apparent. The strike of the dike is N. 30° E. It is opened by a pit 35 feet deep and contains a 12-inch flint band near the middle. The dike structure is variable, showing bands of soft kaolin comparatively free from sand and mica and also many bands containing 0.1 per cent of sand and small mica, as well as much semi-kaolinized material. In this shaft was noted a streak of garnet sand similar to streaks in North Carolina dikes. The overburden in few places exceeds 6 to 8 feet and the prospect is for the most part on an elevated tract of land one-half mile from Wolfe Creek and is crossed by Double Branch, a tributary of Wolfe Creek.

The kaolinized part of this dike was sampled. Washed by the standard laboratory process the sample yielded 27 per cent of kaolin having a refractory value above 1,710° C. The color is grade 4. The shrinkage of the kaolin dried at 110° C. is 6.2 per cent, and fired at 1,350° C. is 16.4 per cent. The tensile strength of the kaolin dried at 110° is 17 pounds per square inch.

Properties in standard porcelain mixture.

When introduced into the mixture and fired at 1,350° C. this kaolin gives a translucency of 0.69 and the transmitted light is yellow. Absorption is 5.1 per cent. The color is grade 4. When dried at 110° C. the shrinkage is 5.4 per cent, and when fired at 1,350° C. is 15 per cent. Tested under the raw-lead and fritted glazes this mass shows a very pale green tint, equally apparent under each glaze.

HENRY. BLUE RIDGE MINE.

This mine is 3½ miles southeast of Henry, Henry County, Va., on a ridge 100 feet above the creek. There is either a series of separate dikes of no great width or perhaps one broad dike with numerous bands of foreign material. The majority of the kaolinized pegmatite bands now exposed are not more than 3 to 8 feet wide, and most of the associated bands of foreign material are gray sand carrying little or no kaolin. The area that has been worked over covers about 10 acres, and a few of the shafts have been sunk about 80 feet. There are small lenses of garnet sand and iron-stained blocks of mica, large and small, which necessitate careful hand picking in order to make a marketable kaolin. The mine has been abandoned several years, and the washing plant is dismantled. Whether additional kaolin still remains on this property in commercial quantities could not be determined.

ASSOCIATED MINERALS IN THE PEGMATITE DIKES.

OCHER.

AQUONE, N. C. YONCE FARM PROSPECT.

Ocher is found on the Yonce farm (16) 2 miles north of Aquone on Nantahala River, in Macon County, N. C.

A deposit of this material is exposed in a creek bed for a width of about 15 feet. The dike strikes N. 35° E., and consists of four bands, of which a 4-foot band along the west wall and a 2-foot band along the east wall are very rich. The central portion of the dike is very sandy. No attempt has been made to develop this deposit, and no other exposures in either direction were found. A small deposit of similar material 100 yards east of this exposure is opened along a hillside, but from the associated material this is not believed to be the same body, although it may be a stringer from this body.

The richest parts of this deposit were sampled and washed and yielded 42.5 per cent of high-grade golden ocher having the following composition:

Composition of ocher.

Volatile matter	13.59
SiO_2	15.40
Al_2O_3	16.25
Fe_2O_3	51.00
TiO_2	.30
	96.54

Alkali and alkaline earths were not determined.

SPRUCEPINE, N. C. HARRIS CLAY CO. KAOLIN MINE.

This mine (96) is north of Sprucepine, Mitchell County, N. C. The part of this deposit immediately below the overburden is a golden color in many places for a depth of 5 to 8 feet.

This material was sampled and washed and found to contain 34 per cent of ocher. It contains much very fine mica, however, and must be washed with great care.

Practically all the kaolin deposits in the Mount Mitchell district display this yellow material near the surface, and it may be washed to form a marketable product having a value equal to that of the kaolin.

SCHROETTERITE.

DILLSBORO, N. C. HARRIS CLAY CO. KAOLIN MINE.

This mine (60) is 5 miles southeast of Dillsboro, Jackson County, N. C. Associated with the kaolinized pegmatite found in this dike is a material similar to semikaolinized feldspar in appearance, but widely different in composition.

This material occurs as small lenses or bands in the dike material and is reported as occurring at all levels, although its occurrence is noted oftenest at levels below 60 feet. Samples of this material show the following composition:

Composition of schroetterite.

H_2O	27.90
SiO_2	21.90
Al_2O_3	49.60
Fe_2O_3	.30
TiO_2	Trace.
CaO	Trace.
MgO	Trace.
K_2O	.10
Na_2O	.00
	99.80

The composition approaches that of the mineral schroetterite, the formula of which is: $Al_{16}Si_3O_{30}.30H_2O$. This substance has a formula $Al_{16}Si_3O_{30}.25.4H_2O$, and differs from schroetterite in the amount of combined water only.

SUGAR QUARTZ.

Sugar quartz is apparently of uniform quality wherever found, except that in some cases it is stained with infiltrated iron-bearing material or with incrustations of wad. If the quartz is to be used in the manufacture of pulverized flint that which is stained must be removed by hand.

Samples of sugar quartz from numerous mines and prospects have been tested. An analysis of this material is as follows:

Analysis of sugar quartz.

SiO_2	99.32
Al_2O_3	.49
Fe_2O_3	Trace.
H_2O and organic	.10
	99.91

Pulverized and fired this material is a white powder that shows no bonding strength when heated to 1,350° C.

Properties in standard porcelain mixture.

Introduced into the mixture this sugar quartz shows a translucency of 0.69 and has a pale-yellow tint. The color is grade 5. The shrinkage when dried at 110° C. is 3.2 per cent; fired at 1,350° C. it is 16 per cent. Under the raw-lead and fritted glazes the color is unaltered.

WAD.

In most of the kaolinized pegmatite dikes throughout the region investigated are nodules of wad scattered through the mass or incrusted in fissures in the quartz bands. Wad is an earthy manganese ore and carries some cobalt and other metal oxides. These nodules are found occasionally in the Gurney kaolin mines and are very abundant in the Isinglass Hill mica mine.

Wad is found in nearly all other dikes examined as crusts in the crevices of the ruptured quartz bands. Samples of this material have been taken and its identity established by determinative mineralogy methods.

In the kaolin mine of the Southern Clay Co., 1 mile northwest of Franklin, Macon County, N. C., a large amount of this material was found, which was sampled and analyzed. The chemical composition is as follows:

Composition of nodule of wad.

Volatile matter	15.30
SiO_2	33.20
Al_2O_3	24.60
Fe_2O_3	4.00
TiO_2	.25
Mn_3O_4	21.80
$CaO+NiO$	.75
CuO	.50
	100.40

PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF MINING.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.

BULLETIN 15. Investigations of explosives used in coal mines, by Clarence Hall, W. O. Snelling, and S. P. Howell; with a chapter on the natural gas used at Pittsburgh, by G. A. Burrell, and an introduction by C. E. Munroe. 1911. 197 pp., 7 pls., 5 figs.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice; with chapters by J. C. W. Frazer, Axel Larson, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs. Reprint of United States Geological Survey Bulletin 425.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell. 1913. — pp., — pls.

BULLETIN 44. First national mine-safety demonstration, Pittsburgh, Pa., October 30 and 31, 1911, by H. M. Wilson and A. H. Fay; with a chapter on the explosion at the experimental mine, by G. S. Rice. 1912. 75 pp., 7 pls., 4 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1913. 50 pp., 3 pls., 7 figs.

BULLETIN 50. The inflammability of coal dust, by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, jr. 1913. — pp.

BULLETIN 51. The analysis of black powder and dynamite, by W. O. Snelling and C. G. Storm. 1913. 80 pp., 5 pls., 5 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent lamps, by H. H. Clark and L. C. Ilsley. 1913. 31 pp., 6 pls., 2 figs.

TECHNICAL PAPER 6. The rate of burning of fuse as influenced by temperature and pressure, by W. O. Snelling and W. C. Cope. 1912. 28 pp.

TECHNICAL PAPER 7. Investigation of fuse and miners' squibs, by Clarence Hall and S. P. Howell. 1912. 19 pp.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

TECHNICAL PAPER 14. Apparatus for gas analysis at coal mines, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 7 figs.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs.

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